Interspecific hybridization in *Capsicum*

BY

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DECLARATION

I hereby declare that this thesis entitled **"Interspecific hybridization in Capsicum"** 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.

Vellanikkara,
24-7-1990.

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CERTIFICATE

Certified that this thesis entitled **"Interspecific hybridization in *Capsicum*"** is a record of research work done independently by **Mr. Pradeepkumar, T.,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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CONTENTS

		Page No.
I	INTRODUCTION	1
II	REVIEW OF LITERATURE	4
III	MATERIALS AND METHODS	18
IV	RESULTS	36
V	DISCUSSION	84
VI	SUMMARY	100
	REFERENCES	i-ix
	APPENDICES	

LIST OF TABLES

Table No.

1. Source and morphological description of 84 chilli accessions.

2. Percentage of fruit set and number of seeds/fruit in *Capsicum* species and interspecific crosses (F_o level).

3. Percentage of seed germination and seedling survival in *Capsicum* species and interspecific crosses (F_1 level).

4. Percentage seed set efficiency of interspecific crosses at F_o level.

5. Crossability index among *Capsicum* species.

6. Percentage of fruit set in interspecific hybrids.

7. Seeds/fruit and percentage of seed germination in F_2.

8. Percentage of meiotic abnormalities and its relation to pollen fertility in *Capsicum* species and interspecific hybrids.

9. Stomatal density in *Capsicum* species and interspecific hybrids.

10. Comparison of parental species and hybrids for discrete characters.

11. Capsaicin content, oleoresin content and total extractable colour of *Capsicum* species and interspecific hybrids.

12. Mean performance of *Capsicum* species and F_1 hybrids and extent of relative heterosis (RH) and heterobeltiosis (HB) for plant height and plant spread.

13. Mean performance of *Capsicum* species and F_1 hybrids and extent of relative heterosis (RH) and heterobeltiosis for days to flower and first harvest.

14. Mean performance of *Capsicum* species and F_1 hybrids and extent of relative heterosis (RH) and heterobeltiosis (HB) for fruit length and width.

15. Mean performance of *Capsicum* species and F_1 hybrids and extent relative heterosis (RH) and heterobeltiosis (HB) for pericarp thickness and average fruit weight.

16. Mean performance of *Capsicum* species and F_1 hybrids and extent of relative heterosis (RH) and heterobeltiosis (HB) for yield/plant and fruits/plant.

17. Mean performance of *Capsicum* species and F_1 hybrids and extent of relative heterosis (RH) and heterobeltiosis (HB) for seed diameter and 1000 seed weight.

Appendix I Meteorological data during the cropping period (month-wise).

II Reagents for Agarose Gel Iso Electric Focussing (AGIEF)

III CD matrix for comparison of treatment means (at 1 per cent level)

LIST OF ILLUSTRATIONS

Fig.1 Diagramatic representation of protein band patterns of *Capsicum* species on AGIEF at p^H 3-8.

Fig.2 Crossability polygon for five *Capsicum* species.

Plates

1. Plant morphology of *C. annuum*
2. Plant morphology of *C. frutescens*
3. Plant morphology of *C. chinense* (P)
4. Plant morphology of *C. chinense* (NP)
5. Plant morphology of *C. baccatum*
6. Plant morphology of *C. chacoense*
7. Pherograms resolved on AGIEF at p^H 3-8 using *C. chinense* (P), *C. baccatum* and *C. chacoense*
8. Plant morphology of *C. annuum* x *C. chinense* (P)
9. Plant morphology of *C. chacoense* x *C. annuum*
10. Plant morphology of *C. chinense* (P) x *C. frutescens*
11. Plant morphology of *C. frutescens* x *C. chinense* (NP)
12. Plant morphology of *C. baccatum* x *C. frutescens*
13. *C. annuum* - metaphase-I showing 12 bivalents
14. *C. chinense* (P) - metaphase-I showing multivalents
15. *C. annuum* x *C. chinense* (NP) - metaphase-I showing non orientation

16. *C. frutescens* x *C. chinense* (P) - metaphase-II showing non orientation

17. *C. frutescens* x *C. chinense* (NP) - anaphase-I showing persistent bridge

18. *C. baccatum* x *C. frutescens*- anaphase-I showing laggards

19. *C. frutescens* x *C. chinense* (P) - telophase-II showing micronuclei

20. *C. baccatum* x *C. frutescens* - telophase-II showing micronuclei

21. *C. chinense* (P) x *C. baccatum* - anaphase-II showing persistent bridge

Introduction

INTRODUCTION

India, the leading chilli growing country in the world is endowed with a wide range of morphological forms. Green chilli, chili powder, cayenne peppers, tabasco, paprika, bell peppers and pimentos are all derived from the berry of various species of Capsicum. Though introduced to India late in the 17th century, chillies have become an essential part of Indian cusine and are valued for their characteristic pungency, colour and aroma. It is an excellent source of vitamins A (870 I.U/100 g) and C (175 mg/100 g) and is widely used in curry powder, paste, pickles, sauces and ketchups.

Indian chilli belonging to Capsicum annuum L. is distinguished for its medium pungency and short duration. Heavy incidence of viral and bacterial diseases and susceptibility to sucking insects are perennial problems facing the cultivation of chilli in the country. Since the crop is mainly grown under rainfed conditions, susceptibility to frequent occurrence of drought results in considerable loss in yield. Until recently, plant breeders were concentrating on hybridization and/or selection solely within C. annuum for overcoming these problems. Since the range of variability for the above economic attributes are limited in C. annuum, related and wild species of Capsicum need to be explored. Studies by Smith and Heisser (1957) and Pickersgill (1971) revealed that none of the *Capsicum* species were completely isolated from other species, which pointed to the possibility of incorporating genes for desirable characters, in the present day *C. annuum* cultivars.

C. chinense Jacq. and *C. frutescens* L. are notable for biennial or perennial habit and for highly pungent and deep-red coloured fruits (Shaw and Khan, 1928). *C. baccatum* L. is valued for its resistance to Cucumber Mosaic Virus and potato virus Y. (IBPGR, 1983). Studies by Mini (1989) revealed the possibility of incorporating desirable genes from *C. chacoense* to *C. annuum*. Incorporation of genes for perennial habit, highly pungent nature, resistance to both biotic and abiotic stresses would be a breakthrough, in chilli production in the country. The present investigation was formulated with the following objectives:

1. To study cross compatibility among *C. annuum*, *C. frutescens*, *C. chinense*, *C. baccatum* and *C. chacoense*.

2. To study cytogenetics and meiotic behaviour of five *Capsicum* species and the interspecific hybrids.

3. To transfer desirable genes for perennial habit, pungency, aroma and colour from allied species to *C. annuum* and

4. To assess the scope of exploitation of heterosis in interspecific hybrids.

Review of Literature

REVIEW OF LITERATURE

The available literature on chilli relevant for the study are reviewed and presented under the following heads:

A. Taxonomy of the genus Capsicum

B. Chemotaxonomy of the genus Capsicum

C. Crossability among Capsicum species

D. Cytological studies

E. Interspecific heterosis in the genus Capsicum

A. Taxonomy of the genus Capsicum

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 great number, the transitory nature of many of them and constant creation of new ones through hybridization and selection. Linnaeus (1737) in "Hortus Cliffortianus" described two species, C. annuum and C. frutescens. In his Mantissa (1767) two more additional species C. grossum and C. baccatum were also proposed. In 1891, Kuntze proposed C. annuum with five botanical varieties namely C. annuum var. cerasiforme; C. annuum var. conoides; C. annuum var. fasiculatum; C. annuum var. longum and C. annuum var. grossum. Irish (1898) accepted the original two species of Linnaeus stating that all the leading cultivars should be referred as C. annuum.

Bailey (1923) recognised only one species C. frutescens and proposed five botanical varieties of C. annuum as suggested by Kuntze (1891) under C. frutescens. In 1932, Erwin accepted Bailey's treatment which was later supported by Miller and Fineman (1937) and is presently followed by American Taxonomists.

Smith and Heisser (1957) described cultivated species of C. sinense Jacq a synonym of C. chinense, originally described in India as C. luteum by Lamark (1793) and C. umbilicatum from Brazil.

Historically C. baccatum has been separated into two species C. microcarpum and C. 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, C. baccatum and should be treated as botanical varieties namely C. baccatum var. baccatum and C. baccatum var. pendulum. Pickersgill (1971) observed the distant nature of C. baccatum from C. chinense, C. annuum and C. frutescens complex.

Casali and Couto (1984) proposed a key for identification of C. annuum, C. baccatum, C. frutescens, C. chinense and three wild species, C. praetermissum, C. bufforum and C. schotllianum. Different authors (Irish, 1898; Shaw and Khan, 1928) used characters like fruit size, fruit orientation, leaf size and shape, calyx shape, flower size etc. for separating the species. Because of great variability within species these characters offer little value. lBPGR (1983) suggested characters like seed colour, corolla colour, flowers/axil, presence of yellow-spotted corolla and annular constriction at calyx-pedical junction for separating the species. The modern taxonomists recognising the extent of variability have consolidated the cultivated Capsicum into following five species (Eshbaugh, 1980; Pickersgill, 1980).

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

B. Chemotaxonomy of the genus Capsicum

After conducting flavanoid analysis on three Capsicum species, Lopes et al. (1978) suggested that there exists greater affinity between C. annuum and C. frutescens than between C. pendulum and C. frutescens. Based on starch gel electrophoresis Mc Leod (1978) classified 14 taxa into five biological species, with C. cardenasii, C. eximium and C. pubescens representing a single species, C. baccatum var. baccatum and C. baccatum var. pendulum and C. praetermissum representing another and the wild and cultivated C. annuum, C. frutescens, and C. chinense yet another. C. chacoense and an unnamed species are considered valid wild species.

Slightly deviating from the above classification based on the electrophoresis of peroxidase isozyme extracted from functional leaf, Wang and MA (1987) assigned eight Capsicum species to the following four groups:

Group 1. C. annuum, C. frutescens and C. chinense
Group 2. C. chacoense and C. pubescens
Group 3. C. praetermissum
Group 4. C. baccatum and C. eximium

Though protein electrophoresis has been widely used to understand the species relationship in several crop species only a meagre attempt has been made in the genus Capsicum. Varietal differences in the protein banding patterns were reported by Rick and Deshborough (1978) in potato and Konarev et al. (1979) in oats. Through electrophoresis of leaf extracts from different purple flowered Capsicum species viz. C. cardenasii, C. eximium and

C. "tovari", Mc Leod et al. (1979) coded 25 loci for 15 proteins and concluded that the first two species were identical and belong to the same complex as C. pubescens where as C. "tovari" was electrophoretically distinct. The seed protein composition 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.

C. Crossability among Capsicum species

Despite of constancy in chromosome number, attempts on interspecific hybridization has succeeded only in a few cases (Smith and Heisser, 1957; Pickersgill, 1971). The first significant contribution in this field was made by Smith and Heisser (1957). In the interspecific hybridization involving C. annuum and C. frutescens, they obtained 2% viable seeds when C. frutescens was used as female parent. The F_1 plants ranged from partially fertile to completely sterile. Eventhough back cross and F_2 generations were made, they exhibited high pollen sterility. Pickersgill (1967) also reported successful crossing between C. frutescens and C. annuum var. minimum but the hybrids were sterile. Goud et al. (1970) observed the varietal variation in the success of interspecific hybridization between C. annuum and C. frutescens. Out of the three C. annuum varieties used as female parent, fruit set was observed only in Pendulous Long. In a hybridization programme involving three varieties of *C. annuum* with *C. frutescens*, Keshavram and Saini (1971) succeeded to get completely fertile F_1 s which readily set seed. Krishna Kumari (1984) also reported varietal influence in the interspecific hybridization between *C. annuum* and *C. frutescens*. She crossed *C. annuum* cultivars Jwala and K_2 with *C. frutescens* cultivars White Kanthari, Ornamental Type and Green Chuna as female parent and obtained perfect set between the two species except in two combinations while White Kanthari was used as female parent. Radhakrishnan *et al.* (1977) developed a technique in which the upper part of the style and stigma were excised and a drop of 5% sucrose solution was applied to cut surface prior to pollination. By this way they got fruit set and seed set in crosses between *C. annuum* and *C. frutescens*. When *C. annuum* was used as female parent the percentage of fruit set was considerably lower than the reciprocal. A similar result was noticed by Nair *at al.* (1979) in a cross of *C. annuum* with *C. frutescens* as male parent. In a cross between *C. annuum* and *C. frutescens* Sundaresan and Chandrasekaran (1979) noticed one-way incompatibility. The failure of pollen grains of *C. frutescens* in the stigma of *C. annuum* revealed the existence of prefertilization barrier. But when *C. frutescens* was used as female parent, fruit set was to the extent of 17.1%.

However, all the seeds were not plumpy indicating different intensities of post-fertilization barriers. Quite contrary to the above positive attempts, Pillai at al. (1977) and Balasubramanian (1981) obtained negligible seed set in the cross C. frutescens x C. annuum. Peter and Mc Collum (1984) observed pollen-stigma compatibility in the cross C. frutescens x C. annuum; but plants failed to set fruits after artificial pollination in the green house, though pollen tubes reached ovule within 24 hours after pollination.

In interspecific hybridization involving C. annuum and C. chinense, Smith and Heisser (1957) obtained moderately fertile to completely sterile pollen in F_1 plants. Crosses were more easy when C. annuum was used as the female parent.

In crosses between C. chinense and C. annuum, conducted at the Institute of Horticultural Plant Breeding, Netherlands (1977) revealed that those crosses in which primitive forms were used generally gave better seed set than those using cultivars. Yazawa et al. (1980) and Subramanya (1982) reported fertile hybrids between C. annuum and C. chinense. Subramanya (1982) obtained F_1 plants with two flowers/node in the cross C. annuum x C. chinense. From a study of F_1, F_2 and BC_1 progenies in a cross between C. annuun x C. chinense, Tanskley and Iglesias-olivas (1984) found that a minimum of five independently segregating chromosomal regions control the difference in flowering behaviour between these two species.

Pickersgill (1971) found out that when C. annuum was crossed with weedy C. baccatum, the F_1 hybrids grew normally and produced flowers, although they were extremely sterile. F_1 seed was often set in the cross of cultivated C. annuum with cultivated C. baccatum but seedlings did not survive. Vaul and Pitrat (1978) got F_1 plants from a cross between C. annuum and C. baccatum with very low pollen fertility (0.8%-2.6%). F_1 resembled C. baccatum in which yellow spot on the corolla was controlled by a single dominant gene, Y_s. Molhova and Michalova (1982) got sterile hybrid plants from a cross between C. annuum and C. pendulum. Radhakrishnan et al. (1977) obtained fruit set and seed set in crosses between C. annuum and C. pendulum after applying sucrose solution to the excised stigma prior to pollination. The percentage of fruit set was considerably lower, when C. annuum was used as the female parent (2.1%). Kiku (1987) recommended two pollinations, at an interval of 24 hours to increase seed and fruit set in crosses involving C. pendulum and C. annuum. He also suggested pollination following the treatment of the stigma with a mixture of Vit.B_2 and Vit.B_6 at a concentration of 0.001%. Smith and Heisser (1957) and Pillai et al. (1977) did not get seed set in crosses between C. baccatum and C. annuum. But after resorting to embryo culture technique, Smith and Heisser (1957) got F_1 plants using C. pendulum as female parent. Molhova and Fileva (1969) reported abnormal development of embryo and endosperm in crosses between C. pendulum and C. annuum and suggested this as one of the causes for their partial or complete sterility.

Smith and Heisser (1957) observed that C. annuum and C. pubsecens were completely cross sterile. Molhova (1966) found that in a cross between C. annuum (2n = 48) and C. pubescens R. & P. (2n = 24) it is possible to overcome the incompatibility barrier, by using tetraploid forms of C. annuum as the female parent. Similar result was obtained by Molhova and Michalova (1982).

Boukema (1982) reported male sterile hybrids between C. chacoense and C. annuum. These hybrids had larger leaves and were much vigorous than C. chacoense. Work conducted at the Institute of Horticultural Plant Breeding, Netherlands (1985) revealed that BC_1 and BC_2 of (C. chacoense x C. annuum) x C. annuum were both male sterile with rudimentary stamens and flowers. Kumar et al. (1988) reported partly fertile hybrids from the cross C. chacoense x C. annuum.

Smith and Heisser (1957) observed moderately fertile to completely sterile F_1 hybrids in direct and reciprocal crosses between C. frutescens and C. chinense. Hybridization studies by Pickersgill (1967) showed that C. frutescens is the most closely related species to C. chinense. Eshbaugh (1975) reported high level of cross compatibility between C. chinense and C. frutescens. Greenleaf (1975) got partially fertile hybrids from crosses between C. frutescens and C. chinense.

Smith and Heisser (1957) successfully crossed C. frutescens and C. pendulum on either direction, but F_1 plants were highly sterile. Pillai et al. (1977) got fruit set in the cross between C. frutescens x C. baccatum, but the reciprocal cross failed.

Smith and Heisser (1957) observed that the cross, C. sinense x C. pendulum can be made with some difficulty with C. pendulum as female parent. Pickersgill (1967) found that F_1 plants from the cross C. pendulum x C. chinense were morphologically normal and partially fertile. F_1 plants from the reciprocal cross were all morphologically abnormal and completely sterile. His work revealed that hybrids between C. chinense and wild forms of C. pendulum were less abnormal than plants from crosses involving cultivated C. pendulum. But Saccardo (1978) did not get fruit set, in direct and reciprocal crosses involving C. chinense and C. baccatum.

Smith and Heisser (1957) observed fruit set from the cross C. sinense x C. pubsescens. The fruit at maturity contained seeds with fully developed embryos but with no endosperm.

Kumar et al. (1988) obtained hybrids from the C. chacoense x C. chinense cross. But the reciprocal cross was a failure.

D. Cytological studies

Bigotti (1972) observed normal meiosis with 12 bivalents in 30 varieties of C annuum. Molhova (1977) observed 3% chromosomal disorders in C. annuum var nigrum resulting from micronuclei in the microspores. Carluccio and Saccardo (1978) reported that in C. annuum, the chromosomes could be characterised by arm length, the ratio between short arm and long arm length and the total chromosomal length. Raman et al. (1964) observed quadrivalents in meiosis of C. frutescens and proposed that origin of this species may be due to allopolyploidy.

Shopova (1966) made cytological comparison of chromosome structure and behaviour of C. annuum, C. frutescens and C. pubescens. Although they share a common chromosome number they differed in chiasma frequency, amount of heterochromatin and distribution of nucleolar organising materials. Turkov et al. (1970) did not find significant differences in the karyotypes of C. annuum, C. angulosum and

C. annuum. Carluccio and Saccardo (1978) observed that *C. annuum* and *C. chinense* had one pair of satellite chromosomes, while *C. frutescens* and *C. pendulum* had two pairs. Sundaresan and Chandrasekharan (1979) reported regular bivalent formation and normal orientation at metaphase-I in *C. annuum* and *C. frutescens*.

Molhova (1965) ascribed complete or partial sterility in the F_1 and F_2 hybrids of *C. pendulum* var. *longisiliuam* x *C. annuum* var. *nigrum* and *C. pendulum* var. *bicoloratum* x *C. annuum* due to disturbed meiosis of the pollen mother cells (PMC) and by structural and functional defects of the embryosac. Sundaresan and Chandrasekharan (1979) observed quadrivalent and trivalent associations and few pentads in meiosis of the F_1 of *C. frutescens* x *C. annuum*. Egawa and Tanaka (1984) observed regular chromosome pairing at metaphase-I of PMC in interspecific hybrids of *C. baccatum* x *C. frutescens* and *C. frutescens* x *C. chinense*. From this, they concluded that *C. baccatum*, *C. chinense* and *C. frutescens* were originally derived monophyletically from a common ancestoral species and that their geographical distribution resulted in reproductive isolation among the species. Morkova and Molhova (1985) reported meiotic disturbance in the PMCs of the cross *C. pendulum* x *C. annuum* var. *nigrum*, expressed as univalents at metaphase-I, laggards at anaphase-I and anaphase-II and micronuclei at telephase-I and telephase-II. Egawa and Tanaka (1986) studied meiosis of the interspecific hybrids viz., C. annuum x C. chinense, C. annuum x C. baccatum, C. chinense x C. frutescens, C. chinense x C. baccatum and C. baccatum x C. frutescens. Multivalents (trivalents, quadrivalents, and hexavalents) and low pollen stainability were observed in all the hybrids except C. chinense x C. frutescens. Kumar et al. (1987a) reported irregular chromosome pairing, univalents and multivalents and partial pollen sterility in the hybrid between C. chinense and C. frutescens. From the analysis of irregular meiosis of C. frutescens x C. annuum, Kumar et al. (1987b) concluded that parental species differ by two chromosomal translocations, one inversion and other minor structural changes. Cytological analysis of the hybrids viz. C. annuum x C. chinense and C. annuum x C. baccatum revealed that the genome of C. annuum differs from that of C. chinense by two translocations and some minor structural alterations and from that of C. baccatum by two translocations and a single inversion with some minor structural alterations (Kumar et al. 1987 c). Kumar et al. (1988) reported irregular chromosome disjunction, multivalents, bridges, fragments and laggards in meiosis of interspecific hybrids viz. C. chacoense x C. annuum, C. chacoense x C. frutescens and C. chacoense x C. chinense. Mini (1989) reported multivalents and laggards in a few cells of the hybrid C. annuum x C. chacoense.

