GENETIC IMPROVEMENT OF BIRD PEPPER (*Capsicum frutescens* L.) BY SELECTION

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THESIS

Submitted in partial fulfilment of the
requirements for the degree

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DECLARATION

I hereby declare that the thesis entitled '**Genetic improvement of bird pepper (*Capsicum frutescens* L.) by selection**' is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society

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Certified that the thesis entitled '**Genetic improvement of bird pepper (*Capsicum frutescens* L.) by selection**' is a record of research work done independently by **Smt.K.B.Sheela**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Introduction

INTRODUCTION

Chilli is highly valued throughout the world both as a vegetable and as a spice for its intrinsic qualities like pungency, flavour, appealing colour and nutritive value. India is the largest producer of chillies in the world, with an annual production of 7.48 lakh tonnes from an area of 8.10 lakh hectares (Spices Board, 1997).

The two well recognised species of *Capsicum* are *C. annuum* L. and *C. frutescens* L. But only *C. annuum* is cultivated on an extensive scale throughout India. This is early maturing, grown as annual and is milder in pungency.

The perennial chilli, *C. frutescens* L. also known as bird pepper, bird chilli or bird's eye chilli is characterized by highly pungent fruits with distinctive flavour. It is widely used in preparation of hot sauces, pickles and special dishes for festival and marriage feasts in Kerala. The longer crop duration and ability to yield under shade, render it an ideal crop for the homesteads. Commercial cultivation of bird pepper is rather confined to Kerala, Sikkim and North east.

Chilli is unique among all the spice crops, being the only source of capsaicin. The pungent principle capsaicin has significant physiological action and is used in many pharmaceutical preparations like balms, linaments and ointments for cold, sore throat and chest congestion. It also finds use in cosmetics like prickly heat powders and skin ointments where capsaicin acts as an effective counter irritant and chemical scratcher.

Indian chillies belong to the medium pungency type and are not suitable for the manufacture of high pungency oleoresin required by the pharmaceutical industry. Ideal extraction material for the industry should contain above one per cent capsaicin (Tewari, 1990). The commercial Indian varieties yield only product conforming to Oleoresin Red Pepper with medium pungency and high colour value which is the reason for its poor acceptability in pharmaceutical industry.

Bird pepper has high capsaicin content. These highly pungent chillies are included in British Pharmacopoeia and find maximum use in pharmaceuticals. However, low productivity and small fruit size are major constraints in large scale cultivation of this crop. Inspite of its economic importance, little efforts have been made for genetic improvement of this group of chillies.

High variability existing in this crop has not been fully exploited so far. Though there are a few improved varieties of bird pepper in India, the types grown are mostly indigenous ones exhibiting a wide spectrum of variability for plant and fruit characters. The breeding work conducted in chillies so far, has been concentrated on *C. annuum* paying little attention to *C. frutescens*. It is therefore imperative to take intensive steps towards the genetic improvement of bird pepper.

Different methods of selection have been effectively utilized for crop improvement in chillies (Govindarajan, 1985). Economic characters like fruit size and yield in chillies have shown high heritability coupled with high genetic advance and therefore, offer good scope for improvement by selection (Arya and Saini, 1986).

The genetic advance from selection in a crop breeding programme is dependant on the variability present in the germplasm, for the economic characters. A knowledge of association of plant characters with yield and among themselves will be helpful in the improvement of a complex trait like yield for which direct selection is not very effective.

A knowledge about various aspects of floral biology including time of anthesis, anther dehiscence and ideal time of pollination is a prerequisite for embarking upon an effective crop breeding programme.

Isozyme analysis by electrophoresis is a well defined and effective method to detect genetic differences among individuals and is widely used as a supplementary tool along with morphological methods of plant classification.

The economic and commercial value of chilli are determined not only by yield, but also by quality traits like capsaicin, oleoresin, carotenoids and ascorbic acid content. Although the chemical constituents of *C. annuum* have been studied in detail, no comprehensive efforts have been made to assess the chemical composition of bird pepper, hitherto.

The stage of maturity is another important criterion affecting the chemical composition. Estimation of chemical constituents at different stages of maturity help to assess the optimum stage of harvest for better quality.

Taking into consideration all the above aspects, the present study was undertaken with the following objectives:

1. to estimate the variability and genetic diversity in bird pepper,
2. to identify superior line(s) adopting mass and single plant selection and to compare the relative efficiency of the selection methods,
3. to study the floral biology of bird pepper,
4. to estimate the important chemical constituents in relation to fruit quality and
5. to characterize *Capsicum frutescens* through isozyme analysis.

Review of Literature

REVIEW OF LITERATURE

Bird pepper, *Capsicum frutescens* L. is an economically important species, valued for its perennial nature and highly pungent fruits with characteristic flavour. Though considerable efforts have been made for genetic improvement of *Capsicum annuum* L. not much efforts have been made for improvement of bird pepper. In spite of the wide spectrum of variability available in this species, it has not been exploited for development of varieties.

2.1 Variability and genetic diversity in chilli

Variability either natural or created artificially, forms the basis for any crop improvement programme. Considerable variability was reported for most of the characters by Arya and Saini (1976) and Elengovan *et al.* (1981) in chillies.

2.1.1 Morphological characters

High variability for plant height was pointed out by many workers in *C. annuum* (Legg and Lippert, 1966; Ramalingam and Muragarajendran, 1977; Singh and Singh, 1979; Elengovan *et al.*, 1981; Gupta and Yadav, 1984; Sekhar, 1984; Thangaraj, 1984; Jayasankar, 1985; Pawade, 1991 and Sarma and Roy, 1995). On the other hand, Kshirsagar *et al.* (1983); Suthanthirapandian and Rangaswamy (1983) and Arya and Saini (1986) observed moderate variability for plant height and Ramakumar *et al.* (1981) and Vadivel *et al.* (1983) reported a low co-efficient of variation.

High variability for number of primary branches was reported by Sethupathiramangalam and Murugarajendran (1977); Bavaji and Murthy (1982); Gupta and Yadav (1984) and Jayasankar (1985) whereas moderate values for this trait were reported by Arya and Saini (1986). In contrast, Ramakumar *et al.* (1981), Varalakshmi and Hari Babu (1991) and Sarma and Roy (1995) obtained only a low phenotypic variance for number of primary branches.

2.1.2 Economic characters

2.1.2.1 Number of fruits and yield

Genetic variability for fruit yield in *C. annuum* was reported by Arya and Saini (1976); Singh and Brar (1979); Singh and Singh (1979); Elengovan *et al.* (1981); Ramakumar *et al.* (1981); Bavaji and Murthi (1982); Rajput *et al.* (1982); Amarchandra *et al.* (1983); Suthanthirapandian and Rangasamy (1983); Sekhar (1984); Thangaraj (1984); Ahmed *et al.* (1990); Varalakshmi and Hari Babu (1991) and Nandi (1992).

2.1.2.2 Fruit characters

Amarchandra *et al.* (1983) noted high genotypic coefficient of variation for fruit length, fruit circumference, fresh and dry weight of fruits. Gupta and Yadav (1984) observed high co-efficient of variation for fruit girth. Choudhury *et al.* (1985) reported that fruit weight, length and girth resulted in higher yield and hence these characters should be given due consideration while making selection. Ahmed *et al.* (1990) and Rani (1996a) observed high variation for fruit length and girth. Jayasankar (1985) reported low variability for fruit length and girth.

2.1.3 Heritability and genetic advance

Nandpuri *et al.* (1971) reported that expected genetic advance was high for number of branches per plant.

High estimates of heritability for plant height in *C. annuum* were reported by Milkova (1981) and Raju *et al.* (1984) whereas Singh *et al.* (1972) reported moderate heritability for this character.

High heritability coupled with high genetic advance was observed for fruit yield by Nandpuri *et al.* (1970); Singh *et al.* (1972); Hiremath and Mathapati (1977); Bavaji and Murthy (1982); Arya and Saini (1986); Ahmed *et al.* (1990); Bhagyalakshmi *et al.* (1990) and Nandi (1992) whereas Gopalakrishnan *et al.* (1984) observed moderate heritability for this trait.

High heritability coupled with high genetic advance was reported by Awasthi *et al.* (1974); Elengovan *et al.* (1981); Amarchandra *et al.* (1983); Choudhury *et al.* (1985) and Natarajan *et al.* (1993) for fruit length.

Elengovan *et al.* (1981); Ramakumar *et al.* (1981); Choudhury *et al.* (1985) and Ahmed *et al.* (1990) realised high heritability estimates in *C. annuum* for fruit girth.

2.1.4 Correlation among characters

A positive correlation between number of fruits and primary branches with yield was reported by Legg and Lippert (1966); Hiremath and Mathapati

(1977); Sethupathiramalingam (1979); Nair *et al.* (1984); Bhagyalakshmi *et al.* (1990) and Aliyu *et al.* (1991).

Padda *et al.* (1970) observed that yield in chillies is governed by fruit size, since fruit size (length x breadth) was positively correlated with fruit length and yield per plant. They had further suggested that selection for fruit size is likely to result in increased yield. Suthanthirapandian *et al.* (1979) in a study of 125 accessions in *C. annuum* obtained a positive correlation of crop duration and plant height with yield in chilli.

Factor analysis of chilli by Rao *et al.* (1981) indicated that fruit yield per plant had high significant positive correlation with fruits per plant, plant spread and height. They further reported that harvest index, ripe fruit yield per plant and fruits per plant exhibited high positive direct effect on dry chilli yield per plant.

Bhagyalakshmi *et al.* (1990) and Aliyu *et al.* (1991) observed a negative correlation between fruit length and fruit diameter. Khurana *et al.* (1993) in a study of ten accessions in chilli observed a significant positive correlation of fruit yield with mean fruit weight, number of fruits, fruit length, leaf area and number of branches. They further reported that fruit weight had the highest direct effect followed by number of fruits.

Sarma and Roy (1995) observed a positive association of fruit weight with fruit diameter and fruit length which indicated that selection for any of these traits would lead to an increase in fruit size. The correlation was negative and significant for days to 50 per cent flowering and days taken from fruit set to maturity.

2.1.5 Genetic divergence in chilli

The D^2 statistics is a powerful tool to estimate genetic divergence among populations (Arunachalam and Ram, 1967 and Singh and Singh, 1976). Singh and Singh (1976) subjected 45 lines of chilli to Mahalanobis D^2 analysis and observed that clustering pattern followed geographical distribution. D^2 analysis conducted by Mehra and Peter (1980) revealed that fruits per plant contributed maximum towards diversity.

Sundaram *et al.* (1980) conducted D^2 analysis in *C. frutescens* and observed that there was no relation between genetic and geographic diversity. Factor analysis in chilli by Rao *et al.* (1981) indicated that flowering, maturity, fruiting ability in summer and pods per plant were important characters, accounting for 55.34 per cent of total divergence. Pandey and Dobhal (1993) evaluated 30 accessions of chilli for genetic divergence and grouped them into seven clusters.

Indira (1994) grouped chilli accessions into nine clusters during the first season. Renthlei *et al.* (1994) grouped 45 varieties of chillies into 18 clusters using Mahalanobis D^2 statistics.

2.2 Genetic improvement through selection

Elengovan *et al.* (1981) reported that genotypic and phenotypic variances were higher for plant height, plant spread, seeds per fruit and fruits per plant indicating the scope for phenotypic selection for these traits. Choudhury *et al.* (1985) reported that weight of fruits, fruit length and girth resulted in higher yield and hence these characters should be given due consideration while making selection. Characters like fruit size and fruit yield per plant had high heritability

coupled with high genetic advance and therefore could be improved by selection (Arya and Saini, 1986; Ahmed *et al.*, 1990; Natarajan *et al.*, 1994 and Sarma and Roy, 1995).

2.2.1 Mass selection

Chaudhary (1968) reported that success in mass selection depends on heritability, population size, intensity of selection, linkage relationships and variability of characters. Singh and Singh (1976) remarked that mass selection could be used to exploit both additive and dominance variance. Swarup (1977) stated that mass selection was effective to improve highly heritable characters. Celine (1981) in her study on the efficiency of selection, reported that tomato progenies developed through mass selection were superior to those developed through bulking, for days to harvest, fruits per plant and total fruit weight per plant. Rajan (1985) reported that mass selection was effective to improve fruits per plant, locules per fruit, yield per plant and fruit weight in tomato.

2.2.2 Single plant selection

Sheela (1982) reported that single plant selection was effective to improve total fruits per plant and yield in brinjal. Valentine (1979) reported that the efficiency of single plant selection for yield may be improved by selection for yield components having higher broad sense heritability at the individual plant level. Jessykutty (1985) reported that mass selection and single plant selection were superior to pure line selection and single seed descent to improve economic characters in brinjal.

2.3 Floral biology of chilli

Floral biology of *Capsicum annuum* was studied in detail by many workers but only a few attempts were made to have an insight into floral biology of *C. frutescens*.

2.3.1 Anthesis

Erwin (1929) reported that period of anthesis in chillies was comparatively shorter and in most cases less than a full day. The flowers according to him opened from 5.15 to 10 am. Gopalaratnam (1933) observed that chilli flowers opened as early as 2 am and continued upto 4 pm with a maximum rush of anthesis occurring between 3 am and 6 am. Majority of flowers opened before 6 am and on cloudy and dewy days it was delayed. Jagdish (1964) studied the anthesis of *C. frutescens* and observed that flowers of *C. frutescens* started opening at 7 am and continued up to 12 noon with peak period between 8 to 10 am. Nanjappa (1965) and Vijay *et al.* (1979) observed that full opening of flowers in chilli was between 7 am and 11 am. On the other hand, Padda and Singh (1971) found that majority of chilli flowers opened between 5 am and 6 am.

2.3.2 Anther dehiscence

In chillies, anther dehiscence takes place longitudinally commencing from tip and runs downwards along edge of the anthers. Srivastava (1916) observed that the anther sacs burst simultaneously with the opening of the flower, but the observations recorded by Shaw and Khan (1928) and Gopalaratnam (1933) indicated that the anther dehiscence followed flower opening and interval between flower opening and anther dehiscence depended on the diurnal atmospheric

conditions. The interval between anther dehiscence and flower opening, varied from 1 to 10 hours.

Paul (1940) on the other hand, observed that the dehiscence of anthers commenced from 7 to 10.30 am, depending on the variety and that the bursting was complete between 10 am and 12 noon. Padda and Singh (1971) found that pollen shedding takes place at 9 am and continued until 11 am. Vijay *et al.* (1979) in a study of floral biology of two sweet pepper varieties observed that anther dehiscence commenced at 7.45 am and continued up to 11.45 am with maximum at 7.45 am in both varieties.

2.3.3 Pollen studies

Gopalaratnam (1933) reported that viability of pollen in chilli plants lasted for 24 hours under field conditions. Popova (1973), on the other hand observed that viability of pollen can be preserved between 8 to 10 days when it was kept at a temperature of 20 to 22°C at an atmospheric humidity of 50 to 55 per cent. Vijay *et al.* (1979) observed that pollen grains remained fertile up to two days after anthesis in sweet pepper varieties, at an atmospheric temperature of 26.5°C and RH of 74.4 per cent. Barai and Roy (1986) observed that pollen remained viable up to 48 hours after anthesis.

Nectar secretion in chilli flowers was noted to commence at 4 am (Erwin, 1929; Gopalaratnam, 1933). Gopalaratnam (1933) and Vijay *et al.* (1979) observed that stigma remained receptive for 48 hours after anthesis. Nanjappa (1965) observed that under glass house conditions, the stigma was receptive even 12 hours prior to anthesis and continued to be receptive for 60 hours after anthesis with peak receptivity for 24 hours after anthesis. Padda and Singh (1971) reported that stigma

was not receptive one day before and after anthesis. According to Hosmani (1993) stigma was receptive a day earlier to anthesis and continued for two days after anthesis.

Nanjappa (1965) reported that chilli pollen germinated best in a medium of five per cent sugar and 100 ppm boric acid. He further reported that pollen tube reached the ovary within eight hours of deposition of pollen on the stigmatic surface.

2.3.4 Stigma receptivity, pollination and fruitset

Though chilli is classified as a self pollinated crop, outcrossing ranging from 7 to 98 per cent was reported (Odland and Popter, 1941; Gopalaratnam, 1933; Murthy and Murthy, 1962 and Tanksley, 1984). Murthy and Murthy (1962) had further stated that very high degree of cross pollination may be due to the fact that anther dehiscence in chilli started much later than opening of the flowers.

Nanjappa (1965) reported that under open pollination, the per cent of fruit set was 10.6. However in the emasculated plants and exposed to visit of ants, fruitset varied from 0 to 70 per cent.

2.4 Chemical constituents of chilli

The quality of chillies is decided by its pungency, colour, aroma and nutritive value. The chemical composition of *Capsicum annuum* has been well studied, whereas information on constituents of *C. frutescens* is meagre.

2.4.1 Secondary metabolites

2.4.1.1 Capsaicin

Pungency in chilli is due to a mixture of various amides, commonly designated as capsaicinoids. Capsaicin is the most important among these. Capsaicin ($C_{18}H_{27}O_3$) is a condensation product of 3-hydroxy 4-methoxy benzylamine and decyclemic acid.

Lute and Louden (1968) reported that *C. frutescens* have equal content of capsaicin and dihydrocapsaicin. Bird pepper had the highest capsaicin content (Sankarikutty *et al.*, 1982 and Narayanan, 1988).

Ogbadu *et al.* (1989) estimated total capsaicinoid content of *C. frutescens* and *C. annuum* spectrophoto metrically and reported the range of capsaicin in *C. frutescens* and *C. annuum* as 33.7 to 266.5 and 0 to 107.2 mg per 100 g respectively.

Reddy and Murthy (1988) reported that chillies can be classified based on capsaicin content as follows, high (1 to 1.5%) medium high (0.75 to 1.25%) medium low (0.5 to 0.75%) and low (0.11 to 1.25%).

Wide variation in capsaicin content of chilli fruits was reported by many workers which are summarised below.

Variation in capsaicin content in chilli varieties

No. of varieties tested	Range of capsaicin (%)	Reported by
4	0.0075-0.08	Ananthasamy *et al.* (1960)
12	0.272-1.497	Deb *et al.* (1963)
5	0.45-1.84	Kamalam and Rajamani (1965)
12	0.272-1.498	Ramanujam and Tirumalachar (1966)
10	0.0024-0.0044	Gorde (1969)
20	0.33-0.49	Sooch *et al.* (1977)
25	0.03-0.15	Bajaj *et al.* (1978)
5	0.732-4.2	Luhadiya and Kulkarni (1978)
10	0.053-0.912	Pankar and Magar (1978)
14	0.12-0.53	Sankarikutty *et al.* (1978)
24	0.15-0.925	Bajaj *et al.* (1980)
19	0.09-0.59	Theymoli *et al.* (1982)
	0.03-1.81	Deshpande and Anand (1983)
7	0.0027-0.0033	Maurya *et al.* (1984)
12	0.13-0.47	Raina and Teotia (1986)
12	0.018-0.098	Teotia and Raina (1986)
47	0.013-0.199	Teotia and Raina (1987)
1	0.6-0.7	Tewari (1990)
12	0.243-0.474	Rajput *et al.* (1991)
8	0.24-0.420	Amarchandra *et al.* (1992)
12	0.42-0.72	Narayanankutty *et al.* (1992)
	0.199-0.344	Natarajan *et al.* (1994)
73	0.056-1.810	Rani (1996b)

2.4.1.2 Oleoresin

Chilli oleoresin represents the total flavour extracts of ground chilli. It contains both pungency and colour fractions of chilli.

Yield of oleoresin from a few chilli varieties ranged from 8.7 to 16.5 per cent with the lowest in bird pepper (8.7%) (Sumathykutty and Mathew, 1984).

Lewis (1972) observed distinct differences in quality and yield of oleoresin in different varieties of chilli. Bajaj *et al.* (1980) in a varietal evaluation of oleoresin yield in 24 accessions of chilli found it to range from 29.52 to 111.52 ASTA units. Oleoresin content of a few varieties of chilli evaluated by Teotia and Raina (1986) varied from 9.6 to 18.0 per cent.

Pradeepkumar (1990) reported that *C. frutescens* had an oleoresin content of 27.3 per cent. In a study conducted by Narayanankutty *et al.* (1992) in 11 varieties of chilli, the oleoresin content ranged from 9.65 to 15.4 per cent. According to Pruthi (1993) the oleoresin content of Indian varieties ranged from 6.2 to 12.4 per cent on moisture free basis. Indira (1994) reported a range of 14 to 28 per cent in yield of oleoresin from five chilli accessions, belonging to different species.

2.4.1.3 Colour

Colour of chilli is due to carotenoid pigments. Pigment content of chilli is 0.2 to 0.5 per cent. The principal colouring matter is the carotenoid pigment capsanthin, the other pigments being ß carotene, capsorubin, zeaxanthin, cryptoxanthin and violaxanthin.

Grubben (1977) reported that the carotene content in hot and sweet pepper was 6.6 mg per 100 g and 1.8 mg per 100 g respectively.

Bajaj *et al.* (1980) evaluated the varietal variation for capsanthin content in 24 chilli accessions and found it to range from 22.3 to 118.63 ASTA units.

Chalukova *et al.* (1987) estimated carotenoid composition of ripe fruits of eight pepper varieties and observed that *C. frutescens* had the highest level of ß carotene.

Narayanankutty *et al.* (1992) reported high extractable colour (90 to 136.36 ASTA units) in 11 varieties of *C. annuum* studied. Papalkar *et al.* (1992) in a study of extractable colour in six varieties of chilli found it to range between 7119 to 8550 ASTA units. Rani (1996b) analysed 73 accessions of *C. annuum* for capsanthin content and found it varying from 0.126 to 0.407 per cent with an overall average of 0.245 per cent.

2.4.1.4 Ascorbic Acid

Capsicums are among the richest known plant sources of vitamin C. Wide variation was observed in ascorbic acid content of chillies.

Ascorbic acid content of Indian chillies

Number of varieties tested	Ascorbic acid content (mg per 100 g)	Reported by
11	85.7-22.0	Padda *et al.* (1970)
4	113.06-228	Bajaj *et al.* (1977)
5	4.85-18.5	Luhadiya and Kulkarni (1978)
24	53.77-221.86	Bajaj *et al.* (1980)
--	70-176.8	Bajaj *et al.* (1983)
--	58.7-192.1	Deshpande and Anand (1983)
11	53.77-221.86	Reddy and Murthy (1988)
33	133-399	Srivastava *et al.* (1990)
36	104.6-239.02	Pawade (1991)
8	83.33-208.33	Amarchandra *et al.* (1992)
18	66.03-157.33	AVRDC (1992)
11	14.2-220	Narayanankutty *et al.* (1992)
6	64.5-168.9	Papalkar *et al.* (1992)
19	78.8-179.9	AVRDC (1993)
73	58.73-193.1	Rani (1994)

2.4.1.5 Harvest maturity on quality of chillies

The stage of maturity is an important factor affecting the chemical constituents in the fruits.

2.4.1.5.1 Capsaicin

The degree of pungency differs from variety to variety, stage of maturity and soil and climatic factors. It was reported that capsaicinoids in *C. annuum* increased with maturation (Balbaa *et al.*, 1968) or slightly decreased (Kosuge and Inagaki, 1962) after reaching maximum (Kanner *et al.*, 1977).

Gorde (1969) observed that pungency could not be detected until fruits were four weeks old and it increased from 1.54 to 3.3 mg per 100 g in green fruit to 2.4 to 4.38 mg per 100 g in red fruit.

Awasthi and Singh (1979) reported that the content of capsaicin had high positive correlation with age of fruit. Ahmed *et al.* (1987) reported that the capsaicinoid content increased with fruit maturation in relation to the increase in dry matter content. Mini (1997) observed that chilli fruits were the least pungent at mature stage, moderate at full ripe and the highest in turning stage.

2.4.1.5.2 Colour

Cholnoky (1939) evaluated several varieties of paprika for two yearly harvests and found that total colour was higher for the first harvest than for the second.

Davis *et al.* (1970) found that the increase in carotenoids at the ripe stage was by a factor of ten fold in the red variety, while it was five fold in the yellow variety. Benedick (1972) reported that mature, but still unripe chilli fruits when harvested became red later on, however it contained less colouring matter than fruits harvested red ripe. Rahman *et al.* (1978) recorded that the total pigment at the ripe stage increased 2 to 13 fold in the green variety over the concentration at immature stage.

Quantitative analysis of carotenoid pigments of five capsicum cultivars at four stages of maturation by Rahman and Buckle (1980) resulted in isolation and identification of 10, 12, 29 and 26 pigments at immature, mature, half ripened and fully ripened fruits respectively. Saga and Ogawa (1995) found that carotenoid content increased rapidly during seven to ten weeks after flowering.

2.4.1.5.3 Ascorbic Acid

Increase in ascorbic acid content with maturity in *C. annuum* was reported by many workers (Simons, 1960; Awasti *et al.*, 1975; Awasti and Singh, 1979 and Amarchandra *et al.*, 1992). On the other hand Maurya *et al.* (1984) reported that ascorbic acid content in all varieties decreased slightly when the fruits passed from green to red stage. Lakshmi *et al.* (1992) reported a higher ascorbic acid content in ripe fruits than in unripe fruits of *C. frutescens* green (161.2 and 104 mg per 100 g) and *C. frutescens* white (150.8 and 78 mg per 100 g) respectively.

2.4.2 Fatty acid, nucleic acid, enzyme and flavour components

2.4.2.1 Fatty acid

The distribution of fixed oil in the fruit is uneven, being found mainly in the seeds. Narayanan *et al.* (1980) extracted chilli seeds with ethylene dichloride and obtained an oil yield of 19 per cent containing 0.024 per cent capsaicin. Govindarajan (1985) reported that fat content in capsicums is mostly in seed and content varies from 9 to 16 per cent. Seeds of paprika extracted with petroleum ether gave 25.4 per cent of fat. Reddy and Murthy (1988) reported that chilli seeds contain 26 per cent of fatty oil which is chiefly made up of triglycerides of palmitic, oleic and linolenic acid.

The fatty oil (9 to 18%) from dry fruit is red and viscous with sharp tart (Kachru and Srivastava, 1990). The chilli seed contains 26.1 per cent oil and meal free of oil. The seeds of capsicums contain 19 to 27 per cent of fatty oil. The per cent of saturated and unsaturated fatty acids in fruits of *C. frutescens* has been reported as 22.1 and 75.3 respectively (Purseglove *et al.*, 1981).

2.4.2.2 Nucleic acid

Quantitative determination of nucleic acid in different plant organs by the colourimetric method had been attempted by many workers (Gospar ikova, 1974; Kadam and Salunke, 1980; Bose *et al.*, 1988).

Bose *et al.* (1988) had reported that nucleic acids are primarily a reserve material to be transfered to the embryonic axis during germination.

2.4.2.3 Enzyme activity

Peroxidases and polyphenol oxidases are key enzymes responsible for synthesis of quinones from phenolics. Quinones are highly bactericidal and fungitoxic. Increased activity of these enzymes might be responsible for disease resistance.

2.4.2.3.1 Peroxidase activity

Peroxidase enzyme occurs in higher plants and catalyses the dehydrogenation of a large number of organic compounds such as phenols, aromatic amines, hydroxyquinones etc. (Sadasivam and Manickam, 1992).

Peroxidase activity in leaves of 60 day old seedlings of chilli varieties Ujwala and Pusa Jwala was 193.37 and 99.96 units per litre of enzyme extract respectively (Markose, 1996).

2.4.2.3.2 Polyphenol oxidase

Polyphenol oxidase acts on phenolic constituents present in green chillies and converts them to brown pigments known as melanins. The activity of these enzymes is important with regard to plant defence mechanism against pests and diseases and appearance, palatability and use of plant products.

Luhadiya and Kulkarni (1978) studied the chemical composition of green fruits of *C. frutescens* and reported that polyphenol oxidase activity and protein content per gram of pulp ranged from 118 to 510 units per gram of pulp and 27.3 to 40.5 mg g^{-1} respectively. A study of polyphenol oxidase activity in 18 varieties of

brinjal showed that it ranged from 0.33 to 1.25 arbitary units per mg of protein (Bajaj *et al.*, 1981). In a study conducted by Bajaj *et al.* (1983) in eight varieties of chilli, the polyphenol oxidase activity ranged from 0.3 to 1.4.

Markose (1996) reported variation in polyphenol oxidase activity between varieties Ujwala and Pusa Jwala.

2.4.2.4 Flavour components

The fruits of *Capsicum* sp. had a relatively low volatile oil content which had been reported to range from 0.1 to 2.6 per cent in paprika and similar large forms of *C. annuum* (Winton and Winton, 1939; Szabo, 1970). Huffman *et al.* (1978) reported that flavour in Jalapeno pepper was attributed to 2-isobutyl-3 methoxy pyrazine, the values of which ranged from zero in the seed to 88.33 mg g^{-1} in the outer wall on dry weight basis.

Govindarajan (1985) reported the content of ether extract volatiles as 0.4 per cent in whole chillies. High vacuum distillation of capsicums yielded only 1 to 2 ppm on a fresh weight basis. The steam volatile constituents of tabasco peppers after lyophilization were isolated and presence of 125 components reported (Raina *et al.*, 1986).

2.5 Biochemical characterization of *Capsicum* sp.

Another approach to morphological and genetic studies for classification of the genus *Capsicum*, is to use the secondary metabolites of the plant, known to be under genetic regulation and unaffected by environmental fluctuations. Isozyme variations are used as powerful tools to complement phytogenetic studies (Gottlieb,

1971, 1977, 1982; Rick *et al.*, 1976; Rick and Tanksley, 1981 and Crawford, 1983).

Oliver and Zapater (1985) had opined that among organic molecules, isozymes are very useful aids in deciphering evolutionary relationship within different groups of plant and animal organisms. Isozymes are used as supplementary tools, along with morphological and other methods of plant classification.

Mathe and Wu (1988) studied 17 enzyme systems as isozymic genetic markers in genus *Capsicum* and good results were obtained with esterase, glutamate dehydrogenase, peroxidase, phosphoglucomutase, glutamate oxalo acetate transaminase and lactate dehydrogenase.

Mcleod *et al.* (1979) used horizontal starch gel electrophoresis techniques with 15 enzymes for classification of *Capsicum* species and obtained zymograms of 14 enzymes and one nonspecific protein after electrophoresis and histochemical staining.

Marsalek (1981) reported that isoperoxidases in leaves determined by means of PAGE displayed differences in pattern according to accession. These differences were more discernible at the stage with six leaves or eight leaves than at the beginning of flowering.

Wang and Dehua (1987) analysed *Capsicum* germplasm of North Western Agricultural University, China using gel electrophoresis technique. They observed that ideal sampling tissue for electrophoresis of peroxidase isozymes, were functional leaves at flowering stage.

Belletti *et al.* (1992) studied allozyme variability among four domesticated species of *Capsicum* viz., *C. annuum*, *C. baccatum*, *C. chinense* and *C. frutescens*. Twenty one enzyme systems were identified. Higher degree of polymorphism was found between accessions of *C. annuum* and *C. baccatum*, whereas no such polymorphism was found within *C. frutescens*.

Bernal *et al.* (1994) studied the expression of peroxidases in vegetative and flowering phases of *C. annuum* and observed that leaf development in both phases was accompanied by a significant increase in the level of the peroxidase isoenzyme.

Materials and Methods

MATERIALS AND METHODS

The present investigations were carried out at the College of Horticulture, Kerala Agricultural University, Vellanikkara during 1993-1997. The crops were raised at the vegetable research plot of the Department of Olericulture located at an altitude of 22.5 m above MSL and between 10° 32' N latitude and 76° 16' E longitude. The area enjoys a warm humid tropical climate. The experimental site has a sandy loam soil with a pH of 5.1.

The studies comprised of the following experiments.

1. Survey, collection, evaluation and cataloguing of bird pepper (*Capsicum frutescens* L.) germplasm.
2. Somatic analysis for yield, quality and their components.
3. Improvement of selected lines through single plant and mass methods of selection and comparing the relative effectiveness of the methods.
4. Biochemical analysis for various constituents in bird pepper
   A. Analysis of secondary metabolites
   B. Analysis of fatty acid, nucleic acids, protein, enzyme activities and flavour components.
5. Study on floral biology of bird pepper.
6. Biochemical characterization of *C. frutescens*.

3.1 Survey, collection, evaluation and cataloguing of bird pepper (*Capsicum frutescens*) germplasm

3.1.1 Experimental materials

Eightysix diverse accessions of *Capsicum frutescens* were collected through survey and correspondence. Since there are no released varieties of bird pepper in the country, all the accessions included in the study were local accessions. The accessions were evaluated during the season October '93 to June '94. Twenty plants of each accession were planted at a spacing of 60 cm x 60 cm. The crop was raised as recommended by the Kerala Agricultural University (KAU, 1993). Meteorological data during the cropping period are given in Appendix-I.

3.1.2 Observations

Characterization of the bird pepper accessions was done, as per the descriptor list of IBPGR for *Capsicum* (IBPGR, 1983). Observations were recorded on the following morphological characters.

Descriptor list of chillies

1. Plant growth habit - Prostrate, compact, erect
2. Stem pubescence - Glabrous, sparse, intermediate, abundant
3. Stem colour - Green, purple
4. Leaf pubescence - Glabrous, sparse, intermediate, abundant
5. Number of pedicels per axil - 1, > 1

6. Pedicel position at anthesis	- Pendent, intermediate, erect
7. Corolla colour	- White, grey white, lavender, blue, violet and others
8. Corolla spot	- Absent/present
9. Calyx margin shape	- Smooth, intermediate, dentate
10. Annular constriction at junction of calyx and peduncle	- Absent/present
11. Anther colour	- Yellow, pale blue, blue, purple, others
12. Filament colour	- White, blue
13. Fruit position	- Declining, intermediate, erect
14. Fruit colour in immature stage	- Green, yellow, orange, red, purple, brown, black, others
15. Fruit colour in mature stage	- Green, yellow, orange, red, purple, brown, black, others
16. Fruit shape	- Elongate, oblate, round, conical, companulate, bell or blocky
17. Fruit shape at peduncle attachment	- Acute, obtuse, truncate, cordate, lobate
18. Neck at base of fruit	- Absent, present
19. Fruit shape at blossom end	- Pointed, blunt, sunken
20. Fruit cross sectional corrugation	- Smooth, slightly corrugated, intermediate, very corrugated

21. Fruit persistence - Deciduous, persistent

22. Seed colour - Straw colour, dark brown

Biometric characters

Five plants were selected at random from each accession and observations on the following quantitative characters recorded. Five fruits were selected at random for recording observations on fruit characters.

Plant height (cm) - From ground level to the tip of the plant measured in cm.

Primary branches per plant - Number of branches arising from main stem were counted.

Days to 50% flowering - Number of days from sowing to flowering of 50% of plants was computed.

Days from sowing to first harvest - Number of days from sowing to first harvest of green chillies was computed.

Fruit length - Measured as the distance from pedicel attachment to apex in cm.

Pedicel length - Distance between point of attachment of stem and fruit measured in cm.

Fruit pedicel ratio - Ratio of fruit length to pedicel length.

Fruit girth - Measured using twine and scale at its maximum width in cm.

Fruit size - Fruit length x Fruit girth

Fruit weight - Ten fruits were weighed and average expressed in grams.

The data were analysed statistically as for a completely randomized block design with five replications (Panse and Sukhatme, 1978). Frequency per cent for each character in the population was worked out as per Mohammed (1994).

3.2 Somatic Analysis for yield and its components

Twenty five promising accessions exhibiting variability for fruit characters were selected from the first experiment, these included both green and white fruited accessions. The accessions were grown in a randomized block design with two replications for two seasons (July to December '94 and January to July '95). Fifty plants were included per accession in each replication, with a spacing of 60 cm x 45 cm.

3.2.1 Biometric characters

Five plants were randomly selected from each replication for recording observations on the following characters.

Plant height (cm)

Primary branches per plant

Days to 50% flowering

Days to first harvest

Number of harvests

Fruit length (cm)

Pedicel length (cm)

Fruit size (cm^2)

Average fruit weight (g)

Driage (%)

Crop duration

The analysis of variance was done for season I and II separately as per Panse and Sukhatme (1978).

3.2.2 Variability parameters in bird pepper

Variability for different quantitative characters was estimated as suggested by Burton (1952). Heritability in the broad sense was estimated as per Burton and Davis (1953). Expected genetic advance at 5 per cent intensity of selection was calculated using the formula suggested by Johnson et al. (1955).

3.2.3 Genetic divergence

The genetic divergence among 25 bird pepper accessions was calculated adopting the Non-hierarchical Euclidean cluster analysis. All possible $n(n-1)/2$ D^2 values between 25 accessions were calculated utilizing the varietal means. The clustering of the accessions was done by the iterative method suggested by Suresh and Unnithan (1996).

3.3 Improvement of selected lines through single plant and mass methods of selection and comparing the relative effectiveness of the methods

3.3.1 Materials

Six promising lines from the second experiment were selected based on fruit size and yield. These included four white fruited accessions (CF 19, CF 23, CF 36, CF 103) and two green fruited accessions (CF 5, CF 10). The selected accessions were advanced through two methods of selection, single plant and mass selection for three generations viz., September '95 to April '96; August '96 to March '97 and April '97 to November '97. A comparison of the performance of the selected accessions was made separately in each generation.

The lines were grown in a randomized block design with two replications. There were 50 plants/ accession/selection method/replication.

3.3.2 Methods of selection

3.3.2.1 Mass selection

Observations were made on each plant on yield and quantitative characters. The plants were selected based on fruit size and yield. Intensity of selection followed was five per cent and plants falling in the upper five per cent limit in each group was selected, fruits collected, seeds extracted and bulked.

