DIVERSITY INTER REALATIONSHIPS AMONG *Capsicum* Spp. AND FORMS AND DEVELOPMENT OF PAPRIKAS

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "**Diversity interrelationships among *Capsicum* spp. and forms and development of paprikas**" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or other similar title, of any other University or Society.

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Dedicated to my
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father-in-law Sri. A.Madhavan

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Introduction

INTRODUCTION

Chilli is a diverse crop and has been a part of the human diet since 7500 B.C. Since their discovery by Columbus, chillies are incorporated into majority of the world's cuisines. Even with this widespread acceptance, a little is known about *Capsicum*, and its diversity interrelationships. As an economic crop, chilli is a spice cum vegetable of commercial importance. Green chilli, chilli powder, cayenne pepper, tabasco, paprika, sweet or bell pepper, pimentos and serrano pepper are all derived from the berries of *Capsicum* spp. Different terms are used in different countries and even within the same country. The term chilli is not generally used in the U.S.A. But is used in Britain, India, Africa and countries in the East. Chilli is valued for its pungency, spicy taste and aroma besides the appealing colour it adds to the food. The two important chemical constituents of fruits are, "Capsaicinoids" imparting pungency and "Carotenoid pigments" imparting colour.

Annual trade of chilli in the world is 55 to 65 thousand tonnes which is 16.7% of the total spice trade in the world. India ranks first in area (9.17 lakh ha) and production (7.79 lakh tonnes) in the world. During 1993-94, India exported 33.45 thousand tonnes of chilli valued Rs.75.50 crores. Though chilli is grown throughout India, Andhra Pradesh leads in area and production.

The varieties which got established in India, are generally long, moderately pungent and have varying shades of red colour. Besides differences in soils, climate and cultivation conditions, natural hybridisation and selection possibly played important roles in the characteristic capsicum cultivars varying in shape, size,

colour, pungency and aroma, which established themselves in different regions. The considerable variation in shape, size and colour led to much confusion in early botanical classification. The early botanists selected the term Capsicum to denote the genus. *Capsicum* terminology is confusing. It was derived from the greek word "Kapso" meaning to "bite" a reference to dominant pungency stimulated by the spice. It is also derived from the latin word "Capsa" for the box referring to shape of fruit. *Capsicum* is official in both the U.S. National Formulary XI and British Pharmaceutical Codex, 1973. The documents describe them as the small fruited and pungent fruits of both *Capsicum frutescens* and *Capsicum annuum*. But the International Standards Organisation recognizes only two types, "Chillies" and "Paprika" to cover the easily perceivable to strong pungent types and the big fleshy vegetable and the sweet or just recognizable pungent types of capsicums respectively.

Though the taxonomists used the term *Capsicum*, the trade and scientific literature continues to use the term "pepper" with various prefixes like red pepper, bird pepper, chilli pepper, bell pepper etc. Capsicum investigators use chile, pepper or aji as vernacular terms. The spanish word 'chile' is a variation of chilli from the Nahuatl dialect of Mexico's Aztecs, whereas 'aji' is a variation of 'axi' from the Arawak dialect of Caribean. Chile pepper means pungent cultivars. There are chilli types which have both pungent and nonpungent cultivars. These include wax, cherry and paprika types.

Paprika is a product in the United States of America. The word paprika means pepper in Hungarian. Paprika is defined in the United States of America as a sweet, dried red powder. This mild powder can be made from any type of *Capsicum annuum*, that is nonpungent and has brilliant red colour. Colour is measured by

American Spice Trade Association (ASTA) procedures and is expressed in ASTA Units. In Europe, paprika is made from two principal fruit types (1) a round fruit about the size of a peach and called Spanish or Moroccan paprika and (2) a longer, more conical and pointed type grown in Balkan countries called Hungarian paprika. Spanish, Hungarian and U.S. paprika each has a slightly different taste.

The increasing commercial importance world over of paprika both as paprika powder and oleoresin resulted in establishing breeding programme for its improvement with the aim to develop varieties/hybrids to the standard of international market especially in Europe and U.S.A. In India, as yet, there is no spice paprika variety grown commercially. Hence breeding programmes were initially started at IARI Sub Station Katrain. The breeding objectives were aimed at consumers and growers and to meet processing requirements for developing suitable varieties. Three breeding lines of paprika viz. Kt-Pl-8, Kt-Pl-18 and Kt-Pl-19 were identified as promising at Katrain.

Capsicum a new world genus, has richness in diversity, which has not yet received due attention. The cultivated chilli varieties offer many difficulties in classification because of their great number, the transitory nature and creation of new ones through hybridisation and selection processes.

Pepper breeding got evolved through domestication of *Capsicum* species by the indigenous people of Americas. Global diversification was facilitated by age of exploration and subsequent establishment of land races and farmers selections. Classical genetic and cytogenetic exploitation of *Capsicum* species began in 1940s and continued throughout this century.

Genetic diversity is an important factor which helps in the selection of parents for hybridisation. Isozyme analysis by electrophoresis creates a well defined and effective method to detect genetic differences among individuals. But they are used only as a supplementary tool, alongwith morphological and other methods of plant classification.

Conventional and modern biochemical analysis would throw light on diversity interrelationships among chilli morphotypes, forms and species. Information on phases of diversification and core areas of similarity and dissimilarity are vital for any chilli improvement work. The genus *Capsicum* is less studied both for isozymic genetic markers and genetic divergence.

Considering all the above aspects the present study was taken up with the following specific objectives:

1) To study genetic diversity interrelationships among *Capsicum* spp. and forms through conventional and modern methods.
2) Chemotaxonomic grouping of *Capsicum* spp. and forms based on isozyme analysis.
3) Evaluation of paprikas under warm, humid tropical conditions of Kerala and selection of resistant type(s) to bacterial wilt.

Review of Literature

REVIEW OF LITERATURE

Importance of assemblage and maintenance of crop germplasm in breeding for high yield and for acceptable quality is appreciated by geneticists and breeders. The basic difficulty lies in recognizing and estimating such diversity. Mahalanobis D^2 statistic provides direct and reliable estimate of genetic diversity.

Although biochemical genetics is known and is used in research since many years, its application to study population genetics is dated back only 20 years ago with development of gel electrophoretic techniques (Ferguson, 1980). Isozyme analysis by electrophoresis creates a very well defined and effective medium to detect genetical differences among individuals.

Genetic divergence and clustering of genotypes

Importance of genetic divergence in selection of parents for hybridisation was stressed by Murthy and Arunachalam (1966), Singh and Gupta (1968) and Rai (1979). Singh and Gupta (1968) reported that more diverse the parents, within a reasonable range, more would be the chance of improving the character in question. Major reasons for origin of genetic diversity in plants are mutations, recombination and polyploidization, whether they are accomplished through natural agencies or through artificially controlled means (Rai, 1979). Usually in many of the conventional heterosis breeding programmes, geographical diversity at times and phenotypic diversity in majority of times are taken as criteria to choose genetically divergent populations to isolate inbred lines. Phenotypic divergence in a population is also

considered as an index and criteria of genetic diversity (Rai, 1979). Generally ecogeographic diversity is an index of genetic diversity in crop plants. However, this may not be true for every case as many workers postulate that geographic diversity(s) need not necessarily be related to genetic diversity. Varieties from widely separated localities are usually included in hybridisation programmes presuming genetic divergence and greater likelihood of yielding better segregants. Validity of the above presumption depends upon the association between geographical diversity and genetic diversity (Singh and Bains, 1968).

Forty five lines of chilli were subjected to Mahalanobis D^2 analysis by Singh and Singh (1976). The lines differed significantly for plant height, branches/plant, days to flower, days to maturity, fruit length, fruit thickness, fruits/plant and yield/plant. Branches/plant, fruit thickness, fruits/plant and yield/plant, contributed more towards total divergence. The clustering pattern of lines followed geographical distribution. From a D^2 analysis on 27 varieties of chilli, Mehra and Peter (1980) reported that fruits/plant contributed maximum towards diversity (88.03). Sundaram *et al.* (1980) could not observe any relation between genetic and geographic diversity when they subjected 35 Indian and 15 exotic lines of *Capsicum frutescens* to D^2 analysis. Branches/plant and fruits/plant were the important characters contributing to genetic divergence. Factor analysis in chilli reported by Rao *et al.* (1981) indicated that flowering maturity and fruiting ability in summer and pods/plant were more important characters, accounting for 55.34% of total divergence.

Deshpande *et al.* (1988) attempted to find out factors responsible for genetic diversity within a species. One hundred and fourty four lines, including 139

in different horticultural groups of *Capsicum annuum*, three in *Capsicum baccatum* var. *pendulum* and one each in *Capsicum praetermissum* and *Capsicum sinense* were observed for nine characters and subjected to factor analysis. Through use of principal component analysis, two factors were determined. Factor one accounted for 39% of the variability and factor two, 24% thus explaining in all 63% of the variability. Considerable portion of the variation was thus explained by characters chosen for the study. In factor one fruit number, fruit diameter besides yield itself had positive loadings while days to flower showed negative loadings. Yield and its major component fruits/plant were accommodated by the first factor and hence this factor was referred as "productivity factor". In factor two only plant height and spread had positive loadings while average fruit weight had negative loadings. Plant height and spread together were considered as an index of vegetative vigour and therefore it was referred as "vegetative factor". Four classes viz. (1) high vegetative vigour and high productivity (2) high vegetative vigour with low productivity (3) moderate vegetative vigour and moderate productivity and (4) low vegetative vigour and high productivity were made depending on the two factors.

Taxonomy of genus *Capsicum*

Capsicum terminology is confusing. Pepper, chili, chile, chilli, aji, paprika and Capsicum are used interchangeably for plants in the genus *Capsicum*. The word *Capsicum* is reserved for taxonomic discussion (Bosland, 1992).

Pepper breeding got evolved through domestication of *Capsicum* species by the indigenous people of Americas. Global diversification was facilitated by age of exploration, and subsequent establishment of land races and farmers selections. Classical genetic and cytogenetic exploitation of *Capsicum* species began in 1940s

and continued throughout this century (Poulos, 1994).

Early taxonomic treatment of the genus resulted in more than 100 species and botanical varieties (Fingerhuth, 1832, Irish, 1898). The cultivated chilli varieties offer many difficulties in classification because of their number, the transitory nature, and creation of new ones through hybridisation and selection processes. Linnaeus (1737) in "Hortus cliffortianus" described two species, *Capsicum annuum* and *Capsicum frutescens*. In his Mantissa (1767) two more additional species, *Capsicum grossum* and *Capsicum baccatum* were also proposed. Kuntze (1891) proposed *Capsicum annuum* with five botanical varieties namely *Capsicum annuum* var. *cerasiforme, Capsicum annuum* var. *conoides; Capsicum annuum* var. *fasciculatum; Capsicum annuum* var. *longum* and *Capsicum annuum* var. *grossum*. Irish (1898) reviewed comprehensively over 100 binomials, proposed in 100 years. Since Linnaeus classified *Capsicum* spp. based primarily on fruit shape, size and colour and acquired the status of species possibly as the cultivars generally bred true. The morphological characteristics of fruits are found subsequently quite variable in varieties which developed in different regions. There is much parallel variation. Irish (1898) recognized only two species, *Capsicum annuum* and *Capsicum frutescens* and opined that *Capsicum annuum* is the most widely cultivated species with seven botanical varieties and 42 named horticultural forms. This classification was widely adopted by European and Asian botanists.

Bailey (1923), who reviewed the genus *Capsicum* later, concluded that since all capsicum plants are perennials, there is only one species which he called *Capsicum frutescens* (Syn. *Capsicum annuum*). This proposal was followed in the U.S.A.

Capsicum frutescens L. (Syn. *Capsicum annuum* L., *Capsicum baccatum*) is described as annual to perennial of tropical American Origin, and a very variable species. The following subspecies are distinguished.

1. Subsp. *cerasiforme* Bailey - cherry peppers, very pungent; varying colours; cv. Oxheart
2. Subsp. *fasciculatum* Irish - red cluster pepper, very pungent
3. Subsp. *conoides* Bailey - cone pepper, very pungent
4. Subsp. *longum* Sendt. long and mild cv. Country Fair
5. Subsp. *grossum* Sendt. Sweet bell pepper, apple to tomato shaped, used as salad or for stuffing cv. California Wonder
6. Subsp. *accuminatum* Fingh. longer than fasciculatum cv. Long Cayenne

Erwin (1932) accepted Bailey's treatment which was later supported by Miller and Fineman (1937) on the basis of hybridisation experiments. Melchior and Kastner (1974) in their book on spices, assigned all paprikas to *Capsicum annuum* and all pungent forms to *Capsicum frutescens*.

Key to classification

Systematic study of cultivated forms from the Old World and the source in the New World since the 1950's showed that four distinct species could be recognized based on a number of morphological characteristics. Smith and Heiser (1951) recognized both *Capsicum annuum* L. and *Capsicum frutescens* L. as valid species based on distinct floral characteristics and lack of crossability between them. Flower morphology provides more consistent characters for taxonomic identification. According to Shinners (1956), *Capsicum annuum* L. is correct under current rules of botanical nomenclature. Shaw and Khan (1928) recognized two cultivated

species in India as *Capsicum frutescens* and *Capsicum annuum*. Bravo (1934) also recognized both the species among Mexican peppers.

Smith and Heiser (1951) also described three other species cultivated in Latin America viz. *Capsicum pendulum* Willd. *Capsicum pubescens* R & P, and *Capsicum sinense* Jacq. These were keyed and described by Heiser and Smith (1953) and Heiser and Pickersgill (1969). With sufficient plant materials made available, the crossing behaviour of a few identified species were studied over a decade and the results were summarised by Smith and Heiser (1957) (Table 1).

A thorough knowledge of small fruited cultivated forms and their related wild species is necessary to understand evolution and relation among species. Such a study of cultivated capsicums and corresponding weedy types was undertaken by Pickersgill (1971) using parameters like geographic distribution, range of types, crossability, karyotypic variation and available archeological evidence. The taxonomic identity of cultivated and corresponding weedy forms collected from Latin America are:

a. *Capsicum annuum* var. *annuum*

aa. *Capsicum annuum* var. *glabriusculum* (Dunal) Heiser and Pickersgill (earlier var. *minimum*)

b. *Capsicum baccatum* var. *pendulum* (Willd) Eshbaugh

bb. *Capsicum baccatum* var. *baccatum*

c. *Capsicum chinense* Jacq.

cc. *Capsicum frutescens* L.

d. *Capsicum pubescens* Ruiz. et Pav.

dd. no weedy race was located

Table 1. Seedset in crosses among cultivated *Capsicum* species

Crosses	Initial cross	Viable F_2 seed	Viable back cross seed
Capsicum annuum x *Capsicum frutescens*	+	+	+
Capsicum annuum x *Capsicum chinense*	++	++	++
Capsicum annuum x *Capsicum pendulum*	E	+	-
Capsicum annuum x *Capsicum pubescens**	-	-	-
Capsicum frutescens x *Capsicum chinense*	+	+	+
Capsicum frutescens x *Capsicum pendulum*	++	+	+
Capsicum frutescens x *Capsicum pubescens**	-	-	-
Capsicum chinense x *Capsicum pendulum*	+	-	-
Capsicum chinense x *Capsicum pubescens*	E	-	-
Capsicum pendulum x *Capsicum pubescens**	-	-	-

Note: Arrow at the combination indicates direction of female parent
- no viable seeds
+ viable seeds
++ many viable seeds
E - seed germinated by embryo culture
* information on direction of cross is not available

Smith and Heiser (1957) described the cultivated species *Capsicum sinense* Jacq; a synonym of *Capsicum chinense*, originally described in India as *Capsicum luteum* by Lamark (1793) and *Capsicum umbilicatum* from Brazil. According to Heiser *et al.* (1971) *Capsicum frutescens* and *Capsicum chinense* form a complex of wild and cultivated peppers, comparable to the range of forms included within *Capsicum annuum* and *Capsicum baccatum*. In spite of closer morphological similarities between *Capsicum frutescens* and *Capsicum chinense*, the two species have a highly developed sterility barrier which effectively keeps them separate.

Emboden (1961) used the name *Capsicum baccatum* to refer to the small fruited bird pepper which is considered now the progenitor of cultivated *Capsicum annuum*.

Heiser (1969) recognized this error and indicated that much of the material referred to as *Capsicum baccatum* in the literature actually, should be designated *Capsicum annuum* var. *minimum* (Mill.) Heizer. Historically *Capsicum baccatum* is separated into two species *Capsicum microcarpum* and *Capsicum pendulum* (Lippert *et al.*, 1966). Noting the close morphological and cytogenetical relation of these two species; Hunziker (1961) and Eshbaugh (1968, 1970) suggested that they may be included within one species, *Capsicum baccatum* and should be treated as botanical varieties namely *Capsicum baccatum* var. *baccatum* and *Capsicum baccatum* var. *pendulum*. Pickersgill (1971) observed the distinct nature of *Capsicum baccatum* from *Capsicum chinense, Capsicum annuum* and *Capsicum frutescens* complex.

Casali and Couto (1984) proposed a key for identification of *Capsicum annuum, Capsicum baccatum, Capsicum frutescens, Capsicum chinense* and three

wild species *Capsicum praetermissum, Capsicum bufforum* and *Capsicum schottlianum.* Irish (1898) and Shaw and Khan (1928) used characters like fruit size, fruit orientation, leaf size and shape, calyx shape, flower size etc. to separate the species. Because of great variability within species, these characters offer little value.

Eshbaugh (1980) and Pickersgill (1980), recognising the extent of variability, consolidated the cultivated *Capsicum* into following five species.

1. *Capsicum annuum* L. Syn: *Capsicum purpureum, Capsicum grossum, Capsicum cerasiforme*
2. *Capsicum frutescens* L. Syn: *Capsicum minimum*
3. *Capsicum chinense* Jacq. Syn: *Capsicum luteum, Capsicum umbilicatum, Capsicum sinense*
4. *Capsicum baccatum* L. Syn: *Capsicum pendulum, Capsicum microcarpum, Capsicum angulosum*
5. *Capsicum pubescens* R & P

Biochemical diversity of *Capsicum* spp.

Another approach to morphological and genetic studies for classification of genus *Capsicum*, is to use secondary constituents of the plant, known to be under genetic regulation and are not affected by environmental fluctuations. Use of biochemical constituents like flavanoid, terpenoid, fatty acid and amino acid profiles for taxonomic purposes has definite advantages. Isozyme variations are used as powerful tools to compliment conventional phylogenic studies (Crawford, 1983; Gottlieb, 1971, 1977a, 1982; Rick *et al.*, 1976 and Rick and Tanksley, 1981).

Isozyme analysis by electrophoresis creates a well defined and effective

method to detect genetic differences among individuals. When the heredity represented by different bands in the zymograms is known, description of a single individual can be made at gene level (Yndgaard and Hoskuldsson, 1989). Among organic molecules, isozymes are very useful aids in deciphering evolutionary relationships within different groups of plant and animal organisms (Oliver and Zapater, 1985). Isozymes are used only as a supplementary tool, along with morphological and other methods of plant classification.

Uses of isozymes in the taxonomy of genus *Capsicum*

The genus *Capsicum* is less studied for isozymic genetic markers. Among 17 enzyme systems studied, the best result was expected by using the following: esterase, glutamate dehydrogenase, peroxidase, phosphoglucomutase, glutamate oxaloacetate transaminase and lactate dehydrogenase (Mathe and Wu, 1988).

Studies by Smith and Heiser (1957), Hirose *et al.* (1960), Eshbaugh (1964, 1970), Pickersgill (1969, 1971) and Novak and Betlakh (1971) determined breeding behaviour and relationship among several wild and domesticated species. Cytological investigations by Ohta (1962), Chennaveeraiah and Habib (1966), Shopova (1966) and Pickersgill (1971) grouped several taxa on the basis of specific karyotypes. Systematic biochemical research was initiated by Ballard *et al.* (1970) using flavanoid pattern analysis. After conducting flavanoid analysis on three *Capsicum* species, Lopes *et al.* (1978) suggested that there existed great affinity between *Capsicum annuum* and *Capsicum frutescens*. Twenty six genetic loci were analysed with four loci (TP, EST-6, GOT-3, GOT-5) being monomorphic for the same allele and 22 loci being polymorphic, when considered over the whole genus. Many of those loci, which were polymorphic, were found monomorphic or essentially so

when considered only for the purple flowered or white flowered taxa or sub groups of those taxa. The purple flowered taxa (*Capsicum cardinasii, Capsicum eximium, Capsicum pubesens* and the unnamed species) were all fixed for the a-allele at GPH and to be essentially monomorphic for the C-allele at the EST-7 locus. In addition, a consistent pattern was found at the various GOT loci for the entire purple flowered group.

This study was combined with the breeding data and both yielded similar results and thus genetic distance between different species was also estimated. The different *Capsicum* spp. are divided into white flowered taxa and purple flowered taxa. Within white flowered taxa, two subgroups were also identified.

Sub group I - *Capsicum baccatum* complex
Capsicum baccatum var. *baccatum*
Capsicum baccatum var. *pendulum*
Capsicum praetermissum

Sub group II - *Capsicum annuum* complex
Capsicum annuum var. *annuum*
Capsicum annuum var. *aviculare*
Capsicum frutescens

The status of *Capsicum chacoense* has not yet been studied in detail.

The seed protein compositions of eight taxa of *Capsicum* were compared by Panda *et al.* (1986) using disc electrophoresis. All protein bands differed among taxa and all taxa could be distinguished by seed protein electrophoresis.

Mcleod *et al.* (1979) used horizontal starch gel electrophoresis techniques with 15 enzymes for classification of *Capsicum* species. The enzymes resolved were esterase (EST), catalase (CAT), peroxidase (PRX), general protein (TP), 6-phospho-gluconate dehydrogenase (6-PGDH), lactose dehydrogenase (LDH), phosphoglucomutase (PGM), glutamate dehydrogenase (GDH), malate dehydrogenase (MDH), indophenol oxidase (IPO), glutamate oxaloacetate transaminase (GOT), isocitrate dehydrogenase (IDH), malic enzyme (ME), phosphogluco isomerase (PGI) and xanthine dehydrogenase (XDH). Zymograms of the 15 proteins (14 enzymes and 1 non-specific protein) were obtained after electrophoresis and histochemical staining.

Wang and Dehua (1987) analysed *Capsicum* germplasm of Northwestern Agricultural University, China using gel electrophoresis technique. They found that the best sampling tissue and sampling time for electrophoresis of peroxidase isozymes were functional leaves at flowering stage. Eight species were divided into 4 groups based on their zymograms;

Group A - *Capsicum annuum, Capsicum frutescens, Capsicum chinense*

Group B - *Capsicum chacoense, Capsicum pubescens*

Group C - *Capsicum praetermissum*

Group D - *Capsicum baccatum, Capsicum eximium*

Eighty accessions of *Capsicum annuum* var. *annuum*, with many of them being chinense land races, fell into three types, 73 belonged to type 'A' and 5 to type 'B' and 2 to type 'C'. Pradeepkumar (1990) reported that among five *Capsicum* species, close relationship was established between *Capsicum chinense* and *Capsicum*

frutescens. Protein electrophoretic studies revealed species specific protein bands in *Capsicum chinense, Capsicum baccatum* and *Capsicum chacoense*.

Andrzejewski *et al.* (1990) studied electrophoretic banding patterns of 13 enzymes in *Capsicum annuum* cv. Poznan Sweet and *Capsicum baccatum* and *Capsicum chacoense* with which they were crossed. Superoxide dismutase electrophoretic variants were species specific while those of four other enzymes were found to differentiate between *Capsicum annuum* and *Capsicum chacoense* but not between *Capsicum annuum* and *Capsicum baccatum*. These differences were used to confirm hybrid origin of progeny from interspecific crosses.

Merino *et al.* (1992) analysed 16 populations of *Capsicum annuum* L. using three different systems of electrophoresis. Belletti *et al.* (1992) studied allozyme variability among four domesticated species of *Capsicum (Capsicum annuum, Capsicum baccatum, Capsicum chinense* and *Capsicum frutescens*). Twenty one enzyme systems were identified and resulted in zymograms. Higher extent of polymorphism was found between genotypes of *Capsicum annuum* and *Capsicum baccatum*, whereas no variants were found within *Capsicum frutescens*.

Evaluation of paprikas

The increasing commercial importance world over of paprikas both as sources of paprika powder and oleoresin has resulted in establishing breeding programmes on its improvement to develop varieties/hybrids to meet international demand. Spice paprika, a mild variety of long fruited *Capsicum annuum* is a basic raw material for paprika oleoresin and also used as ground product.