E. Interspecific heterosis in the genus *Capsicum*

In crosses involving *C. frutescens* and *C. baccatum* the F_1 hybrids exhibited heterosis for flowering duration, percentage of fruit set, branches/plant, leaves/plant, plant height, plant spread and fruits/plant (Pillai *et al*. 1977). They also recorded positive heterosis for plant height in *C. microcarpum* x *C. frutescens* and negative heterosis in the reciprocal cross.

Sundaresan and Chandrasekharan (1979) found that F_1s from the cross *C. frutescens* x *C. annuum*, in general, were more vigorous than the parents. The hybrids were intermediate in plant height, spread and flower and fruit characters. The F_1s resembled the female parent in pigmentation of plant parts and also in the deciduous nature of fruit. The hybrids resembled the male parent in respect of leaf shape , flowers/node and protrusion of style. Boukema (1982) reported that *C. chacoense* x *C. annuum* hybrids had larger leaves and were more vigorous than the *C. chacoense* parent but, they were male sterile. In interspecific crosses involving two *C. annuum* lines (Jwala and K_2) and three *C. frutescens* lines (White Kanthari, Green Chuna and Ornamental Type), Krishnakumari (1984) reported significant heterosis for days to flower, days to first harvest, days to fruit ripening, plant height, seeds/fruit, seed yield/plant, fruits/plant and yield/plant.

Materials and Methods

MATERIALS AND METHODS

The present studies were conducted at the College of Horticulture, Kerala Agricultural University, Vellanikkara, Trichur during the year 1988-'90. The experiment was spread over three seasons, September-December 1988, February-August 1989 and September-April 1989-'90. The station is located at an altitude of 22.25 m above mean sea level and at 10° 32'N latitude and 76° 16'E longitude. Weather parameters during periods of experimentation are given in Appendix I.

The study was undertaken in the following heads:

A. Evaluation of germplasm and selection of parental materials
B. Interspecific hybridization in the genus *Capsicum*
C. Estimation of heterosis in the interspecific hybrids

A. Evaluation of germplasm and selection of parental materials

1. Materials

The germplasm collection of chilli maintained in the ICAR adhoc scheme on "Breeding for resistance to bacterial wilt in chilli and brinjal" at the Department of Olericulture, College of Horticulture, Vellanikkara were grown during September-December 1988 to make morphological description of the lines/varieties and to place them under different *Capsicum* species.

2. Methods

The experiment was conducted in a randomised block design with two replications. Plants were grown in ridges at a spacing of 60 x 45 cm. There were 10 plants/genotype/replication. Crop management was done as per package of practices (KAU, 1986).

a. Taxonomic treatment

Morphological description of the entire germplasm was done as per the descriptive list of IBPGR (1983). The following observations were recorded.

i.	Plant growth	-	(Prostrate, Compact, Erect)
ii.	Stem pubescence	-	(Glabrous, Sparse, Intermediate, Abundant)
iii.	Stem colour	-	(Green, Purple)
iv.	Leaf pubescence	-	(Glabrous, Sparse, Intermediate, Abundant)
v.	No. of pedicels/axil	-	
vi.	Pedicel position at anthesis	-	(Pendant, Intermediate, Erect)
vii.	Corolla colour	-	(White, Green-White, Lavender, Blue, Violet, Other)
viii.	Corolla spot	-	(Absent, White, Yellow, Green-Yellow, Green)
ix.	Anther colour	-	(Yellow, Pale blue, Blue, Purple)

x.	Filament colour	-(White, Blue)
xi.	Stigma position in relation to anthers	-(Included, Same level, Exserted)
xii.	Calyx margin shape	-(Smooth, Intermediate, Dentate)
xiii.	Presence of annular constriction at calyx pedicel junction	-(Absent, Present)
xiv.	Fruit shape at pedicel attachment	-(Acute, Obtuse, Truncate, Cordate, Lobate)
xv.	Neck at base of fruit	-(Absent, Present)
xvi.	Fruit shape at blossom end	-(Pointed, Blunt, Sunken)
xvii.	Fruit persistence	-(Deciduous, Persistent)
xviii.	Fruit position	-(Declining, Intermediate, Erect)
xix	Fruit colour in immature stage	-(Green, Yellow, Orange, Red, Purple, Brown, Black)
xx.	Fruit colour in mature stage	-(Green, Yellow, Orange, Pale, Purple, Brown, Black)
xxi.	Fruit length	-(Very short, Short, Medium, Long, Very long)
xxii.	Fruit shape	-(Elongate, Oblate, Round, Conical, Companulate, Bell or Blocky)

The entire germplasm was subjected to taxonomic treatment as per the key proposed by IBPGR (1983).

b. Chemotaxonomy

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

i. Sample preparation

Plant samples were collected from newly emerging leaves of the various Capsicum species 10 g of leaf sample was homogenized with 10 ml of distilled water, and centrifuged at 6000 rpm for 30 minutes. The supernatant was decanted and stored at 4°C until subjected to AGIEF.

ii. Preparation of Agarose Gel (1 mm thick)

The glass plates (125 mm x 80 mm x 2 mm) were thoroughly cleaned to make it grease free and then dried. Isogel agarose solution (0.5%) prepared in distilled water by boiling was used to coat 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. Iso agarose (0.100 g) (LKB) and 1.0 g Sorbital (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 Sarvalyte (Serva) of the required p^H 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 solidity. 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.

iii. 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 to 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 II) and cathode solution (Appendix II) respectively and were placed on the respective ends of the gel. The sample application strips (LKB) were then 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 micro litre extracts of the sample.

iv. Electrofocussing

The cryothermostat multi temperature cooling system (colora) was switched on in advance to attain an effective cooling temperature of 8°C. The electrofocussing lid of the multiphor was placed above the gel so 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 a 200 volts, 50 mA, 10 W for the first 10 minutes. The voltage was raised to 500 volts, 53 mA and 10 W for the next 20 minutes. At the end of 30 minutes run, the power supply was switched off and multiphor opened to remove the sample application strips from the surface of the gel. After removal of sample application strips, the multiphor was closed and power supply switched on to deliver 1000 V, 50 mA and 20 W for 30 minutes. At the end of one hour run, the power supply was switched off and multiphor opened to remove the electrode strips from the gel.

v. Fixing

The gel plate was immediately transferred to a glass container and kept immersed in fixing solution (Appendix II) for 20 minutes. The gel is 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.1 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.

vi.. Staining and destaining

The gel was then dried under warm air from hair drier when the gel was completely dry, it was stained with staining solution (Appendix II) 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. Interspecific hybridization

1. Materials

Based on the morphological characters and by adopting the key proposed by IBPGR (1983) the following accessions under four Capsicum spp. were selected for hybridization programme.

CA 94	(C. annuum)		(Plate 1)
CA 308	(C. frutescens)		(Plate 2)
CA 307	(C. chinense)	(Pungent/P)	(Plate 3)
CA 317	(C. chinense)	(Non-pungent/NP)	(Plate 4)
CA 302	(C. baccatum)		(Plate 5)

One typical species Capsicum chacoense introduced from Plant Germplasm Quarentine Centre, BARC- East Beltsville, Maryland, USA (Plate 6) was also utilized for two interspecific hybridization.

The above five species of Capsicum were grown in pot culture during February-August 1989 and were crossed in all possible combinations to develop the following F_1s:

a. C. annuum x C. frutescens
b. C. annuum x C. chinense (P)
c. C. annuum x C. chinense (NP)
d. C. annuum x C. baccatum

Plate 1. Plant morphology of _C_. _annuum_

Plate 2. Plant morphology of _C_. _frutescens_

Plate 3. Plant morphology of C. chinense (P)

Plate 4. Plant morphology of C. chinense (NP)

Plate 5. Plant morphology of *C. baccatum*

Plate 6. Plant morphology of *C. chacoense*

e. *C. annuum* x *C. chacoense*

f. *C. frutescens* x *C. chinense* (P)

g. *C. frutescens* x *C. chinense* (NP)

h. *C. frutescens* x *C. baccatum*

i. *C. frutescens* x *C. chacoense*

j. *C. chinense* (P) x *C. baccatum*

k. *C. chinense* (P) x *C. chacoense*

l. *C. chinense* (NP) x *C. baccatum*

m. *C. chinense* (NP) x *C. chacoense*

n. *C. baccatum* x *C. chacoense*

The reciprocals of the above crosses were also studied to understand the cytoplasmic influence in the crossing behaviour.

2. Methods

The maximum receptivity of stigma under Vellanikkara condition was found between 7 to 8.30 AM and hence crossing work was done during this time.

a. Selfing

Well developed flower buds, which would open the next day were covered with tissue paper bags during the evening and labelled. The bags were allowed to remain for about three days and then removed.

b. Crossing

The well developed flower buds, which would open the next day morning were emasculated in previous day evening. Pollination was performed between 7 and 8.30 AM in next day morning using pollen from covered male flowers. The bags were removed after three days.

c. Observations

Following observations were recorded to study the percentage of success in crossing:

i. Percentage of fruit set in F_o plant and in maternal parent (A)

ii. No. of seeds/fruit in F_o fruit and in maternal parent (B)

iii. Percentage of seed germination in F_o fruit and in maternal parent (C)

iv. Percentage of seedling survival in F_o plant and in maternal parent (D)

v. Percentage of fertile pollen grains in F_1

vi. Percentage of fruit set in F_1

vii. Seeds/fruit in F_1

viii. Percentage of germination of F_2 seeds

Crossability index (CI) was calculated as per (Rao, 1979)

$$C.I. = \frac{\text{Crossing efficiency of the cross}}{\text{Selfing efficiency of the female parent}} \times 100$$

$$= \frac{A^{C+} \times B^{C+} \times C^{C+} \times D^{C+}}{A^{S+} \times B^{S+} \times C^{S+} \times D^{S+}} \times 100$$

c^{+} - Crosses

s^{+} - Selfs

$$\text{Percentage of seed set efficiency} = \frac{\text{Seeds in crosses}}{\text{Seeds in selfed maternal parent}} \times 100$$

d. Cytological studies

i. Studies on pollen mother cells

The flower buds of suitable size were fixed in carnoys fluid (1 acetic acid : 3 chloroform : 6 ethyl alcohol) taken at 8.30 to 9 AM. The fixed buds were kept at room temperature for 48 hours.

Meiosis was studied from temporary acetocarmine smears of pollen mother cells. The anthers were kept in a drop of acetocarmine (1%) in the slide and squashed gently to facilitate the separation of cells. After putting a cover glass the slide was slightly warmed and gently pressed between folds of a blotting paper and sealed. Meiotic stages were observed under the Olympus microscope and photomicrographs were taken.

ii. Pollen studies

Pollen grains collected from flowers immediately after its opening were used for pollen studies. Fertility was assessed on the basis of stainability of pollengrains in acetocarmine glycerine mixture. The pollen grains were mounted in a drop of glycerine-acetocarmine stain on a clean slide. The counts were taken after two hours from 25 fields for each treatment. Well filled and uniformly stained pollen grains were taken as fertile and the rest as sterile.

e. Inheritance studies

Peformance of the interspecific hybrids were compared with the respective parents for the following discrete morphological characters.

i. Plant growth habit
ii. Stem pubescence
iii. Stem colour
iv. Leaf pubescence
v. Pedicels/axil
vi. Pedicel position at anthesis
vii. Corolla spot

viii. Anther colour

ix. Filament colour

x. Stigma position in relation to anthers

xi. Calyx margin shape

xii. Presence of annular constriction at calyx pedicel junction

xiii. Fruit shape at pedicel attachment

xiv. Neck at base of fruit

xv. Fruit shape at blossom end

xvi. Fruit persistence

xvii. Fruit position

xviii. Fruit colour in immature stage

xix. Fruit colour in mature stage

xx. Fruit shape

C. Estimation of heterosis in the interspecific hybrids

1 Materials

The materials under this experiment consisted of following five Capsicum species and 11 F_1 hybrids.

a. Parents

i. C. annuum

ii. C. frutescens

iii. C. chinense (P)

iv. *C. chinense* (NP)

v. *C. baccatum*

vi. *C. chacoense*

b. F_1 hybrids

i. *C. annuum* x *C. chinense* (P)

ii. *C. annuum* x *C. chinense* (NP)

iii. *C. frutescens* x *C. annuum*

iv. *C. frutescens* x *C. chinense* (P)

v. *C. frutescens* x *C. chinense* (NP)

vi. *C. frutescens* x *C. baccatum*

vii. *C. chinense* (P) x *C. frutescens*

viii. *C. chinense* (P) x *C. baccatum*

ix. *C. chinense* (NP) x *C. frutescens*

x. *C. baccatum* x *C. frutescens*

xi. *C. chacoense* x *C. annuum*

2. Methods

Experiment was conducted in a completely randomized block design under pot culture during September 89-April 1990. There were 10 plants/species/hybrids. All the plants were considered for taking observations.

a. Observations

Observations on the following quantitative characters were recorded:

i.	Plant height (cm)	- Measured at 15 days interval from 30 days after planting and averaged
ii.	Plant spread (cm)	- Measured after full growth of the plant
iii.	Days to flower	-
iv.	Days to harvest	- Days to first red chilli harvest was taken
v.	Fruit length (cm)	-
vi.	Fruit width (cm)	-
vii.	Pericarp thickness	-
viii.	Average fruit weight (g)	- (Fresh weight)
ix.	Fruit yield/plant (g)	- (Fresh weight)
x.	Fruits/plant	-
xi.	Seed diameter	-
xii.	1000 seed weight	-
xiii.	Capsaicin	-

The capsaicin content of chilli fruits were estimated as per Theymoli et al. (1982). Red ripe chillies were dried and the stalks and seeds were removed before powdering. 0.5 g of dry chilli powder was shaken for 3 hours with 10 ml of acetone in a mechanical shaker, after which it was centrifuged at 5000 rpm for 10 minutes. Ten ml of clear supernatent was pipetted out into a test tube and evoporated to dryness in a hot water both. The residue was dissolved in 500 ml of 0.4% Na OH, 3 ml of 3% phosphomolybdic acid was added and kept for one hour after shaking. The contents were then centrifuged at 5000 rpm for 10-15 minutes and filtered. The clear blue solution was transferred directly into the cuvette and the absorbance was read at 650 nm in Spectronic 20.

xiv. Oleoresin

Oleoresin was estimated using Soxhlet apparatus and acetone as the solvent.

xv. Total extractable colour

Total extractable colour was estimated as per ASTA method (Hort and Fisher, 1971).

0.1 g of ground chilli powder was weighed into a 250 ml Erlenmeyer flask. One hundred ml of isopropanol was then pipetted into the flask and kept overnight at room temperature. The contents were then filtered through a Whatman 42 paper, discarding the first 10 ml. 25 ml of the filtrate was pipetted out into a 50 ml volumetric flask and diluted to the mark with isopropanol. Absorbance was read at 450 nm against isopropanol as blank.

Standard colour solution was prepared by dissolving 0.5 mg of reagent grade $K_2 Cr_2 O_7$ in 1.8 m $H_2 SO_4$.

b. Statistical analysis

The data on various quantitative characters were analysed and heterobeltiosis (HB) and relative heterosis (RH) were estimated as per Hayes et al. (1965) and Briggle (1963) respectively.

$$H.B. = \frac{\overline{F}_1 - \overline{BP}}{\overline{BP}} \times 100$$

Heterobeltiosis was tested using the standard error,

$$S.E. = \sqrt{\frac{\sigma^2 F_1}{n_1} + \frac{\sigma^2 BP}{n_2}}$$

Where,

$\sigma^2 F_1$ = F_1 variance

$\sigma^2 BP$ = Better parental variance

n_1 = Number of F_1 plants

n_2 = Number of better parents

$$R.H. = \frac{\overline{F}_1 - \overline{MP}}{\overline{MP}} \times 100$$

Relative heterosis was tested using standard error,

$$SE = \sqrt{\frac{\sigma^2_{F_1}}{n_1} + \frac{1}{4}\left[\frac{\sigma^2_{P_1}}{n_1} + \frac{\sigma^2_{P_2}}{n_3}\right]}$$

Where,

$\sigma^2_{P_1}$ = Maternal parental variance

$\sigma^2_{P_2}$ = Paternal parental variance

n_2 = Number of maternal parents

n_3 = Number of paternal parents

Results

RESULTS

Results from the present sets of experiments are presented under the following heads:

A. Evaluation of germplasm and selection of parental materials

B. Interspecific hybridization in the genus *Capsicum*

C. Estimation of heterosis in interspecific hybrids

A. Evaluation of germplasm and selection of parental materials

1. Taxonomic treatment

The 84 chilli accessions grown during September-December 1988 exhibited considerable variability for morphological characters like growth habit, pubescence of stem and leaves, colour of stem, corolla, anther, filament and fruit, number of pedicels/axil, presence of yellow spot at the base of corolla lobes and for presence of annular constriction at the calyx pedicel junction (Table 1). The accessions when subjected to the following taxonomic treatment were found to fall under four *Capsicum* species viz., *C. annuum* (62 accessions), *C. frutescens* (7 accessions), *C. chinense* (14 accessions) and *C. baccatum* (1 accession).

Table 1 Source and morphological description of 84 chilli accessions

Accession number	Source	Plant growth habit	Stem pubescence	Stem colour	Node colour	Leaf pubescence	No. of pedicels/axil	Pedicel position at anthesis	Corolla colour	Corolla spot	Anther colour	Filament colour	Stigma position in relation to anthers
	1	2	3	4	5	6	7	8	9	10	11	12	13
CA 33 (KAU Cluster)	GBPUAT, Pantnagar	Comp.	Inter.	G	G	Glb.	4-5	Er.	W	A	B	W	Exser.
CA 53 (Pant-C_1)	GBPUAT, Pantnagar	Comp.	Glb.	G	G	Glb.	1	Er.	W	A	G	W	Exser.
CA-60 (Jwala)	IARI, New Delhi	Comp.	Glb.	G	G	Glb.	1	Pend.	W	A	G	W	Exser.
CA 87 (Andra Jyothi)	Lam, Gundoor	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	P.B.	W	Exser.
CA 89 (White Kanthari)	Trichur	Er.	Glb.	G	G	Glb.	1	Er.	G.W.	A	B	P	Exser.
CA 94 (K_2)	TNAU Coimbatore	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	P.B.	W	Exser.
CA 160	Cochin	Prost.	Glb.	G	G	Glb.	2	Er.	W	A	B	B	Exser.
CA 164	Quilon	Er.	Glb.	G	G	Sp.	1	Pend.	W	A	B	W	Exser.
CA 165	Quilon	Er.	Glb.	G	G	Sp.	1	Pend.	W	A	B	W	Exser.
CA 166	Quilon	Prost.	Abund.	G	G	Inter	1	Er.	W	A	B	V	Exser.
CA 169	Quilon	Er.	Glb.	G	G	Glb.	1	Er.	G.W.	A	B	P	Exser.
CA 171	Quilon	Prost.	Sp.	G	G	Sp.	2	Inter.	G.W.	A	B	V	Exser.
CA 175	Quilon	Prost.	Sp.	G	G	Sp.	2	Inter.	G.W.	A	B	B	Exser.
CA 179	Quilon	Prost.	Inter.	G	G	Sp.	2	Inter.	W	A	B	V	Exser.
CA 180	Quilon	Prost.	Sp.	G	G	Sp.	2	Pend.	W	A	B	V	Exser.
CA 181	Quilon	Prost.	Sp.	P	P.G.	Sp.	2-3	Inter.	V	A	B	B	Exser.
CA 182	Quilon	Prost.	Glb.	G	G	Glb.	2-3	Er.	W	A	D.B.	B	Same level
CA 189	Malappuram	Er.	Sp.	G	G	Glb.	1	Pend.	W	A	P.B.	W	Exser.
CA 192 (Jawahar 218)	Jabalpur	Comp.	Glb.	G	G	Glb.	1	Er.	W	A	P.B.	Y	Exser.
CA 201	Cochin	Comp.	Glb.	G	G	Glb.	1	Pend.	W	A	B	W	Exser.
CA 205	Trichur	Prost.	Glb.	G	G	Glb.	2-3	Er.	W	A	D.B.	B	Exser.
CA 206	Trichur	Er.	Glb.	P	P	Glb.	1	Er.	V	A	B	B	Exser.
CA 207	Trichur	Prost.	Glb.	G	G	Glb.	1	Pend.	W	A	B	W	Exser.
CA 209	Trichur	Comp.	Sp.	G	G	Glb.	1	Inter.	W	A	B	P.B	Exser.
CA 211	Trichur	Prost.	Sp.	P	P	Glb.	2	Inter.	W	A	D.B.	B	Exser.
CA 212	Trichur	Prost.	Sp.	G	G	Glb.	1	Pend.	W	A	D.B.	B	Exser.
CA 213	Trichur	Comp.	Glb.	G	G	Glb.	1	Pend.	W	A	B	W	Exser.