3.3.2.2 Single plant selection

The most promising elite plant within each group was selected, fruits harvested, seeds extracted and progressed.

3.3.3 Observations

Observations were recorded on morphological and productive characters as follows:

Morphological characters - Plant height (cm)
Primary branches per plant

Productive characters - Days to first harvest
Number of harvests
Fruits per cluster
Fruit length (cm)
Pedicel length (cm)
Fruit/pedicel ratio
Fruit girth
Fruit size
Average fruit weight
Crop duration
Yield per plant

The data were analysed as suggested by Panse and Sukhatme (1978). Analysis of variance was done to find out relative effectiveness of selection methods.

The superiority of one selection method over other was assessed by comparing the realised genetic gain (Response to selection). The realised genetic gain under different methods of selection was calculated as follows.

Realised genetic gain = Mean performance of the accession in the advanced generation - Mean performance of base population of the accession.

3.4 Floral biology of bird pepper

Major aspects of floral biology namely time of anthesis, anther dehiscence, stigma receptivity and pollen characteristics were studied.

Materials

Six selected accessions of bird pepper CF 5, CF 10, CF 19, CF 23, CF 36 and CF 103 were used for the study. Of these CF 5 and CF 10 were green fruited and others white fruited.

3.4.1 Anthesis and anther dehiscence

This study was conducted in accessions CF 5 and CF 23. The flower buds become swollen and turgid one day prior to opening. One hundred such flower buds were tagged at 3 pm. Observations on flower opening and anther dehiscence were recorded at hourly intervals starting from 6 am on the following day. The study was conducted on a rainy day with rainfall of 66.6 mm (from 6 am to 6 pm), maximum and minimum temperature of 26.1°C and 23.3°C respectively.

The number of fully opened flowers at hourly intervals were recorded and percentage worked out. The duration and peak time of flower opening was also observed.

Anther dehiscence was also recorded at hourly interval with the help of a hand lens. Dehiscence of a single anther in each flower bud was considered as anther dehiscence. Time of start of anther dehiscence, duration and peak period of dehiscence were observed.

3.4.2 Stigma receptivity

The study was conducted in accessions CF 5 and CF 23. The receptivity of stigma was studied by the fruit set method using assisted pollination. In each of the above accessions, four hundred flower buds likely to open the next day, were emasculated and bagged over a period of one week. The flower buds/flowers were pollinated at different stages as indicated below.

1) Bud pollination: Immediately after emasculation on the previous day at 9 am ie. 24 hours before flower opening.
2) Pollination at the time of flower opening i.e. at 9 am.
3) Pollination at 3 pm ie. 5 to 6 hours after flower opening.
4) Late pollination: Pollination 24 hours after flower opening ie. at 9 am on the next day.

One hundred flower buds were selected to represent each stage in each of the accessions. Fruit set was recorded one week after pollination.

3.4.3 Pollen studies

The pollen studies were undertaken in the selected accessions of bird pepper, CF 5, CF 10, CF 19, CF 23, CF 36 and CF 103. Different aspects of pollen such as morphology, fertility, viability and total number of pollen grains per anther were studied.

3.4.3.1 Pollen fertility

Anthers about to dehisce were collected separately from each accession and the pollen grains were mounted in a drop of Acetocarmine : Glycerine mixture (1:1). The slides were kept for about 30 minutes to allow pollen grains to take stain properly before examining under a microscope. The pollen fertility was studied by counting the well filled and stained pollen grains in 10 microscopic fields in each accession. Unfilled and unstained pollen grains were considered as sterile. Pollen fertility was calculated as follows:

$$\text{Percentage of fertile pollen} = \frac{\text{Number of well filled and stained pollen grains}}{\text{Total number of pollen grains}} \times 100$$

The diameter of 100 well shaped and well stained pollen grains from each of the accessions was measured using an occular micrometer and expressed in microns.

3.4.3.2 Pollen viability

Pollen germination studies were conducted in a medium of 5 per cent sucrose and 100 ppm boric acid to estimate the viability.

Pollen collected from fresh flower buds just before opening were dusted in cavity slides containing the medium (5% sucrose and 100 ppm boric acid) and kept in a dessicator. The required humidity in the dessicator was maintained by pouring water at the base. The germination counts were recorded five hours after sowing of the pollen.

$$\text{Pollen germination (\%)} = \frac{\text{Number of pollen germinated}}{\text{Total number of pollen}} \times 100$$

3.4.3.3 Pollen production

Number of pollens produced per anther was counted in all the accessions using haemocytometer. Flower buds were collected just before anther dehiscence. Distilled water 0.1 ml containing 0.05 per cent teepol was taken in a glass vial. Five anthers from each flower bud were transferred to the glass vial and crushed gently to release the pollen. The contents were stirred thoroughly in order to attain an even dispersion of pollen grains in the suspension. A drop of this suspension was drawn in a micropipette and transferred to each of the two counting chambers of a Improved Neubauer haemocytometer. Each of the chamber had an area of 0.0025 mm^2 divided into square millimeter areas. The counting chambers were 0.1 mm in depth so that the volume of solution that can be held in each chamber was 0.00025 ml.

The pollen grains in each of the counting chamber were counted by using low power objectives of the microscope. For each accession ten such estimates were made. The number of pollen per anther was calculated as follows.

Volume of each chamber = 0.00025 ml

If X is the average number of pollen per counting chamber ie. in 0.00025 ml

Number of pollen in 0.1 ml of solution (ie. in 5 anthers or one flower) $= \frac{X \times 0.1}{0.00025} = 40\ X$

Pollen output per anther $= \frac{40\ X}{5}$

The data on pollen studies were statistically analysed as in a completely randomised block design with 3 replications.

3.4.4 Heterostyly

One hundred flowers each in accessions CF 5 and CF 23 were examined for differences in style length. The flowers so examined were grouped into different categories based on the position of stigma in relation to anther tip as follows:

Long styled flowers - Position of stigma well above the level of anthers.

Medium styled flowers - Position of stigma at the same level of anthers.

Short styled flowers - Position of stigma well below the level of anthers.

The per cent of flowers in each category was calculated.

3.5 Biochemical analysis for chemical constituents in bird pepper

3.5.1 Analysis of secondary metabolites

The chemical constituents of 25 selected accessions of *Capsicum frutescens* at two stages of fruit maturity were analysed. The constituents estimated were capsaicin, vitamin C, oleoresin and carotenoids. Influence of harvest maturity on these constituents was studied by biochemical analysis at the following stages of maturity.

A - Fully mature, but green

B - Red ripe

3.5.1.1 Capsaicin

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

Reagents

Folin-Dennis Reagent (Preparation of Folin-Dennis reagent is given in Appendix II).

25% Acqeous sodium carbonate solution

Acetone

Procedure

The bird pepper fruits harvested at two stages of maturity were dried in a hot air oven at 50°C and powdered finely in a Sumeet mixer-grinder. One gram each of the samples were weighed into test tubes, added 10 ml acetone and kept overnight. Aliquots of 1 ml were pipetted into 100 ml conical flasks, added 25 ml of Folin-Dennis reagent and allowed to stand for 30 minutes. Added 25 ml of freshly prepared sodium carbonate solution and shook vigorously. The volume was made up to 100 ml with distilled water and the optical density was determined after 30 minutes at 725 nm against reagent blank (1 ml acetone + 25 ml Folin-Dennis reagent + 25 ml aqueous sodium carbonate solution using a UV spectrophotometer).

To determine the EI per cent value for pure capsaicin, a stock solution of standard capsaicin (200 μg ml^{-1}) was prepared by dissolving five milligram in 25 ml acetone. From this a series of solutions of concentrations 400 μg, 600 μg, 800 μg and 1000 μg were prepared and their optical density measured at 725 nm. Standard graph was prepared and calculated the content of capsaicin in the samples.

3.5.1.2 Oleoresin

Oleoresin in chilli was extracted in a Soxhlet's apparatus using solvent acetone.

Procedure

Chilli fruits harvested at two stages of maturity were dried in a hot air oven at 50°C, powdered to pass through a 100 mesh sieve.

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

Yield of oleoresin on dry weight basis was calculated using formula

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

3.5.1.3 Carotenoids

Carotenoids present in fruits of bird pepper was extracted using acetone and its optical density measured at 450 nm.

Procedure

Two hundred milligrams of fresh fruit was cut into small pieces and homogenised in a blender with acetone. The homogenate was transferred into a volumetric flask, made up to 100 ml and kept overnight in dark. The optical density

was measured at 450 nm (Jensen, 1978). The carotenoids present in the extract was calculated using the formula

$$C = \frac{D \times v \times f \times 10}{2500}$$

where

C = total amount of carotenoids in mg

D = absorbance at 450 nm in a 1 cm cell

v = volume of the original extract in ml

f = dilution factor

2500 = average extinction coefficient of the pigments

3.5.1.4 Ascorbic Acid

Ascorbic acid content of the selected bird pepper accessions at two stages of maturity was estimated by 2,6-dichlorophenol indophenol dye method (Mahadevan and Sridhar, 1974).

Reagents

Metaphosphoric acid (3%)

Ascorbic acid standard

2,6-dichlorophenol indophenol dye

Procedure

Five grams of fresh fruits were extracted in an acid medium (3% HPO_3) and titrated against 2,6-dichlorophenol indophenol dye to a pink colour which persisted for at least five seconds.

Ascorbic acid content of the sample was calculated using the formula

$$\text{Mg of Ascorbic acid per 100 gram of fresh fruits} = \frac{\text{Titre xDye factor x Vol. made up x 100}}{\text{Aliquot of extract taken x weight of sample taken}}$$

3.5.2 Estimation of fatty acid, nucleic acids, enzymes and flavour components

A comparison of *Capsicum annuum* and *C. frutescens* based on nucleic acid and fatty acid content, enzyme activities and flavour components was attempted. The varieties used for estimation of nucleic acids, fatty acids and enzymes were

Capsicum annuum	Ujwala
,, ,,	K-2
C. frutescens green	CF 5
,, ,,	CF 10
C. frutescens white	CF 19
,, ,,	CF 36

3.5.2.1 Estimation of fatty acid

The free fatty acid content of chilli seed oil was estimated gravimetrically.

3.5.2.1.1 Estimation of oil in chilli seeds

Oil from 20 g of seed was extracted with petroleum ether. Solvent was then distilled off completely, dried, the oil weighed and per cent of oil was calculated.

Materials

Petroleum ether (40-60°C)

Whatman No. 2 filter paper

Procedure

The chilli seeds were dried in a hot air oven at 50°C and ground to a fine powder. Exactly 20 grams of the sample was placed in the filter paper fold and placed in the butt tubes of the Soxhlet extraction apparatus. The oil was extracted with petroleum ether (250 ml) for 20 hours by gentle heating. The solvent was evaporated by vacuum evaporation and weight of the oil recorded. The oil content of the sample was estimated using the formula

$$\text{Oil in ground sample \%} = \frac{\text{Weight of oil (g)}}{\text{Weight of sample (g)}} \times 100$$

3.5.2.1.2 Estimation of free fatty acid content of oil

A small quantity of Free Fatty Acids (FFA) is usually present in oil along with triglycerides. The acid number/acid value is an indication of the free fatty acids in an oil.

The FFA in the oil was estimated by titrating it against KOH in presence of phenolphthalein as indicator. The acid number is defined as the mg KOH required to neutralize the free fatty acids present in 1 g of the sample. The free fatty acid is expressed as oleic acid equivalents.

Reagents

0.1 N KOH

Phenophthalein indicator

Neutral solvent - Preparation given in Appendix III.

Procedure

Dissolved 1 g of oil in 50 ml of neutral solvent. Added a few drops of phenolphthalein indicator and titrated against 0.1 N KOH to a pink colour which persisted for 15 sec.

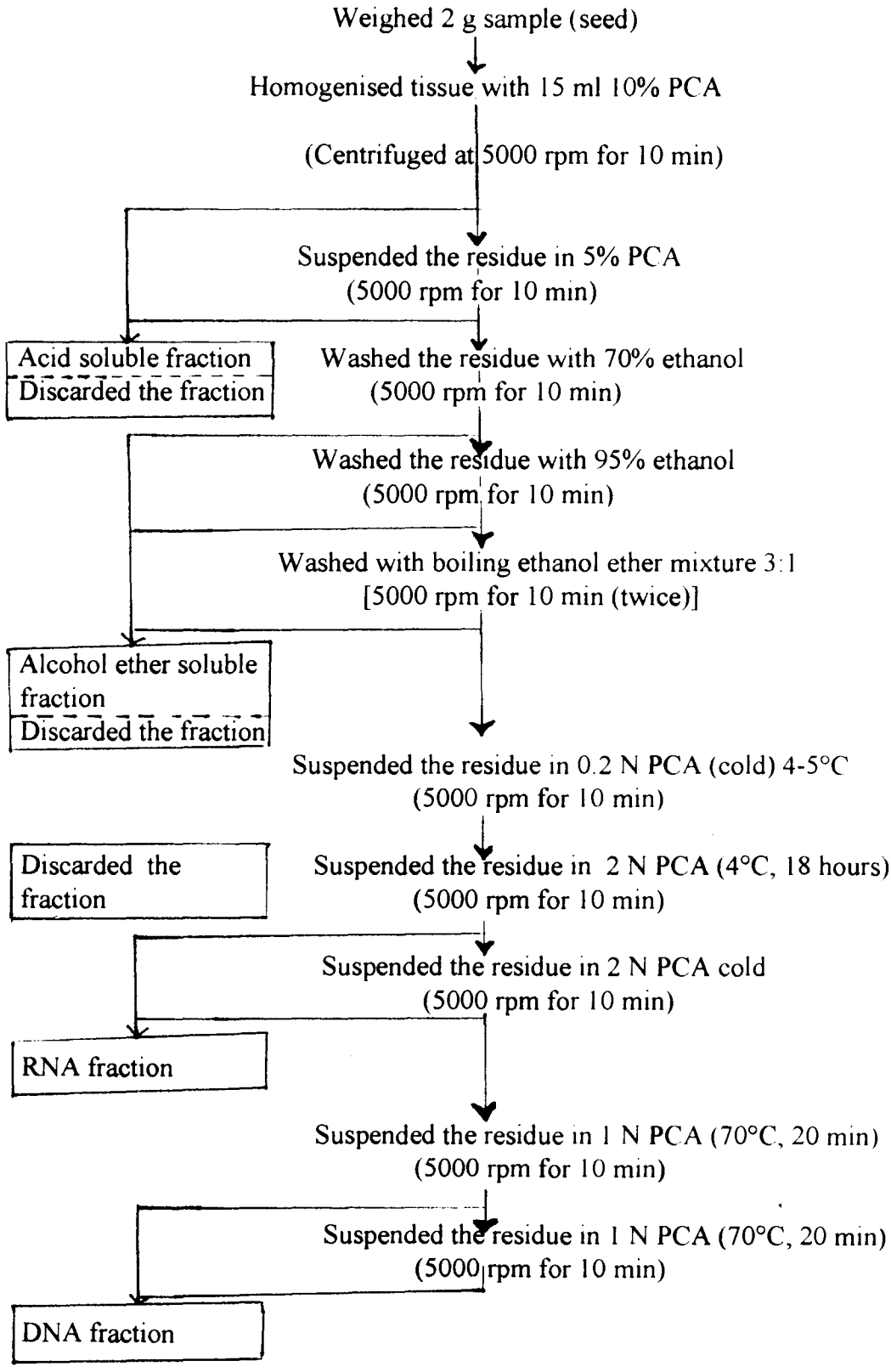
$$\text{Acid value (mg KoH/g)} = \frac{\text{Titre value x Normality of KOH x 56.1}}{\text{Weight of sample (g)}}$$

3.5.2.2 Nucleic acids

Deoxyribonucleic acid and ribonucleic acid content of six accessions in *Capsicum* sp. were estimated. The nucleic acids were isolated based on methods outlined by Schneider (1945) and Ogur and Rosen (1950).

Extraction

The procedure for extraction of nucleic acid is presented as a flow chart below:


Weighed 2 g sample (seed)
Homogenised tissue with 15 ml 10% PCA
(Centrifuged at 5000 rpm for 10 min)
Suspended the residue in 5% PCA
(5000 rpm for 10 min)
Acid soluble fraction
Discarded the fraction
Washed the residue with 70% ethanol
(5000 rpm for 10 min)
Washed the residue with 95% ethanol
(5000 rpm for 10 min)
Washed with boiling ethanol ether mixture 3:1
[5000 rpm for 10 min (twice)]
Alcohol ether soluble fraction
Discarded the fraction
Suspended the residue in 0.2 N PCA (cold) 4-5°C
(5000 rpm for 10 min)
Discarded the fraction
Suspended the residue in 2 N PCA (4°C, 18 hours)
(5000 rpm for 10 min)
Suspended the residue in 2 N PCA cold
(5000 rpm for 10 min)
RNA fraction
Suspended the residue in 1 N PCA (70°C, 20 min)
(5000 rpm for 10 min)
Suspended the residue in 1 N PCA (70°C, 20 min)
(5000 rpm for 10 min)
DNA fraction

3.5.2.2.1 Estimation of DNA

DNA content was estimated by the diphenylamine test for deoxyribose.

Reagents

Diphenylamine reagent (Preparation given in Appendix IV).

Procedure

Pipetted out 1 ml of PCA extract of DNA, added 1 ml of diphenylamine reagent and kept at room temperature for 16 hours in the dark. After dilution with 18 ml of glacial acetic acid, the absorbance was read at 595 nm.

DNA standard

Stock solution of concentration 2000 µg was prepared by dissolving 60 mg of DNA standard in 30 ml of 1N PCA. From this, a series of solutions of concentration 500, 600, 800, 1000, 1200 and 1400 µg were prepared. To 1 ml of each of these solutions, 1 ml diphenylamine dye was added and kept for 18 hours in dark. The volume was made up to 20 ml with glacial acetic acid and absorbance read at 595 nm against reagent blank. Standard graph was prepared.

3.5.2.2.2 Estimation of RNA

Pentose sugar in RNA reacts with orcinol in the presence of ferric iron and yield a variety of products which have absorbance maximum at 660 nm.

Reagent

Orcinol reagent (Preparation given in Appendix IV).

Procedure

Pipetted out 1 ml of sample 7.5 ml 2 N PCA and added 1.5 ml of orcinol reagent A. Heated for 25 minutes in a boiling water bath. Cooled to room temperature in cold water and absorbance read at 660 nm against reagent blank (8.5 ml 2 N PCA + 1.5 ml orcinol reagent A).

RNA standard

Stock solution of RNA of concentration 2000 µg was prepared by dissolving 20 mg in 10 ml 2 N perchloric acid. From this stock solution, a series of solutions of concentrations 200, 300, 400, 500, 600, 800, 1000, 1200 and 1400 µg were prepared. Pipetted out 1 ml each of the above solutions, added 1.5 ml orcinol reagent and made up volume to 10 ml with 7.5 ml 2 N PCA. Heated in a boiling water bath for 25 minutes, cooled and read absorbance at 660 nm against reagent blank. Standard graph was plotted.

3.5.2.3 Estimation of protein

Protein content was determined by Lowry's method (Lowry *et al.*, 1951). The blue colour developed by reduction of phosphomolybdic phosphotungstic components in the Folin-Ciocalteau reagent by the aminoacids tyrosine and

trytophan present in the protein plus the colour developed by the biuret reaction of the protein with the alkaline cupric tartrate are measured in the Lowry's method.

Reagents

A. 2% sodium carbonate in 0.1 N NaOH (Reagent A)

B. 0.5% $CuSO_4$ in 1% potassium sodium tartarate (Reagent B)

C. Alkaline Copper solution. Mixed 50 ml of A and 1 ml of B prior to use (Reagent C)

D. Folin-Ciocalteau Reagent (Reagent D) (Preparation given in Appendix V.

E. Protein solution (stock standard)Weighed accurately 50 mg of Bovine serum albumin, dissolved in distilled water and made up to 50 ml ie. 1000 mg.

F. Working standard

From the stock solution prepared a series of solutions of concentrations, 100, 200, 300, 400, 500, 600 and 1000 µg were prepared.

G. Extraction buffer (Tris buffer, pH 7.0) -

(Preparation given in Appendix V)

Leaves of 60 day old seedlings were used for the study. Extracted 2 g of fresh plant tissue in 10 ml of extraction buffer (pH 7) by grinding in a precooled mortar and pestle. The homogenised material was centrifuged at 18,000 rpm for 15 minutes at 5°C. The supernatants were used as enzyme source. To 1 ml of enzyme extract, 2 ml of 10% TCA was added, kept for 30 minutes at 0°C and centrifuged at 8000 rpm for 10 minutes. The supernatant was discarded and the precipitate washed twice with alcohol:ether (1:1) and once with alcohol. The precipitate was dissolved in 1 ml of 0.1 N NaOH.

Procedure

Pipetted out 1 ml each of working standard solutions and 0.1 ml of sample extracts into a series of test tubes. Made up the volume to 1 ml with distilled water in all the test tubes. A tube with 1 ml of water served as the blank. Added 5 ml of reagent C to each tube including blank. Mixed well and allowed to stand for 10 minutes. Then added 0.5 ml of reagent D, mixed well and kept for 30 minutes at room temperature for blue colour development and read the absorbance at 660 nm. A standard graph was drawn and calculated the protein content in the sample.

Expressed the amount of protein as mg g^{-1} of sample.

3.5.2.4 Enzyme activities

The activities of two enzymes viz. polyphenol oxidase and peroxidase were determined. Leaves of *Capsicum annuum*, *C. frutescens* (green) and *C. frutescens* (white) were used for the study.

3.5.2.4.1 Peroxidase

Guaiacol was used as substrate for assay of peroxidase.

$$\text{Guaiacol} + H_2O_2 \xrightarrow{\text{Peroxidase}} \text{Oxidised guaiacol} + 2\ H_2O$$

The rate of formation of guaiacol dehydrogenation product is a measure of the peroxidase activity. Peroxidase activity was assayed as per the method of Sadasivan and Manikam (1992).

Reagents

Extraction buffer - Phosphate Buffer 0.1 M

Stock solution

A - 0.2 M solution of monobasic sodium phosphate

B - 0.2 M solution of dibasic sodium phosphate

39 ml of A and 61 ml of B diluted to 200 ml with distilled water

Substrate

Guaiacol solution 20 mM

Dissolved 240 mg guaiacol in water and made up to 100 ml.

Hydrogen peroxide solution

Diluted 0.14 ml of 30 per cent H_2O_2 to 100 ml water. (Prepared fresh).

Enzyme extract

Extracted 1 g of fresh plant tissue (leaves of 45 and 75 days old seedling) in 3 ml of phosphate buffer along with 0.040 g of insoluble PVP in a precooled mortar and pestle. All operations were carried out at 4°C. The homogenised material was centrifuged at 18000 rpm for 15 minutes in a refrigerated centrifuge at 4°C. The supernatant was used as enzyme source within 2 to 4 hours.

Procedure

Set the spectrophotometer at 436 nm with 3.1 ml buffer, 0.05 ml guaiacol and 0.03 ml H_2O_2. Pipetted out 3 ml buffer solution, 0.05 ml guaiacol, 0.1 ml enzyme extract and 0.03 ml H_2O_2 solution in a cuvette, mixed well and placed in the spectrophotometer. Waited until the absorbance has increased by 0.05 and noted the time in minutes (Δt) to increase the absorbance by 0.1.

Calculation

$$\text{Enzyme activity units/ litre of extract} = \frac{3.18 \times 0.1 \times 1000}{6.39 \times 1 \times t \times 0.1}$$

$$= \frac{500}{\Delta t}$$

The extinction coefficient of guaiacol dehydrogenation product at 436 nm is 6.39 per micromole.

3.5.2.4.2 Polyphenol oxidase

Polyphenol oxidase activity was assayed by the method suggested by Malik and Singh (1980). The enzyme comprises of catechol oxidase and laccase and catalyses mainly the following reaction.

$$\text{Catechol} \xrightarrow[\text{Oxidase}]{\text{Catechol}} \text{quinone}$$

Reagents

Extraction Buffer : (Same as for protein estimation).

Buffer for assay : Phosphate buffer (0.1 M)

Monobasic sodium phosphate solution 0.2 M - 87.7 ml

Dibasic sodium phosphate solution 0.2 M - 12.3 ml

Water - 200 ml

Substrate : Catechol - 0.110 g/50 ml of assay buffer

Enzyme extract : (Same as for protein estimation)

Procedure

Pipetted out 1 ml extraction buffer and 5.5 ml phosphate buffer in a cuvette and set the spectrophotometer at 495 nm. One ml enzyme extract and 5.5 ml phosphate buffer were taken in a burette and noted the reading (catechol blank). Pipetted out 1 ml enzyme extract, 5.4 ml buffer and 0.1 ml catechol in the cuvette, mixed immediately and started recording changes in absorbance for every 30 seconds up to 1 minute.

Calculation

Plotted the increase in absorbance values and noted the changes in absorbance per minute from the linear phase of the curve. Expressed enzyme activity in terms of the rate of increased absorbance per unit time per mg protein.

$$\text{Specific activity} = \frac{\text{1 minute activity}}{\text{Protein (mg)}}$$

3.5.2.5 Analysis of flavour components in *Capsicum* sp.

The flavour components of volatile oil extracted from fresh and dehydrated fruits were analysed by gas chromatography.

The materials used for the study were local accessions of *Capsicum annuum* and *Capsicum frutescens* (green and white types).

Extraction of essential oil

The fruits were harvested at maturity. The fresh fruits used for extraction were cut into small pieces and coarsely ground in a mixer-grinder. The second set of samples were dehydrated in a hot air oven at 40°C. The essential oil from the fruits was extracted by hydrodistillation using clevenger trap (lighter than water) ASTA (1968).

Analysis of flavour components

Analysis of aroma bearing constituents in the essential oil was done in a Perkin Elmer Autosystem Gas Chromatograph equipped with model 1022 GC PENNELSON integrator. The compounds were separated in an OV17 column using Nitrogen as carrier (@ 30 ml per minute) gas using a Flame Ionisation Detector. The oven temperature was programmed from 70 to 200°C @ 5°C per minute. The retention time and peaks (with area per cent > 0.5%) were noted for

each sample. The relative proportion of each component to total area per cent was worked out for every sample.

3.6 Biochemical characterization of *C. frutescens* by isozyme analysis

The electrophoretic pattern of isoenzyme, peroxidase was studied in two species of *Capsicum, viz. C. frutescens* L. and *C. annuum* L.

Polyacrylamide gel electrophoresis

Polyacrylamide gel electrophoresis using vertical slab gel was carried out by the methods suggested by Hames and Rickwood (1994) for identifying the electrophoretic pattern of isozymes. Acrylamide monomers were polymerised with N-N methylene bis acrylamide CH_2 (NHCONH = $CH_2)_2$ to obtain the gel. Freshly prepared ammonium persulphate acted as catalyst and N,N,N'N' - tetramethyl ethylene diamine (TEMED) as chain initiator.

Polyacrylamide gel was preferred because of its chemical inertness, high resolution, ease in handling, transparency of the gel and easiness in preparation.

3.6.1 Materials

Capsicum annuum	- Ujwala
,,	- K-2
C. frutescens (white)	- CF 19
,,	- CF 36
C. frutescens (green)	- CF 5
,,	- CF 10

Two accessions each under *C. annuum*, *C. frutescens* (white) and *C. frutescens* (green) were used for the study.

Extraction buffer

Tris.HCl	- to pH 7.4
Cysteine	- 0.1%
Ascorbic acid	- 0.1%
Sucrose	- 17%

3.6.2 Preparation of the sample

Three grams of tender leaves were homogenised in 5 ml of the extraction buffer in a chilled mortar and pestle. It was then filtered through a cheese cloth into centrifugation tubes and centrifuged at 4°C at 10,000 rpm for 20 minutes. After centrifugation, the clear supernatant was collected and stored below subzero temperature.

3.6.3 Preparation of the gel

The following stock solutions were prepared.

1) Acrylamide-bis acrylamide (30:0.8 w/w)

Acrylamide

Bisacrylamide

Distilled water

Solution was filtered through Whatman No.1 filter paper and stored at 4°C in dark bottles.

2) Resolving gel buffer stock - 3 M Tris.HCl, pH 8.8

Tris

1N HCl

Distilled water

3) Stacking gel buffer stock - 0.5 M Tris.HCl, pH 6.8

Tris

1N HCl

Distilled water

4) Reservoir buffer stock - 0.025 M Tris - Glycine, pH 8.3

Tris

Glycine

Distilled water

5) Ammonium persulphate 1.5%

Ammonium persulphate

Water

6) Riboflavin 0.004% stored at 4°C in dark

7) TEMED

8) Gel mixture preparation (Given in Appendix VI).

Preparation of gel column

The mini dual model of Genei Vertical Slab Gel Electrophoresis system was used for the study. The dimensions of the slab gel was 8 x 7 x 0.1 cm. The separating and stacking solutions were gently injected by a micropipette in between glass plates kept in polymerisation stand to form 7.5% and 2.5% of gel respectively. The combs were pushed in for making wells and allowed to polymerise in the

electrophoretic column. After polymerisation, the gels were transferred to electrophoretic apparatus. The upper and lower tanks were filled with pre-cooled electrode buffer. The combs were removed carefully and 75 µl of sample was applied to each well with a micropipette. Upper tank was connected to the cathode and lower tank to the anode.

Electrophoresis was carried out at a constant 70 V until proper stacking was achieved and then at 200 V until tracking dye reached the end of the slab gel.

3.6.4 Staining of gel

Gels were soaked for 15 to 30 minutes in 15 mM sodium phosphate buffer (pH 6.0) containing 1 mM Hydrogen peroxide and 0.1 mM 0-Methoxy phenol (Guaiacol) till orange red bands of peroxidase developed. Gels were rinsed with deionised water. The reaction was arrested by adding 7% acetic acid (Shimoni and Reuveni, 1988).

3.6.5 Qualitative analysis

The relative positions of each visualised band in the gel were drawn schematically for easy reference and the Rm (Relative mobility) value calculated using the formula.

$$Rm = \frac{\text{Distance migrated by the sample}}{\text{Distance migrated by the dye}}$$

3.7 Statistical analysis

The data obtained from different experiments were subjected to statistical analysis as per Panse and Sukhatme (1978) (Appendix VII to XIII).

Results

RESULTS

The experimental results obtained from the present investigation are presented under the following heads.

1. Survey,collection and evaluation of bird pepper accessions
2. Somatic analysis for yield and its components
3. Improvement of selected lines through single plant and mass methods of selection and comparing the relative effectiveness of the methods
4. Biochemical analyses for important constituents
5. Study on floral biology
6. Biochemical characterization of *Capsicum frutescens* by isozyme analysis

4.1 Survey, collection and evaluation of bird pepper accessions

4.1.1 Characterization of bird pepper germplasm

Bird pepper accessions were collected from different locations through survey, correspondence and personal contact. Since there are no improved varieties of bird pepper in the country all the accessions included in the study were local types.

Eighty six accessions were grown and evaluated for morphological and yield parameters during October'93 to June'94. Characterization was done using the IBPGR descriptor list for *Capsicum* (IBPGR, 1993). The source and detailed description of accessions are presented in Table 1.

Table 1. Morphological description of bird pepper accessions

Sl. No.	Acc. No.	Source	Plant growth habit	Stem pubescens	Stem colour	Leaf pubescens	Number of pedicels	Pedicel position at anthesis	Calyx margin shape	Corolla colour	Anther colour	Filament colour	Fruit position	Fruit colour in immature stage
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	CF 1	Panjal	Compact	Sparse	Green	Glabrous	1	Erect	Intermediate	Greenish white	Bluish green	Cream	Erect	Green
2	CF 2	Puzhakkal	Compact	Glabrous	Green	Glabrous	1-2	Erect	Dentate	Greenish white	Greenish white	Purple	Erect	Light green
3	CF 3	Wadak-kanchery	Compact	Glabrous	Green	Glabrous	1	Erect	Dentate	Greenish white	Greenish white	Purple	Declining	White
4	CF 4	..	Compact	Sparse	Green	Glabrous	1-2	Erect	Intermediate	Greenish white	Bluish green	Cream with purple tinge	Erect	Yellowish green
5	CF 5	Peechi	Compact	Glabrous	Green	Glabrous	1-2	Erect	Dentate	Greenish white	Bluish green	Purple	Declining	Green
6	CF 7	Manna-mangalam	Compact	Sparse	Green	Glabrous	1	Erect	Intermediate	Greenish white	Bluish green	Cream with purple tinge	Declining	Light green
7	CF 8	..	Erect	Sparse	Green	Glabrous	1-2	Erect	Intermediate	Greenish white	Bluish green	Purple	Declining	Green
8	CF 9	Panjal	Compact	Sparse	Green	Glabrous	1	Erect	Dentate	Greenish white	Bluish green	Purple	Declining	Green

Contd

Table 1 Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
9	CF 10	Panjal	Prostrate	Sparse	Green with purple nodes	Glabrous	1-2	Erect	Intermediate	Greenish white	Bluish green	Cream with purple tinge	Erect	Green
10	CF 11	,,	Compact	Sparse	Green	Glabrous	1	Erect	Dentate	Greenish white	Bluish green	Purple	Declining	Green
11	CF 13	Wadak-kanchery	Prosbate	Sparse	Green	Glabrous	1	Erect	Intermediate	Greenish white	Greenish white	Purple	Erect	Green
12	CF 14	Kunnam-kulam	Compact	Sparse	Green	Glabrous	1	Erect	Dentate	Greenish white	Bluish green	Purple	Declining	Light green
13	CF 15	Alathur	Compact	Sparse	Green	Glabrous	1-2	Erect	Intermediate	Greenish white	Cream	Purple	Erect	Green
14	CF 16	,,	Compact	Sparse	Green	Glabrous	1-2	Erect	Intermediate	Greenish white	Greenish white	Cream with purple tinge	Declining	White
15	CF 17	,,	Compact	Sparse	Green	Glabrous	1-2	Erect	Dentate	Greenish white	Bluish green	Purple	Declining	Green
16	CF 18	Pattambi	Compact	Sparse	Green	Glabrous	1-2	Erect	Intermediate	Greenish white	Bluish green	Purple	Erect	Green
17	CF 19	Nemmara	Prostrate	Sparse	Green	Glabrous	1	Erect	Intermediate	Greenish white	Bluish green	Purple	Declining	White

Contd

Table 1. Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
18	CF20	Thrissur	Compact	Sparse	Green	Glabrous	1	Erect	Smooth	Greenish white	Bluish green	Cream with purple tinge	Erect	Green
19	CF 22	Puzhakkal	Prostrat	Glabrous	Green	Glabrous	1-2	Erect	Smooth	Greenish white	Bluish green	Cream with purple tinge	Declining	White
20	CF 23	..	Compact	Spadrse	Green	Glabrous	1	Erect	Dentate	Greenish white	Bluish green	Cream with purple tinge	Declining	White
21	CF 24	..	Compact	Glabrous	Green	Glabrous	1	Erect	Intermediate	Greenish white	Bluish green	Cream	Declining	White
22	CF 25	Peechi	Compact	Glabrous	Green	Glabrous	1-2	Erect	Dentate	Greenish white	Cream with purple tinge	Cream with purple tinge	Erect	Green
23	CF 27	Ayyanthole	Compact	Glabrous	Green with purple at nodes	Glabrous	1-2	Erect	Dentate	Greenish white	Greenish white	Purple	Erect	Light green
24	CF 28	Pattikkad	Compact	Sparse	Green	Glabrous	1-2	Erect	Intermediate	Greenish white	Bluish green	Purple	Pendant	Light green
25	CF 29	..	Compact	Sparse	Green	Glabrous	1	Erect	Intermediate	Greenish white	Greenish white	Purple	Erect	Green

Contd

Table 1. Contd.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
26	CF 30	Mannuthy	Compact	Sparse	Green with purple at nodes	Glabrous	1-2	Erect	Intermediate	Greenish white	Bluish green	Cream	Erect	Green
27	CF 32	..	Compact	Sparse	Green	Glabrous	1-2	Erect	Intermediate	Greenish white	Bluish green	Cream with purple tinge	Erect	Green
28	CF 33	Vettikkal	Compact	Glabrous	Green	Glabrous	1	Erect	Intermediate	Greenish white	Greenish white	Purple	Pendant	White
29	CF 34	Alathur	Compact	Sparse	Green	Glabrous	1	Erect	Dentate	Greenish white	Bluish green	Purple	Declining	White
30	CF 35	..	Compact	Sparse	Green	Glabrous	1-2	Erect	Dentate	Greenish white	Bluish green	Cream with purple tinge	Erect	Yellowish green
31	CF 36	Nemmara	Erect	Sparse	Green	Glabrous	1	Erect	Dentate	Greenish white	Cream	Purple	Declining	White
32	CF 37	..	Prostrate	Sparse	Green	Glabrous	1-2	Erect	Dentate	Greenish white	Bluish green	Purple	Declining	White
33	CF 38	..	Prostrate	Glabrous	Green with purple at nodes	Glabrous	1-2	Erect	Intermediate	Greenish white	Bluish green	Purple	Erect	Green
34	CF 39	Nedum-kandam	Prostrate	Glabrous	Green	Glabrous	1-2	Erect	Intermediate	Greenish white	Greenish white	Purple	Erect	Green

Contd

Table 1. Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
35	CF 40	Iravi-mangalam	Compact	Glabrous	Green	Glabrous	1-2	Erect	Intermediate	Greenish white	Bluish green	Cream	Erect	White
36	CF 41	Wynad	Compact	Sparse	Green	Glabrous	1-2	Erect	Smooth	Greenish white	Cream with purple tinge	Cream with purple tinge	Erect	Green
37	CF 47	..	Prostrate	Sparse	Green with purple at nodes	Glabrous	1-2	Erect	Intermediate	Greenish white	Bluish green	Purple	Erect	Green
38	CF 48	Thrissur	Compact	Sparse	Green	Glabrous	1-2	Erect	Intermediate	Greenish white	Cream	Cream with purple tinge	Erect	Yellowish green
39	CF 49	Vandi-periyar	Compact	Glabrous	Green	Glabrous	1	Erect	Intermediate	Greenish white	Cream	Cream with purple tinge	Erect	Green
40	CF 52	Kozhikode	Prostrate	Glabrous	Green with purple at node	Glabrous	1-2	Erect	Intermediate	Greenish white	Cream	Cream with purple tinge	Pendant	white
41	CF 53	Wynad	Prostrate	Sparse	Green with purple at node	Glabrous	1-2	Erect	Intermediate	Greenish white	Bluish green	Cream with purple tinge	Erect	Green

Contd

Table 1. Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
42	CF 54	Kozhikode	Prostrate	Sparse	Green with purple at nodes	Glabrous	1	Erect	Intermediate	Greenish white	Cream	Purple	Erect	Green
43	CF 56	..	Compact	Sparse	Green	Glabrous	1	Erect	Intermediate	Greenish white	Bluish green	Purple	Erect	White
44	CF 57	Wyanad	Compact	Sparse	Green	Glabrous	1-2	Erect	Intermediate	Greenish white	Bluish green	Purple	Erect	Green
45	CF 58	..	Erect	Sparse	Green	Glabrous	1-2	Erect	Dentate	Greenish white	Greenish white	Purple	Erect	Light green
46	CF 61	Vettikkal	Compact	Sparse	Green	Glabrous	1	Erect	Intermediate	Greenish white	Bluish green	Cream	Erect	Green
47	CF 62	..	Compact	Sparse	Green	Glabrous	1	Erect	Intermediate	Greenish white	Greenish white	Purple	Declining	Yellowish green
48	CF 63	Alathur	Compact	Glabrous	Green	Glabrous	1-2	Erect	Intermediate	Greenish white	Greenish white	Purple	Ereect	Yellowish green
49	CF 65	..	Compact	Glabrous	Green with purple at nodes	Glabrous	1-2	Erect	Smooth	Greenish white	Bluish green	Cream	Declining	Green
50	CF 66	..	Prostrate	Sparse	Green	Glabrous	1-2	Erect	Dentate	Greenish white	Bluish green	Cream with purple tinge	Erect	Green

Contd.