The word 'paprika' means pepper in Hungarian language (Somos, 1984). Another confusing point is that in this language paprika means pepper whether they are pungent or nonpungent (Andrews, 1984; Bosland *et al.*, 1988). In New Mexico, when chilli peppers are harvested at the mature red stage of development they are used as paprika. Even though paprika is considered a product, in New Mexico and California, chile peppers with low and no pungency are commonly called paprika peppers (Bosland *et al.*, 1991). In Europe, paprika is made from two principal fruit types (1) a round fruit about the size of a peach and called Spanish or Moroccan paprika and (2) a longer more conical and pointed type grown in the Balkan countries called Hungarian paprika. Paprika may be pungent in Hungary; but in international trade paprika is always nonpungent. Spanish, Hungarian and U.S. paprika each has a slightly different taste (Bosland, 1992). Paprikasare distinguished by zero or no pungency and concentration of capsaicin range from zero to 30 ppm (Verghese *et al.*, 1992). Demand for sweet paprika (*Capsicum annuum* L.) oleoresins has increased due to ban on artificial colouring substances in the U.S.A. and other countries (Wolf and Alper, 1984).

Low yield being a limiting factor for paprika production in New Mexico, attempts were made to develop a suitable cultivar by Bosland *et al.* (1991). As a result 'NuMex Conquistador', a nonpungent, high yielding cultivar with high extractable red pigment was developed by crossing New Mexico 6-4 with NuMex R Naky. Capsaicinod analysis indicated that pungency in 'NuMex Conquistador' was less than 10 ppm. ASTA colour was significantly greater than (16%) for NuMex R Naky and 'New Mexico 6-4' (28%).

As there was no paprika variety grown commercially in India, breeding programmes were started at IARI, substation at Katrain (Joshi *et al.*, 1988 and 1993). The work on paprika improvement was taken up at this station to meet potential market of paprika in India and abroad by establishing superior genotypes/hybrids for commercial cultivation. The horticultural classification of 74 genotypes of paprika was done as per Smith *et al.* (1987).

1. Fruit large smooth, thick fleshed

A. Bell group - Fruit large, 7.5-12.5 cm long, blocky, blunt or rectangular, green when immature, turning red or orange yellow at maturity, mostly nonpungent - California Wonder, Yolo Wonder, Arka Gaurav, Arka Mohini, Early Bounty, Suttons Gem Giant, Bharat, Sweet Bullnose, HC-201, HC-202, Kt-2, Kt-Pl-5, Kt-Pl-6, EC-12202, EC-119043, EC-119051, EC-119058, EC-143567, EC-143570, EC-157029, EC-160093, EC-174852, EC-240610.

B. Pimento group - Fruits heart shaped 3.7-12 cm long, smooth thick walled mostly nonpungent - EC-93056, Kt-Pl-13, EC-203586.

2. Fruits yellow when immature

A. Waxy conical group, fruits large 7.5-12.5 cm long, blocky, blunt or conical. Turns red at maturity mostly nonpungent - Russian yellow, AC-216, AC-217, Kt-Pl-12, Kt-Pl-16, EC-109050, EC-129392, EC-129393, EC-157030, EC-165834, EC-174857, EC-202463, EC-202467, EC-203581, EC-203582, EC-203583, EC-203584, EC-203585, EC-203587, EC-203588, EC-203589, EC-20350.

B. Long waxy group - fruits 8.5-17.5 cm long, pointed or blunt, thick walled both pungent and nonpungent, turns red at maturity - EC-114366, EC-157031, EC-202469, EC-203592, EC-203593, EC-203594, EC-203595, EC-203597, EC-203598, EC-203599, EC-203600.

3. Fruit broad, smooth, thin-walled

A. Ancho group - fruits 8-15 cm long, heart shaped, pointed, thin walled, fruits with sweet, mild and pungent forms, green when immature, turning red at maturity - AC-215, AC-218, Kt-1, Kcp-1, Kcp-2, Kt-Pl-7, Kt-Pl-8, Kt-Pl-9, Kt-Pl-10, Sel-4, Venedale, EC-109054, EC-119049, EC-114362, EC-129391, EC-165831, EC-174816, EC-174867, EC-202468, Pt-19-1-2.

4. Fruits long slender

A. Anaheim chilli group - Fruits medium to dark green, smooth, 15-20 cm long, tapering to pointed tip flesh medium thick, sweet, mild and pungent form, turns red at maturity. Sweet Banana, Cubanelle, Harris Early Giant, AC-219, N-16, Kt-Pl-4, Kt-Pl-14, Kt-Pl-15, N-106, Pt-19-3, EC-109048, EC-119048, EC-165832, EC-173372, EC-173374, EC-174854, EC-174862.

B. Long thin cayenne group - Fruits, long slender, medium to dark green, 9.5-25 cm, characteristically wrinkled, irregular in shape thin walled, mostly pungent mature fruits mostly red with a few orange yellow. NP-46-A, Hot Portugal, Perennial, Cluster, Indonesian Sel, Pachhad Yellow, Bunchy Oange, Kalyanpur No.1, 1-65, LCA-206, LCA-235, Kt-PC-11, LC-5, LC-8, EC-222247.

5. Fruits elongated to 8.5 cm long, green when immature

A. Serrano group - Fruits slender, cylindrical often slightly constricted near middle, highly pungent, turns red - Serrano.

B Small hot group - Fruits slender, medium to thin walled, less than 7.5 cm highly pungent, immature fruits green, black or dark purple. Turning red at maturity. Pant C1, Local chilli, Gaubat Black, CA-586, LC-4, LC-4, LC-6, EC-174858.

6. Fruits small, globular to oblate, thick flesh

A. Cherry group - Cherry shaped fruits green turning red pungent - EC-203603.

B. Tomato shaped - thick fleshed waxy or green fruits, smooth to corrugated, red at maturity, sweet or moderately pungent. Sel-2, EC-203591, EC-203602.

Among 230 lines evaluated at Katrain, three breeding lines viz. Kt-Pl-8, Kt-Pl-18 and Kt-Pl-19 were identified as promising. On the basis of overall performance, genotype Kt-Pl-19 was superior to Kt-Pl-18 and Kt-Pl-8 with colour units of 86925, 64812 and 66337 EOA, much higher in comparison with chilli varieties.

Morphological characteristics of these promising lines following Joshi *et al.* (1988) are as follows:

Kt-Pl-8 - Indeterminate pendent bearing, nonpungent fruits between ancho and anaheim group tapering to a pointed tip, green turning bright red, productive.

Kt-Pl-18 - Indeterminate, pendent bearing, nonpungent, belongs to anaheim group, tapering to slightly sunken tip, dark green turning red at maturity, productive.

Kt-Pl-19 - Indeterminate, pendent bearing, nonpungent fruits, belongs to anaheim group, tapering to slightly curved tip, highly productive.

Research on development of disease resistant and highly productive paprika varieties, selection of genotypes with fruits which do not lose its elasticity and remain intact while packing, and standardisation of seed production techniques, are in progress at Katrain.

Materials and Methods

MATERIALS AND METHODS

The present investigations were carried out in the Department of Olericulture, College of Horticulture, Kerala Agricultural University, Vellanikkara during the period from 1990 to 1993. The experimental field was located at an altitude of 22.5 M above MSL between 70° 32' N latitude and 76° 16' E longitude. The area enjoyed a warm humid tropical climate. The experimental site had a sandy loam soil with a pH of 5.0.

The studies were conducted on the following aspects:

A. Diversity interrelationships between *Capsicum* spp. and forms

B. Evaluation of paprikas for adaptability and resistance to bacterial wilt

A. Diversity interrelationship between *Capsicum* spp. and forms

The experiment has two parts -

1) Biometric method of estimating diversity

2) Biochemical methods of estimating diversity

1) Biometric method of estimating diversity

Experimental materials

Eighty two genotypes of chilli belonging to four cultivated *Capsicum* spp and to different horticultural groups of *Capsicum annuum* were collected through survey and correspondence. Most of them were from Indian Institute of Horticultural Research, Bangalore and IARI, Regional Station, Katrain. There were a few exotic

strains in the collections made. Details of the genotypes used are depicted in Tables 2 and 3.

Methods

Two seasons (August 1991 to January 1992 and May 1992 to September 1992) were selected for the evaluation of the genotypes. During the first season 71 genotypes were evaluated and during the second season 72 types were evaluated, of which 61 genotypes were common. Seeds of all the genotypes were sown in sterilised nursery beds and the seedlings were transplanted to pots (30 cm) at six weeks. The potting mixture had a composition of soil : sand : farmyard manure in the ratio 1 : 1 : 1. The mixture was chemically sterilised using formalin. The solution was prepared by mixing formaldehyde with water in the ratio 1 : 30; 3 litres of the solution was applied per m^2 of soil when the soil was moist. The pot was covered for two days, stirred, covered again for 3 days and kept in open condition for 10 days.

There were six pots under each genotype and observations were recorded from 5 plants. There was only one seedling per pot. A fertiliser dose of 3:1:0.50 g of N, P and K/pot was given. Half N, full P_2O_5 and full K_2O were applied as basal dose and the remaining N was applied in 3 split doses. Raking was done at two weeks interval to keep down weeds. The plants were watered daily except during rainy season. Plant protection measures were undertaken as per Package of Practices (Kerala Agricultural University, 1989). Morphological evaluation of these lines was done based on the descriptor list prepared by IBPGR (1983). The following observations were recorded.

Table 2. Genotypes used during first season (August 1991 - January 1992)

Sl. No.	Acc. No.	Source	Sl. No.	Acc. No.	Source
1	2	3	4	5	6
1	CA 33 (Manjari)	COH, Vellanikkara	18	CA 537	IARI, Katrain
			19	CA 539	"
2	CA 60 (Jwala)	IARI, New Delhi	20	CA 540	"
3	CA 89 (White kanthari)	Local	21	CA 542	"
			22	CA 543	"
4	CA 219	COH, Vellanikkara	23	CA 544	"
5	CA 516	IIHR, Bangalore	24	CA 545	"
6	CA 517	"	25	CA 546	"
7	CA 519	"	26	CA 547	"
8	CA 521	"	27	CA 548	"
9	CA 523	"	28	CA 549	"
10	CA 525	"	29	CA 553 (Bharat Hybrid)	IAHS, Bangalore
11	CA 530	IAHS, Bangalore			
12	CA 531 (Yolo Wonder)	IARI, Katrain	30	CA 556	"
			31	CA 557	"
13	CA 532 (California Wonder)	"	32	CA 559	IIHR, Bangalore
			33	CA 560	Local
14	CA 533	"	34	CA 562	Kodaikanal
15	CA 534 (Russian (Yelow)	"	35	CA 564	Local
			36	CA 568	IIHR, Bangalore
16	CA 535	"	37	CA 569	South Moravia
17	CA 536	"	38	CA 570 (Vesna)	"

Table 2. Continued

1	2	3	4	5	6
39	CA 572 (Jova)	South Marava	58	CA 603 (Papri King)	Belts Ville, USA
40	CA 573 (Klenot Early)	"	59	CA 604 (Papri Queen)	"
41	CA 574 (Jova)	"	60	CA 605 (Papri Mild)	"
42	CA 575	IIHR, Bangalore	61	CA 610	IIHR, Bangalore
43	CA 576	Turkey	62	CA 611	"
44	CA 579	IARI, Katrain	63	CA 612	"
45	CA 582	IIHR, Bangalore	64	CA 628 (Green Chuna)	Local
46	CA 586	"	65	CA 629	COH, Vellanikkara
47	CA 587	"	66	CA 631	Local
48	CA 589	Sikkim	67	CA 632	Local
49	CA 590	IIHR, bangalore	68	CA 635	Local
50	CA 591 (Byadagi)	Dharwad	69	CA 636	Local
51	CA 593	IIHR, Bangalore	70	CA 638	Local
52	CA 594 (Arka Mohini)	"	71	CA 640	Local
53	CA 595	"			
54	CA 597 (Arka Gaurav)	"			
55	CA 598	"			
56	CA 600	"			
57	CA 601	Spices Board, Cochin			

Table 3. Genotypes used during second season (May 1992 to September 1992)

Sl. No.	Acc. No.	Souce.	Sl. No.	Acc. No.	Source
1	CA 33 (Manjari)	COH, Vellanikkara	17	CA 536	IARI, Katrain
			18	CA 537	"
2	CA 60 (Jwala)	IARI, New Delhi	19	CA 539	"
3	CA 89 (White Kanthari)	Local	20	CA 540	"
			21	CA 543	"
4	CA 219	COH, Vellanikkara	22	CA 544	"
5	CA 451 (Jwalamukhi)	COA, Vellayani	23	CA 546	"
			24	CA 547	"
6	CA 452 (Jwalasakhi)	"	25	CA 548	"
7	CA 561	IIHR, Bangalore	26	CA 549	"
8	CA 517	"	27	CA 553 (Bharat Hybrid)	IAHS, Bangalore
9	CA 519	"			
10	CA 521	"	28	CA 554	"
11	CA 523	"	29	CA 556	"
12	CA 530 (Hungarian Wax)	"	30	CA 557	"
			31	CA 558	Local
13	CA 531 (Yolo Wonder)	IARI, Katrain	32	CA 559	IIHR, Bangalore
			33	CA 560	Local
14	CA 532 (California Wonder)	"	34	CA 561	"
			35	CA 564	"
15	CA 533	"	36	CA 567	Thirupathisaram
16	CA 534 (Russian Yellow)	"	37	CA 568	IIHR, Bangalore

Contd.

Table 3. Continued

1	2	3	4	5	6
38	CA 569	South Moravia	57	CA 605 (Papri Mild)	Beltsville
39	CA 570 (Vesna)	"	58	CA 610	IIHR, Bangalore
40	CA 572 (Jara)	"	59	CA 611	"
41	CA 573 (Klenot Early)	"	60	CA 612	"
42	CA 574 (Jova)	"	61	CA 613	"
43	CA 575	IIHR, Bangalore	62	CA 628 (G. Chuna)	Local
44	CA 576	Turkey	63	CA 629	COH, Vellanikkara
45	CA 577	IIHR, Bangalore	64	CA 630	Local
46	CA 579	IARI, Katrain	65	CA 631	Local
47	CA 582	IIHR, Bangalore	66	CA 632	Local
48	CA 586	"	67	CA 635	Local
49	CA 587	"	68	CA 636	Local
50	CA 589	Sikkim	69	CA 638	Local
51	CA 590	IIHR, Bangalore	70	CA 639	Local
52	CA 591 (Byadagi)	Dharwad	71	CA 640	Local
53	CA 597 (A. Gaurav)	IIHR, Bangalore	72	CA 622	Trinidad
54	CA 600	"			
55	CA 603 (Papri King)	Beltsville			
56	CA 604 (Papri Queen)	"			

Plant growth	- prostrate, compact, erect
Stem pubescence	- glabrous, sparse, intermediate,abundant
Stem colour	- green, purple
Leaf pubescence	- glabrous, sparse, intermediate,abundant
No. of pedicels/axil	- solitary, clustered
Pedicel position at anthesis	- pendant, intermediate, erect
Corolla colour	- white, green, lavender, blue, violet, other
Corolla spot	- absent, white, yellow, green
Calyx margin	- smooth, intermediate, dentate
Presence of annular constriction at calyx pedicel junction	- absent, present
Fruit shape at pedicel attachment	- acute, obtuse, truncate, cordate, lobate
Neck at base of fruit	- absence, present
Fruit shape at blossom end	- pointed, blunt, sunken
Fruit persistence	- deciduous, persistent
Fruit position	- declining, intermediate, erect
Fruit colour in immature stage	- green, yellow, orange, red, purple, brown, black
Fruit colour in mature stage	- green, yellow, orange, pale purple, brown, black
Fruit length	- very short, short, medium long, very long
Fruit shape	- elongate, oblate, round, conical, companulate, bell or blocky

Observations on following quantitative characters were also recorded.

Plant height (cm)

Primary branches/plant

Days from sowing to first flowering

Yield/plant (g)

Pedicel length (cm)

Fruit length (cm)

Fruit girth (cm)

Seeds/fruit (cm)

Capsicum annuum accessions were subjected to horticultural classification as per Greenleaf (1986) and Smith *et al.* (1987) (Fig. 1).

Statistical analysis

Assessment of genetic divergence

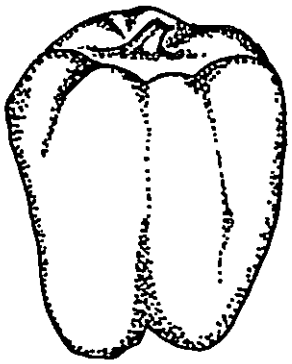
The genetic distances among the genotypes were calculated, considering the above 8 quantitative characters. The method suggested by Mahalanobis (1928) was used to estimate D^2 with x_1, x_2, x_3 ..... x_p as the multiple measurements available on each individual and d_1, d_2, d_3 ....., d_p as $x_1^{(1)} - x_1^{(2)}$, $x_2^{(1)} - x_2^{(2)}$, ..., $x_p^{(1)} - x_p^{(2)}$ respectively, being the difference in means of two populations, where superscripts denote genotypes and suffix denotes characters. Mahalanobis D^2 statistic is defined as

$$D^2_p = b_1d_1 + b_2d_2 + \ldots\ldots b_pd_p$$

Fig.1. Horticultural classification of Capsicum annuum (Smith et al., 1987)

I. Fruit large, smooth, thick fleshed

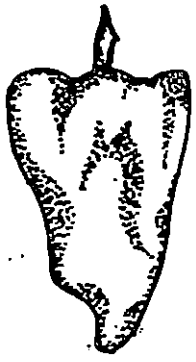
A
BELL GROUP



B
PIMENTO GROUP

II. Fruit broad, smooth, thinwalled

A. ANCHO GROUP

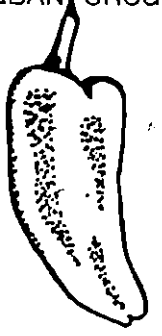


III. Pods long, slender

A
ANAHEIM GROUP

B
CAYENNE GROUP

C
CUBAN GROUP

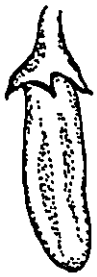


IV. Fruit elongated to 7.5 cm long, green when immature

A
JALAPENO GROUP

B
SERRANO GROUP

C
SMALL HOT GR

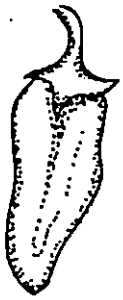


V. Fruit small (to 5 cm) globlar to oblate, thick flesh

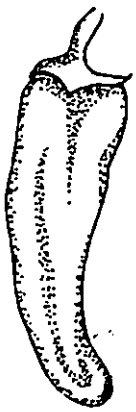
A. CHERRY GROUP

VI. Fruit yellow when immature

A
SHORT WAX GROUP

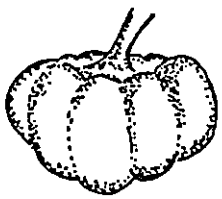


B
LONG WAX GROU



VII. Fruit small-large, wider than deep, rounded

A. SQUASH/CHEESE GROUP (Greenleaf, 1986)



Here, the b values are to be estimated, such that the ratio of variance between populations to the variance within the population is maximised. In terms of variances and co-variances, the D^2 value between population 1 and population 2 is obtained as follows:

$$D^2_p = \sum_{i,j=1}^{P} W^{ij} (x_i^{(1)} - x_i^{(2)}) (x_j^{(1)} - x_j^{(2)})$$

where W^{ij} is the i, j^{th} element of inverse of the estimated variance covariance matrix.

The square root of D^2 value was calculated to obtain generalised statistical distance between two genotypes.

Clustering of genotypes

All the genotypes were grouped into a number of clusters by the computer oriented interactive algorithm proposed by Suresh (1986) as follows:

The two genotypes having maximum D^2 value between them were identified and they were termed the nuclei of two clusters.

Each genotype was considered in turn and allocated to the cluster for which its D^2 value with the nucleus genotype was minimum

To increase the number of clusters by one, the maximum D^2 within the above two clusters was found and the genotypes having maximum D^2 was considered as the nuclei, in addition to the nucleus genotype of the remaining clusters. The genotypes were re-assigned as in second step.

The initial clusters thus obtained were further optimised using the interactive algorithm as described below.

(a) Number the genotypes from 1 to 72

(b) Take out genotype No.1 from the cluster to which it was allocated and calculate the average D^2 values between this genotype and each cluster. Allocate this genotype to the cluster for which the average D^2 value is minimum.

(c) Repeated (b) for all genotypes numbered from 1 to 72 with the clustering obtained in step (c) a second iteration may be started, if necessarcy.

The iterations were continued till two successive iterations ended up with the same configuration of clusters.

2) Biochemical methods of estimating diversity

Two biochemical methods viz. polyacrylamide gel electrophoresis (PAGE) and Agarose Gel Iso electric focussing (AGIEF) were used to estimate biochemical diversity.

Polyacrylamide gel electrophoresis

Polyacrylamide gel electrophoresis (PAGE) using disc gel (Ornstein and Davis, 1962) was carried out for identifying the electrophoretic pattern of isozymes. Acrylamide monomer (CH_2 = CHCO NH_2) was co-polymerised with N-N'-methylene bis acrylamide (CH_2 (NH CO NH = CH_2) = bis). Freshly prepared ammonium persulphate acted as catalyst and N, N, N', N' - tetra methylethylene diamine (TEMED) as chain initiator.

Poly acrylamide gel was preferred to other gels because of its ease in preparation and handling, high resolution, transparency of the gel and its chemical inertness.

Isozyme variations of two enzymes viz. peroxidase and esterase were studied.

Preparation of the sample

For peroxidase enzyme roots of one month old seedlings and for esterase enzyme, mature leaves were used. They were collected from the plants raised in pots. Samples for electrophoretic study was prepared as per methods suggested by Wendel (1990).

The plant parts were washed under tap water and then rinsed with distilled water. The adhering water was removed using blotting sheets. One gram of sample along with 2 ml of 0.1 M Tris buffer (pH 7.6) having 0.1 per cent mercaptoethanol and L-cysteine hydrochloride was blended in a chilled mortar and pestle. The homogenised material was centrifuged at 3000 rpm for 10 minutes. After centrifugation the clear supernatant was collected and used for electrophoretic studies.

Preparation of the gel

Reagents

All the enzymes were analysed in anionic system. The following stock solutions were prepared.

A_1 - 1M HCl 48.0 ml

Tris 36.6 g

TEMED 0.23 ml

(pH 8.9)

Total volume made upto 100 ml with distilled water.

A_2 - Acrylamide 30.0 g

Bis acrylamide 0.8 g

Total volume made upto 100 ml with distilled water.

A_3 - Ammonium persulphate 0.14 g

Water 100 ml
(Prepared fresh for each run)

Preparation of gel column

Acrylamide (7.7%) was prepared using the above stocks. A_1, A_2, A_3 and A_4 (distilled water) was mixed in the proportion 1:2:4:1 and this solution was allowed to polymerise in the electrophoretic column.

Electrode buffer

Stock solution

Tris 6 g

Glycine 28.8 g

Water volume to 1 lit. pH 8.3

The stock buffer was diluted 1:9 before use.

After polymerisation, the gel columns were transferred to the electrophoretic apparatus. The upper and lower tanks were filled with electrode buffer. Upper tank was connected to the cathode and lower one to the anode. 0.01 ml of sample was applied to each tube. A drop of 0.2 per cent Bromophenol blue was added to each tube as marker dye.

Electrophoresis was carried out at 8°C for about 4½ hrs. A constant current of 2.5 mA per tube was maintained throughout the run. The buffer employed was Tris - glycine (pH 8.3). On completion of the electrophoretic run, the gels were removed under a fine stream of water.

Staining solution for peroxidase

a. Acetate buffer (0.2 M) - 200 ml pH 5.6

b. Benzidine - 0.2 g

c. H_2O_2 (3%) - Diluted 1 ml of stock solution (30%) to make 10 ml with distilled water

Prepared fresh stain by mixing 'a' and 'b' which was boiled, cooled and filtered. Added 0.8 ml of 3 per cent H_2O_2. Immersed the gels in the above solution till brown bands appeared. The gels were washed with 7 per cent acetic acid.

