EVALUATION OF ORNAMENTAL CHILLIES AND SELECTION FOR DWARF CLUSTERED PLANT TYPES

By

MINI. C.

THESIS

Submitted in partial fulfilment of the

requirement for the degree

Master of Science in Horticulture

Faculty of Agriculture

Kerala Agricultural University

Department of Olericulture

COLLEGE OF HORTICULTURE

Vellanikkara - Trichur

1989

DECLARATION

I hereby declare that this thesis entitled "Evaluation of ornamental chillies and selection for dwarf clustered plant types" 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,
1-6-1989.

MINI C.

CERTIFICATE

Certified that this thesis entitled "Evaluation of ornamental chillies and selection for dwarf clustered plant types" is a record of research work done independently by Miss Mini C., under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Dr. K.V. Peter,
Chairman,
Advisory Committee,
Professor & Head
Dept. of Olericulture.

Vellanikkara,
1-6-1989.

CERTIFICATE

We, the undersigned members of the Advisory Committee of Miss. Mini C., a candidate for the degree of Master of Science in Horticulture agree that the thesis entitled "Evaluation of ornamental chillies and selection for dwarf clustered plant types" may be submitted by Miss. Mini C., in partial fulfilment of the requirement for the degree.

Dr. K.V. Peter
(Chairman)
Professor and Head
Department of Olericulture

Dr. T.R. Gopalakrishnan
Associate Professor
Department of Olericulture

Sri. V.K. Raju
Associate Professor
Department of Olericulture

Sri. V.K.G. Unnithan
Associate Professor
Department of Agrl. Statistics

ACKNOWLEDGEMENT

I have immense pleasure to express my deep sense of gratitude and indebtedness to Dr. K.V. Peter, Chairman of my Advisory Committee, Professor and Head, Department of Olericulture, for his valuable suggestions, constant encouragement, helpful and constructive criticism and keen interest at every stage of the investigation and preparation of the thesis.

I consider it as my privilege to express my heartfelt thanks and indebtedness to Dr. T.R. Gopalakrishnan, Associate Professor, Department of Olericulture and Sri. V.K.G. Unnithan, Associate Professor, Department of Agrl. Statistics, for their pertinent suggestions and keen interest in the preparation of the manuscript.

I wish to acknowledge the heartiest thanks to Sri. V.K. Raju, Associate Professor, Dept. of Olericulture and Mrs. V.K. Mallika, Associate Professor, Dept. of Ag. Botany, for their timely help, sustained interest and valuable suggestions given throughout the period of investigation.

I sincerely acknowledge my gratitude to the staff members of the Department of Olericulture for their sincere help.

To my parents

The help rendered by my friends at various stages of this investigation, was invaluable and I thank them all from the bottom of my heart. Three names that had to be distinctly mentioned here are Latha, A; Mini Jose and Ambika, S., without whose assistance it would not have been so easy for me to complete this venture successfully.

A word of appreciation goes to Mr. V.P. Asokan and Antony T.P. for the neat typing.

I express my heartfelt gratitude to my beloved parents and relatives, whose affectionate encouragement and blessings have always been a source of inspiration for me.

I cast a special vote of thanks to Mr. Sugathan, Farm Assistant, for extending limitless help and co-operation during the course of this investigation.

Above all, I bow my head before God Almighty who blessed me with lot of health, confidence and luck to complete my M.Sc. programme successfully.

Vellanikkara,
1-6-1989.

MINI. C.

To my parents

C O N T E N T S

		PAGE NO.
I.	INTRODUCTION	1
II.	REVIEW OF LITERATURE	3
III.	MATERIALS AND METHODS	16
IV.	RESULTS	34
V.	DISCUSSION	69
VI.	SUMMARY	78
VII.	REFERENCES	
VIII.	APPENDIX	
IX.	ABSTRACT	

LIST OF TABLES

Table No.	Title
Table 1	Crossability in the interspecific hybrids involving five species of *Capsicum*.
Table 2	Source and salient features of ornamental chillies collected.
Table 3	Descriptor list of ornamental chillies.
Table 4	Morphological description of ornamental chillies.
Table 5	Quantitative characteristics of ornamental chillies.
Table 6	Morphological description of ornamental chillies.
Table 7	Quantitative characteristics of ornamental chillies.
Table 8	Crossability between *Capsicum annuum*, *Capsicum chinense* and *Capsicum chacoense* after hand pollination.
Table 9	Morphological description of parental species and their interspecific F_1s.
Table 10	Quantitative characteristics of parental species and their interspecific F_1s.
Table 11	Percentage of sterile and fertile pollen in three parental species and their interspecific F_1s.
Appendix I	Weekly average weather data for the cropping period (May 1988 to April 1989).

LIST OF FIGURES

Fig. 1 Crossability polygon for *Capsicum* species.

Fig. 2 CA 352-1

Fig. 3 CA 474

Fig. 4 CA 476-1

Fig. 5 CA 479-1a

Fig. 6 CA 481

Fig. 7 CA 485

Fig. 8 CA 486-1

Fig. 9 CA 488

Fig. 10 CA 489

Fig. 11 CA 493

Fig. 12 CA 504

Fig. 13 Interspecific F_1, *Capsicum annuum x Capsicum chinense*.

Fig. 14 Interspecific F_1, *Capsicum annuum x Capsicum chacoense*.

Fig. 15 Fertile pollen of *Capsicum annuum*

Fig. 16 Pollen of *Capsicum chinense*

Fig. 17 Pollen of *Capsicum chacoense*

Fig. 18 Sterile pollen of *Capsicum annuum x Capsicum chinense*

Fig. 19 Sterile Pollen of *Capsicum annuum x Capsicum chacoense*

Fig. 20 Multivalents at metaphase

Fig. 21 Non orientation at metaphase I

Fig. 22 Laggards at anaphase I

Fig. 23 Non orientation at metaphase II

Fig. 24 Presence of three nuclei at the end of division

Fig. 25 Variability in fruit shape

Introduction

INTRODUCTION

Chilli, native to the New World Tropics, is now widely grown for use as spices or vegetables. In addition to the above specific uses, chillies have some roles in medicines and a few are valued as ornamentals (Grubben, 1977). Use of chillies for ornamental purposes is mentioned in Encyclopedias (Anon, 1768; Novak, 1965 and Vernon, 1982), monographs like Exotica (Graf, 1982) and in many ancient literatures. Corley and Dempsey (1971), Graf (1982) and Essig(1983) conducted evaluation trials and described several ornamental chillies. In India, studies on collection and evaluation of ornamental chillies are rather limited.

Ornamental chillies can be tailored to suit as borders, small beds, pot plants and background material for large beds or mass plantings. It can also be successfully grown as indoor pot plants.

Many research and development organizations have advanced scientific methods for production and export of different varieties and seeds of ornamental chillies.

An ideal plant type of ornamental chilli should be dwarf with small, dark green leaves and a large number of branches bearing more number of fruits of attractive colour

and shape. The plant should also have well developed root system which makes it suitable to grow as a pot plant. These characters are present in different species of genus *Capsicum* and by proper combination of such species, an ideotype for ornamental chillies can be developed.

Considering the above aspects, the present investigation was undertaken with following specific objectives.

1. To evaluate, catalogue and document ornamental chillies and select dwarf clustered plant types.

2. To use *Capsicum chinense* Jacq. and *Capsicum chacoense* Hunz. in order to develop ornamental chillies.

3. To evaluate interspecific F_1s for aesthetic characters and study the possible uses of related species to synthesise ornamental types.

Review of Literature

REVIEW OF LITERATURE

The available literature on origin, history, improvement, management and potentialities of ornamental chillies and interspecific crossability among different *Capsicum sp.* are reviewed.

A. Ornamental chillies

1. Origin and history

Cultivated forms of genus *Capsicum* were included under a single species *Capsicum annuum* L. with several varieties. Among them, *Capsicum annuum* var. *abbreviatum* was used as ornamental bush pepper (Anon, 1768). Erwin (1929) and Tillinghast (1939) described several ornamental peppers. Stolz (1965) listed sweet pepper varieties suited to cultivation under glass. Wit (1965) suggested a few of the capsicum varieties with decorative branches which can be cultivated as indoor plants. Species of ornamental peppers were limited to *Capsicum annuum* L. and *Capsicum frutescens* L. until modern taxonomists (Heiser and Smith, 1958 and Lippert *et al.*, 1966) described new species from South America (Corley and Dempsey, 1971). All available plant accessions have been screened (Corley, 1967; Anon, 1970 and Dempsey, 1970) for new sources of ornamental peppers. Corley and Dempsey (1971) listed plant and fruit characteristics of 36 cultivars and accessions of *Capsicum annuum* L., *Capsicum Chinense* Jacq. and *Capsicum pendulum* wild. Eighteen accessions were compared relatively with the ornamental cultivats currently existing in

the seed trade. Yoneda (1974) reported three edible and two ornamental cultivars of sweet pepper while making morphological observations during early stage of flower bud differentiation and development. A review and discussion with mention of plants with ornamental fruits such as *Solanum* and *Capsicum* spp were given by Vidalie (1975). Heiser (1976) suggested that in addition to use as food or condiment, peppers had some use in medicine and some were valued as ornamentals. Graf (1982) listed ten different types of ornamental peppers suited as pot plants. They were Birdseye, Christmas Candle, Acorn, Candle Pepper, Celestial, Red Chile, Piccolo, Robert Craig, Weatherillii and *Capsicum laccatum* L. Plant and fruit characteristics of these different varieties were described by him. Essig (1983) described and illustrated five outstanding cultivars of ornamental capsicums. They were Purple Fiesta with fruits 40-50 mm long; Fire Ball with round fruits 8-10 mm wide; Hot Bed Slim with fruits 40-60 mm long; Holiday Flames with fruits 40-55 mm long and Candelabra with oval fruits 25-35 mm long.

2. Improvement

Angeli (1964) developed bouquet type peppers with a determinate type of growth and suitable for cultivation under glass. In that type, the main stem stopped growing when 17-21 cm high, the flowers and leaves were borne in clusters and all the fruits ripened at the same time.

3. Management

Work conducted at UK (Stock Bridge House Experimental Horticultural Station, 1973) gave preliminary data on cultivation and cultivars of ornamental capsicums. Production techniques of ornamental capsicum for the Christmas market were described by them. Christensen (1975) tabulated data for blue print production of the ornamental fruited *Capsicum annuum*. He recommended the cultivar Zulu Tricolor as an ornamental pot plant. Khademi and Khosh-khui (1977) studied effect of growth regulators such as indole-3-acetic acid, benzyl adenine and ethephon on vegetative and reproductive characters of ornamental peppers (*Capsicum annuum* L. cv. Teno). Ethephon increased number of lateral branches, but reduced growth, delayed flowering, reduced number of flowers/branch thus reducing fruit production. Reduction in plant diameter, plant height and leaf size were observed due to ethephon application. Indole-3-acetic acid and benzyl adenine had no desirable effect on ornamental characteristics of treated plants. Harbaugh and Waters (1979) evaluated flower and foliage quality characteristics of 53 cultivars belonging to 21 genera of flowering potted plants including ornamental capsicum. Evaluations were based on a 1 to 5 scale. Mixed gloxinia seedlings or chrysanthemum cv. Puritan were used as standards for comparison. The study indicated that ornamental capsicum variety Fiesta can easily be maintained and expected to flower for 4 to 8 weeks under home

conditions. Emino (1981) supplied container grown green house *Capsicum annuum* cv. Fips, with inorganic nutrient solutions (150 ml/10 cm pot) containing 140, 280 or 560 mg N/l, fish emulsion (5 N: 0.44 P: 0.44 K) or an amended fish soluble nutrient from fish emulsion, sea weed and sugarcane extracts with urea, phosphoric acid and potassium sulphate (5N: 1.7 p: 3.3 K) at weekly intervals. Fresh weight of ornamental pepper plants was significantly lowered with the amended fish soluble nutrient. Six ornamentals including ornamental capsicums were grown by Holcomb (1982) as autumn plants to develop production schedule and to test effect of soil heating (24°C) in a green house with a night temperature of 16°C. Of four ornamental capsicum cultivars, only one, Red Missile, responded to soil heat by increased growth. Johnson *et al.* (1983) studied use of zeolite as an additive for compost for ornamental pot plants. The zeolite clinoptilolite, milled fine and mixed with compost, showed promise as a source of slow release potassium. Potted capsicum plants responded well to use of 7.5% clinoptilolite with 800 g N/m^3 compost. Foliage growth, plant quality and fruit production of ornamental capsicums were optimal at 600 g N, 300 g P_2O_5 and 500 g K_2O/m^3 medium. Lime at 6 kg/m^3 was recommended (Thomas, 1984). Thomas and Leong (1984) studied effect of shade and nitrogen on production of container grown ornamental peppers. There were marked interactions between shade and nitrogen application on most aspects of foliage and fruit

development. Optimum plant quality was obtained with 600 g N/m^3 under 0% shade.

4. Potentialities

A survey of literature by Corley and Dempsey (1971) indicated that early interest in ornamental peppers, *Capsicum* spp was mainly for use as indoor pot plants. The wide variation of plant height observed among cultivars suggested that ornamental peppers had several potential uses as borders, small beds, pot plants and background material for large beds or mass plantings. Consumer and biological value of the fruits of some ornamental capsicum cultivars grown in green houses were studied by Cebula *et al.* (1987). Fruit weight, length and pericarp thickness of certain cultivars were also described.

B. Interspecific crossability

Smith and Heiser (1957) studied crossing behaviour of five *Capsicum* spp. - *Capsicum annuum* L., *Capsicum frutescens* L., *Capsicum pendulum* wild., *Capsicum pubescens* R.& P. and *Capsicum sinense* Jacq. About two per cent of the seeds were viable when *Capsicum frutescens* was used as the female. The reciprocal cross had never been successfully made. The F_1 plants ranged from completely pollen sterile to partially fertile. Emboden (1961) made reciprocal interspecific crosses between *Capsicum baccatum* L. and single strains of *Capsicum annuum*, *Capsicum cardenasii*

Heiser & Smith., *Capsicum chacoense* Hunz., *Capsicum chinense* Jacq., *Capsicum frutescens* L., *Capsicum galapagoense* Hunz., *Capsicum microcarpum* cav., *Capsicum praetenmissum* Heiser & Smith, and *Capsicum cerasiforme* Irish. Crosses involving *Capsicum annuum* were successful in both directions, pollen fertility of the hybrids ranging from 21% to 81%. Crosses with *Capsicum chinense* were successful only when *Capsicum baccatum* races were used as female parents, the reciprocal crosses failed to produce seeds. Crosses with *Capsicum chacoense* were successful in both directions, the stainable pollen percentage in hybrids ranging from 0 to 41%. Hirose *et al.* (1961) made the following crosses, *Capsicum frutescens x Capsicum annuum; Capsicum annuum x Capsicum pendulum; Capsicum pendulum x Capsicum frutescens; Capsicum sinense x Capsicum frutescens* and *Capsicum sinense x Capsicum pendulum.* All crosses except those involving *Capsicum annuum* were heterotic. Pollen fertility of the hybrids ranged from 0 to 51.8%. Gozenbus (1965) reported that no fertile hybrids were obtained from interspecific hybridization among *Capsicum annuum, Capsicum conicum, Capsicum angulosum* M. and *Capsicum pubescens.* Incompatibility between *Capsicum annuum* (2n = 48) and *Capsicum pubescens* (2n = 24) could be overcome by using tetraploid form of *Capsicum annuum* as the female parent (Molhova, 1966). Pickersgill (1967) reported that F_1 plants from crosses with *Capsicum pendulum x Capsicum chinense* were morphologically normal, but partially sterile. F_1 plants from the reciprocal cross were morphologically abnormal and completely

sterile. He also reported that *Capsicum frutescens* would hybridize only with *Capsicum annuum* var. *minimum* and the hybrids would be sterile. Yaqub (1968) reported that all strains of *Capsicum frutescens* and *Capsicum annuum* tested were self compatible. Peppers produced by Mihov (1969) from crosses of *Capsicum annuum x Capsicum fasciculatum* Bailey, were wilt resistant and of good quality. Goud *et al.* (1970) made interspecific hybridization between *Capsicum annuum* and *Capsicum frutescens*. The *Capsicum annuum* varieties Pendulous Long, Erect Long and Erect Round were pollinated by *Capsicum frutescens*. Fruit was only set in crosses with Pendulous Long. *Capsicum annuum* and *Capsicum frutescens* were successfully intercrossed by Keshavram and Saini (1971) in all directions and the F_1s were fertile and set seeds readily. Pickersgill (1971) found out the relationships between the weedy and cultivated forms in some species of *Capsicum*. When *Capsicum annuum* was crossed with weedy *Capsicum 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 *Capsicum annuum* with cultivated *Capsicum baccatum*. According to him, no natural hybrids were obtained between *Capsicum frutescens* and weedy forms of *Capsicum baccatum*, nor between weedy *Capsicum baccatum* and *Capsicum annuum* var. *minimum*. Eshbaugh (1974) reported that *Capsicum cardenasii* and *Capsicum eximium* Hunz. formed fertile F_1s and F_2s when crossed with *Capsicum pubescens*. Interspecific hybrids between *Capsicum fasciculatum* and *Capsicum annuum* were reported by Alekseeva (1975). *Capsicum frutescens*

crossed readily with *Capsicum chinense*, producing partially fertile hybrids (Greenleaf, 1975). Work conducted at Institute of Horticultural Plant Breeding, Netherlands (1977) revealed that in reciprocal crosses of *Capsicum annuum* and *Capsicum chinense*, those in which primitive forms were used generally gave better seed sets than those using cultivated materials. Pillai *et al.* (1977) studied interspecific hybrids of five species of *Capsicum*. No cross with *Capsicum annuum* as the female parent was successful and seedlings from *Capsicum frutescens* x *Capsicum pendulum* did not survive. There was no seed set in *Capsicum baccatum* x *Capsicum annuum* and no viable seed from *Capsicum pendulum* x *Capsicum annuum*. Maximum seed germination (73%) was observed in *Capsicum frutescens* x *Capsicum baccatum* and the lowest (9%) in *Capsicum microcarpum* x *Capsicum frutescens*. Radhakrishnan *et al.* (1977) developed a technique in which the upper part of the style and stigma were excised and a drop of sucrose solution (five per cent) applied to the cut surface prior to pollination. This resulted in fruit and seed set in crosses among *Capsicum annuum*, *Capsicum frutescens* and *Capsicum pendulum*. In crosses where *Capsicum annuum* was female, percentage of fruit set was considerably lower than in reciprocals. Of fifteen interspecific crosses attempted by Saccardo (1978) only those of *Capsicum annuum* with *Capsicum chinense* and *Capsicum pendulum* gave viable seeds. Two methods for assisting interspecific hybridization between

Capsicum annuum and *Capsicum baccatum* were described by De Vaulx and Pitrat (1979). Pickersgill (1980) studied crossability among eleven *Capsicum* spp. (Fig. 1). Hybrids of three *Capsicum annuum* cultivars with *Capsicum chinense* '3341' from Bolivia were compared by Yazawa *et al.* (1980). Attempts made to cross *Capsicum frutescens* (var. White Kanthari) with *Capsicum annuum* (var. Jwala) resulted in negligible seed set and flower fall (Balasubramanian, 1981). Boukema (1982) reported that *Capsicum chacoense* and *Capsicum annuum* hybrids had larger leaves and were much vigorous than the *Capsicum chacoense* parent, but they were male sterile. Some of these male sterile hybrids gave parthenocarpic fruits, but these could be distinguished from fruits with seeds because of short and wrinkled nature. Cook and Guevara (1982) reported that hypersensitive resistance from *Capsicum chacoense* was inherited as a single dominant character in progenies of *Capsicum chacoense* and *Capsicum annuum*. Sterile hybrid plants were obtained from cross of *Capsicum annuum* and *Capsicum pendulum*. Hybrid seeds of *Capsicum pendulum* and *Capsicum annuum* were obtained with difficulty and plants with partial fertility were grown from them (Molchova and Michailova, 1982). The F_1 generation of the cross *Capsicum annuum* having single flower/node and *Capsicum chinense* having multiple flower/node was produced by Subramanya (1982) and all the F_1 plants had two flowers/node. Smith (1983) studied the crossability of fourteen *Capsicum* spp. (Table 1). Research report of Kerala Agricultural University (1983-84) mentioned the compatibility of *Capsicum annuum* and *Capsicum frutescens* by

Fig.1 Crossability polygon for *Capsicum* species.