Table 1. Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
51	CF 67	Sreekaryam	Compact	Sparse	Green with purple at nodes	Glabrous	1	Erect	Intermediate	Greenish white	Bluish green	Cream	Erect	Green
52	CF 68	..	Compact	Sparse	Green	Glabrous	1	Erect	Intermediate	Greenish white	Greenish white	Cream with purple tinge	Declining	Green
53	CF 69	Ettumuna	Compact	Sparse	Green	Glabrous	1-2	Erect	Intermediate	Greenish white	Greenish white	Cream	Erect	Green
54	CF 70	..	Prostrate	Sparse	Green with purple at node	Glabrous	1	Erect	Intermediate	Greenish white	Bluish green	Cream with purple tinge	Erect	Green
55	CF 71	..	Compact	Glabrous	Green	Glabrous	1-2	Erect	Intermediate	Greenish white	Bluish green	..	Erect	Green
56	CF 72	Gramala	Compact	Sparse	Green	Glabrous	1	Erect	Smooth	Greenish white	Greenish white	..	Erect	Green
57	CF 73	Nemmara	Compact	Sparse	Green	Glabrous	1-2	Erect	Intermediate	Greenish white	Greenish white	..	Erect	Green
58	CF 75	..	Compact	Sparse	Green with purple at nodes	Glabrous	1	Erect	Intermediate	Greenish white	Bluish green	Cream	Erect	Green

Contd

Table 1. Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
59	CF 77	Alathur	Prostrate	Sparse	Green with purple nodes	Glabrous	1-2	Erect	Intermediate	Greenish	Bluish	Cream white tinge	Erect green	Green with purple
60	CF 80	..	Erect	Glabrous	Green	Glabrous	1	Erect	Intermediate	Greenish white	Bluish green	..	Erect	White
61	CF 81	Idukki	Compact	Sparse	Green	Sparse	1-2	Erect	Intermediate	Greenish white	Greenish white	..	Erect	Green
62	CF 83	..	Compact	Sparse	Green	Sparse	1-2	Erect	Intermediate	Greenish white	Bluish green	Purple	Declining	Green
63	CF 84	Chelakkara	Prostrate	Sparse	Green with purple nodes	Sparse	1-2	Erect	Intermediate	Greenish white	Bluish green	Cream with purple tinge	Erect	Green
64	CF 86	..	Compact	Glabrous	..	Sparse	1-2	Erect	Intermediate	Greenish white	Bluish green	..	Erect	Green
65	CF 87	Pazhaya-noor	Prostate	Sparse	Green	Sparse	1-2	Erect	Intermediate	Greenish white	Bluish green	..	Declining	Green
66	CF 91	..	Compact	Sparse	Green with purple at nodes	Sparce	1-2	Erect	Dentate	Greenish white	Bluish green	..	Erect	Green
67	CF96	Ernakulam	Prostrate	Sparse	..	Sparse	1	Erect	Smooth	Greenish white	Bluish green	..	Erect	Green

Contd

Table 1. Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
68	CF 103	Peechi	Prostrate	Sparse	Green	Sparse	1	Erect	Dentate	Greenish white	Greenish white	Purple	Declining	White
69	CF 106	Kondazhy	Compact	Sparse	Green	Sparse	1	Erect	Intermediate	Greenish white	Bluish green	Cream with purple tinge	Erect	Yellowish green
70	CF 108	Kunnam-kulam	Compact	Glabrous	Green	Sparse	1	Erect	Intermediate	Greenish white	Greenish white	..	Declining	White
71	CF 110	Kanjany	Erect	Sparse	Green	Sparse	1-2	Erect	Dentate	Greenish white	Cream	Cream	Declining	White
72	CF111	Sherthalai	Prostrate	Sparse	Green	Sparse	1	Erect	Intermediate	Greenish white	Bluish green	Cream	Erect	Green
73	CF 112	Idukki	Erect	Sparse	Green	Sparse	1	Erect	Intermediate	Greenish white	Bluish green	Purple	Erect	White
74	CF 114	Perumbavur	Compact	Sparce	Green with purple at nodes	Sparse	1	Erect	Intermediate	Greenish white	Bluish green	Cream with purple tinge	Erect	Green
75	CF 115	..	Prostrate	Sparse	..	Sparse	1	Erect	Dentate	Greenish white	Bluish green	..	Erect	Green
76	CF 125	Idukki	Compact	Sparse	..	Sparse	1	Erect	Intermediate	Greenish white	Bluish green	..	Erect	Light green
77	CF 134	Kozhikode	Prostrate	Sparse	Green	Sparse	1	Erect	Intermediate	Greenish white	Bluish green	..	Declining	White

Contd

Table 1. Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
78	CF 135	Vellani-kkara	Prostrate	Sparse	Green	Sparse	1	Erect	Intermediate	Greenish white	Bluish green	Purple	Declining	White
79	CF 136	Thiruna-vaya	Compact	Sparse	Green with purple at nodes	Sparse	1	Erect	Intermediate	Greenish white	Bluish green	Cream with purple tinge	Erect	Light green
80	CF 138	Aluva	Compact	Sparse	Green	Sparse	1-2	Erect	Intermediate	Greenish white	Bluish green	Cream	Declining	White
81	CF 139	..	Prostrat	Glabrous	Green with purple at nodes	Sparse	1	Erect	Intermediate	Greenish white	Bluish green	Cream	Declining	White
82	CF 146	Aroor	Erect	Sparse	Green	Sparse	1	Erect	Intermediate	Greenish white	Bluish green	Purple	Pendant	White
83	CF 147	..	Erect	Sparse	Green	Sparse	1	Erect	Dentate	Greenish white	Bluish green	Purple	Declining	White
84	CF 149	Vellani-kkara	Compact	Glabrous	Green	Sparse	1	Erect	Dentate	Greenish white	Cream	Cream with purple tinge	Declining	White
85	CF 153	Marotti-chal	Erect	Sparse	Green	Sparse	1	Erect	Dentate	Greenish white	Bluish green	Purple	Declining	White
86	CF 156	..	Prostrate	Sparse	Green	Sparse	1	Erect	Dentate	Greenish white	Bluish green	Cream with purple tinge	Declining	White

Table 1 Continued

Sl. No.	Acc. No.	Fruit colour in mature stage	Fruit shape	Fruit shape at peduncle end	Neck at base of fruit	Fruit shape at blossom end	Fruit cross sectional corrugation	Fruit persistence	Seed colour
		16	17	18	19	20	21	22	23
1	CF 1	Red	Elongate	Acute	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
2	CF 2	Orange red	Conical	Obtuse	Absent	Pointed	Smooth	Persistent	Straw brown
3	CF 3	Orange red	Conical	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
4	CF 4	Orange red	Conical	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Cream
5	CF 5	Red	Conical	Obtuse	Absent	Blunt	Slightly corrugated	Persistent	Straw brown
6	CF 7	Orange red	Elongate	Acute	Absent	Pointed	Smooth	Persistent	Straw brown
7	CF8	Red	Conical	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
8	CF 9	Red	Conical	Obtuse	Absent	Blunt	Slightly corrugated	Persistent	Straw brown
9	CF 10	Red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
10	CF 11	Red	Elongate	Obtuse	Absent	Blunt	Slightly corrugated	Persistent	Cream
11	CF 13	Red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
12	CF 14	Orange Red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
13	CF 15	Red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
14	CF 16	Red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
15	CF 17	Red	Conical	Obtuse	Absent	Pointed	Smooth	Persistent	Straw brown
16	CF 18	Red	Conical	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
17	CF 19	Red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown

Contd

Table 1. Continued

		16	17	18	19	20	21	22	23
18	CF 20	Red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
19	CF 22	Orange red	Elongate	Acute	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
20	CF 23	Orange red	Elongage	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
21	CF 24	Orange red	Elongate	Acute	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
22	CF 25	Red	Conical	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
23	CF 27	Orange red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
24	CF 28	Orange red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Cream
25	CF29	Red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
26	CF 30	Red	Elongate	Obtuse	Absent	Blunt	Smooth	Persistent	Straw brown
27	CF 32	Red	Elongae	Acute	Absent	Blunt	Slightly corrugated	Persistent	Straw brown
28	CF 33	Orange red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
29	CF 34	Orange red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Cream
30	CF 35	Orange red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
31	CF 36	Orange red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
32	CF 37	Orange red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
33	CF 38	Red	Elongate	Acute	Absent	Pointed	Slightly corrugated	Persistent	Cream
34	CF 39	Red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Cream
35	CF 40	Orange red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Cream
36	CF 41	Red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown

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Table 1. Continued

		16	17	18	19	20	21	22	23
37	CF 47	Red	Elongate	Obtuse	Absent	Pointed	Smooth	Persistent	Straw brown
38	CF 48	Orange red	Elongate	Acute	Absent	Pointed	Slightly corrugated	Persistent	Cream
39	CF 49	Red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
40	CF 52	Orange red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
41	CF 53	Red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
42	CF 54	Red	Elongate	Acute	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
43	CF 56	Orange red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
44	CF 57	Red	Elongate	Acute	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
45	CF 58	Orange red	Elongate	Acute	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
46	CF 61	Red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
47	CF 62	Orange red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
48	CF 63	Orange red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
49	CF 65	Red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
50	CF 50	Red	Conical	Obtuse	Absent	Blunt	Slightly corrugated	Persistent	Straw brown
51	CF 67	Red	Elongate	Acute	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
52	CF 68	Red	Elongate	Obtuse	Absent	Blunt	Smooth	Persistent	Straw brown
53	CF 69	Red	Conical	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
54	CF 70	Red	Elongate	Acute	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
55	CF 71	Red	Conical	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown

Contd

Table 1 Continued

		16	17	18	19	20	21	22	23
56	CF 72	Red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
57	CF 73	Red	Elongate	Acute	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
58	CF 75	Red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Cream
59	CF 77	Red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
60	CF 80	Orange red	Elongate	Acute	Absent	Pointed	Smooth	Persistent	Cream
61	CF 81	Red	Elongate	Obtuse	Absent	Blunt	Slightly corrugated	Persistent	Straw brown
62	CF 83	Red	Elongate	Obtuse	Absent	Blunt	Smooth	Persistent	Straw brown
63	CF 84	Red	Elongate	Acute	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
64	CF 86	Red	Elongate	Acute	Absent	Blunt	Slightly corrugated	Persistent	Straw brown
65	CF 87	Red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
66	CF 91	Red	Elongate	Acute	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
67	CF 96	Red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
68	CF 103	Orange red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
69	CF 106	Orange red	Elongate	Acute	Absent	Pointed	Smooth	Persistent	Straw brown
70	CF 108	Orange red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
71	CF 110	Orange red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
72	CF 111	Red	Elongate	Acute	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
73	CF 112	Orange red	Elongate	Acute	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
74	CF 114	Red	Elongate	Acute	Absent	Pointed	Slightly corrugated	Persistent	Straw brown

Contd

Table 1. Continued

		16	17	18	19	20	21	22	23
75	CF 115	Red	Elongate	Acute	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
76	CF 125	Orange red	Elongate	Acute	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
77	CF 134	Orange red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
78	CF 135	Orange red	Conical	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
79	CF 136	Orange red	Elongate	Acute	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
80	CF 138	Orange red	Elongate	Acute	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
81	CF 139	Orange red	Elongate	Acute	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
82	CF 146	Orange red	Elongate	Acute	Absent	Pointed	Slightly corrugated	Persistent	Cream
83	CF 147	Orange red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
84	CF 149	Orange red	Elongate	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Cream
85	CF 153	Orange red	Conical	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Straw brown
86	CF 156	Orange red	Conical	Obtuse	Absent	Pointed	Slightly corrugated	Persistent	Cream

A wide range of variability was observed among bird pepper accessions for morphological traits. The frequency percentage of each character out of the total variants in the bird pepper germplasm is given in Table 2 and Fig.1a and 1b. Variability was more pronounced for flower and fruit characters (Plate 1). Variability was relatively low in characters like stem colour, stem pubescens, fruit shape, fruit cross sectional corrugation and seed colour. All the accessions were identical with respect to characters like leaf pubescens (glabrous), corolla colour (greenish white) and fruit persistence (persistent). Corolla spot and annular constriction at junction of calyx and pedicel were absent in all the accessions.

The germplasm could be divided into four phenotypic classes for fruit colour - white (31.4%), green (51.16%), light green (9.3%) and yellowish green (8.14%). Among the accessions evaluated 82.56 per cent of the accessions had elongate fruits while the remaining 17.44 per cent had conical fruits (Plate 2).

4.1.2 Estimation of biometric characters

General analysis of variance revealed significant differences among the 86 accessions for all the biometric characters studied, viz. plant height, spread, fruit length, pedicel length, fruit/pedicel ratio, fruit size and yield. Mean values of 11 biometric characters studied are presented in Table 3.

4.1.2.1 Plant height

There was significant difference among accessions for plant height. It ranged from 41.6 to 105.2 cm with an overall mean of 70.66 cm. CF 156 was the

Table 2. Frequency percentage of descriptor states in bird pepper germplasm

Sl.No.	Descriptor	Descriptor state and its frequency percentage			
1	Plant growth habit	Erect (10.47%)	Compact (61.63%)	Prostrate (27.9%)	
2	Stem pubescens	Sparse (75.58%)	Glabrous (24.42%)		
3	Stem colour	Green (74.42%)	Green with purple at nodes (24.58%)		
4	Number of pedicels	1 (51.16%)	> 1 (48.84%)		
5	Calyx margin shape	Smooth (6.98%)	Intermediate (65.12%)	Dentate (27.91%)	
6	Anther colour	Bluish green (67.44%)	Greenish white (19.77%)	Cream (6.98%)	Cream with purple tinge (5.81%)
7	Filament colour	Cream (15.12%)	Cream with purple tinge (44.19%)	Purple (40.70%)	
8	Fruit position	Erect (59.3%)	Declining (36.05%)	Pendant (4.65%)	
9	Fruit colour at immature state	White (31.4%)	Green (51.16%)	Light green (9.30%)	Yellowish green (8.14%)
10	Fruit colour at mature stage	Red (54.65%)	Orange red (45.35%)		
11	Fruit shape	Elongate (82.56%)	Conical (17.44%)		
12	Fruit shape at peduncle attachment	Acute (31.4%)	Obtuse (68.6%)		
13	Fruit shape at blossom end	Pointed (88.37%)	Blunt (11.63%)		
14	Fruit cross sectional corrugation	Slightly corrugated (89.53%)	Smooth (10.49%)		
15	Seed colour	Straw brown (82.56%)	Cream (17.44%)		

Table 3. Mean values of biometric characters in 86 bird pepper accessions

Sl. No.	Acc. No.	Plant height (cm)	Plant spread (cm)	Fruit length (cm)	Pedicel length (cm)	Fruit / pedicel ratio	Fruit girth (cm)	Fruit size (cm^2)	Days to * 50 per cent flowering	Days to* first harvest	Mean* fruit weight(g)	Yield (g)
1	2	3	4	5	6	7	8	9	10	11	12	13
1	CF 1	88.2	59.2	2.08	2.68	0.79	1.76	3.63	97.00	149.00	0.32	59.4
2	CF 2	87.4	56.5	3.14	3.22	0.98	3.24	10.17	97.00	150.00	0.49	44.6
3	CF 3	66.8	52.8	4.92	2.76	1.79	3.26	16.03	95.00	150.00	1.17	42.6
4	CF 4	66.2	53.3	3.74	2.66	1.41	3.18	11.97	109.00	165.00	0.85	30.0
5	CF 5	76.0	48.1	2.96	2.86	1.05	3.14	9.29	107.00	164.00	1.05	115.4
6	CF 7	61.8	53.1	2.64	1.90	1.39	2.68	7.08	99.00	158.00	0.52	63.6
7	CF 8	70.0	46.5	3.42	2.70	1.29	2.60	8.92	97.00	149.00	0.81	54.0
8	CF 9	87.8	60.2	3.16	3.02	1.05	3.00	9.58	99.00	164.00	0.95	52.2
9	CF 10	85.0	69.1	3.34	3.42	0.98	3.48	11.63	99.00	150.00	1.12	136.2
10	CF 11	70.8	56.0	3.68	3.20	1.16	3.00	11.05	112.00	170.00	1.01	61.4
11	CF 13	53.8	51.5	2.60	2.56	1.03	2.86	7.46	103.00	166.00	0.50	47.4
12	CF 14	57.2	51.0	2.10	2.54	0.83	2.26	4.75	100.00	149.00	0.50	45.2
13	CF 15	65.4	48.2	2.48	1.88	1.35	2.18	5.40	91.00	154.00	0.79	90.4
14	CF 16	63.6	48.8	3.30	2.20	1.51	2.14	7.08	93.00	158.00	0.87	84.0
15	CF 17	54.6	48.3	3.94	3.00	1.34	3.24	12.77	91.00	154.00	0.97	54.8
16	CF 18	54.2	41.7	2.52	2.18	1.16	2.02	5.09	89.00	134.00	0.62	98.2
17	CF 19	54.8	48.6	4.42	2.40	1.96	3.60	15.94	88.00	132.00	1.45	158.2
18	CF 20	57.4	48.8	2.60	2.66	0.98	2.12	5.51	86.00	134.00	0.54	67.2
19	CF 22	92.4	78.4	3.42	2.56	1.34	3.32	11.39	99.00	149.00	0.75	35.6
20	CD 23	71.6	58.7	4.58	2.64	1.85	3.24	14.85	88.00	134.00	1.31	143.6
21	CF 24	83.0	63.9	4.04	2.82	1.44	2.90	11.71	105.00	152.00	1.11	32.2
22	CF 25	84.0	63.8	3.68	3.34	1.10	3.82	14.12	92.00	149.00	1.01	31.8

Contd

Table 3. Continued

1	2	3	4	5	6	7	8	9	10	11	12	13
23	CF 27	50.4	46.8	2.16	2.48	0.87	2.08	4.49	106.0	149.0	0.61	50.6
24	CF 28	62.0	54.1	2.20	2.26	1.00	2.18	4.80	90.0	134.0	0.39	89.4
25	CF 29	72.4	38.1	2.42	2.24	1.09	2.40	5.80	101.0	148.0	0.60	25.6
26	CF 30	98.0	51.0	2.34	2.38	1.00	2.36	5.52	103.0	153.0	0.59	27.2
27	CF 32	78.8	59.9	2.16	1.72	1.26	1.88	4.07	97.0	152.0	0.57	35.8
28	CF 33	62.8	44.2	4.44	2.46	1.84	3.04	13.49	94.0	154.0	0.91	41.0
29	CF 34	64.6	65.8	3.96	3.06	1.30	2.34	9.33	93.0	148.0	1.23	92.4
30	CF 35	57.4	49.0	3.32	2.18	1.52	2.56	8.49	110.0	158.0	0.70	28.8
31	CF 36	85.8	54.1	5.72	3.22	1.78	3.26	18.67	93.0	134.0	1.55	151.4
32	CF 37	81.6	80.8	3.96	2.10	1.92	3.14	12.45	91.0	134.0	1.25	124.2
33	CF 38	65.8	53.7	2.06	1.84	1.10	1.86	3.94	101.0	148.0	0.39	68.8
34	CF 39	92.6	75.0	2.94	2.18	1.35	2.34	6.89	97.0	148.0	0.49	43.8
35	CF 40	64.4	51.9	3.30	2.48	1.33	2.74	9.04	95.0	148.0	0.69	24.8
36	CF 41	60.8	55.8	3.94	2.96	1.34	2.94	11.57	115.0	165.0	0.73	15.6
37	CF 47	87.8	76.4	2.08	2.50	0.84	1.86	3.90	102.0	149.0	0.35	23.0
38	CF 48	72.4	62.0	1.74	2.12	0.83	1.76	3.05	78.0	139.0	0.19	28.8
39	CF 49	64.0	62.5	2.54	2.64	0.97	2.20	5.58	79.0	142.0	0.54	21.0
40	CF 52	63.4	47.4	4.44	2.94	1.51	3.76	16.64	104.0	155.0	1.58	24.2
41	CF 53	71.4	60.6	3.10	3.10	1.00	2.22	6.88	98.0	148.0	0.56	95.6
42	CF 54	78.4	64.3	2.28	2.38	0.97	2.00	4.56	92.0	148.0	0.38	87.0
43	CF 56	69.0	58.5	3.26	1.94	1.68	3.26	10.64	104.0	160.0	0.21	29.0
44	CF 57	67.4	61.7	1.42	1.86	0.78	1.44	2.06	101.0	155.0	1.07	29.8
45	CF 58	47.2	70.4	2.70	2.96	0.93	2.16	5.83	84.0	148.0	0.53	53.2
46	CF 61	58.2	49.5	3.34	2.92	1.15	2.66	8.88	78.0	139.0	0.98	30.8
47	CF 62	65.6	56.4	3.30	3.10	1.07	2.12	6.99	98.0	161.0	0.62	22.6
48	CF 63	67.4	66.8	2.08	2.50	0.83	2.52	5.28	103.0	158.0	0.50	27.0

Contd.

Table 3. Continued

1	2	3	4	5	6	7	8	9	10	11	12	13
49	CF 65	81.2	57.8	1.48	2.82	0.53	1.36	2.04	97.0	153.0	0.33	22.4
50	CF 66	77.4	69.9	4.06	3.10	1.32	3.12	12.66	88.0	134.0	1.25	107.0
51	CF 67	61.0	45.5	1.60	2.82	0.37	1.58	2.53	96.0	149.0	0.20	45.6
52	CF 68	82.8	51.9	3.74	2.96	1.27	2.48	9.29	85.0	144.0	0.75	23.6
53	CF 69	72.4	52.7	2.34	2.34	1.00	2.46	5.57	94.0	157.0	0.50	33.0
54	CF 70	75.2	69.9	1.90	2.52	0.76	1.58	3.01	84.0	134.0	0.42	28.4
55	CF 71	71.2	52.5	3.46	2.52	1.38	3.08	10.68	102.0	149.0	0.81	34.4
56	CF 72	51.2	45.6	1.94	2.32	0.84	2.06	4.02	107.0	166.0	0.20	42.0
57	CF 73	61.6	42.3	2.06	2.68	0.77	1.76	3.63	77.0	134.0	0.26	34.4
58	CF 75	64.8	51.1	2.62	2.44	1.10	1.92	5.05	102.0	149.0	0.41	33.6
59	CF 77	85.8	86.8	3.68	3.04	1.22	2.56	9.42	85.0	134.0	0.80	100.6
60	CF 80	44.2	40.7	3.42	1.80	1.90	2.78	9.50	107.0	164.0	1.00	38.2
61	CF 81	70.8	58.8	2.00	2.18	0.94	1.84	3.68	106.0	159.0	0.39	41.0
62	CF 83	56.6	49.5	3.44	3.18	1.08	2.64	9.13	85.0	147.0	0.65	68.6
63	CF 84	70.4	71.8	2.12	2.50	0.85	1.70	3.64	100.0	149.0	0.45	95.0
64	CF 86	60.0	55.2	2.82	2.74	1.04	2.58	7.31	99.0	149.0	0.53	49.0
65	CF 87	52.0	50.6	3.10	2.14	1.46	2.38	7.37	85.0	134.0	0.57	40.4
66	CF 91	60.0	52.1	1.78	2.34	0.77	1.64	2.92	100.0	149.0	0.19	38.6
67	CF 96	85.6	74.1	3.20	2.98	1.09	2.22	7.11	85.0	144.0	0.75	31.4
68	CF 103	80.8	62.8	3.26	2.94	1.11	2.66	8.69	89.0	134.0	0.90	129.4
69	CF 106	62.4	55.4	3.52	2.42	1.46	2.68	9.44	96.0	147.0	1.10	47.0
70	CF 108	96.6	65.5	4.34	2.88	1.52	3.82	16.62	97.0	149.0	1.49	36.0
71	CF 110	45.4	40.0	4.28	2.46	1.76	3.42	14.64	89.0	146.0	1.35	48.6
72	CF 111	51.8	47.9	5.00	3.10	1.61	3.42	17.14	95.0	151.0	1.58	49.0
73	CF 112	41.6	40.8	2.10	2.04	1.03	2.38	5.00	101.0	149.0	0.53	33.0
74	CF 114	69.6	54.0	3.34	2.76	1.22	3.26	10.89	82.0	134.0	1.03	46.4

Contd.

Table 3. Continued

1	2	3	4	5	6	7	8	9	10	11	12	13
75	CF 115	76.6	73.2	1.94	3.26	0.60	1.76	3.44	89.0	134.0	0.39	60.4
76	CF 125	56.2	60.7	3.98	2.40	1.66	3.04	12.12	92.0	156.0	0.59	42.6
77	CF 134	83.8	64.9	4.10	2.48	1.67	2.92	11.98	95.0	146.0	1.48	62.0
78	CF 135	85.6	53.0	3.42	2.98	1.15	3.08	10.52	104.0	155.0	1.21	103.0
79	CF 136	85.2	53.4	3.58	2.96	1.22	2.00	7.17	107.0	159.0	1.04	132.6
80	CF 138	70.2	46.6	2.70	2.54	1.07	2.82	7.59	107.0	166.0	0.92	132.0
81	CF 139	99.6	75.4	2.18	2.12	1.03	2.16	4.71	103.0	158.0	0.46	131.4
82	CF 146	87.8	60.7	3.88	2.30	1.69	2.68	10.40	98.0	151.0	1.30	118.8
83	CF 147	65.4	52.6	3.04	2.10	1.45	2.64	8.03	79.0	134.0	1.05	121.6
84	CF 149	78.2	53.2	3.42	2.30	1.49	3.30	11.30	97.0	148.0	1.13	63.4
85	CF 153	89.2	63.9	4.26	3.02	1.41	3.44	14.65	88.0	145.0	1.30	98.6
86	CF 156	105.2	69.5	3.68	1.92	1.92	2.78	10.24	94.0	152.0	1.37	97.0
CD(P=0.05)		11.92	11.61	0.33	0.33	0.21	0.25	1.40	--	--	--	17.42

* Not considered for statistical analysis

Plate 1. Variability for fruit characters in *Capsicum frutescens*

1a. *C. frutescens* white

1b. *C. frutescens* green

tallest with a height of 105.2 cm which was on par with CF 139 (99.6 cm), CF 30 (98.0 cm) and CF 108 (96.6 cm). Accession CF 112 was the shortest (41.6 cm).

4.1.2.2 Plant spread

Mean plant spread varied from 38.1 to 86.8 cm with a general mean of 56.92 cm. Plant spread was maximum in CF 77 (86.8 cm) and was on par with CF 37 (80.8 cm), CF 22 (78.4 cm), CF 47 (76.4 cm) and CF 139 (75.4 cm). Plant width was the lowest in CF 29 (38.1 cm).

4.1.2.3 Fruit length

Fruit length also varied considerably from 1.42 to 5.72 cm with an overall mean of 3.10 cm. Maximum fruit length was recorded in CF 36 (5.72 cm) followed by CF 111 (5 cm). Other accessions with high values for fruit length were CF 3 (4.92 cm), CF 23 (4.58 cm), CF 33 and CF 52 (4.44 cm) and CF 19 (4.42 cm). The accession CF 57 had the least fruit length of (1.42 cm).

4.1.2.4 Pedicel length

Pedicel length differed from 1.72 cm in CF 32 to 3.42 cm in CF 10 with an overall mean of 2.58 cm.

Plate 2. Fruits of important accessions in bird pepper germplasm


CF 35
CF 2
CF 6
CF 58
CF 36
CF 65
CF 84
CF 15
CF 87


CF 20
CF 65
CF 28
CF 303
CF 18
CF 14
CF 105
CF 37
CF 3


CF 125
CF 53
CF 68


CF 61
CF 40
CF 49
CF 52
CF 56


CF 71
CF 4


CF 149
CF 24
CF 134

4.1.2.5 Fruit/pedicel ratio

Fruit/pedicel ratio among accessions was found to vary from 0.37 to 1.96. The accessions on an average had a fruit/pedicel ratio of 1.22. Fruit/pedicel ratio was the highest in CF 19 (1.96) and the lowest in CF 67 (0.37).

4.1.2.6 Fruit girth

Girth of fruits varied significantly among accessions from 1.36 cm to 3.82 cm with an overall average of 2.58 cm. Maximum fruit girth was recorded in CF 25 and CF 108 (3.82 cm) which was on par with CF 52 (3.76 cm) and CF 19 (3.6 cm). Accession CF 65 had the lowest fruit girth (1.36 cm).

4.1.2.7 Fruit size

There was significant difference among accessions for fruit size (length x girth) which ranged from 2.04 to 18.67 cm^2, with an average of 8.46 cm^2. Biggest fruits were obtained from CF 36 (18.67 cm^2), followed by CF 52 (16.64 cm^2), CF 108 (16.62 cm^2), CF 3 (16.03 cm^2), CF 19 (15.94 cm^2) and CF 23 (14.85 cm^2). Fruits of accession CF 65 were the smallest (2.04 cm^2).

4.1.2.8 Average fruit weight

Range in average fruit weight among accessions was from 0.19 to 1.58 g, highest in CF 52 and CF 111 (1.58 g) and the lowest in CF 48 (0.19 g). Accessions

CF 36 (1.55 g), CF 108 (1.49 g), CF 134 (1.48 g) and CF 19 (1.45 g) also recorded higher average fruit weight.

4.1.2.9 Days to 50 per cent flowering

The range for days to 50 per cent flowering was from 77 to 115 days. Accession CF 73 was the earliest to flower (77 days) and CF 41 the last (115 days).

4.1.2.10 Days to harvest

Days to harvest varied from 132 days in CF 19 to 170 days in CF 11.

4.1.2.11 Yield

Analysis of variance showed significant variation among accessions for fruit yield per plant. It was observed to range from 15.6 to 158.2 g per plant. The highest yielding accessions were CF 19 (158.2 g per plant), CF 36 (151.4 g per plant) and CF 23 (143.6 g per plant). The other high yielding accessions in the germplasm were CF 10 (136.2 g per plant), CF 136 (132.6 g per plant) and CF 138 (132 g per plant). CF 41 was the poorest yielder with an average yield of 15.6 g per plant.

4.1.3 Estimation of genetic parameters

The genetic parameters like phenotypic and genotypic variance, phenotypic and genotypic coefficient of variation and heritability in broad sense were estimated and results presented in Table 4.

Table 4. Genetic parameters of 86 bird pepper accessions

Characters	Range	Mean	Genotypic variance	Phenotypic variance	Genotypic coefficient of variation	Phenotypic coefficient of variation	Heritability in broad sense (%)
Plant height (cm)	41.6 - 105.2	70.66	174.88	267.48	18.71	23.15	65.38
Plant spread(cm)	38.1 - 86.8	56.92	86.40	174.18	16.33	23.18	49.60
Fruit length (cm)	1.42 - 5.72	3.10	0.80	0.87	28.85	30.15	91.53
Pedicel length (cm)	1.70 - 3.42	2.58	0.15	0.22	15.01	18.17	68.18
Fruit/pedicel ratio	0.53 - 1.96	1.22	0.11	0.14	27.19	30.66	78.57
Fruit girth (cm)	1.36 - 3.82	2.58	0.36	0.40	23.25	24.51	87.80
Fruit size (cm^2)	2.04 - 18.67	8.46	15.97	17.26	47.24	49.16	92.53
Yield per plant (g)	15.6 - 158.0	61.62	1329.44	1526.85	59.17	63.14	87.07

High values for genotypic and phenotypic coefficients of variation were registered for yield per plant (59.17, 63.14), fruit size (47.24, 49.16) and fruit length (28.85, 30.15). Heritability in broad sense was high for fruit size (92.53%), fruit length (91.53%), fruit girth (87.8%) and yield per plant (87.07%).

4.2 Somatic analysis for yield and its components

Twenty five accessions were selected from the first experiment for replicated trial for two seasons. These included promising accessions having high yield as well as better fruit size. Besides, green and white fruited accessions representing variability for plant and fruit characters were also selected (Plate 3)

General analysis of variance revealed significant differences among cultivars for all the characters studied in the two seasons. The mean values of the biometric characters of bird pepper accessions for the two seasons are presented in Table 5a and 5b.

4.2.1 Biometric characters

4.2.1.1 Plant height

Plant height ranged from 41.9 to 75.7 cm in the first season and 49.8 to 90.0 cm in the second season. Maximum plant height was recorded for CF 19 in the first (75.7 cm) and second (90.0 cm) season. Plant height was the lowest in CF 77 in the first (41.9 cm) as well as the second (49.8 cm) season. The overall mean for the character during the first and second season was 57.68 cm and 70.37 respectively.

Table 5a. Mean values of biometric characters of 25 selected accessions during July '94 to December '94

Sl. No.	Acc. No.	Plant height (cm)	Primary branches per plant	Plant spread (cm)	Days to first harvest	Crop duration	No. of harvests	Fruit length (cm)	Pedicel length (cm)	Fruit / pedicel ratio	Fruit girth (cm)	Fruit size (cm^2)	Mean fruit weight (g)	Driage (%)	Yield per plant (g)
1	CF 5	74.5	6.3	43.5	143.0	187.0	5.6	2.86	2.67	1.07	2.85	8.15	1.07	24.52	80.76
2	CF 10	71.9	5.9	41.5	145.5	191.0	5.7	3.77	3.45	1.09	3.23	12.19	1.12	25.50	92.12
3	CF 11	44.1	4.7	38.1	167.5	208.0	5.3	3.71	2.91	1.28	2.96	10.98	1.22	21.73	71.03
4	CF 15	47.0	5.0	38.5	146.5	196.0	5.3	2.57	1.96	1.31	2.08	5.35	0.85	21.78	61.33
5	CF 18	67.0	5.5	42.3	162.0	205.0	4.9	2.48	2.53	0.98	2.33	5.84	0.74	23.00	47.29
6	CF 19	75.7	5.5	47.8	141.0	173.5	5.6	3.94	2.46	1.61	3.30	13.01	1.53	21.88	89.81
7	CF 23	71.4	6.1	46.0	142.0	194.0	6.0	4.62	3.20	1.44	3.18	14.69	1.34	22.87	92.65
8	CF 27	48.1	4.5	36.5	167.0	210.0	4.6	2.34	2.47	0.94	1.96	4.59	0.64	24.88	46.95
9	CF 28	42.2	3.8	39.4	158.5	195.0	5.4	2.14	2.05	1.05	2.08	4.45	0.46	22.88	64.33
10	CF 34	65.0	4.6	43.3	148.5	189.0	5.3	3.93	2.80	1.40	2.00	7.86	1.32	20.67	68.54
11	CF 36	69.0	5.8	44.1	144.0	190.0	6.0	5.08	3.45	1.47	3.84	19.51	1.87	25.15	95.96
12	CF 37	53.0	4.2	36.6	147.0	196.0	4.7	3.91	1.91	2.05	2.88	11.26	1.20	21.72	64.18
13	CF 53	44.0	4.7	33.0	153.0	208.0	4.7	2.62	2.78	0.94	2.09	5.48	0.54	20.82	49.82
14	CF 66	75.0	5.5	40.2	161.5	205.0	4.7	3.51	2.98	1.18	3.05	10.70	1.28	25.00	53.14
15	CF 77	41.9	4.0	40.3	150.5	193.0	5.2	3.35	2.90	1.16	2.45	8.20	0.95	23.03	56.63

Contd.