Staining solution for esterase

a. Phos - A Na_2HPO_4 (0.2 M) pH 8.8

b. Phos - B NaH_2PO_4 (0.2 M) pH 4.6

c. Fast Blue RR - 200 mg

d. α - naphthyl acetate - 0.1 g dissolved in 10 ml of 50 per cent acetone

Prepared fresh stain by mixing 20 ml of a, 100 ml of b, 200 mg of c, 4 ml of d and 80 ml of distilled water. Incubated the gels till dark bluish bands appeared.

Isozyme pattern in different parts of the plant

This experiment was done for both enzymes viz. peroxidase and esterase. The following parts were analysed.

1. Roots
2. Young leaves
3. Mature leaves

Nomenclature of isozymes

The enzyme peroxidase was designated by abbreviation - PRX and esterase as EST. The Rm (relative mobility) value was calculated using the formula

$$\frac{\text{Distance migrated by the band}}{\text{Distance migrated by the dye}}$$

The *Capsicum* spp. were subjected to agarose gel isoelectric focussing (A.G.I.E.F.) technique as detailed below:

Sample preparation

Root tissues (0.5 g) of the three species viz. *Capsicum annuum, Capsicum chinense* and *Capsicum frutescens* were homogenised separately in precooled mortar and pestle using 1.5 ml Tris buffer. This mixture was centrifuged at 3000 rpm for 10 minutes and the supernatant was decanted out for the study.

Preparation of Agarose Gel (1 mm thick)

The glass plates (125 mm x 80 mm x 2 mm) were throughly cleaned to make it grease free and then dried. Isogel agarose solution (0.5%) prepared in distilled water by boiling was used for coating the glass plates in order to facilitate adhesion of agarose gel. The glass plates were then dried and kept ready for use. The LKB horizontal table was properly levelled using the spirit level and screw legs. Isoagarose (0.100 g) (LKB) and 1.0 g sorbitol (Merck) were mixed thoroughly with 9.5 ml glass distilled water taken in a test tube. This was placed in a shallow water bath at 100°C and allowed to dissolve completely by constant stirring. When the agarose was completely dissolved and when no more air bubbles were formed in the solution, the test tube was taken out of the water bath. Ampholine (LKB) 0.5 ml or servalyte (serva) of the required pH range was added immediately into the test tube and mixed thoroughly using a glass rod. The mixed solution was immediately poured on to the agarose pre-coated glass plate kept on the horizontal table. The solution was allowed to spread evenly on the glass plate surface and allowed to solidify. The gel was kept at room temperature for 30 minutes and then transferred to a humid chamber and was kept in refrigerator at 4°C overnight before use.

Application of sample

The gel plates were removed from the humid chamber and blotted with Whatman Filter paper No.1 to remove excess moisture present on the gel surface. A few drops of detergent solution was poured on the cooling plate of multiphor (LKB) in order to aid thermal exchange. Care was taken to avoid trapping of air bubbles under the glass plate when the gel plate was transferred on to the cooling plate of the

multiphor. The anode and cathode electrode strips were soaked in anode solution (Appendix-I) and cathode solution (Appendix-I) respectively and were placed on the respective ends of the gel. The sample application strips (LKB) were then placed on the anode end about 2 cm away from the anode and at 5 mm apart. The strips were then charged with 10 microlitre extracts of the sample.

Electro focussing

The cryothermostat multitemperature cooling system (colora) was switched on in advance to allow an effective cooling temperature of 8 °C. The electro focussing lid of the multiphor was placed above the gel taking care to ensure that the platinum electrodes were touching the electrode strips evenly to attain proper contact. The anode and cathode terminals were then connected to the multiphor and the upper lid of the multiphor was closed. The lead wire of the multiphor was connected to the power supply (LKB 2103). The power supply was set at 200 volts, 50 mA, 10W for the first 10 minutes. The voltage was raised to 500 volts, 50 mA and 10W for the next 20 minutes. At the end of 30 minutes run, the power supply was switched off and the multiphor was opened to remove the sample application strips from the surface of the gel. After removal of sample application strips, the multiphor was closed and the power supply set at 1000V, 50 mA and 20W was switched on and allowed to run for 30 minutes. At the end of 30 minutes run, the power supply was switched off and multiphor opened to remove the electrode strips from the gel.

Fixing

The gel plate was immediately transferred to a glass container and kept

immersed in fixing solution (Appendix-I) for 20 minutes. The gel was then kept immersed in ethanol for 15 minutes. After washing in ethanol, the gel plate was placed securely on a glass plate kept on a level surface. Whatman No.2 filter paper cut to the size of the gel plate was soaked in ethanol and placed carefully over the gel surface avoiding trapping of air bubbles between the gel and filter paper. A few more layers of filter paper were placed on the gel and then the surface was covered with a glass plate. The gel was kept pressed using a weight of 1 kg placed on the glass plate covering the gel. After 30 minutes the weight was removed and the filter paper sheets were removed from the gel surface.

Staining and destaining

The gel was then dried under warm air using a hair drier. When the gel was completely dry, it was stained with staining solution (Appendix-I) for 15 minutes. Destaining was performed using several changes of destaining solution for 20-30 minutes. After proper destaining the gel was again dried under warm air.

B. Evaluation of paprikas for adaptability and resistance to bacterial wilt

Experiment 1: Survey, collection, evaluation and cataloguing of paprikas

Twenty lines were collected through correspondence and personal contact. They were first raised in sterilized pots and described as per IBPGR plant descriptor.

Experiment 2: Field evaluation of paprika

Twenty accessions of paprikas from different sources were sown in a

nursery and 6 weeks old seedlings were transplanted to the main field. This experiment was conducted during two seasons (October-March, 1992, May-October, 1992). There were 20 plants/line. The crop was raised as per Package of Practices (Kerala Agricultural University, 1989), for chilli and the following observations were recorded from 5 randomly selected plants.

Days to first flowering

Days to first harvest

Plant height (cm)

Plant spread (cm)

Fruits/plant

Yield/plant (g)

Reaction to bacterial wilt (% wilt)

Number of plants wilted at different stages viz. 15, 30, 45, 60 DAP and at final harvest stage were recorded and percentage worked out. The genotypes were scored according to Mew and Ho (1976).

R - Resistant (< 20% wilted plants)

MR - Moderately resistant (20-40%)

MS - Moderately susceptible (40-60%)

S - Susceptible (> 60%)

Colour value (ASTA Units)

This was estimated as per Hort and Fisher (1971). Red ripe chillies were dried and the stalk and seeds were removed before powdering. 0.1 g of ground chilli powder was transferred into a 250 ml Erlenmeyer flask, pipetted 100 ml of

isopropanol into the flask and kept overnight at room temperature. Filtered the contents through a Whatman No.42 paper, discarding the first 10 ml. Pippetted out 25 ml of the filtrate into a 50 ml volumetric flask and diluted to the mark with isopropanol. The absorbance was read at 450 nm against isopropanol as blank.

Standard colour (b) solution was prepared by dissolving 0.5 mg/ml of reagent grade $K_2Cr_2O_7$ in 1.8 M H_2SO_4(c).

Absorbitivity (a) of standard colour solution =

$$\frac{\text{Absorbance of standard colour solution at 450 nm}}{\text{Cell length x concentration (mg/ml)}}$$

Extractable colour (ASTA Units) =

$$\frac{\text{Absorbance of extract at 450 nm x 200}}{\text{Cell length (cm) x a x concentration of solution (mg/ml)}}$$

Pungency (Capsaicin content)

This was estimated using the procedure of Theymoli *et al.* (1982). Ripe red chilli fruits were dried uniformly in a hot air oven at 50°C and the stalk and seeds were removed. The remaining part was powdered and 0.5 g of this powder was shaken for 3 hrs with 10 ml of acetone in a mechanical shaker. Then it was centrifuged at 5000 rpm for 10 minutes. Pippetted out 1 ml of clear supernatent into a test tube and evaporated to dryness in a hot water bath. Dissolved the residue in 5 ml of 0.4% NaOH, added 3 ml of 0.3% phosphomolybdic acid and made up to 10 ml. It was kept for one hour. After shaking, centrifuged the contents at 5000 rpm for 10-15 minutes and filtered. Transferred the clear blue solution directly into the cuvette and read the absorbance at 650 nm on spectronic 20.

Data recorded for quantitative characters were analysed as described by Panse and Sukhatme (1978).

Results

RESULTS

Observations from the present study were analysed statistically and are presented under following heads:

A. Morphological description of chilli germplasm

B. Assessment of genetic divergence and grouping of genotypes

C. Biochemical grouping

D. Evaluation of paprikas

A. Morphological description of chilli germplasm

The 82 chilli accessions grown during two seasons exhibited variation for morphological characters like growth habit, pubescence of stem and leaves, stem colour, corolla and fruit, number of pedicels/axil, presence/absence of yellow spot at the base of corolla lobes and for presence of annular constriction at the calyx pedicel junction. Elongate, conical, heart shaped, round and bell fruit shapes and different sizes were observed among the accessions (Plates 1 and 2). The accessions, when subjected to the taxonomic treatments fell under four *Capsicum* species viz. *Capsicum annuum* (74 genotypes), *Capsicum frutescens* (two genotypes), *Capsicum chinense* (five genotypes) and *Capsicum baccatum* (one genotype). CA 89 (White Kanthari) and CA 628 (Green Chuna) belonged to *Capsicum frutescens*. Accessions CA 559, CA 560, CA 631, CA 622 and CA 640 belonged to *Capsicum chinense* and CA 519 to *Capsicum baccatum*.

Plate 1. Variability in fruit shape


VARIABILITY

Plate 2. Variability in fruit size

Plate 3. CA 536


CA 536

Key to domesticated species of *Capsicum*

1. Seeds dark, corolla purple.....*Capsicum pubescens*

2. Seeds straw coloured, corolla white or greenish white.....2

2. Corolla with diffused yellow spots at base of lobes ..... *Capsicum baccatum*

CA 519

3. Corolla without diffused yellow spots at base of lobes 3

3. Corolla purple 4

4. Flowers solitary ..... *Capsicum annuum* CA 546, CA 556, CA 557, CA 632, CA 638, CA 639

5. Flowers 2 or more at each node ..... *Capsicum chinense*

3. Corolla white or greenish white 5

5. Calyx of mature fruit with annular constriction at junction with pedicel ..... *Capsicum chinense* CA 559, CA 560, CA 622, CA 631, CA 640

Calyx of mature fruit without annular constriction at junction with pedicel 6

Flowers solitary 7

7. Corolla milky white, lobes usually straight, pedicels often declining at anthesis ..... *Capsicum annuum* CA 60, CA 451, CA 452, CA 516, CA 517, CA 521, CA 523, CA 525, CA 530, CA 531, CA 533, CA 534, CA 535, CA 536, CA 537, CA 539, CA 540, CA 542, CA 543, CA 544, CA 545, CA 546, CA 547, CA 548, CA 549, CA 553, CA 554, CA 558, CA 561, CA 562, CA 564, CA 567, CA 568, CA 569, CA 570, CA 572, CA 573, CA 574, CA 575, CA 576, CA 577, CA 579, CA 582, CA 586, CA 587, CA 589, CA 590, CA 591, CA 593, CA 594, CA 595, CA 597, CA 598, CA 600, CA 601, CA 603, CA 604, CA 605, CA 610, CA 611, CA 612, CA 613, CA 630, CA 635 and CA 636.

7. Corolla greenish white, lobes usually slightly revolute, pedicels erect at anthesis ..... *Capsicum frutescens*

CA 89

6. Flowers 2 or more at each node.....8

8. Corolla milky white ..... *Capsicum annuum*

CA 33, CA 219, CA 629

8. Corolla greenish white 9

9. Pedicels erect at anthesis, corolla lobes usually slightly revoluted ..... *Capsicum frutescens*

CA 628

9. Pedicels declining at anthesis, corolla lobes straight ..... *Capsicum chinense*

CA 631, CA 622

The 74 accessions belonging to *Capsicum annuum* fell into different horticultural groups like pimento, waxy conical, long wax, ancho, anaheim, tomato shaped, cherry shaped, small hot and bell or blocky. There were two genotypes under pimento group (CA533 and CA 600), two genotypes under conical waxy (CA 534 and CA535), one under short waxy (CA 536) (Plate 3), three under long waxy (CA 530 (Plate 4), CA 537 and CA 554), three under ancho (CA 539 (Plate 5), CA 540 and CA 542), ten genotypes under anaheim (CA 543, CA 544, CA 545, CA 603 (Plate 6), CA 604, CA 605, CA 610, CA 611, CA 612 and CA 613), four genotypes under cherry (CA 521, CA 547 (Plate 7), CA 561 and CA 636), four under cheese group (Tomato shaped) (CA 548, CA 549, CA 574 (Plate 8) and CA

Plate 4. CA 530 (Hungarian Wax)

Plate 5. CA 539


HUNGARIAN WAX


CA#39

Plate 6. CA 603 (Papri King)

Plate 7. CA 547


PAPRI KING


CA347

595) and ten under blocky group (CA 531, CA 532, CA 533, CA 562, CA 567, CA 570 (Plate 9), CA 572, CA 573, C 594 and CA 597).

B. Assessment of genetic divergence and grouping of genotypes

General analysis of variance showed significant differences among genotypes for the eight characters studied for both seasons (Table 4).

During the first season (August, 1991 - January 1992), 71 chilli genotypes were grouped into nine clusters based on Mabalanobis D^2 statistics. Clusters I, II, III, IV, V, VI, VII, VIII and IX comprised of 11, 11, 11, 5, 8, 3, 8, 3 and 11 genotypes respectively (Table 5).

During second season (May 1992 to September 1992), 72 accessions were grouped into six clusters. Clusters I, II, III, IV, V, and VI comprised of 24, 15, 5, 21, 5 and 2 accessions respectively (Table 6).

Intra and intercluster D^2 and D values of nine clusters during first season and six clusters during second season are presented in tables 7, 8, 9 and 10 respectively (Fig. 2 and 3). The intra cluster distances in nine clusters ranged from 10.64 in cluster VII to 103. 54 in cluster VIII. The remaining intra cluster values were 12.67, 13.12, 14.88, 17.04, 19.58, 20.95 and 28.73 in clusters V, III, II, VI, I, IX and IV respectively. Cluster I had maximum average inter cluster distance with other clusters. It had maximum distance in six out of the eight combinations. The intercluster D^2 value between cluster I and cluster II was 156.02, between cluster III was 193.16, between cluster V was 233.33, between cluster VI was 307.04, between cluster VII was 280.62 and between cluster VIII was 698.16.

Plate 8. CA 574 (Jova)

Plate 9. CA 570 (Vesna)


cv VESNA

Table 4. General analysis of variance of chilli genotypes during two seasons

Sources of variation		df	Mean squares							
			1	2	3	4	5	6	7	8
Genotypes	S_1	70	366.120	917.441	41.602	2.370	50.696	131.560	26193.272	5855.402
	S_2	71	508.455	1088.690	24.116	2.744	46.479	79.849	5461.054	4636.503
Error	S_1	284	4.261	30.665	19.287	0.130	0.656	2.357	1426.670	289.980
	S_2	288	11.757	17.750	1.703	0.088	5.597	0.280	806.788	249.121

S_1 - August 1991 to January 1992
S_2 - May 1992 to September 1992

** p = 0.01

1. Days to first flower
2. Plant height (cm)
3. Primary branches/plant
4. Pedicel length (cm)
5. Fruit length (cm)
6. Fruit perimeter (cm)
7. Yield/plant (g)
8. Seeds/fruit

Table 5. Chilli genotypes clustered based on D^2 statistic during S_1

Cluster Number	Accessions	Total
I	CA 600, CA 601, CA 603, CA 604, CA 605, CA 610, CA 611, CA 612, CA 628, CA 629, CA 631	11
II	CA 562, CA 564, CA 568, CA 569, CA 570, CA 572, CA 573, CA 574, CA 575, CA 576, CA 579	11
III	CA 544, CA 545, CA 546, CA 547, CA 548, CA 549, CA 553, CA 556, CA 557, CA 559, CA 560	11
IV	CA 632, CA 635, CA 636, CA 638, CA 640	5
V	CA 33, CA 60, CA 516, CA 517, CA 519, CA 521, CA, 523, CA 525	8
VI	CA 89, CA 219, CA 530	3
VII	CA 531, CA 532, CA 534, CA 535, CA 537, CA 539, CA 542, CA 543	8
VIII	CA 533, CA 536, CA 540	3
IX	CA 582, CA 586, CA 587, CA 589, CA 590, CA 591, CA 593, CA 594, CA 595, CA 597, CA 598	11

Table 6. Chilli genotypes clustered based on D^2 statistic during S_2

Cluster Number	Accessions	Total
I	CA 523, CA 531, CA 532, CA 534, CA 536, CA 537, CA 539, CA 548, CA 549, CA 553, CA 564, CA 574, CA 577, CA 579, CA 582, CA 589, CA 597, CA 600, CA 603, CA 611, CA 632, CA 635, CA 639, CA 640	24
II	CA 519, CA 521, CA 533, CA 547, CA 556, CA 557, CA 558, CA 539, CA 561, CA 568, CA 575, CA 586, CA 629, CA 630, CA 636	15
III	CA 546, CA 560, CA 591, CA 628, CA 631	5
IV	CA 451, CA 452, CA 516, CA 530, CA 540, CA 543, CA 544, CA 554, CA 567, CA 569, CA 572, CA 573, CA 587, CA 590, CA 604, CA 605, CA 610, CA 612, CA 613, CA 638	21
V	CA 33, CA 60, CA 89, CA 219, CA 517	5
VI	CA 576, CA 622	2

Table 7. Intra and inter cluster D^2 values of 9 clusters of chilli grown during S_1

Cluster Number	1	2	3	4	5	6	7	8	9
1	19.58								
2	156.02	14.88							
3	193.16	60.68	13.12						
4	85.32	140.31	163.05	28.73					
5	233.33	107.58	72.19	117.23	12.67				
6	307.04	225.19	191.02	195.63	70.48	17.04			
7	280.62	127.65	82.86	141.55	49.84	179.08	10.64		
8	698.16	529.66	463.88	457.99	352.48	503.25	204.64	103.54	
9	55.01	107.03	149.42	104.31	228.19	345.47	236.20	653.21	20.95

Table 8. Intra and inter cluster D values of 9 clusters of chilli grown during S_1

Cluster Number	1	2	3	4	5	6	7	8	9
1	4.424								
2	12.490	3.857							
3	13.898	7.790	3.62						
4	9.240	11.850	12.77	5.36					
5	15.275	10.372	8.50	10.82	3.56				
6	17.523	15.010	13.82	13.99	8.40	4.13			
7	16.750	11.300	9.10	11.90	7.06	13.38	3.26		
8	26.420	23.010	21.54	21.40	18.77	22.43	14.31	10.18	
9	7.420	10.350	12.22	10.21	15.11	18.59	15.37	25.56	4.58

Table 9. Intra and inter cluster D^2 values of 6 clusters of chilli grown during S_2

Cluster Number	1	2	3	4	5	6
1	25.68					
2	71.71	31.17				
3	116.36	96.95	75.63			
4	69.48	207.66	228.46	21.69		
5	133.96	131.36	255.06	225.92	100.40	
6	183.94	365.89	411.56	91.54	340.49	220.50

Table 10. Intra and inter cluster D values of 6 clusters of chilli grown during S_2

Cluster Number	1	2	3	4	5	6
1	5.070					
2	8.468	5.583				
3	10.787	9.846	8.696			
4	8.335	14.410	15.114	4.657		
5	11.574	11.461	15.970	15.030	10.010	
6	13.562	19.128	20.286	9.567	18.452	14.849

Fig. 2. Mutual relationship among clusters during S_1

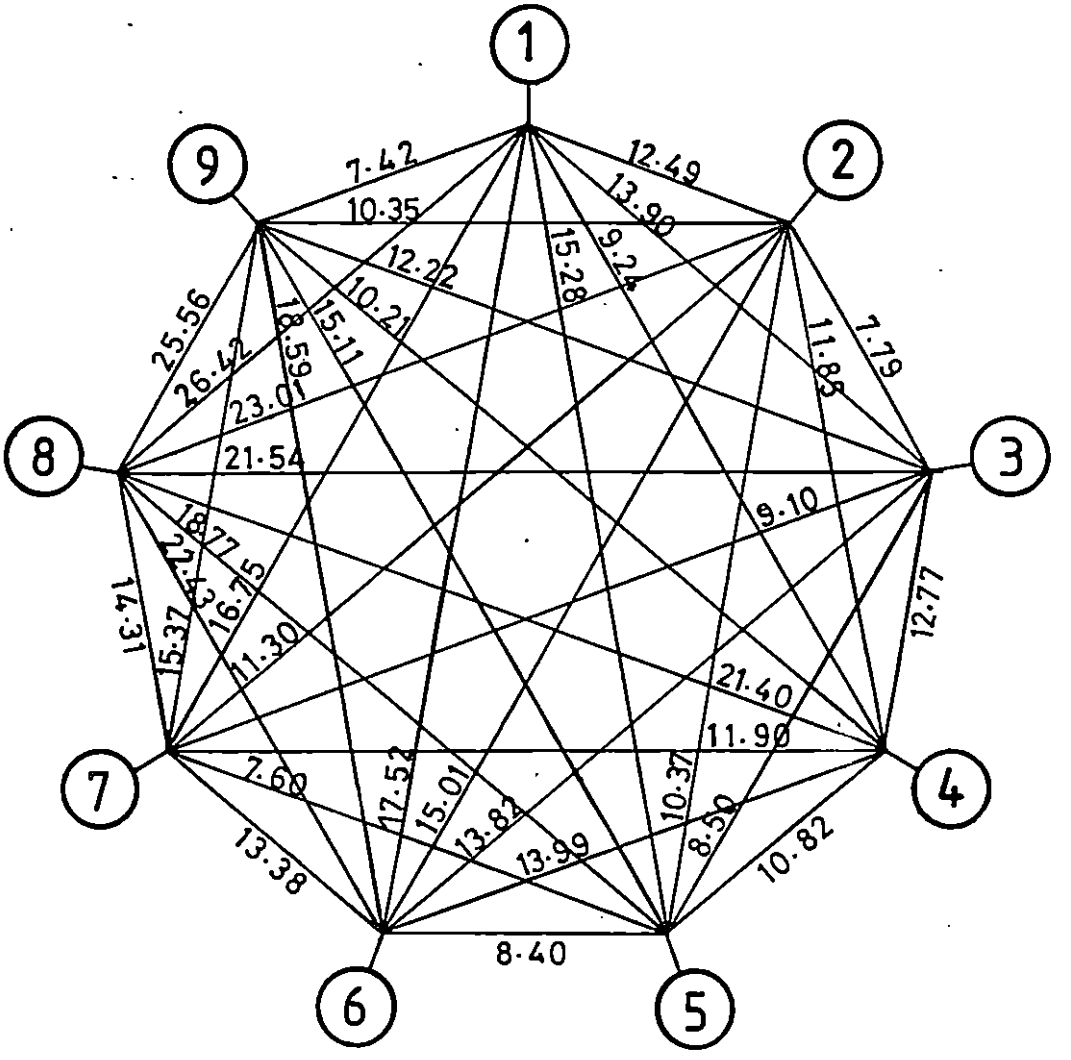
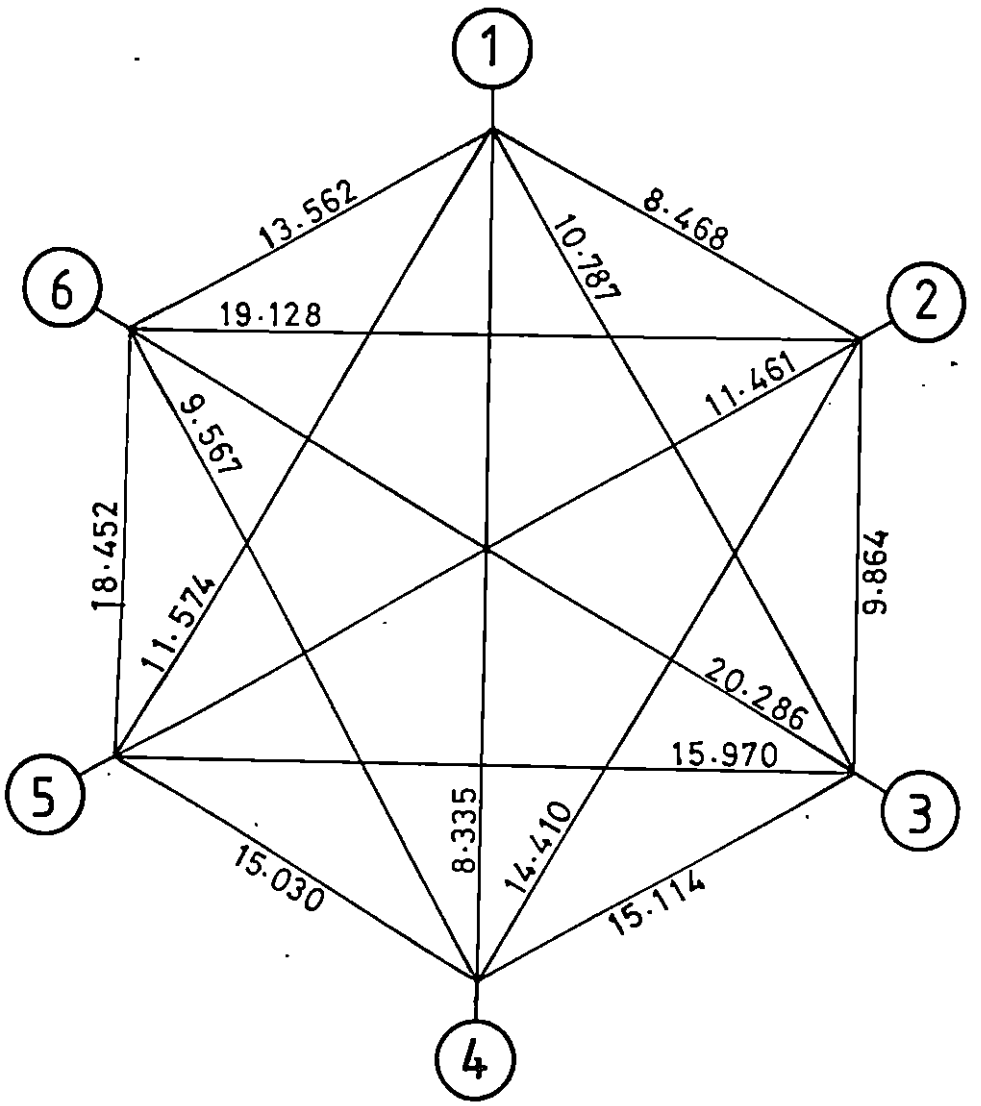


Fig. 3. Mutual relationship among clusters during S_2



During second season, the intra cluster distances in six clusters ranged from 21.69 in cluster IV to 22.5 in cluster VI. The remaining intra cluster D^2 values were 25.68, 31.17, 75.63, 100.40 in clusters I, II, III and V respectively. The maximum genetic distance was between cluster III and VI (D^2 = 411.56) and minimum between I and IV (D^2 = 69.48) (Table 9).