—— F_1 hybrids germinate normally.

- - - F_1 hybrids raised by embryo culture.

····· Fruits and/or seeds set, but F_1 seeds in viable.

-o-o-o- F_1 hybrid partially fertile.

-*-*-*- F_1 hybrid highly fertile.

◀ Points in direction of female parent.

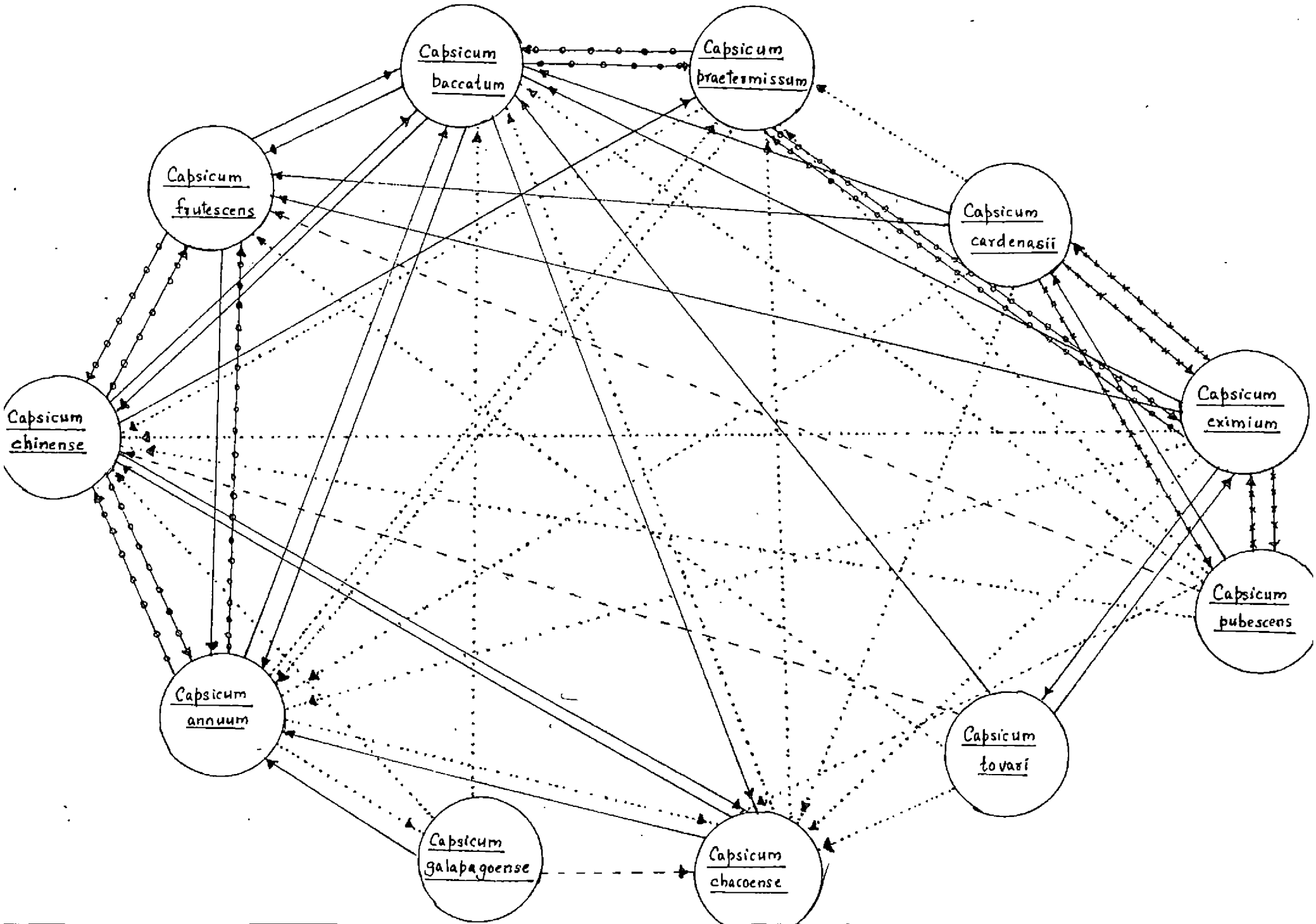

Capsicum baccatum
Capsicum praetermissum
Capsicum frutescens
Capsicum cardenasii
Capsicum chinense
Capsicum eximium
Capsicum pubescens
Capsicum annuum
Capsicum tovari
Capsicum galapagoense
Capsicum chacoense

Table 1. Crossability in the interspecific hybrids involving five species of *Capsicum*

	Initial cross	Viable F_2 seed	Viable back cross seed
Capsicum annuum x Capsicum frutescens	+	+	+
Capsicum annuum x Capsicum sinense	++	++	++
Capsicum annuum x Capsicum pendulum	E	+	-
Capsicum annuum x Capsicum pubescens	-	-	-
Capsicum frutescens x Capsicum sinense	+	+	+
Capsicum frutescens x Capsicum pendulum	++	+	+
Capsicum frutescens x Capsicum pubescens	-	-	-
Capsicum sinense x Capsicum pendulum	+	-	-
Capsicum sinense x Capsicum pubescens	E	-	-
Capsicum pendulum x Capsicum pubescens	-	-	-

E = Seed germinated by embryo culture only
\- = No viable seed
\+ = Few viable seed
++ = Many viable seed

working out crossability index at Fo level. All crosses including directs and reciprocals were compatible except in two combinations where White Kanthari was used as the female parent. Boukema (1984) reported that the F_1 *Capsicum chacoense x Capsicum chinense* was completely male sterile. The varying success of interspecific crosses was reported by Casali and Couto (1984). *Capsicum baccatum* (female) crossed with *Capsicum frutescens, Capsicum annuum* or *Capsicum chinense* gave hybrids with low fertility. *Capsicum baccatum* when crossed with *Capsicum praetermissum* gave highly fertile hybrids. According to Egawa and Tanaka (1984), meiotic pairing was regular with 12 bivalents and pollen stainability was high for interspecific hybrid between *Capsicum chinense* and *Capsicum frutescens*. Peter and Mc Collum (1984) observed pollen-stigma compatibility in reciprocal crosses of *Capsicum annuum* and *Capsicum frutescens*, but plants failed to set fruits after artificial pollination in the green house. Pundeva (1984) reported that in hybridization between *Capsicum frutescens* and *Capsicum praetermissum*, the percentage of successful crosses was 12.76 and the viable seeds were 20.83%. Crossing between *Capsicum praetermissum* and *Capsicum frutescens* resulted in 17.14% successful crosses and 9.37% viable seeds. In both the cases, F_1 hybrids were intermediate in their habits. Kounovasky *et al.* (1985) reported that *Capsicum chinense* had a good cross fertility with *Capsicum annuum*. New lines were obtained by Miladinovic *et al.* (1985) from progenies of (*Capsicum annuum x Capsicum chinense*) and *Capsicum pendulum*. Work conducted

at Institute for Horticultural Plant Breeding, Netherlands (1985) revealed that F_1 plants from cross between *Capsicum annuum* and *Capsicum chacoense* had normal flowers, but only 0 to 5% pollen germinated. Casali and Campos (1986) reported that seed germination of the hybrids obtained by crossing *Capsicum frutescens* with *Capsicum praetermissum* was 22.4% to 77.4% and the plant survival was over 70.8%. Employing *Capsicum praetermissum* as female parent, maximum seed germination observed was 65.5% and no plants survived. The following crosses were studied by Egawa and Tanaka (1986), *Capsicum annuum x Capsicum chinense, Capsicum annuum x Capsicum baccatum, Capsicum chinense x Capsicum frutescens, Capsicum chinense x Capsicum baccatum* and *Capsicum baccatum x Capsicum frutescens.* Multivalents and low pollen stainability were observed in all the hybrids except *Capsicum chinense x Capsicum frutescens.* A few multivalents were observed, the highest frequency (1.64/cell) being in *Capsicum baccatum x Capsicum frutescens.* Of 12 direct and reciprocal interspecific crosses made by Krishnakumari and Peter (1986), involving two lines of *Capsicum annuum* and three of *Capsicum frutescens,* ten were successful. Kiku (1987) reported that interspecific hybridization was largely unsuccessful when wild species were used as the maternal parent. To increase seed and fruit set in reciprocal crosses involving *Capsicum annuum, Capsicum pendulum* and *Capsicum angulosum,* two pollinations were recommended at an interval of 24 hours and also pollination following

treatment of the stigma with a mixture of Vitamins B_1 and B_6 at a concentration of 0.001%. Hybrids were obtained by Kumar *et al.* (1987) between *Capsicum annuum* (cv. G_3 and var. *Cerasiforme*) and *Capsicum frutescens*, using the latter as female parent. Todorova and Kunovski (1988) made hybrids from crosses of *Capsicum annuum* cv Albena and *Capsicum chinense* cv AC 2176 and the hybrids had multiple disease resistance.

Ornamental chillies are assuming importance as decorative cum economic plants. Studies regarding collection and evaluation of ornamental chillies are a few in India. The present study aims to generate information and materials in this direction.

Materials and Methods

MATERIALS AND METHODS

The present studies were conducted at the College of Horticulture, Vellanikkara, Trichur during May-October, 1988 and October-April 1988-'89. 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. The area experiences a typical warm humid tropical climate. Weather parameters like maximum temperature, minimum temperature, relative humidity, rainfall and evaporation rate at weekly interval during periods of experimentation are given in Appendix-I.

The experiment consisted mainly of three parts. A) Evaluation, cataloguing and documentation of ornamental types of chillies and selection of dwarf clustered plant types. B) Use of *Capsicum chinense* Jacq. and *Capsicum chacoense* Hunz. to develop ornamental chillies. C) Evaluation of interspecific F_1s.

A) Evaluation, cataloguing and documentation of ornamental types of chillies and selection of dwarf clustered plant types

The materials for the study comprised of fifty one lines of ornamental chillies. They were collected through survey, correspondence and exchange. The ornamental nurseries, house holds, research stations and other institutions were approached to collect variability. The source

and the salient features of the lines collected are given in Table 2. The collected lines were grown in 30 cm pots during July-October 1988 and January-April 1989.

Potting mixture and potted plant management

Potting mixture used had a composition of soil:sand: farm yard manure in the ratio of 1:1:1.

Soil sterilization

Chemical sterilization of the potting mixture was done using formalin. The solution was prepared by mixing formaldehyde with water in the ratio 1:30, 3.01 litres of the solution was applied per sq. metre of soil. Application was done when the soil was moist. The pot was covered for two days, stirred, covered again for three days and kept in open condition for ten days. Thus a total of fifteen days was needed for sterilization.

Five plants were grown in each genotype under controlled green house conditions. The transplanted seedlings were given temporary shade for two to four days. Farm yard manure was applied at the rate of 20-25 t/ha at the time of planting. A fertilizer dose of 75 kg, 40 kg, 20 kg NPK was given per hectare. Half of nitrogen, full phosphorus and half of potash were applied as basal dose first before transplanting. The 1/4th of nitrogen and half of potash were applied 20 to 25 days after transplanting and the remaining quantities were applied one month after the first application. Raking was done to control weeds,

Table 2. Source and salient features of ornamental chillies collected

Accession No.	Source	Salient features		
		Fruit colour	Fruit shape	Leaf colour
CA 352	Germplasm collection at KAU	Red	Round	Green
CA 455	Rajeswari Nursery, Trichur	Red	Round	Green
CA 456	IIHR, Bangalore	Red	Elongate	Green
CA 457	IIHR, Bangalore	Red	Elongate	Green
CA 458	IIHR, Bangalore	Red	Oblate	Green
CA 459	IIHR, Bangalore	Red	Conical	Green
CA 460	IIHR, Bangalore	Red	Conical	Green
CA 461	IIHR, Bangalore	Red	Conical	Green
CA 462	IIHR, Bangalore	Orange	Conical	Green
CA 463	IIHR, Bangalore	Orange	Conical	Green
CA 464	IIHR, Bangalore	Red	Conical	Green
CA 466	IIHR, Bangalore	Red	Oblate	Green
CA 467	IIHR, Bangalore	Red	Elongate	Green
CA 468	IIHR, Bangalore	Orange	Elongate	Green
CA 469	IIHR, Bangalore	Red	Elongate	Green
CA 470	IIHR, Bangalore	Red	Round	Green
CA 471	NBPGR, Vellanikkara	Red	Conical	Green

(contd.)

Table 2. (contd.)

Accession No.	Source	Salient features		
		Fruit colour	Fruit shape	Leaf colour
CA 473	Shalimar Nursery, Trivandrum	Red	Conical	Green
CA 474	Shalimar Nursery, Trivandrum	Red	Conical	Green
CA 475	Cochin Flower Show	Red	Elongate	Green
CA 476	Cochin Flower Show	Red	Oblate	Green
CA 477	Shalimar Nursery, Trivandrum	Red	Conical	Violet
CA 478	Shalimar Nursery, Trivandrum	Red	Oblate	Green
CA 479	Cochin Flower Show	Red	Conical	Green
CA 480	NBPGR, Vellanikkara	Red	Conical	Green
CA 481	Cochin Flower Show	Orange	Conical	Green
CA 482	Germplasm Collection, KAU	Red	Bell	Green
CA 483	Shalimar Nursery, Trivandrum	Red	Conical	Green
CA 484	NBPGR, Vellanikkara	Red	Conical	Green
CA 485	Cochin Flower Show	Red	Round	Green
CA 486	Cochin Flower Show	Red	Round	Green
CA 487	NBPGR, Vellanikkara	Red	Conical	Green
CA 488	Cochin Flower Show	Red	Conical	Green
CA 489	Rajeswari Nursery, Trichur	Red	Round	Green
CA 490	Germplasm Collection, KAU	Orange	Elongate	Green
CA 491	Cochin Flower Show	Red	Conical	Green
CA 492	Cochin Flower Show	Red	Bell	Green
CA 493	Cochin Flower Show	Red	Conical	Green

Table 2 (Contd.)

Accession No.	Source	Salient features		
		Fruit colour	Fruit shape	Leaf colour
CA 494	Beena Nursery, Trivandrum	Red	Conical	Variegated leaf
CA 495	NBPGR, Vellanikkara	Red	Elongate	Green
CA 496	NBPGR, Vellanikkara	Red	Conical	Green
CA 497	Raja Nursery, Trichur	Red	Conical	Purple
CA 498	Germplasm Collection, KAU	Orange	Elongate	Green
CA 499	NBPGR, Vellanikkara	Red	Conical	Green
CA 500	NBPGR, Vellanikkara	Orange	Elongate	Green
CA 501	NBPGR, Vellanikkara	Red	Elongate	Green
CA 502	Germplasm Collection, KAU	Red	Elongate	Green
CA 503	Germplasm Collection, KAU	Red	Conical	Green
CA 504	Ornamental Nursery, Parassala	Red	Round	Green
CA 505	Germplasm Collection, KAU	Red	Bell	Green
CA 506	NBPGR, Vellanikkara	Red	Conical	Green
CA 507	NBPGR, Vellanikkara	Red	Conical	Green

and the plants were irrigated daily. Plant protection measures were taken without hampering the foilage, flowers and fruits. Evaluation of the lines was done based on the descriptor list prepared by IBPGR (1983) (Table 3).

Chilli lines having ornamental value were selected based on visual observation and planted again during January-April 1989. The selected lines were CA 352, CA 458, CA 459, CA 470, CA 473, CA 474, CA 476, CA 477, CA 479-1, CA 479-2, CA 481, CA 482-1, CA 482-2, CA 483, CA 486-1, CA 486-2, CA 486-3, CA 486-4, CA 486-5, CA 488, CA 489, CA 493, CA 494, CA 497 and CA 504.

In addition to the normal KAU Package of practice recommendation, half teaspoon of vegetable mixture (7:10:5) was given to each plant once in a week, to make the plant grow vigorously.

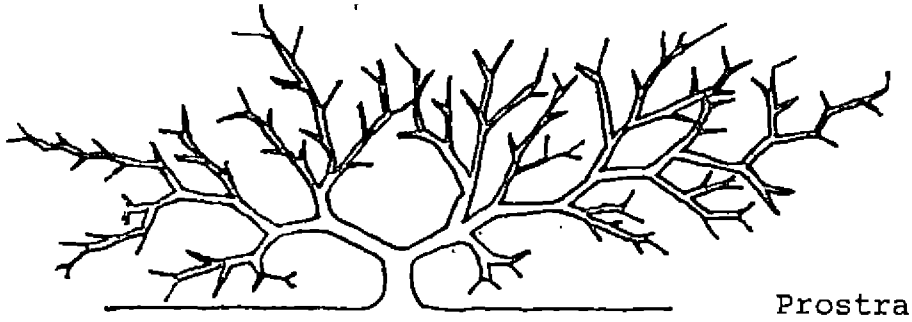
Observations were recorded as per descriptor list for capsicum (IBPGR, 1983). Beautiful plant types having dwarf stature and clustered fruiting habit were selected as ornamental types of chillies.

B) **Use of *Capsicum chinense* Jacq. and *Capsicum chacoense* Hunz. to develop ornamental chillies.**

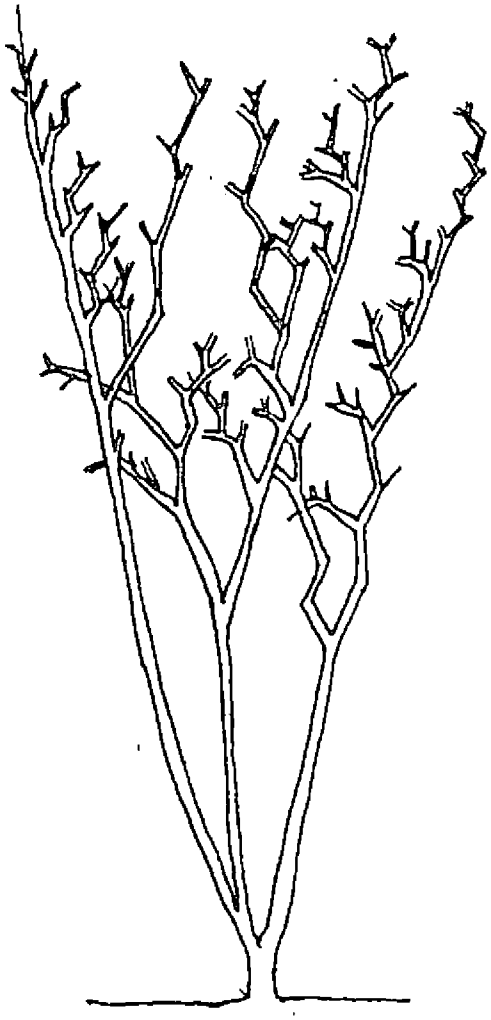
One line each of *Capsicum chinense* (CA 317); *Capsicum chacoense* (CA 306) and KAU cluster (*Capcicum annuum* L.) were grown. These lines were selected from germplasm maintained at the Department of Olericulture, College of Horticulture, K.A.U. Vellanikkara.

Table 3. Descriptor list of ornamental chillies.