Contd.

Table 1 (contd.)

Accession number	Source	Plant growth habit	Stem pubescence	Stem colour	Node colour	Leaf pubescence	No. of pedicels/axil	Pedicel position at anthesis	Corolla colour	Corolla spot	Anther colour	Filament colour	Stigma position in relation to anthers
CA 219	IIHR, Bangalore	Comp.	Glb.	G	G	Glb.	5-7	Er.	W	A	G.B.	W	Exser.
CA 221	Trichur	Er.	Glb.	G	G	Glb.	1	Er.	G.W.	A	G.B.	W	Exser.
CA 222	Trichur	Er.	Glb.	G	G	Glb.	4-5	Er.	G.W.	A	B	P	Exser.
CA 223	Cochin	Comp.	Glb.	G	G	Glb.	1	Pend.	W	A	B	W	Exser.
CA 225	Cochin	Comp.	Glb.	G	G	Glb.	1	Pend.	W	A	B	W	Exser.
CA 282	NBPGR,	Comp.	Glb.	G	G	Glb.	1	Pend.	W	A	B	W	Exser.
CA 302	Plant Germplasm Quarentine Centre, Beltsville, U.S.	Comp.	Sp.	G	G	Sp.	1	Er.	Y.W.	P	Y	W	Exser.
CA 307	Plant Germplasm Quarentine Centre, Beltsville, U.S.	Prost.	Abund.	G	G	Abund.	2-3	Pend.	G.W.	A	D.B.	P.B.	Exser.
CA 308	Plant Germplasm Quarentine Centre, Beltsville, U.S.	Er.	Sp.	G	G	Glb.	2-3	Er.	G.W.	A	P.B.	W	Exser.
CA 317	Plant Germplasm Quarentine Centre, Beltsville, U.S.	Prost.	Abund.	G	G	Abund.	1	Pend.	G.W.	A	D.B.	P.B.	Same level
CA 337	PAU, Ludhiana	Comp.	Glb.	G	G	Glb.	1	Er.	W	A	G	W	Exser.
CA 345	Trichur	Comp.	Glb.	G	G	Glb.	1	Pend.	W	A	G	W	Exser.
CA 354	Tirunelveli	Comp.	Glb.	G	G	Sp.	2	Er.	G.W.	A	B	W	Same level
CA 355	Vellanikkara	Prost.	Sp.	G	G	Sp.	1	Er.	G.W.	A	B	V	Exser.
CA 356	NBPGR, Vellanikkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	P.B.	W	Exser.
CA 361	NBPGR, Vellanikkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	P.B.	W	Exser.
CA 367	NBPGR, Vellanikkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	P.B.	W	Exser.

Contd.

Table 1 (contd.)

Accession number	Source	Plant growth habit	Stem pube-scence	Stem colour	Node colour	Leaf pube-scence	No. of pedi-cels/ axil	Pedicel posi-tion at anthesis	Corolla colour	Corolla spot	Anther colour	Fila-ment colour	Stigma position in relation to anthers
CA 379	NBPGR, Vellani-kkara	Comp.	Inter.	G	G	Sp.	1	Inter.	W	A	G	W	Exser.
CA 388	NBPGR, Vellani-kkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	B	W	Exser.
CA 389	NBPGR, Vellani-kkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	B	W	Exser.
CA 393	NBPGR, Vellani-kkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	P.B.	W	Exser.
CA 394	NBPGR, Vellani-kkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	P.B	W	Exser.
CA 395	NBPGR, Vellani-kkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	P.B.	W	Exser.
CA 396	NBPGR, Vellani-kkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	P.B.	W	Exser.
CA 399	NBPGR, Vellani-kkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	P.B	W	Exser.
CA 407	NBPGR, Vellani-kkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	P.B.	W	Exser.
CA 408	NBPGR, Vellani-kkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	P.B	W	Exser.
CA 409	NBPGR, Vellani-kkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	P.B.	W	Exser.
CA 416	NBPGR, Vellani-kkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	P.B.	W	Exser.
CA 417	NBPGR, Vellani-kkara	Comp.	Glb.	G	G	Glb.	1	Pend.	W	A	G.B.	W	Exser.
CA 418	NBPGR, Vellani-kkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	P.B.	W	Exser.
CA 419	NBPGR, Vellani-kkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	P.B.	W	Exser.
CA 420	NBPGR, Vellani-kkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A.	P.B.	W	Exser.
CA 421	NBPGR, Vellani-kkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	P.B.	W	Exser.
CA 423	NBPGR, Vellani-kkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	P	W	Exser.
CA 424	NBPGR, Vellani-kkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	P	W	Exser.

Contd.

Table 1 (contd.)

Accession number	Source	Plant growth habit	Stem pube-scence	Stem colour	Node colour	Leaf pube-scence	No. of pedi-cels/axil	Pedicel position at anthesis	Corolla colour	Corolla spot	Anther colour	Fila-ment colour	Stiga position in relation to anthers
CA 425	NBPGR, Vellani-kkara	Comp.	Glb.	G	G	Glb.	1	Er.	W	A	G	W	Exser.
CA 431	NBPGR, Vellani-kkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	G	W	Exser.
CA 437	NBPGR, Vellani-kkara	Comp.	Glb.	G	G	Glb.	1	Er.	W	A	G	W	Exser.
CA 438	NBPGR, Vellani-kkara	Comp.	Glb.	G	G	Glb.	1	Er.	M	A	G	W	Exser.
CA 439	NBPGR, Vellani-kkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	B	W	Exser.
CA 440	NBPGR, Vellani-kkara	Er.	Glb.	P	P	Glb.	1	Er.	V	A	B	W	Exser.
CA 441	NBPGR, Vellani-kkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	B	W	Exser.
CA 442	NBPGR, Vellani-kkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	P.B.	W	Exser.
CA 444	NBPGR, Vellani-kkara	Comp.	Glb.	G	G	Glb.	1	Pend.	W	A	G	W	Exser.
CA 445	NBPGR, Vellani-kkara	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	P.B.	W	Exser.
CA 446	NBPGR, Vellani-kkara	Er.	Glb.	G	G	Glb.	1-2	Er.	G.W.	A	P.B.	W	Exser.
CA 447	NBPGR, Vellani-kkara	Er.	Glb.	G	G	Glb.	1	Pend.	W	A	B	W	Exser.
CA 448	NBPGR, Vellani-kkara	Er.	Glb.	G	G	Glb.	1	Pend.	W	A	B	W	Exser.
CA 449	NBPGR, Vellani-kkara	Er.	Sp.	G	G	Sp.	1	Er.	G.W.	A	B	Y	Exser.
CA 451 (Jwala Mukhi)	College of Agri-culture, Vellayani	Comp.	Glb.	G	G	Glb.	1	Pend.	W	A	G	W	Exser.
CA 452 (Jwala Sakhi)	College of Agri-culture, Vellayani	Comp.	Glb.	G	G	Glb.	1	Pend.	W	A	G.B.	W	Exser.
CA 508	Palghat	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	B	W	Exser.
CA 509	Palghat	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	P.B.	W	Exser.
CA 510	Palghat	Comp.	Glb.	G	G	Glb.	1	Pend.	W	A	G	W	Exser.
CA 511	Palghat	Er.	Sp.	G	G	Sp.	1	Pend.	W	A	B	W	Exser.

Contd.

Table 1 (contd.)

Accession number	Calyx margin shape	Annular constriction at calyx pedicel junction	Fruit position	Fruit colour in immature stage	Fruit colour in mature stage	Fruit length	Fruit shape	Fruit shape at peduncle attachment	Neck at base of fruit	Fruit shape at blossom end	Fruit cross sectional corrugation	Fruit persistence	Anthocyanin in unripe fruit	Anthocyanin in ripe fruit
	14	15	16	17	18	19	20	21	22	23	24	25	26	27
CA 33 (KAU Cluster)	Dent.	A	Er.	G	R	Short	El.	Obt.	P	Pnt.	Smooth	Pst.	A	A
CA 53 (Pant-C_1)	Smooth	A	Er.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 60 (Jwala)	Smooth	A	Decl.	L.G.	R	Long	El.	Obt.	A	Pnt.	Sl.Corg.	Pst.	A	A
CA 87 (Andra Jyothi)	Inter.	A	Decl.	D.G.	R	Med.	El.	Ac.	A	Pnt.	Smooth	Pst.	A	A
CA 89 (White Kanthari)	Dent.	A	Decl.	W	W	Short	El.	Obt.	A	Pnt.	Sl.Corg.	Pst.	A	A
CA 94 (K_2)	Inter.	A	Decl.	G	R	Med.	EL.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 160	Smooth	A	Decl.	G	R	Short.	Obl.	Obt.	A	Pnt.	V.Corg.	Pst.	A	A
CA 164	Smooth	A	Decl.	G	R	Med.	El.	Obt.	A.	Pnt.	Smooth	Pst.	A	A
CA 165	Smooth	A	Decl.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 166	Inter.	P	Inter	G	R	Short.	Obl.	Obt.	A	Pnt.	Sl.Corg.	Pst.	A	A
CA 169	Dent.	A	E	W	R	Short	El.	Obt.	A	Pnt.	Sl.Corg.	Pst.	A	A
CA 171	Smooth	P	Decl.	G	R	Short	Obl.	Obt.	A	Pnt.	Inter.	Pst.	A	A
CA 175	Inter.	P	Decl.	G	R	Short.	Blo.	Obt.	A	Pnt.	Sl.Corg.	Pst.	A	A
CA 179	Smooth	P	Decl.	G	R	Short	Round	Cord.	A	Blt.	V.Corg.	Pst.	A	A
CA 180	Smooth	P	Decl.	L.G.	R	Short	Round	Cord.	A	Blt.	V.Corg.	Pst.	A	A
CA 181	Smooth	P	Decl.	P.	R	Short	Round	Trunc.	A	Skn.	Inter.	Pst.	A	A
CA 182	Smooth	P	Decl.	G	R	Short	Round	Trunc.	A	Blt.	Inter.	Pst.	A	A
CA 189	Inter.	A	Decl.	G	R	Med.	El.	Trunc.	A	Blt.	Smooth	Pst.	A	A
CA 192	Inter.	A	Inter	G	R	Short	El.	Obt.	P	Pnt.	Smooth	Pst.	A	A
CA 201	Inter.	A	Decl.	G	R	Long	El.	Trunc.	A	Blt.	Smooth	Pst.	A	
CA 205	Smooth	P	Decl.	G	R	Short	Round	Trunc.	A	Blt.	Inter.	Pst.	A	
CA 206	Smooth	A	Er.	P	R	Short.	El.	Obt.	A	Pnt.	Sl.Corg.	Pst	P	
CA 207	Inter.	A	Decl.	G	R	Long	El.	Obt.	A	Blt.	Smooth	Pst.	A	
CA 209	Smooth	A	Decl.	G	R	Med.	El.	Obt.	A	Ptd.	Smooth	Pst.	P	
CA 211	Smooth	P	Inter	L.P.	R	Short	Round	Trunc.	A	Skn.	V.Corg.	Pst.	A	
CA 212	Inter.	P	Inter	G	R	Short	Obl.	Trunc.	A	Pnt.	inter.	Pst.	A	
CA 213	Inter.	A	Decl.	G	R	Long	El.	Trunc.	P	Pnt.	Smooth	Pst.	A	
CA 219	Smooth	A	Er.	G	R	Short	El.	Obt.	P	Pnt.	Sl.Corg.	Pst.	A	
CA 221	Dent.	A	Er.	W	R	Short	El.	Obt.	A	Pnt.	Sl.Corg.	Pst.	A	
CA 222	Dent.	A	Er.	G.W.	R	Short	El.	Ac.	A	Pnt.	Smooth	Pst.	A	
CA 223	Inter.	A	Decl.	G	R.	Med.	El.	Ac.	A	Pnt.	Smooth	Pst.	A	

Contd.

Table 1 (contd.)

Accession number	Calyx margin shape	Annular constriction at calyx pedicel junction	Fruit position	Fruit colour in immature stage	Fruit colour in mature stage	Fruit length	Fruit shape	Fruit shape at peduncle attachment	Neck at base of fruit	Fruit shape at blossom end	Fruit cross sectional corrugation	Fruit persistence	Anthocyanin in unripe fruit	Anthocyanin in ripe Fruit
CA 225	Inter.	A	Decl.	G	R	Long	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 282	Inter.	A	Er.	G	R	Med.	El.	Ac.	A	Pnt.	Smooth	Pst.	A	A
CA 302	Inter.	A	Er.	L.G.	R	Short	Obl.	Obt.	P	Blt.	Smooth	Pst.	A	A
CA 307	Smooth	P	Decl.	G	R.	Short	Blo.	Cord.	A	Blt.	V.Corg.	Pst.	A	A
CA 308	Inter.	A	Er.	G	R	Short	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 317	Smooth	P	Decl.	G	R	Med.	El.	Obt.	P.	Pnt.	Sl.Corg.	Pst.	A	A
CA 337	Smooth	A	Er.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 345	Smooth	A	Er.	G	R	Short	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 354	Smooth	A	Decl.	G	R	Med.	Con.	Lob.	A	Pnt.	Inter.	Pst.	A	A
CA 355	Dent.	A	Er.	G	R	Short	El.	Obt.	A	Blt.	Sl.Corg.	Pst.	A	A
CA 356	Inter.	A	Decl.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 361	Inter.	A	Decl.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 367	Inter.	A	Decl.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 379	Smooth	A	Decl.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 382	Dent.	A	Er.	G	R	Short	El.	Obt.	P	Pnt.	Smooth	Pst.	A	A
CA 388	Smooth	A	Decl.	G	R	Med.	El.	Ac.	A	Pnt.	Smooth	Pst.	A	A
CA 389	Smooth	A	Decl.	G	R	Short.	Con.	Obt.	A	Blt.	Smooth	Pst.	A	A
CA 393	Inter.	A	Decl.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 394	Inter.	A	Decl.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 395	Inter.	A	Decl.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 396	Inter.	A	Decl.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 399	Inter.	A	Decl.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 407	Inter.	A	Decl.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 408	Inter.	A	Decl.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 409	Inter.	A	Decl.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 416	Inter.	A	Decl.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 417	Smooth	A	Decl.	G	R	Short	Round	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 418	Inter.	A	Decl.	D.G.	R	Med.	El.	Ac.	A	Pnt.	Smooth	Pst.	A	A
CA 419	Inter.	A	Decl.	D.G.	R	Med.	El.	Ac.	A	Pnt.	Smooth	Pst.	A	A
CA 420	Inter.	A	Decl.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 421	Inter.	A	Decl.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 423	Inter.	A	Decl.	P.G.	R	Med.	El.	Ac.	A	Pnt.	Smooth	Pst.	P	A
CA 424	Inter.	A	Decl.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 425	Smooth	A	Decl.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 431	Inter.	A	Decl.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A

Contd.

Table 1 (contd.)

Accession number	Calyx margin shape	Annular constriction at calyx pedicel junction	Fruit position	Fruit colour in immature stage	Fruit colour in mature stage	Fruit length	Fruit shape	Fruit shape at peduncle attachment	Neck at base of fruit	Fruit shape at blossom end	Fruit cross sectional corrugation	Fruit persistence	Anthocyanin in unripe fruit	Anthocyanin in ripe fruit
CA 437	Smooth	A	Decl.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 438	Smooth	A	Decl.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 439	Smooth	A	Decl.	G	R	Short	Con.	Obt.	A	Blt.	Smooth	Pst.	A	A
CA 440	Smooth	A	Er.	P	R	Short	El.	Obt.	A	Pnt.	Sl.Corg.	Pst.	P	P
CA 441	Inter.	A	Decl.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 442	Smooth	A	Decl.	G	R	Med.	El.	Obt.	A	Blt.	Smooth	Pst.	A	A
CA 444	Smooth	A	Decl.	G	R	Long	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 445	Inter.	A	Decl.	D.G.	R	Med.	El.	Ac.	A	Pnt.	Smooth	Pst.	A	A
CA 446	Dent.	A	Decl.	G	R	Short	El.	Obt.	A	Pnt.	Sl.Corg.	Pst.	A	A
CA 447	Smooth	A	Decl.	D.G.	R	Long	Cont.	Trunc.	A	Bnt.	Smooth	Pst.	A	A
CA 448	Smooth	A	Er.	G	R	Med.	El.	Ac.	A	Pnt.	Smooth	Pst.	A	A
CA 449	Dent.	P	Inter.	W	R	Short	El.	Obt.	P	Pnt.	Sl.Corg.	Pst.	A	A
CA 451	Dent.	A	Decl.	G.W.	R	Med.	El.	Trunc.	A	Pnt.	Sl.Corg.	Pst.	A	A
CA 452	Inter.	A	Decl.	G.W.	R	Med.	El.	Trunc.	A	Pnt.	Sl.Corg.	Pst.	A	A
CA 508	Smooth	A	Decl.	L.G.	R	Long.	Con.	Obt.	A	Blt.	Smooth	Pst.	A	A
CA 509	Inter.	A	Decl.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 510	Smooth	A	Decl.	G	R	Med.	El.	Obt.	A	Pnt.	Smooth	Pst.	A	A
CA 511	Smooth	A	Decl.	G	R	Short	Con.	Obt.	A	Blt.	Smooth	Pst.	A	A

A.	- Absent	Exser.	-	Exserted	P.B.	-	Pale Blue
Abund.	- Abundant	G.	-	Green	Pnt.	-	Pointed
Ac.	- Acute	G.B.	-	Greenish Blue	Prost.	-	Prostrate
B.	- Blue	G.W.	-	Greenish White	Pst.	-	Persistant
Blo.	- Blocky	Glb.	-	Glabrous	R.	-	Red
Blt.	- Blunt	Inter.	-	Intermediate	Sp.	-	Sparse
Comp.	- Compact	L.G.	-	Light Green	Skn.	-	Sunken
Con.	- Conical	Med.	-	Medium	Sl. Corg.	-	Slightly Corrugated
Cord.	- Cordate	Obl.	-	Oblate	Trunc.	-	Truncate
D.B.	- Dark Blue	Obt.	-	Obtuse	V.	-	Violet
D.G.	- Dark Green	P.	-	Purple	V. Corg.	-	Very Corrugated
Decl.	- Declining	P.	-	Present	W.	-	White
Dent.	- Dentate	P.G.	-	Purplish Green	Y.	-	Yellow
El.	- Elongate	Pend.	-	Pendant	Y.W.	-	Yellowish White
Er.	- Erect						

The 62 accessions belonging to C. annuum comes under three groups. The first group comprises of accessions CA 206 and CA 440 which are having solitary flowers with purple corolla. Second group consists of comparatively large number of accessions which have got solitary flower with milky white corolla and this includes varieties like Pant-C_1, Jwala, Andhra Jyothi and K_2. CA 33, CA 219 and CA 302, having two or more flowers at each node and milky white corolla falls under the third group.

Mainly two groups are coming under C. frutescens. One group is having solitary flowers while the other group is having two or more flowers at each node. In both cases pedicels were erect at anthesis with slightly revoluted greenish-white corolla lobes.

C. chinense consists of morphologically three distinct groups. The first group with purple corolla has only a single accession, CA 181. The second group, consisting of 12 accessions, was characterized by white or greenish-white corolla. In both the groups annular constriction at the junction of pedicel and calyx was prominent. But this annular constriction is lacking in the last group. C. chinense comprised of 13 pungent accessions and one nonpungent accession (CA 317).