Results pertaining to the maximum, minimum and mean values of different characters of the genotypes in each cluster and the cluster means for different characters of different clusters during two seasons are presented in tables 11 to 27 respectively. The maximum, minimum and mean values of different clusters are furnished characterwise below.

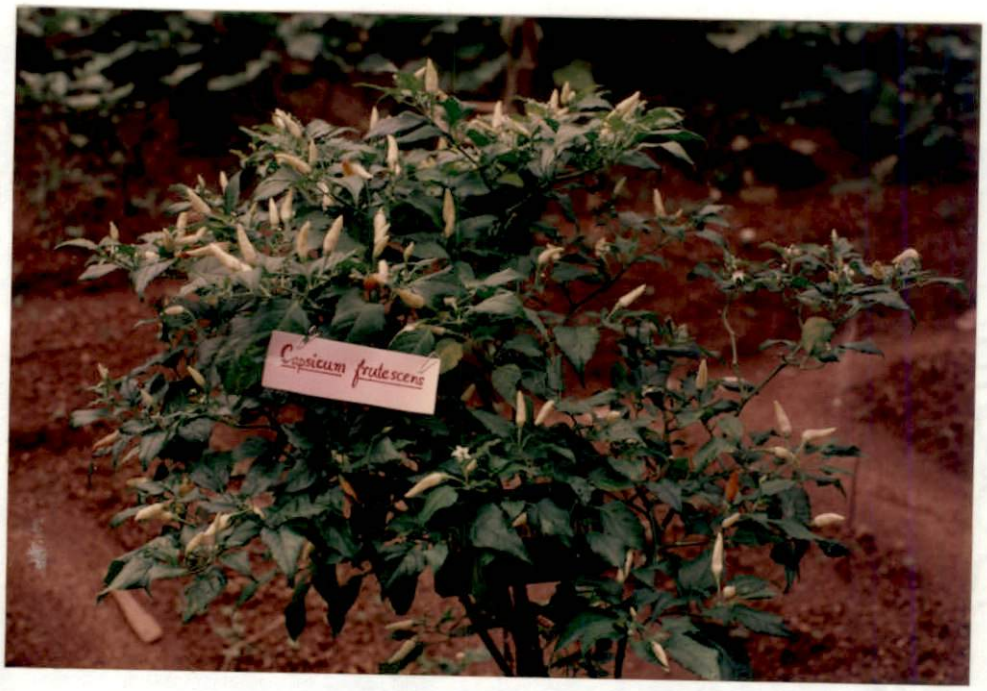
Days to first flower

The genotypes CA 628 and CA 605 in cluster I flowered 89.8 and 64.8 days after sowing with a cluster mean of 77.3. The maximum and minimum values for this trait in cluster II were 74.6 (CA 576) and 58.4 (CA 576) with a cluster mean of 66.5. The corresponding values in cluster III were 80.2 (CA 560) and 61.2 (CA 549) with a cluster mean of 70.7. In cluster IV CA 640 flowered very late which took 86 days to flower and CA 636 flowered earlier (48.4). The mean value for this cluster was 67.2. CA 519 (Plate 10) flowered very late (90.2 days) in cluster V while CA 60 was early (62.2). The mean value was 76.2. In cluster VI, CA 89 (Plate 11) flowered late (90.4) and CA 219 and CA 530 were early (73.8), with a cluster mean of 82.1. In cluster VII, CA 534 was late (68.2) and CA 531 (62.6) was early, with a mean value of 65.4 for that cluster. In cluster VIII, CA 540 was late (64.2) and CA 533 was early (62.8) with a cluster mean of 63.5. CA 593 flowered

Plate 10. CA 519 (*Capsicum baccatum*)

Plate 11. CA 89 (White Kanthari)


Capsicum baccatum


Capsicum frutescens

late (86.8) in cluster II and CA 582 and CA 589 were early (63.6) with a cluster mean of 75.2.

Maximum mean value for days to first flower during first season was shown by cluster VI (82.1) and minimum by cluster VIII (63.5).

During second season the two genotypes in cluster I produced first flower 93 (CA 640) and 56 (CA 531) days after sowing with a cluster mean of 74.

The cluster II the maximum and minimum values were 92.0 (CA 519) and 55.4 (CA 636) with a cluster mean of 73.7. The corresponding values in cluster III were 92.4 (CA 546) and 70.6 (CA 591) with a cluster mean of 81.5, in cluster IV were 88.4 (CA 530) and 66.8 (CA 567) with a cluster mean of 77.6, in cluster V 86.4 (CA 89) and 66 (CA 60) with a cluster mean of 76.2 and in cluster VI 116.8 (CA 622) and 75 (CA 576) with a cluster mean of 95.9.

Maximum mean value was 95.6 in cluster VI and minimum value was 73.7 in cluster II.

Plant height

During first season the two genotypes CA 631 (Plate 12) and CA 629 in cluster I recorded maximum height of 89.2 cm and minimum height of 43.4 cm respectivley with a mean value of 66.3 cm. In cluster II CA 575 (76.8 cm) was the tallest while CA 593 (42.8 cm) was the smallest with a mean value of 59.8 cm. The corresponding values in cluster III were 97.8 cm in CA 546 and 40 cm in CA 549 with a mean of 68.9 cm, in cluster IV 70.6 cm (CA 638) and 41.6 cm (CA 636) with a mean value of 56.1, in cluster V, 79.6 cm (CA 523) and 43.4 cm (CA 519)

Plate 12. CA 631 (*Capsicum chinense*)

Plate 13. CA 546


Capsicum chinense

with a mean value of 61.5 cm; in cluster VI, 100 cm (CA 89) and 60.8 cm (CA 530) with a mean of 80.4 cm; in cluster VII 81.2 cm in CA 542 and 43.6 cm in CA 532 with a mean value of 62.4 cm; in cluster VIII 62.2 cm in CA 533 and 53 cm in CA 540 with a mean of 57.6 and in cluster IX 77.4 cm in CA 582 and 40 cm in CA 597 with a mean of 58.7 cm respectively.

Maximum mean value of 80.4 cm was in cluster VI and the minimum was 56.1 cm in cluster IV.

During second season, the genotypes CA 523 and CA 531 in cluster I recorded maximum and minimum values of 79.6 cm and 41.6 cm respectively with a mean of 60.6 cm. In cluster II, CA 521 was the tallest (70.2 cm) and CA 559 was the smallest (41.6 cm) with a mean value of 55.9. The corresponding values in cluster III were 111.4 (CA 631) and 80.0 (CA 591) with a mean of 95.7 cm.

In cluster IV, CA 590 recorded maximum height of 75.4 cm and CA 573 recorded minimum value of 42 cm with a mean of 58.7 cm. The genotypes CA 89 and CA 517 recorded maximum and minimum values of 102.4 cm and 43 cm respectively in cluster V, with a mean of 72.7 cm. In cluster VI, highest value of 41.8 cm was recorded by CA 576 and the lowest value was 41.6 cm for CA 622 with a mean of 41.7 cm. The highest cluster mean was 95.7 cm in cluster III and the lowest value was 41.7 cm in cluster VI.

Primary branches/plant

The genotypes CA 631 and CA 604 recorded maximum and minimum values of 11.2 and 2.8 in cluster I during first season. The cluster mean was seven. In cluster II, the corresponding values were 6.4 and 2.6 in CA 579 and CA 576 with

a mean of 4.5, in cluster III, 9 and 2.8 in CA 557 and CA 545 with a mean of 5.9; in cluster IV, 7.6 and 4.2 in CA 636 and CA 635 with an average of 5.9, in cluster V, 9.2 and 4.4 in CA 517 and CA 60 with a mean of 6.8; in cluster VI, 11.2 and 3.4; in CA 89 and CA 530, with a mean of 7.3, in cluster VII 8.2 and 3 in CA 532 and CA 537 with a mean of 5.6, in cluster VIII 7.4 and 4.6 in CA 536 and CA 540, mean value being 6.0, in cluster IX 10.6 and 3.2 in CA 582 and CA 597 with an average value of 6.9. Among different clusters, cluster mean was maximum in cluster VI (7.3) and minimum in cluster II (4.5).

During second season in cluster I the genotypes CA 640 and CA 548 recorded maximum and minimum values of 9.0 and 2.6 respectively with a mean of 5.8. In cluster II, CA 629 recorded maximum value of 9.39, minimum being 3.2 in CA 521. The mean value was 6.30. The corresponding values are 13.0 and 4.6 in CA 631 and CA 560 of cluster III, 6.4 and 3.2 in CA 638 and CA 587 of cluster IV, 11.0 and 4.8 in CA 89 and CA 60 of cluster V and 4.8 and 4.0 in CA 622 and CA 576 of cluster VI. The mean values were 8.8, 4.8, 4.9 and 4.4 in cluster III, IV, V and VI respectively. The highest mean value was 8.8 in cluster III and the lowest 4.4 in cluster VI.

Pedicel length

The genotypes CA 611 and CA 628 recorded the maximum and minimum pedicel length of 4.9 cm and 2.16 cm in cluster I during first season. In cluster II CA 572 and CA 562 recorded 4.16 cm and 1.92 cm respectively. In cluster III, CA 545 and CA 549 showed the maximum and minimum values of 3.74 and 2.22 respectively. Similarly the values were 3.38 and 2.1 in CA 638 and CA 635 of cluster IV, 3.58 and 1.6 of CA 519 and CA 521 of cluster V, 3.6 and 2.5 in CA

530 and CA 89 of cluster VI, 5.24 and 1.58 in CA 539 and CA 542 of cluster VII, 2.94 and 2.24 in CA 540 and CA 533 of cluster VIII, 3.92 and 1.8 in CA 590 and CA 593 of cluster IX respectively.

The mean values for nine clusters were 3.53, 3.04, 2.98, 2.74, 2.59, 3.05, 3.41, 2.59 and 2.86 respectively in clusters I to IX. The highest value was 3.53 in cluster I and lowest value was 2.59 in cluster V and VIII respectively.

During second season, in cluster I the genotype CA 611 recorded maximum pedicel length of 4.52 cm and the genotype CA 536 had minimum length of 1.78 cm. The corresponding values in cluster II were 3.86 cm (CA 629) and 1.36 cm (CA 558), in cluster III, 3.3 cm (CA 546) (Plate 13) and 1.9 cm (CA 591), in cluster IV, 4.02 cm (CA 543) and 2.48 cm (CA 573), in cluster V, 5.22 cm (CA 517) and 2.72 cm (CA 89) and in cluster VI, 3.26 cm (CA 576) and 3.14 cm (CA 622) respectively. The mean values of each cluster were 3.15 cm, 2.61 cm, 2.6 cm, 3.25 cm, 3.97 cm and 3.2 cm in clusters I to VI respectively. The highest value was in cluster V and the lowest one in cluster II.

Fruit length

The genotypes CA 603 and CA 628 of cluster I recorded maximum and minimum fruit length of 12.06 cm and 1.92 cm during first season. Similarly the values were 16.16 cm (CA 576) and 3.88 cm (CA 575) in cluster II, 17.2 cm (CA 545) and 1.54 cm (CA 557) in cluster III, 8.92 cm (CA 638) and 4.66 cm (C 636) in cluster IV, 10.48 cm (CA 60) and 2.48 cm (CA 521) in cluster V, 13.26 cm (CA 530) and 4.2 cm (CA 89) in cluster VI, 13.44 cm (CA 543) and 6.86 cm (CA 532) in cluster VII, 11.22 cm (CA 540) and 3.34 in (CA 533) in cluster VIII and 11.8 cm

(CA 587) and 3.64 cm (CA 586) in cluster IX respectively.

The mean values were 6.99 cm, 10.02 cm, 9.37 cm, 6.76 cm, 6.48 cm, 8.73 cm, 10.15 cm, 7.28 cm and 7.92 cm respectively in clusters I to IX. The maximum value was in cluster VIII (10.15 cm) and minimum in cluster V (6.48 cm) respectively.

During second season, in cluster I the genotypes CA 582 and CA549 had maximum fruit length of 8.14 cm and 5.12 cm respectively. In cluster II, the genotypes CA 636 and CA 557 recorded maximum and minimum length of 5.04 cm and 1.4 cm respectively. The corresponding values in cluster III were 7.56 cm (CA 591) and 2.0 cm (CA 628), in cluster IV, 11.92 cm (CA 530) and 8.28 cm (CA 569), in cluster V, 10.76 cm (CA 60) and 4.06 cm (CA 517) and in cluster VI, 15.22 cm (CA 576) and 8.02 cm (CA 622) respectively.

The mean values were 6.63 cm, 3.22 cm, 4.78 cm, 10.1 cm, 7.41 cm and 11.62 cm in clusters I to VI respectively. The highest value (11.62 cm) was in cluster VI and the lowest one (3.22 cm) in cluster II.

Fruit perimeter

The genotyes, CA 600 and CA 628 in cluster I recorded maximum and minimum fruit girth of 14.68 cm and 1.56 cm; during first season. The corresponding values in cluster II were 16.44 cm (CA 574) and 4.52 cm (CA 568), in cluster III, 21.9 cm (CA 548) and 2.18 cm (CA 546), in cluster IV, 9.18 cm (CA 635) and 4.1 cm (CA 640), in cluster V, 7.06 cm (CA 521) and 3.08 cm (CA 33), in cluster VI, 8.16 cm (CA 530) and 3.04 cm (CA 219) (Plate 14) in cluster VII, 18.38 cm (CA 531) and 7.6 cm (CA 539) in cluster VIII, 15.74 cm (CA 540) and 12.38 cm

Plate 14. CA 219

Plate 15. CA 559 (*Capsicum chinense*)


CA 219


Capsicum chinense

(CA 536) and in cluster IX, 17.28 cm (CA 594) and 4.0 cm in CA 582 respectively.

The mean values were 8.12 cm, 10.48 cm, 12.04 cm, 5.64 cm, 5.07 cm, 5.6 cm, 12.99 cm, 14.06 cm and 10.64 cm in cluster I to IX respectively, the maximum being in cluster VIII and minimum in cluster V.

During second season, the genotypes CA 553 and CA 523 recorded maximum and minimum fruit girth of 17.96 cm and 3.08 cm respectively, in cluster I. In cluster II the corresponding values were 11.22 cm (CA 533) and 3.84 cm (CA 557), in cluster III, 7.2 cm (CA 631) and 1.42 cm (CA 628), in cluster IV, 13.1 cm (CA 573) and 4.8 cm (CA 516), in cluster V, 3.82 cm (CA 89) and 2.92 cm (CA 60) and in cluster VI, 8.93 cm (CA 622) and 5.04 cm (CA 576) respectively.

The mean values were 10.52 cm, 7.53 cm, 4.31 cm, 7.95 cm, 3.37 cm and 6.98 cm respectively in clusters I to VI. The highest value was in cluster I and the lowest one in cluster V.

Yield/plant

The genotypes CA 600 and CA 629 were the highest (172 g) and lowest (67.6 g) yielders in cluster I, during first season while in cluster II, the maximum and minimum yield were recorded by CA 574 (380 g) and CA 562 (87 g). The corresponding values in cluster III were 234 g (CA 556) and 62 g (CA 560), in cluster IV; 100.6 g (CA 638) and 62.2 g (CA 632) in cluster V, 159 g (CA 517) and 61 g (CA 521) in cluster VI, 304 g (CA 530) and 194 g (CA 219) in cluster VII, 146 g (CA 531) and 75 g (CA 534) in cluster VIII, 372 g (CA 533) and 203 g (CA 536) and in cluster IX, 238.8 g (CA 598) and 59 g (CA 586) respectively.

The maximum mean value was in cluster VIII (287.5 g) and the minimum in cluster IV (18.4 g). The other values being 119.8 g, 233.5 g, 148 g, 110 g, 249 g, 110.5 g and 148.9 g in cluster I, II, III, V, VI, VII and IX respectively.

During second season, the genotypes CA 579 and CA 523 of cluster I gave maximum and minimum yield of 134.6 g and 55 g respectively. In cluster II, the maximum yield was 142.6 g (CA 533) and minimum was 50 g (CA 521). Similarly the values were 116.8 g (CA 631) and 80.0 g (CA 546) in cluster III, 133 g (CA 542) and 58.4 g(CA 569) in cluster IV, 247 g (CA 89) and 97 g (CA 60), in cluster V and 79 g (CA 622) and 77 g (CA 576) in cluster VI respectively.

The mean values were 94.8 g, 96.3 g, 98.4 g, 95.7 g, 172 g and 78 g in clusters I to VI respectively; the maximum being (172 g) in cluster V and minimum (78 g) in cluster VI.

Seeds/fruit

The genotype CA 600 had maximum number of seeds (140.8) in cluster I and the genotype CA 628 had minimum number of seeds (14.6) during first season. In cluster II maximum seed count was in CA 564 (118.6) and minimum in CA 572 (39.2). In cluster III, CA 556 had maximum seeds (194.8) and CA 559 (Plate 15) recorded minimum count (30). Similarly the values were 124.2 (CA 632) and 33 (CA 640) in cluster IV, 100.8 (CA 33) and 37.2 (CA 519), in cluster V, 69.6 (CA 219) and 43.2 (CA 89) in cluster VI, 142.6 (CA 531) and 64.4 (CA 535) in cluster VII, 152 (CA 533) and 82.4 (CA 536) in cluster VIII and 135.2 (CA 594) and 49 (CA 591) in cluster IX respectively.

Table 11. Extremes and means of genotypes in cluster I during S_1

Sl.No.	Characters	Maximum	Acc. No.	Minimum	Acc. No.	Mean
1	Days to first flower	89.80	CA 628	64.80	CA 605	77.30
2	Plant height (cm)	89.20	CA 631	43.40	CA 629	66.30
3	Primary branches/ plant	11.20	CA 631	2.80	CA 604	7.00
4	Pedicel length (cm)	4.90	CA 611	2.16	CA 628	3.53
5	Fruit length (cm)	12.06	CA 603	1.92	CA 628	6.99
6	Fruit perimeter (cm)	14.68	CA 600	1.56	CA 628	8.12
7	Yield/plant (g)	172.00	CA 600	67.60	CA 629	119.80
8	Seeds/fruit	140.80	CA 600	14.60	CA 628	77.70

Table 12. Extremes and means of genotypes in cluster II during S_1

Sl.No.	Characters	Maximum	Acc. No.	Minimum	Acc. No.	Mean
1	Days to first flower	74.60	CA 576	58.40	CA 570	66.50
2	Plant height (cm)	76.80	CA 575	42.80	CA 573	59.80
3	Primary branches/ plant	6.40	CA 579	2.60	CA 576	4.50
4	Pedicel length (cm)	4.16	CA 572	1.92	CA 562	3.04
5	Fruit length (cm)	16.16	CA 576	3.88	CA 575	10.02
6	Fruit perimeter (cm)	16.44	CA 574	4.52	CA 568	10.48
7	Yield/plant (g)	380.00	CA 574	87.00	CA 562	233.50
8	Seeds/fruit	118.60	CA 564	39.20	CA 572	78.90

Table 13. Extremes and means of characters in cluster III during S_1

Sl.No.	Characters	Maximum	Acc.No.	Minimum	Acc. No.	Mean
1	Days to first flower	80.20	CA 560	61.20	CA 549	70.70
2	Plant height (cm)	97.80	CA 546	40.00	CA 559	68.90
3	Primary branches/ plant	9.00	CA 557	2.80	CA 545	5.90
4	Pedicel length (cm)	3.74	CA 545	2.22	CA 549	2.98
5	Fruit length (cm)	17.20	CA 545	1.54	CA 557	9.37
6	Fruit perimeter (cm)	21.90	CA 548	2.18	CA 546	12.04
7	Yield/plant (g)	234.00	CA 556	62.00	CA 560	148.00
8	Seeds/fruit	194.80	CA 553	30.00	CA 559	112.40

Table 15. Extremes and means of characters in cluster V during S_1

Sl.No.	Characters	Maximum	Acc.No.	Minimum	Acc.No.	Mean
1	Days to first flower	90.20	CA 519	62.20	CA 60	76.20
2	Plant height (cm)	79.60	CA 523	43.40	CA 519	61.50
3	Primary branches/ plant	9.20	CA 517	4.40	CA 60	6.80
4	Pedicel length (cm)	3.58	CA 519	1.60	CA 521	2.59
5	Fruit length (cm)	10.48	CA 60	2.48	CA 521	6.48
6	Fruit perimeter (cm)	7.06	CA 521	3.08	CA 33	5.07
7	Yield/plant (g)	159.00	CA 517	61.00	CA 521	110.00
8	Seeds/fruit	100.80	CA 33	37.20	CA 519	69.00

Table 14. Extremes and means of characters in cluster IV during S_1

Sl.No.	Characters	Maximum	Acc.No.	Minimum	Acc.No.	Mean
1	Days to first flower	86.00	CA 640	48.40	CA 636	67.20
2	Plant height (cm)	70.60	CA 638	41.60	CA 636	56.10
3	Primary branches/ plant	7.60	CA 636	4.20	CA 635	5.90
4	Pedicel length (cm)	3.38	CA 638	2.10	CA 635	2.74
5	Fruit length (cm)	8.92	CA 638	4.66	CA 636	6.79
6	Fruit perimeter (cm)	7.18	CA 635	4.10	CA 640	5.64
7	Yield/plant (g)	100.60	CA 638	62.20	CA 632	81.40
8	Seeds/fruit	124.20	CA 632	33.00	CA 640	78.60

Table 16. Extremes and means of characters in cluster VI during S_1

Sl.No.	Characters	Maximum	Acc.No.	Minimum	Acc.No.	Mean
1	Days to first flower	90.40	CA 89	73.80	CA 219 & CA 530	82.10
2	Plant height (cm)	100.00	CA 89	60.80	CA 530	80.40
3	Primary branches/ plant	11.20	CA 89	3.40	CA 530	7.30
4	Pedicel length (cm)	3.60	CA 530	2.50	CA 89	3.05
5	Fruit length (cm)	13.26	CA 530	4.20	CA 89	8.73
6	Fruit perimeter (cm)	8.16	CA 530	3.04	CA 219	5.60
7	Yield/plant (g)	304.00	CA 530	194.00	CA 219	249.00
8	Seeds/fruit	69.60	CA 219	43.20	CA 89	56.40