Table 5a. Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
16	CF 84	54.3	4.7	40.3	153.5	206.5	4.8	1.66	2.50	0.66	1.67	2.77	0.49	23.98	51.41
17	CF 103	68.5	6.9	40.3	147.0	193.5	6.3	3.36	2.60	1.29	2.86	9.61	0.95	22.85	97.73
18	CF 135	56.4	6.2	49.1	148.0	196.5	5.6	3.09	2.50	1.24	2.58	7.97	1.27	23.70	79.06
19	CF 136	47.0	4.5	46.0	162.5	205.0	5.1	2.99	2.75	1.09	3.00	8.97	1.07	25.61	50.34
20	CF 138	49.7	5.8	42.2	163.0	208.0	5.0	2.63	2.17	1.21	2.21	5.81	0.86	22.10	60.07
21	CF 139	42.5	3.8	45.1	165.5	210.0	5.0	2.08	2.03	1.03	2.07	4.31	0.47	21.08	43.39
22	CF 146	50.3	5.6	46.1	150.0	202.5	4.8	3.89	2.30	1.70	2.70	10.50	1.25	23.35	45.39
23	CF 147	65.5	6.0	40.3	145.0	192.0	4.8	2.94	1.96	1.50	2.62	7.70	1.07	25.00	45.53
24	CF 153	60.1	5.4	38.9	150.0	204.5	4.9	4.06	3.16	1.29	3.30	13.40	1.39	20.25	62.46
25	CF 156	58.0	6.2	44.5	142.0	198.5	4.5	3.61	1.88	1.93	2.67	9.64	1.28	24.03	48.38
CD (P=0.05)		9.38	1.16	2.18	5.25	6.42	0.52	0.23	0.18	0.15	0.24	1.24	0.07	0.56	6.66

Table 5b . Mean values of biometric characters of 25 selected accessions during January '95 to July '95

Sl. No.	Acc. No.	Plant height (cm)	Primary branches per plant	Plant spread (cm)	Days to first harvest	Crop duration	No. of harvests	Fruit length (cm)	Pedicel length (cm)	Fruit / pedicel ratio	Fruit girth (cm)	Fruit size (cm^2)	Mean fruit weight (g)	Driage (%)	Yield per plant (g)
1	CF 5	82.1	6.8	54.2	153.0	201.0	5.5	2.92	3.12	0.95	2.75	8.03	1.15	23.48	90.24
2	CF 10	85.8	7.3	53.1	151.0	208.5	5.6	3.68	3.29	1.12	3.13	11.52	1.24	24.75	106.67
3	CF 11	55.4	5.5	44.4	168.0	212.0	5.2	3.58	2.76	1.30	2.74	9.81	1.29	22.48	75.39
4	CF 15	50.1	4.7	41.5	173.5	214.0	4.8	2.44	1.69	1.45	2.19	5.34	0.96	22.18	63.65
5	CF 18	71.2	6.2	52.6	166.5	213.0	4.7	2.68	2.77	0.97	2.43	6.51	0.84	23.57	66.59
6	CF 19	90.0	5.4	58.4	146.0	184.0	5.8	5.36	3.14	1.71	3.82	20.51	1.64	22.79	101.68
7	CF 23	87.4	5.6	55.7	146.0	201.0	6.0	4.07	3.33	1.22	3.21	13.07	1.46	23.65	110.44
8	CF 27	60.8	4.9	40.6	173.5	212.0	4.4	2.55	2.56	1.00	2.15	5.48	0.80	25.73	49.84
9	CF 28	53.7	4.0	45.8	165.0	207.5	4.9	2.25	2.08	1.08	2.15	4.84	0.57	23.11	66.74
10	CF 34	74.4	5.7	50.2	153.0	197.0	5.2	4.06	2.99	1.36	2.31	9.38	1.43	21.85	77.92
11	CF 36	87.0	6.3	48.8	153.0	198.0	6.0	5.59	3.58	1.56	4.05	22.64	2.02	25.61	112.16
12	CF 37	60.5	4.1	38.5	154.5	207.0	4.7	3.95	2.09	1.89	3.01	11.89	1.30	22.40	66.14
13	CF 53	62.7	5.2	43.0	164.0	210.5	4.8	2.79	2.87	0.97	2.16	6.04	0.67	21.28	52.49
14	CF 66	82.7	5.5	41.9	164.0	208.0	5.0	3.68	3.21	1.15	3.32	12.21	1.33	25.43	58.67
15	CF 77	49.8	4.5	54.1	157.0	213.0	4.6	3.42	2.96	1.16	2.54	8.69	1.03	23.30	61.49

Contd

Table 5b Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
16	CF 84	72.7	4.7	54.1	156.0	207.5	4.90	1.90	2.42	0.79	1.79	3.40	0.52	24.53	61.25
17	CF103	83.2	6.5	53.2	154.0	200.0	5.80	3.50	3.06	1.14	2.94	10.29	1.09	24.32	112.42
18	CF 135	79.9	7.1	55.2	151.0	200.0	6.20	3.55	2.73	1.30	2.80	9.93	1.36	24.35	90.23
19	CF136	63.9	7.0	49.0	163.0	202.5	5.00	3.41	3.07	1.11	3.17	10.82	1.19	25.82	62.01
20	CF 138	54.4	5.3	44.4	165.0	209.0	5.00	2.72	2.08	1.32	2.02	5.51	0.88	22.58	68.16
21	CF 139	58.1	4.5	53.3	173.5	214.0	4.70	2.22	2.07	1.07	2.17	4.82	0.49	21.43	46.03
22	CF 146	63.9	7.2	43.7	157.0	209.0	4.70	3.90	2.32	1.68	2.59	10.11	1.35	23.93	55.32
23	CF 147	84.2	7.1	49.5	156.0	210.0	4.80	3.07	2.08	1.48	2.72	8.35	1.17	25.63	54.04
24	CF 153	76.2	5.7	50.9	149.0	198.0	5.30	4.49	3.04	1.49	3.55	15.92	1.43	21.08	80.88
25	CF 156	69.1	7.4	53.1	153.0	209.0	4.70	3.87	2.06	1.88	2.96	11.47	1.37	24.70	56.94
CD(P=0.05)		8.55	1.02	5.98	5.64	6.43	0.46	0.24	0.32	0.20	0.23	1.23	0.07	0.59	9.64

Plate 3. Fruits of selected accessions of bird pepper


CF39
CF8
CF53
CF15
CF77


CF136
CF18
CF10
CF27
CF16
CF68


CF151
CF135
CF21
CF134
CF13
CF31
CF153
CF145
CF35
CF107

4.2.1.2 Primary branches per plant

Primary branches per plant varied from 3.8 to 6.9 during the first and 4.0 to 7.4 during the second season with an overall mean of 5.25 and 5.77 respectively. Primary branches per plant was highest in CF 103 (6.9) in the first season and CF 156 (7.4) in the second season. Primary branches per plant was the least in CF 28 during the first (3.8) and second season (4.0).

4.2.1.3 Plant spread

The accessions differed significantly for plant spread in the two seasons with a range of 33.0 to 49.1 cm in the first and 38.5 to 58.4 cm in the second season. The general mean for plant spread was 41.76 cm and 49.17 cm for the first and second season respectively. Maximum plant spread was in CF 135 (49.1 cm) in the first season and CF 19 (58.4 cm) in the second season. Plant spread was the lowest in CF 53 (33.0 cm) in the first season and CF 37 (38.5 cm) in the second season.

4.2.1.4 Number of harvests

Among the accessions, the number of harvest was found to vary from 4.5 to 6.3 and 4.4 to 6.2 in the first and second season respectively. Maximum number of harvests of green chilli was obtained from CF 103 (6.3) in the first season and in from CF 135 (6.2) in the second season.

4.2.1.5 Days to first harvest

Accessions varied significantly in days taken to first harvest, 141.0 to 167.5 days in the first season and 146.0 to 173.5 days in the second season. Accession CF 19 was the earliest to yield fruit in the first as well as the second season (141 and 146 days, respectively). Accession CF 11 was the last to yield fruit in the first season (167.5 days) and CF 15, CF 27 and CF 139 in the second season (173.5 days).

4.2.1.6 Crop duration

Crop duration was observed to vary from 173.5 days in CF 19 to 210 days in CF 27 and CF 139 with a general mean of 198.3 days in the first season. In the second season, duration of crop ranged from 184.0 days in CF 19 to 214.0 days in CF 15 and CF 139.

4.2.1.7 Fruit girth

The fruit girth was found to vary from 1.67 to 3.84 cm in the first season and 1.79 to 4.05 cm in the second season. Maximum fruit girth was registered in CF 36 in the first and second season (3.84 and 4.05 cm, respectively). The girth of fruits was the least in CF 84 in both the seasons, 1.67 cm and 1.79 cm being the respective values for the two seasons.

4.2.1.8 Fruit length

The fruit length differed from 1.66 to 5.08 cm during the first season and 1.9 to 5.59 cm in the second season. Maximum fruit length was observed in CF 36 in the first (5.08 cm) as well as the second season (5.59 cm). Higher values of fruit length were also recorded in CF 23 (4.62 cm), CF 153 (4.06 cm), CF 19 (3.94 cm) and CF 34 (3.93 cm) in the first season and CF 19 (5.36 cm), CF 153 (4.49 cm), CF 23 (4.07 cm), CF 34 (4.06 cm) in the second season. Length of fruits was the lowest in CF 84 during the first (1.66 cm) and the second season (1.9 cm).

4.2.1.9 Pedicel length

Pedicel length among accessions varied from 1.88 to 3.45 in the first season and 1.69 to 3.58 in the second season with a general mean of 2.58 and 2.70 respectively for the first and second seasons. During the first season CF 10 and CF 36 had the maximum pedicel length (3.45 cm) and CF 156 the least (1.88 cm). In the second season maximum and minimum pedicel length was for CF 36 (3.58 cm) and CF 15 (1.69 cm), respectively.

4.2.1.10 Fruit/pedicel ratio

In the first season, fruit/pedicel ratio ranged from 0.66 in CF 84 to 2.05 in CF 37 with a grand mean of 1.28. The range for the character in the second season was 0.79 in CF 84 to 1.89 in CF 37.

4.2.1.11 Fruit size

Highly significant variation was recorded among accessions for fruit size in both the seasons, with an average of 8.92 cm^2 and 9.86 cm^2 respectively in the first and second seasons (Fig.2). Fruit size ranged from 2.77 to 19.51 cm^2, the highest in CF 36 and the lowest in CF 84. The same trend was observed in the next season also with a range of 3.40 to 22.64 cm^2, the highest in CF 36 and the lowest in CF 84. Other accessions with higher values for fruit size were CF 23 (14.69 cm^2), CF 153 (13.40 cm^2), CF 19 (13.01 cm^2), CF 10 (12.19 cm^2) in the first season and CF 19 (20.51 cm^2), CF 153 (15.92 cm^2), CF 23 (13.07 cm^2), CF 66 (12.21 cm^2) and CF 10 (11.52 cm^2) in the second season.

4.2.1.12 Mean fruit weight

Mean fruit weight of accessions varied significantly from 0.46 to 1.87 g in the first season and 0.49 to 2.02 g in the second season. The accessions on an average had a fruit weight of 1.04 g and 1.14 g in the first and second seasons respectively. The highest fruit weight was registered in CF 36, (1.87 and 2.02 g) for the first and second season respectively. Fruit weight was the lowest in CF 28 (0.46 g) in the first season and CF 139 (0.49 g) in the second season.

4.2.1.13 Driage (%)

The accessions differed significantly for this character with a range of 20.25 to 25.61 per cent during the first and 21.08 to 25.82 per cent in the second season. Driage (%) was highest in CF 136 in the first and second season. Recovery of dry chilli was the lowest in CF 153 (20.25%).

4.2.1.14 Yield

There was significant variation among accessions for yield per plant, 43.39 to 97.73 g in the first and 46.03 to 112.42 g in the second season (Fig.3). CF 103 recorded significantly higher yield in the first season (97.73 g) which was on par with CF 36 (95.96 g) and CF 23 (92.65 g). The other high yielding accessions in the first season were CF 10 (92.12 g) and CF 19 (89.81 g). Evaluation during the second season revealed again the superiority of the above accessions with respect to yield, CF 103 (112.42 g), CF 36 (112.16 g), CF 23 (110.44 g), CF 10 (106.67 g) and CF 19 (101.68 g). The low yielders were CF 139 (43.39 g), CF 146 (45.39 g) and CF 147 (45.53 g) in the first season and CF 139 (46.03 g) and CF 27 (49.84 g) in the second season. Among the green fruited accessions, CF 10 ranked first in yield followed by CF 5 in the two seasons.

Four white fruited accessions of bird pepper, CF 19, CF 23, CF 36 and CF 103 and two green fruited accessions CF 5 and CF 10 which gave consistent high yield combined with better fruit size were selected from the replicated trial for further improvement. The accessions CF 153 and CF 66 though had comparatively better fruit size registered low yields in the two seasons.

4.2.2 Estimation of variability and genetic parameters in bird pepper

The variability parameters like genotypic and phenotypic variances, coefficients of variation, heritability in broad sense, genetic advance and genetic advance as percentage of mean were estimated and data presented in Table 6.

Table 6. Variability parameters for 14 characters in bird pepper

Sl.No.	Character	General mean	Genotypic variance	Phenotypic variance	Genotypic coefficient of variation	Phenotypic coefficient of variation	Heritability in broad sense (%)	Genetic advance	Genetic advance as per cent of mean
1	Plant height (cm)	64.03	141.38	163.01	18.57	19.94	86.70	22.81	35.62
2	Primary branches per plant	5.51	0.72	1.08	15.37	18.82	66.70	1.42	25.77
3	Plant spread (cm)	45.47	15.11	27.63	8.55	11.56	54.70	4.92	13.02
4	Number of harvests	5.16	0.21	0.27	8.87	10.15	76.40	0.82	15.89
5	Days to first harvest	155.39	61.33	75.72	5.04	5.60	80.80	14.50	9.33
6	Crop duration	178.99	37.69	54.65	3.43	4.13	69.20	11.89	6.64
7	Fruit girth (cm)	2.70	0.30	0.32	20.32	20.93	94.30	1.09	40.37
8	Fruit length (cm)	3.34	0.72	0.77	25.43	26.25	93.90	1.69	50.60
9	Pedicel length (cm)	2.51	0.20	0.23	17.97	18.99	89.50	0.92	36.65
10	Driage (%)	23.35	2.28	2.40	6.47	6.66	94.20	3.02	12.93
11	Mean fruit weight (g)	1.10	0.13	0.13	32.98	33.10	99.30	0.74	67.27
12	Fruit / pedicel ratio	1.29	0.09	0.09	23.25	24.27	91.70	0.59	45.74
13	Fruit size (cm^2)	9.39	17.23	18.50	44.21	45.80	93.20	8.26	87.97
14	Yield per plant (g)	69.30	370.89	393.92	27.79	28.64	94.20	38.60	55.70

4.2.2.1 Phenotypic and genotypic variance

Wide variation was observed in phenotypic and genotypic variances among characters. The maximum values of genotypic and phenotypic variances were recorded for yield per plant (370.89 and 393.92, respectively). Fruit/ pedicel ratio exhibited the least phenotypic and genotypic variance (0.09).

4.2.2.2 Phenotypic Coefficient of Variation (PCV) and Genotypic Coefficient of Variation (GCV)

The values for GCV and PCV ranged from 3.43 to 44.21 and 4.13 to 45.80 respectively. The estimates of GCV and PCV were the highest for fruit size (44.21, 45.80) and the least for crop duration (3.43, 4.13). High magnitudes of GCV and PCV were displayed by characters mean fruit weight (32.98, 33.10), yield per plant (27.79, 28.64) and fruit length (25.43, 26.25) whereas it was low for days to first harvest (5.04, 5.60) and driage per cent (6.47, 6.66).

4.2.2.3 Heritability and genetic advance

Heritability in the broad sense varied from 54.7 for plant spread to 99.3 per cent for mean fruit weight. In general, heritability estimates were high for most of the characters studied, fruit girth (94.3%), yield per plant (94.2%), driage per cent (94.2%), fruit length (93.9%), fruit/pedicel ratio (91.7%), pedicel length (89.5%), plant height (86.7%), days to first harvest (80.8%) and number of harvests (76.4%). Moderate estimates of heritability were observed for crop duration (69.2%), primary branches per plant (66.7%) and plant spread (54.7%).

Genetic advance was the highest for yield per plant (38.6) and the lowest for fruit/pedicel ratio (0.59). The expected genetic advance ranged from 6.64 for crop duration to 87.97 for fruit size. The expected genetic advance was high for important economic attributes like fruit size (87.97), mean fruit weight (67.27), yield per plant (55.7) and fruit length (50.6).

High heritability in conjunction with high GCV and expected genetic advance was obtained for fruit size and mean fruit weight. High heritability coupled with low genetic advance was observed for dry chilli recovery, days to first harvest and number of harvests.

4.2.3 Correlation studies

The phenotypic (rp), genotypic (rg) and environmental (re) correlation coefficients were estimated for 14 characters and results presented in Table 7.

4.2.3.1 Correlation of characters with yield

A significant positive association of plant height, primary branches per plant and plant spread with yield was observed at genotypic and phenotypic levels (Fig.4). Economic characters like number of harvests, fruit girth, fruit length, pedicel length, mean fruit weight and fruit size also exhibited significant positive phenotypic and genotypic correlations with yield. Association of days to first harvest and crop duration with fruit yield was negative and significant. Correlation study revealed dominance of genotypic effect over the phenotypic effect. Number

of harvests had maximum positive correlation on fruit yield per plant (rg = 0.997), followed by plant height (rg = 0.651) and fruit size (rg = 0.645).

4.2.3.2 Inter-correlations among characters

The association of different quantitative characters with each other was studied and results given in Table 7.

All the characters except days to first harvest, crop duration, fruit/pedicel ratio and driage per cent had significant positive association with each other. The association of days to first harvest and crop duration was negative and significant with other characters. A higher degree of correlation was observed for the character fruit size with fruit length (rg = 0.960), fruit girth (rg = 0.956) and mean fruit weight (rg = 0.928).

4.2.4 Genetic divergence

The genetic divergence in bird pepper accessions was tested by Non-hierarchical Euclidean Cluster Analysis.

4.2.4.1 D^2 analysis

The data on fourteen biometric characters in the twenty five accessions for two seasons were pooled and analysed for genetic divergence. The D^2 values were computed for all possible pairs of accessions. By application of the clustering

Table 7. Genotypic (G), phenotypic (P) and environmental (E) correlations among a few quantitative characters in bird pepper

Sl. No.	Character		Yield	Plant height	Primary branches per plant	Plant spread	No. of harvests	Days to first harvest	Crop duration	Fruit girth	Fruit length	Pedicel length	Driage (%)	Mean fruit weight	Fruit / pedicel ratio	Fruit size
1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Yield	P	1.000*	0.593 *	0.345*	0.393*	0.848*	-0.579*	-0.613*	0.589*	0.564*	0.577*	0.072*	0.557*	0.112*	0.606*
		G	1.000*	0.651*	0.445*	0.482*	0.997*	-0.640*	-0.761*	0.623*	0.603*	0.616*	0.078*	0.573*	0.134*	0.645*
		E	1.000	0.058	-0.061	0.288*	0.022	-0.192	0.008	0.018	-0.051	0.150	-0.018	0.112	-0.171	0.022
2	Plant height	P		1.000	0.590*	0.389*	0.532*	-0.586*	-0.557*	0.598*	0.508*	0.521*	0.333*	0.551*	0.124*	0.565*
		G		1.000	0.683*	0.561*	0.608*	-0687*	-0.699*	0.634*	0.537*	0.565*	0.360*	0.593*	0.136*	0.601*
		E		1.000	0.332*	0.010	0.206*	-0.069	-0.076	0.284*	0.258*	0.195*	0.079*	0.016*	0.029	0.260
3	Primary branches per plant	P			1.000	0.286*	0.342*	-0.411*	-0.220*	0.404*	0.330*	0.234*	0.370*	0.441*	0.205*	0.331*
		G			1.000	0.556*	0.463*	-0.549*	-0.352*	0.489*	0.394*	0.306*	0.512*	0.534*	0.236*	0.405*
		E			1.000	-0.130	0.039*	-0.030	0.061	0.119	0.131	-0.016	-0.255	0.136	0.119	0.075
4	Plant spread	P				1.000	0.392*	-0.409*	-0.361*	0.250*	0.207*	0.244*	0.120*	0.245*	-0.006	0.236*
		G				1.000	0.630*	-0.506*	-0.646*	0.333*	0.280*	0.294*	0.178*	0.332*	0.026	0.318*
		E				1.000	-0.049	-0.110	0.098	0.068	0.035	0.178	-0.049	0.011	-0.126	0.052
5	Number of harvests	P					1.000	-0.490*	-0.585*	0.510*	0.462*	0.511*	0.088	0.450*	0.025	0.518*
		G					1.000	-0.564*	-0.712*	0.557*	0.511*	0.606*	0.090	0.520*	0.015	0.562*
		E					1.000	-0.217	-0.250	0.398	0.245	0.065	0.101	-0.056	0.088	0.344*
6	Days to first harvest	P						1.000	0.722*	-0.493*	-0.580*	-0.292*	-0.074	-0.570*	0.428*	-0.549*
		G						1.000	0.806*	-0.559*	-0.652*	-0.318*	-0.068	-0.645*	-0.507*	-0.620*
		E						1.000	0.491	-0.051	0.107	-0.152	-0.139	0.203*	0.069	-0.097

Contd.

Table 7 Continued

1	2		4	5	6	7	8	9	10	11	12	* 13	14	15	16
7	Crop duration	P						1.000	-0.491*	-0.546*	-0.289*	-0.047*	-0.538*	-0.346*	-0.543*
		G						1.000	-0.601*	-0.649*	-0.381*	-0.018*	-0.660*	-0.388*	-0.655*
		E						1.000	-0.043	-0.169	0.063	-0.247	0.193	-0.229	-0.118*
8	Fruit girth	P							1.000	0.850*	0.586*	0.258*	0.834*	0.454*	0.845*
		G							1.000	0.870*	0.608*	0.255*	0.860*	0.483*	0.956*
		E							1.000	0.529	0.356	0.308	0.105	0.067	0.785*
9	Fruit length	P								1.000	0.546*	0.042	0.925*	0.649*	0.956*
		G								1.000	0.568*	0.034	0.957*	0.662*	0.960*
		E								1.000	0.317	0.165	0.073*	0.483*	0.912*
10	Pedicel length	P									1.000	0.195*	0.478*	-0.265*	0.590*
		G									1.000	0.205*	0.505*	-0.228*	0.609*
		E									1.000	0.082	0.071	-0.629*	0.408*
11	Driage (%)	P										1.000	0.178	-0.102	0.151
		G										1.000	0.183	-0.108	0.142
		E										1.000	0.030	-0.017	0.276*
12	Mean fruit weight	P											1.000	0.637*	0.894*
		G											1.000	0.668*	0.928*
		E											1.000	-0.027	0.094
13	Fruit/pedicel ratio	P												1.000	0.550*
		G												1.000	0.570*
		E												1.000	0.308*
14	Fruit size	P													1.000
		G													1.000
		E													1.000

technique, the twenty five accessions could be grouped into six clusters. The constituents of different clusters are presented in Table 8.

Among the six clusters identified Cluster I was the largest with eight accessions. Clusters II and VI had five accessions each, Cluster V had three accessions and Clusters III and IV had two accessions each.

4.2.4.2 Intra and Inter cluster divergence

The intra and inter cluster D^2 values are presented in Table 9. Adequate diversity between the strains was observed with D^2 values ranging from 3.275 to 8.683.

Inter cluster divergence was maximum between Clusters I and IV (8.68) and minimum between II and III (3.28).

4.2.4.3 Cluster mean value of characters

The mean values of biometric characters of the clusters are given in Table 10. Cluster IV had the maximum values for plant height (88.5 cm), number of harvests (5.9), fruit girth (3.94 cm), fruit length (5.47 cm), pedicel length (3.36 cm), mean fruit weight (1.83 g), fruit/ pedicel ratio (1.64), fruit size (21.57 cm^2) and yield per plant (106.92 g). Maximum cluster means for primary branches per plant (6.84) and driage per cent (25.1) were registered for Cluster V, for plant spread (54.28 cm) for Cluster VI and days to first harvest and crop duration for Cluster I.

Table 8. Genotypes in each cluster in D^2 analysis

Clusters	No. of genotypes	Genotypes
I	8	CF 15, CF 18, CF 27, CF 28, CF 53, CF 84, CF 138, CF 139
II	5	CF 11, CF 34, CF 37, CF 77, CF 147
III	2	CF 66, CF 136
IV	2	CF 19, CF 36
V	3	CF 146, CF 147, CF 156
VI	5	CF 5, CF 10, CF 23, CF 103, CD 135

Table 9. Inter and Intra (diagonal) cluster average D^2 values

Cluster	I	II	III	IV	V	VI
I	00	3.764	4.035	8.683	4.548	5.751
II		00	3.275	5.576	3.431	4.032
III			00	6.073	3.491	4.004
IV				00	6.283	4.048
V					00	4.432
VI						00

Table 10. Cluster means for 14 biometric characters of bird pepper

Sl.No.	Characters	General mean	Clusters					
			I	II	III	IV	V	VI
1	Plant height (cm)	64.03	56.63	66.62	64.57	88.50	72.76	83.68
2	Primary branches per plant	5.51	4.77	5.25	5.13	5.85	6.84	6.66
3	Plant spread (cm)	45.47	44.77	46.00	53.60	53.60	47.44	54.28
4	Number of harvests	5.16	4.77	5.10	4.73	5.90	4.84	5.82
5	Days to first harvest	155.39	169.08	156.12	159.83	149.50	158.60	151.00
6	Crop duration	178.99	211.17	203.50	211.17	191.00	207.70	202.10
7	Fruit girth (cm)	2.70	2.14	2.90	2.25	3.94	2.95	2.97
8	Fruit length (cm)	3.34	2.50	4.02	2.67	5.47	3.59	3.54
9	Pedicel length (cm)	2.51	2.22	2.72	2.72	3.36	2.55	3.11
10	Driage (%)	23.35	22.71	21.95	23.80	24.20	25.10	24.11
11	Mean fruit weight (g)	1.10	0.73	1.36	0.80	1.83	1.28	1.26
12	Fruit / pedicel ratio	1.29	1.15	1.51	0.97	1.64	1.46	1.15
13	Fruit size (cm^2)	9.39	5.34	11.75	6.20	21.57	10.59	10.57
14	Yield per plant (g)	69.30	57.82	75.08	63.11	106.92	57.28	102.00

4.2.4.4 Genetic diversity vs geographic diversity

Genetic diversity was not found related to geographic diversity. The accessions of same geographical origin came under different clusters and vice versa.

4.3 Improvement of bird pepper accessions through single plant and mass methods of selection and comparing the relative effectiveness of the methods

Six accessions viz., CF 5, CF 10, CF 23, CF 36 and CF 103 were advanced through two methods of selection, single plant and mass selection for three generations. The general analysis of variance indicated that the selection methods were significantly different to effect changes in fruit length, pedicel length, fruit size, number of harvests and yield in three consecutive generations, plant height in the third generation, primary branches per plant in the first generation, fruit girth in the first and third generations, fruit weight in the second and third generation and crop duration in the first and second generation. The characters of the base population of selected accessions are given in Table 11.

4.3.1 Plant height

Significant variation was observed between accessions for plant height in the first and third generations. The maximum plant height was observed in CF 5 under mass selection (86.45 cm) and single plant selection (85.28 cm) in the third generation of selection (Table 12a and b).

Table 11 . Characters of base population of selected accessions in bird pepper

Sl. No.	Accession No.	Plant height (cm)	Pr. Branches per plant	Days to first harvest	No. of harvests	Fruit length (cm)	Pedicel length (cm)	Fruit girth (cm)	Fruit size (cm^2)	Fruit weight (g)	Crop duration	Yield (g)
1	CF 5	81.2	6.8	153.0	5.5	2.92	3.12	2.75	8.03	1.15	201.0	90.24
2	CF 10	85.8	7.3	151.0	5.6	3.68	3.29	3.13	11.52	1.24	208.5	106.67
3	CF 19	90.0	5.4	146.0	5.8	5.36	3.14	3.82	20.51	1.64	184.0	101.68
4	CF 23	87.4	5.6	146.0	6.0	4.07	3.33	3.27	13.07	1.46	201.0	110.44
5	CF 36	87.0	6.3	153.0	6.0	5.59	3.58	4.05	22.64	2.02	198.0	112.16
6	CF 103	83.2	6.5	154.0	5.8	3.50	3.06	2.94	10.29	1.09	200.0	112.42

Table 12a . Mean performance of selected lines under single plant selection

Acc No.	Height (cm)			Pr. branches per plant			Days to first harvest			Fruit length (cm)			Pedicel length (cm)			Fruit girth (cm)		
	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3
CF 5	75.66	67.12	85.28	5.40	4.60	5.50	147.0	150.5	146.0	3.15	2.85	3.51	2.80	2.54	2.52	2.85	2.74	2.82
CF 10	78.04	70.71	84.33	5.50	4.50	5.60	143.0	153.5	140.0	3.68	3.52	3.89	2.52	2.55	2.94	3.30	3.25	3.58
CF 19	81.11	68.14	83.30	4.60	4.20	5.40	139.5	145.0	134.0	5.39	4.94	5.50	2.96	2.77	2.88	3.96	4.06	4.41
CF 23	75.24	73.10	80.84	4.70	4.00	5.40	148.0	151.0	137.0	4.19	3.99	4.29	2.24	2.25	2.66	3.46	3.36	3.44
CF 36	78.09	70.71	84.33	4.50	4.20	5.50	145.0	151.0	137.0	5.54	4.94	5.66	3.16	2.98	3.34	4.12	3.91	4.19
CF 103	75.12	63.21	74.87	5.50	4.60	5.40	147.0	149.5	141.0	3.83	3.36	4.20	2.43	3.06	2.5	3.30	3.16	3.32
CD (P=0.05)	4.7	6.11	0.55	0.35	0.48	0.23	4.86	3.55	4.48	0.13	0.13	0.07	0.09	0.13	0.22	0.08	0.11	0.09

Acc No	Fruit weight (g)			Fruit size (cm^2)			Crop duration			Number of harvests			Yield per plant (g)		
	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3
CF 5	1.17	1.16	1.18	8.98	7.81	9.90	218.0	207.0	224.5	5.80	5.80	6.70	117.17	102.48	131.44
CF 10	1.29	1.37	1.46	12.14	11.44	13.93	222.5	209.0	217.5	6.90	6.20	7.10	139.76	122.57	163.63
CF 19	1.90	1.73	2.15	21.84	20.06	24.26	200.0	183.0	205.0	6.80	6.10	7.00	151.32	132.46	185.38
CF 23	1.47	1.47	1.50	14.50	13.40	14.76	209.0	201.5	217.5	5.90	5.60	6.60	130.92	122.51	148.15
CF 36	2.15	1.13	2.28	22.89	19.32	23.72	207.5	197.5	212.0	5.90	5.70	6.20	119.64	110.79	123.64
CF 103	1.14	1.15	1.19	12.64	10.61	13.95	199.0	187.0	222.5	6.40	6.00	6.50	135.36	120.70	156.90
CD (P=0.05)	0.09	0.07	0.04	0.59	0.55	0.53	5.63	3.82	10.97	0.18	0.29	0.25	9.35	7.90	7.71

G1 - Generation 1; G2 - Generation 2; G3 - Generation 3

Table 12b. Mean performance of selected lines under mass selection

Acc. No	Height (cm)			Pr. branches per plant			Days to first harvest			Fruit length (cm)			Pedicel length (cm)			Fruit girth (cm)		
	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3
CF 5	79.49	68.77	86.45	4.90	4.50	5.40	149.5	152.0	151.0	2.96	2.82	3.48	2.56	2.36	2.37	2.81	2.84	2.83
CF 10	83.67	64.25	82.19	5.00	5.00	5.20	149.0	150.0	149.0	3.74	3.46	3.76	2.65	2.58	2.62	3.31	3.25	3.27
CF 19	78.26	76.68	80.07	4.60	4.40	5.60	144.0	147.0	142.0	5.09	4.65	5.40	2.68	2.55	2.67	3.79	3.86	4.09
CF 23	75.29	66.42	77.72	4.40	4.20	5.30	152.5	151.0	140.0	4.02	3.74	4.21	2.08	2.16	2.25	3.28	3.18	3.23
CF 36	83.68	64.25	82.19	4.50	4.00	5.50	149.0	157.0	149.0	5.22	4.87	5.14	3.04	2.92	2.95	4.06	3.88	4.09
CF 103	66.26	64.05	73.11	5.40	5.00	5.30	151.0	154.0	148.0	3.74	3.21	3.91	2.34	3.02	2.30	3.16	3.18	3.12
CD (P=0.05)	4.7	6.11	0.55	0.35	0.48	0.23	4.86	3.55	4.48	0.13	0.13	0.07	0.09	0.13	0.22	0.08	0.11	0.09

Acc. No	Fruit weight (g)			Fruit size (cm^2)			Crop duration			Number of harvests			Yield per plant (g)		
	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3
CF 5	1.16	1.15	1.16	8.32	8.01	9.85	217.0	202.5	220.5	5.60	5.60	5.90	101.45	92.08	107.79
CF 10	1.26	1.29	1.41	12.38	11.25	12.30	215.0	206.5	221.5	6.10	5.60	6.70	122.67	111.05	141.17
CF 19	1.78	1.68	1.75	19.29	17.95	22.09	193.0	182.5	208.0	6.50	5.80	6.60	131.77	109.47	151.04
CF 23	1.46	1.46	1.48	13.19	11.90	13.60	193.0	195.5	210.0	5.80	5.60	6.10	122.01	109.35	128.12
CF 36	2.09	2.07	2.19	21.20	18.90	21.02	207.0	195.5	208.5	5.80	5.60	5.90	112.73	102.44	121.05
CF 103	1.11	1.06	1.16	11.80	10.21	12.20	196.5	155.0	221.0	5.90	5.70	6.40	118.58	110.07	139.18
CD (P=0.05)	0.09	0.07	0.04	0.59	0.55	0.53	5.63	3.82	10.97	0.18	0.29	0.25	9.35	7.9	7.71

G1 - Generation 1; G2 - Generation 2; G3 - Generation 3

4.3.2 Primary branches per plant

Accessions varied significantly for primary branches per plant in the first and second generations of selection. Selection methods differed significantly in influencing this trait in the first generation only. The number of primary branches per plant was maximum in the third generation in CF 10 (5.6) and CF 19 (5.6) under single plant and mass methods of selection, respectively.

4.3.3 Days to harvest

Methods of selection and accessions differed significantly among themselves for days to harvest in the first and third generations. The accessions evolved through single plant selection were the earliest to yield fruits. The accession CF 19 gave the earliest yield in all the three generations under single plant selection; taking only 134 days to first harvest in the third generation.

4.3.4 Fruit length

Fruit length varied significantly between accessions and methods of selections in the three generations of selection. Fruit length excluding pedicel ranged from 3.15 to 5.54 cm, 2.85 to 4.94 cm and 3.51 to 5.66 cm respectively under first, second and third generation of single plant selection. The corresponding range observed in accessions progressed through mass selection were 2.96 to 5.22 cm; 2.82 to 4.87 cm and 3.48 to 5.4 cm. Among the accessions evaluated, maximum fruit length was noticed in CF 36 (5.66 cm), followed by CF 19 (5.5 cm)

under single plant selection, whereas under mass selection fruits were the longest in CF 19 (5.4 cm) followed by CF 36 (5.14 cm).

4.3.5 Pedicel length

In the three generations of selection, variation between accessions and selection methods were significant for this trait. Pedicel was longest in CF 36 under both methods of selection.

4.3.6 Fruit girth

Fruit girth differed between accessions in three consecutive generations and methods of selection in the first and third generations. In general, girth of fruits was more in progenies evolved through single plant selection, maximum in CF 19 (4.41 cm) followed by CF 36 (4.19 cm).