Key to domesticated species of Capsicum

1. Seeds dark, corolla purple .... C. pubescens
2. Seeds straw-coloured, corolla white or greenish white 2
    2. Corolla with diffused yellow spots at base of lobes .... C. baccatum

        CA 302

    2. Corolla without diffused yellow spots at base of lobes 3
        3. Corolla purple 4
            4. Flowers solitary .... C. annuum

                CA 206, CA 440

            4. Flowers 2 or more at each node .... C. chinense

                CA 181

        3. Corolla white or greenish-white 5
            5. Calyx of mature fruit with annular constriction at junction with pedicel.. C. chinense

                CA 166, CA 171, CA 175, CA 179, CA 180, CA 182
                CA 205, CA 211, CA 212, CA 307, CA 317, CA 449

            5. Calyx of mature fruit without annular constriction at junction with pedicel 6
                6. Flowers solitary 7
                    7. Corolla milky white, lobes usually straight, pedicels often declining as anthesis .... C. annuum

                        CA 53, CA 60, CA 87, CA 94, CA 164, CA 165, CA 189,
                        CA 192, CA 201, CA 207, CA 209, CA 213, CA 223, CA 225,
                        CA 282, CA 337, CA 438, CA 345, CA 354, CA 356, CA 361,
                        CA 367, CA 379, CA 388, CA 389, CA 393, CA 394, CA 395,
                        CA 396, CA 399, CA 407, CA 408, CA 409, CA 416, CA 417,
                        CA 418, CA 419, CA 420, CA 421, CA 423, CA 424, CA 425,
                        CA 431, CA 437, CA 439, CA 441, CA 442, CA 444, CA 445,
                        CA 447, CA 448, CA 451, CA 452, CA 508, CA 509, CA 510, CA 511.

                    7. Corolla greenish-white, lobes usually slightly revolute, pedicels erect at anthesis .... C. frutescens

                        CA 89, CA 169, CA 221

                6. Flowers 2 or more at each node 8
                    8. Corolla milky white .... C. annuum

                        CA 33, CA 219, CA 382

                    8. Corolla greenish white 9
                        9. Pedicels erect at anthesis, corolla lobes usually slightly revoluted .... C. frutescens

                            CA 222, CA 308, CA 355, CA 446

                        9. Pedicels declining at anthesis, corolla lobes straight .... C. chinense

                            CA 160

C. baccatum is characterized by a distinct yellow spot at base of corolla lobes. Only one accession CA 302 belonged to C. baccatum.

Based on key characters, the five accessions typical of the following four Capsicum species were selected for further studies.

C. annuum	-	CA 94
C. frutescens	-	CA 308
C. chinense (P)	-	CA 307
C. chinense (NP)	-	CA 317
C. baccatum	-	CA 302

2. Chemotaxonomy

Capsicum species were subjected to Agarose gel isoelectric focussing. Typical pherograms were obtained for C. chinense (P), C. chacoense and C. baccatum (Plate 7). It was found that C. chinense (P), C. chacoense and C. baccatum had species specific protein band patterns. The total protein bands present in three Capsicum species were taken together and numbered serially (Fig.1). Out of the total 21 bands, 11 bands were present in C. chinense (P) (1, 2, 3, 5, 8, 9, 12, 13, 15, 17, and 20). C. baccatum had eight bands (1, 2, 4, 6, 11, 13, 14 and 21). C. chacoense was characterized by eight bands (1, 2, 5, 7, 10, 15, 16 and 19) which was distinct

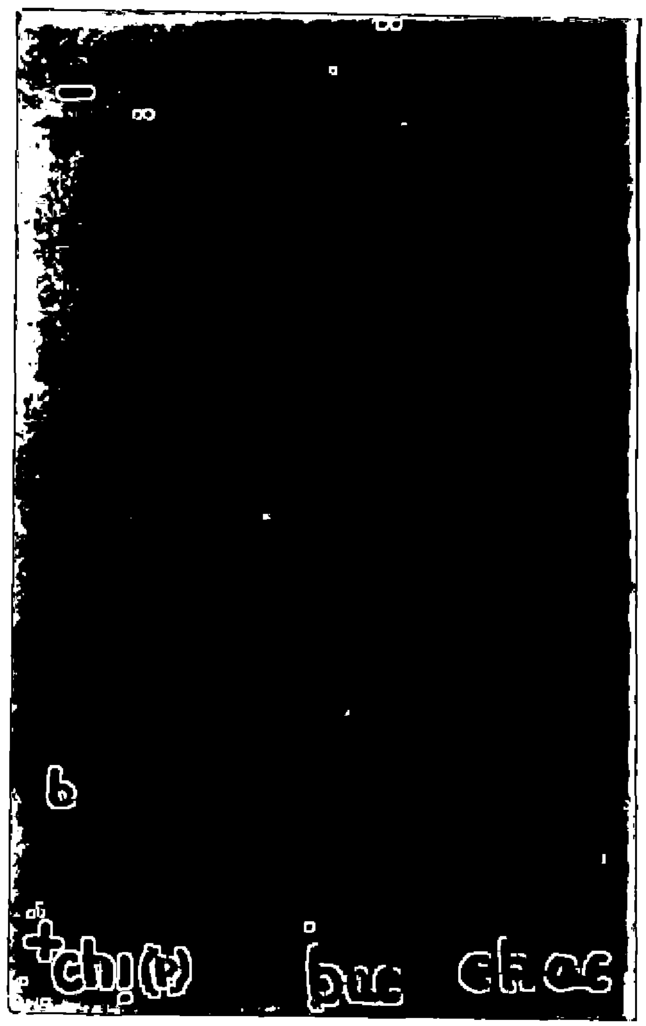


Plate 7. Pherograms resolved on AGIEF at p^H 3-8 using *C. chinense* (P), *C. baccatum* and *C. chacoense*

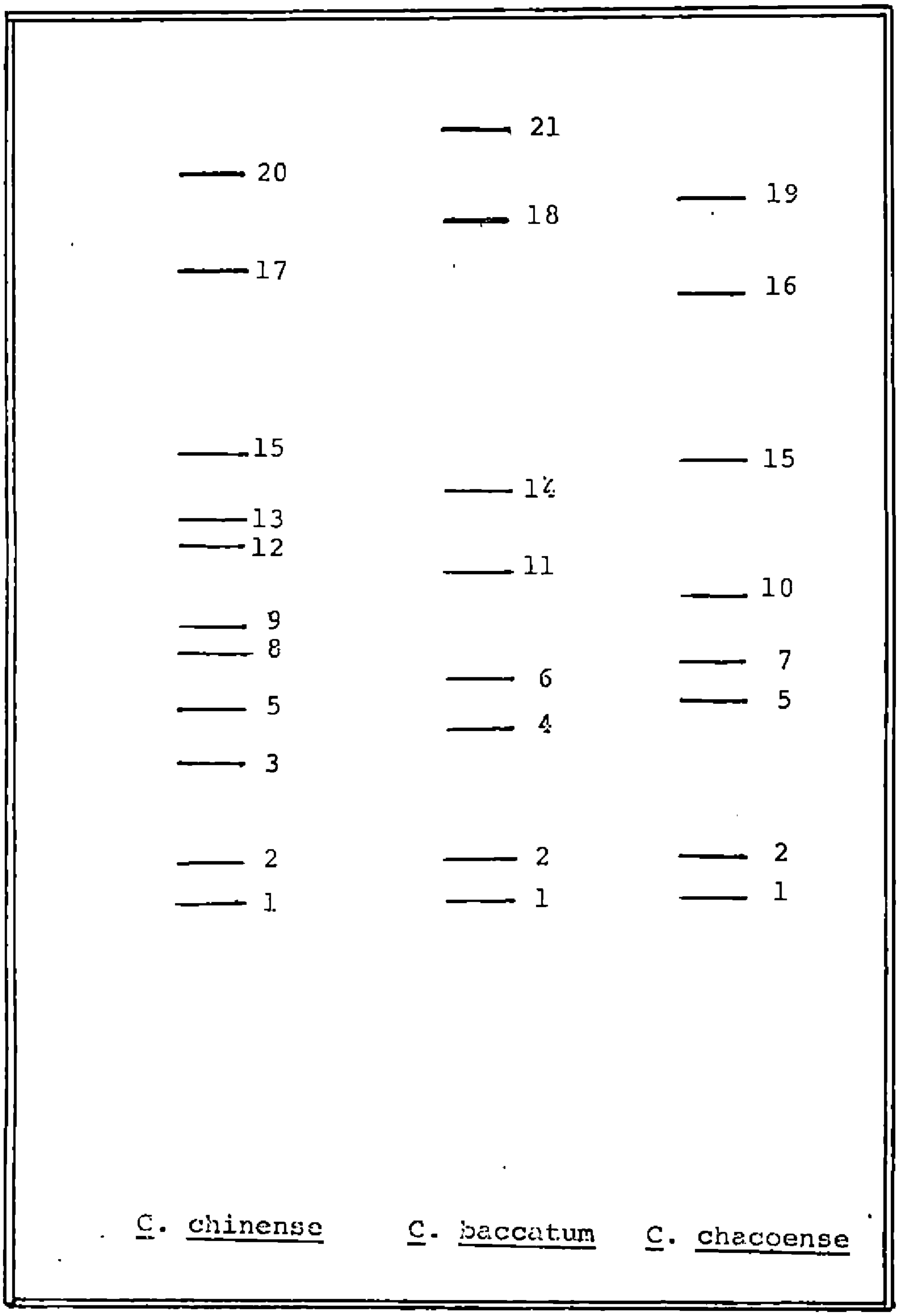


FIG.1 DIAGRAMMATIC REPRESENTATION OF PROTEIN BAND PATTERNS OF CAPSICUM SPECIES ON A.G.I.E.F. AT pH 3-8

from *C. baccatum*. Band (1) and (2) were common in all the three species. In addition to the above two bands, bands 5 and 15 were common in *C. chinense* (P) and *C. chacoense*. Bands 3, 5, 7, 8, 9, 10, 12, 13, 15, 16, 17, 19 and 20 were absent in *C. baccatum* and this species was found to be electrophoretically distinct from *C. chinense* (P) and *C. chacoense*. Ten bands were absent in *C. chinense* (P) viz. band number 4, 6, 7, 10, 11, 14, 16, 18, 19 and 21 while band numbers 3, 4, 6, 8, 9, 11, 12, 13, 14, 17, 18, 20 and 21 were absent in *C. chacoense*.

B. Interspecific hybridization in the genus *Capsicum*

1. Crossability among *Capsicum* species

Five *Capsicum* species viz., *C. annuum*, *C. frutescens*, *C. chinense*, *C. baccatum* and *C. chacoense* grown during February-August 1989 were crossed in all possible combinations and compatibility among species were studied. Percentage of fruit set was fair in all crosses, except when *C. chacoense* and *C. chinense* (NP) were used as one of the parents (Table 2). Number of seeds/fruit was maximum (47) in *C. annuum* x *C. chinense* (P) and minimum (2) in *C. frutescens* x *C. chacoense*. Irrespective of parents involved, there was variation in seed germination in different cross combinations. Percentage of seedling survival was high in all crosses, except those involving *C. chinense* and *C. chacoense* (Table 3). Further details are elaborated below.

Table 2 Percentage of fruit set and number of seeds/fruit in *Capsicum* species and interspecific crosses (F_o level)

Species/crosses	Number of flowers: Selfed	Number of flowers: Crossed	No. of fruits obtained	Fruit set (%)	No. of seeds/ fruit
C. annuum	28		25	89.28	44
C. frutescens	29		25	86.20	89
C. chinense (P)	28		22	78.57	42
C. chinense (NP)	28		18	64.28	40
C. baccatum	32		26	81.25	10
C. chacoense	35		21	60.00	5
C. annuum x *C. frutescens*		31	3	9.67	18
C. frutescens x *C. annuum*		20	4	20.00	3
C. annuum x *C. chinense* (P)		10	9	90.00	47
C. chinense (P) x *C. annuum*		17	6	35.29	10
C. annuum x *C. chinense* (NP)		32	2	6.25	22
C. chinense (NP) x *C. annuum*		41	2	48.70	16
C. annuum x *C. baccatum*		12	8	66.66	31
C. baccatum x *C. annuum*		25	3	12.00	5
C. annuum x *C. chacoense*		51	2	3.92	3
C. chacoense x *C. annuum*		40	3	7.50	3
C. frutescens x *C. chinense* (P)		11	4	36.36	6
C. chinense (P) x *C. frutescens*		31	4	12.90	25

Contd.

Table 2 (contd.)

Species/crosses	Number of flowers: Selfed	Number of flowers: Crossed	No. of fruits obtained	Fruit set (%)	No. of seeds/fruit
C. frutescens x *C. chinense* (NP)		32	6	18.75	7
C. chinense (NP) x *C. frutescens*		33	2	6.06	30
C. frutescens x *C. baccatum*		26	9	34.61	8
C. baccatum x *C. frutescens*		26	10	38.46	8
C. frutescens x *C. chacoense*		48	1	2.08	2
C. chacoense x *C. frutescens*		42	2	4.76	2
C. chinense (P) x *C. baccatum*		25	4	16.00	22
C. baccatum x *C. chinense* (P)		22	6	27.27	6
C. chinense (P) x *C. chacoense*		38	1	2.63	5
C. chacoense x *C. chinense* (P)		46	3	6.52	4
C. chinense (NP) x *C. baccatum*		33	1	3.03	15
C. baccatum x *C. chinense* (NP)		58	2	3.44	3
C. chinense (NP) x *C. chacoense*		48	1	2.08	12
C. chacoense x *C. chinense* (NP)		40	2	5.00	3
C. baccatum x *C. chacoense*		52	1	1.92	6
C. chacoense x *C. chacoense*		30	1	2.00	2

Table 3 Percentage of seed germination and seedling survival in *Capsicum* species and their interspecific crosses (F_1 level)

Species/crosses	Seed germination (%)	Seedling survival (%)
C. annuum	78.53	82.00
C. frutescens	57.14	90.00
C. chinense (P)	80.00	70.00
C. chinense (NP)	85.00	70.00
C. baccatum	60.00	85.00
C. chacoense	40.00	90.00
C. annuum x *C. frutescens*	0	-
C. frutescens x *C. annuum*	66.66	66.66
C. annuum x *C. chinense* (P)	59.57	80.00
C. chinense (P) x *C. annuum*	0	-
C. annuum x *C. chinense* (NP)	22.72	80.00
C. chinense (NP) x *C. annuum*	0	-
C. annuum x *C. baccatum*	0	-
C. baccatum x *C. annuum*	0	-
C. annuum x *C. chacoense*	0	-
C. chacoense x *C. annuum*	66.66	80.00
C. frutescens x *C. chinense* (P)	66.66	85.00
C. chinense (P) x *C. frutescens*	61.53	90.00

Contd.

Table 3 (contd.)

Species/crosses	Seeds germination (%)	Seedling survival (%)
C. frutescens x C. chinense (NP)	50.00	82.00
C. chinense (NP) x C. frutescens	40.00	75.00
C. frutescens x C. baccatum	57.14	80.00
C. baccatum x C. frutescens	75.00	85.00
C. frutescens x C. chacoense	0	-
C. chacoense x C. frutescens	0	-
C. chinense (P) x C. baccatum	13.63	70.00
C. baccatum x C. chinense (P)	0	-
C. chinense (P) x C. chacoense	20.00	-
C. chacoense x C. chinense (P)	0	-
C. chinense (NP) x C. baccatum	0	-
C. baccatum x C. chinense (NP)	0	-
C. chinense (NP) x C. chacoense	41.66	-
C. chacoense x C. chinense (NP)	0	-
C. baccatum x C. chacoense	0	-
C. chacoense x C. baccatum	0	-

a. C. annuum x C. frutescens

Out of the 31 flowers crossed, only three fruits were obtained with a set of 9.67%. Though there was 40.90% seed set efficiency, all the seeds failed to germinate.

Reciprocal cross was successful with 20% fruit set. Fruits contained 3 seeds with a seed set efficiency of 33.33% (Table 4). Out of the 27 seeds sown 18 germinated with 66.66% of seedling survival. Crossability index was only 6.67% (Table 5). The percentage of fruit set at F_1 level was only 113.33% (Table 6). There were 6.33 seeds/fruit with 28.57% of viable F_2 seeds (Table 7).

b. C. annuum x C. chinense (P)

This cross was highly successful with 90% fruit set (Plate 8). On an average a fruit contained 47 seeds with a seed set efficiency of 106.81%. 59.57% of seeds germinated of which 80% survived in the field. Crossability index was high (79.68%) compared to other crosses. Out of the 25 flowers selfed in the F_1 plant 15 fruits were obtained with an average of 25 seeds/fruit. Thirty five percentage of the F_2 seeds were viable. When C. chinense was used as the female parent, fruit set was only 35.29%, and none of the F_1 seeds were viable.

Plate 8. Plant morphology of *C. annuum* x *C. chinense* (P)

Plate 9. Plant morphology of *C. chacoense* x *C. annuum*

Table 4 Percentage seed set efficiency in interspecific crosses at F_o level

Species/crosses	No. of seeds in maternal parent (selfed)	No. of seeds in crosses	Seed set efficiency (%)
C. annuum	44		
C. frutescens	9		
C. chinense (P)	42		
C. chinense (NP)	40		
C. baccatum	10		
C. chacoense	5		
C. annuum x C. frutescens		18	40.90
C. frutescens x C. annuum		3	33.33
C. annuum x C. chinense (P)		47	106.81
C. chinense (P) x C. annuum		10	23.80
C. annuum x C. chinense (NP)		22	50.00
C. chinense (NP) x C. annuum		16	40.00
C. annuum x C. baccatum		31	70.45
C. baccatum x C. annuum		5	50.00
C. annuum x C. chacoense		3	6.81
C. chacoense x C. annuum		3	60.00
C. frutescens x C. chinense (P)		6	66.66
C. chinense (P) x C. frutescens		25	59.52

Contd.

Table 4 (contd.)

Species/crosses	No. of seeds in maternal parent (selfed)	No. of seeds in crosses	Seed set efficiency (%)
C. frutescens x *C. chinense* (NP)		7	77.77
C. chinense (NP) x *C. frutescens*		30	75.00
C. frutescens x *C. baccatum*		8	88.88
C. baccatum x *C. frutescens*		8	80.00
C. frutescens x *C. chacoense*		2	22.22
C. chacoense x *C. frutescens*		2	40.00
C. chinense (P) x *C. baccatum*		22	52.38
C. baccatum x *C. chinense* (P)		6	60.00
C. chinense (P) x *C. chacoense*		5	11.90
C. chacoense x *C. chinense* (P)		4	80.00
C. chinense (NP) x *C. baccatum*		15	37.50
C. baccatum x *C. chinense* (NP)		3	30.00
C. chinense (NP) x *C. chacoense*		12	30.00
C. chacoense x *C. chinense* (NP)		3	60.00
C. baccatum x *C. chacoense*		3	60.00
C. chacoense x *C. baccatum*		2	40.00

Table 5 Crossability index among *Capsicum* species

Species/hybrids	A^{sx}	B^{sx}	C^{sx}	D^{sx}	A^{cx}	B^{cx}	C^{cx}	D^{cx}	Crossability index (%)
C. *annuum*	89.28	44.0	78.53	82.00					
C. *frutescens*	86.20	9.0	57.14	90.00					
C. *chinense* (P)	78.57	42.0	80.00	70.00					
C. *chinense* (NP)	64.28	40.0	85.00	70.00					
C. *baccatum*	81.25	10.0	60.00	85.00					
C. *chacoense*	60.00	5.0	40.00	50.00					
C. *annuum* x C. *chinense* (P)					90.00	47	59.57	80.00	79.68
C. *annuum* x C. *chinense* (NP)					6.25	22	22.72	80.00	0.98
C. *frutescens* x C. *annuum*					20.00	3	66.66	66.66	6.67
C. *frutescens* x C. *chinense* (P)					36.36	6	66.66	85.00	30.98
C. *chinense* (P) x C. *frutescens*					12.90	25	61.53	90.00	1.97
C. *frutescens* x C. *chinense* (NP)					18.75	7	50.00	82.00	13.48
C. *chinense* (NP) x C. *frutescens*					6.06	30	40.00	75.00	3.56
C. *frutescens* x C. *baccatum*					34.61	8	57.14	80.00	31.72
C. *baccatum* x C. *frutescens*					38.46	8	75.00	85.00	47.33
C. *chinense* (P) x C. *baccatum*					16.00	22	13.63	70.00	1.81
C. *chacoense* x C. *annuum*					7.50	3	66.66	80.00	19.99

Table 6 Percentage of fruit set in interspecific hybrids

Interspecific hybrids	Flowers selfed	Fruits obtained	Fruit set (%)
C. annuum x *C. chinense* (P)	25	15	60.00
C. annuum x *C. chinense* (NP)	28	12	42.85
C. frutescens x *C. annuum*	30	4	13.33
C. frutescens x *C. chinense* (P)	31	16	51.61
C. chinense (P) x *C. frutescens*	24	15	62.50
C. frutescens x *C. chinense* (NP)	32	14	43.75
C. chinense (NP) x *C. frutescens*	30	15	50.00
C. frutescens x *C. baccatum*	22	2	9.09
C. baccatum x *C. frutescens*	28	2	7.14
C. chinense (P) x *C. baccatum*	28	3	10.71
C. chacoense x *C. annuum*	24	8	33.33

Table 7 Seeds/fruit and percentage of seed germination in F_2

Interspecific hybrids	Average number of seeds/fruit	Percentage of seed germination
C. annuum x *C. chinense* (P)	25.60	35.00
C. annuum x *C. chinense* (NP)	25.80	66.66
C. frutescens x *C. annuum*	6.33	28.57
C. frutescens x *C. chinense* (P)	8.50	51.85
C. chinense (P) x *C. frutescens*	6.44	50.00
C. frutescens x *C. chinense* (NP)	6.30	68.75
C. chinense (NP) x *C. frutescens*	3.28	41.20
C. frutescens x *C. baccatum*	0	-
C. baccatum x *C. frutescens*	0	-
C. chinense (P) x *C. baccatum*	0	-
C. chacoense x *C. annuum*	4.50	20.00

c. C. annuum x C. chinense (NP)

The fruit set was only 6.25% in this combination. The cross had a seed set efficiency of 50% with an average of 22 seeds/fruit. 22.72% of seeds germinated of which 80% survived in the field. Though crossability index was low (0.98%) fruit set was satisfactory (42.85%) in F_1 plants with 25.80 seeds fruit and 66.66% of viable F_2 seeds. In the reciprocal cross fruit set was low (6.25%) and none of the F_1 seeds germinated.

d. C. annuum x C. baccatum

The fruit set and seed set efficiency of this cross was comparatively high (66.60% and 70.45% respectively). Though the seeds were quite normal, none of the seeds germinated. The reciprocal combination also exhibited the same trend.

e. C. annuum x C. chacoense

Even though 51 flowers were crossed, only two fruits were obtained. On an average fruits contained three seeds with a seed set efficiency of 60%. Seeds were shrivelled, brown coloured and failed to germinate.