Table 17. Extremes and means of characters in cluster VII during S_1

Sl.No.	Characters	Maximum	Acc.No.	Minimum	Acc.No.	Mean
1	Days to first flower	68.20	CA 534	62.60	CA 531	65.40
2	Plant height (cm)	81.20	CA 542	43.60	CA 532	62.40
3	Primary branches/ plant	8.20	CA 534	3.00	CA 532 & CA 537	5.60
4	Pedicel length (cm)	5.24	CA 539	1.58	CA 542	3.41
5	Fruit length (cm)	13.44	CA 543	6.86	CA 532	10.15
6	Fruit perimeter (cm)	18.38	CA 531	7.60	CA 539	12.99
7	Yield/plant (g)	146.00	CA 531	75.00	CA 534	110.50
8	Seeds/fruit	142.60	CA 531	64.40	CA 538	103.50

Table 18. Extremes and means of characters in cluster VIII during S_1

Sl.No.	Characters	Maximum	Acc.No.	Minimum	Acc.No.	Mean
1	Days to first flower	64.20	CA 540	62.80	CA 533	63.50
2	Plant height (cm)	62.20	CA 533	53.00	CA 540	57.60
3	Primary branches/ plant	7.40	CA 536	4.60	CA 540	6.00
4	Pedicel length (cm)	2.94	CA 540	2.24	CA 533	2.59
5	Fruit length (cm)	11.22	CA 540	3.34	CA 533	7.28
6	Fruit perimeter (cm)	15.74	CA 540	12.38	CA 536	14.06
7	Yield/plant (g)	372.00	CA 533	203.00	CA 536	287.50
8	Seeds/fruit	152.00	CA 533	82.40	CA 536	117.20

Table 19. Extremes and means of characters in cluster IX during S_1

Sl.No.	Characters	Maximum	Acc.No.	Minimum	Acc.No.	Mean
1	Days to first flower	86.80	CA 593	63.60	CA 582 & CA 589	75.20
2	Plant height (cm)	77.40	CA 582	40.00	CA 597	58.70
3	Primary branches/ plant	10.60	CA 582	3.20	CA 597	6.90
4	Pedicel length (cm)	3.92	CA 590	1.80	CA 593	2.86
5	Fruit length (cm)	11.80	CA 587	3.64	CA 586	7.72
6	Fruit perimeter (cm)	17.28	CA 594	4.00	CA 582	10.64
7	Yield/plant (g)	238.80	CA 598	59.00	CA 586	148.90
8	Seeds/fruit	135.20	CA 594	49.00	CA 591	92.10

Table 20. Extremes and means of genotypes in cluster I during S_2

Sl.No.	Characters	Maximum	Acc.No.	Minimum	Acc.No.	Mean
1	Days to first flower	92.80	CA 640	55.60	CA 531	74.20
2	Plant height (cm)	79.60	CA 523	41.60	CA 531	60.60
3	Primary branches/ plant	9.00	CA 640	2.60	CA 548	5.80
4	Pedicel length (cm)	4.52	CA 611	1.78	CA 536	3.15
5	Fruit length (cm)	8.14	CA 582	5.12	CA 549	6.63
6	Fruit perimeter (cm)	17.96	CA 553	3.08	CA 523	10.52
7	Yield/plant (g)	134.60	CA 579	55.00	CA 523	94.80
8	Seeds/fruit	152.60	CA 600	34.40	CA 549	93.50

Table 21. Extremes and means of genotypes in cluster II during S_2

Sl.No.	Characters	Maximum	Acc.No.	Minimum	Acc.No.	Mean
1	Days to first flower	92.00	CA 519	55.40	CA 636	73.70
2	Plant height (cm)	70.20	CA 521	41.60	CA 559	55.90
3	Primary branches/ plant	9.39	CA 629	3.20	CA 521	6.30
4	Pedicel length (cm)	3.86	CA 629	1.36	CA 558	2.61
5	Fruit length (cm)	5.04	CA 636	1.40	CA 557	3.22
6	Fruit perimeter (cm)	11.22	CA 533	3.84	CA 557	7.53
7	Yield/plant (g)	142.60	CA 533	50.00	CA 521	96.30
8	Seeds/fruit	150.60	CA 533	25.20	CA 559	87.90

Table 22. Extremes and means of genotypes in cluster III during S_2

Sl.No.	Characters	Maximum	Acc.No.	Minimum	Acc.No.	Mean
1	Days to first flower	92.40	CA 546	70.60	CA 591	81.50
2	Plant height (cm)	111.40	CA 631	80.00	CA 591	95.70
3	Primary branches/ plant	13.00	CA 631	4.60	CA 560	8.80
4	Pedicel length (cm)	3.30	CA 546	1.90	CA 591	2.60
5	Fruit length (cm)	7.56	CA 591	2.00	CA 628	4.78
6	Fruit perimeter (cm)	7.20	CA 631	1.42	CA 628	4.31
7	Yield/plant (g)	116.80	CA 631	80.00	CA 546	98.40
8	Seeds/fruit	69.80	CA 546	13.40	CA 628	41.60

Table 23. Extremes and means of genotypes in cluster IV during S_2

Sl.No.	Characters	Maximum	Acc.No.	Minimum	Acc.No.	Mean
1	Days to first flower	88.40	CA 530	66.80	CA 567	77.60
2	Plant height (cm)	75.40	CA 590	42.00	CA 573	58.70
3	Primary branches/ plant	6.40	CA 638	3.20	CA 587	4.80
4	Pedicel length (cm)	4.02	CA 543	2.48	CA 573	3.25
5	Fruit length (cm)	11.92	CA 530	8.28	CA 569	10.10
6	Fruit perimeter (cm)	13.10	CA 573	4.80	CA 516	8.95
7	Yield/plant (g)	133.00	CA 452	58.40	CA 569	95.70
8	Seeds/fruit	124.60	CA 567	38.00	CA 452	81.30

Table 24. Extremes and means of genotypes in cluster V during S_2

Sl.No.	Characters	Maximum	Acc.No.	Minimum	Acc.No.	Mean
1	Days to first flower	86.40	CA 89	66.00	CA 60	76.20
2	Plant height (cm)	102.40	CA 89	43.00	CA 517	72.70
3	Primary branches/ plant	11.00	CA 89	4.80	CA 60	7.90
4	Pedicel length (cm)	5.22	CA 517	2.72	CA 89	3.97
5	Fruit length (cm)	10.76	CA 60	4.06	CA 517	7.41
6	Fruit perimeter (cm)	3.82	CA 89	2.92	CA 60	3.37
7	Yield/plant (g)	247.00	CA 89	97.00	CA 60	172.00
8	Seeds/fruit	72.80	CA 33	42.40	CA 89	57.60

Table 25. Extremes and means of genotypes in cluster VI during S_2

Sl.No.	Characters	Maximum	Acc.No.	Minimum	Acc.No.	Mean
1	Days to first flower	116.80	CA 622	75.00	CA 576	95.90
2	Plant height (cm)	41.80	CA 576	41.60	CA 622	41.70
3	Primary branches/ plant	4.80	CA 622	4.00	CA 576	4.40
4	Pedicel length (cm)	3.26	CA 576	3.14	CA 622	3.20
5	Fruit length (cm)	15.22	CA 576	8.02	CA 622	11.62
6	Fruit perimeter (cm)	8.93	CA 622	5.04	CA 576	6.99
7	Yield/plant (g)	79.00	CA 622	77.00	CA 576	78.00
8	Seeds/fruit	80.60	CA 576	39.40	CA 622	60.00

Table 26. Cluster means of eight quantitative characters during S_1

Sl. No.	Characters	Cluster number								
		I	II	III	IV	V	VI	VII	VIII	IX
1	Days to first flower	77.30	66.50	70.70	67.20	76.20	82.10	65.40	63.50	75.20
2	Plant height (cm)	66.30	59.80	68.90	56.10	61.50	80.40	62.40	57.60	58.70
3	Primary branches/ plant	7.00	4.50	5.90	5.90	6.80	7.30	5.60	6.00	6.90
4	Pedicel length (cm)	3.53	3.04	2.98	2.74	2.59	3.05	3.41	2.59	2.86
5	Fruit length (cm)	6.99	10.02	9.37	6.79	6.48	8.73	10.15	7.28	7.72
6	Fruit peri-meter (cm)	8.12	10.48	12.04	5.64	5.07	5.60	12.99	14.06	10.64
7	Yield/plant (g)	119.80	233.50	148.00	81.40	110.00	249.00	110.50	287.50	148.90
8	Seeds/fruit	77.70	78.90	112.40	78.60	69.00	56.40	103.50	117.20	92.10

Table 27. Cluster means of eight quantitative characters during S_2

Sl. No.	Characters	Cluster number					
		I	II	III	IV	V	VI
1	Days to first flower	74.20	73.70	81.50	77.60	76.20	95.90
2	Plant height (cm)	60.60	55.90	95.70	58.70	72.70	41.70
3	Primary branches/plant	5.80	6.30	8.80	4.80	7.90	4.40
4	Pedicel length (cm)	3.15	2.61	2.60	3.25	3.97	3.20
5	Fruit length (cm)	6.63	3.22	4.78	10.10	7.41	11.62
6	Fruit perimeter (cm)	10.52	7.53	4.31	8.95	3.37	6.98
7	Yield/plant (g)	94.80	96.30	98.40	95.70	172.00	78.00
8	Seeds/fruit	93.50	87.90	41.60	81.30	57.60	60.00

The mean values were 77.7, 78.9, 112.4, 78.6, 69, 56.4, 103.5, 117.2 and 92.1 in clusters I to IX. The highest seed content (117.2) was in cluster VIII and the lowest (56.4) in cluster VI.

During second season in cluster I, CA 600 recorded maximum seed content (152.6) and CA 549 had minimum count (34.4). In cluster II, CA 533 had maximum value (150.6) and CA 559 recorded minimum (25.2). The corresponding values were 69.8 (CA 546) and 13.4 (CA 628) in cluster III, 124.6 (CA 567) and 38.0 (CA 452) in cluster IV, 72.8 (CA 33) and 42.4 (CA 89) in cluster V, 80.6 (CA 576) and 39.4 (CA 622) in cluster VI respectively.

The mean values were 93.5, 87.9, 41.6, 81.3, 57.6 and 60 in cluster I to VI, the maximum being (93.5) in cluster I and minimum (41.6) in cluster III.

C. Biochemical grouping

Two methods viz. AGIEF (Agrose Gel Iso Electric Focusing) and PAGE (Poly Acrylamide Gel Electrophoresis) were tried for estimating biochemical diversity. Among these two methods clear bands were obtained by the second method (PAGE) and hence this method was utilised for further studies.

The results are presented under the following heads.

a) Isozymes in different parts of the plant

1. Peroxidase

Five varieties were analysed to find out variation, if any, in the zymogram of 3 different *Capsicum* spp. viz. *Capsicum annuum, Capsicum frutescens* and

Capsicum chinense. Root, tender leaves and mature leaves were used for this study. Clear bands were obtained from extracts in the roots as well as mature leaves. In the case of tender leaves only faint bands were seen (Plates 16, 17 and 18). Best results were obtained from the root tissue of the three species. In the case of mature leaves though the bands were clear, interference of chlorophyll resulted in reduced sharpness of bands.

2. Esterase

The root, tender and mature leaves were analysed in the three *Capsicum* spp. to identify esterase pattern. However the bands were not as much clear as that of peroxidase. Number of bands were also less. Mature leaves showed clear bands compared to the other two tissues (Plates 19, 20 and 21).

b) Peroxidase pattern of different species

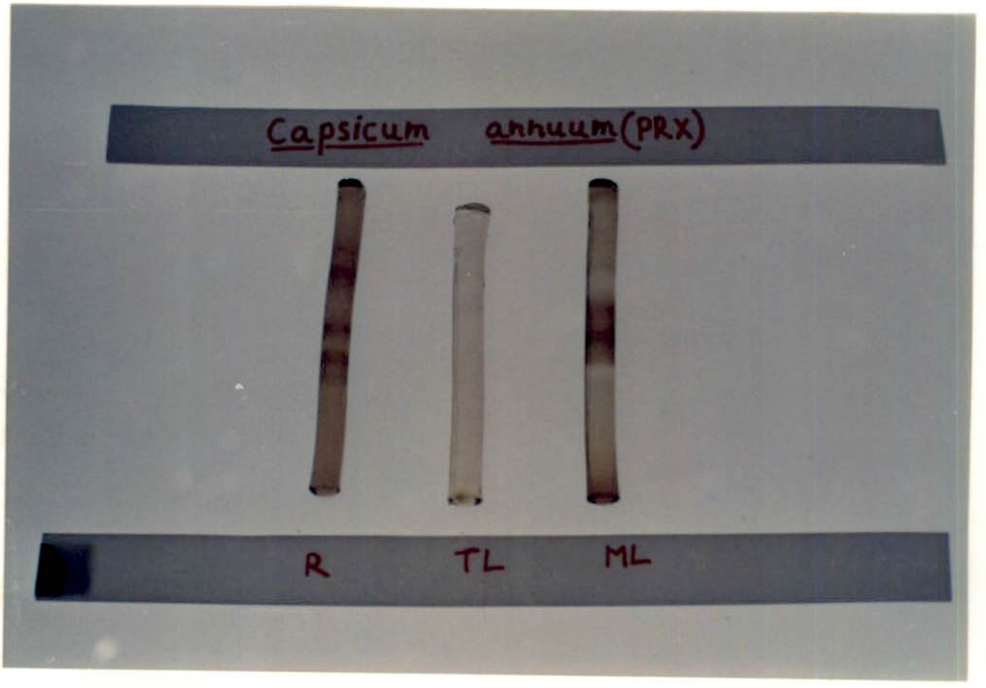
The peroxidase pattern of three different *Capsicum* spp. are represented in Plate 22. There were altogether 15 bands of which six bands were specific to *Capsicum annuum* 5 bands to *Capsicum frutescens* and four bands to *Capsicum chinense* (Fig. 4). The Rm (Relative mobility) values of these bands ranged from 0.08 to 0.63. No bands were common to all the three species. Hence the bands obtained were species specific.

Esterase pattern of different species

Esterase pattern also showed variation among different species (Plate 23). There were altogether 12 bands, of which three bands were in *Capsicum annuum*, five bands in *Capsicum frutescens* and four bands in *Capsicum chinense*.

Plate 16. Peroxidase pattern of different plant parts in *Capsicum annuum*)

Plate 17. Peroxidase pattern of different plant parts in *Capsicum frutescens*


Capsicum annuum (PRX)
R
TL
ML

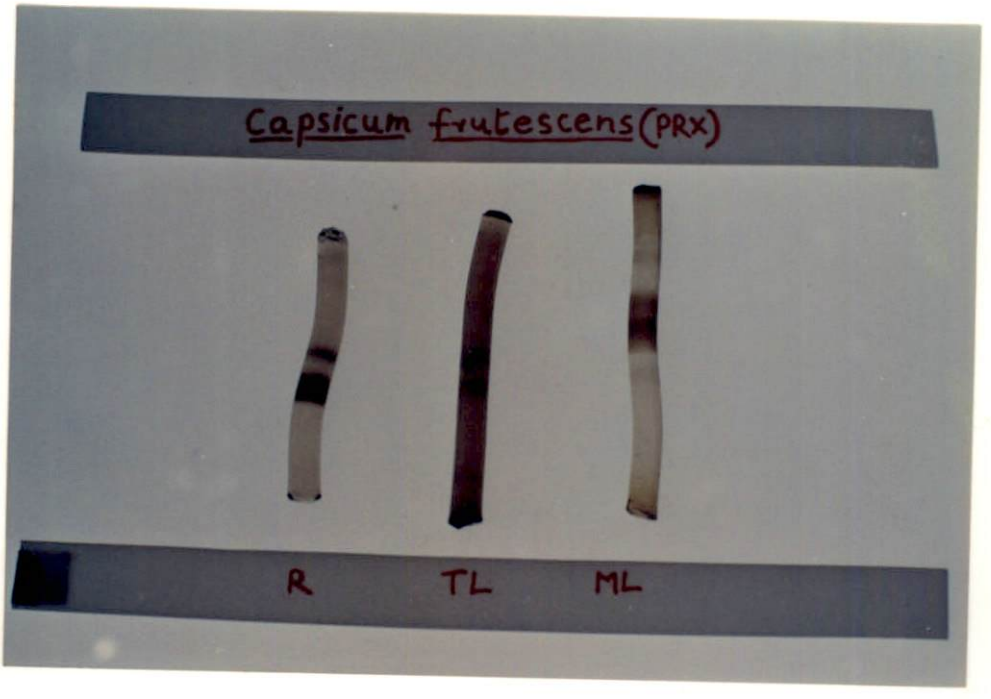
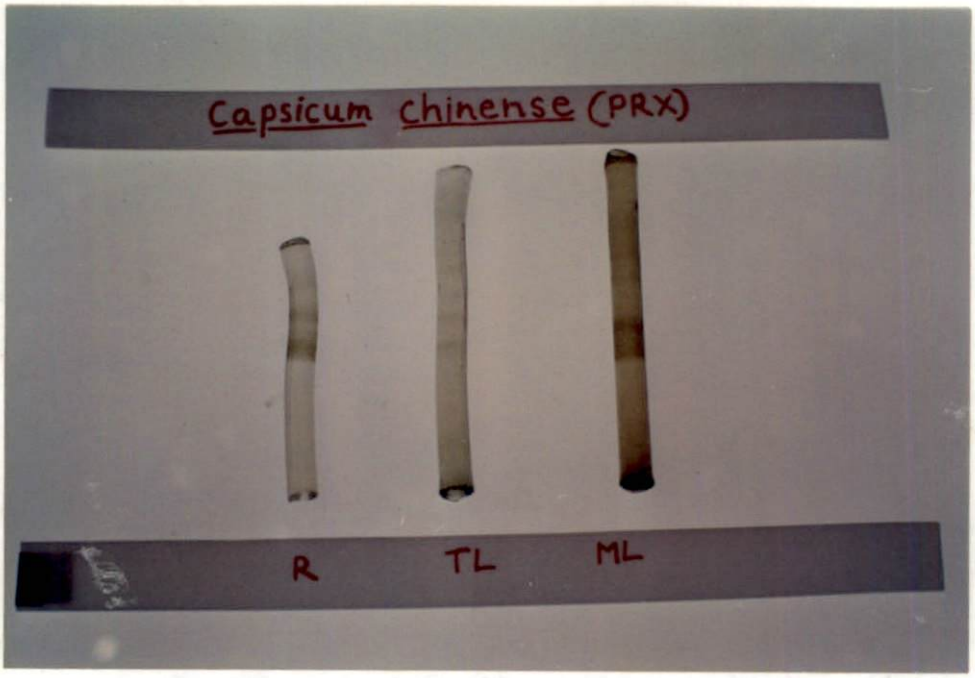

Capsicum frutescens (PRX)
R
TL
ML

Plate 18. Peroxidase pattern of different plant parts in *Capsicum chinense*

Plate 19. Esterase pattern of different plant parts in *Capsicum annuum*


Capsicum chinense (PRX)
R
TL
ML

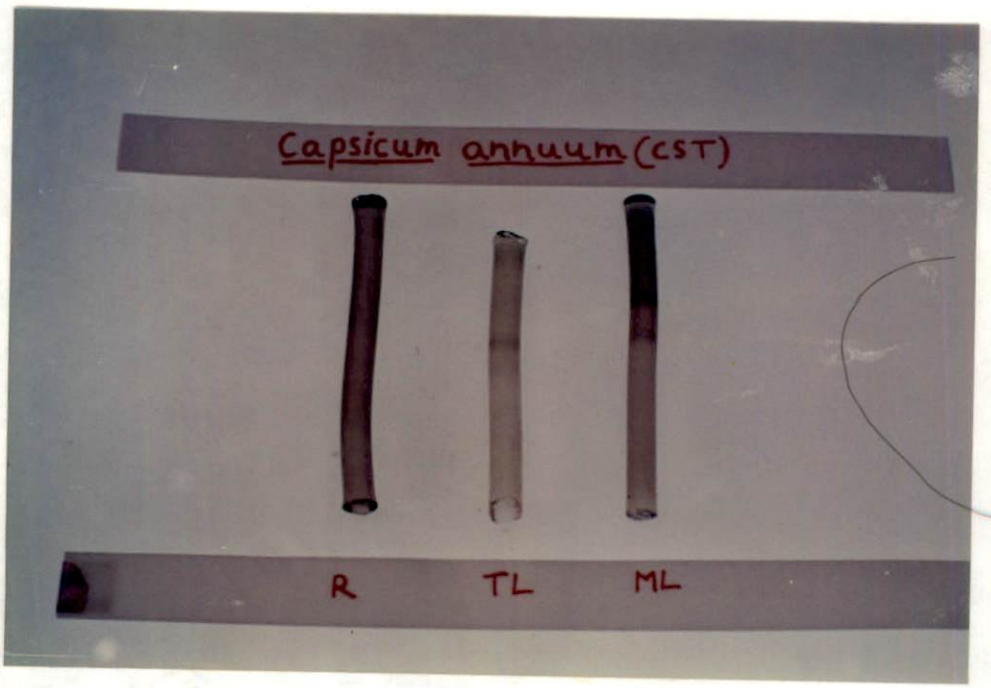
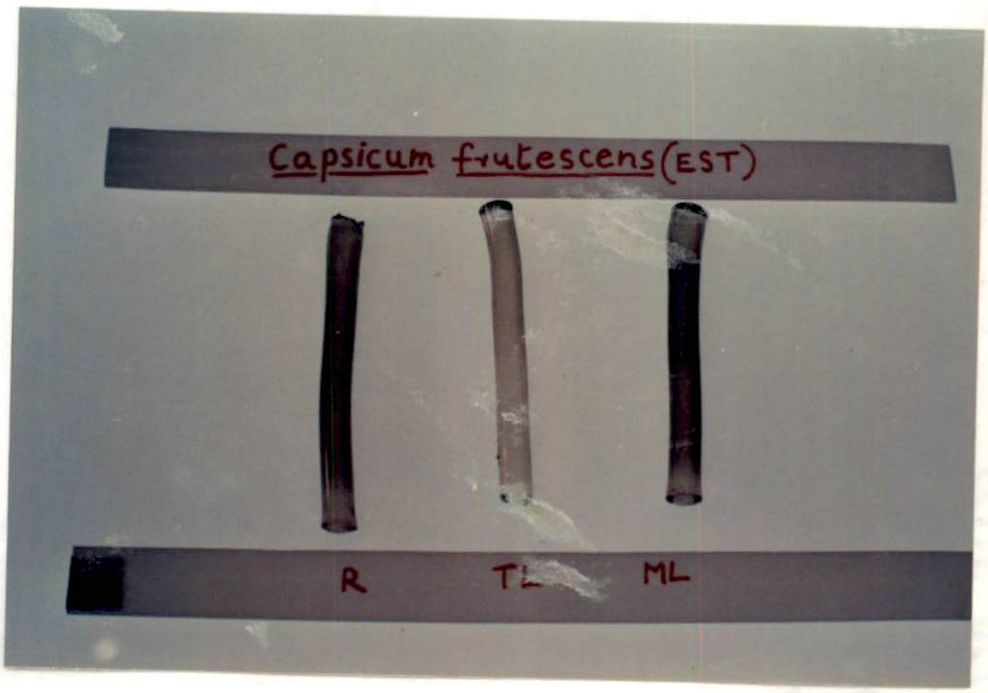