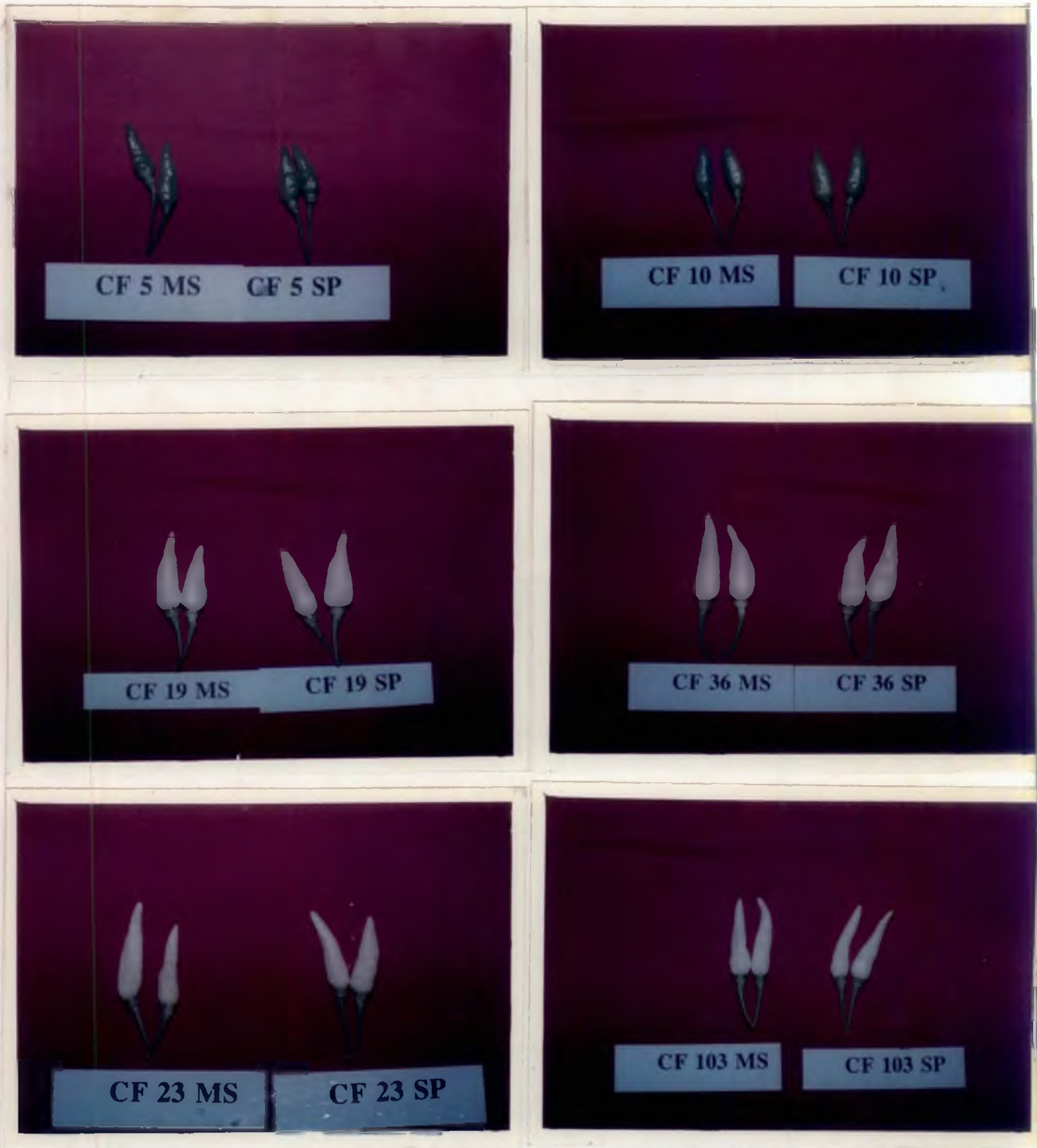
4.3.7 Fruit size

Fruit size in progenies of single plant and mass selection were significantly different and better sized fruits were obtained through single plant selection. The maximum fruit size attained in the third generation was 24.26 cm^2 in CF 19 followed by 23.72 cm^2 in CF 36 (Plate 4).

4.3.8 Fruit weight

Maximum fruit weight was recorded in the single plant progenies of CF 36 (2.28 g) followed by CF 19 (2.15 g) in the third generation of selection.

Plate 4. Fruits of promising accessions of bird pepper evolved by single plant and mass selection


CF 5 MS
CF 5 SP
CF 10 MS
CF 10 SP
CF 19 MS
CF 19 SP
CF 36 MS
CF 36 SP
CF 23 MS
CF 23 SP
CF 103 MS
CF 103 SP

4.3.9 Crop duration

The methods of selection were found to significantly change the crop duration in the first and second generations of selection. The crop duration ranged from 205.0 to 224.5 and 208.0 to 221.5 days respectively in third generation of single plant and mass selection.

4.3.10 Number of harvests

Number of harvests were significantly high in accessions evolved through single plant compared to mass selection. Maximum number of harvests obtained was in the third generation in accession CF 10 (7.1), closely followed by CF 19 (7.0).

4.3.11 Yield per plant

Yield of green chillies per plant depended significantly on accessions and methods of selection. The highest yield was registered by accessions progressed through single plant selection, maximum in CF 19 (185.38) followed by CF 10 (163.63 g). The same trend was observed in progenies of mass selection CF 19 (151.04 g) and CF 10 (141.17 g).

4.3.12 Assessment of relative efficiency of two methods of selection

Efficiency of the two methods of selection were assessed in terms of the realised genetic gain as compared to the overall mean of the characters of the base population of each selected accession.

A positive shift in values of biometric characters were observed for crop duration, number of harvests and yield in all the accessions under both methods of selection (Table 13). Genetic gain was attained in fruit characters like fruit length, pedicel length and fruit girth in all accessions except CF 36. Realised genetic gain obtained for yield and fruit size was considerable for progenies developed through single plant selection (Fig.5a and b).

4.4 Floral biology of bird pepper

The important aspects of floral biology namely time of anthesis, anther dehiscence, stigma receptivity and pollen characteristics were studied in detail.

4.4.1 Anthesis

The study was conducted in CF 5 and CF 23, the green and white fruited accessions of bird pepper respectively. The stages in development of flower buds in accessions CF 5 and CF 23 is depicted in Plate 5.

Flower buds which will open the following day could be distinguished by their swollen and turgid nature. As flower bud commenced opening the anther

Table 13. Realised genetic gain under single plant and mass selection

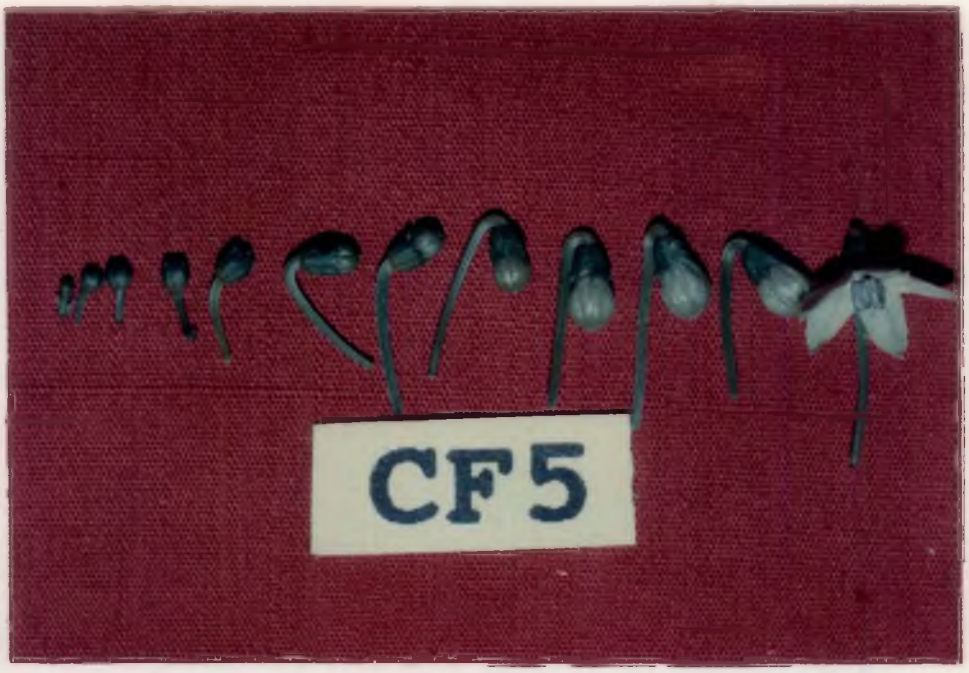
Acc.No.	Selection method	Height (cm)	Primary branches per plant	Days to harvest	Fruit length	Pedicel length	Fruit girth	Fruit weight	Fruit size	Crop duration	No. of harvests	Yield per plant
CF 5	SPS	+3.18	-1.30	-7.00	+0.59	-0.60	+0.07	+0.03	+1.87	+41.50	+1.20	+41.20
	MS	+4.35	-1.40	-2.00	+0.56	-0.75	+0.08	+0.01	+1.82	+36.50	+0.40	+17.55
CF 10	SPS	-1.47	-1.70	-11.00	+0.21	-0.35	+0.45	+0.22	+2.41	+ 9.00	+1.50	+56.96
	MS	-3.61	-2.10	-2.00	+0.08	-0.67	+0.14	+0.17	+0.78	+19.00	+1.10	+34.50
CF 19	SPS	-6.70	+0.00	+12.00	+0.14	-0.26	+0.59	+0.51	+3.75	+21.00	+1.20	+83.70
	MS	-9.93	+0.20	-4.00	+0.04	-0.47	+0.27	+0.11	+1.58	+24.00	+0.80	+49.36
CF 23	SPS	-6.56	-0.20	-9.00	+0.22	-0.67	+0.23	+0.04	+1.69	+16.50	+0.60	+37.71
	MS	-9.68	-0.30	-6.00	+0.14	-1.08	+0.02	+0.02	+0.53	+ 9.00	+0.10	+17.68
CF 36	SPS	-2.67	-0.80	-16.00	+0.07	-0.24	+0.14	+0.26	+1.08	+14.00	+0.20	+11.48
	MS	-4.81	-0.80	-4.00	-0.45	-0.63	+0.01	+0.17	-1.62	+10.50	+0.10	+ 8.89
CF 103	SPS	-8.33	-1.10	-13.00	+0.70	-0.56	+0.26	+0.10	+3.66	+22.5	+0.70	+44.48
	MS	-10.09	-1.20	-6.00	+0.41	-0.76	+0.10	+0.07	+1.91	+21.0	+0.60	+26.76

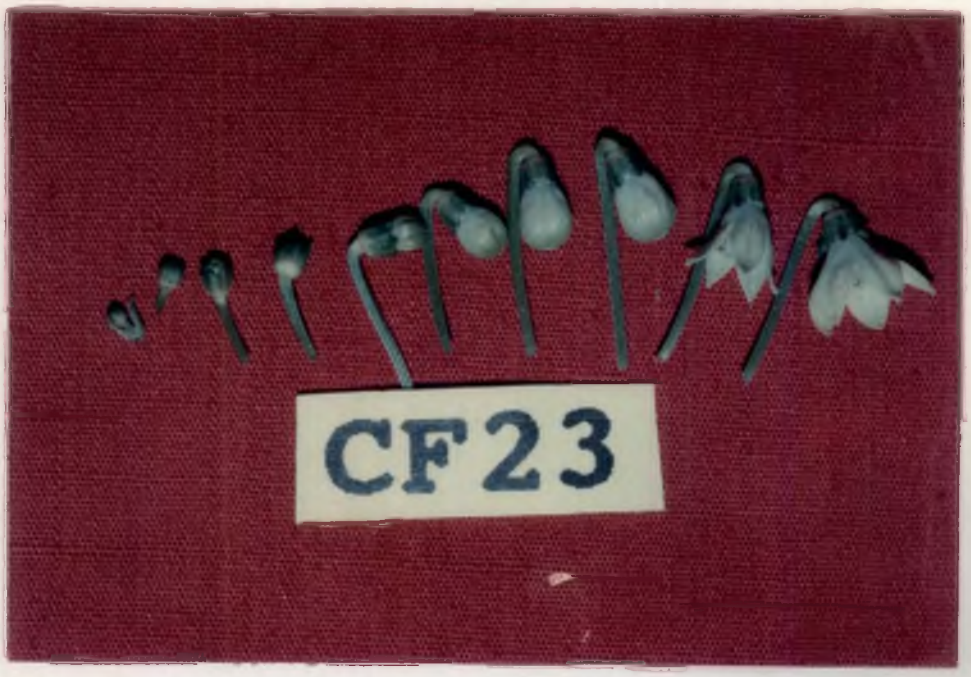
MS - Mass selection; SPS - Single plant selection

Plate 5. Stages in flower bud development in green and white fruited accessions of bird pepper

5a. CF 5 - *C. frutescens* green

5b. CF 23 - *C. frutescens* white


CF5


CF23

aperture at the tip became prominent. Flower buds started opening by about 6 am in both the accessions. The number of flowers opened fully, starting from the time of anthesis till the last bud opened were recorded at hourly intervals. The per cent of anthesis is presented in Table 14 and Fig.6. By about 8 am many of the flowers were half opened. Flowers started opening fully from 8 to 9 am in both the accessions. The peak period of flower opening in CF 5 and CF 23 was 9 to 10 am with a percent of flower opening of 87.0 and 67.62 respectively. The duration of anthesis was from 8 am to 1 pm in CF 5 and 8 am to 12 noon in CF 23. The green fruited accession CF 5 had a comparitively longer period of anthesis than the white fruited accession, CF 23. The smaller flower buds in CF 5, took the longest time to open.

4.4.2 Anther dehiscence

Dehiscence of anthers was evident with the deposition of pollen grains on apical pore and side sutures of anthers. Anther dehiscence commenced at 8 am and continued up to 11 am with peak period between 9 to 10 am in both the accessions. The per cent of anther dehiscence from 9 to 10 am was 63 and 66.66 in accessions CF 5 and CF 23 respectively (Fig.6). The anther dehisence commenced even before full opening of flowers in both the accessions. The per cent of anther dehiscence at 9 am respectively in CF 5 and CF 23 (30, 30.48) were higher than per cent of anthesis (7, 20). The duration of anther dehiscence was also shorter (3 hours) in both accessions compared to duration of anthesis. Anther dehiscence was complete with full opening of the flowers.

Table 14 . Duration of anthesis and anther dehiscence in two accessions of bird pepper

Sl.No.	Period of opening	Anthesis* (full opening of flowers)		Anther dehiscence	
		CF 5	CF 23	CF 5	CF 23
1	8-9 am	7.00	20.00	30.00	30.48
2	9-10 am	87.00	67.62	63.00	66.66
3	10-11 am	2.00	9.52	7.00	2.86
4	11-12 Noon	2.00	2.86	-	-
5	12-1 pm	2.00	-	-	-

* Flower buds were half opened in both the accessions by 8 am

4.4.3 Stigma receptivity

The stigma receptivity was studied by the fruit set method and data are presented in Table 15 and Fig.7. The per cent of fruit set observed in flowers pollinated one day prior to anthesis in accessions CF 5 and CF 23 was 28 and 32 respectively. Pollination done at the time of flower opening resulted in a fruit set per cent of 32 and 28 respectively for accessions CF 5 and CF 23. Thereafter a decrease in fruit set was observed, the least (12%) registered in CF 23 when pollination was done one day after anthesis.

4.4.4 Pollen studies

The different aspects of pollen grains viz., pollen size, fertility, viability and output per anther were studied in all the six selected accessions and mean values are presented in Table 16. General analysis of variance revealed that there was no significant difference among the selected accessions for pollen grain characters except pollen production per anther.

4.4.4.1 Pollen size

Pollen was almost spherical in CF 23 and triangular in shape in CF 5 (Plate 6). There was no significant difference among accessions with respect to pollen size (Fig.8). The mean size of the pollen grains varied from 37.11 μ in CF 103 to 42.11 μ in CF 19.

Table 15. Stigma receptivity in two accessions of bird pepper

Sl. No.	Flower maturity at the time of pollination	Per cent fruit set	
		CF 5	CF 23
1	Bud pollination (9 am)	28	32
2	Pollination on the day of opening (9 am)	32	28
3	Pollination on the day of opening (3 pm)	20	20
4	Late pollination (9 am on the following day)	20	12

Table 16 . Pollen characteristics in six accessions of bird pepper

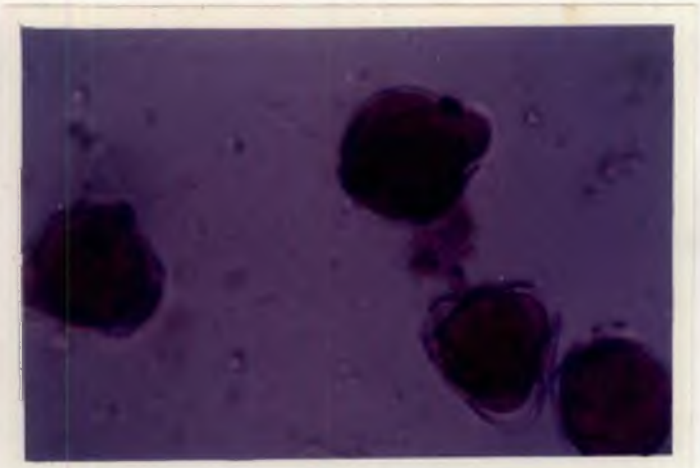
Sl. No.	Acc. No.	Pollen size (μ)	Pollen fertility (%)	Pollen germination (%)	Pollen output per anther
1	CF 5	39.74	88.24	30.72	2746.67
2	CF 10	40.64	88.28	38.04	2666.67
3	CF 19	42.11	84.03	38.09	4560.00
4	CF 23	38.08	88.27	36.04	2826.67
5	CF 36	41.10	87.59	32.21	2986.67
6	CF 103	37.11	83.89	36.22	1866.67
CD (P = 0.05)		NS	NS	NS	229.98

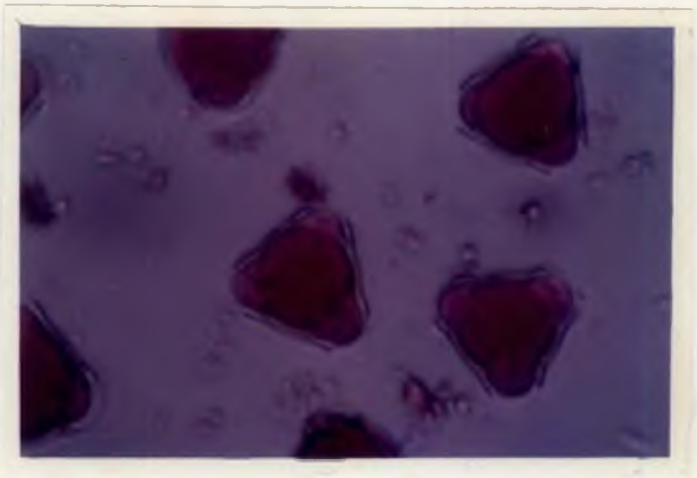
Plate 6. Pollen grains of *C. frutescens*

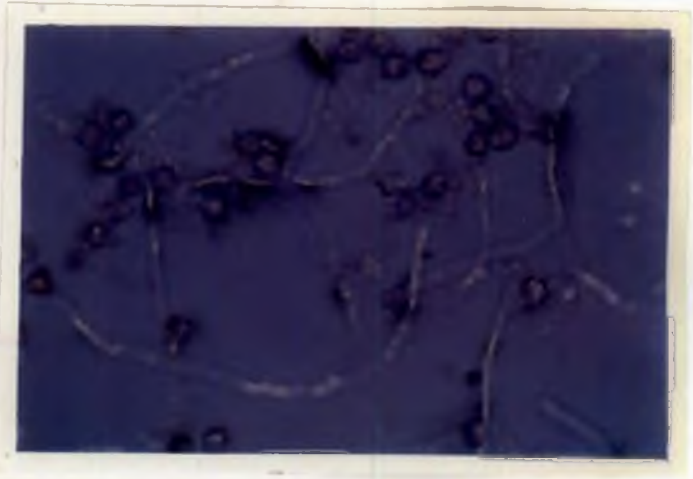
6a. *C. frutescens* white

6b. *C. frutescens* green

6c. Pollen germination







4.4.4.2 Pollen fertility

The variation in pollen fertility among accessions was not significant. However it ranged from 83.9 per cent in CF 103 to 88.3 per cent in CF 10.

4.4.4.3 Pollen viability

Pollen germination ranged from 30.7 per cent in CF 5 to 38.1 per cent in CF 19 in media supplemented with sugar and boric acid (Plate 6).

4.4.4.4 Pollen production per anther

The accessions varied significantly for pollen output per anther. It was observed to vary from 1866.7 in CF 103 to 4560.0 in CF 19.

4.4.5 Heterostyly

Heterostyly was observed in the white fruited accession of bird pepper, CF 23 producing long styled (76%), medium styled (18%) and short styled (6%) flowers. All the flowers in the green fruited accession, CF 10 were long styled.

4.5 Biochemical analysis in bird pepper

4.5.1 Analysis of secondary metabolites

The 25 selected accessions were estimated at two stages of maturity, mature green and red ripe for constituents like capsaicin, oleoresin, carotenoids and

ascorbic acid content. Analysis of variance revealed significant variation among accessions for the secondary metabolites. The mean values of chemical constituents at the two stages of maturity are presented in Table 17a and b.

4.5.1.1 Capsaicin

A significant variation was noticed among accessions for capsaicin content at both stages of maturity. The capsaicin content in accessions ranged from 0.21 to 1.57 per cent when harvested in the mature green stage. In the ripe fruits a range of 0.43 to 1.70 per cent was observed. When harvested at the ripe stage the highest content of capsaicin was recorded in CF 53 (1.7%), followed by CF 18 (1.65%). Analysis of mature green fruits revealed the highest content of capsaicin in CF 5 (1.57%) followed by CF 28 (1.56%). Capsaicin content was the least in CF 156 at both stages of maturity.

The accessions can be classified based on capsaicin content as high (1 to 1.5%), medium (0.25 to 0.75%) and low (0.11 to 0.25%). Eighteen accessions had high or medium high capsaicin content at the ripe stage. Capsaicin content was low in mature green fruits of accessions CF 36 (0.25%) and CF 156 (0.21%). The accessions with high capsaicin content (> 1%) at the mature green stage were CF 5 (1.57%), CF 28 (1.56%), CF 10 (1.41%), CF 147 (1.16%), CF 15 (1.07%) and CF 77 (1.06%). The capsaicin content of accession CF 10 was reduced drastically on ripening (Table 17b).

Table 17a.Quality parameters of 25 accessions of bird pepper at maturity

Sl.No.	Accession No.	Ascorbic acid (mg per100 g)	Capsaicin (%)	Oleoresin (%)	Carotenoids (%)
1	CF 5	26.7	1.57	8.25	0.17
2	CF 10	74.9	1.41	6.25	0.21
3	CF 11	26.7	0.81	10.25	0.33
4	CF 15	77.6	1.07	6.25	0.24
5	CF 18	60.4	0.83	13.75	0.29
6	CF 19	33.6	0.50	10.00	0.20
7	CF 23	53.5	0.90	14.25	0.28
8	CF 27	21.0	0.76	5.00	0.42
9	CF 28	21.6	1.56	8.75	0.17
10	CF 34	43.2	0.52	6.25	0.24
11	CF 36	21.4	0.25	12.50	0.16
12	CF 37	48.6	0.93	4.75	0.17
13	CF 53	42.8	0.51	6.75	0.32
14	CF 66	26.7	0.78	10.05	0.48
15	CF 77	37.4	1.06	8.75	0.42
16	CF 84	21.0	0.85	5.50	0.14
17	CF 103	26.6	0.65	13.75	0.14
18	CF 135	48.1	0.53	12.75	0.25
19	CF 136	21.4	0.78	8.50	0.28
20	CF 138	21.2	0.79	8.00	0.50
21	CF 139	21.6	0.81	4.50	0.31
22	CF 146	31.5	0.82	7.75	0.25
23	CF 147	26.7	1.16	5.00	0.14
24	CF 153	42.0	0.96	7.75	0.41
25	CF 156	21.4	0.21	8.15	0.28
CD (P = 0.05)		10.91	0.24	4.51	0.09

Table 17b. Quality parameters of 25 accessions of bird pepper at ripe stage

Sl.No.	Accession No.	Ascorbic acid mg per 100 g	Capsaicin (%)	Oleoresin (%)	Carotenoids (%)
1	CF 5	73.10	1.31	11.25	0.57
2	CF 10	135.75	0.64	21.25	0.68
3	CF 11	43.20	1.13	12.50	0.56
4	CF 15	106.00	1.34	8.75	0.56
5	CF 18	63.60	1.65	21.25	0.50
6	CF 19	84.80	0.51	17.75	0.26
7	CF 23	96.30	0.61	20.25	0.45
8	CF 27	73.50	1.39	13.35	0.52
9	CF 28	62.54	1.63	12.50	0.62
10	CF 34	90.10	0.53	24.25	0.50
11	CF 36	44.40	0.87	21.25	0.47
12	CF 37	82.75	1.39	8.75	0.32
13	CF 53	54.30	1.70	13.75	0.56
14	CF 66	42.80	0.98	17.75	0.67
15	CF 77	48.60	1.07	12.50	0.69
16	CF 84	31.50	1.12	10.00	0.41
17	CF 103	46.65	0.74	17.75	0.36
18	CF 135	90.90	0.87	14.50	0.47
19	CF 136	80.20	0.85	11.25	0.47
20	CF 138	79.50	1.50	12.50	0.53
21	CF 139	43.30	1.14	8.75	0.45
22	CF 146	84.00	1.17	17.90	0.35
23	CF 147	59.40	1.17	11.50	0.26
24	CF 153	76.85	0.57	18.50	0.52
25	CF 156	96.30	0.43	13.25	0.33
CD (P=0.05)		9.48	0.28	6.4	0.09

4.5.1.2 Oleoresin

The oleoresin content in the selected accessions varied from 4.5 to 14.25 per cent in mature green stage to 8.75 to 24.25 per cent in red ripe stage. The content of oleoresin at the mature green stage was the maximum in CF 23 (14.25%), followed by CF 103 (13.75%), CF 135 (12.75%) and CF 36 (12.5%). However in red ripe fruits oleoresin content was the maximum in CF 34 (24.25%). This was on par with CF 10 and CF 18 (21.25%), CF 23 (20.25%), CF 153 (18.5%) and CF 146 (17.9%). CF 139 recorded the least content of oleoresin both at red ripe (8.75%) and mature green stages (4.5%).

Variation between accessions in colour of oleoresin was also observed. Green and yellow coloured oleoresin was obtained respectively from *C. frutescens* green and white types. Harvesting at the ripe stage, yielded oleoresin, red in colour in both types (Plate 7).

4.5.1.3 Carotenoids

Significant differences between bird pepper accessions were observed for total carotenoid content, varying from 0.14 to 0.50 per cent in mature and 0.26 to 0.69 per cent in red ripe fruits. Carotenoids in ripe fruits was high in CF 77 (0.69%), CF 10 (0.68%) and CF 66 (0.67%). Among the accessions evaluated, the lowest content of carotenoids in ripe fruits was observed in CF 19 and CF 147 (0.26%). Estimation of total carotenoid content of mature green fruits revealed the highest content in CF 138 (0.50%) followed by CF 66 (0.48%) and least (0.14%) in CF 84, CF 103 and CF 147. It was observed that most of the green fruited

Plate 7. Oleoresin from bird pepper fruits at different maturity stages

7a. Mature fruits (green)

7b. Mature fruits (white)

7c. Red ripe fruits

accessions of *C. frutescens* had higher carotenoid content as compared to white fruited types.

4.5.1.4 Ascorbic acid

The bird pepper accessions exhibited significant variation in ascorbic acid content at both stages of maturity. It ranged from 21.0 to 77.6 mg 100 g^{-1} in mature fruits to 31.5 to 135.75 mg 100 g^{-1} in red ripe fruits with an overall mean of 35.90 mg 100 g^{-1} and 71.6 mg 100 g^{-1} respectively. Among the accessions evaluated, ascorbic acid content was the highest in CF 15 (77.6 mg 100 g^{-1}) on par with CF 10 (74.9 mg 100 g^{-1}) and the lowest in CF 27 and CF 84 (21 mg 100 g^{-1}) at mature stage. The same trend was observed at red ripe stage also. The maximum ascorbic acid content was observed in CF 10 (135.75 mg 100 g^{-1}) and CF 15 (106 mg 100 g^{-1}) and minimum in CF 84 (31.5 mg 100 g^{-1}). High content of ascorbic acid was also registered at mature stage in CF 18 (60.4 mg 100 g^{-1}), CF 23 (53.5 mg 100 g^{-1}), CF 37 (48.6 mg 100 g^{-1}) and CF 135 (48.1 mg 100 g^{-1}). In red ripe fruits high content of ascorbic acid was recorded in CF 23 and CF 156 (96.3 mg 100 g^{-1}) CF 135 (90.9 mg 100 g^{-1}) and CF 34 (90.1 mg 100 g^{-1}).

4.5.1.5 Influence of harvest maturity on quality of chilli

The chemical constituents of fruits viz. ascorbic acid, oleoresin and carotenoids registered an significant increase with ripening of fruits in all accessions (Table 17b and Fig.9). Capsaicin content was high in red ripe fruits compared to mature green fruits in all accessions except CF 5, CF 10, CF 23 and CF 153. In these accessions, a slight decrease in capsaicin content on ripening was

noted. The range of ascorbic acid, capsaicin, oleoresin and carotenoids respectively in mature green fruits were 21.0 to 77.6 mg 100 g^{-1}; 0.21 to 1.57 per cent; 4.5 to 14.25 per cent and 0.14 to 0.5 per cent. The corresponding values in ripe fruits were 31.5 to 135.75 mg 100 g^{-1}; 0.43 to 1.7 per cent; 8.75 to 24.25 per cent and 0.26 to 0.69 per cent respectively.

4.5.2 Estimation of fatty acid, nucleic acid, enzyme and flavour components

Fatty acid and nucleic acid content in two accessions each in *C. annuum* (Ujwala and K-2), *C. frutescens* white (CF 19 and CF 36) and *C. frutescens* green (CF 5 and CF 10) were estimated and mean values presented in Table 18 and 19.

4.5.2.1 Fatty acid content

Estimation of oil yield in chilli seeds and free fatty acid content of oil revealed significant differences among accessions for these parameters (Table 18 and Fig.10).

4.5.2.1.1 Oil yield

Extraction of oil (fixed oil) from dry chilli seeds with solvent petroleum ether yielded 11.0 to 21.5 per cent oil from different *Capsicum* sp. Cultivar K-2 recorded the highest content of oil (21.5%) followed by CF 10 (16.32%). The cultivar Ujwala had the least oil (11.0%) content. Variation was also observed in colour of oil, cultivar K-2 yielded an oil with attractive golden yellow colour. Green

Table 18. Fatty acid content of six accessions in *Capsicum* sp.

Accession	Fixed oil %	Acid Value (AV) of seed oil
Ujwala (*C. a*)	11.00	6.04
K-2 (*C. a*)	21.50	3.43
CF 19 (*C. f. w*)	12.26	4.37
CF 36 (*C.f.w*)	14.02	3.36
CF 10 (*C. f.g*)	16.32	5.33
CF 5 (*C.f.g*)	15.31	4.82
CD(P = 0.05)	1.22	1.08

C. a - *C. annuum*
C.f.w - *C. frutescens* white
C.f.g - *C. frutescens* green

fruited accessions of *C. frutescens* yielded orange yellow coloured and white fruited accessions lemon yellow coloured oils.

4.5.2.1.2 Free fatty acid content of oil

The gravimetric estimation of Free Fatty Acid (FFA) content of chilli seed oil revealed a range of 3.36 to 6.04 in different accessions of *Capsicum* sp. The highest Acid Value was registered for seed oil of Ujwala (6.04) followed by CF 10 (5.33) and the lowest in CF 36 (3.36).

4.5.2.2 Nucleic acid content

The results of quantitative analysis of DNA and RNA are presented in Table 19 and Fig.11. Variation in nucleic acid (DNA and RNA) content between the accessions were significant.

4.5.2.2.1 DNA content

The colour reaction between deoxyribose and diphenylamine was used for determination of DNA. The DNA content in seeds of six accessions of *Capsicum* sp. varied from 1.62 to 2.26 mg g^{-1}. The DNA content was comparatively low in accessions of *C. annuum*, Ujwala (1.63 mg g^{-1}) and K-2 (1.62 mg g^{-1}). It was highest in CF 5, an accession of *C. frutescens* green (2.26 mg g^{-1}).

Table 19.Nucleic acid and protein content of six accessions in *Capsicum* sp.

Sl. No.	Accession	DNA content (mg g^{-1})	RNA content (mg g^{-1})	Protein (mg g^{-1})
1	Ujwala (*C. a*)	1.63	4.97	13.85
2	K-2 (*C. a*)	1.62	4.79	10.79
3	CF 19 (*C. f.* w)	1.79	4.65	5.77
4	CF 36 (*C. f.* w)	1.90	5.48	12.15
5	CF 10 (*C. f.* g)	2.23	4.46	14.20
6	CF 5 (*C. f.* g)	2.26	3.02	12.35
CD (P = 0.05)		0.33	0.58	0.96

C. a - *C. annuum*
C.f.w - *C. frutescens* white
C.f.g - *C. frutescens* green

4.5.2.2.2 RNA content

Significant variation in ribonucleic acid content between different accessions was observed. RNA content was found to range from 3.02 to 5.48 mg g^{-1}, highest in the white fruited accession of *C. frutescens*, CF 36 (5.48 mg g^{-1}). The content was the least in CF 5, the green fruited accession of *C. frutescens*.

4.5.2.3 Protein content

A comparison of protein content in leaves of accessions of *C. annuum* and *C. frutescens* (green and white types) revealed significant differences for this constituent. The protein content ranged from 5.77 to 14.2 mg g^{-1} fresh tissue. Protein content was the highest in CF 10 (14.2 mg g^{-1}) followed by Ujwala (13.85 mg g^{-1}) and least in CF 19 (5.77 mg g^{-1}) (Table 18).

4.5.2.4 Enzyme activities

4.5.2.4.1 Peroxidase

The peroxidase activity in leaves of Ujwala, CF 36 and CF 5 belonging respectively to *C. annuum*, *C. frutescens* (white) and *C. frutescens* (green) were assayed at two growth stages, 45th and 75th day after sowing. The activity was the lowest in Ujwala (193.58 units per litre) and the highest in CF 5 (611.21 units per litre) when assayed 45th day after sowing. It is evident from Fig. 12 that there is an increase in activity with age of plants. The rate of increase in activity was maximum in Ujwala (3.74 times) as compared to 3 times in CF 36 and 1.9 times in CF 5. In general maximum peroxidase activity at both stages of growth was in *C.*

frutescens. Ujwala, the cultivar of *C. annuum* was characterized by a low peroxidase activity at both stages (Table 20).

4.5.2.4.2 Polyphenol oxidase activity

The polyphenol oxidase activity in leaves of 60 day old seedlings was assayed. The enzyme activity was studied in accessions Ujwala and K-2 (*C. annuum*), CF 36, CF 103 (*C. frutescens* white) and CF 5 and CF 10 (*C. frutescens* green). The activity of the enzyme was assayed by recording the absorbance at 495 nm for a period of 5 minutes at 30 seconds interval. The activity curve (Fig. 13) shows a similar trend for cultivars K-2 and CF 103 and Ujwala and CF 36. The accession CF 10 registered a steep increase in activity in the first minute, thereafter a gradual decrease was observed. The activity trend was progressive for all the accessions.

The enzyme activity per minute was the highest in CF 36 (2.58×10^{-2} units) followed by Ujwala (2.46×10^{-2} units) (Table 21). The accessions K-2 and CF 103 registered comparatively low polyphenol oxidase activity (1.6×10^{-2} units).

The specific activity of the enzyme (activity per minute per mg protein) was maximum in CF 103 (1.39×10^{-2} units), followed by CF 36 (1.06×10^{-2} units) and minimum in K-2 (0.74×10^{-2} units).

4.5.2.5 Flavour components in *Capsicum* sp.

Analysis of flavour components in volatile oil of six different accessions belonging to *Capsicum* sp. was done by gas chromatography. Volatile oil extracted

Table 20. Peroxidase activity in selected accessions of *Capsicum* sp. at different growth stages (units per litre of enzyme extract)

Sl. No.	Accession	Growth stage	
		45th day	75th day
1	Ujwala (*C. a.*)	193.58	724.64
2	CF 36 (*C. f.* w)	416.70	1282.05
3	CF 5 (*C. f.* g)	611.20	1162.00

C.a. - *Capsicum annuum*
C.f.w. - *C. frutescens* white
C.f.g. - *C. frutescens* green

Table 21. Polyphenol oxidase activity in six accessions in *Capsicum* sp

Accession	Activity per minute (units x 10^{-2})	Specific activity (units/min/mg protein) (units x 10^{-2})
Ujwala (*C. a*)	2.46	0.89
K-2 (*C. a*)	1.60	0.74
CF 36 (*C. f. w*)	2.58	1.06
CF 103 (*C.f.w*)	1.60	1.39
CF 5 (*C.f.g*)	2.16	0.87
CF 10 (*C.f.g*)	2.24	0.79

C. a - *C. annuum*
C.f.w - *C. frutescens* white
C.f.g - *C. frutescens* green

from three fresh and dehydrated (40°C) samples were used for the study. Volatile oil content in *Capsicum* sp. was very low. The oil was found to be lighter than water.

Gas chromatographic profiles of volatile oil obtained from fresh and dehydrated fruits are given in Fig.14a and b. The components could not be identified due to lack of standards at hand. However the number of peaks obtained and their retention time were noted for each sample (Table 22). The number of peaks obtained respectively for fresh samples of *C. annuum*, *C. frutescens* white and *C. frutescens* green were three, seven and thirteen. The corresponding peaks for dehydrated samples were eight, nine and thirteen respectively.

The components with retention time 0.44 and 22.2 were common to all the six samples. The fresh and dehydrated samples of *C. frutescens* white and green types had the components with retention time 18.7 and 19.8, but these were absent in samples of *C. annuum*. The components corresponding to retention time 27.3 and 28.5 were present exclusively in *C. frutescens* green. The relative proportion of each component to total area per cent of the sample are given in Table 22. The preponderance of component with retention time 19.1 was observed in fresh as well as dried samples of *C. annuum*. The relative proportion of the constituent corresponding to retention time 17.2 was highest in fresh samples of *C. frutescens* green (16.22%) and white (18.04%).

4.6 Biochemical characterization of *C. frutescens* by isozyme analysis

Characterization of *C. frutescens* was attempted by studying the electrophoretic pattern of isoenzyme peroxidase. Poly acrylamide gel electrophoresis was carried out for the separation of isoenzymes.