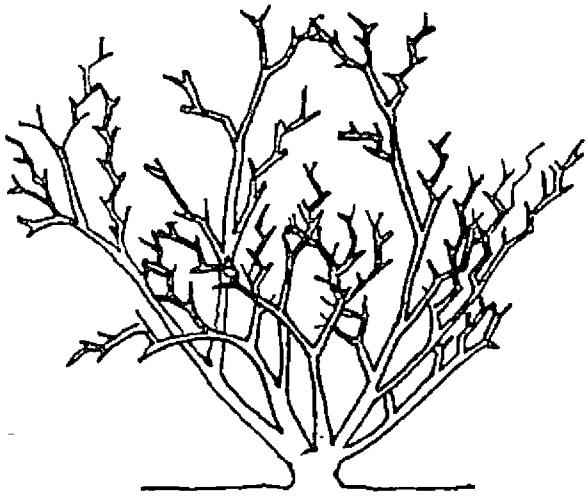
Date of sowing
Date of first harvest
Date of last harvest
Plant growth habit - Prostrate
Compact
Erect



Prostrate

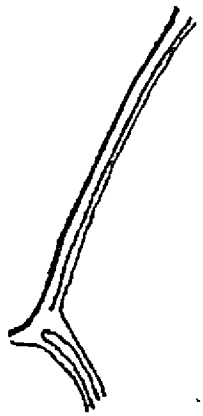


Erect

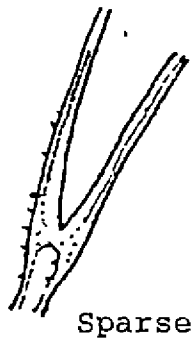


Compact

Stem pubescence - Glabrous
Sparse
Intermediate
Abundant

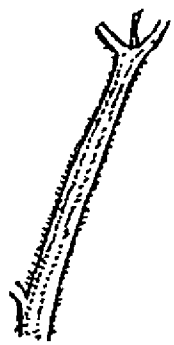


Glabrous



Sparse

Intermediate



Abundant

Stem colour - Green
Purple

Plant height - Measured in cm from soil level to the highest point

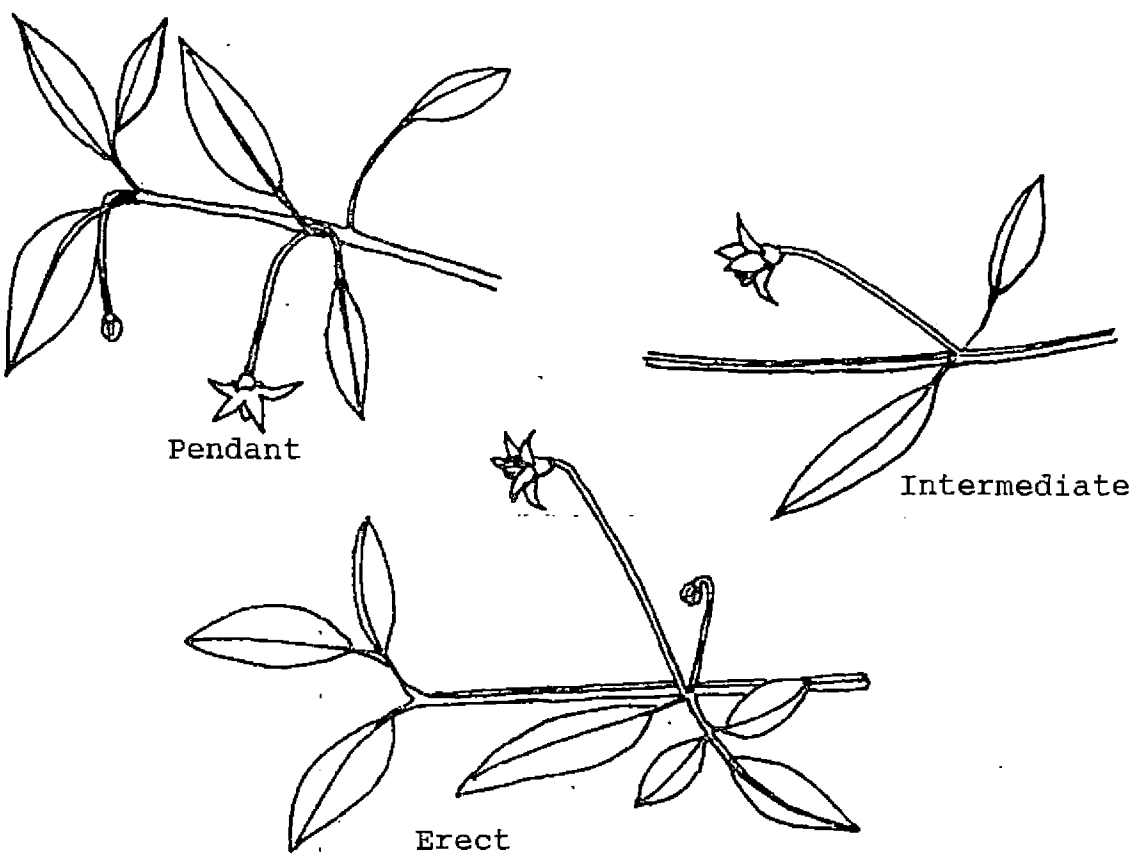
Plant width - Measured in cm at the widest point

Leaf pubescence - Glabrous
Sparse
Intermediate
Abundant

Glabrous Sparse Intermediate Abundant

NUmber of pedicels per axil -

Pedicel position at anthesis - Pendant
Intermediate
Erect

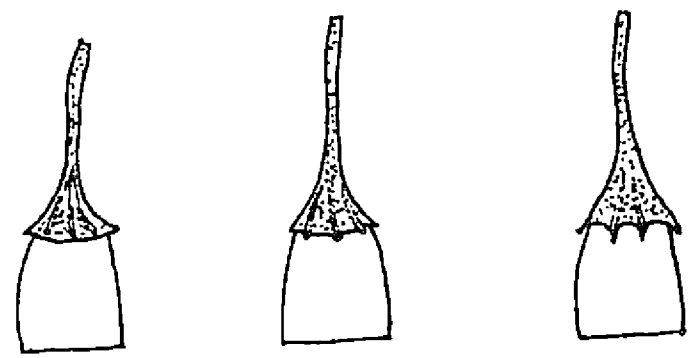


Days to flower - Number of days from sowing until 50% of plants have flowers.

Corolla colour - White
Green-white
Lavender
Blue
Violet
other

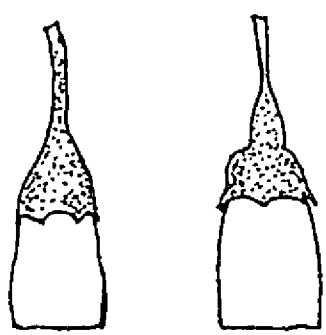
Corolla spot - Absent
Present

Calyx margin shape - Smooth
Intermediate
Dentate



Smooth Intermediate Dentate

Annular constriction at junction of calyx and peduncle - Absent
Present



Absent Present

Anther colour - Yellow
Pale blue
Blue
Purple
Other

Filament colour - White
Blue

Fruit position - Declining
Intermediate
Erect

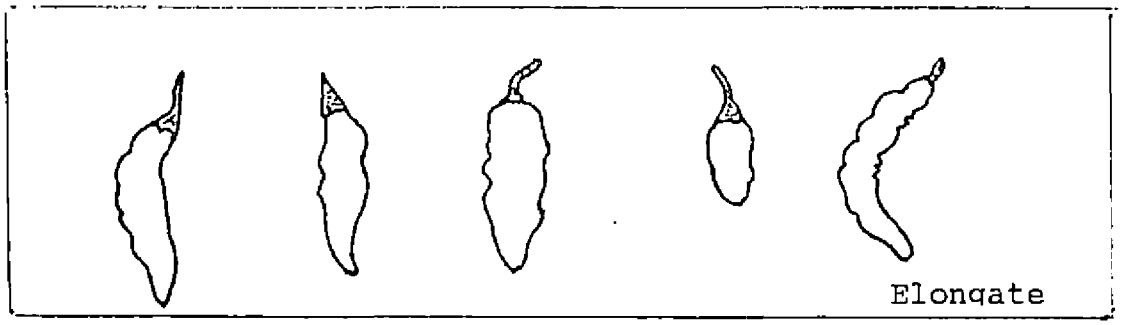
Fruit colour in immature stage - Green
Yellow
Orange
Red
Purple
Brown
Other

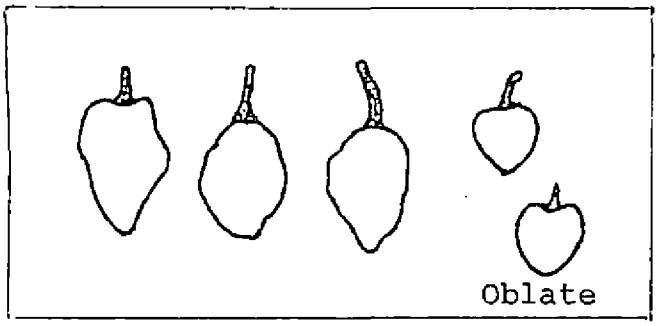
Fruit colour in mature stage - Green
Yellow
Orange
Red
Purple
Brown
Black
Other

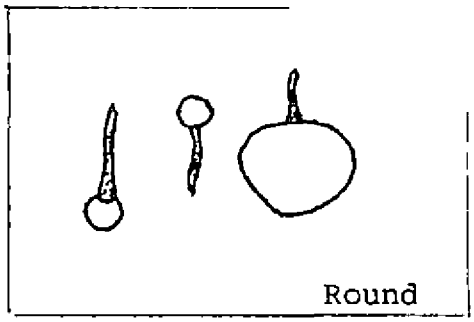
Days to fruiting - Number of days from sowing until 50% of the plants have mature fruits.

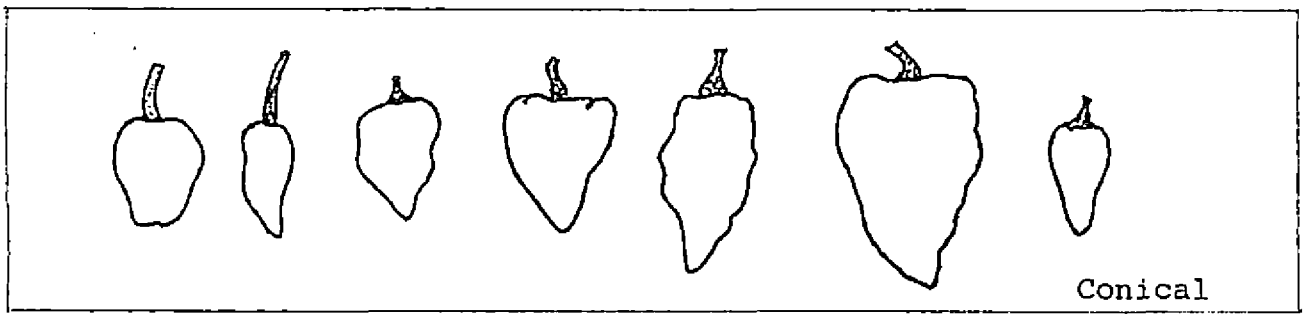
Fruit length -

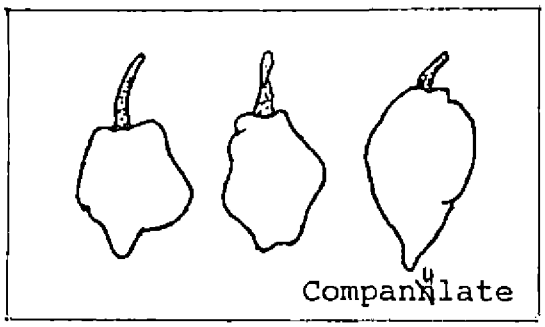
Fruit shape - Elongate
Oblate
Round
Conical
Companulate
Bell or Blocky

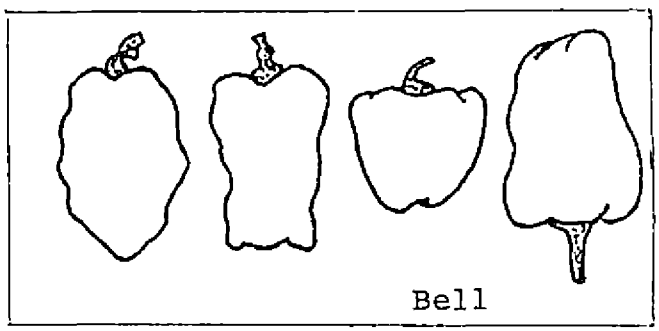

Elongate


Oblate

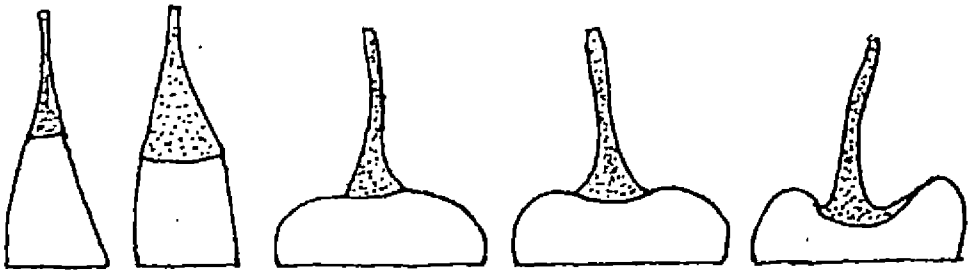

Round


Conical

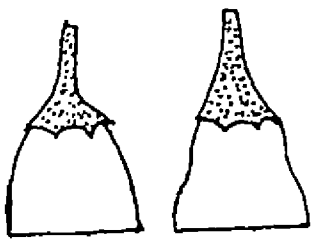

Compannlate


Bell

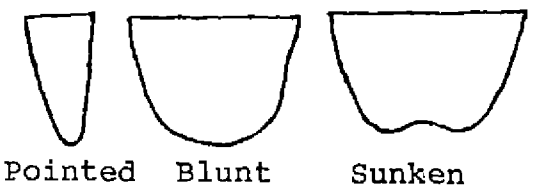
Fruit shape at peduncle attachment - Acute
Obtuse
Truncate
Cordate
Lobate



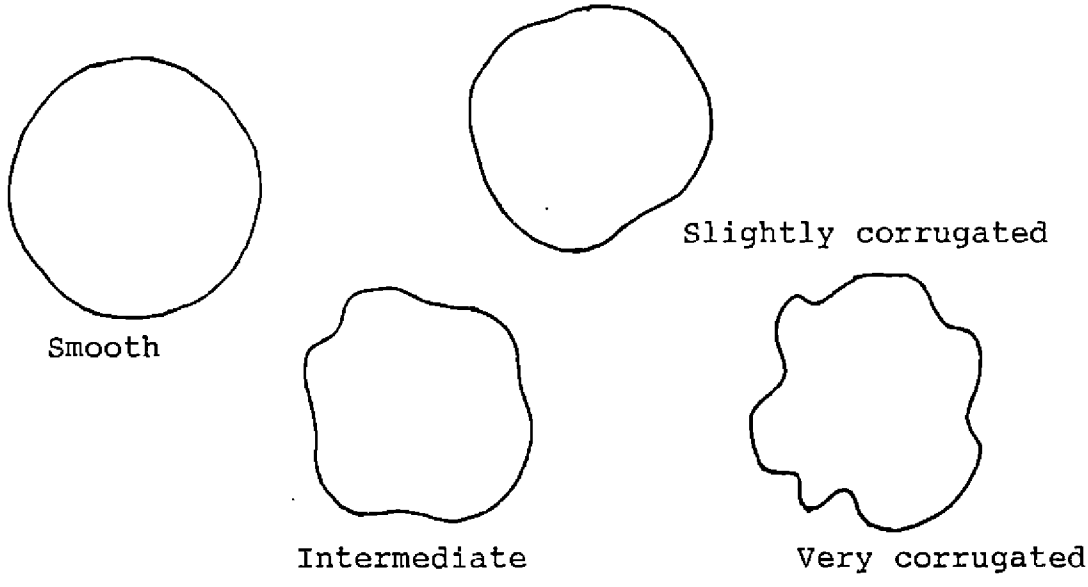
Neck at base of fruit - Absent
Present



Fruit shape at blossom end - Pointed
Blunt
Sunken



Fruit cross - Sectional corrugation - Smooth
Slightly corrugated
Intermediate
Very corrugated



Fruit width - Maximum fruit width (cm)

Fruit weight (g)

Fruit persistence - Deciduous
Persistent

Seed colour - Straw colour
Dark brown

The above three species were grown in pots for hybridization. Hybridization was done during August-September 1988. *Capsicum annuum* was used as female parent and the other two species as male parents. At the same time selfing of the lines were also done.

Procedure for hybridization

The time of flower opening and anther dehiscence were between 7 to 9.30 AM and hence crossing was done during this time interval.

Selfing

The well developed flower buds which would open next day were selected and covered with butter paper bags during the evening prior to opening and labelled. The bags were allowed to remain for about three days and then removed.

Crossing

The well developed flower buds which would open the next day were selected and emasculated with the help of a needle in the evening of the day prior to crossing. The emasculated buds were covered using butter paper bags. The flower buds from male parent were also protected to avoid contamination with foreign pollen grains. Pollination was performed in the very next day of emasculation. Pollinated

flowers were again covered and labelled. The bags were removed after about three days. About 250 crosses were made. Following observations were made after making crosses.

1. Percentage of fruit set in hybrids and in maternal parent (A).
2. Average number of seeds/fruit (B)
3. Percentage of germination in seeds from fruits of hybrid and maternal parent (C)
4. Percentage of seedling survival in hybrid plant and in maternal parent (D)

Crossability index was calculated (Rao, 1979) as

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

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

C = Crosses s = selfs

C. Evaluation of Interspecific F_1s

The materials for the study comprised of three parental species and their two F_1 hybrids as detailed below.

Parental lines *Capsicum annuum* L.(KAU cluster).
Capsicum chinense Jacq. (CA 317)
Capsicum chacoense Hunz. (CA 306)

F_1 hybrids *Capsicum annuum x Capsicum chinense*
Capsicum annuum x Capsicum chacoense

Five plants were grown under each during January-April 1989.

Morphological and cytogenetical description of parental species and interspecific F_1 hybrids were made.

1. **Morphological description**

Plant and fruit characters were recorded based on descriptor list prepared by IBPGR (1983).

2. **Cytogenetical description**

a) **Pollen studies**

POllen studies were carried out in all the three species and their hybrids. Fertility was assessed on the basis of stainability of pollen grains in acetocarmine-glycerine mixture. Pollen grains were extracted from anthers just before anthesis using a sharp needle, stained in a drop of acetocarmine-glycerine mixture on a slide and observed under a microscope. Pollen grains which were stained, were counted as fertile. Pollen fertility was calculated after observing about 500 pollen grains.

Selfing was done inntwo interspecific F_1 hybrids to confirm pollen sterility or fertility.

b) **Meiotic analysis**

Pollen mother cells were used for meiotic analysis. The flower buds of suitable size were fixed in

Carnoyis fluid (1 acetic acid: 3 chloroform: 6 absolute alcohol). The best time of fixing flower buds was found between 8.45 and 9.00 A.M. The fixed flower buds were kept for 24 to 48 hrs. After 48 hrs, the anthers were kept in a drop of 1% acetocarmine on the slide and squashed gently to facilitate the separation of cells. After putting the cover glass, the slide was slightly warmed, pressed between the folds of blotting paper and chromosomes were observed under the microscope for number and abnormalities, if any.

Results

RESULTS

Data collected in the two sets of experiments were analysed and are presented below.

A. Evaluation of ornamental chillies and their classification

The collected ornamental chillies were evaluated and classified based on four different key characters.