Capsicum annuum (CST)
R
TL
ML

Plate 20. Esterase pattern of different plant parts in *Capsicum frutescens*

Plate 21. Esterase pattern of different plant parts in *Capsicum chinense*


Capsicum frutescens (EST)
R
TL
ML

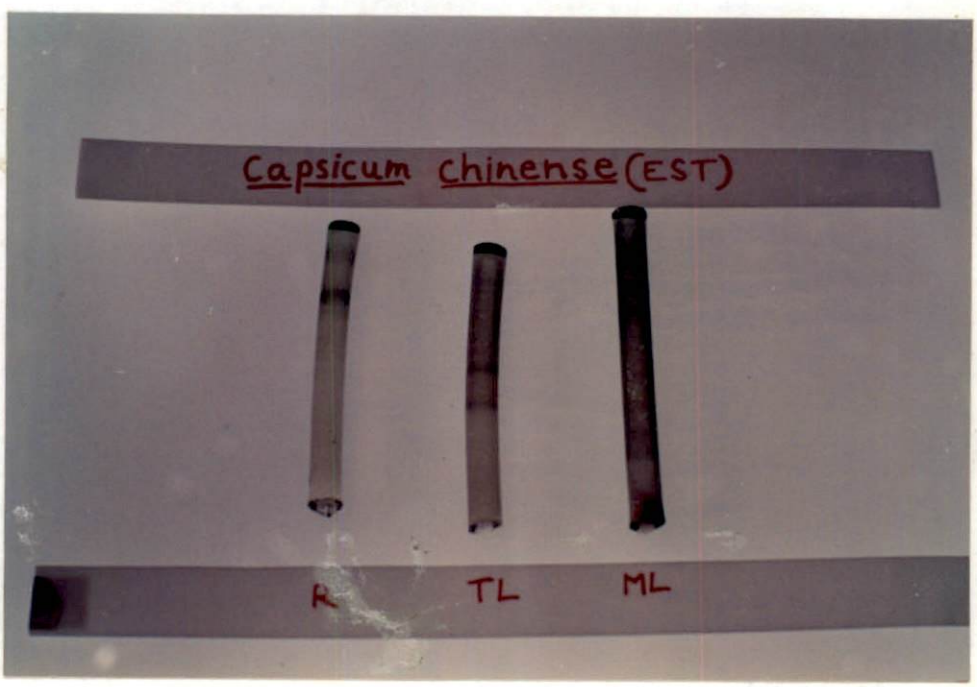
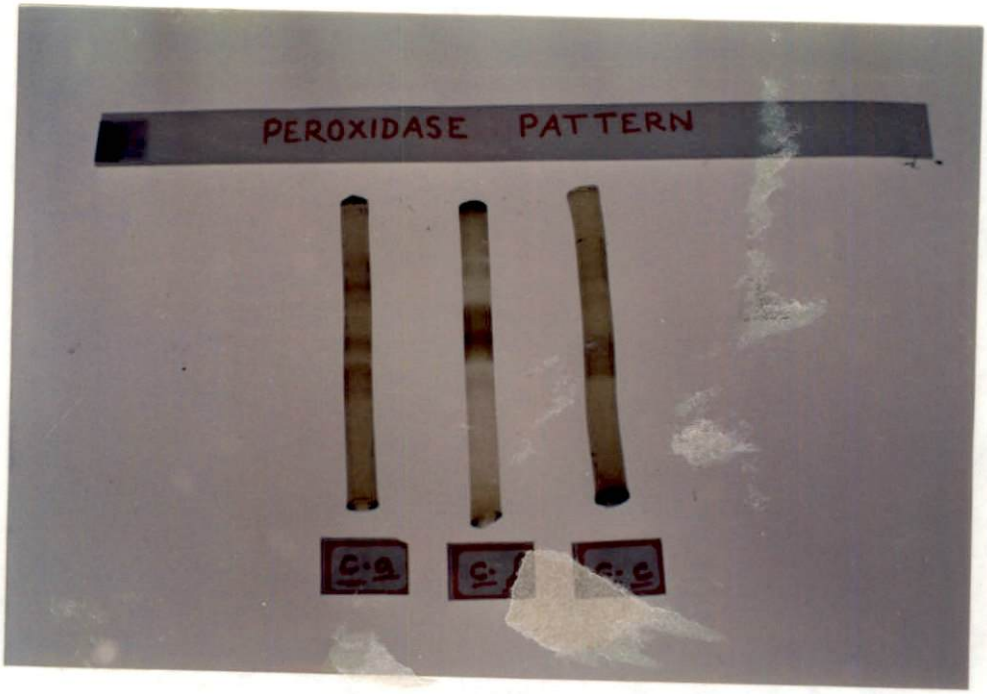
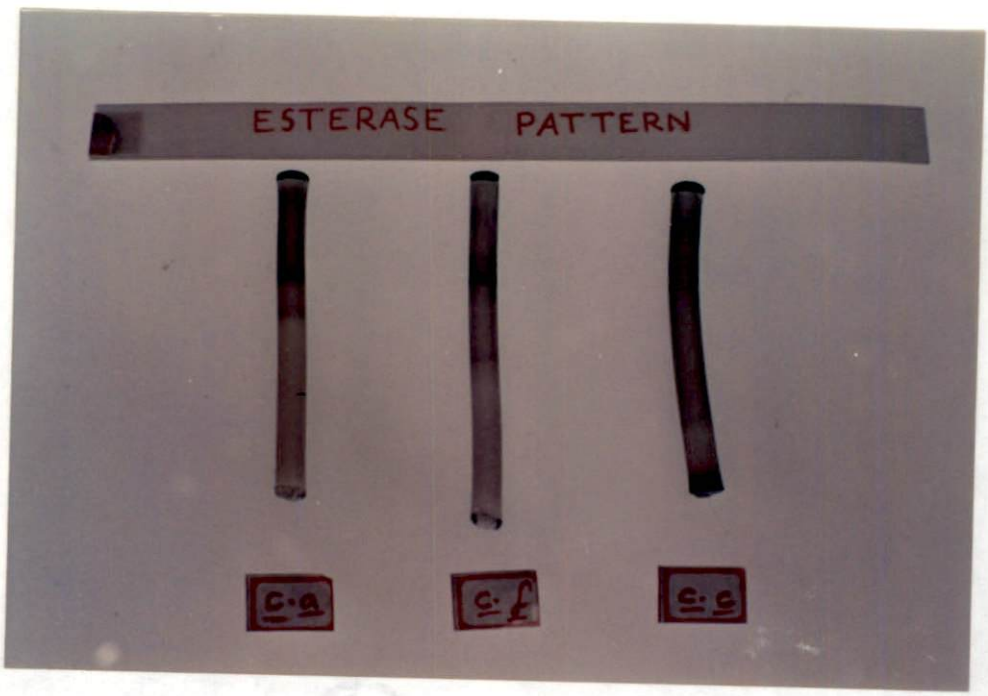

Capsicum chinense (EST)
R
TL
ML

Plate 22. Peroxidase pattern of 3 different *Capsicum* spp.

Plate 23. Esterase pattern of 3 different *Capsicum* spp.


PEROXIDASE PATTERN


ESTERASE PATTERN

4

Fig.4. Peroxidase zymogram of different Capsicum spp.

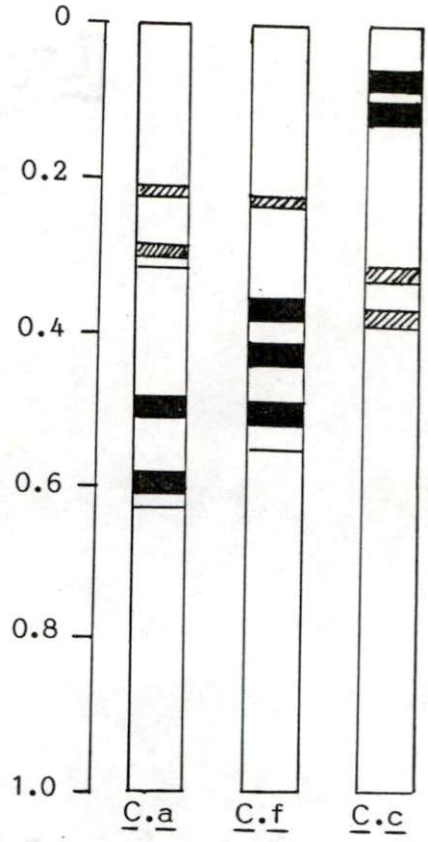
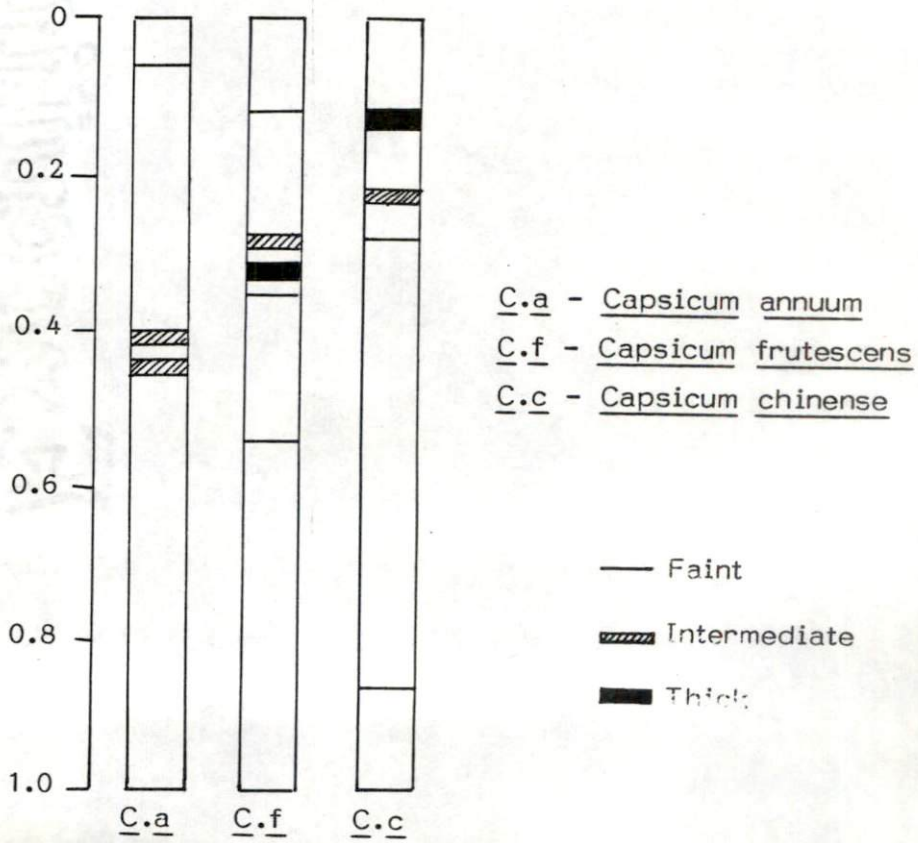


Fig.5. Exterase zymogram of different Capsicum spp.

5



The Rm value ranged from 0.06 to 0.86 thus indicating fastest moving band in *Capsicum chinense* (Fig.5). Though the number of bands were more in *Capsicum frutescens* three bands were very faint. Here also, common bands were not observed.

Peroxidase and Esterase pattern in the biometrical groups

A representative sample of nine biometrical groups was studied for their isozyme pattern. All of them showed variation in their banding pattern (Plate 24). Altogether there were 46 bands. The Rm value ranged from 0.03 to 0.64. There were some common bands at Rm value 0.56, 0.51, 0.41 and 0.28 (Fig.6).

The nine groups showed variation in banding pattern for the esterase enzyme also. There were only 30 bands altogether (Plate 25). Most of the groups were represented by three bands and only two groups showed four and five bands each. The Rm value ranged from 0.06 to 0.79 in group III. There were some common bands at Rm values 0.56, 0.43, 0.31 and 0.06 (Fig. 7).

D. Evaluation of Paprika

a) Survey, collection, evaluation and cataloguing of paprikas

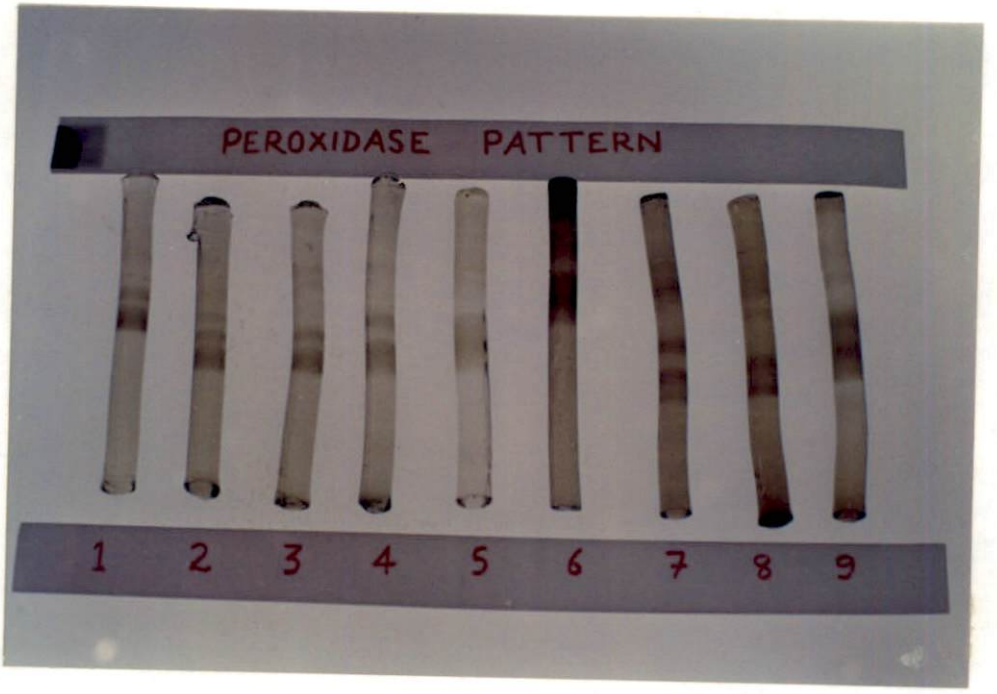
Twenty accessions of paprika were subjected to taxonomic treatment as per IBPGR (1983) and the results are presented in Table 28.

b) Field evaluation of paprikas

General analysis of variance showed significant differences among genotypes for seven characters for two seasons (Table 29). Mean performance of genotypes in two seasons for different characters are presented in tables 30 to 33.

Plate 24. Peroxidase pattern of 9 biometrical groups

Plate 25. Esterase pattern of 9 biometrical groups


PEROXIDASE PATTERN
1 2 3 4 5 6 7 8 9

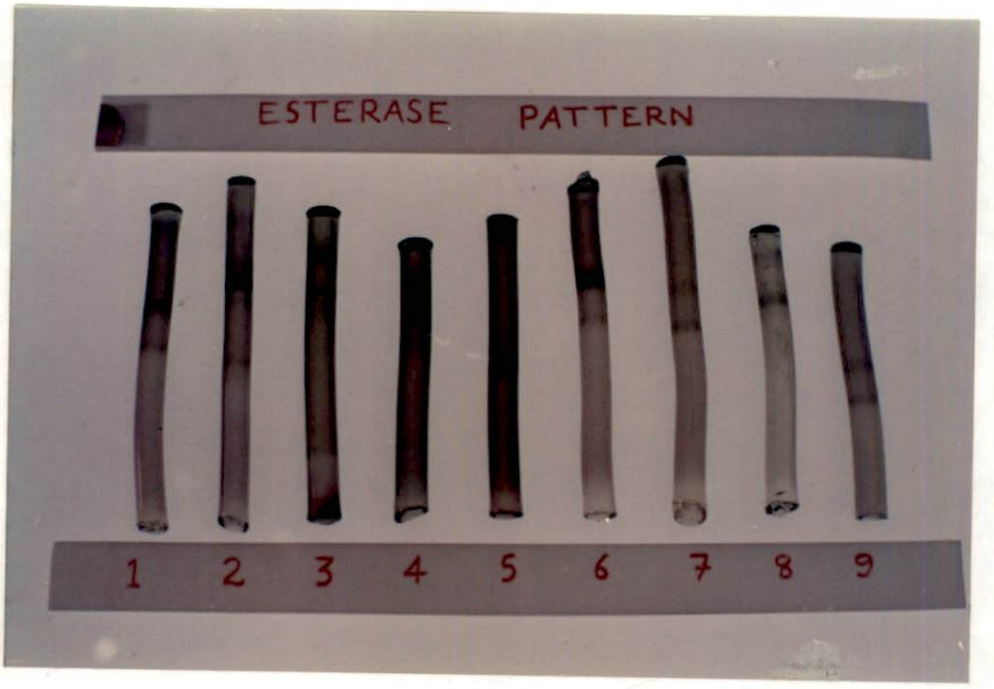

ESTERASE PATTERN
1 2 3 4 5 6 7 8 9

Fig.6. Peroxidase zymogram of 9 biometrical group

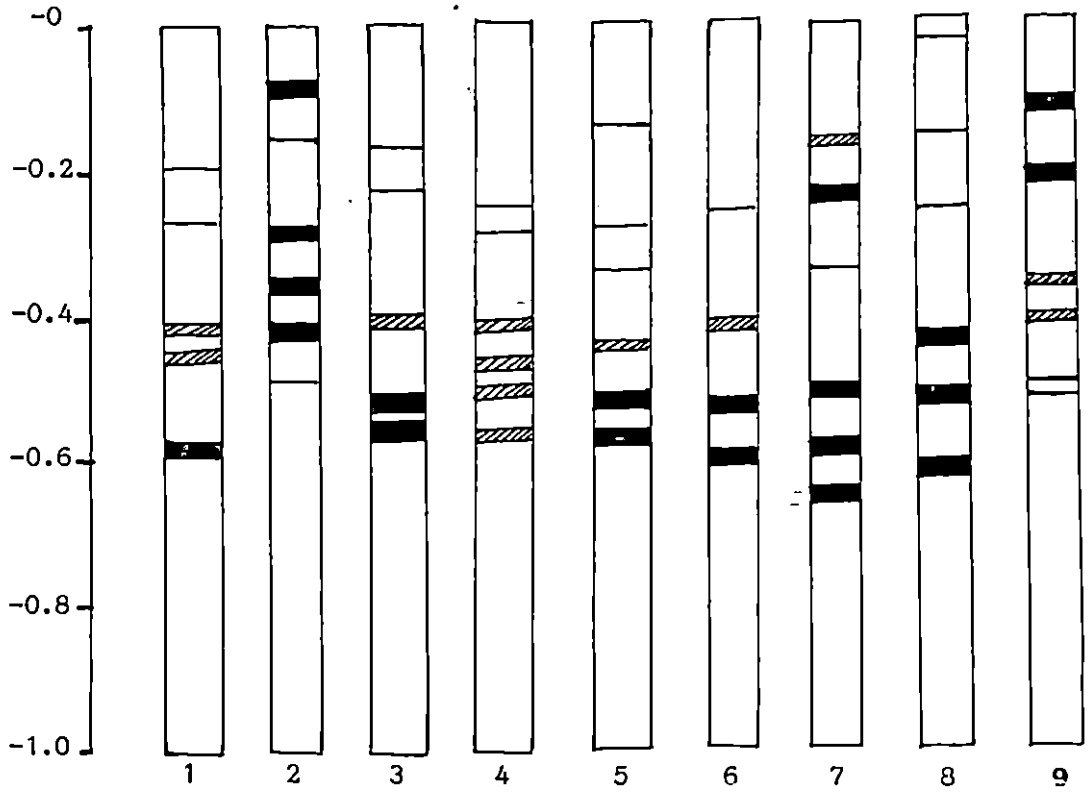


Fig.7. Esterase zymogram of 9 biometrical groups

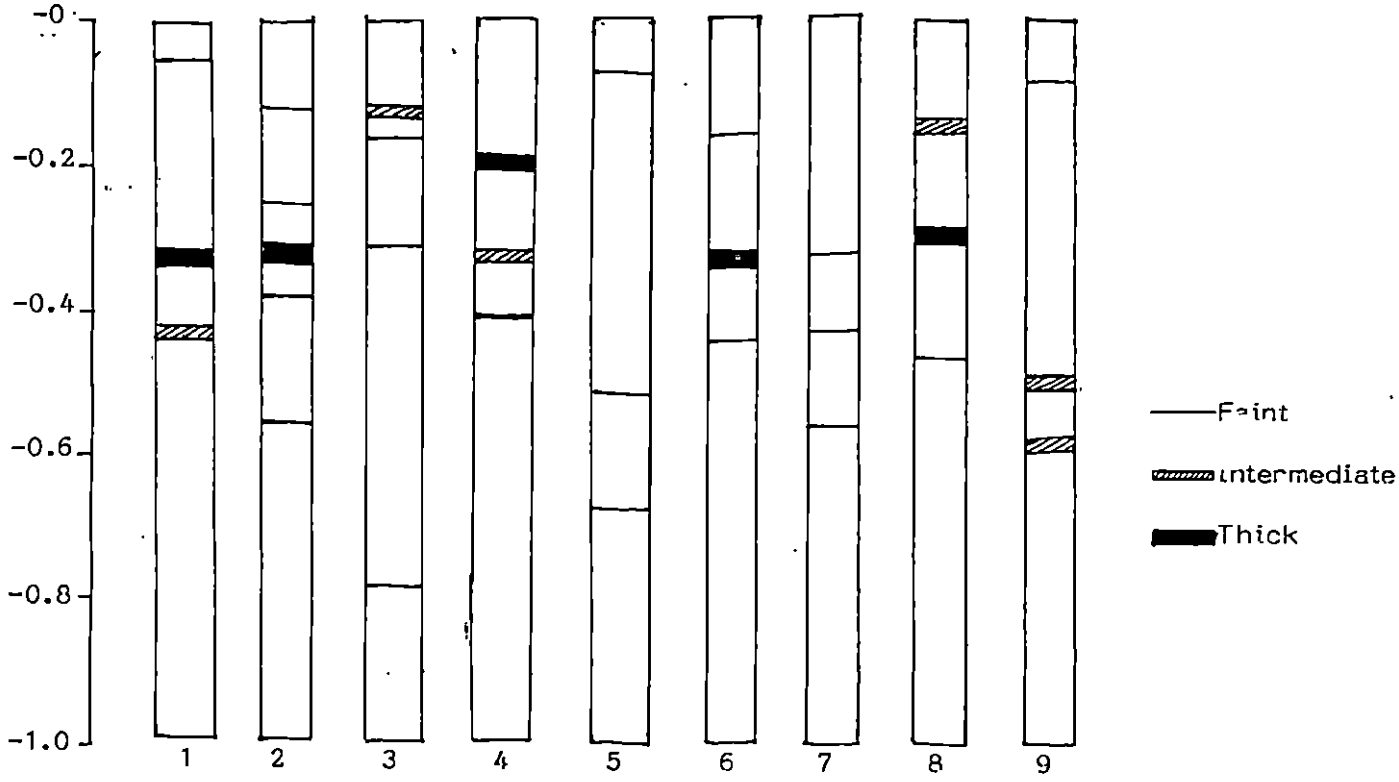


Table 28. Morphological description of 20 paprika genotypes

Sl. No.	Acc.No.	Source	Plant growth habit	Stem pubescence	Stem colour	Node colour	Leaf pubescence	Number of pedicels/ axil	Pedicel position of anthers	Corolla colour	Corolla spot	Calyx margin shape
1	CA 516	IIHR	Compact	Glabrous	Green	Purple	Glabrous	1	Pendant	White	Absent	Intermediate
2	CA 517	IIHR	Compact	Glabrous	Green	Purple	Glabrous	1	Erect	White	Absent	Intermediate
3	CA 544	Katrain	Compact	Glabrous	Green	Purple	Glabrous	1	Pendant	White	Absent	Intermediate
4	CA 590	IIHR	Compact	Glabrous	Green	Purple	Glabrous	1	Erect	White	Absent	Intermediate
5	CA 576	Turkey	Compact	Glabrous	Green	Purple	Glabrous	1	Pendant	White	Absent	Intermediate
6	CA 578	Katrain	Compact	Glabrous	Green	Purple	Glabrous	1	Erect	White	Absent	Intermediate
7	CA 579	Katrain	Compact	Glabrous	Green	Purple	Glabrous	1	Pendant	White	Absent	Intermediate
8	CA 582	IIHR	Compact	Glabrous	Green	Purple	Glabrous	1	Pendant	White	Absent	Intermediate
9	CA 586	IIHR	Compact	Glabrous	Green	Purple	Glabrous	1	Pendant	White	Absent	Intermediate
10	CA 568	IIHR	Compact	Glabrous	Green	Purple	Glabrous	1	Pendant	White	Absent	Intermediate
11	CA 589	Sikkim	Compact	Glabrous	Green	Purple	Glabrous	1	Pendant	White	Absent	Intermediate
12	CA 591	Dharwad	Erect	Glabrous	Green	Purple	Glabrous	1	Pendant	White	Absent	Intermediate
13	CA 605	Beltsville	Compact	Glabrous	Green	Purple	Glabrous	1	Pendant	White	Absent	Dentate
14	CA 603	Beltsville	Compact	Glabrous	Green	Purple	Glabrous	1	Pendant	White	Absent	Dentate
15	CA 609	IIHR	Compact	Glabrous	Green	Purple	Glabrous	1	Pendant	White	Absent	Dentate
16	CA 610	IIHR	Compact	Glabrous	Green	Purple	Glabrous	1	Pendant	White	Absent	Dentate
17	CA 575	IIHR	Erect	Glabrous	Green	Green	Glabrous	1	Pendant	White	Absent	Dentate
18	CA 611	IIHR	Compact	Glabrous	Green	Purple	Glabrous	1	Pendant	White	Absent	Intermediate
19	CA 612	IIHR	Compact	Glabrous	Green	Purple	Glabrous	1	Pendant	White	Absent	Dentate
20	CA 591-1	Dharwad	Erect	Glabrous	Green	Purple	Glabrous	1	Pendant	White	Absent	Intermediate

Contd.