Table 22. Flavour components in *Capsicum* sp

Retention time	Relative area per cent					
	1	2	3	4	5	6
0.44	15.87	6.82	13.07	9.88	4.17	21.88
5.5	-	-	-	-	13.22	4.95
13.8	-	10.88	-	-	-	-
14.1	-	-	-	-	3.10	-
15.0	-	3.80	-	-	-	-
17.2	-	16.22	18.04	-	-	-
18.1	-	5.73	3.82	-	-	-
18.7	-	12.76	17.36	-	15.08	4.37
19.1	31.99	-	-	15.25	-	5.22
19.8	-	2.75	15.48	-	2.76	7.13
22.2	11.46	7.90	7.26	7.22	11.22	6.30
22.8	-	-	2.97	-	-	-
24.6	-	-	-	7.27	8.22	7.02
26.6	-	3.23	-	5.58	3.36	-
27.3	-	4.05	-	-	5.63	-
28.5	-	2.54	-	-	2.36	-
29.0	-	-	-	5.19	4.51	4.94
29.5	-	-	-	-	-	5.26
31.5	-	2.74	-	6.88	6.26	-
33.2	-	1.49	-	6.96	3.77	-

Sample 1 - *C. annuum* fresh
Sample 2 - *C. frutescens* (green) fresh
Sample 3 - *C. frutescens* (white) fresh
Sample 4 - *C. annuum* dried
Sample 5 - *C. frutescens* (green) dried
Sample 6 - *C. frutescens* (white) dried

Six accessions belonging to two different species of *Capsicum*, viz. *C. frutescens* and *C. annuum* were analysed to find variation, if any in the zymogram.

The peroxidase pattern of the six accessions of *Capsicum* are depicted in Plate 8 and Fig.15. It is evident from Fig.15 that isoenzyme polymorphism exists in the genus *Capsicum*. The *C. frutescens* accessions were characterized by two broad bands (PRX_1 and PRX_2) with Rm values 0.395 and 0.465 respectively. Same pattern was observed for white fruited (CF 19, CF 36) and green fruited (CF 5 and CF 10) accessions of *C. frutescens*. The *C. annuum* cultivars Ujwala and K-2, had one additional band PRX_3 with Rm value 0.581. The fastest moving band PRX_4 was represented by a faint band.

Plate 8. Peroxidase electrophorogram of six accessions in *Capsicum* sp.

1. CF 19 (*C. frutescens* white)
2. Ujwala (*C. annuum*)
3. K-2 (*C. annuum*)
4. CF 36 (*C. frutescens* white)
5. CF 5 (*C. frutescens* green)
6. CF 10 (*C. frutescens* green)


1 2 3 4 5 6 6

Discussion

DISCUSSION

The two important cultivated species of *Capsicum* are *C. annuum* L. and *C. frutescens* L. The cultivars of *C. annuum* are annual, early maturing and are cultivated on an extensive scale. In contrast, bird pepper, *C. frutescens* L. is perennial in nature, has highly pungent fruits and cultivation is restricted to small holdings.

Genus *Capsicum* is the unique source of capsaicin, an alkaloid widely used by pharmaceutical and food industries. Cultivars of *C. frutescens* are noted for high capsaicin content and Mombasa chilli of Africa belonging to this group is popular in world market. Indian chillies have moderate pungency with 0.2 to 0.3 per cent capsaicin and are not suitable for the manufacture of high capsaicin oleoresin for pharmaceuticals and export. However, the variety, Pusa Sadabahar developed from *C. frutescens* give oleoresin with 12.0 per cent capsaicin (Tewari, 1988).

Almost all the bird pepper accessions are indigenous types characterized by a wide range of observable variability. Breeding works in *Capsicum* have so far been mainly concentrated on *C. annuum* with little emphasis on *C. frutescens*. Considering the importance of bird pepper in industry and export, it is imperative to make systematic efforts for the genetic improvement of this crop. In this backdrop, the present investigation was taken up to improve indigenous types through various selection methods and to generate a comprehensive knowledge on the agro-morphological, biometric, genetic and biochemical parameters of *C. frutescens* which were hitherto unattempted.

5.1 Collection and characterization of bird pepper germplasm

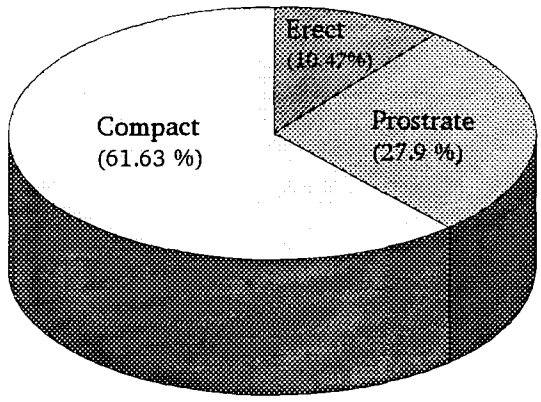
5.1.1 Morphological characters

Eighty six bird pepper accessions collected from different sources were catalogued for morphological characters using the IBPGR descriptor list for *Capsicum*. Success of any breeding programme depends basically on the extent of variability in the base population. In the present study, a wide range of variability was observed for plant, fruit and flower characters. Existence of wide range of variability for morphological characters in *C. annuum* have been reported by many workers (Padda *et al.*, 1970; Geneif, 1984; Amarchandra *et al.*, 1992; Mohammed, 1994 and Olufolaji and Makinde, 1994).

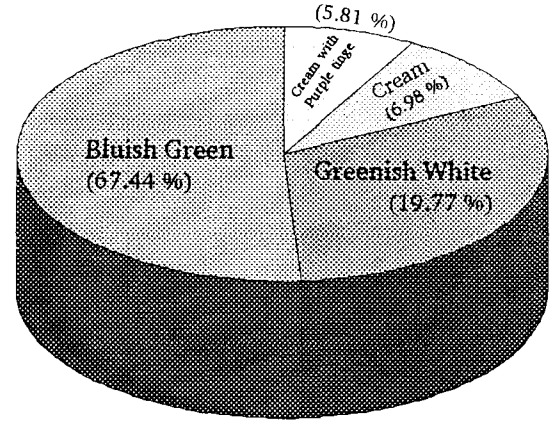
The extent of variability observed for the morphological characters in bird pepper accessions though significant, is on the lower side when compared to *C. annuum*. The extensive cultivation and the consequent natural generation of variability and the consistent breeding efforts, which resulted in artificial creation of variability have all contributed to the comparatively larger extent of variability in *C. annuum*. The fact that the floral biology of bird pepper is more conducive to self pollination is also one of the possible reasons for lesser variability in *C. frutescens*. The two species are difficult to cross and a few F_1 hybrids obtained are highly sterile (Heiser and Smith, 1953).

5.1.2 Biometric characters

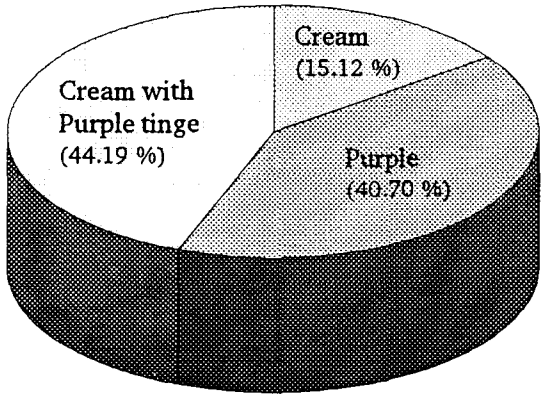
There existed highly significant differences between 86 bird pepper accessions for biometric characters as evident from the analysis of variance of these



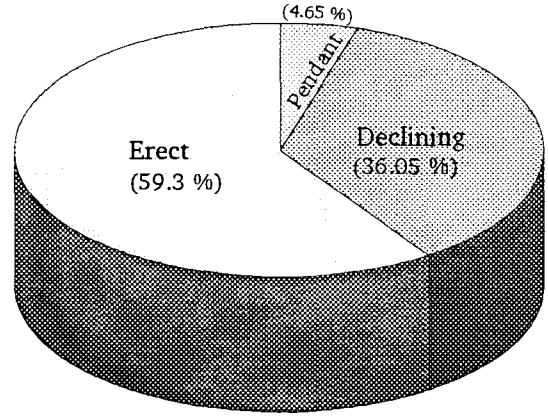
Plant growth habit



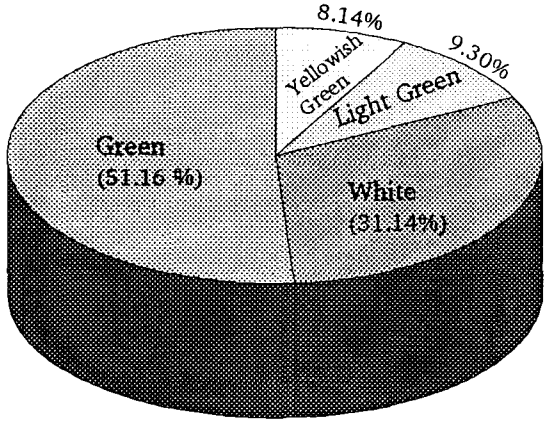
Anther colour



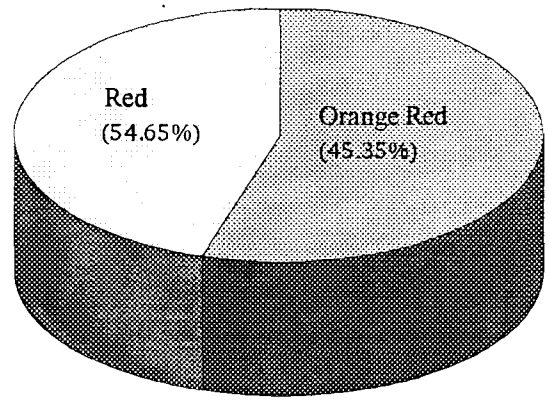
Filament colour



Fruit position

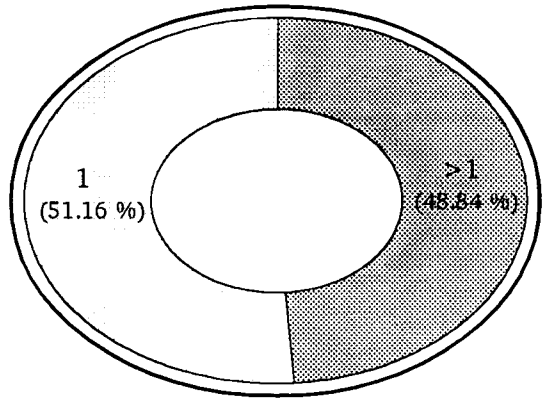


Fruit colour at immature stage

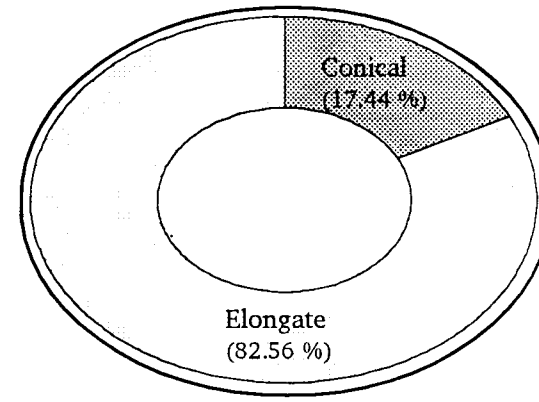


Fruit colour at mature stage

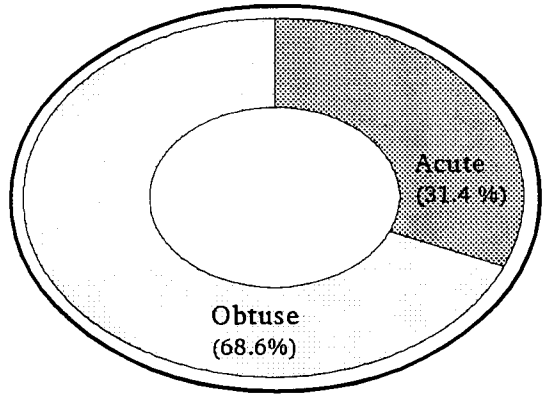
Fig. 1a. Frequency percentage of descriptor states in bird pepper germplasm



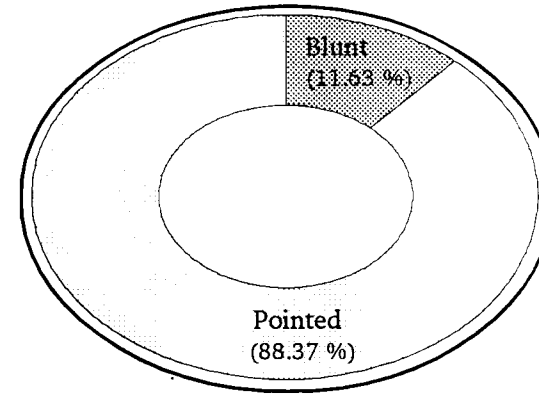
Number of pedicels



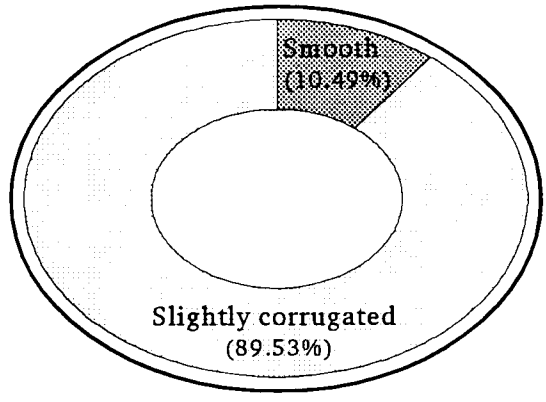
Fruit shape



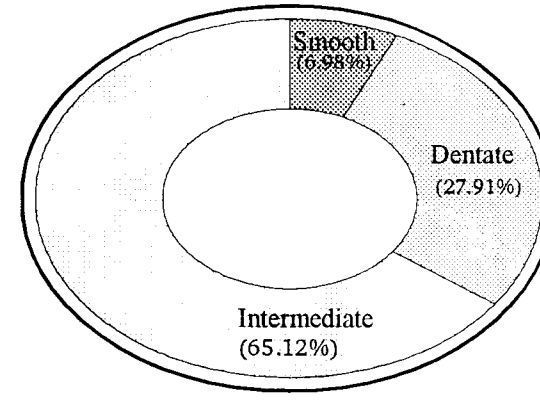
Fruit shape at peduncle attachment



Fruit shape at blossom end



Fruit cross sectional corrugation



Calyx margin shape

Fig. 1 b. Frequency percentage of descriptor states in bird pepper germplasm

characters. Wide range of variability in *C. annuum* for biometric characters were reported by many workers (Arya, 1979; Singh and Brar, 1979; Ramakumar *et al.*, 1981; Nair *et al.*, 1984; Narayanankutty *et al.*, 1992; Papalkar *et al*, 1992 and Sarma and Roy, 1995).

The range of genetic diversity for a particular character is measured with the help of genotypic coefficient of variation and the estimates provide means to compare the genetic variability in the quantitative traits. Yield per plant, fruit size, fruit length and girth displayed higher phenotypic and genotypic coefficients of variation. This indicated the wider variability and scope for further improvement of these characters. These observations are in conformity with the findings of Arya (1979) and Nair *et al.* (1984) who reported a high genotypic coefficient of variation for yield in chillies. Heritability in the broad sense varied from 49.6 per cent for plant spread to 92.53 per cent for fruit size.

Significant variation was also observed for the biometric characters studied. CF 139 was the most vigorous in growth, evident from the highest value for plant height and spread recorded in this accession.

Presence of variability for fruit characters in bird pepper germplasm is evident from the analysis of variance and wider range observed for these characters. Setiamihardja and Knavel (1990) had opined that such differences were due to genetic make up of the accessions. According to Tewari (1990) small fruit size and low productivity are the reasons for limited cultivation of bird pepper. The fruit size of bird pepper accessions in the present study ranged from 2.04 to 18.67 cm^2, suggesting ample variability and scope for improvement of fruit size in bird pepper. Accessions CF 36, CF 52, CF 108, CF 3, CF 19, CF 23 had better fruit size

(>14.0 cm^2). The pedicel length in bird pepper accessions ranged from 1.7 to 3.42 cm. Pedicel portion in chilli is non-edible and its small length is desirable (Pawade *et al.*, 1993). Rani (1996b) also reported considerable variability for fruit and pedicel length in chillies.

Results of the present investigation indicated a range of 0.53 to 1.96 for fruit/pedicel ratio. Accession CF 65 with a fruit/pedicel ratio 0.57 had long pedicel and short fruits whereas CF 19 with fruit/pedicel ratio, 1.96 had longer fruits and comparatively shorter pedicels. Most of the small fruited accessions in *C. frutescens* (green) had a fruit/pedicel ratio less than one.

Cultivars of *C. annuum* are usually early maturing (Tewari, 1990). The bird pepper accessions took 77 to 109 days to flowering and 132 to 170 days to first harvest. The results of the present investigation also closely tally with observations of Olufolaji and Makinde (1994), who observed that accessions of *C. frutescens* was comparatively late in flowering and maturity than *C. annuum*.

Tewari (1990) had opined that production of bird pepper is rather limited because of poor yields and difficulty in harvest. But from the wide range observed for fruit yield per plant (15.0 to 158.0 g), it is obvious that there are high yielding as well as low yielding accessions in bird pepper. These corroborates the findings of Adamu and Ado (1988) and Olufolaji and Makinde (1994).

Many of the high yielding accessions like CF 19, CF 36, CF 23, CF 10 had better fruit size also. These promising types can be further improved by different methods of selection or can be utilized as parents in hybridisation programme.

5.2 Somatic analysis for yield and its components

5.2.1 Biometric characters

Evaluation of the 25 bird pepper accessions selected from the preliminary trial, for biometric characters further established existence of wide variability in bird pepper.

In respect of vegetative characters, ample variability was observed, evident from the wide range obtained for plant height and spread. Among the accessions evaluated, CF 19 was the most vigorous registering the highest values for plant height and spread. The range for primary branches per plant was low as compared to other characters (3.8 to 6.9 and 4.0 to 7.4 during the first and second seasons respectively). Sarma and Roy (1995) reported almost similar range for primary branches in *C. annuum*. The number of branches was the maximum in CF 103 (6.9), which also recorded the highest yield (97.73), indicating that more number of branches would lead to enhanced production in bird pepper. Similar observations were made by Hiremath and Mathapati (1977).

Fruit production was the earliest in CF 19 in the first and second seasons. Pawade *et al.* (1993) in a varietal evaluation trial in *C. annuum* observed a range of 128 to 157 for days to first harvest. In the present study, a range of 141 to 167.5 days and 146 to 173.5 days were observed for days to first harvest, in the first and second season respectively, which proved that accessions of *C. frutescens* are late maturing compared to *C. annuum*.

CF 19 which registered the earliest production, however, had the shortest life span of 173.5 days. Pawade *et al.* (1993) had reported a range of 157 to 180 days for crop duration in *C. annuum*. The present study showed that though *C. frutescens* is characterized by perennial nature, it behaves like an annual crop under intensive cultivation with comparatively longer duration than *C. annuum*. The high incidence of mosaic in all the accessions towards the end of cropping period during both the seasons, led to early senescence of the crop.

Analysis of variance revealed significant differences for fruit characters in the two seasons. Maximum fruit size was observed for CF 36 in the first and second seasons. The other accessions with better fruit size were CF 19, CF 153, CF 23, CF 66 and CF 10. Both fruit length and girth contributed to better fruit size in CF 36. This is in conformity with the reports of Padda *et al.* (1970) in *C. annuum*. CF 36 also recorded the highest value for mean fruit weight (2.02 g) proving its superiority to other accessions in fruit characters.

The driage per cent in bird pepper accessions ranged from 21.08 to 25.82 per cent in the second season. This is in general agreement to Narayanankutty *et al* (1992).

The accessions CF 103, CF 36, CF 23, CF 10, CF 19 and CF 5 gave high yields in both the seasons, revealing their superiority and stability in performance. CF 19 was vigorous in plant growth and gave early (146 days) and high yield (101.68) in a shorter period (184 days). CF 103 was a profuse branching type which gave more number of harvests (6.3) and yield (112.42 g). The accession CF 36 had desirable fruit characters like maximum fruit size, fruit weight etc. Though in

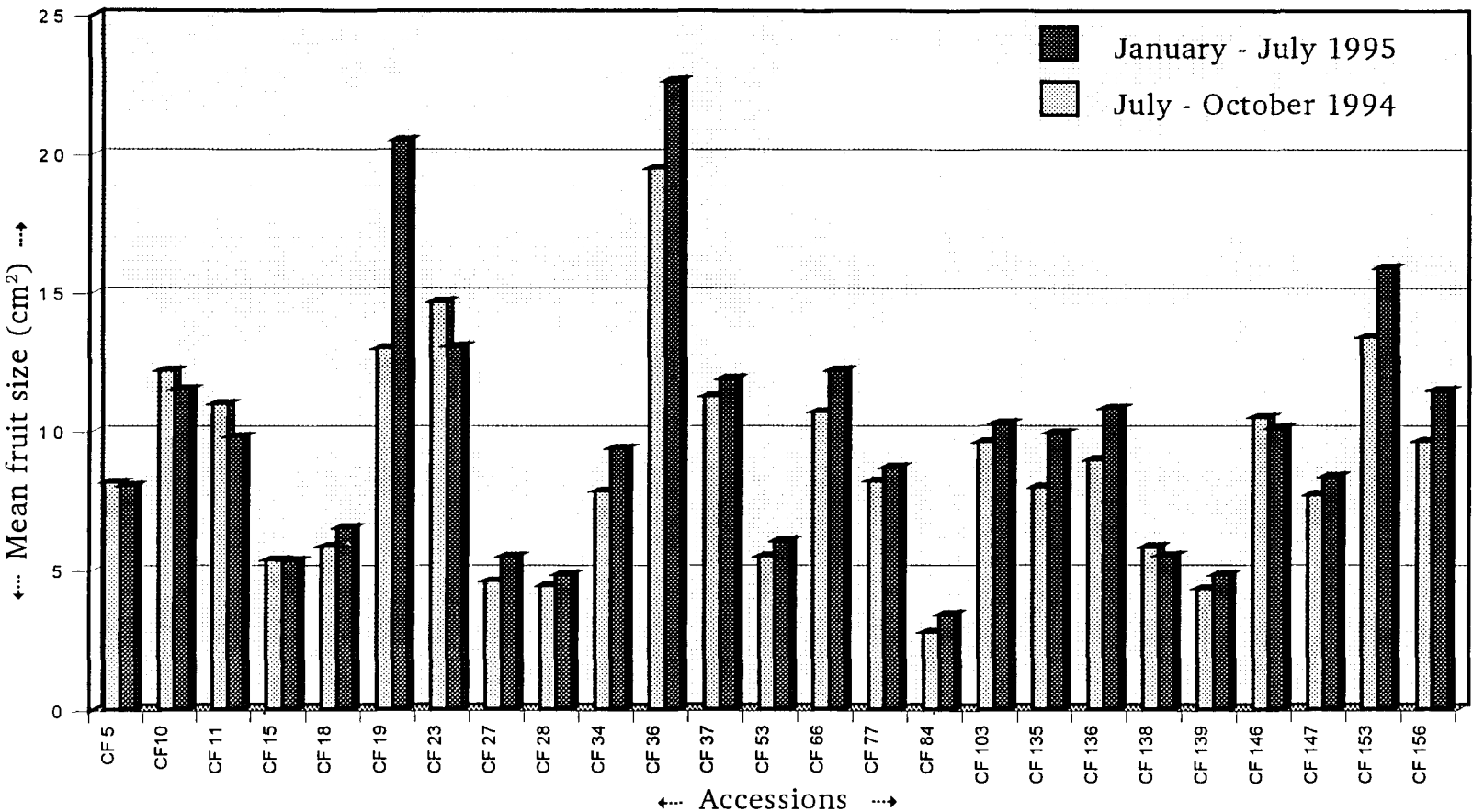


Fig. 2. Mean fruit size of 25 selected accessions of *C. frutescens*

general the green fruited accessions were characterized by small fruit size, CF 10 and CF 5 were promising for fruit size and yield.

A comparison of bird pepper accessions in the two seasons, clearly shows the superiority of performance in the second season (January to July, 1995) compared to the first season (July to December, 1994). Seasonal variation in performance of chilli cultivars was reported by many workers (Nandpuri *et al.*, 1971, Mini, 1997). The climatic and environmental factors greatly influenced the performance of varieties. The second crop was benefitted by the early monsoon showers received during the fruiting period.

5.2.2 Variability and genetic parameters in bird pepper

Information on variability and heritability of polygenic characters and on the association among yield and its component characters are of vital importance in any plant breeding programme. This is more so in a crop like bird pepper where only a little effort work has been taken to improve the genetic potential. Partitioning of the variability into heritable and nonheritable components will enable to know the effectiveness of selection.

Higher coefficients of variation (phenotypic and genotypic) were observed for fruit size, mean fruit weight, yield per plant and fruit length. This indicated the higher magnitude of variability for these traits and consequently more scope for their improvement through selection. The reverse is true for crop duration, days to first harvest and dry chilli recovery which had low phenotypic and genotypic coefficients of variation. Nair *et al.* (1984) reported minimum GCV values for crop

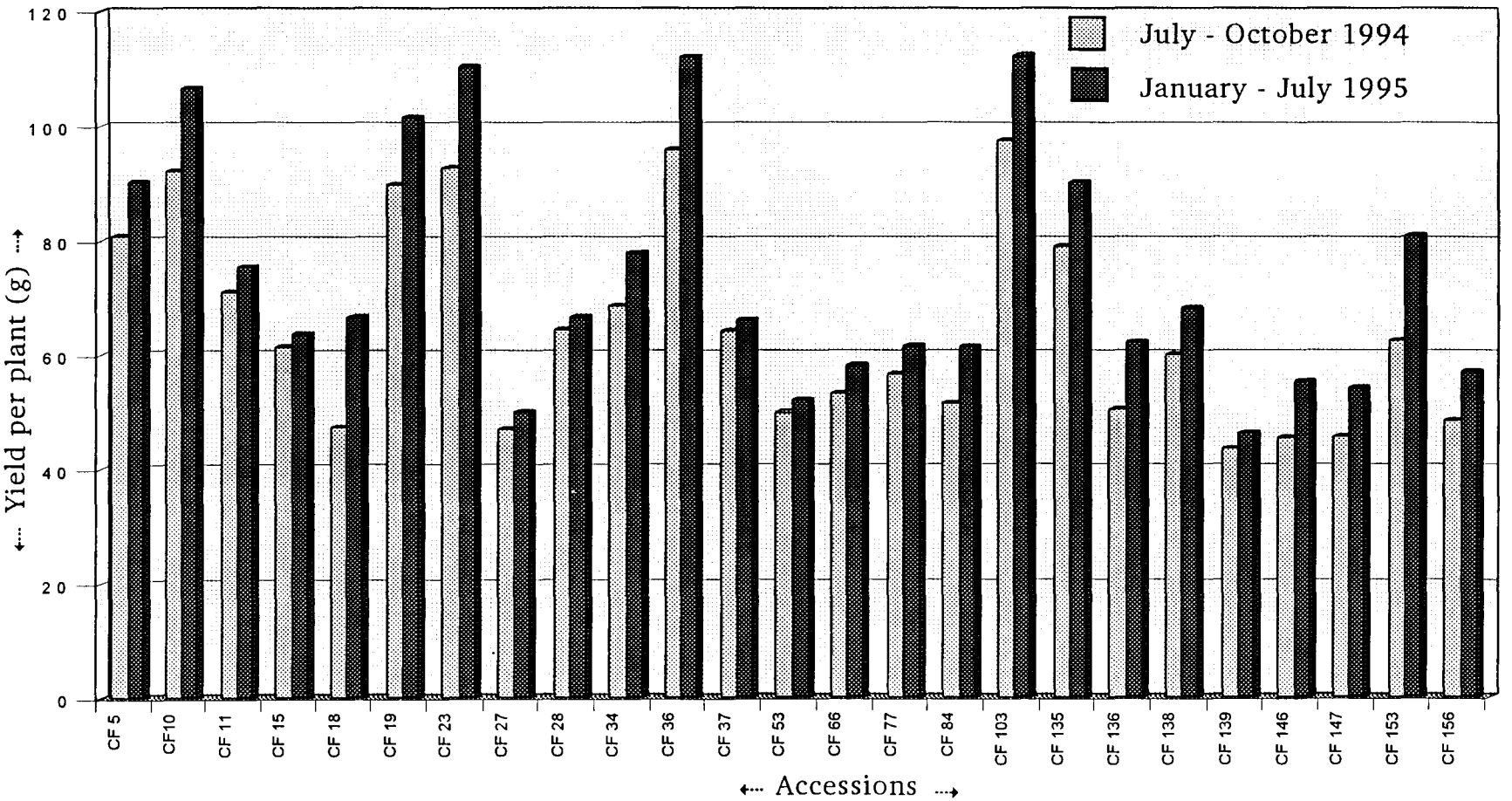


Fig. 3. Yield of 25 selected genotypes of *C. frutescens*

duration. High values of GCV for fruit size were reported by Arya and Saini (1976); Rajput *et al.* (1982); Nandi (1992); Sarma and Roy (1995) and for fruit length by Nandi (1992) and Pawade *et al.* (1993).

High values of heritability were observed for most of the characters studied. Nair *et al.* (1984) had also reported high estimates of heritability for all the characters studied by them in *C. annuum*. Higher magnitude of heritability (>90%) was registered for mean fruit weight, fruit girth, yield per plant, dry chilli recovery and fruit length. High value of heritability for fruit weight was reported by Gopalakrishnan *et al.* (1984) and Choudhary *et al.* (1985), for fruit size by Arya and Saini (1977) and for fruit yield by Arya and Saini (1977) and Bhagyalakshmi *et al.* (1990) in chillies.

Johnson *et al.* (1955) reported that heritability estimates along with genetic gain would be more rewarding than heritability alone in predicting the consequential effect of selection to choose the best individual. The expected genetic advance was high for fruit size, mean fruit weight, yield per plant and fruit length. This is in confirmation to results obtained by Ahmed *et al.* (1990).

High heritability in conjunction with high genetic advance was obtained for fruit size. This is in agreement to Gopalakrishnan *et al.* (1984), Amarchandra *et al.* (1990) and Ahmed *et al.* (1990). High heritability combined with high genetic advance is indicative of additive gene action and consequently a high genetic gain is expected from selection for fruit size. High heritability and medium genetic advance was registered for mean fruit weight, fruit yield per plant, fruit length and fruit girth. Characters like crop duration, driage per cent and days to first harvest had low GCV and genetic gain coupled with high heritability estimates. This signifies that

high value of heritability is not always an indication of high genetic advance (Johnson *et al.*, 1955). Arya and Saini (1986) also reported low genetic advance for driage per cent. It appears that crop duration, driage per cent and days to first harvest are influenced by non-additive gene effect.

On the basis of the present study, fruit size, mean fruit weight, fruit length and fruit girth appear to be characters of major importance and should be given due weightage while formulating selection strategies for improvement of yield in bird pepper. These results tally very closely with findings of Amarchandra *et al.* (1990).

5.2.3 Correlation of characters

Selection for yield *per se* may not be effective since implicitely or explicitely "there may not be genes for yield *per se*, but rather for the various components, the multiplicative interaction of which results in the artifact of yield" (Grafius, 1956). This necessitates identification of appropriate component characters whose selection result in the improvement of complex characters like yield. A better understanding of the contribution of each trait in building up the genetic make up of the crop may be obtained through correlation studies. A study of correlations among yield and its components will be of great value in planning and evaluating breeding programme.

A perusal of correlation coefficients revealed that genotypic correlation coefficients were higher than phenotypic correlation coefficients, indicating presence of inherent association between various characters.

In the present study, heritability estimate in broad sense was high for most of the polygenic characters. This resulted in the higher values of genotypic correlation coefficients than the phenotypic correlation coefficients.

A significant positive association of morphological characters like plant height, plant spread and number of branches with yield was recorded suggesting that selection for these characters would lead to improvement in yield. Positive association of plant height with yield was reported by Dahiya *et al.* (1991) and Sarma and Roy (1995).

The economic traits like number of harvests, fruit girth, fruit length, mean fruit weight and fruit size were significantly correlated with yield. This corroborated the findings of Padda *et al.* (1970), Khurana *et al.* (1993) and Ahmed *et al.* (1997) who reported positive association of mean fruit weight and fruit length with yield. Number of harvests, plant height and fruit size had high positive correlation with yield which showed that these characters should be given due weightage during selection for yield in bird pepper. Significant negative correlation was observed between yield and days to first harvest indicating that early maturing varieties had considerably low yield. This is in agreement of findings of Rao *et al.* (1981) and Bhagyalakshmi *et al.* (1990), who reported that early maturing crop produced less yield in terms of number of fruits.

Study on intercorrelations among characters revealed significant positive correlation between many of the characters studied. Higher magnitude of correlation of fruit size with fruit length, girth and mean fruit weight indicated that selection for any one of these traits would lead to a corresponding increase in fruit size.

Y - Yield

X_1 - Plant height

X_2 - Pr. branches per plant

X_3 - Plant spread

X_4 - Number of harvests

X_5 - Days to first harvest

X_6 - Crop duration

X_7 - Fruit girth

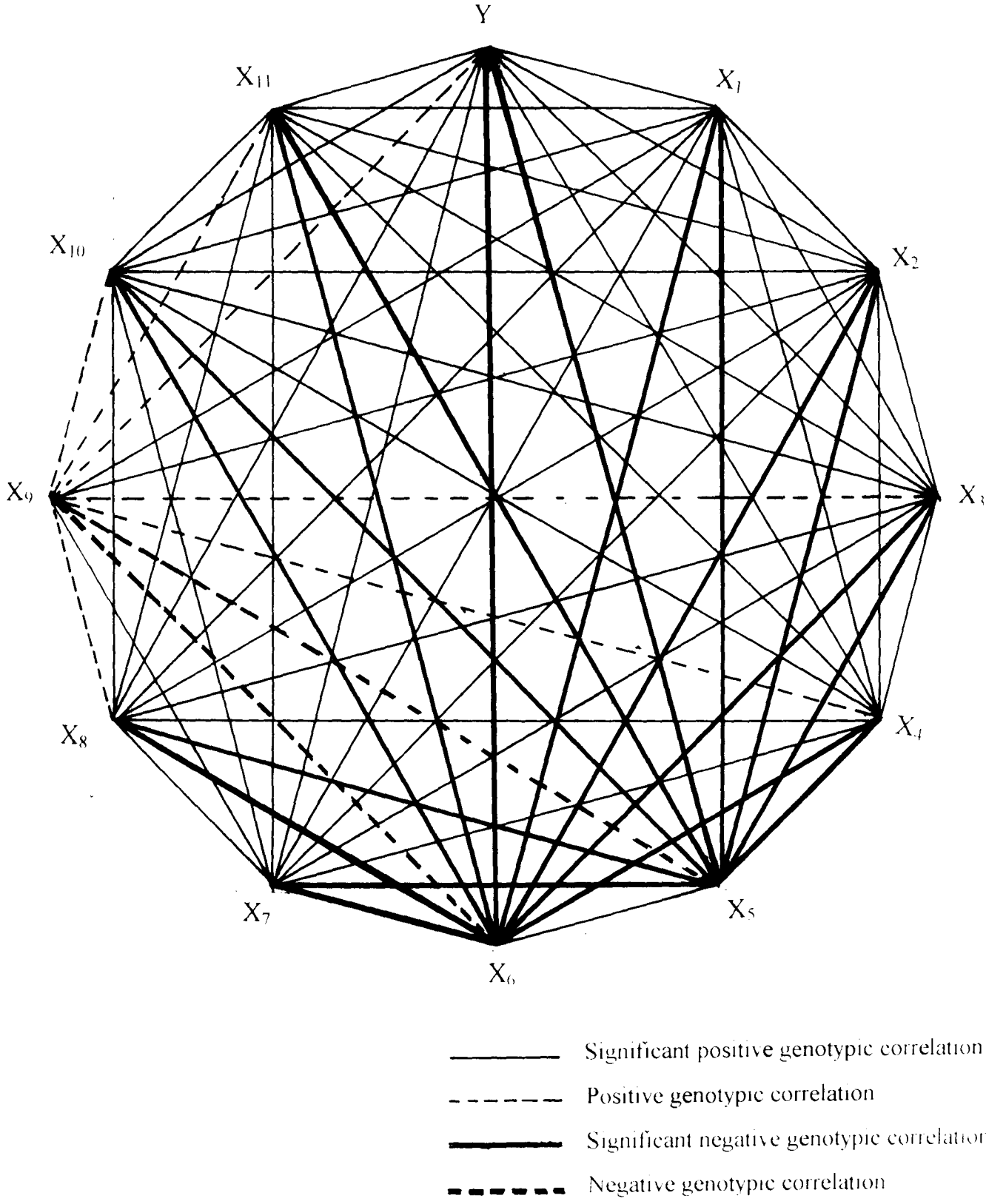
X_8 - Fruit length

X_9 - Driage (%)

X_{10} - Mean fruit weight

X_{11} - Fruit size

Fig.4. Genotypic correlations among different characters in bird pepper



5.2.4 Genetic divergence

Genetic diversity is one of the most important criteria which helps a breeder to choose parents for hybridization either to exploit heterosis or to select desirable segregants. The importance of cluster analysis to determine the extent and nature of variability was reported earlier by Cuartero *et al.* (1983) and Deshpande *et al.* (1988).

The accessions were grouped into six clusters by Non-heirarchical Euclidean cluster analysis. The genetic divergence values ranged from 3.28 between Clusters II and III to 8.68 between Clusters I and IV.

Though an appreciable degree of divergence was observed, it was comparatively low as is evident from the genetic divergence values. This may probably be due to the elimination of diverse accessions after the preliminary experiment. D^2 analysis was done using the 25 selected accessions from the original germplasm pool of 86 accessions. The intracluster divergence value was zero indicating uniformity of accessions within a cluster.