The reciprocal cross was successful with a crossability index of 19.99% (Plate 9). The fruit set was 7.5% with a seed set efficiency of 60%. 66.66% of F_1 seeds were viable of which 80% survived in the field. 33.33% fruit set was obtained in F_1 plant on selfing which contained on an average of 4.5 seeds/fruit and 20% viable F_2 seeds.

f. C. frutescens x C. chinense (P)

The cross was successful with an average of six seeds/fruit and 66.66% of F_1 seeds were viable of which 85% survived in the field. Here, crossability index value was high (30.98%), while in reciprocal cross, it was only 1.97% with 12.90% fruit set and 61.53% of viable seeds (Plate 10). In the F_1 plant, percentage of fruit set was more in reciprocal cross (62.50%) than in direct cross (51.61%). Viability of F_2 seeds were satisfactory in direct and reciprocal crosses (51.85% and 50% respectively).

g. C. frutescens x C. chinense (NP)

Out of 32 flowers crossed, six fruits were obtained, with an average of seven seeds/fruit (Plate 11). Even though 50% of the seeds were viable, crossability index was low (13.48%). 82% of the germinated seedlings survived in the field, which gave 43.75% of fruit set on selfing with 6.30 seeds/fruit and 68.75% of viable F_2 seeds.

Plate 10. Plant morphology of _C_. _chinense_ (P) x _C_. _frutescens_

Plate 11. Plant morphology of _C_. _frutescens_ x _C_. _chinense_ (NP)

When *C. chinense* (NP) was used as the female parent, fruit set was low (6.06%) with an average of 30 seeds/fruit. Here also, crossability index was low (3.56%) with 40% viable seeds. The survival of the germinated seedlings was as high as 75%, with a satisfactory fruit set at F_1 level (50%). On an average, fruits contained 3.28 seeds, of which 41% was viable.

h. *C. frutescens* x *C. baccatum*

Crosses were successful in both directions. When *C. frutescens* was used as female parent, fruit set was 34.61% with a seed set efficiency of 88.88%. Although seed germination and seedlings survival were satisfactory (57.14% and 80% respectively) fruit set was very low in F_1 plant (9.09%). The fruits were shrivelled with no seeds.

In the reciprocal cross also, fruit set and seed set efficiency was high (38.46% and 80% respectively) (Plate 12). 75% of the seeds were viable but in F_1 plants only two fruits that too without any seeds were obtained from 28 flowers selfed. The crossability index of the reciprocal cross was higher (47.33%) than the direct cross (31.72%).

i. *C. frutescens* x *C. chacoense*

Even though 48 flowers were crossed, only one fruit was obtained with two seeds/fruit and 22.22% seed set efficiency. None of the seeds germinated. The reciprocal cross also showed the same trend.

j. *C. chinense* (P) x *C. baccatum*

This cross was successful with 16% fruit set and 52.38% seed set efficiency. 13.63% of seeds germinated of which 70% survived in the field. However, crossability index was very low (1.81%) and in F_1 plants fruit set was low (10.71%) which did not contain any seed. Even though there was fruit set (27.27%) and seed set (6 seeds/fruit), none of the seeds were viable in the reciprocal cross.

k. *C. chinense* (P) x *C. chacoense*

Fruit set and seed set efficiency was very low (2.63% and 11.90% respectively). Even though 20% of the seeds germinated, none of the seedlings survived in the field. When *C. chacoense* was used as the female parent, fruit set was low (6.52%) with four seeds/fruit. But all the seeds failed to germinate.

l. *C. chinense* (NP) x *C. baccatum*

Fruit set and seed set efficiency were low (3.03% and 37.5% respectively). In the direct as well as in the reciprocal crosses, none of the seeds were viable.

m. C. chinense (NP) x C. chacoense

Percentage of fruit set was low (2.08%) with 12 seeds/fruit. Even though 41.66% seeds were viable, none of the seedlings survived in the field. In the reciprocal cross, seeds were dark coloured, which failed to germinate.

n. C. baccatum x C. chacoense

Out of the 52 flowers crossed, only one fruit was obtained. Though there were 6 seeds, none of the seeds were viable. Reciprocal cross also exhibited the same trend.

2. Meiotic studies in Capsicum species and hybrids

All the five species were found to be diploids with 2n=24 (Plate 13). Twelve typical bivalents were observed in C. annuum, C. frutescens and C. baccatum while meiotic abnormalities were observed in C. chinense and C. chacoense. Positive association was observed between percentage of meiotic abnormalities and percentage of pollen fertility. Among the species, C. chacoense exhibited highest percentage of meiotic abnormality (35.75%) with the lowest pollen fertility (37.24%) while C. annuum had the highest pollen fertility (94.11%) (Table 8).

Multivalents including three to four chromosomes were commonly observed in C. chinense (P), C. chinense (NP) (Plate 14) and C. chacoense. In these species anaphase-I was

Table 8 Percentage of meiotic abnormalities and its relation to pollen fertility in *Capsicum* species and interspecific hybrids

Species/hybrids	Meiotic abnormalities (%) (25-40 cells)	Pollen fertility (%)
C. annuum	2.10	94.11
C. frutescens	3.70	90.00
C. chinense (P)	7.50	81.08
C. chinense (NP)	11.50	72.50
C. baccatum	7.00	85.71
C. chacoense	35.75	37.24
C. annuum x *C. chinense* (P)	7.50	66.66
C. annuum x *C. chinense* (NP)	13.50	58.82
C. frutescens x *C. annuum*	52.50	45.45
C. frutescens x *C. chinense* (P)	27.50	51.32
C. chinense (P) x *C. frutescens*	32.75	56.25
C. frutescens x *C. chinense* (NP)	32.76	46.15
C. chinense (NP) x *C. frutescens*	38.90	57.14
C. frutescens x *C. baccatum*	65.75	13.75
C. baccatum x *C. frutescens*	82.70	11.25
C. chinense (P) x *C. baccatum*	84.60	5.88
C. chacoense x *C. annuum*	39.08	44.44

characterized by precocious disjunction leading to laggards and unequal distribution of chromosomes to poles.

All the interspecific hybrids exhibited abnormalities during meiotic division. Among hybrids the highest pollen fertility was found in _C. annuum_ x _C. chinense_ (P) (66.66%) followed by _C. annuum_ x _C. chinense_ (NP) (58.82%). In all the hybrids metaphase-I was characterized by multivalents involving three to four chromosomes. Nonorientation at metaphase plate during the I and II divisions was commonly observed in the PMCs of _C. annuum_ x _C. chinense_ (NP) (Plate 15), _C. frutescens_ x _C. chinense_ (P) (Plate 16) and _C. chacoense_ x _C. annuum_. Multivalents produced dicentric bridges at anaphase-I in a few PMCs of _C. frutescens_ x _C. chinense_ (NP) (Plate 17) and in _C. frutescens_ x _C. baccatum_. Anaphase-I was apparently normal with equal segregation of chromosomes in _C. annuum_ x _C. chinense_ (P) and _C. annuum_ x _C. chinense_ (NP). Preponderance of laggards were observed in both direct and reciprocal crosses involving _C. baccatum_ and _C. frutescens_ (Plate 18) and in _C. frutescens_ x _C. annuum_. Almost all the interspecific hybrids except _C. annuum_ x _C. chinense_ (P) carried five or more nuclei towards the end of meiosis just before tetrad formation. Micronuclei were commonly observed in telephase-II of _C. frutescens_ x _C. chinense_ (P) (Plate 19) and in _C. baccatum_ x _C. frutescens_ (Plate 20).

Among all the hybrids studied, C. chinense (P) x C. baccatum had the highest percentage of meiotic abnormalities. Dicentric bridges were observed even at anaphase-II (Plate 21). This hybrid also recorded the lowest pollen fertility (5.88%).

3. Physiological studies

Among the species C. chinense (P) has the highest stomatal density (201.96/mm^2) while C. baccatum and C. chacoense had the lowest (174.67/mm^2) (Table 9). All the hybrids had more number of stomata than their parents. Maximum stomata was found in C. chacoense x C. annuum (225.7/mm^2) followed by C. frutescens x C. baccatum (207.42/mm^2).

4. Inheritance of discrete characters

C. annuum and C. frutescens are having erect growth habit whereas C. chinense has prostrate growth habit (Table 10). The growth habit in C. baccatum and C. chacoense are compact. The crosses, where C. chinense was involved as one of the parents are having prostrate growth habit. Among the parental species, C. chinense, both pungent and nonpungent had abundant stem pubescence, whereas in all other species it was sparse. In all the F_1 hybrids where C. chinense was involved, abundant pubescence was noticed in the stem

Table 9 Stomatal density in *Capsicum* species and interspecific hybrids

Species/hybrids	Mean stomatal density (per mm^2) (Lower epidermis)
C. annuum	185.58
C. frutescens	185.58
C. chinense (P)	201.96
C. chinense (NP)	196.50
C. baccatum	174.67
C. chacoense	174.67
C. annuum x *C. chinense* (P)	200.90
C. annuum x *C. chinense* (NP)	202.50
C. frutescens x *C. annuum*	198.50
C. frutescens x *C. chinense* (P)	182.50
C. chinense (P) x *C. frutescens*	174.67
C. frutescens x *C. chinense* (NP)	182.75
C. chinense (NP) x *C. frutescens*	181.56
C. frutescens x *C. baccatum*	207.42
C. baccatum x *C. frutescens*	206.50
C. chinense (P) x *C. baccatum*	202.75
C. chacoense x *C. annuum*	225.70

Table 10 Comparison of parental species and hybrids for discrete characters

Species/hybrids	Plant growth habit	Stem pube-scence	Leaf pube-scence	Pedicels/axil	Pedicel position at anthesis	Corolla colour	Corolla spot	Anther colour	Filament colour	Calyx margin shape
Parents										
C. annuum	Er.	Sp.	Sp.	1	Pend.	W	A	PB	W	Inter.
C. frutescens	Er.	Sp.	Glb.	2-3	Er.	GW	A	B	W	Inter.
C. chinense (P)	Prost.	Abund.	Abund.	2-3	Pend.	WLG	A	DB	W	Smooth
C. chinense (NP)	Prost.	Abund.	Abund.	2-3	Pend.	WLG	A	DB	W	Smooth
C. baccatum	Comp.	Sp.	Sp.	1	Er.	YW	P	PY	W	Inter.
C. chacoense	Prost.	Glb.	Sp.	1	Er.	W	A	PYG	W	Dent.
Hybrids										
C. annuum x C. chinense (P)	Prost.	Abund.	Abund.	1-2	Pend.	W	A	B	W	Inter.
C. annuum x C. chinense (NP)	Prost.	Abund.	Inter.	2	Inter.	W	A	DB	W	Inter.
C. frutescens x C. annuum	Comp.	Inter.	Sp.	1	Er.	WLG	A	PB	W	Inter.
C. frutescens x C. baccatum	Comp.	Sp.	Sp.	1-2	Er.	YW	P	PB	W	Smooth
C. baccatum x C. frutescens	Comp.	Inter.	Glb.	1-2	Er.	W	P	Y	W	Inter.
C. frutescens x C. chinense (P)	Prost.	Inter.	Sp.	2-3	Er.	GW	A	GB	PV	Smooth
C. chinense (P) x C. frutescens	Prost.	Inter.	Inter.	3	Er.	GW	A	B	W	Smooth
C. frutescens x C. chinense (NP)	Prost.	Abund.	Abund.	1-2	Inter.	GW	A	B	PB	Inter.
C. chinense (NP) x C. frutescens	Prost.	Abund.	Sp.	2	Er.	LGW	P	B	W	Inter.
C. chinense (P) x C. baccatum	Prost.	Abund.	Inter.	1	Er.	LGW	P	PB	W	Inter.
C. chacoense x C. annuum	Comp.	Sp.	Sp.	1	Er.	W	A	PYG	W	Smooth

Table 10 (contd.)

Species/hybrids	Presence of annular constriction of calyx pedicel junction	Fruit shape at pedicel attachment	Fruit shape at blossom end	Fruit persistence	Fruit position	Fruit colour at immature stage	Fruit shape
Parents							
C. annuum	A	Obt.	Pnt.	Pst.	Decl.	G	El.
C. frutescens	A	Obt.	Pnt.	Pst.	Er.	G	El.
C. chinense (P)	P	Cord.	Blt.	Pst.	Decl.	DG	Blo.
C. chinense (NP)	P	Trunc.	Pnt.	Pst.	Decl.	DG	El.
C. baccatum	A	Obt.	Blt.	Pst.	Er.	LG	Obl.
C. chacoense	A	Obt.	Pnt.	Deciduous	Er.	G	El.
Hybrids							
C. annuum x C. chinense (P)	P	Obt.	Pnt.	Pst.	Decl.	DG	Con.
C. annuum x C. chinense (NP)	P	Trunc.	Pnt.	Pst.	Decl.	DG	Con.
C. frutescens x C. annuum	A	Obt.	Pnt.	Pst.	Er.	G	El.
C. frutescens x C. baccatum	A	Obt.	Pnt.	Pst.	Er.	LG	Obl.
C. baccatum x C. frutescens	A	Obt.	Pnt.	Pst.	Er.	G	Obl.
C. frutescens x C. chinense (P)	A	Obt.	Pnt.	Pst.	Er.	G	El.
C. chinense (P) x C. frutescens	A	Obt.	Pnt.	Pst.	Er.	G	El.
C. frutescens x C. chinense (NP)	A	Obt.	Pnt.	Pst.	Inter.	DG	El.
C. chinense (NP) x C. frutescens	A	Obt.	Pnt.	Pst.	Er.	DG	El.
C. chinense (P) x C. baccatum	A	Trunc.	Pnt.	Pst.	Inter.	LG	Obl.
C. chacoense x C. annuum	A	Obt.	Pnt.	Pst.	Er.	G	El.

A	- Absent	Decl.	- Declining	LGW	- Light green white	Pst.	- Persistent
Abund	- Abundant	Dent.	- Dentate	Obl.	- Oblate	PY	- Pale yellow
Blo.	- Blocky	El.	- Elongate	Obt.	- Obtuse	PYG	- Pale yellow green
Blt.	- Blunt	Er.	- Erect	P	- Present	Sp.	- Sparse
Comp.	- Compact	Glb.	- Glabrous	PB	- Pale blue	Trunc.	- Truncate
Cord.	- Cordate	GW	- Green white	Pend.	- Pendant	W	- White
DB	- Dark blue	Inter.	- Intermediate	Pnt.	- Pointed	WLG	- White light green
DG	- Dark green	LG	- Light green	Prost.	- Prostrate	YW	- Yellow white

as well as in leaf. There were 2-3 pedicels/axil in *C. frutescens* and *C. chinense* and all other species were characterized by solitary flowers. All the crosses except *C. frutescens* x *C. annuum*, *C. chinense* (P) x *C. baccatum* and *C. chacoense* x *C. annuum* had more than one pedicel/axil. Pedicel was pendant at anthesis in *C. annuum* and *C. chinense*, and erect in all other species. Among the hybrids only *C. annuum* x *C. chinense* (P) has got pendant pedicel at anthesis.

Presence of yellow corolla spot is the distinct characteristic of *C. baccatum* and is absent in all other species. All crosses, where *C. baccatum* is involved as one of the parents, has got spotted corolla. Calyx margin shape was dentate in *C. chacoense* where as it was smooth to intermediate in all other species and F_1 hybrids. Annular constriction was distinct at calyx pedicel junction in *C. chinense*, which was absent in all other species. Among hybrids *C. annuum* x *C. chinense* got the prominent constriction at calyx pedicel junction, which was absent in all other crosses.

Fruit was deciduous in *C. chacoense* and persistent in all other species and crosses. In *C. annuum* and *C. chinense*, fruit position is declined while it was erect in all other species. Among hybrids, *C. annuum* x *C. chinense* had declined fruits. Fruits of *C. chinense* and crosses where *C. chinense* was used as one of the parents, were characterized by dark green colour at immature stage.

5. Chemical analysis of Capsicum species and hybrids

The parents and hybrids were analysed for capsaicin content, oleoresin content, and total extractable colour (Table 11). Among the parental species capsaicin content was maximum in C. frutescens (2.54%) and minimum C. chinense (NP) (0.42%). Among the hybrids C. frutescens x C. chinense (P) has got the highest capsaicin content (1.28%) closely followed by C. chinense (P) x C. frutescens (1.18%) and C. chacoense x C. annuum (1.12%). Capsaicin content was the lowest in C. annuum x C. chinense (NP) (0.62%). The direct and reciprocal crosses did not exhibit much variation for capsaicin content.

Oleoresin content of Capsicum species ranged from 18.7% in C. annuum to 31.7% in C. chinense (P). C. frutescens also had a high oleoresin content (27.3%). The F_1 hybrids with high oleoresin content were C. frutescens x C. chinense (NP) (35.27%) and C. annuum x C. chinense (P) (34.40%).

Extractable colour was maximum in C. chinense (NP) (110.34 ASTA unit) and minimum in C. annuum (22.40 ASTA unit). Among the hybrids extractable colour was the highest in

Table 11 Capsaicin content, oleoresin content and total extractable colour of *Capsicum* species and interspecific hybrids

Species/hybrids	Capsaicin content (% on dry weight basis)	Oleoresin content (% on dry weight basis)	Total extractable colour (ASTA units)
C. annuum	0.70	18.70	22.40
C. frutescens	2.54	27.30	48.27
C. chinense (P)	0.62	31.70	55.17
C. chinense (NP)	0.42	19.85	110.34
C. baccatum	0.56	21.00	46.55
C. annuum x *C. chinense* (P)	0.92	34.40	58.62
C. annuum x *C. chinense* (NP)	0.62	21.70	62.06
C. frutescens x *C. chinense* (P)	1.28	24.60	48.27
C. chinense (P) x *C. frutescens*	1.18	20.50	41.37
C. frutescens x *C. chinense* (NP)	0.98	35.27	75.86
C. chinense (NP) x *C. frutescens*	0.86	27.70	41.37
C. chacoense x *C. annuum*	1.12	22.30	34.48

C. frutescens x *C. chinense* (NP) (75.86 ASTA unit) and the lowest in *C. chacoense* x *C. annuum* (34.48 ASTA unit).

C. Interspecific F_1 heterosis

Six parents belonging to five *Capsicum* species and 11 F_1 hybrids were grown during September-April 1989-91. The mean performance of parents and their F_1s (Appendix III) and the extent of heterobeltiosis and relative heterosis were calculated.

1. Plant height

Among the parental species, *C. frutescens* had the maximum plant height (68.21 cm) followed by *C. annuum* (47.50 cm) (Table 12). Out of the 11 hybrids, *C. chinense* (NP) x *C. frutescens* was the tallest (61.28 cm) which exhibited significant relative heterosis (14.03%) along with *C. chinense* (P) x *C. baccatum* (38.87%). Out of the remaining nine hybrids, seven exhibited significant negative heterosis for plant height. Only *C. chinense* (P) x *C. baccatum* exhibited significant positive heterobeltiosis (21.19%). In general, the hybrids were taller than the parents.