28. Continued

cc.No.	Fruit position	Fruit colour		Fruit length	Fruit shape	Fruit shape		Neck at base of fruit	Fruit cross sectional corrugation	Fruit persistence
		Immature stage	Mature stage			at peduncle attachment	at blossom end			
A 516	Declining	L. green	Red	Long	Elongate	Obtuse	Pointed	Absent	Smooth	Persistent
A 517	Intermediate	L. green	Red	Medium	Elongate	Obtuse	Pointed	Absent	Smooth	Persistent
A 544	Declining	Green	Red	Medium	Elongate	Obtuse	Pointed	Absent	Smooth	Persistent
A 590	Intermediate	L. green	Red	Medium	Elongate	Obtuse	Pointed	Absent	Smooth	Persistent
A 576	Declining	L. green	Red	Long	Elongate	Obtuse	Pointed	Absent	Slightly corrugated	Persistent
A 578	Intermediate	Green	Red	Medium	Elongate	Obtuse	Pointed	Absent	Smooth	Persistent
A 579	Declining	Green	Red	Medium	Elongate	Obtuse	Blunt	Absent	Smooth	Persistent
A 582	Declining	Green	Red	Medium	Elongate	Obtuse	Pointed	Absent	Smooth	Persistent
A 586	Declining	Green	Red	Short	Conical	Obtuse	Blunt	Absent	Smooth	Persistent
A 568	Declining	Green	Red	Medium	Elongate	Obtuse	Pointed	Absent	Smooth	Persistent
A 559	Declining	Green	Red	Long	Elongate	Obtuse	Pointed	Absent	Smooth	Persistent
A 591	Declining	Green	Red	Long	Elongate	Obtuse	Pointed	Absent	Slightly corrugated	Persistent
A 605	Declining	Green	Red	Long	Elongate	Obtuse	Pointed	Absent	Smooth	Persistent
A 603	Declining	Green	Red	Long	Elongate	Obtuse	Pointed	Absent	Smooth	Persistent
A 609	Declining	Green	Red	Long	Elongate	Obtuse	Pointed	Absent	Smooth	Persistent
A 610	Declining	Green	Red	Long	Elongate	Obtuse	Pointed	Absent	Slightly corrugated	Persistent
A 575	Declining	Green	Red	Short	Conical	Truncate	Blunt	Absent	Smooth	Persistent
A 611	Declining	Green	Red	Long	Elongate	Obtuse	Pointed	Absent	Smooth	Persistent
A 612	Declining	Green	Red	Long	Elongate	Obtuse	Pointed	Absent	Smooth	Persistent
A 591-1	Declining	Green	Brownish red	Long	Elongate	Obtuse	Pointed	Absent	Slightly corrugated	Persistent

Table 29. General analysis of variance in 20 paprika types

Sources of variation	df	Days to first flower	Days to frist ripe fruit harvest	Plant height	Plant spread	Fruits/ plant	Fruit weight/ plant	Bacterial wilt incid-ence
Replications	1							
	S_1	6.400	0.729	51.984	7.744	0.003	0.900	0.032
	S_2	8.649	0.729	26.569	0.529	0.123	261.121	0.023
Genotypes	19							
	S_1	40.571	40.279	243.777	22.040	2.409	1198.260	0.041
	S_2	59.102	39.824	245.485	29.857	3.406	859.204	0.035
Error	19							
	S_1	2.257	1.009	3.449	5.220	0.033	13.222	0.011
	S_2	4.969	3.424	8.620	3.085	0.038	47.630	0.004

S_1 = October-March 1992

S_2 = May-October 1992

**p = 0.01

Days to first flower

Genotypes differed significantly during both seasons. The earliest flowered genotype was CA 604 in the first season and CA 579 in the second season, which took 62.2 days and 61 days respectively after sowing to flower. The late flowering genotypes were CA 578 (78.3 days) and CA 568 (98.2) during the first and second seasons.

Days to first ripe fruit harvest

There was significant difference among genotypes in both seasons for this character also. During the first season the genotype CA 544 (68.4 days after transplanting) came to harvest first while the genotype CA 589 (69.3 days after transplanting) ranked first during the second season. The late genotype was CA 591-1 (84.6 days) for first season and CA 591 (84.5 days) for second season.

Plant height

Significant difference was observed among genotypes for plant height for both seasons. The smallest genotype was CA 576 (43.3 cm) during the first season and CA 517 (Plate 26) (44.10 cm) during the second season. The tallest one was CA 591 (83.7 cm or 83.5 cm) during both seasons.

Plant spread

The genotypes differed significantly for plant spread during both seasons. CA 576 recorded minimum plant spread of 29.2 cm and 30.3 cm during the first and second seasons. Maximum spread was recorded by CA 575 (Plate 27) (42.9 cm and 47.6 cm).

Plate 26. CA 517

Plate 27. CA 575


CA 517

Table 30. Mean performance of 20 paprika types during two seasons

Sl. No.	Acc.No.	Days to first flower		Days to first ripe fruit harvest		Plant height (cm)	
		S_1	S_2	S_1	S_2	S_1	S_2
1	CA 516	76.3	72.0	79.4	79.1	67.8	67.90
2	CA 517	71.0	69.4	77.4	73.8	45.3	44.10
3	CA 544	69.9	61.3	68.4	70.2	56.5	66.30
4	CA 590	68.1	69.7	79.5	76.9	60.6	74.50
5	CA 576	71.0	66.2	80.0	78.9	43.3	49.10
6	CA 578	78.3	66.9	77.9	77.9	53.4	49.00
7	CA 579	65.7	61.0	72.1	71.2	67.9	64.70
8	CA 582	65.4	63.9	72.3	74.4	80.8	80.00
9	CA 586	93.4	77.7	80.1	77.1	72.2	73.80
10	CA 568	67.7	78.2	71.6	73.7	60.9	70.30
11	CA 589	65.3	61.9	79.6	69.3	57.5	60.50
12	CA 591	76.3	72.3	81.5	84.5	83.7	83.50
13	CA 605	63.1	60.4	71.5	70.7	53.3	56.60
14	CA 604	62.2	61.0	72.2	71.9	50.6	51.00
15	CA 609	72.6	69.3	80.0	73.6	59.8	54.70
16	CA 610	70.3	72.4	79.5	82.1	58.6	61.50
17	CA 575	72.1	70.6	81.7	76.4	71.8	72.80
18	CA 611	70.6	65.0	79.8	72.1	47.4	51.70
19	CA 612	71.6	70.3	72.7	73.1	59.6	60.60
20	CA 591-1	75.7	72.8	84.6	83.8	68.8	69.70
CD (p=0.01)		4.4	6.4	2.9	5.3	5.3	8.40
Range		62.2	61.0	68.4	69.3	43.3	44.10
		78.3	78.2	84.6	84.5	83.7	83.50

Fruits/plant

There was significant difference among genotypes for this character also. During first season CA 576 produced minimum number of fruits (6.8). While during second season CA 612 has produced only 5.6 fruits. The maximum number was produced by CA 582 (Plate 28) (43.2) during first season and CA 579 (40.6) during second season.

Fruit weight

Fruit weight differed significantly among genotypes during both seasons. It was minimum for CA 576 (41.2 g) during first season and for CA 605 (39.10 g) during second season. CA 575 was the highest yielder (137.5 g) during the first season and CA 517 (120.3 g) during the second season.

Incidence of bacterial wilt

Significant difference was observed in genotypes for wilt (%) during both seasons. Minimum percentage of wilting was recorded by CA 517 (Plant 29) (15% and 12.5%) during first and second season and the maximum of 67.5 per cent was recorded by CA 576 during both seasons.

Colour value

The genotype CA 586 (85.89 ASTA units) recorded minimum value during first season and CA 578 (75 ASTA units) showed minimum value during second season. The maximum colour value of 132.14 ASTA units was recorded by CA 582 during first season and CA 612 (135.71 ASTA units) during second season.

Plate 28. CA 582

Plate 29. CA 517 (Field view)


CHILLI
CA 517

Table 31. Mean performance of 20 paprika genotypes during two seasons

Sl. No.	Acc.No.	Plant spread (cm)		Fruits/plant	
		S_1	S_2	S_1	S_2
1	CA 516	38.9	37.10	4.313 (17.6)	3.694 (13.7)
2	CA 517	36.1	36.20	5.822 (32.9)	5.576 (31.10)
3	CA 544	42.3	39.90	3.224 (9.4)	2.983 (8.9)
4	CA 590	39.9	40.80	4.505 (19.3)	3.714 (13.8)
5	CA 576	29.2	30.30	2.793 (6.8)	2.569 (6.6)
6	CA 578	37.5	36.80	3.940 (18.3)	4.416 (20.4)
7	CA 579	36.3	40.10	6.244 (38.0)	6.534 (40.6)
8	CA 582	42.8	45.50	6.646 (43.2)	6.512 (39.3)
9	CA 586	38.5	42.50	4.725 (21.1)	5.301 (27.9)
10	CA 568	34.0	40.00	4.191 (16.6)	3.899 (15.1)
11	CA 589	40.5	40.30	3.390 (10.5)	2.718 (6.4)
12	CA 591	41.8	43.70	4.668 (20.8)	5.060 (21.8)
13	CA 605	37.9	34.30	3.066 (8.4)	2.607 (6.3)
14	CA 604	37.5	37.50	2.966 (7.8)	2.830 (8.9)
15	CA 609	40.8	40.10	3.271 (9.7)	2.863 (7.0)
16	CA 610	36.5	39.70	3.317 (10.0)	2.757 (7.8)
17	CA 575	42.9	47.60	4.461 (18.9)	3.144 (10.3)
18	CA 611	39.6	39.60	3.741 (13.0)	3.817 (14.6)
19	CA 612	39.1	36.10	3.162 (9.0)	2.530 (5.6)
20	CA 591-1	41.7	40.40	4.490 (19.2)	4.170 (17.4)
CD (p=0.01)		6.534	5.023	0.522	0.556
Range		29.2 - 42.9	30.30 - 47.60	6.8 - 43.2)	(5.6 - 40.6)

Data in parenthesis indicates value in original scale

Table 32. Mean performance of 20 paprika genotypes in two seasons

Sl. No.	Acc.No.	Fruit weight (g/plant)		% of wilted plants	
		S_1	S_2	S_1	S_2
1	CA 516	98.9	86.90	0.649 (60.0)	0.584 (55.0)
2	CA 517	129.9	125.30	0.151 (15.0)	0.125 (12.5)
3	CA 544	58.2	54.30	0.587 (55.0)	0.645 (60.0)
4	CA 590	96.0	67.40	0.621 (57.5)	0.625 (50.0)
5	CA 576	41.2	54.90	0.746 (67.5)	0.746 (67.5)
6	CA 578	73.2	60.80	0.528 (50.0)	0.553 (52.5)
7	CA 579	77.0	72.70	0.645 (60.0)	0.525 (50.0)
8	CA 582	106.3	82.20	0.253 (25.1)	0.279 (27.5)
9	CA 586	71.2	71.90	0.467 (45.0)	0.467 (45.0)
10	CA 568	60.3	59.70	0.441 (42.5)	0.616 (57.5)
11	CA 589	85.3	65.30	0.676 (62.5)	0.525 (50.0)
12	CA 591	87.8	102.10	0.495 (47.5)	0.495 (47.5)
13	CA 605	60.3	39.10	0.645 (60.0)	0.497 (47.5)
14	CA 604	49.3	46.00	0.676 (62.5)	0.613 (57.5)
15	CA 609	69.7	59.40	0.553 (52.5)	0.524 (50.0)
16	CA 610	97.6	70.30	0.497 (47.5)	0.467 (45.0)
17	CA 575	137.5	85.30	0.468 (45.0)	0.412 (40.0)
18	CA 611	76.4	79.20	0.467 (45.0)	0.553 (52.5)
19	CA 612	80.3	57.80	0.555 (52.5)	0.582 (55.0)
20	CA 591-1	80.4	82.70	0.555 (52.5)	0.616 (57.5)
CD (p=0.01)		10.40	20.977	0.302	0.177
Range		41.2	39.10	15.0	12.5
		137.50	125.30	67.5	67.5

Data in parenthesis indicate value in original scales

Capsaicin

CA 605 and CA 604 were the least pungent (0.21%) during first season while CA 589 (0.19%) was less pungent during second season. CA 612 was highly pungent (0.46%) during first season followed by CA 575 (0.44%) and CA 590 (0.44%). During second season CA 575 (0.48%) recorded maximum pungency.

Table 33. Mean performance of 20 paprika genotypes in two seasons

Sl. No.	Acc.No.	Colour value (ASTA Units)		Capsaicin %	
		S_1	S_2	S_1	S_2
1	CA 516	105.180	110.71	0.240	0.230
2	CA 517	114.290	92.86	0.365	0.350
3	CA 544	92.860	78.57	0.300	0.320
4	CA 590	96.430	78.57	0.440	0.430
5	CA 576	96.790	82.14	0.265	0.270
6	CA 578	103.035	75.00	0.320	0.340
7	CA 579	110.710	96.43	0.400	0.360
8	CA 582	132.140	125.00	0.280	0.300
9	CA 586	85.890	82.14	0.270	0.240
10	CA 568	88.035	89.29	0.410	0.360
11	CA 589	118.035	78.57	0.230	0.170
12	CA 591	105.355	96.43	0.310	0.270
13	CA 605	117.860	103.57	0.210	0.220
14	CA 604	110.710	110.71	0.210	0.210
15	CA 609	111.790	107.14	0.320	0.320
16	CA 610	121.790	110.71	0.365	0.310
17	CA 575	106.250	96.43	0.440	0.480
18	CA 611	110.710	103.57	0.415	0.350
19	CA 612	125.000	135.71	0.455	0.380
20	CA 591-1	103.570	92.86	0.270	0.255
Range		85.890 132.140	75.00 135.71	0.210 0.455	0.170 0.480

Discussion

DISCUSSION

Chilli (*Capsicum* spp.) is a spice cum vegetable of commercial importance and is being cultivated in the tropical and sub-tropical regions of the world. Green chilli, chilli powder, cayenne pepper, tabasco, paprika, sweet or bell pepper, pimentos and serrano pepper are all derived from the berry of many *Capsicum* species. Capsaicin - the pungent principle, capxanthin - the colouring pigment, chilli oleoresin, chilli seed oil, ascorbic acid - precursor of vitamin C etc. are a few products from chilli. Annual trade of chilli in the world is 55 to 65 thousand tonnes which is 16.7 per cent of total spice trade in the world. India ranks first in area (4.17 lakh ha) and production (7.79 lakhs t) in the world. During 1993-94, India exported 33.45 thousand tonnes of chilli valued Rs.75.59 crores. Target for 1994-95 is 27.5 thousand tonnes valued Rs.70.00 crores. Still it is only 45 per cent of chilli trade in the world. Chilli is grown throughout India. Andhra Pradesh leads in area and production. As a vegetable, chilli fruit is rich in vitamin C (96 mg/100 g) and thiamine (0.37 mg/100 g) (Peter, 1994).

Capsicum terminology is confusing. Pepper, chili, chile, chilli, aji, paprika and *Capsicum* are used interchangeably for plants in the genus *Capsicum*. *Capsicum* investigators use chile, pepper, or aji as vernacular terms. *Capsicum* is reserved for taxonomic discussion (Bosland, 1992). Chile means pepper (Capsicum) whether the fruits are pungent or not. Generally chili is used to identify the state dish of Texas, USA which is a combination of pungent chile cultivars and meat (Domenici, 1983). Bell peppers refer generally to nonpungent blocky chilli types. Chilli types are usually classified by fruit characteristics i.e., size, pungency, colour, shape, flavour and use (Smith *et al.*, 1987).

In any crop improvement programme, the main objective is the development of varieties through production breeding. The basic information, a breeder usually requires, as a pre-requisite to any breeding programme, is the extent of variability in the available germplasm. Pepper breeding got evolved through domestication of *Capsicum* species by the indigenous people of the Americas, global diversification facilitated by age of exploration, and subsequent establishment of landraces and farmers selections. Classical genetic and cytogenetic exploration of *Capsicum* species began in 1940s and continued throughout this century (Poulose, 1994).

Modern pepper breeding relies on a relatively narrow gene base within various cultivar groups, despite morphological genetic diversity apparent both intra-specifically and interspecifically. This may be explained partly by the traditional market demands for specific phenotypes and use of pureline or backcross breeding with open-pollinated commercial varieties. Great difficulty was faced in classification of cultivated chilli varieties because of their large number, the transitory nature of many of them and creation of new ones through hybridisation and selection. Due to complexities in *Capsicum* taxonomy, the hot pungent perennial chillies and all the wild types grown traditionally in India were considered as *Capsicum frutescens* by Shaw and Khan (1928) and based on this, crossability was worked out which led to controversial results. Unlike the early taxonomic system, where classification was based on specific key characteristics, modern taxonomists used a combination of characters and assigned cultivated *Capsicum* spp. into five species - *Capsicum annuum, Capsicum frutescens, Capsicum chinense, Capsicum baccatum* and *Capsicum pubescens* (Eshbaugh, 1980).

A. Morphological description of chilli germplasm

In the present study, 82 chilli genotypes grown during two seasons were subjected to modern taxonomic treatments as suggested by IBPGR (1983) and later assigned to four *Capsicum* species - *Capsicum annuum, Capsicum frutescens, Capsicum chinense* and *Capsicum baccatum*. Out of 82 chilli accessions evaluated, 74 belonged to *Capsicum annuum. Capsicum frutescens* was characterised by greenish white corolla lobes and *Capsicum chinense* by presence of annular constriction at junction of pedicel and calyx. There was only one accession (CA 519) under *Capsicum baccatum*, characterised by prostrate growth habit and yellow corolla spot.

The 74 genotypes belonging to *Capsicum annuum* were subjected to horticultural classification as per Smith *et al.* (1987). Two genotypes CA 533 and CA 600 belonged to pimento group, CA 534 and CA 535 to waxy conical group, CA 536 to short wax group (Plate 30), CA 530 (Hungarian Wax) (Plate 31), CA 537 and CA 554 to long wax group (Plate 31), CA 539, CA 540 and CA 542 to ancho group (Plate 32) and 10 genotypes to anaheim group (Plate 33) (CA 543, CA 544, CA 545, CA 603, CA 604, CA 605, CA 610, CA 611, CA 612 and CA 613), represented mostly by long, deep red coloured spice chilli types. Under cherry group (Plate 34), there are four genotypes (CA 521, CA 547, CA 561 and CA 636), 4 genotypes under squash or cheese group (Plate 35) (CA 548, CA 549, CA 574 and CA 595) characterised by tomato shaped fruits and about 10 genotypes under blocky group (CA 531, CA 532, CA 533, CA 562, CA 567, CA 570, CA 572, CA 573, CA 594 and CA 597). Bharat Hybrid, Yolo Wonder, California Wonder, Arka Gaurav and Arka Mohini are characterised by blocky fruits. Similar classification was reported by Joshi *et al.* (1988). The remaining genotypes belonged to *Capsicum*

Plate 30. Short wax group

Plate 31. Long wax group

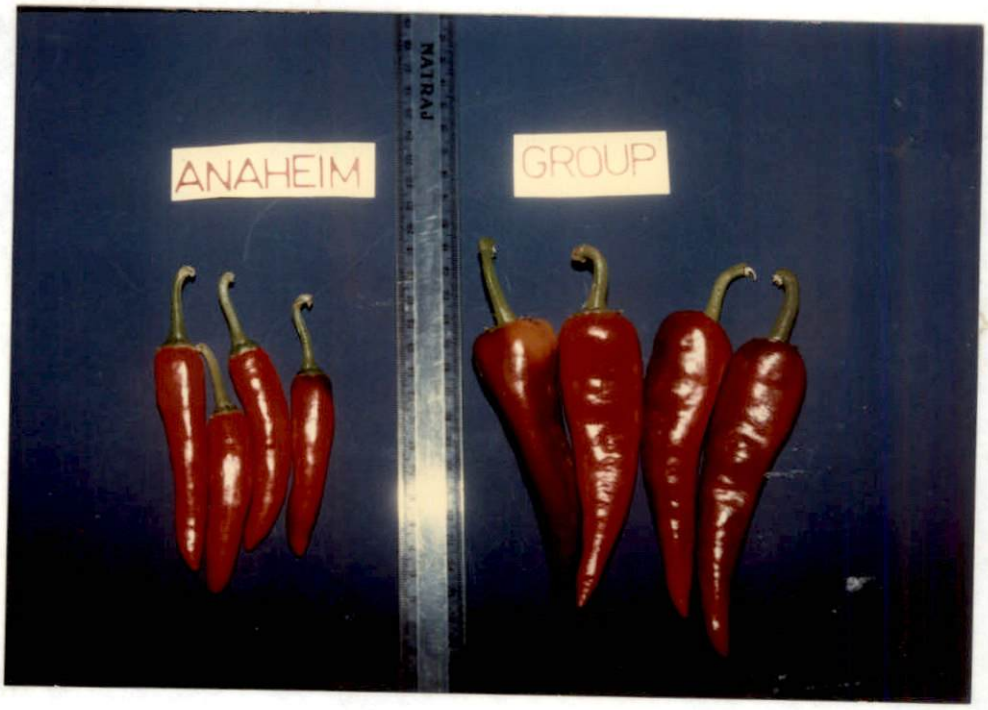

SHORT WAX GROUP
CA 536

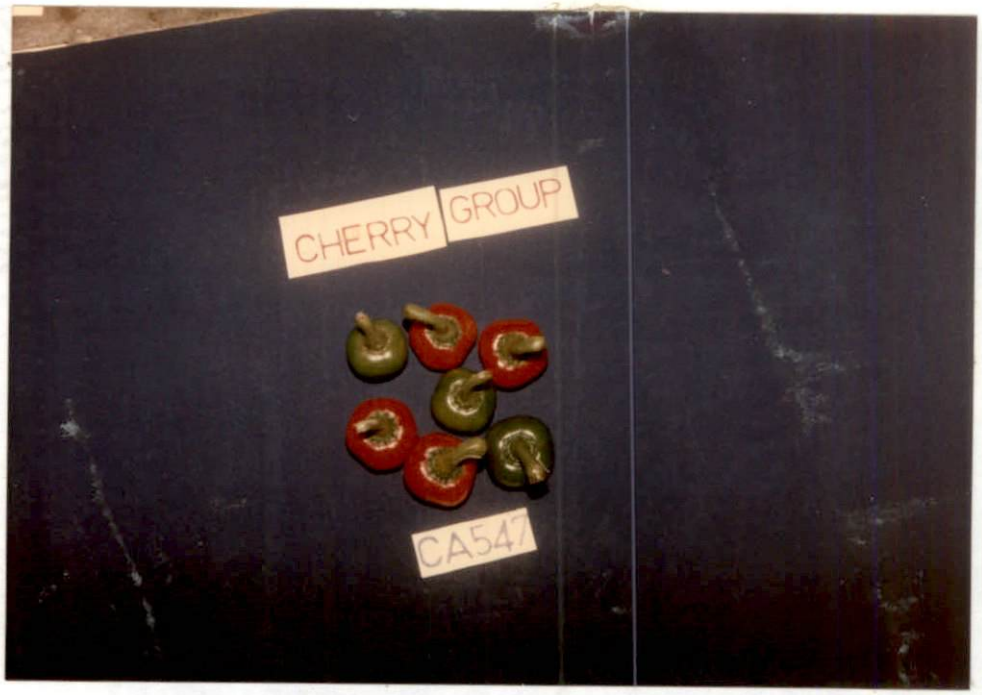

LONG WAX GROUP
HUNGARIAN
WAX

Plate 32. Ancho group

Plate 33. Anaheim group


ANCHO GROUP
CA 539


ANAHEIM
GROUP
NATRAJ


CHERRY GROUP
CA547


CA549
JOVA
CHEESE GROUP
CA 548

chinenese, Capsicum baccatum and *Capsicum frutescens*. There were 3 clustered accessions CA 33 (Manjari), CA 219 and CA 629, CA 622, a collection from Trinidad, with highly irregular fruits, belonged to *Capsicum chinense*.