The clustering pattern in the present investigation revealed that geographic diversity did not have a direct association with genetic diversity. The same cluster included accessions from different localities whereas accessions from the same location were dispersed in different clusters. This was supported by reports of Sundaram *et al.* (1980), Pandey and Dobhal (1993) and Renthlei *et al.* (1994) in *C. annuum*. Diversity among lines of same geographical origin may be

due to ecogeographical distribution (Sood *et al.*, 1989). Free exchange of seed materials among different regions and other human interference might have contributed to genetic diversity (Katiyar and Singh, 1979). Populations from areas with complex environments may have in the long run adjusted to several ecological niches and have accumulated enormous genetic variability (Chandel and Joshi, 1981). Diversity could also be ascribed to genetic drift and selection under diverse environment, which could cause greater diversity than geographical isolation alone.

Of the six clusters, Cluster IV had the maximum value for most of the economic characters, plant height, number of harvests, mean fruit weight, fruit size and yield per plant. Accessions from this cluster can be effectively used as donor parents in hybridisation programme. The accessions in the same cluster had little divergence from each other for the aggregate effect of all the characters studied. The crossing between the accessions of the same cluster may not provide good segregants. The crosses may be attempted between accessions of the clusters separated by large inter cluster distances to get desirable segregants i.e., Cluster I and IV.

5.3 Improvement of selected accessions through single plant and mass methods of selection

Pickersgill (1989) opined that there is considerable variability in *Capsicum* sp., that can be exploited through conventional breeding. Selection methods were successfuly utilized for crop improvement in chillies and *Capsicum* (AVRDC, 1992; Singh, 1993; Singh *et al.*, 1993). In the present study six superior accessions of bird pepper were progressed through two methods of selection, single plant and mass selection for three generations. Sankar (1984); Jessykutty (1985) and

Rajan (1985) reported efficiency of single plant and mass selection for genetic improvement of tomato and brinjal.

The results indicated that the progenies developed through single plant selection performed better for fruit length, fruit size, number of harvests and yield per plant in three consecutive generations. This is in agreement with results obtained by Sankar (1985) in brinjal.

The two methods of selection were equally effective in improving plant height, days to harvest and fruit girth in the second generation and primary bracnhes per plant in the second and third generations, fruit weight in the first generation and crop duration in the third generation The results proved that improvement in fruit length, fruit size and yield were stable and significant. The performance for plant height, primary branches per plant, days to harvest and fruit weight were not consistent in the three generations probably due to effect of season or season into variety interaction. Amarchandra *et al.* (1990) observed that fruit length and weight are characters of major importance and should be given due weightage while making selection for improvement of yield in chilli.

Assessment of the realised genetic gain through selection revealed that there was a positive shift in productive characters like fruit length, girth, weight, size, crop duration, number of harvests and yield per plant in all accessions except CF 36. Improvement in performance in respect of these character were observed in all the three generations under both methods of selection. The magnitude of gain varied with the three generations. The improvement in fruit size and yield were considerable in progenies developed through single plant selection.

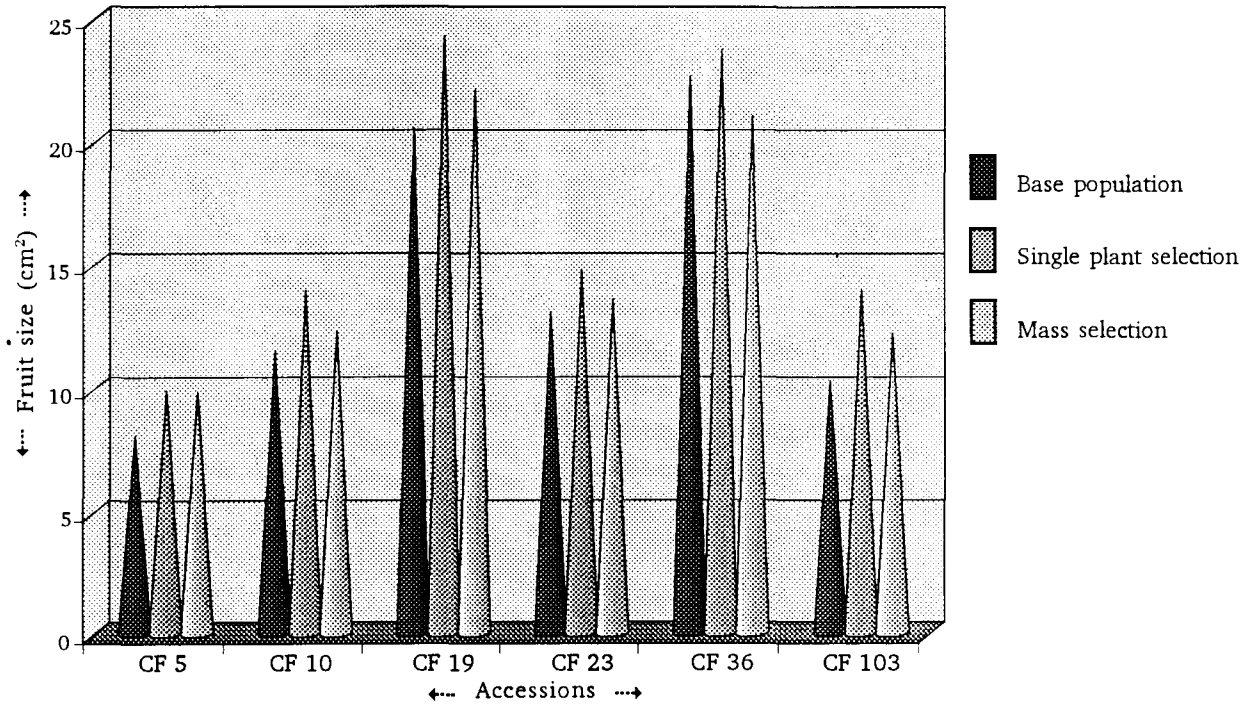


Fig. 5a. Relative efficiency of two methods of selection in improving fruit size

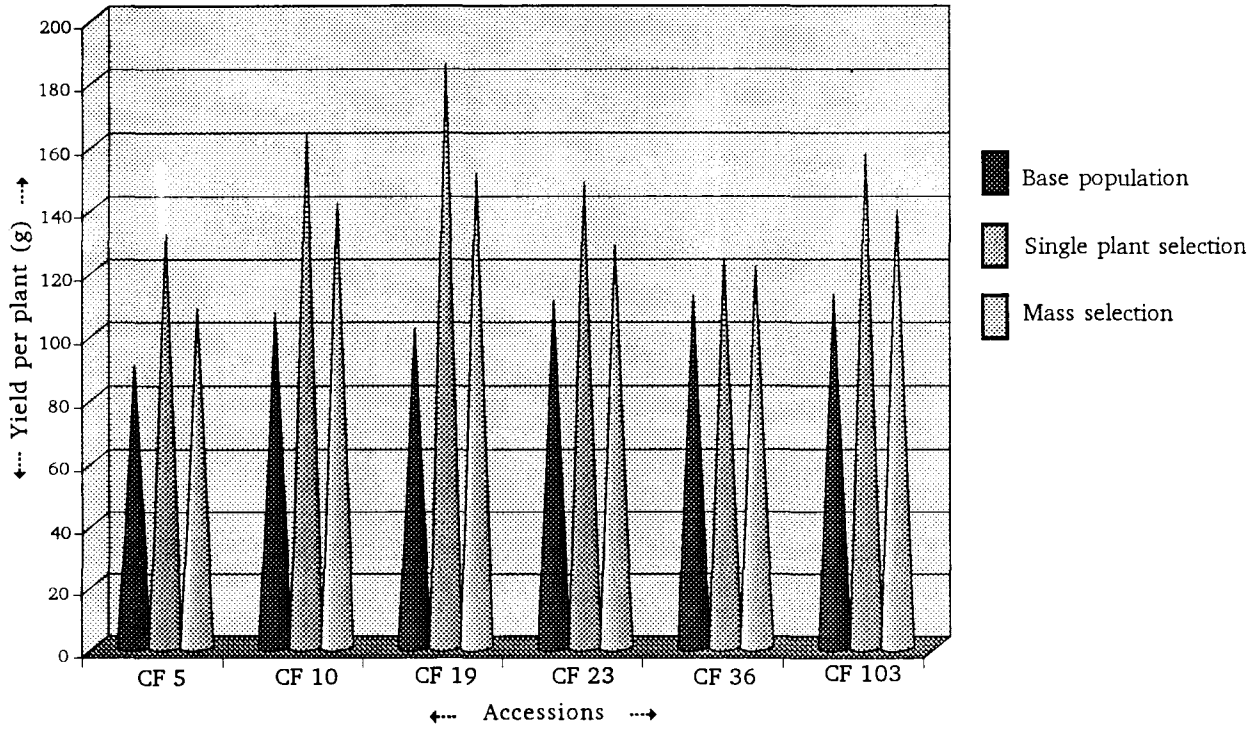


Fig. 5b. Relative efficiency of two methods of selection in improving yield

Evaluation of performance of the six accessions for three consecutive generations revealed the overall superiority of accession CF 19 for early and high yield and better fruit size (Plate 9). Accession CF 36 though had good fruit size, its performance was comparatively poor and unstable. The accession CF 103 was characterized by a spreading habit with closer internodes and more number of fruits, though the size was comparatively small. Among the green fruited accessions, CF 10 ranked top with high yield and more number of harvests per plant (Plate 10). Tewari (1990) opined that production of bird pepper is rather limited because of poor yield and difficulty to harvest due to smaller fruit size. The present study revealed that there are accessions in *C. frutescens* (white) with large fruit size and high pungency. The fruit length excluding pedicel in CF 19 (*C. frutescens* white) was 5.5 cm and in CF 10 (*C. frutescens* green) 3.89 cm, which is comparable to fruit length of cultivars of *C. annuum*.

5.4 Floral biology

A knowledge about important aspects of floral biology, viz. time of anthesis, anther dehiscence and stigma receptivity are prerequisites for embarking upon a crop breeding programme, particularly for chalking out the methodology for selfing and crossing. Even though the floral biology of *C. annuum* has been well studied, information on this aspect in *C. frutescens* is quite meagre. The results on these aspects are discussed below.

5.4.1 Anthesis

The results of the study conducted revealed that flowers started opening fully from 8 to 9 am in both green and white fruited accessions of *C. frutescens*.

Plate 9. Plants of promising accessions of bird pepper

9a. CF 19

9b. CF 103

9c. CF 36

The duration of flower opening respectively in CF 5 and CF 23 was 8 am to 1 pm and 8 am to 12 noon with peak period of flower opening from 9 to 10 am in both the accessions. Jagdish (1964) had reported that in *C. frutescens*, flowers started opening by 7 am and continued up to 12 noon with peak period from 8 to 10 am. The slight differences observed in time of anthesis may be due to the differences in the cultivars used for the studies and variations in climatic conditions. Vijay *et al.* (1979) has observed that full opening of flowers in *C. annuum* was between 7 am and 11 am which supports the above observations.

5.4.2 Anther dehiscence

Anther dehiscence commenced at 8 am and continued up to 11 am with peak period of dehiscence between 9 to 10 am in both accessions of bird pepper. These results are in general agreement with findings of Vijay *et al.* (1979) in sweet pepper. Anther dehiscence started even before full opening of flowers in both accessions. Srivastava (1916) had reported that anther dehiscence started simultaneously with full opening of flowers. Contrary to this, Shaw and Khan (1928), Gopalaratnam (1933) and Jagdish (1964) have observed that anther dehiscence was followed by flower opening.

Though chilli is classified as a self pollinated crop, out crossing ranging from 7 to 98 per cent has been reported (Odland and Popter, 1941, Tanskley, 1984). According to Murthy and Murthy (1962), a lapse of one to ten hours between anthesis and anther dehiscence is responsible for cross pollination in chillies. In the present study dehiscence of anthers commenced even before full opening of flowers, a situation favouring self pollination.

The data on receptivity of stigma indicated that the stigma was receptive one day prior to and after anthesis. This is supported by reports of Hosmani (1993) in *C. annuum*. Barai and Roy (1986) had reported that stigma was receptive from 12 hours before anthesis and continued up to 48 hours after anthesis. In contrast, Padda and Singh (1971) observed that stigma was not receptive one day before and after anthesis. Nanjappa (1965) had observed that peak period of stigma receptivity was 24 hours after anthesis. There was no marked difference in the receptivity of the stigma one day prior to anthesis and on the day of anthesis in the present study. A decline in receptivity of stigma was observed 6 hours after anthesis. Since the stigma was receptive even one day prior to anthesis the process of hybridisation in bird pepper would be simplified as emasculation and hand pollination can be done simultaneously.

5.4.4 Pollen studies

There were no significant differences between accessions evaluated for pollen characteristics like pollen size, germination and fertility. The accessions varied significantly for pollen production per anther.

Pollen size in bird pepper accessions ranged from 37.11 μ to 42.11 μ. Vijay *et al.* (1979) also found the size of pollen grains in *C. annuum* cultivar California Wonder to range from 26.6 μ to 39.9 μ. Pollen fertility of cultivars evaluated, ranged from 83.89 to 88.28 per cent. These findings are in conformity

Plate 10. Plants of promising accessions of bird pepper

10a. CF 23

10b. CF 5

10c. CF 10

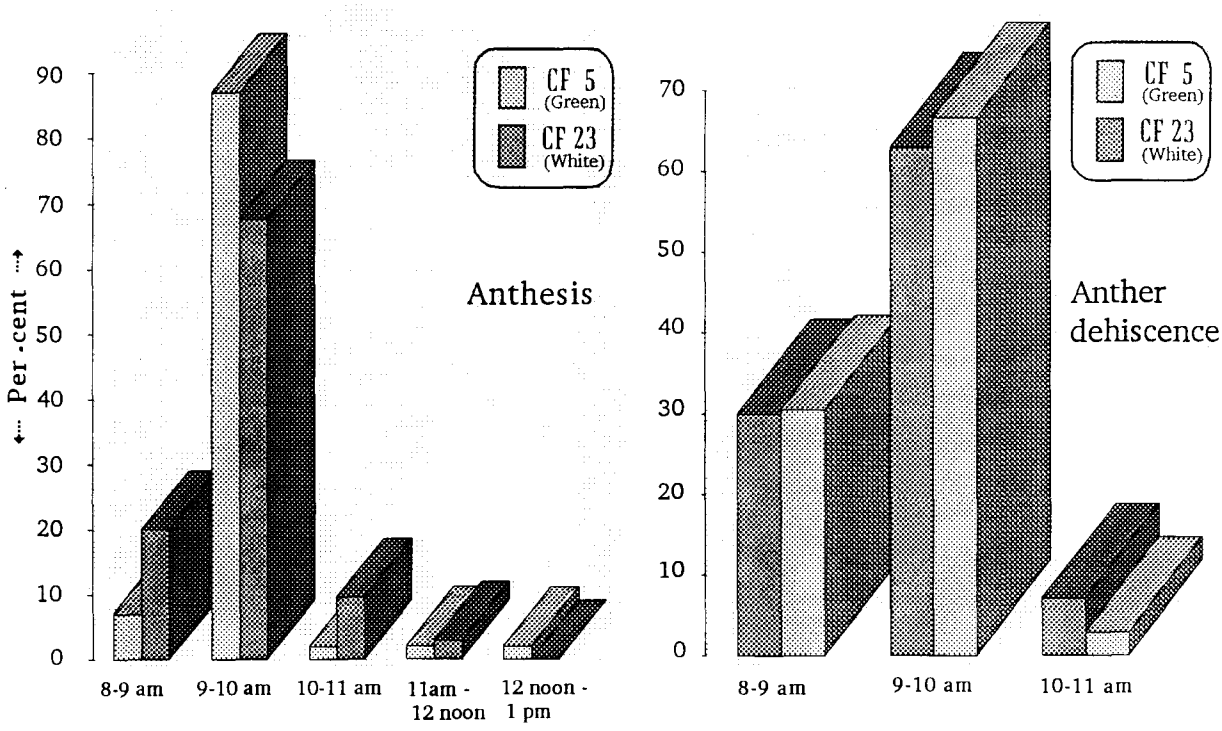


Fig. 6. Duration of anthesis and anther dehiscence in bird pepper

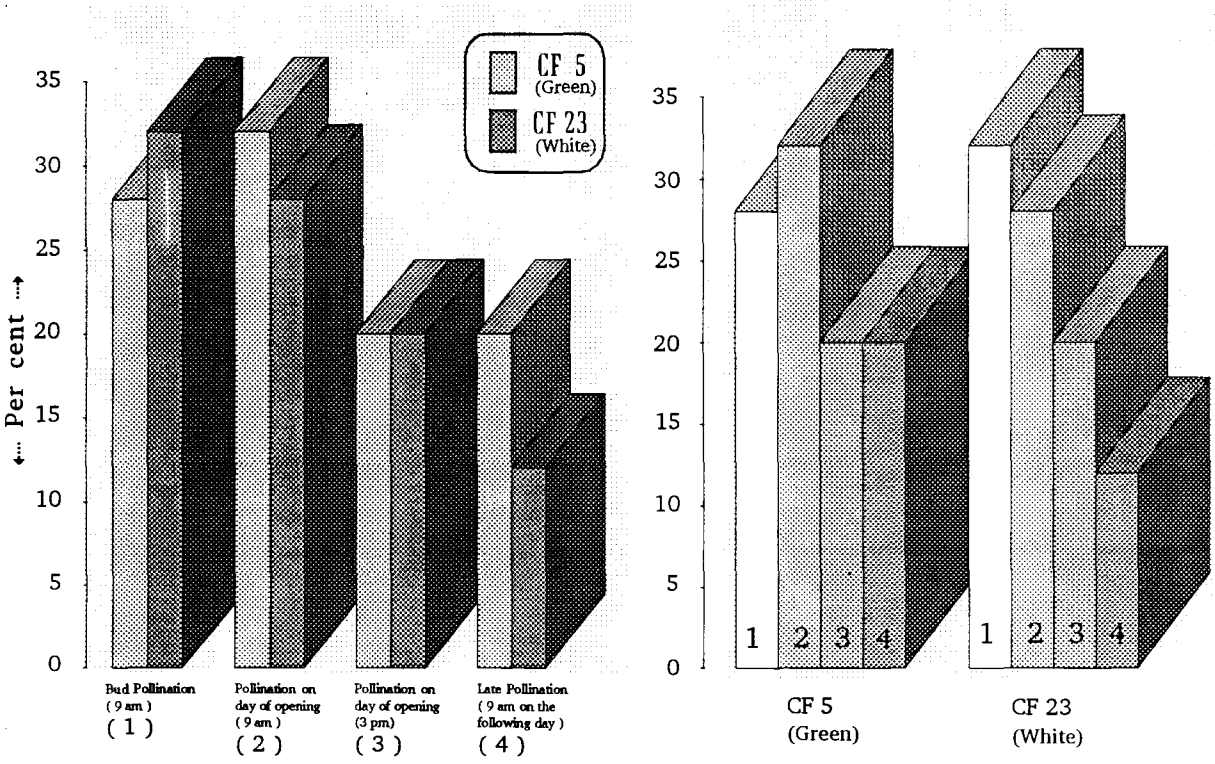


Fig. 7. Stigma receptivity in green and white fruited accessions of bird pepper

with that of Vijay *et al.* (1979) who observed a fertility of 95.6 to 96.0 per cent on the day of anthesis. In the present study pollen was germinated in a media containing 5 per cent sucrose and 100 ppm boric acid. Nanjappa (1965) had reported that pollen germinated best in a media containing 5 per cent sucrose and 100 ppm boric acid. Pollen germination per cent ranged from 30.7 to 38.09 in the accessions evaluated in the present study. The differences observed between accessions for pollen germination was not significant which is in consonance with the results obtained by Ramaseshaiah *et al.* (1982).

The yield in a sexually reproducing crop is more or less related to the quantity of out put of fertile pollen by the plant. Pollen production per anther in bird pepper cultivars ranged from 1866.67 to 4560.00. A higher out put of pollen per anther was reported in *C. annuum* by Nanjappa (1965). Maximum pollen production per anther was in the high yielding accession CF 19.

5.4.5 Heterostyly

Heterostyly was observed in CF 23, the white fruited accession of bird pepper producing 76, 18 and 6 per cent of long, medium and short styled flowers respectively, whereas all the flowers in CF 5 (*C. frutescens* green) were long styled.The position of stigma in relation to anther tip, is an important factor affecting fruit set and mode of pollination. Popova (1973) had opined that per cent of cross pollination is higher in flowers with stigmas at a higher level than anthers. Nanjappa (1965) had also observed heterostyly in *C. annuum*.

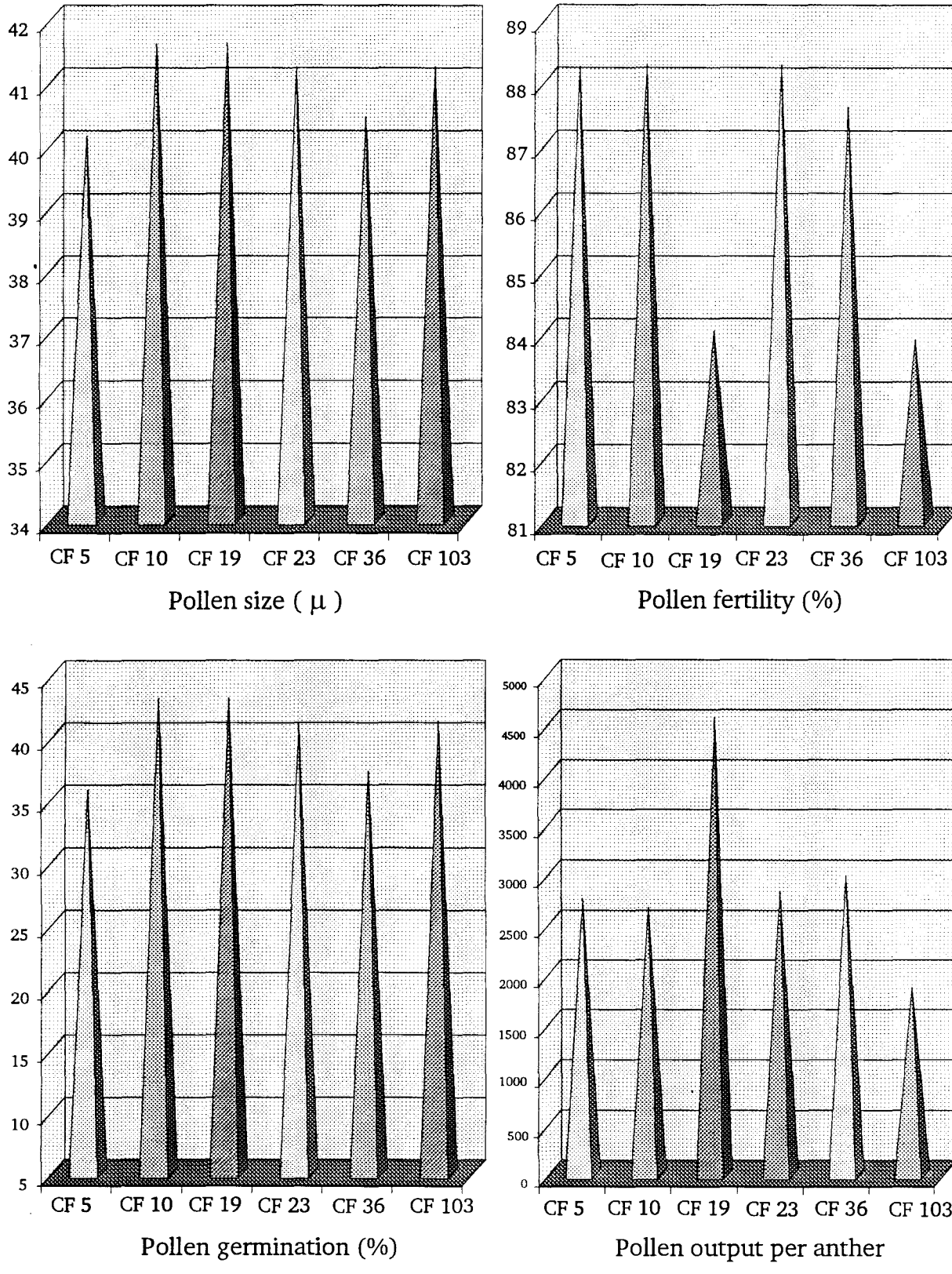


Fig. 8. Pollen characteristics in six accessions of bird pepper

The results of the study indicates that floral biology of the crop favours self pollination. Hybridisation procedure in bird pepper is easier as emasculation and pollination can be done simultaneously. There was no significant differences between white and green fruited accessions of bird pepper as far as floral biology is concerned.

5.5 Biochemical analysis in bird pepper

5.5.1 Estimation of secondary metabolites

The spice value of chilli is determined by content of capsaicin, oleoresin, carotenoids and ascorbic acid. Capsaicin, an alkaloid responsible for pungency is also a digestive stimulant and curative for many rheumatic troubles. The green fruits are valuable on account of their richness in ascorbic acid.

5.5.1.1 Capsaicin

Pungency is considered the most important quality trait in chillies. Capsaicin, the pungent principle of chillies, is a condensation product of 3-hydroxy 4-methoxy benzylamine and decylenic acid. Capsaicin has significant physiological action and is used in many pharmaceutical and cosmetic preparations.

Significant variation was observed between bird pepper accessions for capsaicin content in green (0.21 to 1.57%) and ripe fruits (0.43 to 1.7%). The pungency is influenced by factors like cultivars, geographic locations, climatic and environmental conditions, harvest maturity and processing procedures (Varghese *et al.*, 1992). The degree of pungency among varieties varied considerably. This could

probably be due to the presence of gene modifying factors for pungency and the ratio of placental tissue to seed and pericarp. Varietal variation in capsaicin content in *C. annuum* had been reported by many workers (Ananthasamy *et al.*, 1960; Arya and Saini, 1977; Bajaj *et al.*, 1978; Teotia and Raina, 1987; Narayanankutty *et al.*, 1992 and Theymoli *et al.*, 1992).

A comparison of capsaicin content reported for accessions of *C. annuum* with that obtained in the present study clearly indicated that accessions of *C. frutescens* contained higher capsaicin than *C. annuum*. Pruthi (1993) had reported that the capsaicin content of Indian bird chillies is quite high (up to 1.2%) and in African bird chillies and tabasco, it is still higher (1.8%). Ogbadu *et al* (1989) obtained a capsaicin content of 21.7 to 119.7 mg 100 g^{-1} for unripe and 33.7 to 266.5 mg 100 g^{-1} for ripe fruits of *C. frutescens*.

Most of the accessions evaluated in the present study had high (> 1%) or medium high (0.75 to 1.0%) capsaicin content indicating their enormous economic potential. High pungency chillies are particularly valued for their pungency and are used for manufacture of high capsaicin oleoresin (Maga, 1975 and Govindarajan, 1985).

The findings of Theymoli *et al.* (1992) that darker the colour of fruits, the higher was their capsaicin content, is in general agreement with the results of the present study. The green fruited types of *C. frutescens* had a higher capsaicin content compared to white fruited accessions. The green fruited accessions CF 5, CF 28, CF 10, CF 15 and CF 77 had high capsaicin content compared to white fruited ones. But there were accessions with high capsaicin content in white fruited *C. frutescens* also viz. CF 146 and CF 147 (1.17%).

5.5.1.2 Oleoresin

Oleoresin represents the total flavour extracts of ground spices. Chilli extracts are now being extensively used in processed foods and also pharmaceutical products. The advantage of using chilli extract over ground spices are elimination of microbial contamination, uniformity of colour and flavour strength. The oleoresin consists of fixed oil, capsaicin, pigments, sugars and resin (Bajaj *et al.*, 1980).

The oleoresin extracted from highly pungent chillies is referred to as Oleoresin Capsicum. This oleoresin has very high pungency and used mainly to impart pungency to manufactured foods and beverages (Purseglove *et al.*, 1981).

The results of the present study indicated significant variation between accessions for oleoresin content in mature and ripe fruits. Sumathykutty and Mathew (1984) had opined that oleoresin content was the lowest in bird chillies. The results obtained in the current investigation revealed that there are accessions with high content of oleoresin in bird pepper also. This is in agreement with results obtained by Pradeepkumar (1990) who reported an oleoresin content of 27.3 per cent in *C. frutescens*. Variation in oleoresin content between *C. annuum* cultivars was reported by many workers (Lewis, 1972; Bajaj *et al.*, 1980; Teotia and Raina, 1986; Narayanankutty *et al.*, 1992 and Mini, 1997).

The highest content of oleoresin in mature stage was registered in accession CF 23, followed by CF 18 and CF 103 and in ripe stage in CF 34,

followed by CF 10, CF 18, CF 36 and CF 23. CF 139 had the least oleoresin content at both stages of maturity.

The commercial Indian varieties of chilli yield only product conforming to Oleoresin Red Pepper with medium pungency and high colour, which was the reason for poor export performance of Indian chilli oleoresin (Narayanan *et al.*, 1980). High pungency oleoresin from bird pepper types has tremendous commercial and export potential.

5.5.1.3 Carotenoids

Colour is a prized quality characteristic of capsicums 'aesthetically rewarding' and commercially important (Verghese *et al.*, 1992). The principal colouring matter of chilli fruit is the carotenoid pigments. Information on the extent of colouring matter present in a particular chilli variety is important for spice industry.

The red colour of chillies is mainly due to the carotenoid pigments, nearly 37 pigments have been isolated out of which 27 pigments were identified (Krishnamurthy and Natarajan, 1973). Capsanthin and capsorubin are the main contributors to red colour of chillies.

In the present study a wide variation in total carotenoid content between bird pepper accessions was observed. Similar results were reported by Bajaj *et al.* (1980); Reddy and Murthy (1988); Narayanankutty *et al.* (1992) and Rani (1996b)

The total carotenoid content was to found to range from 0.14 to 0.5 per cent in mature green and 0.26 to 0.69 per cent in ripe fruits which corroborated the reports of Sumathykutty and Mathew (1984), Raina and Teotia (1986) and Rani (1996b).

The accessions CF 77, CF 10, CF 66 and CF 138 had comparatively high colour value as evidenced by the values of total carotenoid content. The use of varieties with high capsanthin contents in enhancing the red colour of other popular varieties has been stressed by Ahmed *et al.* (1996).

In general, the accessions of *C. frutescens* (green) had higher carotenoid content. Laszlo (1970) had also observed that varieties with higher chlorophyll in their fruits had more carotenoid pigments.

5.5.1.4 Ascorbic acid

The nutritive value of chillies is largely determined by content of ascorbic acid. The vitamin C content of *Capsicum* varieties varied with the variety, locality and stage of fruit maturity. Significant variation in ascorbic acid content between varieties at both stages of maturity was observed in the present study. Varietal differences in ascorbic acid content was reported by many workers in *C. annuum* (Saimbhi *et al.*, 1972; Pankar and Magar, 1978; Bajaj *et al.*, 1980; Srivastava *et al.*, 1990; Amarchandra *et al.*, 1992; Narayanankutty *et al.*, 1992; Rani, 1994 and Ahmed *et al.*, 1996). Lakshmi *et al.* (1992) had recorded an ascorbic acid content of 78 and 104 mg 100 g^{-1} respectively in white and green types of *C. frutescens*. Accessions CF 10, CF 15, CF 23, CF 37 and CF 135 with high ascorbic acid

content are suitable for vegetable purposes. Bajaj *et al* (1980) opined that for salad purposes capsicum fruits with low capsaicin and high ascorbic acid content are desirable, whereas for spice purposes high capsaicin content is desirable

5.5.1.5 Influence of harvest maturity on quality of chilli

The stage of maturity is an important factor affecting the chemical constituents in fruits. Estimation of the constituents at different stages of maturity would help in determining the optimum harvest maturity for maximum quality. A significant variation in constituents like capsaicin, oleoresin, carotenoids and ascorbic acid was observed with stage of maturity in the present study.

5.5.1.5.1 Capsaicin

The pungency level of *Capsicum* is affected by the genetic make up, weather, growing conditions and fruit age (Bosland, 1993). The present finding that capsaicin content is more in ripe than in green fruits in most of the bird pepper accessions is in conformity with findings of Ogbadu *et al.* (1981) in *C. frutescens*. Balbaa *et al.* (1968); Gorde (1969); Awasti and Singh (1979); Maurya *et al.* (1984); Ahmed *et al.*, (1987) and Mini (1997) also reported increase in capsaicinoid content with ripening in *C. annuum*. The increase in capsaicinoid content with fruit maturation in relation to increase in dry matter content was observed by Ahmed *et al* (1987). The accessions CF 5, CF 10, CF 23 and CF 153 registered a slight decrease in pungency on ripening. Similar results in *C. annuum* were reported by Kosuge and Inagaki (1962) and Raina *et al.* (1986). These accessions have to be harvested at the mature stage for maximum capsaicin content. The site of formation

and total capsaicinoid content are under genetic control and degradation is not clear (Tewari, 1990).

5.5.1.5.2 Oleoresin

A significant increase in oleoresin content with maturity was observed in bird pepper accessions. Oleoresin content was more in red ripe fruits as compared to mature green fruits. Mini (1997) obtained high oleoresin recovery in fruits at withering stage compared to ripe and turning ripe stage, in the rainy season. The oleoresin comprises of fixed oil, capsaicin, pigments, sugars and resin. An increase in these constitutents would lead to increase in oleoresin content. The results of the study indicate that for higher recovery of oleoresin, harvesting in bird pepper should be delayed up to red ripe stage.

5.5.1.5.3 Carotenoids

The amount of carotenoids in fruit tissue at harvest depends on factors such as cultivar, maturity, stage and growing conditions (Reevis, 1987; Verghese *et al.*, 1992).

The carotenoid content of red ripe fruits were significantly higher than mature green fruits. The results of Lease and Lease (1956), Benedick (1972) and Mosquere and Mendez (1994), Govindarajan (1985) and Mini (1997) supported the present study. Capsanthin and capsorubin, the major contributors of red colour in ripe fruits increase proportionally with advanced stage of ripeness (Kanner *et al.*, 1977 and Harkey-Vinkler, 1974). According to Raina *et al.* (1986) the deep colour

of chillies harvested when red ripe is due to increased content of total carotenoids in the pericarp as compared to total dry matter. Rahman and Buckle (1980) have reported that the total pigment at the ripe stage increased 2 to 13 fold in the green variety and up to 70 fold in the yellow variety over the concentration at immature stage. Raina *et al.* (1986) have reported that the ketocarotenoids, capsanthin and capsorubin were absent in green bell peppers, but contained lutein, ß-carotene, violaxanthin and neoxanthin. Chlorophyllic pigments, lutein and neoxanthin disappeared during ripening, betacarotene and violaxanthin increased in concentration and other carotenoid pigments ziaxanthin, capsanthin, capsorubin were synthesised (Mosquera and Mendez, 1994). This may account for the differences in carotenoid content between mature green and red ripe fruits.

5.5.1.5.4 Ascorbic acid

Evaluation of ascorbic acid content at two stages of maturity indicated a higher content in red ripe fruits than in mature green fruits in all the accessions of bird pepper. The results obtained in cultivars of *C. annuum* by Saimbhi *et al.* (1972); Awasti *et al.* (1975); Bajaj *et al.* (1977); Awasti and Singh (1979); Ahmed *et al.* (1987); Khadi *et al.* (1987) and Amarchandra *et al.* (1992) supported the present study. Contrary to this, Maurya *et al.* (1984) observed that the ascorbic acid content in all the varieties decreased slightly when the fruits turned from green to red stage. Lakshmi *et al.* (1992) reported a higher ascorbic acid content in ripe than in green fruits of *C. frutescens*. The results indicated that the bird pepper accessions should be harvested at the ripe stage for better nutritive value.

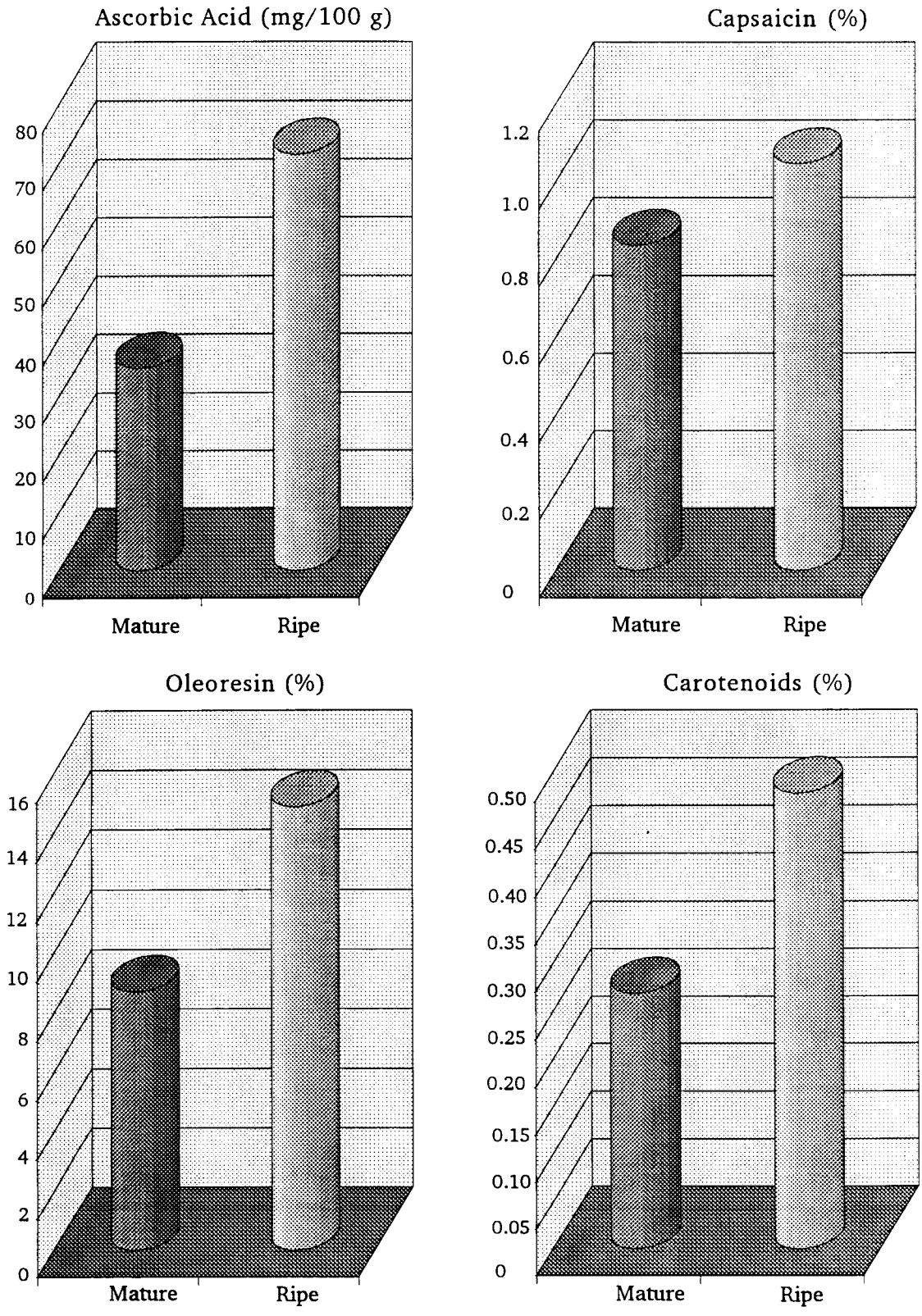


Fig. 9. Quality parameters of bird pepper accessions at two stages of maturity

As the quality attributes like ascorbic acid, capsaicin, oleoresin and carotenoids are better during red ripe stage harvesting of bird pepper fruits can be delayed up to ripe stage for good quality.