2. Plant spread

Six hybrids had more plant spread than their mid parental value. The percentage of increase ranged from 8.96%

Table 12 Mean performance of *Capsicum* species and F_1 hybrids and extent of relative heterosis (RH) and heterobeltiosis (HB) for plant height and spread

Species/ F_1 hybrids	Plant height			Plant spread		
	Mean performance (cm)	R.H. (%)	H.B. (%)	Mean performance (cm)	R.H. (%)	H.B. (%)
C. annuum	47.50			44.39		
C. frutescens	68.21			64.14		
C. chinense (P)	43.10			49.87		
C. Chinense (NP)	39.28			53.74		
C. baccatum	32.12			38.28		
C. chacoense	38.30			38.08		
C. annuum x *C. chinense* (P)	46.07	1.69	-3.01	47.23	-0.21	-5.29**
C. annuum x *C. chinense* (NP)	46.84	7.95	-1.38	53.46	8.96**	-0.52
C. frutescens x *C. annuum*	45.90	-20.66**	-32.70**	40.46	-25.42**	-86.90**
C. frutescens x *C. chinense* (P)	46.61	-16.25**	-31.66**	53.02	-6.99**	-17.33**
C. chinense (P) x *C. frutescens*	51.82	-6.88**	-24.02**	67.95	19.20**	5.94**
C. frutescens x *C. chinense* (NP)	43.76	-18.56**	-35.83**	51.74	-12.20**	-19.32**
C. chinense (NP) x *C. frutescens*	61.28	14.03**	-10.15**	58.84	-0.16	-8.20**
C. frutescens x *C. baccatum*	37.47	-25.30**	-45.06**	71.91	40.41**	12.11**
C. baccatum x *C. frutescens*	46.44	-7.41**	-31.91**	66.12	29.10**	3.09**
C. chinense (P) x *C. baccatum*	52.23	38.87**	21.19**	73.76	67.37**	47.90**
C. chacoense x *C. annuum*	37.91	-12.12**	-20.17**	59.53	44.36**	34.11**
Mean of parents	44.83			48.08		
Mean of hybrids	46.94			58.54		

* P = 0.05

**P = 0.01

in C. annuum x C. chinense (NP) to 67.37% in C. chinense (P) x C. baccatum. The hybrids C. frutescens x C. baccatum, C. chinense (P) x C. frutescens, C. baccatum x C. frutescens and C. chacoense x C. annuum exceeded their better parents for plant spread, which was significant at 1% level. The hybrid C. chinense (P) x C. baccatum had maximum plant spread. In general hybrids had more plant spread than their parents (Table 12).

3. Days to flower

Among the Capsicum species C. annuum was the earliest to flower (66.90 days) (Table 13). The hybrids were earlier to the parents by 9.95 days. Relative heterosis ranged from ¯2.09 in C. frutescens x C. annuum to ¯23.90 in C. chinense (P) x C. frutescens. All the hybrids except C. chacoense x C. annuum were earlier to mid parents. All the hybrids except C. frutescens x C. annuum and C. chacoense x C. annuum flowered earlier than the earlier parents. Among the hybrids C. annuum x C. chinense (NP) was the earliest and flowered 58.60 days after sowing.

4. Days to first harvest

C. annuum became ripe for harvest 117 days after sowing and was the earliest (Table 13). The hybrids exhibited significant negative relative heterosis ranging from ¯0.35% in

Table 13 Mean performance of *Capsicum* species and F_1 hybrids and extent of relative heterosis (RH) and heterobeltiosis (HB) for days to flower and first harvest

Species/ F_1 hybrids	Days to first flower			Days to first harvest		
	Mean performance	R.H. (%)	H.B. (%)	Mean performance	R.H. (%)	H.B. (%)
C. annuum	66.90			117.00		
C. frutescens	97.20			135.20		
C. chinense (P)	88.80			128.60		
C. chinense (NP)	88.70			132.60		
C. baccatum	87.44			127.55		
C. chacoense	84.00			129.50		
C. annuum x *C. chinense* (P)	63.40	-18.56**	-5.23**	107.10	-12.78**	-8.46**
C. annuum x *C. chinense* (NP)	58.60	-20.48**	-12.40**	103.60	-16.98**	-11.45**
C. frutescens x *C. annuum*	80.33	-2.09**	+20.00**	125.33	-0.61*	7.12**
C. frutescens x *C. chinense* (P)	80.00	-13.11**	-9.01**	139.60	5.83**	8.55**
C. chinense (P) x *C. frutescens*	70.77	-23.90**	-20.30**	134.33	1.84**	4.45**
C. frutescens x *C. chinense* (NP)	84.55	-9.03**	-4.67**	135.50	1.19**	2.18**
C. chinense (NP) x *C. frutescens*	72.00	-22.53**	-18.82**	133.42	-0.35	0.61
C. frutescens x *C. baccatum*	83.70	-9.33**	-4.27**	126.80	-3.48**	-0.58
C. baccatum x *C. frutescens*	81.66	-11.54**	-6.61**	139.77	6.39**	9.58**
C. chinense (P) x *C. baccatum*	73.66	-16.40**	-15.79**	138.33	-8.00**	8.45**
C. chacoense x *C. annuum*	81.66	-8.23**	22.06**	138.16	12.09**	18.08**
Mean of parents	85.50			128.40		
Mean of hybrids	75.55			129.26		

* P = 0.05

**P = 0.01

C. chinense (NP) x *C. frutescens* to -16.98% in *C. annuum* x *C. chinense* (NP). *C. annuum* x *C. chinense* (P), *C. annuum* x *C. chinense* (NP), *C. frutescens* x *C. baccatum* and *C. chinense* (NP) x *C. frutescens* were earlier than better parents (H.B. -8.46%, -11.45%, -0.58% and -0.60% respectively).

5. Fruit length

The longest fruit was born in *C. annuum* (6.52 cm). Among the hybrids *per se* performance was promising only in *C. annuum* x *C. chinense* (NP) (5.69 cm) and *C. annuum* x *C. chinense* (P) (5.32 cm) (Table 14). Out of 11 hybrids only one, *C. annuum* x *C. chinense* (P), exceeded their mid parental value (R.H. 35.09%). None of the hybrids had longer fruits than their respective better parents.

6. Fruit width

Fruit width was maximum in *C. chinense* (P) (1.97 cm) among parents and in *C. annuum* x *C. chinense* (NP) among hybrids (2.04 cm) (Table 14). Only *C. annuum* x *C. chinense* (NP) exhibited significant positive relative heterosis and heterobeltiosis (32.89% and 32.09% respectively). All other combinations had negative heterosis.

7. Pericarp thickness

Among species *C. chinense* had fleshy fruit wall (0.16 cm) (Table 15). In the hybrids pericarp thickness was

Table 14 Mean performance of *Capsicum* species and F_1 hybrids and extent of relative heterosis (RH) and heterobeltiosis (HB), for fruit length and width

Species/ F_1 hybrids	Fruit length			Fruit width		
	Mean performance (cm)	R.H. (%)	H.B. (%)	Mean performance (cm)	R.H. (%)	H.B. (%)
C. annuum	6.52			1.52		
C. frutescens	2.30			0.40		
C. chinense (P)	3.13			1.97		
C. chinense (NP)	5.62			1.54		
C. baccatum	1.48			0.70		
C. chacoense	1.81			0.66		
C. annuum x *C. chinense* (P)	5.32	35.09**	-18.40**	1.17	-32.85**	-40.50**
C. annuum x *C. chinense* (NP)	5.69	-6.22**	-12.73**	2.04	32.89**	32.03**
C. frutescens x *C. annuum*	2.50	-43.31**	-61.65**	0.61	-36.03**	-59.60**
C. frutescens x *C. chinense* (P)	1.97	-27.30**	-37.06**	0.66	-44.02**	-66.32**
C. chinense (P) x *C. frutescens*	1.83	-32.37**	-41.43**	0.85	-28.28**	-56.86**
C. frutescens x *C. chinense* (NP)	2.20	-44.44**	-60.85**	0.79	-18.49**	-48.67**
C. chinense (NP) x *C. frutescens*	1.91	-51.71**	-65.97**	0.78	-19.11**	-49.06**
C. frutescens x *C. baccatum*	0.47	-75.13**	-79.56**	0.36	-34.73**	-48.73**
C. baccatum x *C. frutescens*	0.59	-68.51**	-74.17**	0.39	-28.39**	-43.74**
C. chinense (P) x *C. baccatum*	1.05	-54.52**	-66.50**	0.71	-46.48**	-63.74**
C. chacoense x *C. annuum*	2.52	-39.51**	-61.36**	0.50	-53.98**	-67.14**
Mean of parents	3.47			1.13		
Mean of hybrids	2.36			0.80		

* P = 0.05

**P = 0.01

Table 15 Mean performance of Capsicum species and F_1 hybrids and extent of relative heterosis (RH) and heterobeltiosis (HB) for pericarp thickness and average fruit weight

Species/ F_1 hybrids	Pericarp thickness			Average fruit weight (fresh weight)		
	Mean performance (cm)	R.H. (%)	H.B. (%)	Mean performance (g)	R.H. (%)	R.H. (%)
C. annuum	0.103			1.06		
C. frutescens	0.062			0.15		
C. chinense (P)	0.145			2.75		
C. chinense (NP)	0.164			3.24		
C. baccatum	0.061			0.19		
C. chacoense	0.052			0.23		
C. annuum x C. chinense (P)	0.111	-10.48	-23.44**	1.66	-12.96**	-39.60**
C. annuum x C. chinense (NP)	0.118	-11.61**	-28.04**	1.74	-18.79**	-46.03**
C. frutescens x C. annuum	0.073	-11.15**	-28.83**	0.27	-54.75**	-74.13**
C. frutescens x C. chinense (P)	0.104	0.48	-28.27**	0.32	-77.33	-88.03**
C. chinense (P) x C. frutescens	0.096	-7.28**	-33.79**	0.60	-58.66	-78.18**
C. frutescens x C. chinense (NP)	0.104	-7.96**	-36.58**	0.48	-71.39	-85.02**
C. chinense (NP) x C. frutescens	0.094	-16.63**	-42.56**	0.63	-62.67	-80.45**
C. frutescens x C. baccatum	0.047	-23.57**	-24.19**	0.02	-86.77**	-88.05**
C. baccatum x C. frutescens	0.047	-22.43**	-23.06**	0.07	-59.80	-63.68**
C. chinense (P) x C. baccatum	0.073	-29.12**	-49.44**	0.34	-76.42	-87.40**
C. chacoense x C. annuum	0.069	-10.38**	-25.24**	0.22	-65.73	-79.28**
Mean of parents	0.097			1.26		
Mean of hybrids	0.085			0.57		

* P = 0.05

**P = 0.01

lower than the parents. All the hybrids exhibited significant negative heterobeltiosis.

8. Average fruit weight (fresh weight)

All the hybrids had negative values of relative heterosis, which ranged from, −86.77% in *C. frutescens* x *C. baccatum* to −12.96% in *C. annuum* x *C. chinense* (P) (Table 15). *C. annuum* x *C. chinense* (NP) had the maximum fruit weight (1.74 g) which was 46.03% lower than its better parent *C. chinense* (3.24 g). All the hybrids had only negative values of heterobeltiosis.

9. Fruits/plant

Parental species had more fruits than the hybrids (Table 16). Maximum number of fruits were produced by *C. frutescens* (317.60) among parents and *C. frutescens* x *C. chinense* (NP) (135.30) among the hybrids. But it was 57.39% lower than its better parent. Only two hybrids exhibited positive relative heterosis, viz., *C. annuum* x *C. chinense* (P) and *C. annuum* x *C. chinense* (NP) (13.23% and 4.44% respectively). All the crosses had negative heterobeltiosis.

10. Yield (fresh weight)

The mean yield of hybrids was only 54.28 g compared to 108.99 g in the parents (Table 16). Maximum yield was

Table 16 Mean performance of <u>Capsicum</u> species and F_1 hybrids and extent of relative heterosis (RH) and heterobeltiosis (HB) for yield/plant and fruits/plant

Species/ F_1 hybrids	Yield/plant (fresh weight)			Fruits/plant		
	Mean performance (g)	R.H. (%)	H.B. (%)	Mean performance	R.H. (%)	H.B. (%)
C. annuum	152.590			142.60		
C. frutescens	48.795			317.60		
C. chinense (P)	185.312			67.40		
C. chinense (NP)	187.084			57.70		
C. baccatum	40.561			213.00		
C. chacoense	39.562			177.00		
C. annuum x C. chinense (P)	197.64	16.96**	6.62*	118.90	13.23**	-16.61**
C. annuum x C. chinense (NP)	182.980	-7.74**	-2.19**	104.60	4.44	-26.64
C. frutescens x C. annuum	7.383	-92.66**	-95.16**	26.66	-88.43**	-91.62**
C. frutescens x C. chinense (P)	40.295	-65.58**	-78.26**	119.30	-38.02**	-62.43**
C. chinense (P) x C. frutescens	42.844	-63.40**	-76.88**	71.33	-62.94**	-77.54**
C. frutescens x C. chinense (NP)	65.718	-44.27**	-64.87**	135.30	-27.89**	-57.39
C. chinense (NP) x C. frutescens	47.000	-60.14**	-74.87**	74.14	-60.48**	-76.65**
C. frutescens x C. baccatum	0.097	-99.78**	-99.80**	4.10	-98.45**	-98.70**
C. baccatum x C. frutescens	0.433	-99.03**	-99.07**	5.55	-97.90**	-98.25**
C. chinense (P) x C. baccatum	0.890	-99.21**	-99.51**	2.66	-98.10**	-98.73**
C. chacoense x C. annuum	11.828	-87.68**	-92.24**	54.33	-65.99**	-69.30**
Mean of parents	108.992			162.55		
Mean of hybrids	54.283			65.17		

* P = 0.05

**P = 0.01

obtained from C. annuum x C. chinense (P) (197.64 g) which showed significant positive relative heterosis and heterobetiosis (16.96% and 6.62% respectively). Relative heterosis ranged from -99.78% in C. frutescens x C. baccatum to 16.96% in C. annuum x C. chinense (P). The hybrid C. annuum x C. chinense (NP) also performed better than its mid parent, but it was 2.19% lower than its better parent. All other hybrids had only negative values of heterobeltiosis.

11. Seed diameter

Out of 11 interspecific hybrids, seeds were formed only in eight combinations. In general hybrids had more seed diameter than the parents (3.84 mm and 3.48 mm respectively) (Table 17). All the hybrids except C. annuum x C. chinense (NP) had significant positive relative heterosis. C. annuum x C. chinense (P) exhibited significant heterobeltiosis (3.67%).

12. 1000 seed weight

Seed weight was maximum in C. chacoense (5.01 g) though it produced seeds of varying sizes (Table 17). Relative heterosis was negative in all hybrids except in C. chinense (P) x C. frutescens and C. chinense (NP) x C. frutescens (6.34% and 24.04% respectively). 1000 seed

Table 17 Mean performance of Capsicum species and F_1 hybrids and extent of relative heterosis (RH) and heterobeltiosis (HB) for seed diameter and 1000 seed weight

Species/ F_1 hybrids	Seed diameter			1000 seed weight		
	Mean performance (mm)	R.H. (%)	H.B. (%)	Mean performance (g)	R.H. (%)	H.B. (%)
C. annuum	4.02			4.90		
C. frutescens	2.96			2.20		
C. chinense (P)	4.08			4.00		
C. chinense (NP)	3.94			4.27		
C. baccatum	2.84			2.65		
C. chacoense	3.07			5.01		
C. annuum x C. chinense (P)	4.23	22.50**	3.67**	3.51	-21.19**	-28.36**
C. annuum x C. chinense (NP)	3.99	0.17	-0.74	4.10	-10.51**	-16.26**
C. frutescens x C. annuum	3.72	6.67**	-2.97**	2.10	-40.77**	-57.08**
C. frutescens x C. chinense (P)	3.91	11.03**	-4.23**	3.09	-0.41**	-22.85**
C. chinense (P) x C. frutescens	4.06	15.17**	2.88	3.30	6.34**	-17.61**
C. frutescens x C. chinense (NP)	3.34	3.18**	-15.35**	4.13	-27.71**	-3.20**
C. chinense (NP) x C. frutescens	3.33	11.01**	-2.93**	4.01	24.04	-5.99**
C. chacoense x C. annuum	3.70	4.29**	-7.96**	3.27	-34.01**	-34.75**
Mean of parents	3.48			3.84		
Mean of hybrids	3.84			3.44		

* P = 0.05

**P = 0.01

weight was minimum in *C. frutescens* x *C. annuum* (2.10 g) and maximum in *C. frutescens* x *C. chinense* (NP) (4.13 g). All hybrids exhibited negative heterobeltiosis.

Discussion

DISCUSSION

Chilli (Capsicum sp.) is a quintessential spice in every Indian cusine and is being cultivated in the tropical and sub-tropical regions of the world. Green chilli, Chili powder, Cayenne peppers, tabasco, paprika, sweet or bell peppers and pimentos are all derived from the fruit (berry) of various species of Capsicum. Chilli fruit is a rich source of vit. A (870 I.U/100 g) and C (175 mg/100 g) and valued for its characteristic pungency, colour and aroma. Annual trade of chilli in world is 55 to 60 thousand tonnes, which is 16.7% of total spice trade in the world. India ranks first in area and production of chilli in the world, contributing about one fourth of world's production with an average annual production of 0.59 million tonnes.

In India, present day chilli cultivars are belonging to C. annuum and are handicapped by susceptibility to a number of pests and diseases. Since the crop is mainly grown under rainfed condition its susceptibility to drought very often result in heavy loss in yield. Medium pungency and low yield are the other major bottlenecks of C. annuum cultivars to be tackled on a high priority basis.

Until recently plant breeders were concentrating on chilli improvement by hybridization and/or selection solely with C. annuum. Since 1970s, other species of Capsicum have become increasingly available and they can be utilized to incorporate desirable genes particularly stress resistance to the C. annuum cultivars. Phytophthora resistance was reported in C. baccatum and C. frutescens (IBPGR, 1983). Resistance to verticillium wilt in C. chinense and C. frutescens, bacterial leaf spot in C. chacoense and cucumber mosaic virus and potato virus Y in C. baccatum (IBPGR, 1983) may be exploited for solving the disease problem of present day cultivars. C. chinense and C. frutescens were remarkable for their perennial nature, highly pungent and bright coloured fruits. Drought tolerance was observed in C. cardenasi (Pickersgill, 1980) and in C. chacoense. The incorporation of genes for perennial habit, drought tolerance and highly pungent nature to the cultivated C. annuum cultivars will be a breakthrough in chilli production in the country. The present investigation was mainly aimed to find out cross compatibility among five Capsicum species viz., C. annuum, C. frutescens, C. chinense, C. baccatum and C. chacoense and to assess the scope of exploitation of hybrid vigour in interspecific hybrids.

First part of the study was cataloguing of the chilli germplasm and taxonomic treatment of the cultivated types. A great difficulty was faced in the classification of cultivated chilli varieties because of their great number, the transitory nature of many of them and constant creation of new ones through hybridization and selection. Due to complexities prevailed in the Capsicum taxonomy the hot pungent perennial chillies and all the wild types traditionally grown in India were considered as C. frutescens by earlier workers (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 done based on specific key characters, modern taxonomists used a combination of characters, and assigned cultivated Capsicum spp. into five species viz., C. annuum, C. frutescens, C. chinense, C. baccatum and C. pubescens (Eshbaugh, 1980).