B. Assessment of genetic divergence and grouping of genotypes

Selection of parents for hybridisation is based mainly on genetic diversity. The more divergent the parents are more will be the magnitude of heterosis. Major reasons for creation of genetic diversity in plants are mutations, recombination, disruptive selection and polyploidization, whether they are accomplished through natural agencies or through controlled means (Rai, 1979). Usually in many of the conventional heterosis breeding programmes, geographical diversity at times and phenotypic diversity in majority of cases are taken as criteria to choose genetically divergent populations to isolate inbred lines. Phenotypic divergence in a population is also considered as an index and criteria of genetic diversity (Rai, 1979).

Mahalanobis D^2 statistic is a powerful tool to quantify genetic distance in plant breeding experiments. It permits precise comparison in all genotypes by considering a large number of characters simultaneously.

Main objective of the present study is to assess genetic diversity among 82 chilli genotypes of exotic and indigeneous origin and to group them into clusters based on genetic distance. On the basis of genetic distances considering eight quantitative characters, 71 genotypes were grouped into nine clusters during first season and 72 genotypes into six clusters during second season. The distribution of genotypes into clusters showed no regularity. It did not show any relationship with geographical origin. During first season, clusters I, II, III and IX were the largest

Plate 34. Cherry group

Plate 35. Cheese group

having 11 genotypes each, clusters V and VII with 8 genotypes each and cluster IV had five genotypes. Cluster VI and VIII had three genotypes each. Cluster I included both indigenous (CA 628, CA 631) and exotic collections. Cluster II included mostly exotic collections of blocky group like CA 562, CA 564, CA 570, CA 572 etc. Cluster III included genotypes with tomato shaped fruits - CA 547, CA 548, CA 549 and Bharat Hybrid (CA 553) belonging to blocky group. *Capsicum chinense* accessions CA 559 and CA 560 are also included in this cluster. The three genotypes included in cluster VI are CA 89 (White Kanthari), CA 219 and CA 530 (Hungarian Wax). They are comparatively high yielders.

There were no species specific or geographical region specific clusters. Geographically isolated genotypes were included in the same cluster. Similar results were reported by Sundaram *et al.* (1980). Diversity among lines of same geographical origin could be attributed to several reasons. It may be due to ecogeographical distribution (Sood *et al.*, 1989). Populations from areas with complex environments may have in the long run adjusted to several ecological niches and have accumulated enormous genetic variability (Chandel and Joshi, 1981). Diversity could also be ascribed to genetic drift and selection under diverse environment, which could cause greater diversity than geographic isolation alone (Murthy and Arunachalam, 1966). Also, free exchange of seed material among different regions and other human interference might have contributed to diversity (Katiyar and Singh, 1979).

During second season, 72 genotypes were grouped into six clusters, based on eight quantitative characters. This shows influence of climatic factors on expression of characters and further their grouping also. This concurs with Murthy and Arunachalam (1966) who stated that diverse environments could cause larger

diversity than geographic isolation alone. Cluster I was the largest with 24 genotypes. This included mostly the exotic collections of bell and anaheim group only. The *Capsicum chinense* accession CA 640 was also included in cluster I.

Cluster II comprising 15 genotypes included mostly dwarf and ornamental genotypes like CA 561, CA 636, CA 629 (cluster type), CA 556 and CA 557. CA 519 belonging to *Capsicum baccatum* was also included in this cluster. Cluster III with five genotypes had mostly tall types like CA 546, CA 591 (Byadagi), CA 628 (Green Chuna) and CA 631 (*Capsicum chinense*). Cluster IV with 21 genotypes had mostly spice chilli genotypes with long deep red coloured fruits like CA 543, CA 544, CA 569, CA 610 and CA 612. The paprika types CA 604 and CA 605 are also included in this cluster. CA 451 (Jwalamukhi) and CA 452 (Jwalasakhi) also belonged to this group. Cluster V with five accessions had clustered (bunchy), varieties like Manjari (CA 33) and CA 219 and solitary types like Jwala (CA 60), White Kanthari (CA 89) and CA 517.

CA 576, a long paprika type and CA 622, a *Capsicum chinense* collection from Trinidad belonged to the last group. Both are exotic types. As a general rule, genotypes with almost similar characteristics had come together during second season, except in cluster VI.

Out of nine clusters during first season, cluster I which comprised of 11 genotypes, showed high mean value only for pedicel length. Cluster II had maximum number of primary branches, cluster III was intermediary for all the characters, cluster IV recorded minimum plant height and yield/plant. Cluster V had minimum values for pedicel length, fruit length and fruit perimeter, cluster VI was late to flower. Vegetative growth was maximum with tall and highly branched

genotypes. The seed number was minimum. This cluster included only three genotypes CA 89 (White kanthari), CA 219 (cluster type) and CA 530 (Hungarian Wax). Fruit length was maximum in cluster VII. The genotypes of cluster VIII were early to flower with the highest yield. This recorded the highest fruit girth and seed number. The three genotypes CA 533 (Pimento group), CA 536 (wax group) and CA 540 (KT-1) are included in this cluster. Pedicel length was minimum for these three accessions. Cluster IX had mostly bell pepper varieties from IIHR, Bangalore and spicy types like CA 587, CA 589, CA 591 (Byadagi), CA 582 etc. This cluster was intermediate for all the eight characters studied.

During second season, out of six clusters, cluster I with 24 genotypes recorded the highest mean value for fruit perimeter and seed number. Cluster II with 15 genotypes flowered earlier and fruit length was minimum. This cluster included mostly dwarf, ornamental types. Cluster III recorded maximum plant height and number of primary branches. The tall types like CA 546, CA 591, CA 628 and CA 631 are included in cluster III. The pedicel length and seed number were minimum in this cluster. CA 628 (Green chuna) had only 13.4 seeds/fruit. Cluster IV was intermediate for all characters studied. Cluster V was the highest yielding, with maximum pedicel length and minimum fruit girth. The clustered (bunched) accessions CA 33 and CA 219 and the local white Kanthari (CA 89) are included in this cluster. Jwala (CA 60) and CA 517 are also included in this cluster.

Cluster VI included only two genotypes which recorded maximum values for days to first flower and fruit length. This cluster recorded minimum values for plant height, primary branches/plant and yield. The clustering patterns differed in the two seasons.

Crossing among divergent parents is likely to yield heterotic hybrids. In the present study during first season the maximum genetic distance was exhibited between clusters I and VIII (D^2 = 698.16). Clusters having the largest genetic distance show maximum divergence also. Cluster I having 11 genotypes, recorded high mean value only for pedicel length. Cluster VIII with three genotypes recorded the highest yield. Parental lines from cluster I and cluster VIII when crossed are likely to give heterotic hybrids.

The inter cluster distance (D^2) was also high between cluster VIII and IX (653.21), II and VIII (529.66) and VI and VIII (503.25). Clusters I and IX exhibited a minimum distance of 55.01, during first season.

Maximum intracluster distance was shown by cluster VIII (103.54) followed by cluster IV (28.73). High intracluster distance indicated high degree of variability within clusters offering scope for improvement by various selection methods.

During second season, maximum genetic distance was exhibited between clusters III and VI (D^2 = 411.56), followed by cluster II and VI (D^2 = 365.89). Minimum distance was between clusters I and IV (D^2 = 69.48).

Maximum intracluster distance was in cluster VI (220.50) represented only by two genotypes. Minimum distance (21.69) is in cluster IV containing 21 genotypes.

During first season (August, 1991 - January, 1992) maximum and minimum temperature were in the range of 32.6°C - 29°C and 23.6°C - 20.9°C

respectively. Maximum rainfall was only 533.3 mm and rainy days were also minimum (Appendix-II). Since paprikas and bell peppers are adapted to a subtropical climate, these climatic factors were congineal for this crop. According to Cochran (1936) air temperature at the time of bloom affects fruitset in paprikas. The maximum set occurred at constant temperature of 11°C - 18°C, with temperatures below 11°C and above 32°C, preventing fruitset. Since most of the climatic factors were favourable, the performance of bell peppers and paprikas was good during this season.

During second season (May, 1992 - September, 1992) maximum temperature range was 33.8°C - 28.8°C and minimum was 24.8°C - 23.1°C. But the rainfall was maximum during July (979.8 mm) and the number of rainy days were also more. The sunshine hours were also minimum. According to Rylski and Halevy (1974) high day temperature and low light intensity, mainly at early stages of flower development, promoted flower drop in bell peppers. High temperature during later stages of flower development was a pre-requisite for the formation of full shaped fruits. Though bell peppers grow well in warm and humid climate, dry weather is equally necessary during fruit maturity (Joshi and Singh, 1975).

Thus due to adverse climatic factors bell peppers and paprikas were most affected and their yield was comparatively poor during second season. The genotypes like CA 219, Manjari which are already adapted to Kerala conditions gave higher yield during this season. These differences were thus manifested in the clustering pattern also during both seasons.

C. Biochemical diversity

Isozyme analysis by electrophoresis provides a well defined and effective method to detect genetic differences among individuals. Among the organic molecules, isozymes are very useful aids in deciphering evolutionary relationship within different groups of plant and animal organisms (Oliver and Zapater, 1985). Isozymes are used only as a supplementary tool, along with morphological and other methods of plant classification.

In the present study the isozyme pattern of peroxidase and esterase enzymes were studied in three *Capsicum* spp. viz. *Capsicum annuum, Capsicum frutescens* and *Capsicum chinense*. Among the different plant parts used clear bands were visible in the roots and mature leaves for peroxidase enzyme in all the three species. Wang and Dehua (1987) reported that the best sampling tissue for elèctrophoresis of peroxidase isozymes is functional leaves at flowering stage. But in the case of esterase enzyme mature leaves gave clear bands in all the three species. Tender leaves were not good for the study of both the enzymes.

There were species specific bands for peroxidase isozymes. *Capsicum annuum* had six bands, *Capsicum frutescens* - 5 bands and *Capsicum chinense* - four bands. There were no common bands for the three species. Similar results are reported by Pradeep Kumar (1990) after protein electrophoretic studies.

Esterase pattern also showed variation among three species. More number of bands were seen in *Capsicum frutescens*. The fastest moving band was seen in *Capsicum chinense*.

A representative sample of 9 biometrical groups was analysed for their isozyme pattern. Since these groups are represented by all 3 *Capsicum* spp. it shows definite variation from one group to another. Since this biometrical grouping is based on quantitative characters, it will not have much relationship with isozyme pattern. The isozyme variations are used to compliment conventional taxonomic studies based on key characters (Rick *et al.*, 1976). In this study, all the nine groups showed variation for both peroxidase and esterase pattern. Conclusive results can be obtained only after analysing a large number of samples.

D. Evaluation of paprikas

Paprika of diverse horticultural varieties is grown mainly in Southern Europe and commercially in U.S.A., Mexico and Brazil. Paprikas are distinguished by low concentrations of capsaicin (0.30 ppm) (Verghese *et al.*, 1992). The international standards organization recognizes only two types; "chillies" and "paprika" to cover the easily perceivable strong pungent types, the big fleshy vegetable and the sweet or just recognisable pungent types of capsicums respectively.

Chillies and paprika are valued for their colour, pungency and aroma. Generally there is a decrease in pungency from chillies to paprika and a parallel increase in colour, pigment concentration and an increase in size and fleshy nature of pericarp. The group paprika contains less than 0.1 per cent of capsaicinoids. The chillies on the other hand vary considerably in their pungency (Govindarajan, 1985).

The increasing commercial importance world wide of paprika both as paprika powder and oleoresin has resulted in establishing breeding programmes on its improvement to develop varieties/hybrids to meet international demand. Breeding

programmes were initially started at IARI Substation, Katrain. Joshi *et al.* (1988) evaluated paprika genotypes and identified two high yielding types Kt-Pl 8 and Kt-Pl 19.

Spice paprika is entirely a new crop to Kerala. Salad paprika types like 672 Hugarian Wax, Early Calwonder, Cubanelle, Yolo Wonder Improved, Sweet Red Cherry Pickling, Hybrid pepper, Bell Boy and Bharat F_1 hybrid were evaluated under Kerala conditions earlier (Thomas and Peter, 1986). They found that the yield levels were low when compared to yields recorded in other varieties in India. 672 Hungarian Wax, Early Calwonder and Cubanelle were found to be prospective varieties for Kerala.

In the present study 20 spice paprika genotypes collected from the Indian Institute of Horticultural Research, Bangalore, IARI Regional Station, Katrain and Vegetable Research Laboratory, Beltsville were evaluated for their plant and fruit characteristics as well as for bacterial wilt incidence.

General analysis of variance for different characters

General analysis of variance indicated significant differences among 20 genotypes, for the seven characters analysed during two seasons. The performance of the genotypes was poor during second season (May-October, 1992). This may be due to the high rainfall prevalent during that period. The number of rainy days were maximum during this period, and the sunshine hours were minimum. High daytemperature (20-24°C) and low light intensity, mainly at early stages of flower development promotes flower drop in paprikas (Rylski and Halevy, 1974). During the second season all the genotypes took more number of days to flower and the vegetative growth was maximum. During the first season, CA 604 (Papri King) was the

first to flower (62.2 days) while CA 579 flowered first during the second season (61 days).

Paprikas are harvested at red ripe stage. During the first season, CA 544 took only 68 days after transplanting, for ripening and during the second season, CA 589 took 69 days to ripen while the indigenous types (Byadagi) from Dharwad (CA 591 and CA 591-1) took more number of days to ripen (84.5 and 84.6 days). They were also late to flower. CA 591 had maximum plant height during both the seasons. CA 576, an exotic type showed minimum plant height (43.3 cm), plant spread (29.2 cm) and yield (41.2 g) but it produced longer fruits (16.16 cm) than other genotypes.

The 20 genotypes showed significant differences for number of fruits. In general, fruit number was minimum since only ripened fruits were harvested. CA 582 and CA 579 produced more number of fruits (43.2 and 40.6 respectively) but their size was small compared to other types. CA 575 was the highest yielder (137.5 g) during the first season and CA 517 (125.3 g) during the second season. Yields recorded by other genotypes were comparatively low being 41.2 - 137.5 and 39.10 - 125.30 g during first and second seasons respectively. According to Bosland *et al.* (1991) low yield is a limiting factor for paprika production. Difference in performance of paprika genotypes in varying environments could be due to their difference in adaptability and response to changes in environments. This indicates scope for breeding for adaptability to different conditions.

The genotypes showed significant differences for extent of wilt incidence also. Minimum wilting percentage was observed in CA 517 (15% and 12.5%) under field conditions. CA 582 was moderately resistant (25.1% and 27.5% wilted plants)

and others were moderately susceptible. CA 517 needs further study under artificial conditions. CA 576 was highly susceptible to bacterial wilt (67.5%) during both the seasons.

Paprika is valued mainly for its colour. Colour is measured as per American Spice Trade Association (ASTA) procedures and is expressed in ASTA units (ASTA, 1985). The genotypes with ASTA units in the range of 101-150 is classified under high colour group, those with 70-100 ASTA units under medium colour group and those below 70 units under low colour group. Among the 20 genotypes CA 582 recorded maximum colour value (132.14 ASTA units) during first season and CA 612 (135.71 ASTA units) during second season. CA 582 possesses deep red coloured glossy fruits with medium length.

There was seasonal variation for pungency in the 20 genotypes studied. The pungency factor varies among the fruits of the cultivars of the same species and of a single cultivar (Verghese *et al.*, 1992). Within the fruit also the heat level is uneven but the distribution pattern is not precisely delineated. There are many reports that capsaicinoids are mostly accumulated in the placenta, localized in the placenta and dissepiment, predominantly in the cross wall with limited amounts in placenta, concentrated in the pericarp tissue and not in the seed or peduncle, essentially 90 per cent in the pericarp (which includes the dissepiment and placenta) and 10 per cent in the seed probably from contamination. For industrial purpose, it is concluded that capsaicinoids is centered in the pericarp which includes the dissepiment and placenta.

In the case of paprikas, pericarp alone is ground to remove this pungency factor. The seed is a byproduct which is used as an animal feed (Govindarajan,

1985). Genotypes with capsaicin in the range 1.0 - 1.5 per cent are classified as highly pungent, 0.25 - 0.75 per cent, medium pungent and 0.11 - 0.25 per cent as less pungent. In the present study the genotypes CA 604 and CA 605 recorded a pungency of 0.21 per cent (Capsaicin) while during second season CA 589 was the least pungent (0.17%). CA 612 recorded a value of 0.46 per cent during first season and CA 575 (0.48%) was pungent during second season. Joshi *et al.* (1988) reported both pungent and nonpungent paprikas from Katrain. According to Bosland (1992) there are both pungent and nonpungent paprikas.

Field evaluation of paprikas revealed that they are suitable for cultivation during the winter months (August to January) under Kerala conditions. CA 517 was identified to be wilt resistant under field conditions.

Future line of work include crossing among divergent parents in cluster I and VIII and confirming the resistance of CA 517 under laboratory conditions.

Summary

SUMMARY

The present investigations on "Diversity interrelationships among *Capsicum* spp. and forms and development of paprikas" were conducted at the College of Horticulture, Vellanikkara, Trichur during 1990-1993. The experiment consisted of two parts - Diversity interrelationship between *Capsicum* spp. and forms and development of paprikas for adaptability and resistance to bacterial wilt. Both biometrical and biochemical methods were employed to study the diversity. To estimate biometrical diversity, 82 genotypes of chilli belonging to four cultivated *Capsicum* spp. and to different horticultural groups of *Capsicum annuum* were collected initially through survey and correspondence. They were evaluated based on descriptor list prepared by IBPGR (1983) and classified based on different characters. The accessions belonging to *Capsicum annuum* were subjected to horticultural classification as per Smith *et al.* (1987) and assigned to different horticultural groups.

Genetic divergence studies were carried out during two seasons. There were 71 genotypes during first season (August 1991 to January 1992) and 72 types during second season (May 1992 to September 1992). Plants were raised in pots and observations on 8 quantitative characters were recorded from 5 random plants. The data obtained were subjected to D^2 analysis and the genotypes were grouped into different clusters by computer oriented interactive algorithm proposed by Suresh (1986).

The genotypes showed significant differences for eight characters studied during both the seasons. During first season (August 1991 to January 1992), 71

chilli genotypes were grouped into nine clusters based on Mahalanobis D^2 analysis. Clusters I, II, III, IV, V, VI, VII, VIII and IX comprised of 11, 11, 11, 5, 8, 3, 8, 3 and 11 genotypes respectively. During second season (May 1992 to September 1992), 72 genotypes were grouped into six clusters. Clusters I, II, III, IV, V and VI comprised of 24, 15, 5, 21, 5 and 2 genotypes respectively. The clustering pattern confirmed that there is no relationship between genetic distance and geographical distribution. It also varied under different environments. During first season, cluster I had maximum average inter cluster distance with other clusters. During second season, it was maximum in cluster VI which included only two genotypes. Among the different characters studied, yield/plant was maximum in cluster VIII during first season and in cluster V during second season. In general, there was seasonal influence for all the characters studied.

Biochemical diversity was studied using two biochemical methods, viz., PAGE (Polyacrylamide Gel Electrophoresis) and AGIEF (Agarose Isogel Electrofocussing). The three commercially cultivated *Capsicum* spp. were subjected to both these techniques. But clear bands were visible in the PAGE method. Hence it was utilised for further studies.

Isozyme variation of two enzymes viz., peroxidase and esterase were studied. Among the different parts studied roots as well as mature leaves showed clear bands in case of peroxidase enzyme in all the three species. In case of esterase, clear bands were visible in mature leaf tissues. There were species specific bands for both enzymes. The nine biometrical groups showed variation for banding pattern in case of peroxidase and esterase. But this can be confirmed only after analysing a large number of samples. Certain common bands were visible for both the enzymes.

Twenty genotypes of paprikas were collected from different sources and their morphological descriptions were made as per IBPGR (1983). Field studies were conducted during two seasons (October 1991 - March 1992; May - October 1992). Observations were recorded on nine characters from five plants under each genotype, and the data were subjected to statistical analysis. There was significant differences among genotypes for different characters studied during both seasons. CA 575 was the highest yielding genotype during first season and CA 517 recorded the highest yield during second season. CA 517 recorded minimum incidence of wilt during both seasons while CA 576 was highly susceptible to bacterial wilt..

The colour value was maximum in CA 582 during first season and in CA 612 during second season. Minimum pungency was recorded by CA 605 and CA 604 during first season and CA 589 during second season.

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* Originals not seen

Appendices

APPENDIX-I

Reagents for Agarose Gel Iso Electric Focussing (AGIEF)

a) Anode solution 0.5 M Acetic acid

b) Cathode solution 0.5 M NaOH

c) Fixing solution

Sulphosalycilic acid	- 17.3 g
Trichloroacetic acid	- 57.5 g
Methanol	- 150 ml

Mixed and made up the volume to 500 ml with distilled water.

d) Staining solution

1.25 g Coomassie brilliant blue R was dissolved in 250 ml destaining solution. Solution was stirred thoroughly and filtered.

e) Destaining solution

Ethanol	- 350 ml
Acetic acid	- 100 ml

Mixed and made up the volume to one litre with distilled water.

f) Other chemicals

Isogel Agarose LKB, Sweden

Servalyte pH 3-8

Sorbitol D.E. Merck, Germany

Coomassie brilliant blue

APPENDIX-II
Meteorological data during the cropping period

Month	Temperature (°C) Maximum	Minimum	Mean relative humidity (%)	Total rainfall (mm)	No. of rainy days	Mean sunshine hours
1991						
August	29.0	22.7	87	533.3	24	2.8
September	31.5	23.6	78	61.5	7	7.3
October	30.9	23.2	82	281.7	14	4.3
November	31.5	23.0	75	191.3	9	7.1
December	31.9	21.7	64	0.2	0	8.6
1992						
January	32.6	20.9	53	0	0	9.0
February	34.5	21.8	65	0	0	9.2
March	36.9	22.8	61	0	0	9.2
April	36.3	24.4	65	48.6	3	8.8
May	33.8	24.8	73	90.6	6	7.4
June	30.1	23.7	84	979.8	22	3.3
July	28.8	22.7	87	874.5	26	2.1
August	28.9	23.3	88	562.9	25	2.7
September	30.1	23.1	82	302.9	17	4.1
October	30.7	22.9	82	386.7	14	4.6

DIVERSITY INTER REALATIONSHIPS AMONG *Capsicum* Spp. AND FORMS AND DEVELOPMENT OF PAPRIKAS

By

P. INDIRA

ABSTRACT OF A THESIS

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requirements for the degree of

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ABSTRACT

Capsicum, a new world genus, has richness in diversity that has not yet received the needed attention. The cultivated chilli varieties offer many problems in classification because of their great number, the transitory nature and creation of new ones through hybridisation and selection processes.

The present studies on "Diversity inter relationships among *Capsicum* spp. and forms and development of paprikas" were conducted at the College of Horticulture, Vellanikkara. The main objectives were grouping of chilli genotypes biometrically and biochemically and development of paprikas. For biometrical grouping chilli genotypes belonging to four cultivated species of *Capsicum* were evaluated during two seasons (August, 1991 - January, 1992 and May, 1992 - September, 1992). They were clustered into different groups based on D^2 values. There were 9 clusters during first season and 6 clusters during second season. The distribution of genotypes into clusters showed no regularity.

The isozyme patterns of two enzymes viz. peroxidase and esterase were studied in the three cultivated species of *Capsicum* and also for the nine biometrical groups. Among the different plant parts studied roots showed clear bands in case of peroxidase and mature leaves were the best sampling tissue for esterase enzyme. There were species specific bands in all the three species. The nine biometrical groups showed variation for banding pattern in case of peroxidase and esterase. There were some common bands for both the enzymes.

Twenty paprika genotypes were collected from different sources and their morphological descriptions were made as per IBPGR descriptor. Field evaluation was done for two seasons (October-March, 1991; May-October, 1992). There was significant difference among genotypes for the different characters studied. There was much seasonal variation also. CA 517 recorded minimum incidence of bacterial wilt during both seasons under the field conditions. CA 582 showed highest colour value but CA 604 and CA 605 recorded minimum pungency.