1. Growth habit
2. Flower characters
3. Fruit position and colour
4. Fruit shape

1. Growth habit

Based on growth habit, the ornamental chillies were divided into three groups, prostrate, compact and erect. Lines with prostrate growth habit were further divided into three based on stem pubescence and stem colour. The line CA 352 had green stem with intermediate pubescence. Lines CA 455, CA 473, CA 486-1, CA 486-2, CA 486-3, CA 486-4 and CA 486-5 had green stem with sparse pubescence. Purple stem with abundant pubescence was observed in CA 477.

Lines with erect growth habit were divided into five different types based on stem colour and pubescence.

Lines CA 459, CA 460, CA 462, CA 482-1, CA 485, CA 490, CA 496, CA 500, CA 502, CA 503-1, CA 503-2 and CA 505 had erect growth habit with green stem and sparse pubescence. Erect growth habit with purple coloured stem and sparse pubescence were observed in lines CA 482-2 and CA 491. Lines CA 469, CA 492, CA 495 and CA 501 had erect growth habit, green stem and intermediate pubescence. Lines CA 471, CA 480, CA 484, CA 487, CA 499, CA 506 and CA 507 had erect growth habit with green stem and abundant pubescence. The line CA 497 was similar to above lines except for purple stem.

Compact growth habit was again divided into five based on stem colour and pubescence. Compact growth, green stem and sparse pubescence were observed in CA 456, CA 457, CA 463, CA 468, CA 474, CA 476, CA 489 and CA 504. Lines CA 458, CA 464, CA 467 and CA 488 had compact growth, green stem and abundant pubescence. Compact growth, green stem and intermediate pubescence were observed in CA 461, CA 466 CA 475, CA 479-1, CA 479-2, CA 481, CA 483, CA 493 and CA 498. Lines with compact growth and glabrous nature were divided into two - CA 470 had green stem and CA 494, purple stem.

2. **Flower characters**

Based on pedicel position at anthesis, the collected ornamental chillies were divided into three, erect,

intermediate and pendant. Erect flower types were further partitioned based on corolla colour and anther colour. Based on corolla colour, erect flower types were divided into five categories. Lines with yellow corolla were of two types, one with green anther and another with purple anther. CA 495 had erect flowers with yellow corolla and green anthers. CA 500 had erect flowers with yellow corolla and purple anthers. Erect flower types with white corolla were of three different types. CA 352, CA 455, CA 458, CA 459, CA 460, CA 468, CA 474, CA 476, CA 477, CA 479-1, CA 481, CA 486-3, CA 488, CA 493, CA 496 and CA 504 had erect flowers with white corolla and pale blue anthers. CA 462, CA 463, CA 483, CA 486-1 and CA 489 had erect flowers with white corolla and green anthers. CA 502 had erect flowers with white corolla and yellow anthers. CA 466 had violet corolla and purple anthers and CA 470 had purple corolla and purple anthers. Greenish white corolla types coming under erect flowers were of three types. CA 490 had greenish white corolla and purple anthers. CA 498 and CA 492 had yellow anthers and CA 501 had green anthers.

Lines with flowers of intermediate position were partitioned into seven groups. CA 456 and CA 473 had intermediate flowers with white corolla and green anthers. CA 461, CA 469, CA 479-2 and CA 491 had white corolla and pale blue anthers. CA 485 and CA 499 had purple anthers and CA 457, yellow anthers. Lines with intermediate

flowers with violet corolla were divided into two. CA 494 had purple anthers and CA 497 had green anthers. CA 503-1 and CA 503-2 had intermediate flowers with greenish-white corolla and yellow anthers.

Pendant flower types were partitioned into five groups. White flowered lines with pale blue anthers were CA 464, CA 467, CA 471, CA 475, CA 480, CA 484, CA 486-2, CA 486-4, CA 486-5 and CA 507, CA 487 and CA 506 had white corolla and green anthers. CA 505 had white corolla and purple anthers. CA 482-1 had pendant flowers with greenish white corolla and green anthers. Pendant flowers with violet corolla and purple anthers were observed in CA 482-2.

3. **Fruit position and colour**

Based on fruit position, the chillies were divided into erect, declining and pendant.

Erect fruited types were further partitioned into five, based on fruit colour at immature and mature stages. CA 352, CA 474, CA 476 and CA 481 were erect fruited types which turn from yellow to red at maturity. Lines CA 456, CA 457, CA 458, CA 459, CA 460, CA 463, CA 473, CA 486-1, CA 495, CA 496, CA 501, CA 502, CA 503-1, CA 503-2 and CA 504 had erect fruits changing from green to red. CA 462, CA 468, CA 490, CA 498 and CA 500 had erect fruits,

green at immature stage and orange at maturity. CA 455, CA 479-1, CA 483, CA 485, CA 486-3, CA 488, CA 489 and CA 493 had erect fruits turning from cream to red at maturity. CA 466, CA 470, CA 477, CA 491 and CA 497 changed from purple to red on maturity.

Declining fruits were divided into four groups. CA 461, CA 467, CA 469, CA 471, CA 479-2, CA 480, CA 482-1 CA 484, CA 486-2, CA 486-5, CA 487, CA 492, CA 499, CA 505, CA 506 and CA 507 had declining fruits which turn from green to red. CA 475 had yellow at immature stage and red at maturity. CA 482 and CA 494 had purple immature fruits which turn to red at maturity. CA 486-4 was a declining fruit type which turned from cream to red.

A single line CA 464 had intermediate fruit position and fruits turned from green to red.

4. Fruit shape

Based on fruit shape, the collected ornamental chillies were divided into five different groups, round, elongate, oblate, conical and bell shaped.

Round fruited types were further partitioned based on fruit shape at peduncle attachment and blossom end. CA 352, CA 455, CA 470, CA 485, CA 486-3, CA 486-4, CA 486-5, CA 489, CA 503-1 and CA 504 were round fruited lines with truncate shape at peduncle attachment and blunt shape at blossom end.

Elongate fruited lines were divided into four types based on fruit shape at peduncle attachment and blossom end. CA 456, CA 468, CA 486-2, CA 495, CA 498, CA 500 and CA 501 had obtuse shape at peduncle attachment and with blossom end pointed. CA 502 had obtuse shape at peduncle attachment and blunt shape at blossom end. CA 457 had truncate shape at peduncle attachment and pointed shape at blossom end. Lines with elongate fruits with acute shape at peduncle attachment and pointed tip at blossom end were CA 467, CA 469, CA 475 and CA 490.

Oblate fruited lines were of two types, CA 458 had oblate shaped fruits with obtuse shape at peduncle attachment and pointed shape at blossom end. CA 466, CA 476 and CA 486-1 had oblate fruits with truncate shape at peduncle attachment and blunt shape at blossom end.

Conical shape fruited lines were partitioned into six groups. CA 459, CA 464, CA 493, CA 496, CA 497 and CA 503-2 were conical fruited lines with ~~turncate~~ truncate shape at peduncle attachment and blunt at blossom end. CA 460, CA 461, CA 462, CA 463, CA 471, CA 481, CA 484, CA 487, CA 488, CA 491, CA 499, CA 506 and CA 507 had conical fruits with truncate shape at peduncle attachment and pointed at blossom end. CA 473, CA 474 and CA 483 had acute shape at peduncle attachment and pointed shape at blossom end, CA 477 had acute shape at peduncle attachment

and blunt blossom end. CA 479-1 and CA 479-2 had conical fruits with obtuse shape at peduncle attachment and pointed at blossom end. CA 480 and CA 494 had lines with conical fruits with obtuse shape at peduncle attachment and blunt blossom end.

Bell shaped fruits were of two types. CA 482-1 and CA 482-2 had bell shaped fruits with truncate shape at peduncle attachment and with sunken blossom end. CA 492 and CA 505 had bell shaped fruits with truncate shape at peduncle attachment and blunt blossom end.

Morphological description and quantitative characteristics of collected ornamental chillies are summarised in Tables (4 and 5) respectively.

Dwarf ornamental chilli lines were selected based on visual observation from the initial evaluation trial. These lines were further evaluated during January-April, 1989 and their morphological description and quantitative characteristics are summarised in Tables (6 and 7) respectively. When grown during the following season, a few lines segregated and they were given another extended number. Differences observed from the previous season are described below.

CA 459-2 had compact growth habit, green anther, obtuse fruit shape at peduncle attachment, pointed shape at blossom end and fruit cross sectional corrugation was intermediate.

Table 4. Morphological description of ornamental chillies

Accession Number	Plant growth habit	Stem pubes-cence	Stem colour	Leaf pubes-cence	Pedicel position at anth-esis	Corolla colour	Corolla spot	Anther colour	Fila-ment colour	Calyx margin shape
CA 352	Pr	I	Gr	I	E	W	A	PB	W	S
CA 455	Pr	Sp	Gr	Sp	E	W	A	PB	W	S
CA 456	C	Sp	Gr	I	I	W	A	Gr	W	D
CA 457	C	Sp	Gr	I	I	W	A	Y	W	I
CA 458	C	Ab	Gr	I	E	W	A	PB	W	I
CA 459	E	Sp	Gr	I	E	W	A	PB	W	D
CA 460	E	Sp	Gr	I	E	W	A	PB	W	D
CA 461	C	I	Gr	I	I	W	A	PB	B	D
CA 462	E	Sp	Gr	Sp	E	W	A	Gr	W	D
CA 463	C	Sp	Gr	Sp	E	W	A	Gr	W	S
CA 464	C	Ab	Gr	G	Pd	W	A	PB	B	S
CA 466	C	I	Gr	I	E	V	A	Pl	B	S
CA 467	C	Ab	Gr	Sp	Pd	W	A	PB	W	I
CA 468	C	Sp	Gr	G	E	W	A	PB	W	D
CA 469	E	I	Gr	Sp	I	W	A	PB	W	I
CA 470	C	G	Gr	G	E	PL	A	Pl	B	D
CA 471	E	Ab	Gr	Ab	Pd	W	A	PB	W	I
CA 473	Pr	Sp	Gr	Sp	I	W	A	Gr	W	S

(contd.)

Table 4. (contd.)

Accession Number	Plant growth habit	Stem pubes-cence	Stem colour	Leaf pubes-cence	Pedicel position at anthesis	Corolla colour	Corolla spot	Anther colour	Fila-ment colour	Calyx margin shape
CA 474	C	Sp	Gr	Sp	E	W	A	PB	W	I
CA 475	C	I	Gr	I	Pd	W	A	PB	W	I
CA 476	C	Sp	Gr	Sp	E	W	A	PB	W	D
CA 477	Pr	Ab	Pl	Sp	E	W	A	PB	W	D
CA 479-1	C	I	Gr	Ab	E	W	A	PB	W	S
CA 479-2	C	I	Gr	Ab	I	W	A	PB	W	I
CA 480	E	Ab	Gr	I	Pd	W	A	PB	W	I
CA 481	C	I	Gr	Sp	E	W	A	PB	W	I
CA 482-1	E	Sp	Gr	I	Pd	GW	A	Gr	B	S
CA 482-2	E	Sp	Pl	I	Pd	V	A	Pl	B	S
CA 483	C	I	Gr	G	E	W	A	Gr	W	I
CA 484	E	Ab	Gr	Sp	Pd	W	A	PB	W	I
CA 485	E	Sp	Gr	I	I	W	A	Pl	W	I
CA 486-1	Pr	Sp	Gr	Sp	E	W	A	Gr	W	D
CA 486-2	Pr	Sp	Gr	Sp	Pd	W	A	PB	W	D
CA 486-3	Pr	Sp	Gr	Sp	E	W	A	PB	W	D
CA 486-4	Pr	Sp	Gr	Sp	Pd	W	A	PB	W	I
CA 486-5	Pr	Sp	Gr	Sp	Pd	W	A	PB	W	D
CA 487	E	Ab	Gr	Sp	Pd	W	A	Gr	W	I
CA 488	C	Ab	Gr	I	E	W	A	PB	W	I
CA 489	C	Sp	Gr	Sp	E	W	A	Gr	W	I
CA 490	E	Sp	Gr	Ab	E	GW	A	Pl	B	I

(contd.)

Table 4. (contd.)

Accession Number	Plant growth habit	Stem pubes-cence	Stem colour	Leaf pubes-cence	Pedicel position at anthesis	Corolla colour	Corolla spot	Anther colour	Fila-ment colour	Calyx margin shape
CA 491	E	Sp	Pl	I	I	W	A	PB	B	I
CA 492	E	I	Gr	Sp	E	GW	A	Y	W	D
CA 493	C	I	Gr	Sp	E	W	A	PB	W	I
CA 494	C	G	Pl	G	I	V	A	Pl	B	S
CA 495	E	I	Gr	I	E	Y	P	Gr	B	I
CA 496	E	Sp	Gr	G	E	W	A	PB	W	D
CA 497	E	Ab	Pl	G	I	V	A	Gr	B	D
CA 498	C	I	Gr	Ab	E	GW	P	Y	W	D
CA 499	E	Ab	Gr	I	I	W	A	Pl	W	I
CA 500	E	Sp	Gr	I	E	Y	A	Pl	B	I
CA 501	E	I	Gr	I	E	GW	A	Gr	B	I
CA 502	E	Sp	Gr	Sp	E	W	P	Y	W	D
CA 503-1	E	Sp	Gr	Ab	I	GW	p	y	w	D
CA 503-2	E	Sp	Gr	Ab	I	GW	P	Y	W	D
CA 504	C	Sp	Gr	G	E	W	A	PB	W	S
CA 505	E	Sp	Gr	I	Pd	W	A	Pl	W	I
CA 506	E	Ab	Gr	Ab	Pd	W	A	Gr	W	S
CA 507	E	Ab	Gr	Sp	Pd	W	A	PB	W	D

Table 4. (contd.) Morphological description of ornamental chillies

Accession Number	Annular constriction	Fruit position	Immature fruit colour	Mature fruit colour	Fruit shape	Fruit shape at peduncle attachment	Neck	Fruit shape at blossom end	Fruit cross-sectional corrugation	Fruit persistence	Seed colour
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
CA 352	A	E	Y	R	Rd	T	A	Bt	S	Ps	St
CA 455	A	E	Cr	R	Rd	T	A	Bt	S	Ps	St
CA 456	A	E	Gr	R	El	Ot	A	Pt	Sc	Ps	St
CA 457	A	E	Gr	R	El	T	A	Pt	I	Ps	St
CA 458	A	E	Gr	R	Ol	Ot	A	Pt	S	Ps	St
CA 459	A	E	Gr	R	Co	T	A	Bt	Sc	Ps	St
CA 460	A	E	Gr	R	Co	T	A	Pt	S	Ps	St
CA 461	A	Dc	Gr	R	Co	T	A	Pt	Sc	Ps	St
CA 462	A	E	Gr	O	Co	T	A	Pt	S	Ps	St
CA 463	A	E	Gr	R	Co	T	A	Pt	S	Ps	St
CA 464	A	I	Gr	R	Co	T	A	Bt	Sc	Ps	St
CA 466	A	E	Pl	R	Ol	T	A	Bt	S	Ps	St
CA 467	A	Dc	Gr	R	El	Ac	A	Pt	Sc	Ps	St
CA 468	A	E	Gr	O	El	Ot	A	Pt	I	Ps	St
CA 469	A	Dc	Gr	R	El	Ac	A	Pt	Sc	Ps	St
CA 470	A	E	Pl	R	Rd	T	A	Bt	S	Ps	St
CA 471	A	Dc	Gr	R	Co	T	A	Pt	I	Ps	St
CA 473	A	E	Gr	R	Co	Ac	A	Pt	S	Ps	St
CA 474	A	E	Y	R	Co	Ac	A	Pt	Sc	Ps	St

(contd.)

Table 4. (contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
CA 475	A	Dc	Y	R	El	Ac	A	Pt	Sc	Ps	St
CA 476	A	E	Y	R	Ol	T	A	Bt	S	Ps	St
CA 477	A	E	Pl	R	Co	Ac	A	Bt	Sc	Ps	St
CA 479-1	A	E	Cr	R	Co	Ot	A	Pt	S	Ps	DB
CA 479-2	A	Dc	Gr	R	Co	Ot	A	Pt	S	Ps	DB
CA 480	A	Dc	Gr	R	Co	Ot	A	Bt	Sc	Ps	St
CA 481	A	E	Y	R	Co	T	A	Pt	I	Ps	St
CA 482-1	A	Dc	Gr	R	Be	T	A	Sk	Vc	Ps	St
CA 482-2	A	Dc	Pl	R	Be	T	A	Sk	Vc	Ps	St
CA 483	A	E	Cr	R	Co	Ac	A	Pt	Sc	Ps	DB
CA 484	P	Dc	Gr	R	Co	T	A	Pt	Sc	Ps	St
CA 485	A	E	Cr	R	Rd	T	A	Bt	S	Ps	St
CA 486-1	A	E	Gr	R	Ol	T	A	Bt	S	Ps	DB
CA 486-2	A	Dc	Gr	R	El	Ot	A	Pt	Sc	Ps	DB
CA 486-3	A	E	Cr	R	Rd	T	A	Bt	S	Ps	DB
CA 486-4	A	Dc	Cr	R	Rd	T	A	Bt	S	Ps	DB
CA 486-5	A	Dc	Gr	R	Rd	T	A	Bt	S	Ps	DB
CA 487	A	Dc	Gr	R	Co	T	A	Pt	Sc	Ps	St
CA 488	A	E	Cr	R	Co	T	A	Pt	S	Ps	St
CA 489	A	E	Cr	R	Rd	T	A	Bt	S	Ps	DB
CA 490	A	E	Gr	O	El	Ac	A	Pt	Sc	Ps	St
CA 491	A	E	Pl	R	Co	T	A	Pt	S	Ps	St
CA 492	A	Dc	Gr	R	Be	T	A	Bt	I	Ps	St
CA 493	A	E	Cr	R	Co	T	A	Bt	Sc	Ps	DB

(contd.)