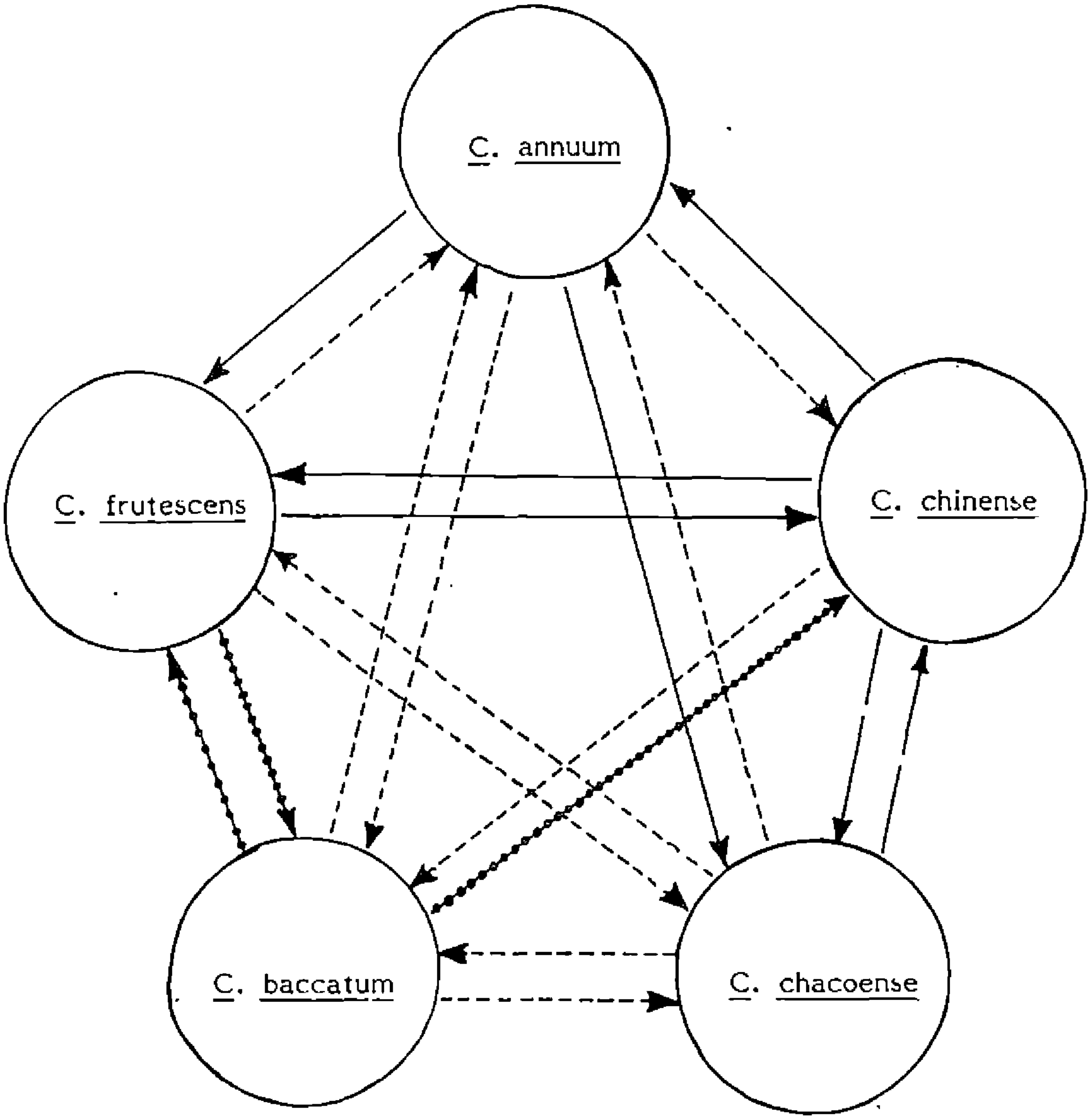
The germplasm collection of chilli maintained in the ICAR adhoc scheme on "Breeding for resistance to bacterial wilt in chilli and brinjal" in the College of Horticulture at Vellanikkara, exhibited considerable variability. The 84 chilli accessions grown during September-December 1988 were subjected to modern toxonomic treatment as suggested by IBPGR (1983) and later assigned to four Capsicum species, C. annuum, C. frutescens, C. chinense and C. baccatum. According to the earlier keys suggested by Irish (1898) and Shaw and Khan (1928), majority of the C. annuum, C. chinense and C. frutescens accessions would have fallen into a single species. Electrophoretic studies also indicated distinct species status of C. chinense (P), C. baccatum and C. chacoense by presence of typical protein bands. Out of

84 chilli accessions evaluated, 62 belonged to C. annuum. C. frutescens was characterized by greenish white corolla lobes and C. chinense by the presence of annular constriction at junction of pedicel and calyx. In C. chinense, one accession (CA 317) was nonpungent in nature, and it was selected for further hybridization programme, designating it as C. chinense (NP). In the germplasm only one accession (CA 302) was found typical of C. baccatum which was characterized by distinct yellow spot at the base of corolla lobes.

Studies by Smith and Heisser (1957) and Pickersgill (1971) revealed that none of the Capsicum sp has completely isolated from all other species, which pointed to the possibility of incorporating genes for resistance against biotic and abiotic stresses and desirable horticultural characteristics to the present day cultivars. The five Capsicum species C. annuum, C. frutescens, C. chinense, C. baccatum and C. chacoense were grown in pot culture during February-August 1989 and were crossed in all possible combinations. In all the interspecific crosses fruit set was obtained indicating the closeness of the species to a certain extent.

C. annuum as female parent produced viable F_2 seeds only with C. chinense which had the highest crossability index of 79.68% (Fig.2). Though there was fruit set in all other combinations, F_1 seed was not viable. As the male parent, *C. annuum* produced viable F_2 seeds in crosses with *C. chacoense* and *C. frutescens* which had the crossability index value of 19.90% and 6.67% respectively. In remaining combinations, the crossability index was zero resulting from inviable F_1 seed.

In crosses involving *C. annuum* and *C. frutescens* viable F_1 and F_2 seeds were obtained only when *C. frutescens* was used as female parent. Though fruit set was obtained using *C. annuum* as female parent, none of the seeds were viable. Pillai *et al*. (1977) and Sundaresan and Chandrasekaran (1979) reported one way incompatibility between the two species. This is in agreement with the present findings. In hybridization programme involving *C. annuum* and *C. frutescens*, Peter and McCollum (1983) observed perfect pollen stigma compatibility and pollen tube growth in direct and reciprocal crosses. Hybrid inviability in *C. annuum* x *C. frutescens* might be due to post fertilization barrier in the form of defective endosperm or embryo or due to abnormal development of endosperm as observed by Sundaresan and Chandrasekaran (1979). The distribution of sterility factors to the gametes and disharmonious gene combination in the zygote render the hybrid seed inviable. The F_1 hybrid (*C. frutescens* x *C. annuum*) had only fewer number of



F1 and F2 seeds viable

F1 seeds inviable

F1 hybrids, highly sterile

F1 seedlings collapsed

Points in direction of female parent

FIG.2 CROSSABILITY POLYGON FOR FIVE CAPSICUM SPECIES seeds (3.4) when compared to its maternal parent (8.99). This may be due to generational sterility as a result of failure of any process concerned with the normal development of pollen, embryosac, embryo and endosperm. PMCs of the hybrid (C. frutescens x C. annuum) exhibited multivalents, bringing low level of pollen fertility (45.45%) to the hybrid.

In crosses involving C. annuum and C. chinense, fertile F_1s were obtained only when C. chinense was used as male parent. However CI value was low (0.98%) when C. chinense (NP) was used as male parent, when compared to C. chinense (P) (79.68%). Poor fruit set (6.25%) resulting from low pollen fertility (58.82%) is the main cause for low CI when C. chinense (NP) was used as male parent. In both cases, though fruit set was obtained in the reciprocal cross, none of the seeds germinated. Based on hybridization programmes involving C. annuum and C. chinense Smith and Heisser (1957) concluded that more easier crosses could be made using C. annuum as female parent. In the present study, F_1 plants were characterized by 2 pedicels/axil as observed by Subramanya (1982). High degree of chromosome pairing as indicated by bivalent associations was observed in the hybrid C. annuum x C. chinense (P). But high proportion of multivalents were seen in C. annuum x C. chinense (NP) which render low pollen fertility to the hybrid. Such meiotic irregularities were also observed by Egawa and Tanaka (1986) and Kumar *et al*. (1987c). Multivalent association shows that these two species of *Capsicum* were differentiated by small structural differences in their chromosome complements.

In crosses involving *C. annuum* and *C. baccatum*, though seed set was obtained with high seed set efficiency (70.75%), none of the seeds were viable. Smith and Heisser (1957) and Pillai *et al*. (1977) also made similar observations. Pickersgill (1977) got F_1 seed, but seedlings did not survive. Electrophoretic studies by Mc Leod *et al*. (1978) proved that *C. baccatum* is distinct from *C. annuum*. This wide genetic distance between the parents might be the reason for hybrid inviability.

Seeds were shrivelled, brown coloured and non-viable in *C. annuum* x *C. chacoense*, while the reciprocal cross was successful with a crossability index of 19.99% and produced 20% viable F_2 seeds. Kumar *et al*. (1988) also reported partly fertile hybrids from *C. chacoense* x *C. annuum*. They observed irregular chromosome disjunction, multivalents, bridges, fragments and laggards in meiosis of interspecific hybrid *C. chacoense* x *C. annuum*. Similar observations were also made in the present investigation. High pollen sterility of *C. chacoense* (62.76%) and certain range of female sterility in *C. annuum* reported by Molhova (1966) might be the reason for poor seed set and hybrid inviability of *C. annuum* x *C. chacoense*.

In direct and reciprocal combinations, C. frutescens produced fertile F_1 plants only with C. chinense. Crossability index was the highest in C. frutescens x C. chinense (30.96%), while lower in reciprocal cross (1.97%). This revealed the high cross compatibility between C. frutescens and C. chinense. This was akin to the observations made by Pickersgill (1967) and Eshbaugh (1975). In both crosses, meiotic analysis of F_1s showed high percentage of multivalents in PMCs which suggested that C. frutescens and C. chinense share a basically homologous but structurally differentiated genome. Genotypic difference in the crossability was observed when two forms of C. chinense were used, as evidenced from CI values (30.98% in C. chinense (P) x C. frutescens and 13.48% in C. chinense (NP) x C. frutescens). Such genotypic difference was also observed by Krihnakumari (1984) in interspecific crosses. Among the two forms of C. chinense, meiosis in C. chinense (NP) was abnormal, resulting in high chromosomal sterility. Obviously, crossability index becomes low, when C. chinense (NP) was used as one of the parents which produced viable F_2 seeds.

F_1 plants were obtained in direct and reciprocal crosses involving C. frutescens and C. baccatum. Both the hybrids were highly vigorous and produced a large number of flowers with spotted corolla. But the flowers failed to set fruit even under open pollinated condition. In a few cases, there was rare occurrence of undersized and malformed fruits, devoid of any seeds. PMCs of both direct and reciprocal crosses showed bridges, laggards, and univalents which brought high pollen sterility as observed by Egawa and Tanaka (1986).

When C. frutescens was crossed with C. chacoense, fruit set was obtained in both ways. But none of the seeds were viable. Kumar et al. (1988) also obtained fruit set in C. chacoense x C. frutescens. But F_1 plants were sterile characterized by high meiotic abnormalities.

Protein electrophoretic studies showed that C. chinense (P) and C. baccatum were distant and share only two common bands. Pickersgill (1967) reported partially fertile F_1 plants from C. pendulum x C. chinense, but the reciprocal crosses were all morphologically abnormal and completely sterile. In the present study though fruit set was obtained in both direct and reciprocal crosses between C. chinense (P) and C. baccatum, seeds were viable only in direct crosses. The F_1 plants were characterized by profuse vegetative growth and high pollen sterility (94.12%). According to Stebbins (1958), hybrid sterility in distant crosses may express in the form of deformed flowers and/or totally sterile pollen and ovules. A number of meiotic abnormalities were observed in the hybrids and significant correlation was found between percentage of meiotic abnormalities and percentage of pollen sterility as observed by Egawa and Tanaka (1986). Viable seeds were not obtained in C. chinense (NP) x C. baccatum and C. baccatum x C. chinense (NP). This may be due to hybrid inviability resulting from defective embryo or endosperm. Saccardo (1978) also could not get fruit set in direct and reciprocal crosses between C. chinense and C. baccatum. Genotypic effect in the production of viable seeds is evident in hybridization between C. baccatum and C. chinense.

When C. chinense (P) was crossed with C. chacoense, viable seeds were obtained only in direct crosses. Later post fertilization barriers were observed, resulting in the collapse of F_1 seedlings at sixth leaf stage. Seedlings expressed symptoms like malformed yellow leaves and slender stems. Since no pathogens were found associated with these symptoms, these developmental defects have obviously a genetic basis. Perhaps this situation reflects a highly disharmonious interaction of parental genomes as combined in the hybrid cell (genic disharmony). Quiet contradictory to the present observation, Kumar et al. (1988) could get F_1 plants from the cross C. chacoense x C. chinense. But the F_1 plants were characterized by considerable meiotic abnormalities resulting in sterility of plant.

In crosses involving C. baccatum and C. chacoense though the fruit set was obtained in direct and reciprocal crosses (1.92% and 2% respectively) none of the seeds germinated. These two species were proved electrophoretically distant and hybrid inviability may be due to defective endosperm, embryo or due to abnormal development of endosperm.

In the interspecific hybridization programme, all the F_1 hybrids had a low number of seeds when compared to their maternal parents. Cytogenetical analyses of all hybrids revealed presence of multivalents in the PMCs, which suggested that segmental interchange might take place during speciation of these Capsicum species, viz., C. annuum, C. frutescens, C. chinense, C. baccatum and C. chacoense. Anaphase bridges in the PMCs of hybrid C. frutescens x C. chinense (NP) and C. frutescens x C. baccatum revealed the occurrence of inversion during the evolutionary process. Meiotic disturbances like the formation of multivalents at diakinesis and bridges and fragments in anaphase-I reflected readily on the pollen sterility and percentage of fruit set. The observation of meiotic abnormalities in the hybrids during present investigation is in agreement with the hypothesis of Shopova (1966) ascribing the irregularities of Capsicum as due to genotypic imbalances. According to Stebbins (1958) in the distant crosses, the time of degeneration generally coincides with some critical or maximal period of tissue differentiation, anywhere from the first division of zygote to a situation where hybrids are produced without constitutional weakness of the plant body but are associated with hybrid sterility that expresses itself in the form of deformed flowers and/or totally sterile pollen and ovules".

The parents and F_1 hybrids were observed for the various discrete characters, which gave some indication of the inheritance. Prostrate growth habit was found dominant over erect and compact growth habit. Incomplete dominance was observed for number of pedicels/axil, with intermediary values in F_1 as observed by Subramanya (1982). Presence of yellow corolla spot character of C. baccatum was dominant over plain corolla. Vaul and Pitrat (1978) also observed F_1 plants with spotted corolla in cross between C. annuum and C. baccatum. Erect fruit orientation manifested dominance over pendent position in crosses between C. frutescens and C. chinense. Effect of maternal parent was pronounced in the anther colour of all hybrids. Sundaresan and Chandrasekaran (1979) also made similar observations in interspecific crosses.

The F_1 hybrids along with the parental species were observed for the economic quantitative characters. Since the parents belonged to different species, majority of the interspecific hybrids exhibited negative heterosis. Similar observations were made by Pillai et al. (1977) in interspecific crosses. However significant positive heterosis was observed for plant height, plant spread, earliness and seed diameter in certain combinations. Earliness in terms of days to flower and days to harvest was observed in most of the hybrids and nine hybrids were earlier than the parents. Pillai et al. (1977) and Krishnakumari (1984) also reported significant heterosis for earliness. Heterobeltiosis being a function of overdominant gene action would lead to generation of considerable variability resulting in transgressive segregants for economic characters such as earliness to bloom and harvest. C. annuum x C. chinense (NP) flowered 58 days after sowing and fruits became red ripe by 103 days and was the earliest . Heterobeltiosis was maximum in cross between C. chinense and C. frutescens for earliness. C. annum x C. chinense (P) and C. annuum x C. chinense (NP) exhibited significant negative heterosis for days to first harvest. Positive heterosis was noted for seed size and hybrids had more seed diameter than the parents (3.84 mm and 3.48 mm respectively). Larger seed size might be due to larger embryo resulting from heterotic effect. Out of 11 hybrids, C. chinense (P) x C. baccatum exhibited significant positive heterobeltiosis for plant height and plant spread. But the plants were completely sterile which may be the obvious reason for profuse vegetative growth. The above hybrid had more stomatal density (202.75/mm^2) which is an indication of high physiological activity. All hybrids exhibited negative heterosis for fruit length, fruit width, pericarp thickness and fruit weight. Among the hybrids C. annuum x C. chinense (P) exhibited positive heterobeltiosis (6.62%) and relative heterosis (13.23%) for fruits/plant. Heterosis for yield was earlier reported by Krishnakumari (1984) in inter-specific crosses. The increased fruit set and yield may be attributed to heterosis while its decrease to the pollen sterility as well as megaspore sterility resulting from meiotic abnormalities. The most economic combinations among the 11 hybrids studied were C. annuum x C. chinense (P) and C. annuum x C chinense (NP).

The fruits of parental species and hybrids were compared for capsaicin oleoresin and colour. Capsaicin is the major capsaicinoid present in chilli which imparts pungency to fruits. In general, hybrids had more capsaicin, oleoresin and colour than their parents. Among the parental species, maximum capsaicin was in C. frutescens (2.54%). Recently Narayanan (1988) also reported the highest capsaicin content in C. frutescens. As observed by him, here also the fruit size is negatively associated with pungency. The total flavour extracts of ground spice are known as oleoresins. Among the species, C. chinense (P) contained highest oleoresin (31.70%) followed by C. frutescens (27.3%). Naturally, hybrids between C. frutescens and C. chinense exhibited high capsaicin and oleoresin content. Colour of chilli is due to carotenoids and major carotenoid present is capsanthin. Among species the highest extractable colour was in C. chinense (NP) (110.34 ASTA unit) which is low in capsaicin content (0.4%).

Since the low pungent paprikas have more demand in the world trade the nonpungent *C. chinense* can be utilized for paprika production.

Considering *per se* performance, hybrid *C. annuum* x *C. chinense* (P) was the most promising one with high values of capsaicin, oleoresin and colour (0.92%, 39.40% and 58.62 ASTA unit). Hence this hybrid can be used as source of pungency and colour for improving the present day cultivars.

The present studies established close relationship between *C. chinense* and *C. frutescens*. Cytological studies revealed that hybrid sterility in the interspecific hybrids is due to meiotic abnormalities. Out of 28 crosses made, F_1s were inviable in 15 combinations. Reason for this hybrid inviability need to be studied through detailed cytogenetical investigations. The possibility of breaking this incompatibility can be explored by resorting to embryo culture, intensifying the crossing programme and by using appropriate F_1 progenies for bridge crossing. In crosses where viable F_2 seeds were produced F_2s can be subjected to rigorous selection for identifying transgressive segregants. These F_2s can be progressed to advanced generations to identify elite plant types having high yield, perennial habit, high pungency, colour and other desirable characters. *C. annuum* x *C. chinense* would be particularly suitable for this task.

The present investigation also revealed the possibility of imparting desirable genes from the wild species, *C. chacoense* to the present day *C. annuum* cutivars.

Summary

SUMMARY

The present studies "Interspecific hybridization in *Capsicum*" were conducted at the College of Horticulture, Vellanikkara, Thrissur, during 1988-'90 in three seasons. The germplasm collection maintained in the Department of Olericulture was subjected to modern taxonomic treatment during September-December, 1988. Five *Capsicum* species, *C. annuum*, *C. frutescens*, *C. chinense*, *C. baccatum* and *C. chacoense* were crossed in all combinations to study cross compatibility among the species, to transfer desirable genes from allied species to *C. annuum* and to estimate the extent of heterosis.

Eighty four accessions when subjected to taxonomic treatment fall under four species viz., *C. annuum* (62), *C. frutescens* (7), *C. chinense* (14) and *C. baccatum* (1).

Fruit set was obtained in all the 28 interspecific crosses and viable F_1 and F_2 seeds were obtained in eight crosses, *C. annuum* x *C. chinense* (P), *C. annuum* x *C. chinense* (NP), *C. frutescens* x *C. annuum*, *C. chacoense* x *C. annuum*, *C. frutescens* x *C. chinense* (P), *C. chinense* (P) x *C. frutescens*, *C. frutescens* x *C. chinense* (NP) and *C. chinense* (NP) x *C. frutescens*.

F_1 hybrids, *C. frutescens* x *C. baccatum*, *C. baccatum* x *C. frutescens* and *C. chinense* (P) x *C. baccatum* were sterile and seedlings collapsed in the cross *C. chinense* x *C. chacoense*. F_1 seeds were inviable in the remaining 15 crosses.

Among the five *Capsicum* species, close relationship was established between *C. chinense* and *C. frutescens*. Protein electrophoretic studies revealed species specific protein bands in *C. chinense*, *C. baccatum* and *C. chacoense*.

Presence of multivalents in PMCs of all interspecific hybrids showed that these species shared a basically homologous but structurally differentiated genomes. Hybrid sterility was proved to be associated with meiotic abnormalities like laggards, bridges, fragments and micronuclei.

In general, hybrids exhibited negative heterosis except for earliness and seed size. In specific combinations, significant positive heterosis was observed for yield, plant height and plant spread.