Table 4. (contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
CA 494	A	Dc	Pl	R	Co	Ot	A	Bt	Sc	Ps	St
CA 495	A	E	Gr	R	El	Ot	A	Pt	Sc	Ps	St
CA 496	A	E	Gr	R	Co	T	A	Bt	S	Ps	St
CA 497	A	E	Pl	R	Co	T	A	Bt	S	Ps	St
CA 498	A	E	Gr	O	El	Ot	A	Pt	S	Ps	St
CA 499	A	Dc	Gr	R	Co	T	A	Pt	I	Ps	St
CA 500	A	E	Gr	O	El	Ot	P	Pt	Sc	Ps	St
CA 501	P	E	Gr	R	El	Ot	A	Pt	Sc	Ps	St
CA 502	A	E	Gr	R	El	Ot	A	Bt	S	Ps	St
CA 503-1	A	E	Gr	R	Rd	T	A	Bt	S	Ps	St
CA 503-2	A	E	Gr	R	Co	T	A	Bt	S	Ps	St
CA 504	A	E	Gr	R	Rd	T	A	Bt	S	Ps	St
CA 505	A	Dc	Gr	R	Be	T	A	Bt	Sc	Ps	St
CA 506	A	Dc	Gr	R	Co	T	A	Pt	S	Ps	St
CA 507	A	Dc	Gr	R	Co	T	A	Pt	Sc	Ps	St

A - Absent
Ab - Abundant
Ac - Acute
B - Blue
Be - Bell
Bt - Blunt
C - Compact
Cr - Cream
Co - Conical
D - Dentate
DB - Dark Brown
Dc - Declining
E - Erect
El - Elongate
G - Glabrous
Gr - Green
GW - Green-white
I - Intermediate
O - Ornage
Ol - Oblate
Ot - Obtuse
P - Present
Pd - Pendant
PB - Pale Blue
Pl - Purple
Pr - Prostrate
Ps - Persistent
Pt - Pointed
R - Red
Rd - Round
S - Smooth
Sc - Slightly corrugated
Sp - Sparse
Sk - Sunken
St - Straw
T - Truncate
V - Violet
Vc - Very corrugated
W - White
Y - Yellow

Table 5. Quantitative characteristics of ornamental chillies

Accession Number	Plant height (cm)	Plant spread (cm)	Days to flower	Pedicels/ axil	Days to fruiting	Days to first harvest	Days to last harvest	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
CA 352	36.0	52.5	52	1-2	63	110	162	1.0	1.2	2.3
CA 455	38.0	37.0	56	1-2	65	113	205	0.7	1.0	1.0
CA 456	62.1	41.5	92	1	109	153	162	7.0	1.0	3.0
CA 457	68.0	37.5	57	1	62	110	162	4.5	1.0	2.3
CA 458	49.0	65.0	57	1	63	146	161	1.3	0.7	1.8
CA 459	48.0	65.0	57	1	62	146	161	3.0	1.8	3.0
CA 460	75.4	41.0	59	1-2	65	113	162	2.5	1.0	2.0
CA 461	63.3	60.0	51	1	59	146	162	5.0	1.3	5.0
CA 462	82.8	47.5	58	1	75	146	161	2.7	2.0	2.5
CA 463	59.0	40.0	102	1	108	153	161	3.5	1.5	1.9
CA 464	69.0	34.5	60	1	66	138	162	4.0	2.0	8.0
CA 466	59.5	50.0	58	1	70	121	205	1.0	1.0	1.3
CA 467	63.2	55.0	55	1	60	110	153	5.0	1.0	0.5
CA 468	73.0	52.5	58	1	65	110	162	7.0	1.0	2.3
CA 469	79.0	65.0	57	1	62	110	162	4.0	0.9	2.0
CA 470	50.5	52.5	60	1	69	153	205	0.7	1.2	1.0
CA 471	71.9	51.5	60	1	69	110	161	3.5	1.5	3.0
CA 473	36.3	38.5	62	1	53	110	161	2.5	1.3	2.5
CA 474	21.7	18.0	55	1	63	110	205	2.0	1.0	1.5
CA 475	58.9	79.5	55	1	62	110	162	5.0	1.0	1.8

(contd.)

Table 5. (contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
CA 476	50.7	41.5	60	1-5	63	113	205	1.7	1.9	1.0
CA 477	38.3	45.0	55	1-2	62	110	205	1.3	1.0	1.0
CA 479-1	31.5	51.5	52	1-2	57	110	205	2.0	1.0	2.0
CA 479-2	42.0	51.5	52	1	57	110	205	1.0	1.0	1.5
CA 480	86.0	56.5	77	1	84	156	162	5.0	1.2	1.0
CA 481	34.7	37.0	57	2-4	62	110	205	3.0	1.0	1.5
CA 482-1	79.0	68.5	84	1-2	90	152	162	2.5	2.0	5.0
CA 482-2	81.0	68.7	86	1-2	93	152	162	2.5	2.0	5.0
CA 483	24.8	29.0	57	1-2	62	110	205	2.8	1.2	2.7
CA 484	79.6	51.0	58	1	72	148	162	3.0	1.3	3.0
CA 485	51.0	32.5	61	2-4	65	146	161	1.0	1.0	1.4
CA 486-1	43.0	48.5	52	1	62	110	205	1.0	1.0	1.0
CA 486-2	52.0	48.2	52	2	63	110	205	2.8	0.8	1.0
CA 486-3	33.0	48.8	52	1-2	63	110	205	1.0	0.8	1.0
CA 486-4	38.5	48.5	53	1	62	110	205	1.0	1.0	1.0
CA 486-5	19.0	48.5	52	1	62	110	205	1.5	1.0	1.0
CA 487	65.5	45.0	92	1	126	161	205	2.7	1.2	0.6
CA 488	31.0	39.5	52	1-2	63	110	205	3.0	1.3	2.9
CA 489	45.3	39.5	58	1-2	62	110	205	2.1	1.5	2.0
CA 490	91.5	50.0	85	1	97	153	162	2.9	0.5	0.1
CA 491	70.7	52.5	72	1	89	146	161	2.7	1.0	1.8
CA 492	72.6	43.5	90	1-3	93	125	162	3.0	1.5	3.5
CA 493	39.0	46.0	57	1-5	62	110	179	1.2	1.5	1.0

(contd.)

Table 5. (contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
CA 494	49.7	47.0	80	1	89	148	162	1.7	1.1	1.0
CA 495	90.3	51.5	90	1	97	128	161	2.5	0.5	0.9
CA 496	68.7	38.5	69	1	74	132	162	2.5	1.5	2.5
CA 497	63.3	56.0	79	1	87	148	162	2.5	1.8	2.3
CA 498	50.7	45.0	104	1-3	109	153	162	1.6	0.6	1.0
CA 499	103.4	51.5	77	1-2	84	121	162	4.0	1.4	0.9
CA 500	84.2	58.5	92	1	106	146	161	2.5	0.7	1.3
CA 501	102.4	45.0	102	1	108	153	161	3.2	0.7	1.0
CA 502	63.0	37.5	101	1	118	146	161	1.0	0.3	0.3
CA 503-1	82.0	45.0	84	1-2	93	128	162	1.2	1.2	1.2
CA 503-2	77.5	45.0	84	1-2	93	128	162	1.5	0.8	0.8
CA 504	51.2	41.0	69	1	75	113	161	0.7	0.9	1.0
CA 505	86.7	56.0	57	1-2	77	153	162	1.5	1.5	2.0
CA 506	102.0	92.5	55	1-2	65	113	162	2.5	1.7	1.0
CA 507	96.0	71.0	67	1	74	153	162	4.2	1.5	3.8

Table 6. Morphological description of ornamental chillies

Accession Number	Plant growth habit	Stem pubes-cence	Stem colour	Leaf pubes-cence	Pedicel position at anthesis	Corolla colour	Corolla spot	Anther colour	Fila-ment colour	Calyx margin shape
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
CA 352-1	Pr	I	Gr	I	E	W	A	PB	W	S
CA 352-2	C	I	Gr	I	I	W	A	PB	W	S
CA 458	C	Ab	Gr	I	E	W	A	PB	W	I
CA 459-1	E	Sp	Gr	I	E	W	A	PB	W	D
CA 459-2	C	Sp	Gr	I	E	W	A	Gr	W	D
CA 470	C	G	Gr	G	E	Pl	A	Pl	B	D
CA 473	Pr	Sp	Gr	Sp	I	W	A	Gr	W	S
CA 474	C	Sp	Gr	Sp	E	W	A	PB	W	I
CA 476-1	C	Sp	Gr	Sp	E	W	A	PB	W	D
CA 476-2	C	Sp	Gr	Sp	E	W	A	PB	W	I
CA 477-1	Pr	Ab	Pl	Sp	E	W	A	PB	W	D
CA 477-2	Pr	Ab	Pl	Sp	E	V	A	Pl	B	D
CA 479-1a	C	I	Gr	Ab	E	W	A	PB	W	S
CA 479-1b	C	Sp	Gr	Sp	I	W	A	B	W	D
CA 479-2	C	I	Gr	Ab	I	W	A	PB	W	I
CA 481	C	I	Gr	Sp	E	W	A	PB	W	I
CA 482-1	E	Sp	Gr	I	Pd	GW	A	Gr	B	S
CA 482-2	E	Sp	Pl	I	Pd	V	A	Pl	B	S
CA 483-1	C	I	Gr	G	E	W	A	Gr	W	I
CA 483-2	C	Sp	Gr	Sp	E	W	A	Gr	W	I
CA 483-3	C	Sp	Gr	I	Pd	W	A	Gr	W	D

(cont

Table 6. (contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
CA 486-1	Pr	Sp	Gr	Sp	E	W	A	Gr	W	D
CA 486-2	Pr	Sp	Gr	Sp	Pd	W	A	PB	W	D
CA 486-3	Pr	Sp	Gr	Sp	E	W	A	PB	W	D
CA 486-4	Pr	Sp	Gr	Sp	Pd	W	A	PB	W	I
CA 486-5	Pr	Sp	Gr	Sp	Pd	W	A	PB	W	D
CA 488	C	Ab	Gr	I	E	W	A	PB	W	I
CA 489	C	Sp	Gr	Sp	E	W	A	Gr	W	I
CA 493	C	I	Gr	Sp	E	W	A	PB	W	I
CA 494	C	G	Pl	G	I	V	A	Pl	B	S
CA 497	E	Ab	Pl	G	I	V	A	Gr	B	D
CA 504	C	Sp	Gr	G	E	W	A	PB	W	S

Table 6. (Contd.) Morphological description of ornamental chillies

Accession Number	Annular constriction	Fruit position	Immature fruit colour	Mature fruit colour	Fruit shape	Fruit shape at peduncle attachment	Neck	Fruit shape at blossom end	Fruit cross sectional corrugation	Fruit persistence	Seed colour
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
CA 352-1	A	E	Y	R	Rd	T	A	Bt	S	Ps	St
CA 352-2	A	T	Y	R	Co	Ot	A	Pt	S	Ps	St
CA 458	A	E	Gr	R	Ol	Ot	A	Pt	S	Ps	St
CA 459-1	A	E	Gr	R	Co	T	A	Bt	Sc	Ps	St
CA 459-2	A	E	Gr	R	Co	Ot	A	Pt	I	Ps	St
CA 470	A	E	Pl	R	Rd	T	A	Bt	S	Ps	St
CA 473	A	E	Gr	R	Co	Ac	A	Pt	S	Ps	St
CA 474	A	E	Y	R	Co	AC	A	Pt	Sc	Ps	St
CA 476-1	A	E	Y	R	Ol	T	A	Bt	S	Ps	St
CA 476-2	A	E	Y	R	Co	Ot	A	Pt	I	Ps	St
CA 477-1	A	E	Pl	R	Co	Ac	A	Bt	Sc	Ps	St
CA 477-2	A	E	Pl	R	Ol	T	A	Bt	Sc	Ps	St
CA 479-1a	A	E	Cr	R	Co	Ot	A	Pt	S	Ps	DB
CA 479-1b	A	I	Cr	R	E1	Ot	A	Pt	S	Ps	DB
CA 479-2	A	Dc	Gr	R	Co	Ot	A	Pt	S	Ps	DB
CA 481	A	E	Y	R	Co	T	A	Pt	I	Ps	St
CA 482-1	A	Dc	Gr	R	Be	T	A	Sk	Vc	Ps	St
CA 482-2	A	Dc	P1	R	Be	T	A	Sk	Vc	Ps	St
CA 483-1	A	E	Cr	R	Co	Ac	A	Pt	Sc	Ps	DB

Table 6. (contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
CA 483-2	A	E	Cr	R	Co	T	A	Bt	Sc	PS	St
CA 483-3	A	Dc	Cr	R	Co	Ot	A	Pt	I	Ps	St
CA 486-1	A	E	Gr	R	Ol	T	A	Bt	S	Ps	DB
CA 486-2	A	Dc	Gr	R	El	Ot	A	Pt	Sc	PS	DB
CA 486-3	A	E	Cr	R	Rd	T	A	Bt	S	Ps	DB
CA 486-4	A	Dc	Cr	R	Rd	T	A	Bt	S	PS	DB
CA 486-5	A	Dc	Gr	R	Rd	T	A	Bt	S	PS	DB
CA 488	A	E	Cr	R	Co	T	A	Pt	S	PS	St
CA 489	A	E	Cr	R	Rd	T	A	Bt	S	Ps	DB
CA 493	A	E	Cr	R	Co	T	A	Bt	Sc	Ps	DB
CA 494	A	Dc	Pl	R	Co	Ot	A	Bt	SC	PS	St
CA 497	A	E	Pl	R	Co	T	A	Bt	S	Ps	St
CA 504	A	E	Gr	R	Rd	T	A	Bt	S	Ps	St

Table 7. Quantitative characteristics of ornamental chillies

Accession Number	Plant height (cm)	Plant Spread (cm)	Days to flower	Pedicels/ axil	Days to fruiting	Days to first harvest	Days to last harvest	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)
CA 352-1	27.0	32.0	76	1-2	87	126	137	1.0	1.2	2.3
CA 352-2	47.5	34.0	82	1	88	126	163	2.3	1.2	1.2
CA 458	27.9	21.0	78	1	87	132	150	1.8	1.0	0.9
CA 459-1	26.9	24.0	77	1	85	137	163	2.6	0.9	1.9
CA 459-2	54.0	23.0	80	1	85	126	163	5.1	2.3	7.4
CA 470	33.9	17.5	85	1	105	137	163	0.5	0.7	0.5
CA 473	27.1	29.5	85	1	90	126	166	2.0	0.8	0.8
CA 474	18.1	27.0	85	1	88	126	166	2.3	0.8	0.8
CA 476-1	33.6	33.0	85	2-6	89	126	150	1.2	1.2	0.9
CA 476-2	47.0	41.0	82	1	89	126	161	3.2	1.0	1.5
CA 477-1	28.7	30.0	77	1	87	126	166	2.7	0.7	1.6
CA 477-2	25.5	37.0	83	1	87	132	166	1.2	0.8	0.9
CA 479-1a	28.2	27.5	82	1-2	108	132	166	2.7	1.1	1.4
CA 479-1b	36.9	35.0	85	1-2	89	126	166	2.9	0.9	1.1
CA 479-2	26.5	32.0	75	1	91	126	160	2.5	1.2	1.9
CA 481	35.2	22.0	95	1-5	101	132	150	4.0	1.2	2.4
CA 482-1	62.9	45.0	120	1-2	130	142	163	2.0	2.0	5.0
CA 482-2	72.3	34.0	107	1-2	115	137	163	1.9	2.1	4.5
CA 483-1	29.7	30.0	80	1-2	85	126	160	2.2	1.0	0.8

(contd.)

Table 7. (contd.)

Accession Number	Plant height (cm)	Plant spread (cm)	Days to flower	Pedicels/ axil	Days to fruit-ing	Days to first harvest	Days to last harvest	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)
CA 483-2	39.8	43.0	80	1	86	132	160	1.6	1.0	1.5
CA 483-3	46.2	41.0	81	1	86	132	160	3.0	0.8	0.9
CA 486-1	32.0	46.0	79	1	86	126	163	1.0	0.7	0.6
CA 486-2	44.3	22.0	92	1-3	88	132	166	2.5	0.9	0.9
CA 486-3	44.3	32.0	94	1	99	137	166	1.7	1.1	2.0
CA 486-4	34.6	26.0	75	1-3	86	137	165	0.7	0.9	0.5
CA 486-5	24.5	18.0	94	1-4	104	137	165	0.3	0.5	0.2
CA 488	34.8	21.0	83	2-4	88	137	165	1.9	1.0	1.2
CA 489	33.5	31.0	82	1-2	91	137	166	1.0	0.9	1.1
CA 493	33.4	27.0	90	2-5	106	132	160	1.2	0.7	0.6
CA 494	24.0	25.0	101	1	105	142	166	1.7	1.1	2.5
CA 497	25.4	28.0	108	1-2	115	152	166	2.5	1.8	3.5
CA 504	25.5	21.0	104	1-2	110	137	166	0.7	0.4	0.2

CA 476-2 had dentate calyx margin, conical fruits with obtuse shape at peduncle attachment and pointed blossom end.

CA 477-2 had violet corolla, purple anther, blue filament, oblate fruit shape with truncate shape at peduncle attachment.

CA 479-1b had sparse stem and leaf pubescence. Pedicel position and fruit position were intermediate and fruit shape was elongate.

CA 486-2 had sparse stem and leaf pubescence, truncate fruit shape at peduncle attachment and blunt shape at blossom end. CA 486-3 had sparse stem pubescence and intermediate leaf pubescence. Pedicel position was intermediate and fruit position was declining. Peduncle attachment of fruit was obtuse and blossom end, pointed. They had straw coloured seeds.

Dwarf types which had clustered fruit habits and attractive fruit colour and shape were selected as ornamental chillies. They were CA 352-1, CA 473, CA 474, CA 476-1, CA 477-1, CA 479-1a, CA 479-2, CA 481, CA 483-1, CA 485, CA 486-1, CA 486-2, CA 486-4, CA 488, CA 489, CA 493 and CA 504. Brief descriptions of the selected lines are given below.

CA 352-1

Prostrate bushy pot plant growing to a height of 27.0 cm, with green leaves and erect fruits changing colour first yellow to orange and finally red. Susceptible to leaf curl (Fig. 2).

CA 473

Prostrate growing type of 27.1 cm height and 27.0 cm width, heavily set with erect, conical green fruits, 2 cm long, later turning to deep red.

CA 474

Compact dwarf plant of 18.1 cm height and 27.0 cm width, bearing yellow conical fruits, turning red at maturity. This line is susceptible to leaf curl disease (Fig. 3).

CA 476-1

Broadly spreading plant with 33.6 cm height and 53.0 cm width, with small erect, oblate shaped fruits, producing in clusters of 2 to 6, which changes from yellow to red (Fig. 4).

CA 477-1

Prostrate growing plant, forming a flattened top with a canopy of green leaves, above which are borne small conical, waxy fruits which change from purple to red. Plant height is 28.7 cm and spread is 30.0 cm.

CA 479-1a

Compact growing plant of 28.2 cm height and 27.5 cm width, producing erect cream coloured conical fruits, turning to orange and finally to red (Fig. 5).

CA 479-2

Compact growing plant, 26.5 cm height and 32.0 cm spread, bearing declining fruits, colouring first cream, then orange and finally red. Susceptible to powdery mildew.

CA 481

Compact plant of 35.2 cm height and 22.0 cm spread, with erect conical fruits, 4.0 cm long, which changes from yellow to red at maturity. Susceptible to powdery mildew (Fig. 6).

CA 483-1

Compact growing plant type of 29.7 cm height and 30.0 cm spread, with a canopy of rich green leaves, producing erect conical fruits, colouring first cream and then red.

CA 485

Erect plant growing to a height of 51.0 cm and a spread of 32.5 cm, producing erect cream coloured fruits

Fig.4 CA 476-1

Fig.5 CA 479-1a

with purple blotches, 1 cm long, in clusters of 2 to 4, turning red at maturity (Fig. 7).

CA 486-1

Broadly spreading plant (46.0 cm) having 32.0 cm height, bearing erect oblate shaped fruits, colouring first green, then brown and finally red (Fig. 8).

CA 486-2

Compact growing plant having almost triangular shape, 44.0 cm height and 22.0 cm width, producing declining, elongated green fruits changing to red at maturity.

CA 486-4

Plant type having prostrate growth habit, growing to 34.6 cm height and 26.0 cm spread, bearing declining fruits, 0.7 cm long, which changes from cream to red.

CA 488

Compact plant, growing to 34.8 cm height and 21.0 cm spread, producing erect conical fruits in clusters of 2 to 4, colouring first cream, then orange and finally to red (Fig. 9).

CA 489

Compact plant type, having 33.5 cm height and 31.0 cm spread, bearing a multitude of white flowers,

Fig.6 CA 481

Fig.7 CA 485

Fig.8 CA 486-1

Fig.9 CA 488

followed by small rounded, waxy, 1.0 cm berry like fruits, first cream, then red. Susceptible to mosaic disease (Fig. 10).

CA 493

Compact growing plant similar to CA 476-1, growing to a height of 33.4 cm and 27.0 cm spread, producing large number of fruits, in clusters of 2 to 5, erect, conical which changes from cream to orange and finally to red (Fig. 11).

CA 504

Compact plant growing to a height of 25.5 cm and 21.0 cm spread, bearing small, round berry like fruits colouring first green and then to red (Fig. 12).

B. **Crossability between *Capsicum annuum* L., *Capsicum chinense* Jacq. and *Capsicum chacoense* Hunz.**

Interspecific hybridization was conducted between *Capsicum annuum* (KAU cluster). *Capsicum chinense* (CA 317) and *Capsicum chacoense* (CA 306). *Capsicum annuum* was used always as female parent.

Crossability index was calculated in crosses involving three species (Table 8). Percentage fruit set was lower in crosses than in selfed maternal parent (88%). Average number of seeds/fruit was higher in the selfed

Fig.10 CA 489

Fig.11 CA 493

Table 8. Crossability between *Capsicum annuum*, *Capsicum chinense* and *Capsicum chacoense* after hand pollination

Material	A^S	B^S	C^S	D^S	A^C	B^C	C^C	D^C	Cross-ability index (%)
Capsicum annuum	88.0	10.0	100.0	90.0	-	-	-	-	-
Capsicum annuum x *Capsicum chinense*	-	-	-	-	58.0	6.4	75.6	58.8	20.8
Capsicum annuum x *Capsicum chacoense*	-	-	-	-	30.0	9.4	70.9	54.5	15.2

S - Selfs C - Crosses

A - Percentage fruit set

B - Average number of seeds/fruit

C - Percentage germination

D - Percentage seedling survival

Fig.13 Interspecific F_1, *Capsicum annuum x Capsicum chinense*

Fig.14 Interspecific F_1, *Capsicum annuum x Capsicum chacoense*

maternal parent (minimum seeds/fruit - 10) than in the crosses (minimum seeds/fruit - 6.4). Percentage germination was higher in selfed maternal parent (100%) than in the crosses. Similarly percentage seedling survival was higher in selfed maternal parent (90%) than in the crosses. Among the crosses, percentage fruit set was 58 in *Capsicum annuum x Capsicum chinense* cross and 30 in the other. *Capsicum annuum x Capsicum chacoense* had higher average number of seeds/fruit (9.4) compared to *Capsicum annuum x Capsicum chinense* (6.4). Higher percentage germination was observed in the cross *Capsicum annuum x Capsicum chinense* (75.6%) than in *Capsicum annuum x Capsicum chacoense* (70.9%). Percentage seedling survival was higher (58.8%) in *Capsicum annuum x Capsicum chinense* cross compared to 54.5% in *Capsicum annuum x Capsicum Chacoense* cross. Higher value of crossability index was observed in *Capsicum annuum x Capsicum chinense* (20.8%) and lower in *Capsicum annuum x Capsicum chacoense* (15.2%) cross.

The three parental species and their two interspecific F_1 hybrids (Fig. 13 and 14) were evaluated in the following season and their morphological description and quantitative characteristics are tabulated in Tables (9 and 10) respectively.

Percentage of sterile and fertile pollen in three parental species and their interspecific F_1s were counted (Table 11) and illustrated in (Fig. 15, 16, 17, 18 and 19).

Fig.13 Interspecific F_1, *Capsicum annuum x Capsicum chinense*

Fig.14 Interspecific F_1, *Capsicum annuum x Capsicum chacoense*

Table 9. Morphological description of parental species and their interspecific F_1s

Characters	*Capsicum annuum*	*Capsicum chinense*	*Capsicum chacoense*	*Capsicum annuum* x *Capsicum chinense*	*Capsicum annuum* x *Capsicum chacoense*
Plant growth habit	Compact	Compact	Compact	Compact	Compact
Stem pubescence	Inter-mediate	Abundant	Sparse	Intermediate	Intermediate
Stem colour	Green	Green with purple tinge	Purple	Green with Purple tinge	Green with Purple tinge
Pedicel position at anthesis	Erect	Inter-mediate	Erect	Intermediate	Intermediate
Corolla colour	White	Green-white	White	Cream	Cream
Corolla spot	Absent	Absent	Absent	Absent	Absent
Anther colour	Pale blue	Blue	Pale blue	Blue	Purple
Filament colour	White	Blue	White	Blue	White
Calyx margin shape	Inter-mediate	Inter-mediate	Dentate	Intermediate	Dentate
Annular const-riction	Absent	Present	Absent	Absent	Absent
Fruit position	Erect	Declining	Erect	Declining	Declining
Immature fruit colour	Green	Green	Green with purple tinge	Green	Green
Mature fruit colour	Red	Red	Orange	Red	Red
Fruit shape	Elongate	Companulate	Oblate	Elongate	Elongate

contd.....

Table 9. (contd.)

Characters	*Capsicum annuum*	*Capsicum chinense*	*Capsicum chacoense*	*Capsicum annuum* x *Capsicum chinense*	*Capsicum annuum* x *Capsicum chacoense*
Fruit shape at peduncle attachment	Obtuse	Truncate	Obtuse	Obtuse	Obtuse
Neck	Absent	Absent	Absent	Absent	Absent
Fruit shape at blossom end	Pointed	Sunken	Blunt	Pointed	Pointed
Fruit cross-sectional corrugation	Slightly corrugated	Very corrugated	Smooth	Slightly corrugated	Slightly corrugated
Fruit persistence	Persistent	Persistent	Deciduous	Persistent	Persistent
Seed colour	Straw	Straw	Straw	Straw	Straw

Table 10. Quantitative characteristics of parental species and their interspecific F_1s.

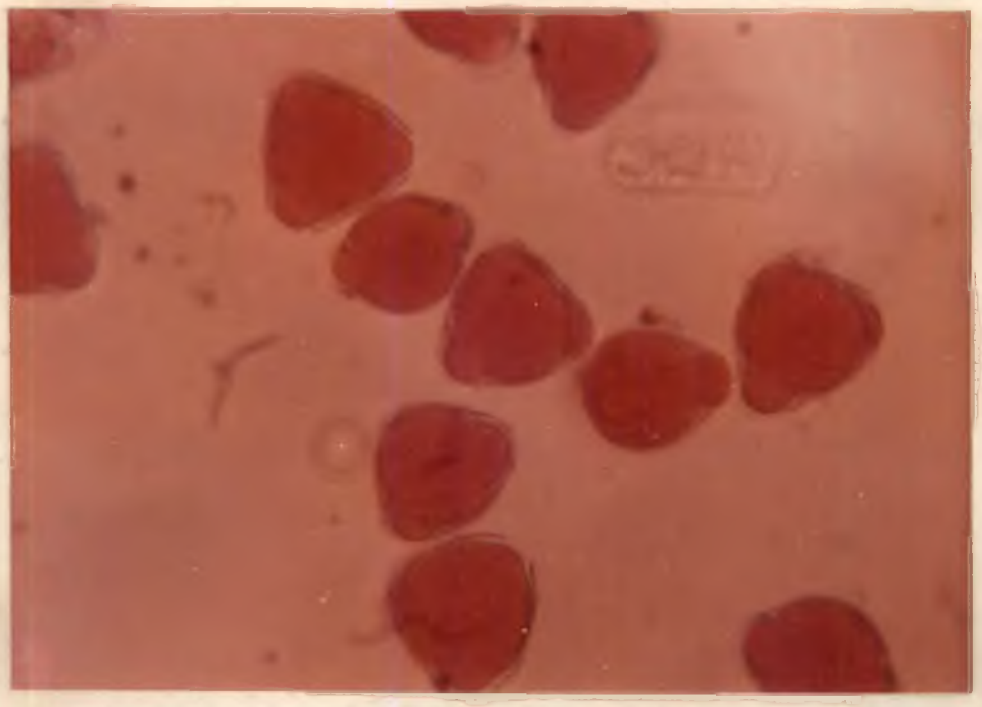
Characters	*Capsicum annuum*	*Capsicum chinense*	*Capsicum chacoense*	*Capsicum annuum* x *Capsicum chinense*	*Capsicum annuum* x *Capsicum chacoense*
Plant height (cm)	40.4	50.0	40.8	59.2	43.2
Plant spread (cm)	29.4	47.4	49.2	49.4	47.2
Days to flower	100	105	102	98	92
Pedicles/axil	5-12	1-3	1	1-2	1-2
Days to fruiting	105	108	105	100	101
Days to first harvest	144	143	143	136	136
Days to last harvest	163	163	163	160	160
Fruit length (cm)	3.6	1.5	0.3	2.7	4.0
Fruit width (cm)	0.8	1.1	0.2	0.7	0.7
Fruit weight (g)	1.6	1.5	0.1	1.1	1.5

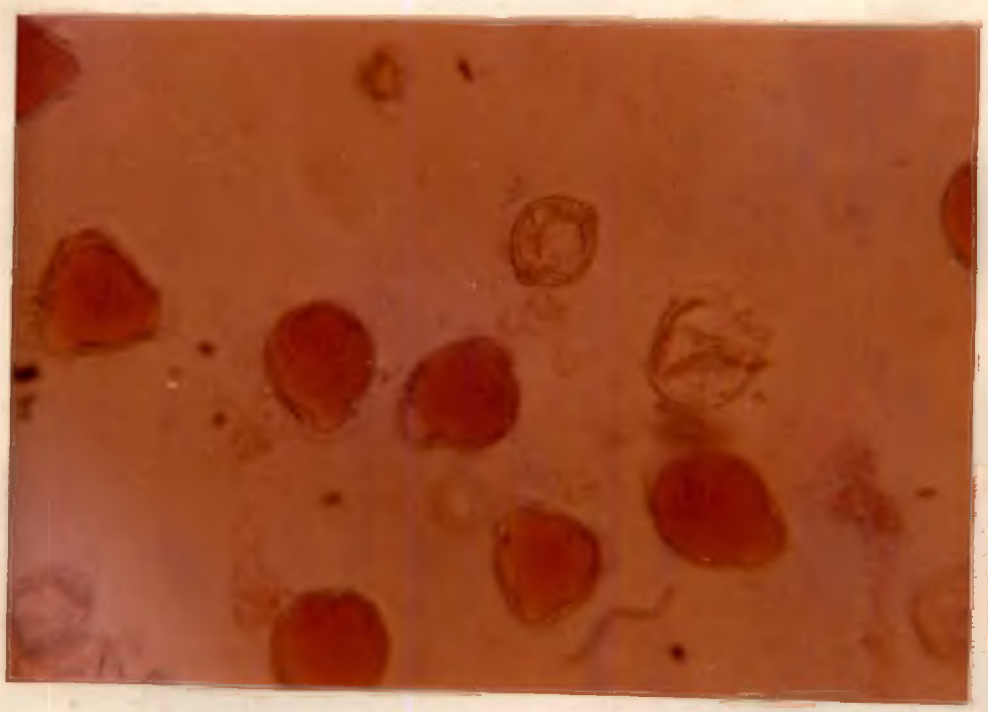
Table 11. Percentage of sterile and fertile pollen in three parental species and their interspecific F_1s

Material	Fertility (%)	Sterility (%)
Capsicum annuum	84.6	15.4
Capsicum chinense	82.6	17.4
Capsicum chacoense	2.4	97.6
Capsicum annuum x Capsicum chinense	5.3	94.7
Capsicum annuum x Capsicum chacoense	3.7	96.3

Fig.15 Fertile pollen of *Capsicum annuum*
(40 x 15 *x*)

Fig.16 Pollen of *Capsicum chinense*
(40 x 10 *x*)





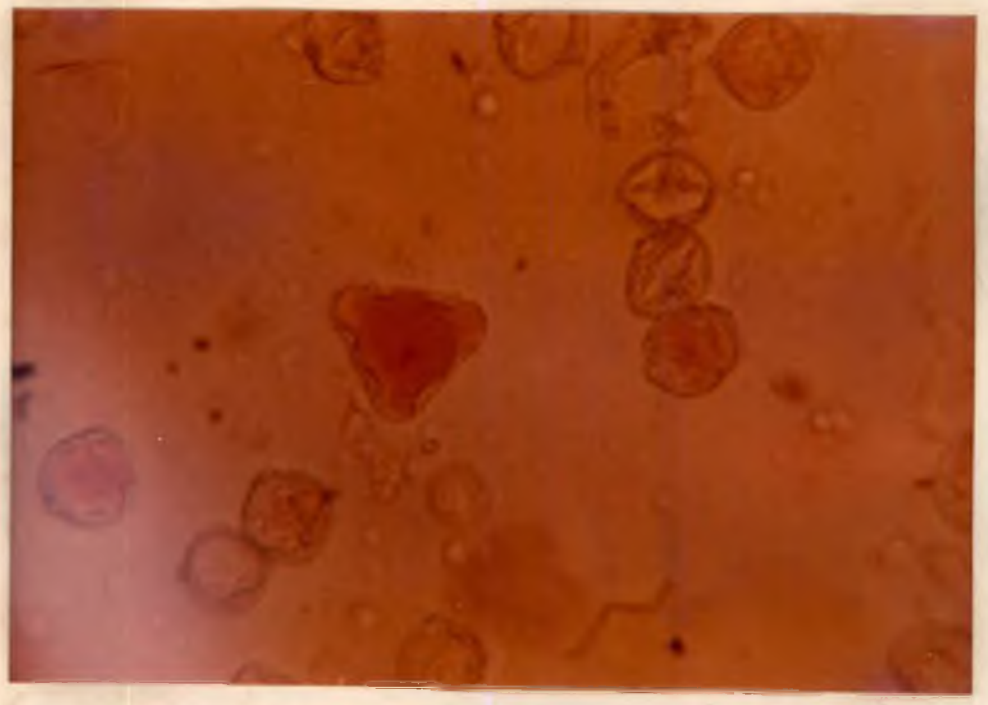
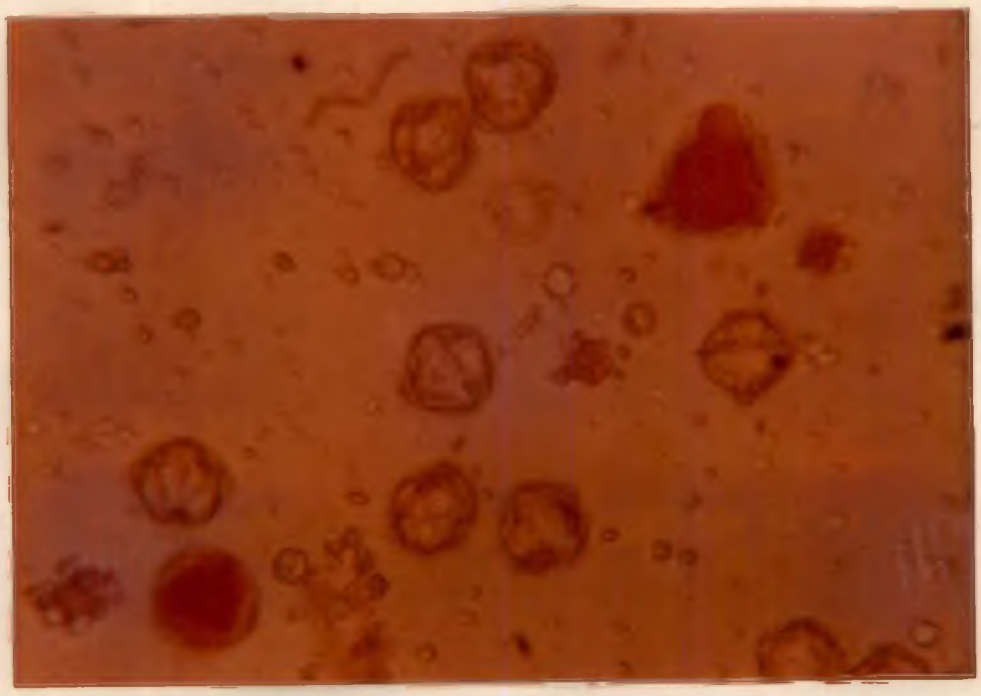
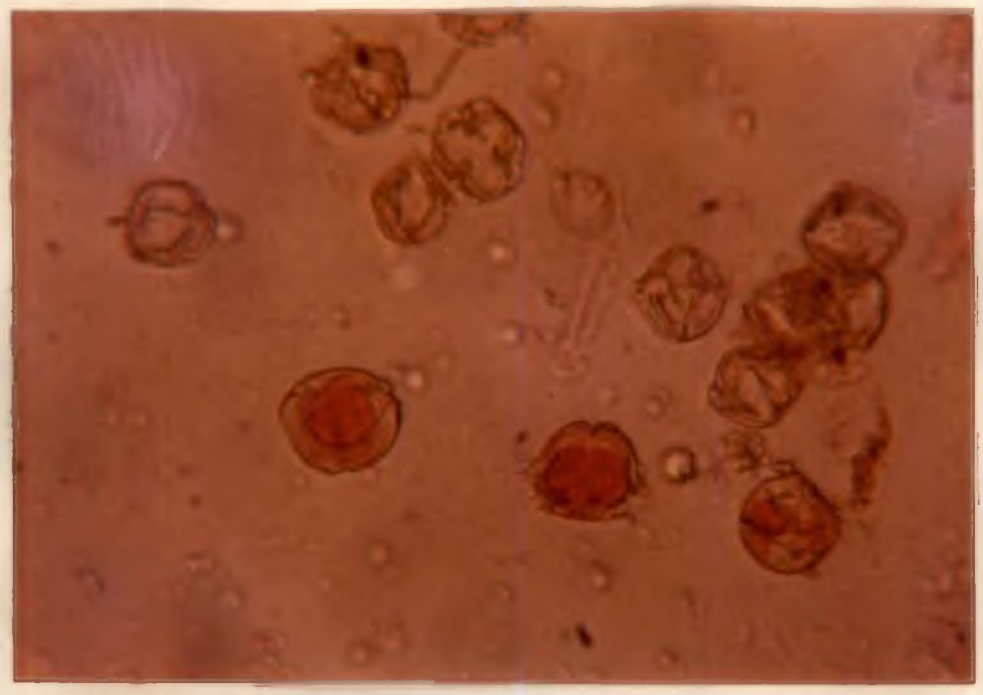


Fig.18 Sterile pollen of *Capsicum annuum x Capsicum chinense* (40 x 10 x)

Fig.19 Sterile pollen of *Capsicum annuum x Capsicum chacoense* (40 x 20 x)





The F_1 plants obtained from the cross between *Capsicum annuum* and *Capsicum chinense* had a lower pollen fertility (5.3%) and a higher sterility (94.7%) than their corresponding parents. *Capsicum annuum* had 84.6% fertile and 15.4% sterile pollen, *Capsicum chinense* had 82.6% fertile and 17.4% sterile pollen. The F_1 obtained by crossing *Capsicum annuum* and *Capsicum chacoense* had a higher pollen fertility (3.7%) and lower pollen sterility (96.3%) compared to one of the parents, *Capsicum chacoense* which had 2.4% fertile and 97.6% sterile pollen.