Hybrids between *C. chinense* and *C. frutescens* had high values of capsaicin and oleoresin compared to other crosses. *C. chinense* (NP) was notable for its high extractable colour (110.34 ASTA unit) and low capsaicin content (0.42%).

Considering *per se* performance, *C. annuum* x *C. chinense* (P) was the most promising hybrid for fresh fruit yield (197.64 g/plant) with high values of capsaicin (0.92%), oleoresin (34.40%) and colour (58.62 ASTA unit).

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* Originals not seen

Appendix

Appendix I

Meterological data during the cropping period (month-wise)

Months	Temperature (°C)		Mean relative humidity (%)	Total rain-fall (mm)	No. of rainy days	Mean sunshine hours
	Maximum	Minimum				
1988						
September	29.9	23.2	85	700.00	24	5.1
October	31.7	23.3	78	116.60	9	7.1
November	32.6	22.9	68	11.00	1	7.9
December	32.6	22.3	57	14.90	2	9.0
1989						
February	36.3	21.2	45	0	0	9.8
March	36.5	23.3	58	31.30	2	9.5
April	35.3	25.1	69	52.60	4	8.3
May	33.7	24.5	74	115.80	7	7.0
June	29.9	22.7	86	784.60	27	3.2
July	29.1	23.3	86	562.00	17	4.2
August	29.5	23.1	83	319.90	19	5.4
September	29.9	23.1	82	180.10	15	5.5
October	31.0	23.0	80	351.30	16	6.2
November	32.5	22.7	63	8.10	2	8.5
December	32.7	23.2	60	0	0	4.7
1990						
January	33.5	20.8	50	3.50	0	9.0
February	34.9	21.9	58	0	0	10.0
March	36.0	23.8	64	4.40	1	9.7
April	35.8	25.4	68	38.80	2	8.3

Appendix II

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 glass distilled water

d) Staining solution

1.25 g Coomassie brilliant blue R was dissolved in 250 ml destaining solution. The 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 glass distilled water

f) Other chemical

Isogel Agarose LKB, Sweden
Ampholine - p^H 3.0-8.0 LKB Sweden
Sorbitol - D. Merck, W. Germany
Coomassie brilliant blue R. Sisco (India)

Appendix III CD matrix for comparison of treatment means (at 1 per cent level)

1. Plant height

	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2
16	2.80															
15	2.96	2.68														
14	3.76	3.54	3.67													
13	2.80	2.51	2.68	3.54												
12	2.80	2.51	2.68	3.54	2.51											
11	2.74	2.44	2.62	3.50	2.44	2.44										
10	2.74	2.44	2.62	3.50	2.44	2.44	2.38									
9	3.76	3.54	2.67	4.34	3.54	3.54	3.50	3.50								
8	3.22	2.97	3.11	3.88	2.97	2.97	2.91	2.91	3.88							
7	2.74	2.44	2.62	3.50	2.44	2.44	2.38	2.38	3.50	2.91						
6	3.43	3.19	3.33	4.06	3.19	3.19	3.15	3.15	4.06	3.57	3.15					
5	2.80	2.51	2.68	3.54	2.51	2.51	2.44	2.44	3.54	2.97	2.44	3.19				
4	2.74	2.44	2.62	3.50	2.44	2.44	2.38	2.38	3.50	2.91	2.38	3.15	2.44			
3	2.74	2.44	2.62	3.50	2.44	2.44	2.38	2.38	3.50	2.91	2.38	3.15	2.44	2.38		
2	2.74	2.44	2.62	3.50	2.44	2.44	2.38	2.38	3.50	2.91	2.38	3.15	2.44	2.38	2.38	
1	2.74	2.44	2.62	3.50	2.44	2.44	2.38	2.38	3.50	2.91	2.38	3.15	2.44	2.38	2.38	2.38

2. Plant spread

	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2
16	1.71															
15	1.81	1.64														
14	2.30	2.17	2.25													
13	1.71	1.53	1.64	2.17												
12	1.71	1.53	1.64	2.17	1.53											
11	1.68	1.49	1.60	2.14	1.49	1.49										
10	1.68	1.49	1.60	2.14	1.49	1.49	1.45									
9	2.30	2.17	2.25	2.66	2.17	2.17	2.14	2.14								
8	1.97	1.81	1.90	2.38	1.81	1.81	1.78	1.78	2.38							
7	1.68	1.49	1.60	2.14	1.49	1.49	1.45	1.45	2.14	1.78						
6	2.10	1.95	2.04	2.49	1.95	1.95	1.92	1.92	2.49	2.18	1.92					
5	1.71	1.53	1.64	2.17	1.53	1.53	1.49	1.49	2.17	1.81	1.49	1.95				
4	1.68	1.49	1.60	2.14	1.49	1.49	1.45	1.45	2.14	1.78	1.45	1.92	1.49			
3	1.68	1.49	1.60	2.14	1.49	1.49	1.45	1.45	2.14	1.78	1.45	1.92	1.49	1.45		
2	1.68	1.49	1.60	2.14	1.49	1.49	1.45	1.45	2.14	1.78	1.45	1.92	1.49	1.45	1.45	
1	1.68	1.49	1.60	2.14	1.49	1.49	1.45	1.45	2.14	1.78	1.45	1.92	1.49	1.45	1.45	1.45

3. Days to flower

	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2
16	0.78															
15	0.83	0.75														
14	1.05	0.99	1.03													
13	0.78	0.70	0.75	0.99												
12	0.78	0.70	0.75	0.99	0.70											
11	0.77	0.68	0.73	0.98	0.68	0.68										
10	0.77	0.68	0.73	0.98	0.68	0.68	0.66									
9	1.05	0.99	1.03	1.22	0.99	0.99	0.98	0.98								
8	0.90	0.83	0.87	1.09	0.83	0.83	0.81	0.81	1.09							
7	0.77	0.68	0.73	0.98	0.68	0.68	0.66	0.66	0.98	0.81						
6	0.96	0.89	0.93	1.14	0.89	0.89	0.88	0.88	1.14	1.00	0.88					
5	0.78	0.70	0.75	0.99	0.70	0.70	0.68	0.68	0.99	0.83	0.68	0.89				
4	0.77	0.68	0.73	0.98	0.68	0.68	0.66	0.66	0.98	0.81	0.66	0.88	0.68			
3	0.77	0.68	0.73	0.98	0.68	0.68	0.66	0.66	0.98	0.81	0.66	0.88	0.68	0.66		
2	0.77	0.68	0.73	0.98	0.68	0.68	0.66	0.66	0.98	0.81	0.66	0.88	0.68	0.66	0.66	
1	0.77	0.68	0.73	0.98	0.68	0.68	0.66	0.66	0.98	0.81	0.66	0.88	0.68	0.66	0.66	0.66

Appendix III (contd.)

4. Days to first harvest

	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2
16	1.32															
15	1.39	1.26														
14	1.77	1.67	1.73													
13	1.32	1.18	1.26	1.67												
12	1.29	1.15	1.23	1.65	1.15											
11	1.29	1.15	1.23	1.65	1.15	1.12										
10	1.29	1.15	1.23	1.65	1.15	1.12	1.12									
9	1.77	1.67	1.73	2.05	1.67	1.65	1.65	1.65								
8	1.52	1.40	1.47	1.83	1.40	1.37	1.37	1.37	1.83							
7	1.29	1.15	1.23	1.65	1.15	1.12	1.12	1.12	1.65	1.37						
6	1.62	1.51	1.57	1.92	1.51	1.48	1.48	1.48	1.92	1.68	1.48					
5	1.32	1.18	1.26	1.67	1.18	1.15	1.15	1.15	1.67	1.40	1.15	1.51				
4	1.29	1.15	1.23	1.65	1.15	1.12	1.12	1.12	1.65	1.37	1.12	1.48	1.15			
3	1.29	1.15	1.23	1.65	1.15	1.12	1.12	1.12	1.65	1.37	1.12	1.48	1.15	1.12		
2	1.29	1.15	1.23	1.65	1.15	1.12	1.12	1.12	1.65	1.37	1.12	1.48	1.15	1.12	1.12	
1	1.29	1.15	1.23	1.65	1.15	1.12	1.12	1.12	1.65	1.37	1.12	1.48	1.15	1.12	1.12	1.12

Fruit length

	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2
16	0.28															
15	0.29	0.26														
14	0.37	0.35	0.36													
13	0.28	0.25	0.26	0.35												
12	0.27	0.24	0.26	0.35	0.24											
11	0.27	0.24	0.26	0.35	0.24	0.23										
10	0.27	0.24	0.26	0.35	0.24	0.23	0.23									
9	0.37	0.35	0.36	0.43	0.35	0.35	0.35	0.35								
8	0.32	0.29	0.31	0.39	0.29	0.29	0.29	0.29	0.39							
7	0.27	0.24	0.26	0.35	0.24	0.23	0.23	0.23	0.35	0.29						
6	0.34	0.32	0.33	0.40	0.32	0.31	0.31	0.31	0.40	0.35	0.31					
5	0.28	0.25	0.26	0.35	0.25	0.24	0.24	0.24	0.35	0.29	0.24	0.32				
4	0.27	0.24	0.26	0.35	0.24	0.23	0.23	0.23	0.35	0.29	0.23	0.31	0.24			
3	0.27	0.24	0.26	0.35	0.24	0.23	0.23	0.23	0.35	0.29	0.23	0.31	0.24	0.23		
2	0.27	0.24	0.26	0.35	0.24	0.23	0.23	0.23	0.35	0.29	0.23	0.31	0.24	0.23	0.23	
1	0.27	0.24	0.26	0.35	0.24	0.23	0.23	0.23	0.35	0.29	0.23	0.31	0.24	0.23	0.23	0.23

6. Fruit width

	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2
16	0.08															
15	0.09	0.08														
14	0.11	0.11	0.11													
13	0.08	0.07	0.08	0.11												
12	0.08	0.07	0.08	0.11	0.07											
11	0.08	0.07	0.08	0.10	0.07	0.07										
10	0.08	0.07	0.08	0.10	0.07	0.07	0.07									
9	0.11	0.11	0.11	0.13	0.11	0.11	0.10	0.10								
8	0.10	0.09	0.09	0.12	0.09	0.09	0.09	0.09	0.12							
7	0.08	0.07	0.08	0.10	0.07	0.07	0.07	0.07	0.10	0.09						
6	0.10	0.09	0.10	0.12	0.09	0.09	0.09	0.09	0.12	0.11	0.09					
5	0.08	0.07	0.08	0.11	0.07	0.07	0.07	0.07	0.11	0.09	0.07	0.09				
4	0.08	0.07	0.08	0.10	0.07	0.07	0.07	0.07	0.10	0.09	0.07	0.09	0.07			
3	0.08	0.07	0.08	0.10	0.07	0.07	0.07	0.07	0.10	0.09	0.07	0.09	0.07	0.07		
2	0.08	0.07	0.08	0.10	0.07	0.07	0.07	0.07	0.10	0.09	0.07	0.09	0.07	0.07	0.07	
1	0.08	0.07	0.08	0.10	0.07	0.07	0.07	0.07	0.10	0.09	0.07	0.09	0.07	0.07	0.07	0.07

Appendix III (contd.)

7. Pericarp thickness

	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2
16	0.011															
15	0.012	0.011														
14	0.015	0.014	0.015													
13	0.011	0.010	0.011	0.014												
12	0.011	0.010	0.011	0.014	0.010											
11	0.011	0.010	0.011	0.014	0.010	0.010										
10	0.011	0.010	0.011	0.014	0.010	0.010	0.010									
9	0.015	0.014	0.015	0.017	0.014	0.014	0.014	0.014								
8	0.013	0.012	0.015	0.016	0.012	0.012	0.012	0.012	0.016							
7	0.011	0.010	0.011	0.014	0.010	0.010	0.010	0.010	0.014	0.012						
6	0.014	0.013	0.013	0.016	0.013	0.013	0.013	0.013	0.016	0.014	0.013					
5	0.011	0.010	0.011	0.014	0.010	0.010	0.010	0.010	0.014	0.012	0.010	0.013				
4	0.011	0.010	0.011	0.014	0.018	0.010	0.010	0.010	0.014	0.012	0.010	0.013	0.010			
3	0.011	0.010	0.011	0.014	0.010	0.010	0.010	0.010	0.014	0.012	0.010	0.013	0.010	0.010		
2	0.011	0.010	0.011	0.014	0.010	0.010	0.010	0.010	0.014	0.012	0.010	0.013	0.010	0.010	0.010	
1	0.011	0.010	0.011	0.014	0.010	0.010	0.010	0.010	0.014	0.012	0.010	0.013	0.010	0.010	0.010	0.010

8. Average fruit weight

	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2
16	0.03															
15	0.03	0.03														
14	0.04	0.04	0.04													
13	0.03	0.03	0.03	0.04												
12	0.03	0.03	0.03	0.04	0.03											
11	0.03	0.03	0.03	0.04	0.03	0.02										
10	0.03	0.03	0.03	0.04	0.03	0.02	0.02									
9	0.04	0.04	0.03	0.05	0.04	0.04	0.04	0.04								
8	0.03	0.03	0.04	0.04	0.03	0.03	0.03	0.03	0.04							
7	0.03	0.03	0.03	0.04	0.03	0.02	0.02	0.02	0.04	0.03						
6	0.04	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.04	0.04	0.03					
5	0.03	0.03	0.04	0.04	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.03				
4	0.03	0.03	0.03	0.04	0.03	0.02	0.02	0.02	0.04	0.03	0.02	0.03	0.03			
3	0.03	0.03	0.03	0.04	0.03	0.02	0.02	0.02	0.04	0.03	0.02	0.03	0.03	0.02		
2	0.03	0.03	0.03	0.04	0.03	0.02	0.02	0.02	0.04	0.03	0.02	0.03	0.03	0.02	0.02	
1	0.03	0.03	0.03	0.04	0.03	0.02	0.02	0.02	0.04	0.03	0.02	0.03	0.03	0.02	0.02	0.02

9. Fruits/plant

	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2
16	11.77															
15	12.42	11.25														
14	15.79	14.89	15.41													
13	11.77	10.52	11.25	14.89												
12	11.53	10.26	11.00	14.70	10.26											
11	11.53	10.26	11.00	14.70	10.26	9.98										
10	11.53	10.26	11.00	14.70	10.26	9.98	9.98									
9	15.79	14.89	15.41	18.23	14.89	14.70	14.70	14.70								
8	13.52	12.45	13.07	16.31	12.45	12.23	12.23	12.23	16.31							
7	11.53	10.26	11.00	14.70	10.26	9.98	9.98	9.98	14.70	12.23						
6	14.41	13.42	13.99	17.05	13.42	13.21	13.21	13.21	17.05	14.98	13.21					
5	11.77	10.52	11.25	14.89	10.52	10.26	10.26	10.26	14.89	12.45	10.26	13.42				
4	11.53	10.26	11.00	14.70	10.26	9.98	9.98	9.98	14.70	12.23	9.98	13.21	10.26			
3	11.53	10.26	11.00	14.70	10.26	9.98	9.98	9.98	14.70	12.23	9.98	13.21	10.26	9.98		
2	11.53	10.26	11.00	14.70	10.26	9.98	9.98	9.98	14.70	12.23	9.98	13.21	10.26	9.98	9.98	
1	11.53	10.26	11.00	14.70	10.26	9.98	9.98	9.98	14.70	12.23	9.98	13.21	10.26	9.98	9.98	9.98

Appendix III (contd.)

10. Yield (freish weight)

	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2
16	8.50															
15	8.98	8.13														
14	11.41	10.76	11.14													
13	8.50	7.61	8.13	10.76												
12	8.33	7.41	7.95	10.62	7.41											
11	8.33	7.41	7.95	10.62	7.41	7.22										
10	8.33	7.41	7.95	10.62	7.41	7.22	7.22									
9	11.41	10.76	11.14	13.18	10.76	10.62	10.62	10.62								
8	9.77	9.00	9.45	11.79	9.00	8.84	8.84	8.84	11.79							
7	8.33	7.41	7.95	10.62	7.41	7.22	7.22	7.22	10.62	8.84						
6	10.42	9.70	10.11	12.33	9.70	9.55	9.55	9.55	12.33	10.83	9.55					
5	8.50	7.61	8.13	10.76	7.61	7.41	7.41	7.41	10.76	9.00	7.41	9.70				
4	8.33	7.41	7.95	10.62	7.41	7.22	7.22	7.22	10.62	8.84	7.22	9.55	7.41			
3	8.33	7.41	7.95	10.62	7.41	7.22	7.22	7.22	10.62	8.84	7.22	9.55	7.41	7.22		
2	8.33	7.41	7.95	10.62	7.41	7.22	7.22	7.22	10.62	8.84	7.22	9.55	7.41	7.22	7.22	
1	8.33	7.41	7.95	10.62	7.41	7.22	7.22	7.22	10.62	8.84	7.22	9.55	7.41	7.22	7.22	7.22

11. Seed diameter

	14	13	12	11	10	9	8	7	6	5	4	3	2
13	0.006												
12	0.005	0.005											
11	0.005	0.005	0.005										
10	0.005	0.005	0.005	0.005									
9	0.007	0.007	0.007	0.007	0.007								
8	0.006	0.006	0.006	0.006	0.006	0.008							
7	0.005	0.005	0.005	0.005	0.005	0.007	0.006						
6	0.007	0.006	0.006	0.006	0.006	0.008	0.007	0.006					
5	0.005	0.005	0.005	0.005	0.005	0.007	0.006	0.005	0.006				
4	0.005	0.005	0.005	0.005	0.005	0.007	0.006	0.005	0.006	0.005			
3	0.005	0.005	0.005	0.005	0.005	0.007	0.006	0.005	0.006	0.005	0.005		
2	0.005	0.005	0.005	0.005	0.005	0.007	0.006	0.005	0.006	0.005	0.005	0.005	
1	0.005	0.005	0.005	0.005	0.005	0.007	0.006	0.005	0.006	0.005	0.005	0.005	0.005

12. Thousand seed weight

	14	13	12	11	10	9	8	7	6	5	4	3	2
13	0.04												
12	0.04	0.04											
11	0.04	0.04	0.04										
10	0.04	0.04	0.04	0.03									
9	0.06	0.06	0.05	0.05	0.05								
8	0.05	0.05	0.04	0.04	0.04	0.06							
7	0.04	0.04	0.04	0.03	0.03	0.05	0.04						
6	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.05					
5	0.04	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.05				
4	0.04	0.04	0.04	0.03	0.03	0.05	0.04	0.03	0.05	0.04			
3	0.04	0.04	0.04	0.03	0.03	0.05	0.04	0.03	0.05	0.04	0.03		
2	0.04	0.04	0.04	0.03	0.03	0.05	0.04	0.03	0.05	0.04	0.03	0.03	
1	0.04	0.04	0.04	0.03	0.03	0.05	0.04	0.03	0.05	0.04	0.03	0.03	0.03

Interspecific hybridization in Capsicum

BY

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ABSTRACT OF A THESIS
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ABSTRACT

The present investigation "Interspecific hybridization in *Capsicum*" was carried out at the College of Horticulture, Vellanikkara, Thrissur during September 1988 - April 1990 to study cross compatibility among five *Capsicum* species and to exploit heterosis in interspecific hybrids. Eighty four chilli accessions, when subjected to the modern taxonomic treatments were found to fall under *C. annuum* L. (62), *C. frutescens* L. (7), *C. chinense* Jacq. (14) and *C. baccatum* L. (1). Protein electrophoretic focussing revealed species specific protein bands in *C. chinense*, *C. baccatum* and *C. chacoense*. Fruit set was obtained in all the 28 crosses made among *C. annuum*, *C. frutescens*, *C. chinense*, *C. baccatum* and *C. chacoense*. Viable F_1 and F_2 seeds were obtained in eight crosses viz., *C. annuum* x *C. chinense* (P), *C. annuum* x *C. chinense* (NP), *C. frutescens* x *C. annuum*, *C. chacoense* x *C. annuum*, *C. frutescens* x *C. chinense* (P), *C. chinense* (P) x *C. frutescens*, *C. frutescens* x *C. chinense* (NP) and *C. chinense* (NP) x *C. frutescens*. Multivalents, bridges, laggards, fragments and micronuclei were observed in pollen mother cells of all interspecific hybrids and hybrid sterility was proved to be associated with meiotic abnormalities. In general, hybrids exhibited negative heterosis except for earliness and seed size. In specific combinations, significant positive

heterosis was observed for yield, plant height and plant spread. Hybrids between _C. frutescens_ and _C. chinense_ had high values of capsaicin and oleoresin. Considering the _per se_ performance, _C. annuum_ x _C. chinense_ (P) was the most promising for fresh fruit yield/plant (197.6 g) with high values of capsaicin (0.92%), oleoresin (34.40%) and colour (58.62 ASTA unit).