Cytological studies in the interspecific hybrids revealed that metaphase I was characterised by presence of mostly bivalents. A few pollen mother cells (PMCs) in the interspecific hybrids showed irregular meiotic behaviour. Metaphase I was characterised by the presence of chromosome association involving more than two chromosomes in a few cells of the hybrid *Capsicum annuum x Capsicum chacoense*. The multivalents had 3-5 chromosomes (Fig. 20). In many of the PMCs, one or two bivalents failed to orient at metaphase plate (Fig. 21). Univalents were not observed. Anaphase I separation was normal in most of the PMCs, but in a few cells laggards were found (Fig. 22). A few cells were also characterised by abnormalities in the second meiotic division. PMCs at metaphase II also showed non-orientation (Fig. 23). During telophase II, a few cells had abnormalities characterised by three nuclei at the time

Fig. 20

Multivalents at Metaphase

Fig. 21

Non orientation at Metaphase I

Fig. 22

Laggards at Anaphase I

Fig. 23

Non orientation at metaphase II

Fig. 20

Multivalents at Metaphase

Fig. 21

Non orientation at Metaphase I

Fig. 22

Laggards at anaphase I

Fig. 23

Non orientation at metaphase II

Fig. 20

Multivalents at Metaphase

Fig. 21

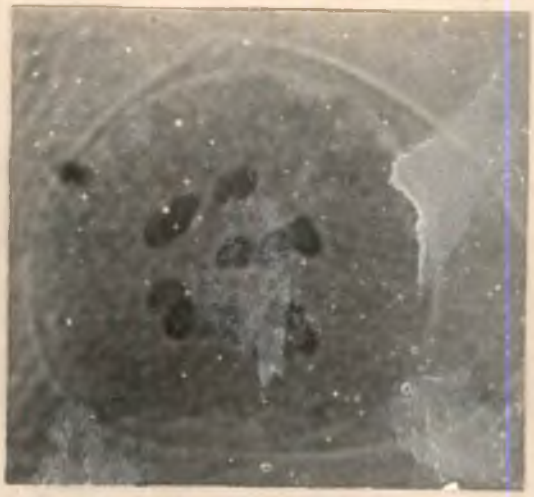
Non orientation at Metaphase I

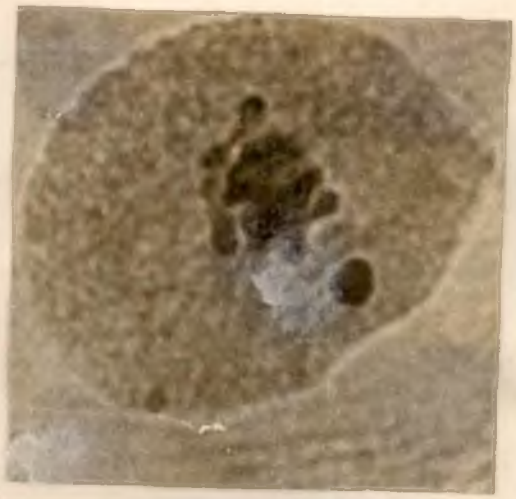
Fig. 22

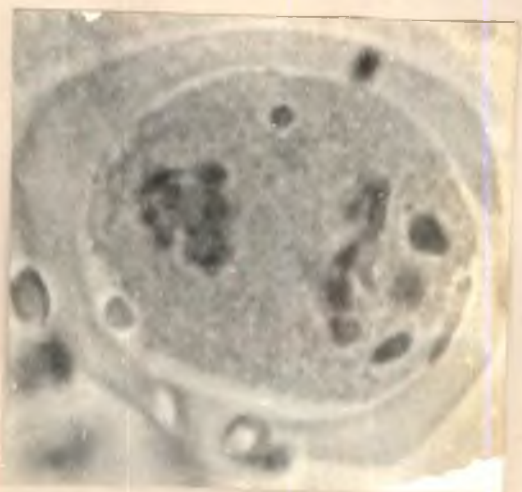
Laggards at Anaphase I

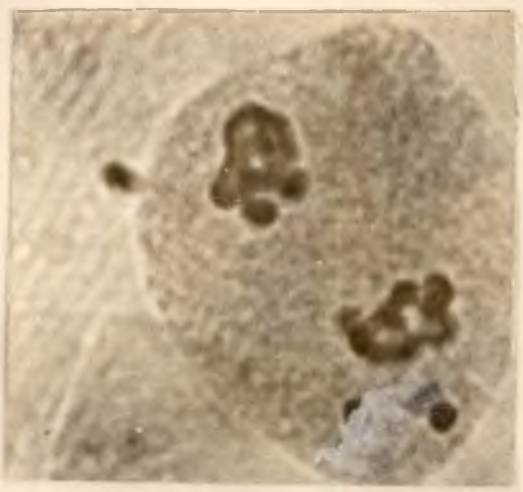
Fig. 23

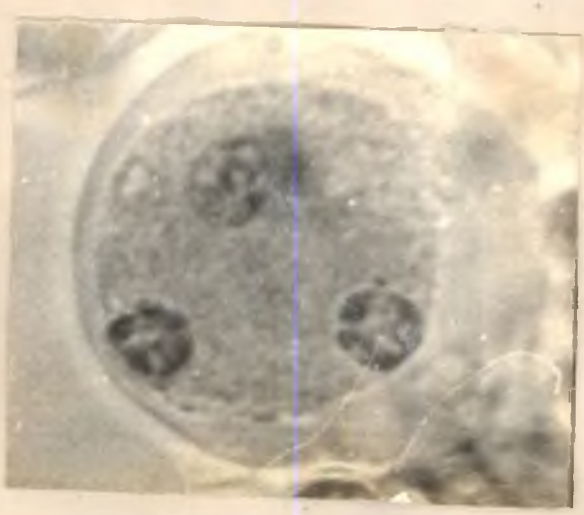
Non orientation at metaphase II











of tetrad formation (Fig. 24). All the above abnormalities contributed to reduction in pollen fertility.

Selfing of two interspecific F_1 hybrids done to confirm pollen sterility or fertility showed that, percentage fruit set was 10 in *Capsicum annuum x Capsicum chinense* and 8 in *Capsicum annuum x Capsicum chacoense* hybrids.

Discussion

DISCUSSION

A. Evaluation of ornamental chillies and selection for dwarf clustered plant types

Flower enthusiasts and home gardeners have long been aware of the aesthetic value of chillies for ornamental purposes. Use of chillies as an ornamental plant is mentioned in ancient literatures. Anon (1768) reported that cultivated forms of the genus *Capsicum* are included under a single species, *Capsicum frutescens* (including those formerly classified as *Capsicum annuum* and *Capsicum baccatum*). This species has several varieties, like var. *cerasiforme*, cherry peppers; var. *conoides*, tabasco and coral gem peppers; var. *fasciculatum*, cluster pepper; var. *grossum*, bell or sweet pepper; var. *typicum*, the bird pepper and var. *abbreviatum*, the ornamental bush pepper. Novak (1965) reported that the long cayenne pepper, *Capsicum annuum* var. *abbreviatum* has small fruits about 5 cm long, which are sometimes used for pickling, but this variety is often grown for ornamental purposes only.

For collection and preservation of *Capsicum* germplasm, four different steps are involved, accessioning, collection, preliminary evaluation and characterization (IBPGR, 1983). IBPGR (1983) endorses these four stages as the minimum that ideally should be followed for any germplasm conservation. The present study was undertaken with an objective of

evaluating ornamental chillies collected from different locations, and then selecting better types suited as ornamentals. Graf (1982) evaluated and briefly described 10 different ornamental capsicums. Essig (1983) conducted cultivar trials and described five outstanding cultivars. Some of the chilli varieties were specially developed for ornamental purpose. A few of the varieties developed at Indo-American Hybrid Seeds, Bangalore, are Christmas Peppers, Ball Christmas, Himiniskhi, Fire Works, Holiday Cheer, Holiday Time and Fiesta type. One F_1 hybrid, Red Missile, was also developed by them (Hosmani, 1982). In the present study, 51 accessions were evaluated for plant and fruit characteristics.

Ornamental chillies are extensively grown for their coloured fruits and foliage (Hosmani, 1982). Fruit number and plant height are also important for attractiveness of ornamental chillies. In the present study, selection of chilli lines suited for ornamental purpose was based on dwarf stature with clustered fruits of attractive colour and shapes.

When the lines are grown for selection after the initial evaluation trial, a few lines CA 459, CA 475, CA 477, CA 479-1 and CA 486 segregated for plant growth habit, fruit colour and fruit shape. This was because of often cross pollinated nature in chillies (Murthy and Murthy, 1962). These segregated lines were given another extended accession number.

Variation in plant height among different chilli lines, suggested the use of ornamental chillies as borders, small beds, potted plants and background material for large beds or mass planting. Dwarf types 48 cm or less in height, were well suited for use as small bedding plants and pot plants. Baby Christmas, Ball Christmas, Candle Pepper, Carrousel, Coral Horn, Craig's Ornamental, Fips, Hottentot, Red Boy, Red Candle, Red Fangs, Red Top, Rooster Spur, Santanka, PI 194881, PI 257053 and PI 273426 were well suited to these roles (Corley and Dempsey, 1971). Graf (1982) recommended a few varieties, Birdseye, Christmas Candle, Candle Pepper, Celestial and Red Chile, as ornamental chillies suited for pot plants. In the present study, all the selected lines had a height less than 48.0 cm and these can be used as pot plants. They include CA 352-1, CA 473, CA 474, CA 476-1, CA 477-1, CA 479-1a, CA 479-2, CA 481, CA 483-1, CA 485, CA 486-1, CA 486-2, CA 486-4, CA 488, CA 489, CA 493 and CA 504. Lines CA 490, CA 495, CA 499, CA 501, CA 506 and CA 507 had plant height greater than 90.0 cm. Corley and Dempsey (1971) opined that the cultivars which grow over 90 cm in height showed promise as background material for large beds and mass plantings.

The most desirable attribute of ornamental chillies appears to be display of colour in foliage and in fruits. The cultivars with normal green foliage showed varying

degrees of green pigmentation. Purple foliage colour was observed in lines CA 470, CA 477-2 and CA 497. Corley and Dempsey (1971) observed purple foliage colour in PI's 194881. 203523, 267730, 267731, 267740, Royal Purple and Zulu. This pigmentation was present in both juvenile and mature stages of leaf growth, enhancing the beauty of plants before the various fruit colours develop. Graf (1982) reported 'Piccolo', a variegated leaf ornamental chilli, with some of the foliage almost entirely creamy white, others cream, milky green and glossy deep green. In the present study, the line CA 494 had variegated leaf colour with a mixture of purple, cream and green.

Elongate, conical, heart shaped, round and bell fruit shapes were observed among the asscessions (Fig. 25). The fruit colours observed were very striking, since common garden chilli fruits turn from green to red as they mature. Fruits of the purple leaved accessions changed from dark purple to red. A few lines with green leaves CA 466, CA 482-2, CA 491 and CA 494 also produced purple immature fruits which turn to red at maturity. Among the 51 accessions evaluated, 32 showed the usual fruit colour change from green to red and five accessions produced green fruits which turn to orange at maturity. Nine accessions had cream immature fruits and five, yellow immature fruits which turn to red at maturity. Fruit colour was displayed over a relatively long period of time and is desirable.

Fig.25 Variability in fruit shape

In the present study, the collected accessions belong to different species, *Capsicum annuum*, *Capsicum frutescens*, *Capsicum chinense*, *Capsicum laccatum* / *Capsicum laccatum* var. *pendulum*. Corley and Dempsey (1971) recognised four species of *Capsicum*, *Capsicum annuum*, *Capsicum frutescens*, *Capsicum chinense* and *Capsicum pendulum*, as ornamental chillies. They reported that mature fruit colour of all cultivars of *Capsicum annuum* is red, while ornamental *Capsicum chinense* accessions have orange, yellow and red mature fruits.

Fruits of ornamental chillies evaluated in the present study were very pungent. Similar observations were also made by Corley (1967). Care should be taken when handling the fruits, since the pungent alkaloid present in the placental tissue can cause severe irritation to hands and eyes.

Bushy plants with more number of branches and fruits of attractive colour are desirable for ornamental chillies (Corley and Dempsey, 1972). Dwarfening of ornamental plants through application of growth retardants is of commercial success. These chemicals inhibit plant growth and plants become easy to manage, and colour contrast is improved because of darkening of leaves and is an important desirable character of ornamental chillies (Khoshoo, 1974). By proper management and tailoring, the selected lines in the present study could be made use of to develop a non pungent accession with good ornamental characters.

B. Crossability between *Capsicum annuum*, *Capsicum chinense* and *Capsicum chacoense*

Attempts in interspecific hybridization in the genus *Capsicum* have succeeded only in a few cases, inspite of numerical similarity in chromosome number. *Capsicum chacoense*, being deep rooted, is drought tolerant and is bushy. *Capsicum chinense* has fruits of ornamental value. Hybridization of the above species may result in production of ornamental plant which is drought tolerant. The present study was aimed to find out crossability between *Capsicum annuum*, *Capsicum chinense* and *Capsicum chacoense* and evaluating the interspecific hybrids for aesthetic values.

Hand emasculation and pollination were done and crossability index calculated as suggested by Rao (1979). Crossability index reflected a measure of crossability since it is a multiplicative function of percentage fruit set, average number of seeds/fruit, percentage germination and percentage seedling survival both in crosses and selfed maternal parent. There was no barrier which prevented the successful crossing between the three species. This agrees with works of Smith and Heiser (1957) and Pickersgill (1980). Percentage fruit set in the present study was 58 in cross between *Capsicum annuum* and *Capsicum chinense* and 30 in cross between *Capsicum annuum* and *Capsicum chacoense*. Csillery (1983) obtained 17% fruit set in cross between *Capsicum annuum* and *Capsicum chacoense*. Average number of seeds/fruit

was 6.4 in cross between *Capsicum annuum* and *Capsicum chinense* and 9.4 in cross *Capsicum annuum x Capsicum chacoense*. Greenleaf (1977) reported almost the same number of 6.3 seeds/fruit in cross between *Capsicum annuum* and *Capsicum chinense*. In the present study, percentage germination was 75.6 in cross between *Capsicum annuum* and *Capsicum chinense* and 70.9 in cross between *Capsicum annuum* and *Capsicum chacoense*. Saccardo (1978) obtained viable seeds in *Capsicum annuum x Capsicum chinense*. But Tanksley and Iglesias (1984) suggested that seeds resulting from *Capsicum annuum x Capsicum chinense* were for the greater part inviable, despite their normal outward appearance. Crossability indices of 20.8% and 15.2% were observed in crosses *Capsicum annuum x Capsicum chinense* and *Capsicum annuum x Capsicum chacoense* respectively. Higher crossability index in the first cross might be due to higher values of all the components of crossability index except average number of seeds/fruit.

Evaluation of interspecific F_1s ~~were~~ was conducted. It was found that they were morphologically normal. The interspecific F_1, *Capsicum annuum x Capsicum chinense* had a plant height (59.2 cm) greater than their parents. Similarly, the F_1 *Capsicum annuum x Capsicum chacoense* had a plant height (43.2 cm) greater than their parents. The F_1s were earlier in days to flower, days to fruiting and days to first harvest compared to their parents. Tanksley and Iglesias (1984) suggested that the F_1 obtained by crossing *Capsicum*

annuum with *Capsicum chinense* can be distinguished from either parents, by virtue of their intermediate morphological characteristics and extreme heterotic vigour. But, Greenleaf (1977) reported that many of the F_1s obtained by crossing *Capsicum annuum* with *Capsicum chinense*, developed abnormally and those survived grew slowly into highly abnormal dwarf plants with thick and malformed leaves.

Eventhough the F_1s appeared to be morphologically normal, they had a lower percentage of pollen fertility. The cross *Capsicum annuum x Capsicum chinense* had a pollen fertility of 5.3%. This agrees with work of Egawa and Tanaka (1986) who observed a low pollen stainability in hybrids of *Capsicum annuum* and *Capsicum chinense*. In the present study, the F_1s obtained by crossing *Capsicum annuum* and *Capsicum chacoense* had a low pollen fertility of 3.7%. Boukema (1984) also reported a low pollen fertility in such interspecific F_1 plant.

The formation of mostly bivalents at diakinesis indicates homology of the parental chromosomes. The presence of multivalents involving 3-4 chromosomes shows that segmental interchanges of chromosomes like translocation are involved in speciation. Meiotic irregularities like multivalent association, laggards, asynchronous orientation etc. are involved in the production of sterile pollen grains in the hybrids (Gopinathan, *et al.*, 1986 and Mallika, 1987).

Summary

Pollen sterility of the hybrids was confirmed by conducting selfing in hybrids and found that the percentage fruit set was very low.

Pickersgill (1980) suggested that none of the species of *Capsicum* were proved to be completely isolated from other species. It is even proved possible to cross white and purple flowered species, which are considered distinct major groups on phytochemical criteria. It thus seems likely that genes from any one species could ultimately be transferred to any other.

Summary

SUMMARY

The present investigations on "Evaluation of ornamental chillies and selection for dwarf clustered plant types" were conducted at the College of Horticulture, Vellanikkara, Trichur during May-October, 1988 and October-April 1988-'89. The experiment consisted of three parts A) Evaluation, cataloguing and documentation of ornamental chillies and selection of dwarf clustered plant types B) Use of *Capsicum chinense* Jacq. and *Capsicum chacoense* Hunz. to develop ornamental chillies and C) Evaluation of interspecific F_1s.

The experimental material consisted of 51 lines of ornamental chillies collected from nurseries, house holds, research stations and other institutions, through survey, correspondence and exchange. They were evaluated based on descriptor list prepared by IBPGR (1983) and classified based on four different characters, growth habit, flower characters, fruit position, fruit colour and fruit shape.

Dwarf ornamental lines were selected based on visual observation from the initial evaluation trial and they were further evaluated and 17 lines were selected as ornamental chillies. They were CA 352-1, CA 473, CA 474, CA 476-1, CA 477-1, CA 479-1a, CA 479-2, CA 481, CA 483-1, CA 485, CA 486-1, CA 486-2, CA 486-4, CA 488, CA 489, CA 493 and CA 504. The selected lines were further described.

The crossability between *Capsicum annuum* L., *Capsicum chinense* Jacq. and *Capsicum chacoense* Hunz. were studied by using *Capsicum annuum* as female parent. Crossability indices were calculated. All crosses were found compatible. Crossability index was 20.8% in *Capsicum annuum* x *Capsicum chinense* and 15.2% in *Capsicum annuum* x *Capsicum chacoense*.

The three parental species and two interspecific F_1s were evaluated for morphological and cytogenetic characters. Eventhough the F_1s appeared to be morphologically normal they had a low percentage of pollen fertility. The interspecific F_1s *Capsicum annuum* x *Capsicum chinense* had a pollen fertility of 5.3% and *Capsicum annuum* x *Capsicum chacoense*, 3.7%.

Cytological studies in the hybrids revealed that metaphase I was characterised by mostly bivalents, but very rarely multivalents involving 3-4 chromosomes were found. A few bivalents failed to orient at metaphase plate, lagged at anaphase I and led to the formation of micro nuclei at the end of the division. PMCs also showed abnormalities in the second meiotic division. These often resulted in high pollen sterility.

Pollen sterility of the hybrids were confirmed by conducting selfing in hybrids and found that the percentage fruit set was very low.

References

REFERENCES

Anon, 1768. Capsicums. *Encyclopedia Britanica* (Vol. 4) A society of Gentlemen in Scotland: p.856

*Anon, 1970. Evaluations of pepper plant introductions. *Ga Agric. Exp. Stn Sou. Coop. Ser. Bul:* p.151.

*Alekseeva, M. 1975. Breeding vegetable crops in Bulgaria. *Kartofel i Ovoshchi.* 1: 47.

*Angeli, L. 1964. Breeding bouquet type peppers, *kert. szol. foisk. koslem.* 28 (1): 65-79.

Balasubramaniam, P. 1981. *Personal communication* (In) Krishnakumari, K. 1984. Compatibility among varieties in *Capsicum annuum* L. and *Capsicum frutescens* L. M.Sc. thesis, Kerala Agric. Univ., Vellanikkara: 65 pp.

Boukema, I.W. 1982. Resistance to a new strain of TMV in *Capsicum chacoense* Hunz. *Capsicum Newsletter.* 1: 49.

Boukema, I.W. 1984. Male and female fertility in interspecific crosses with *Capsicum chacoense* Hunz. *Capsicum Newsletter.* 3: 54-55.

*Casali, V.W.D. and Couto, F.A.A. 1984. Origin and botany of Capsicum. *Informe Agropecuario.* 10 (113): 8-10

Casali, V.W.D. and Campos, J.P. 1986. Additional possibilities of interspecific crosses of *Capsicum frutescens* and *Capsicum praetermissum*. *Capsicum Newsletter.* 5: 40

*Cebula, S., Wojtaszek, T. and Sady, W. 1987. Consumer and biological value of the fruits of some capsicum cultivars grown in green houses. *Zeszyty Naukowe Akademii Rolniczejun Hugona kottataja w krakowie, Ogrodnictwo.* 211 (16): 73-85.

*Christensen, O.V. 1975. Planned production dates and greenhouse growing area use for *Capsicum annuum*. *Gartner Tideude.* 50: 851-852.

Cook, A.A. and Guevara, Y.G. 1982. Characterisation of pepper strain, Race 1 of *Xanthomonas campestris* pv. *vesicatoria*. *Phytopathology.* 72 (3): 356.

*Corley, W.L. 1967. Selected evaluations of ornamental pepper plant introductions and accessions. *Ga Agric. Exp. Stn Res. Rep.* p.8.

Corley, W.L. and Dempsey, A.H. 1971. Evaluation of new ornamental peppers. *Hort Science.* 6 (5): 491-492.

*Corley, W.L. and Dempsey, A.H. 1972. Ornamental pepper evaluation, 1965-1971. *Res. Rep., Ga Coll. Agric. Exp. Stn* 136: p.10.

*Csillery, G. 1983. A contribution to the list of possible interspecific crosses in Capsicum. *Proceedings Vth meeting Capsicum & Eggplant working group of Eucarpia,* 4-7 July Plovdiv, Bulgaria: 15-17.

*Dempsey, A.H. 1970. Ornamental peppers for Georgia. *Ga Agric. Exp. Stn Res. Bull.* p.83.

*De Vaulx, R.D. and Pitrat, M. 1979. Realization of the interspecific cross between *Capsicum annuum* L. and *Capsicum laccatum*. *Institut National de la Recherche Agronomique Rep.* p.75-81.

Egawa, Y. and Tanaka, M. 1984. Cytogenetical relationships among three species of chilli peppers, *Capsicum chinense, Capsicum frutescens* and *Capsicum baccatum*. *Japanese J. breeding*. 34(1): 50-56.

*Egawa, Y. and Tanaka, M. 1986. The pattern of meiotic chromosome pairing of interspecific hybrids among Capsicum pepper species (In) *A. Rep.* 1985. *Natn Inst. Agrobiol. Resources, Japan*. 17-19.

*Emboden, W.A. 1961. A preliminary study of the crossing relationships of *Capsicum baccatum*. *Butler Univ. Bot. Stud.* 14: 9-28.

Emino, E.R. 1981. Effectiveness of fish soluble nutrients as fertilizers on container-grown plants. *Hort Science*. 16 (3): 388.

Erwin, A.T. 1929. A systematic study of the peppers. *Proc. Am. Soc. Hort Sci.* 26: 128-131.

Eshbaugh, W. 1974. Variation and evolution in *Capsicum pubescens* R.& P. *Am. J. Bot.* 61: 42.

Essig, W. 1983. New ornamental capsicum cultivars from the USA. *Zeirpflanzenbau*. 23 (26): 1166.

*Gazenbus, V.L. 1965. Brief results of the work with *Capsicum* peppers at Majkop station of the Institute of Plant Industry. *Sci. Rep. Majkop. Exp. Stn All. Un. Inst. Pl. Industr.*. 1: 49-55.

Graf, A.B. 1982. Capsicums. *Exotica - Pictorial Cyclopedia of Exotic Plants from Tropical and Near Tropic Regions* (Vol 2). Rochrs Company Publishers, USA. p.2219.

Greenleaf, W.H. 1975. The tabasco story. *Hort Science.* 10 (2): 98..

Greenleaf, W.H. 1977. Pepper breeding. (In) *Breeding vegetable crops* (Ed). Bassett, M.J. Avi Publishing Company, INC, West Port. 67-127.

Grubben, G.J.H. 1977. *Tropical vegetables and their Genetic Resources.* IBPGR, Rome. 197 pp.

Gopinathan, M.C., Babu, C.R. and Shivanna, K.R. 1986. Interspecific hybridization between Rice Bean (*Vigna umbellata*) and its wild relative (*Vigna minima*). Fertility - Sterility relationships. *Euphytica.* 35: 1017-1022.

Goud, J.V., Nayar. K.M.D. and Rao, M.G. 1970. Interspecific hybridization in chillies (*Capsicum annuum x Capsicum frutescens*). *Mysore J. Agric. Sci.* 4: 358-361.

Harbaugh, B.K. and Waters, W.F. 1979. Evaluation of flowering potted plants under simulated home conditions. *Hort Science.* 14 (6): 743-745.

*Heiser, C.B.Jr. and Smith, P.G. 1958. New species of *Capsicum* from South America. *Brittonia.* 10: 194-201.

Heiser, C.B. 1976. Peppers *Capsicum* (Solanaceae). (In) Simmonds, N.W. (Ed) *Evolution of crop plants.* Longman, London. 265-268.

*Hirose, T., Nishi, S. and Takashima, S. 1961. Studies on interspecific hybridization between cultivated species of *Capsicum* II. Some characteristics of F_1 interspecific hybrids. *Kyoto Daigaku Gakujutsu Hokoku* 13: 23-28.

*Holcomb, E.J. 1982. Flowering potted plants for fall with soil heating. *Bull. Pennsylvania Flower Growers* 339: 1-5.

Hosamani, M.M.1982. *Chilli.* Mrs. Sarasijakshsi M. Hosmani, Dharward: 79-80.

IBPGR 1983. *Genetic Resources of Capsicum.* IBPGR Secretariat. Rome. 49 pp.

Institute for Horticultural Plant Breeding. 1977. *A. Rep.* Institut Voor De Veredeling Van Tuinbouwgewassen. Netherlands. 57 pp.

Institute for Horticultural Plant Breeding. 1985. *A. Rep.* Institut Voor De Veredeling Van Tuinbouwgewassen. Netherlands. 55 pp.

Johnson, P.A., Hiron, R.P. and Pemberton, A. 1983. The use of zeolite as an additive for composts for vegetable transplants production and pot plants. *J. Sci. Fd Agric.* 34 (3): 267-268

Keshavram, N. and Saini, S.S. 1971. Compatibility studies in some *Capsicum* species. *Himachal J. agric. Res.* 1 (1): 34-39.

Khademi, M. and Khosh-khui, M. 1977. Effect of growth regulators on branching, flowering and fruit development of ornamental peppers. *J. Am. Soc. hort. Sci.* 102 (6): 796-798.

Khoshoo, T.N. 1974. Prospects of ornamental horticulture in India. *Indian J. Hort.* 31 (4): 295-300.

*Kiku, V.N. 1987. Interspecific hybridization in the genus *Capsicum* L. *Izvestiya Akademii Nauk Moldavskoi* SSR *Biologicheskikh i khimicheskikh Nauk.* 2: 32-35.

Krishnakumari, K. 1984. Compatibility among varieties in *Capsicum annuum* L. and *Capsicum frutescens* L. M.Sc. thesis, Kerala Agric. Univ., Vellanikkara 65 pp.

Krishnakumari, K. and Peter, K.V. 1986. Genetic distance and heterosis in interspecific crosses of *Capsicum*. *Agric. Res. J. Kerala*. 24 (2): 122-127.

Kounovasky, J.S., Todorova, J.J. and Stoimenova, E.S. 1985. *Capsicum chinense*, source of resistance to *Leveillula solanacearum* f. sp. *Capsici* Gol. and tobacco mosaic virus. *Capsicum Newsletter*, 4: 68-69.

*Kumar, O.A., Panda, R.C. and Rao, K.G.R. 1987. Gytogenetic behaviour of hybrids between *Capsicum annuum* L. and *Capsicum frutescens* L. *Genetica Iberica*. 39: 147-157

Lippert, L.F., Smith, P.G. and Bergh, B.O., 1966. Cytogenetics of the vegetable crops. Garden Pepper, *Capsicum sp. Bot. Rev.* 32: 24-55.

Mallika, V.K. 1987. Genome analysis in the Genus *Amaranthus*. Ph.D. Thesis, Kerala Agric. Univ., Vellanikkara. 104 p.

*Mihov, A. 1969. Most recent scientific achievements of Bulgarian vegetable growing. *Kartofel i Ovoshchi*. 9: 45-46.

*Miladinovic, Z., Mijatovic, M. and Aleksic, Z. 1985. Reaction of some sublines of interspecific hybrids of *Capsicum* to cucumber mosaic virus. *Zastita Bilja*. 36 (1): 33-38.

Molchova, E. and Michailova, M. 1982. On the interspecific crossability between *Capsicum annuum* L. and *Capsicum pubescens* R. & P.: *Capsicum annuum* L. and *Capsicum pendulum* Wild. (Syn. baccatum). *Capsicum Newsletter.* 1: 38-40.

*Molhova, E. 1966. Hybridisation between *Capsicum annuum* L. (2n = 48) and *Capsicum pubescens* R. & P. (2n = 24). *C. R. Acad. Bulg. Sci.* 19: 225-227.

Murthy, N.S.R. and Murthy, B.S. 1962. Natural cross pollination in chilli. *Andhra agric. J.* 9 (3): 161-165.

Novak, F.A. 1965. *The Pictorial Encyclopedia of Plants and Flowers.* Crown Publishers, INC, New York: 415.

Peter, K.V. and Mc Collum, G.D. 1984. Pollen stigma compatibility in direct and reciprocal crosses of *Capsicum Sp. J. Heredity.* 75 (1): 70.

Pickersgill, B. 1967. Interspecific isolating mechanisms in some South American chilli peppers. *Am. J. Bot.* 54: 654.

Pickersgill, B. 1971. Relationships between weedy and cultivated forms in some species of chilli peppers. (Genus Capsicum). *Evolution* 25: 683-691.

*Pickersgill, B. 1980. Some aspects of interspecific hybridization in *Capsicum.* Paper presented during the IVth Meeting of the EUCARPIA *Capsicum* working Group, 14-16 October 1980. Netherlands.

Pillai, S.E.R., George, M.K. and Mercy, S.T. 1977. Studies on interspecific hybrids of five species of capsicum - with special reference to its qualitative and quantitative characters. *Agric. Res. J. Kerala.* 15 (1): 1-15.

Pundeva, R. 1984. An addition to the list of possible interspecific crosses in Capsicum. *Capsicum Newsletter.* 3: 56.

Radhakrishnan, K.P., Mercy, S.T. and George, M.K. 1977. Crossability studies and analysis of incompatibility in three species of capsicum. *Agric. Res. J. Kerala.* 15 (2): 124-127.

Rao, N.N. 1979. Barriers to hybridization between *Solanum melongena* and some other species of *Solanum* (In) Hawker, J.W., Lester, R.N. and Skelding, A.D. (Ed) *The Biology and Taxonomy of the solanaceae,* Linnaean Society of London. 605-615.

Research Report. 1983-'84. *Kerala Agric. Univ. Vellanikkara* p. 296.

Saccardo, F. 1978. Wild species of *Capsicum* as sources of resistance to pathogens. *Genet. Agraria.* 32 (1): 162-163.

Smith, P.G. and Heiser, C.B.1957. Breeding behaviour of cultivated peppers. *Proc. Am. Soc. Hort. Sci.* 70: 286-290.

*Smith, P.G. 1983. Crossability of Capsicum species. *Personal communication.*

Subramanya, R. 1982. The transfer of multiple flowers per node from *Capsicum chinense* Jacq. to *Capsicum annuum* L. *Capsicum Newsletter.* 1:41.

*Stock bridge House Expt Hort. Stn, 1973. *A. Rep.* Selby. p. 196.

*Stolz, W. 1965. Sweet pepper as a summer crop under glass. *Gemuse.* 1:20-21.

Tanksley, S. and Iglesias - Olivas, J. 1984. Inheritance and transfer of multiple flower character from *Capsicum chinense* into *Capsicum annuum. Euphytica.* 33 (3) : 769-777.

*Thomas, M.B. 1984. The influence of nutrition on production of container grown ornamental peppers. Combined Proceedings; *Int. Pl. Propagators Soc.* 34: 381-396.

*Thomas, M.B. and Leong, A.G.B. 1984. The effect of shade and nitrogen on production of container grown ornamental peppers, *Capsicum annuum. A.J.R. N.S. Inst. Hort.* 12: 57-67.

*Tillinghast, H.M. 1939. Gay ornamental peppers. *Flower Garden.* 26 (3): 125.

*Todorova, I. and Kunovski, Z.H. 1988. Genetic analysis of hybrids between the species *Capsicum annuum* L. and *Capsicum chinense* in respect of their reaction to powdery mildew of pepper. *Genetika i Selektsiya.* 21 (1): 31-35.

Vernon, H. 1982. *Popular Encyclopedia of plants.* Heywood Cambridge University Press, Cambridge, London: p. 72.

*Vidalie, H. 1975. Flowering plants - for potted plant production - requiring little heat. *Pepinieristes Horticulteurs Maraichers*. 154: 43-48.

Wit, H.C.D. 1965, Capsicums. *Plants of the World - The higher plants*-II. Thames and Hudson, London. 149.

Yaqub, C.M. 1968. The genetic basis of self-incompatibility in *Capsicum pubescens* R. and P. and *Capsicum cardenasii* H. and S. *Diss. Abst.* 29: 893-894.

*Yazawa. S.. Kenni, T.. Uemura, N.. Adachi, K. and Takashima, S. 1980. Use of interspecific hybrids of Capsicum as root stocks, *Sci. Rep. Kyoto Perfectural University*, Agriculture 32: 25-29.

*Yoneda, 1974. Studies on flower bud differentiation and development in the solanaceae. V. Morphological observations on the early stage of flower bud differentiation and development in sweet pepper. *Bull. Coll. Agric. Vet. Med.* Nihon University, 31: 79-92.

* Originals not seen

Appendix

Appendix - I

Weekly average weather data for the cropping period (May 1988 to April 1989)

Week No.	Month and date	Temperature (°C)		Humidity		Rainfall (mm)	Evaporation (mm)
		Maximum	Minimum	Forenoon	Afternoon		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
18	30 April - 6 May	33.4	24.6	89	66	41.4	4.7
19	7 May - 13 May	34.0	25.7	90	63	4.0	5.8
20	14 May - 20 May	34.0	26.1	84	58	5.4	4.9
21	21 May - 27 May	34.0	25.4	89	59	9.2	5.3
22	28 May - 3 June	31.7	24.3	93	73	-	3.0
23	4 June - 10 June	29.1	23.9	92	89	144.4	2.2
24	11 June - 17 June	30.4	23.9	91	79	58.0	3.7
25	18 June - 24 June	30.3	23.9	94	76	102.7	2.8
26	25 June - 1 July	29.7	22.6	92	77	154.3	2.8
27	2 July - 8 July	30.4	23.1	90	75	19.7	3.5
28	9 July - 15 July	29.6	23.4	95	75	105.4	2.9
29	16 July - 22 July	28.2	22.8	96	90	245.9	1.5
30	23 July - 29 July	27.6	23.3	92	84	134.9	2.1
31	30 July - 5 August	29.9	24.5	96	76	89.9	2.9
32	6 August - 12 August	28.9	23.9	94	81	61.2	2.8
33	13 August - 19 August	28.2	24.3	95	83	177.6	2.6
34	20 August - 26 August	29.7	24.6	93	74	72.1	3.6

(contd.)

Appendix - I (contd.)

(1)	(2)			(3)	(4)	(5)	(6)	(7)	(8)
35	27 August	-	2 Sept.	29.6	23.6	94	74	200.8	3.5
36	3 Sept.	-	9 Sept.	29.6	23.6	91	78	153.7	3.1
37	10 Sept.	-	16 Sept.	30.5	23.4	92	78	113.7	3.1
38	17 Sept.	-	23 Sept.	29.6	23.4	93	78	240.0	1.0
39	24 Sept.	-	30 Sept.	29.7	22.4	94	76	123.2	3.7
40	1 Oct.	-	7 Oct.	30.4	23.4	92	72	29.8	3.7
41	8 Oct.	-	14 Oct.	31.8	23.3	88	68	19.6	4.1
42	15 Oct.	-	21 Oct.	31.8	24.0	92	65	6.8	3.8
43	22 Oct.	-	28 Oct.	31.9	22.8	90	65	60.4	3.3
44	29 Oct.	-	4 Nov.	33.3	23.4	85	57	6.8	3.8
45	5 Nov.	-	11 Nov.	31.3	23.9	76	64	2.0	3.7
46	12 Nov.	-	18 Nov.	33.2	23.2	80	55	2.2	3.9
47	19 Nov.	-	25 Nov.	32.6	22.6	78	53	-	3.8
48	26 Nov.	-	2 Dec.	32.6	20.1	82	48	-	3.9
49	3 Dec.	-	9 Dec.	31.9	22.7	102	53	2.9	4.8
50	10 Dec.	-	16 Dec.	33.4	22.8	81	44	12.0	4.6
51	17 Dec.	-	23 Dec.	32.6	23.2	64	35	-	9.8
52	24 Dec.	-	31 Dec.	37.7	24.8	79	44	-	8.9
1	1 Jan.(1989)		7 Jan.	33.0	23.5	67	40	-	8.8
2	8 Jan.	-	14 Jan.	33.3	21.2	71	42	-	8.1

(contd.)

Appendix - I (contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
3	15 Jan. - 21 Jan.	33.1	22.7	72	39	-	7.7
4	22 Jan. - 28 Jan.	33.6	21.2	59	17	-	9.4
5	29 Jan. - 4 Feb.	34.9	20.3	59	17	-	9.4
6	5 Feb. - 11 Feb.	36.1	19.1	67	17	-	8.0
7	12 Feb. - 18 Feb.	36.8	21.8	84	23	-	7.6
8	19 Feb. - 25 Feb.	36.6	23.6	73	28	-	7.5
9	26 Feb. - 4 March	37.1	21.3	65	15	-	9.1
10	5 March - 11 March	36.8	23.1	75	35	15.8	7.4
11	12 March - 18 March	36.6	23.7	86	42	-	8.0
12	19 March - 25 March	35.3	23.6	84	48	-	4.2
13	26 March - 1 April	36.8	29.9	82	42	-	7.7
14	2 April - 8 April	35.7	25.2	86	48	-	6.2
15	9 April - 15 April	36.4	25.6	83	50	1.0	6.9

Source: Meteorological observatory, Vellanikkara.

EVALUATION OF ORNAMENTAL CHILLIES AND SELECTION FOR DWARF CLUSTERED PLANT TYPES

By

MINI. C.

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the

requirement for the degree

Master of Science in Horticulture

Faculty of Agriculture

Kerala Agricultural University

Department of Olericulture

COLLEGE OF HORTICULTURE

Vellanikkara - Trichur

1989

ABSTRACT

The present investigations on "Evaluation of ornamental chillies and selection for dwarf clustered plant types" were conducted at the College of Horticulture, Vellanikkara, Trichur during May-October, 1988 and October-April, 1988-'89.

Fifty one accessions of ornamental chillies were collected from different locations through survey, correspondence and exchange. They were evaluated for plant and fruit characteristics and dwarf plant types having clustered fruiting habit were selected as ornamental chillies. The selected lines include CA 352-1, CA 473, CA 474, CA 476-1, CA 477-1, CA 479-1a, CA 479-2, CA 481, CA 483-1, CA 485, CA 486-1, CA 486-2, CA 486-4, CA 488, CA 489, CA 493 and CA 504.

Crossability between *Capsicum annuum* L., *Capsicum chinense* Jacq. and *Capsicum chacoense* Hunz. were studied. Crossability indices were calculated. Crossability index was 20.8% in *Capsicum annuum* x *Capsicum chinense* and 15.2% in *Capsicum annuum* x *Capsicum chacoense*.

Morphological and cytogenetic evaluation of three parental species and their interspecific F_1s were carried

out. The hybrids had a low pollen fertility even though they appeared to be morphologically normal. Meiotic abnormalities leading to the high pollen sterility were elucidated.