5.5.2 Estimation of fatty acid, nucleic acid, enzyme and flavour components

5.5.2.1 Fatty acid content

The fat content of capsicums is mostly in the seed (Govindarajan (1985) which is chiefly made up of triglycerides of palmitic, oleic and linolenic acids (Reddy and Murthy, 1988). Salzer (1975) analysed fat from a sample of chillies and suggested that chillies can be distinguished from paprika according to the relative abundance of certain fatty acids.

The present finding that seeds of different accessions of chilli contain oil of 11.0 to 21.5 per cent is in general agreement with that reported by Narayanan *et al.* (1980), Govindarajan (1985) and Verghese *et al.* (1992). Fixed oil content was high in accessions K-2 and CF 10 and low in Ujwala. Vanblaricon and Martin (1951) suggested that fruits with high fat content are more susceptible to colour deterioration and that removal of seeds, which contain a high proportion of fat might inhibit discolouration. Capsicum oleoresin obtained from the whole fruit contains a considerable amount of fixed oil originating from the seeds and if this oil is not removed, oleoresin would become rancid in storage (Purseglove *et al.*, 1981). The fixed oil should be removed from oleoresin extracted for pharmaceutical purposes. The results indicate that oleoresin from cultivars Ujwala with low fat content retain their quality for longer periods as compared to cultivars with high fat content.

The acid value recorded for cultivars in the present investigation, ranged from 3.36 to 6.04. The maximum content of free fatty acids as evidenced by high acid value was in Ujwala and minimum in CF 36. High acid value indicated enhanced lipase activity. A low free fatty acid content is preferred from health point of view in bird pepper.

5.5.2.2 Nucleic acid content

The results indicate significant variation in content of deoxyribinucleic acid between different accessions of *Capsicum* sp. The variation in DNA content between cultivars of *C. annuum*, Ujwala and K-2 was insignificant indicating that there is little difference in nucleic acid content within the species. However there was considerable difference in DNA content between white and green fruited types of *C. frutescens*. The content of RNA was found to be higher than DNA. Similar results in other crops have been reported by Bose *et al.* (1988) and Kadam and Salunke (1980), Gasparikova (1974) reported a qualitative correlation between RNA content and RNAase activity.

The content of nucleic acid in seeds would give an indication of the dormancy of seeds. Chakrabarti (1978) had reported a higher RNA and lower DNA content in nondormant seeds. The DNA and RNA content of seeds depend on nucleic acids formed at seed maturation. According to Bose *et al.* (1988) nucleic acids are primarily a reserve material to be transferred to the embryonic axis during germination. Further studies have to be conducted on germination of the seeds used for the study to make a correlation between content of nucleic acid and germination.

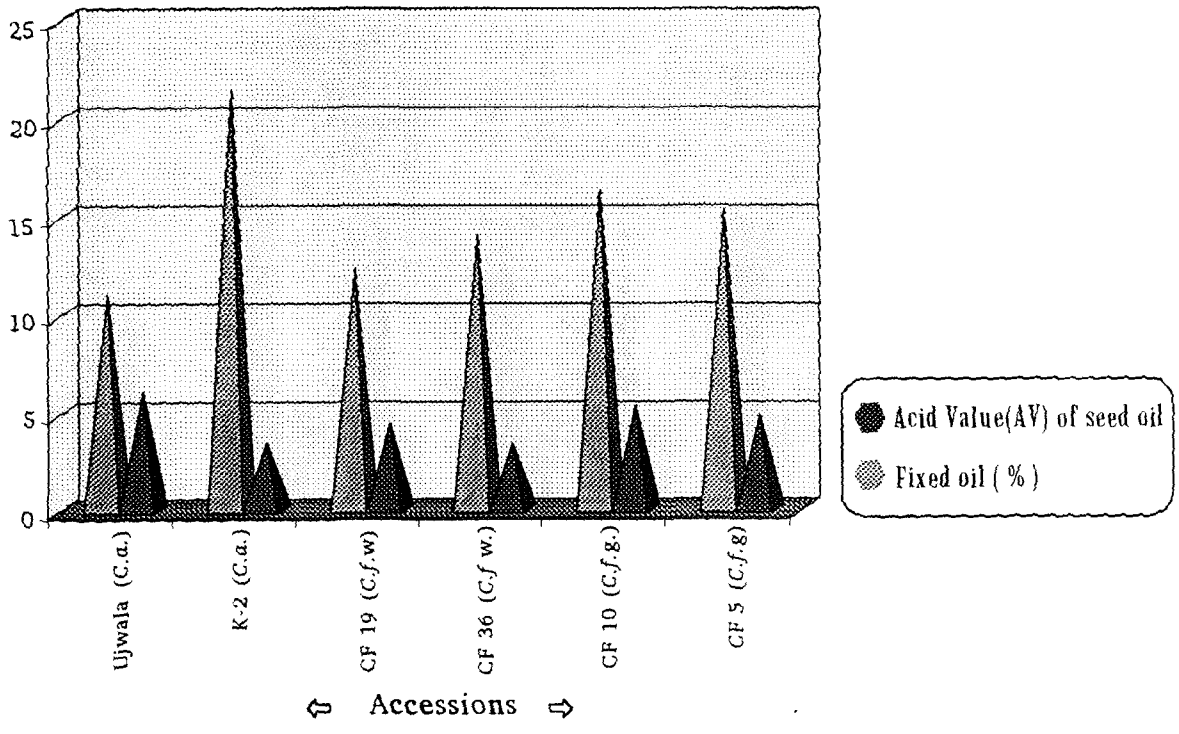


Fig. 10. Fatty acid content in six selected accessions of *Capsicum* sp.

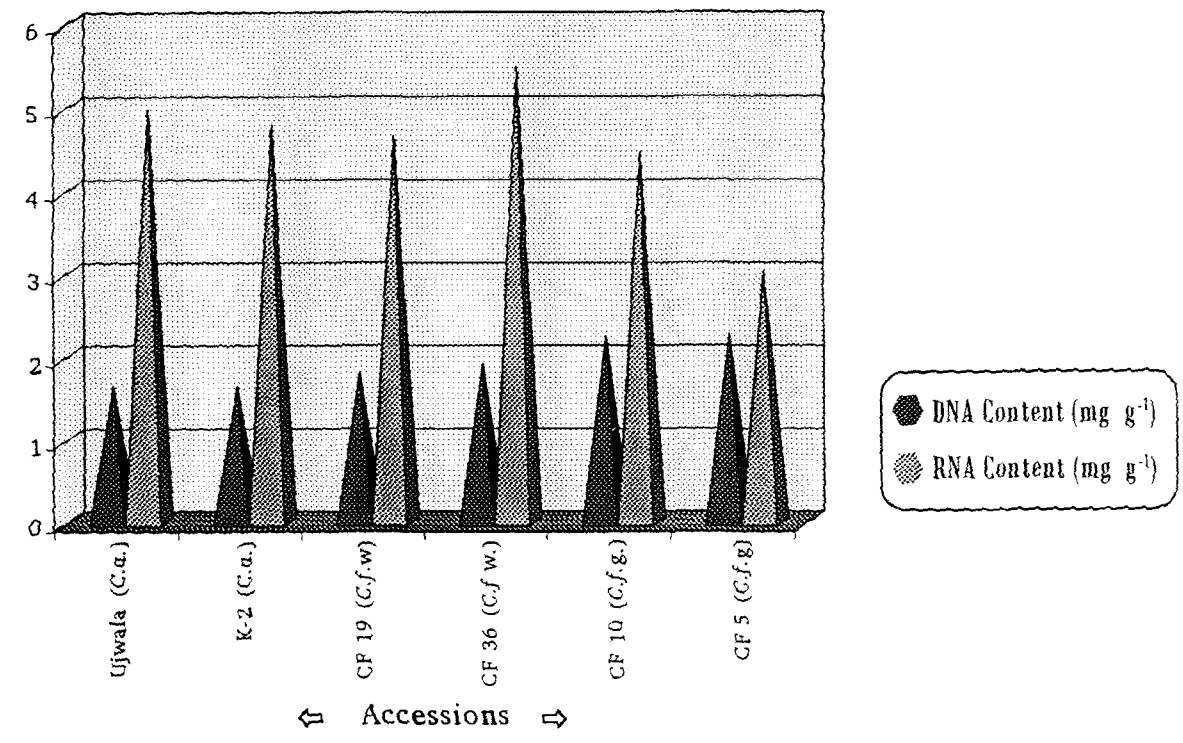


Fig. 11. Nucleic acid content in six selected accessions of *Capsicum* sp.

5.5.2.3 Protein content

The results of the present study indicated significant variation in protein content between accessions belonging to *C. annuum* and *C. frutescens* green and white types. The protein content was maximum in CF 10 followed by Ujwala and minimum in CF 36. It is concluded that protein content in leaves is a varietal character. Luhadiya and Kulkarni (1978) reported that the protein content in fruit pulp of *C. frutescens* ranged from 27.3 to 40.5 mg g^{-1} of pulp. In the present investigation, the protein content in *C. frutescens* ranged from 5.77 to 14.2 mg g^{-1} of leaf indicating that the protein content varies in different plant tissues and is high in fruits as compared to leaves.

5.5.2.4 Enzyme activities

5.5.2.4.1 Peroxidase

Peroxidase is an important enzyme in many plant system which has been correlated with disease resistance. Moreover the enzyme itself was reported to be toxic to micro organisms (Pegg and Young, 1982). The enzyme is also believed to be associated with the degradation of auxins and hence referred to as IAA - Oxidase (Sujatha, 1987). Bernal *et al.* (1995) reported the ability of hot pepper peroxidase to oxidize the phenolic precursors of capsaicin biosynthesis.

The results of the present study indicated that the peroxidase activity in leaves vary with cultivars and age of tissues used for analysis. An increase in peroxidase activity with age of plants was observed, the rate of increase was the highest in Ujwala, a cultivar of *Capsicum annuum*. The peroxidase activity at the

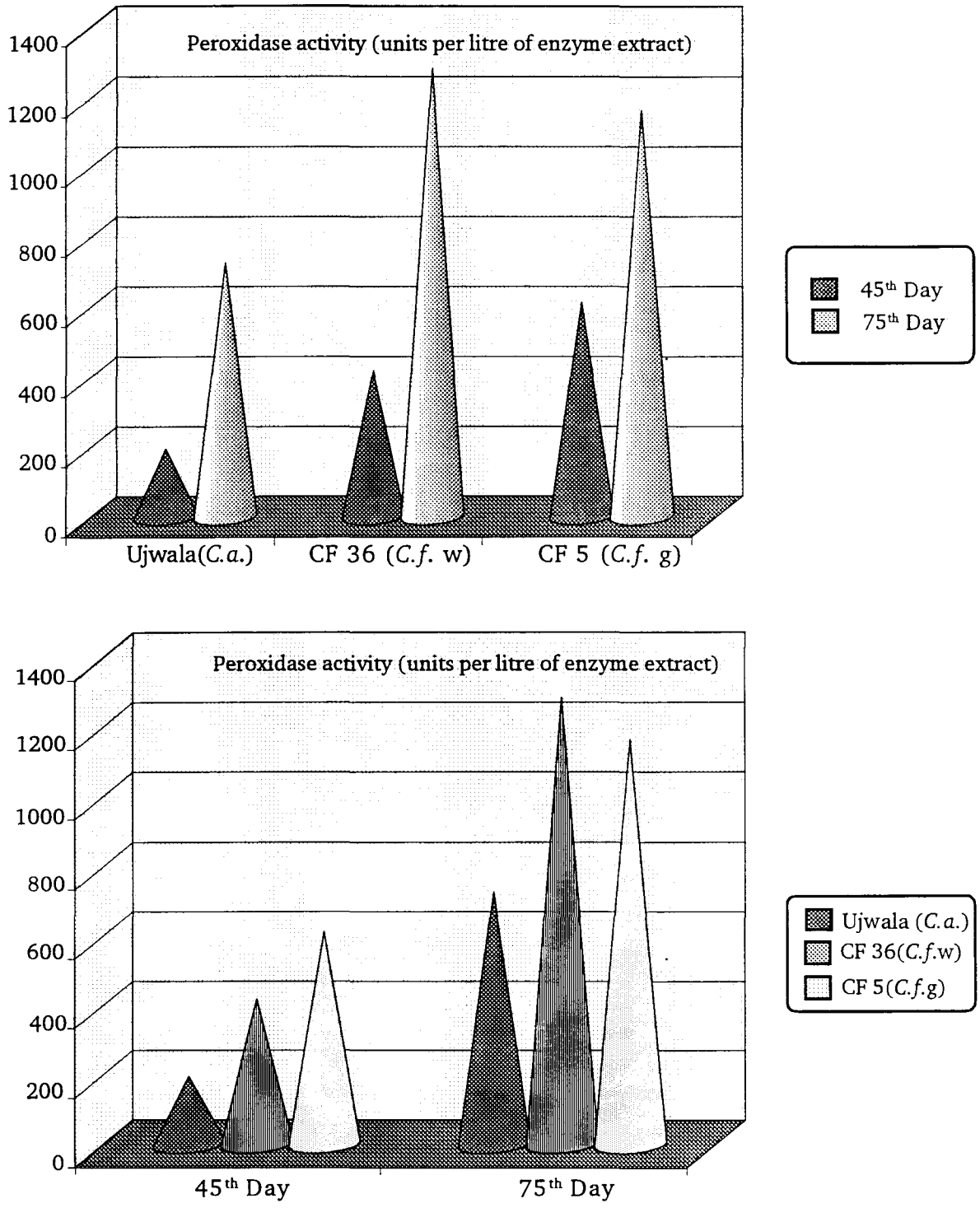


Fig. 12. Peroxidase activity (units per litre of enzyme extract) in selected accessions of *Capsicum* sp. at two growth stages

two growth stages were high in CF 36 and CF 5, the cultivars belonging to *C. frutescens*. The peroxidase activity was comparatively low in *C. annuum* cultivar Ujwala. Cultivars with low peroxidase activity is preferred, since the peroxidase enzyme is involved the oxidation of IAA as well as the phenolic precursors of capsaicin biosynthesis.

5.5.2.4.2 Polyphenol Oxidase

Green chillies discolour when bruised or cut presumably due to the action of polyphenol oxidase (PPO). The polyphenol oxidase act on phenolic constituents present in the tissues and convert them to brown pigments known as melanins.

The activity of polyphenol oxidase is directly influenced by the genetic make up of accessions. The increased activity of this enzyme results in accumulation of potentially bactericidal quinonic substances and tannins possessing antibiotic properties and hence has been assigned a role in disease resistance (Obukuwicz and Kennedy, 1981).

A comparison of the activity of the enzyme, in accessions belonging to *C. annuum* and green and white fruited types of *C. frutescens*, was done in the present study.

The activity curve exhibited a similar pattern for accessions K-2 and CF 103 and Ujwala and CF 36. The sudden spurt in the enzyme activity in the initial minute observed in accession CF 10 may possibly be due to the presence of active enzyme in that variety. This accession had also the highest protein content

(14.2 mg g^{-1}). In the present study cultivars belonging to different species exhibited similar trend in activity indicating that genotypic or phenotypic similarities or dissimilarities are not reflected in the polyphenol oxidase activity.

The total polyphenol oxidase activity was maximum in CF 36 followed by Ujwala and minimum in CF 103 and K-2. Saimbhi (1992) had reported that polyphenol oxidase activity in fruits of *C. annuum* varied from 210 to 2430 units per mg protein and in sweet pepper from 0.3 to 1.4 units per mg protein. Results of the present study showed that the polyphenol oxidase specific activity ranged from 0.74 x 10^{-2} to 1.39 x 10^{-2} units per minute per mg of protein. It can be concluded that polyphenol oxidase activity varies considerably with varieties, stage of growth and types of tissues.

The accessions K-2 and CF 103 had comparatively low polyphenol oxidase activity. However, the specific activity was high in CF 103 and CF 36. Bajaj *et al.* (1983) had opined that varieties with low polyphenol oxidase activity and lesser degree of enzymatic browning are suitable for processing. Contrary to this, Luhadiya and Kulkarni (1978) reported that no relation could be established between the extent of browning and enzyme activity. This may be because the non enzymatic browning had not been taken into account.

The results of the present study indicated that the cultivar K-2 with low polyphenol oxidase activity and specific activity would be less prone to enzymatic browning and hence ideal for processing.

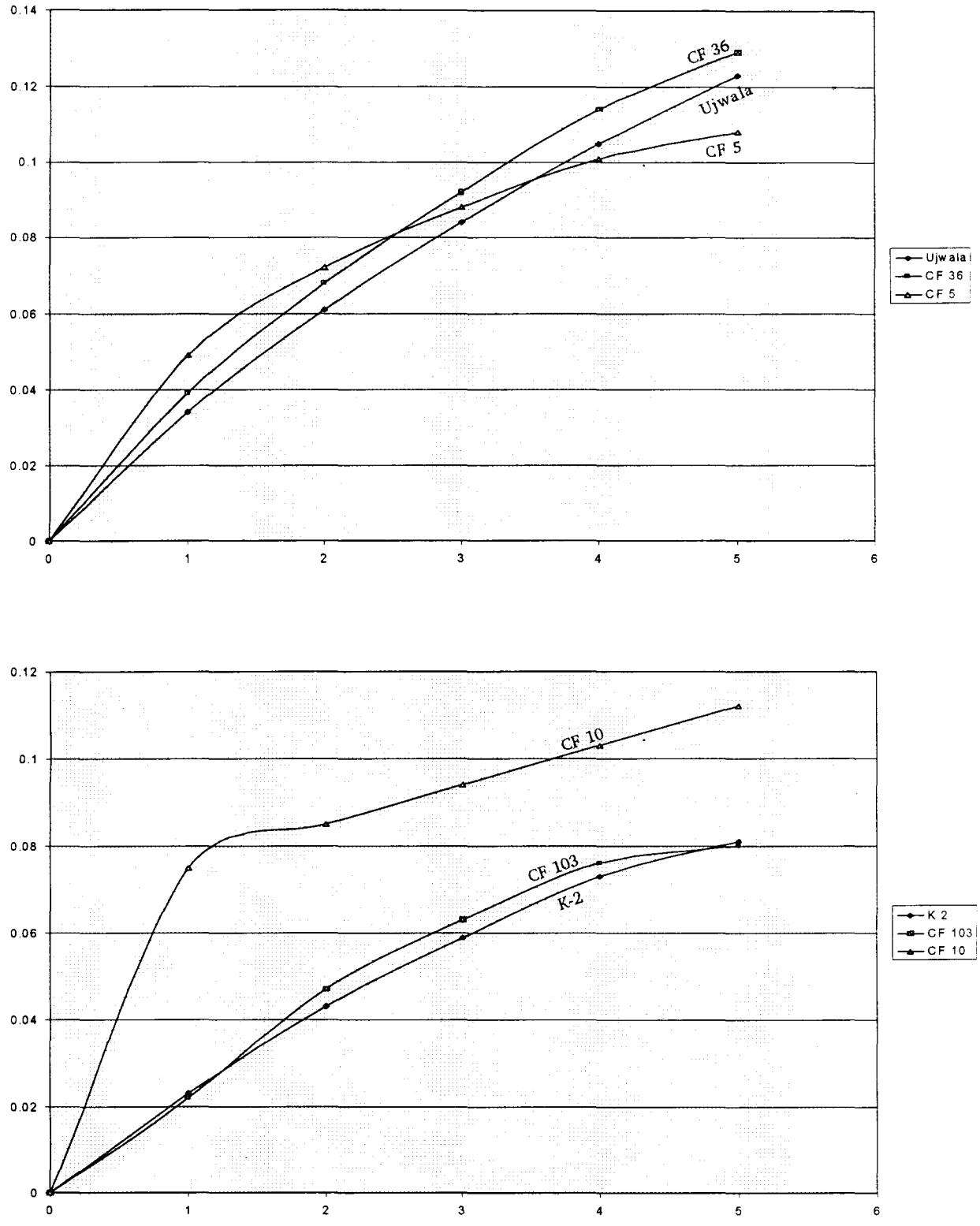


Fig. 13. Poly phenol oxidase activity in accessions of *C. annuum* and *C. frutescens*

5.5.2.5 Flavour components

The characteristic flavour and aroma of fruits and vegetables is imparted by the volatile oil. The fruits of *Capsicum* sp. had a relatively low volatile oil content as evidenced by results of the present study. Similar observations were made by Szabo (1970) and Govindarajan (1985).

The gas chromatographic profile of volatile oil distilled from fresh green and dried fruits revealed differences in quantity and type of components. The components could not be identified due to lack of standards. However data on the number of peaks obtained and corresponding retention time indicated the differences in flavour contributing components between *C. annuum* and *C. frutescens* green and white types. Mathew *et al.* (1973) also reported varietal variation in flavour components in ginger.

Variation was also observed in flavour components of fresh and dehydrated samples, but this cannot be attributed to dehydration alone, as the cultivars used were different.

Maximum number of peaks corresponding to flavour components were observed in *C. frutescens* (green) which accounted for their strong flavour as compared to *C. annuum*. The characteristic flavour of *C. frutescens* (green) may be attributed to the two constituents with retention time 27.3 and 28.5 present exclusively in them. The component with retention time 17.2 may have contributed predominantly to flavour of fresh fruits of white and green fruited *C. frutescens*, since relative proportion of this component is high in them. The compound

contributing maximum to flavour of fresh and dehydrated samples of *C. annuum* corresponded to retention time 19.1. The components with retention time 0.44 and 22.2 were common to all the six samples, indicating there presence in all types of *Capsicum*. The presence of components with retention time 18.7 and 19.8 in four samples of *C. frutescens* imply their role in imparting the characteristic flavour of the species *C. frutescens*. Buttery *et al.* (1969) had identified 23 components in vaccuum steam volatile oil of green bell peppers. The major components were 2-isobutyl-3-methoxy pyrazine, trans-ß-ocimene, limonene and methyl salicylate. Huffman *et al.* (1978) had reported that volatiles of green chilli peppers were in general similar to those of bell peppers. Further studies including more varieties in both species are required to get conclusive results.

5.6 Biochemical characterization of *C. frutescens*

Isozyme analysis is a well defined and effective method to detect genetic differences among individuals. The isozyme variations are used to complement conventional taxonomic studies based on key characters (Rick *et al.*, 1976). Isozyme analysis unlike phenotypic characters gives an accurate picture of the variation present in the population as these biochemical constituents are not affected by direct selection pressure during the course of domestication and evolution of a taxon and also by normal changes in the environment. Mcleod *et al.* (1979) had used starch gel electrophoresis techniques for classification of *Capsicum* sp.

In the present study, a comparison of isozyme pattern of peroxidase enzyme system in six accessions belonging to *C. annuum* and *C. frutescens* were attempted and clear bands were obtained from tender leaves of 60 day old seedlings for peroxidase enzyme. Wang and Dehua (1987) had reported that the best

sampling tissue for electrophoresis of peroxidase enzymes were functional leaves at flowering stage.

Species specific bands were observed for peroxidase isoenzymes. The green and white fruited accessions of *C. frutescens* were characterized by two bands each whereas accessions of *C. annuum* had three bands. Two bands with Rm values 0.395 and 0.465 were common to both *C. annuum* and *C. frutescens*. *C. annuum* had one additional fast moving band, indicating that the species can be characterized biochemically based on the presence of these bands. Belletti *et al.* (1992) observed no variation in peroxidase zymograms between accessions of *C. frutescens* which corroborates the present findings. The pattern of perixodase zymogram indicates that there is no difference between white and green fruited accessions of *C. frutescens*, with respect to certain alleles.

5.7 General discussion

Capsicum frutescens L. though an economically important species, is not extensively cultivated in India. Low productivity and small fruit size are major constraints in large scale cultivation of this crop.

The present study could throw light into variability, genetic and biometric parameters, floral biology and chemical composition of bird pepper. Morphological and biochemical characterization of *C. frutescens* was undertaken.

Genetic gain was realised for fruit characters and yield under single plant and mass selection, the former proving to be more effective in improving the

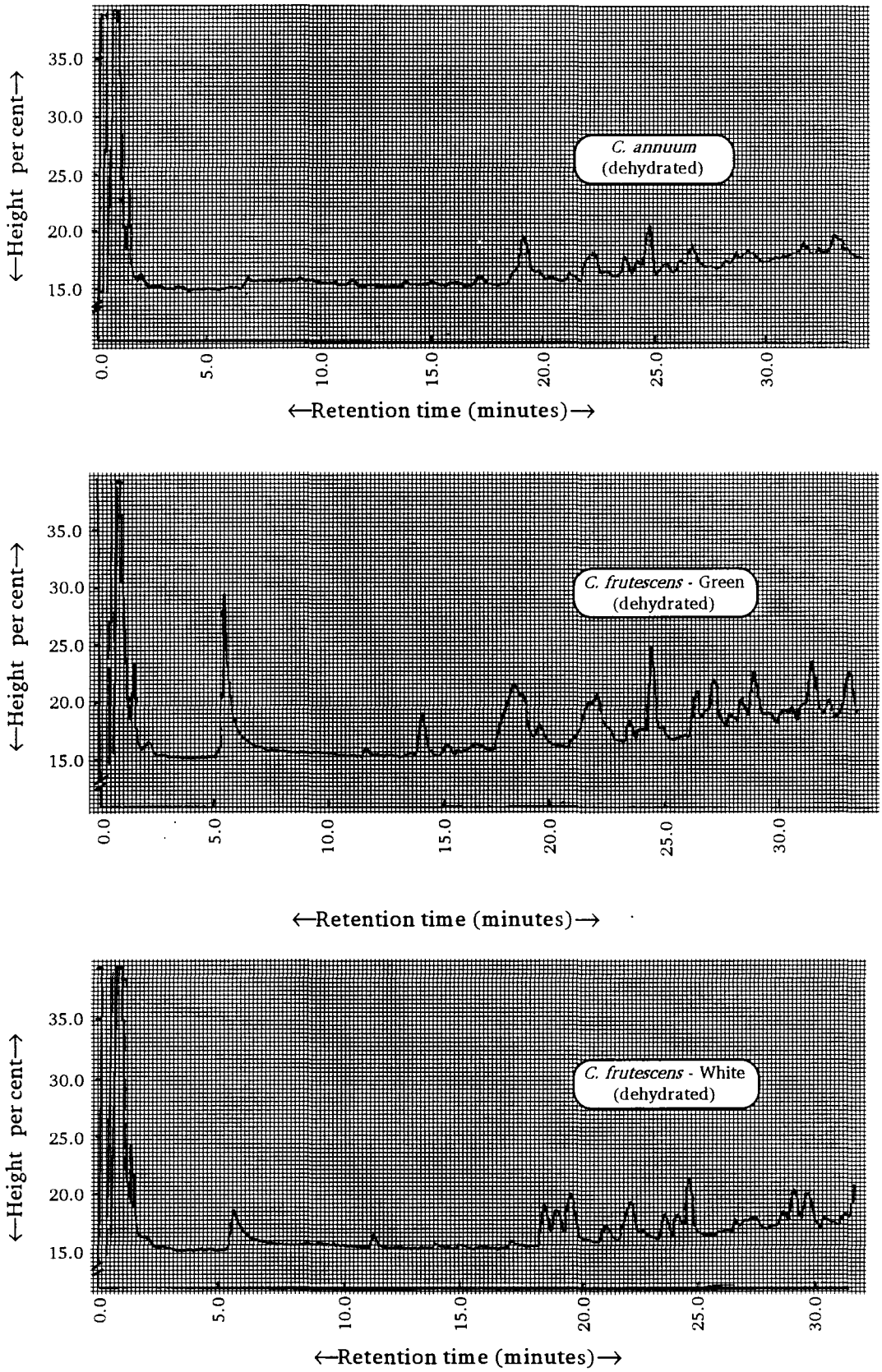


Fig. 14a. Gas chromatographic profile of volatile oil in three accessions of *Capsicum* sp.

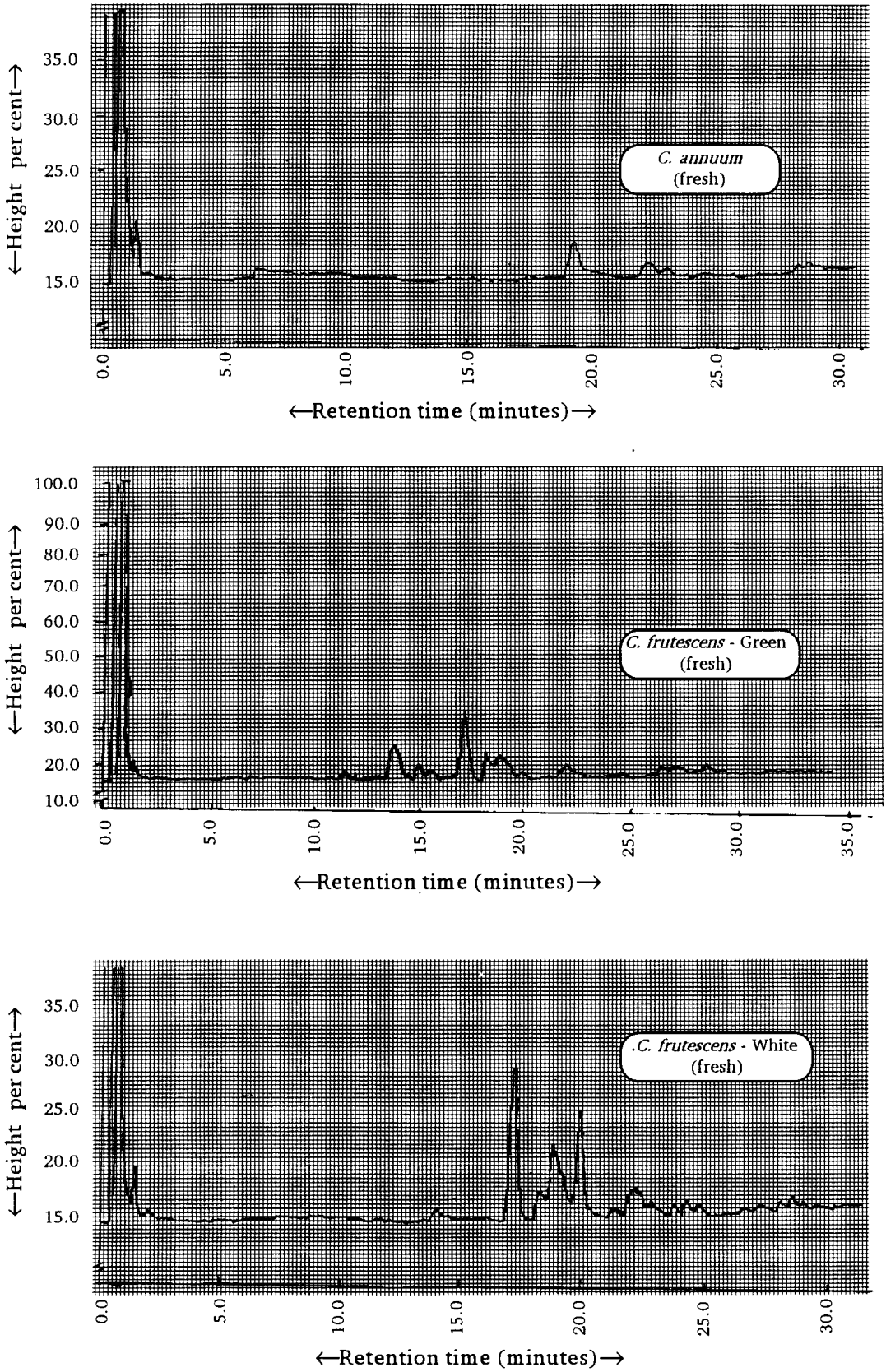


Fig. 14b. Gas chromatographic profile of volatile oil in three accessions of *Capsicum* sp.

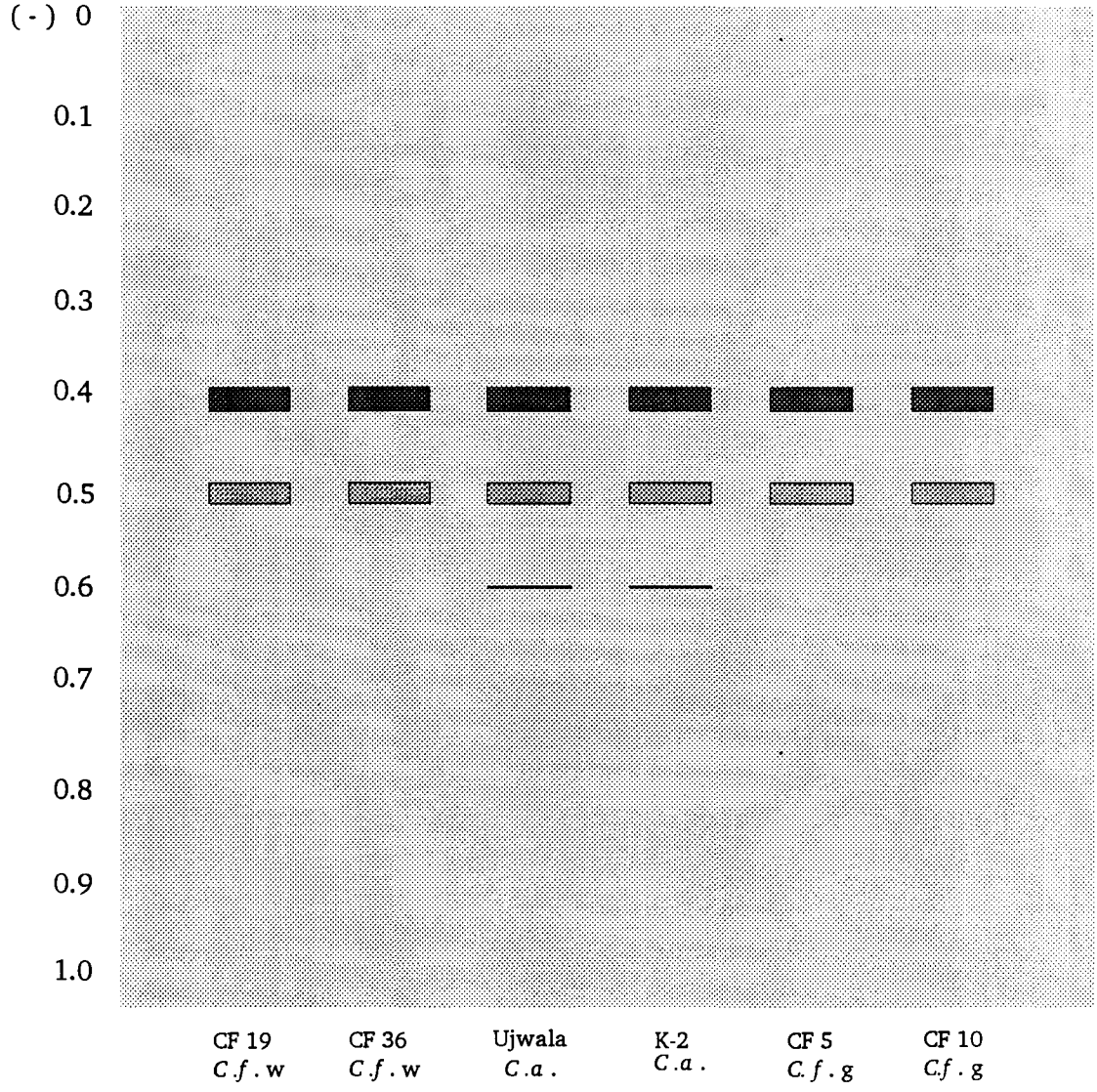


Fig. 15. Peroxidase electrophorogram of six genotypes of *Capsicum* sp.

economic traits. The methods of selection could also bring about uniformity in the accessions.

Bird pepper accessions were identified for high yield, fruit size and quality. Accession CF 19 was the best performer with respect to earliness (134 days), yield (185.38 g per plant), fruit size (24.26 cm^2) and had medium pungency (0.5%). CF 23 had good fruit size (14.76 cm^2) yield (148.15 g per plant), medium high pungency (0.9%) and high oleoresin (14.25%). Among the green fruited accessions, CF 10 gave comparatively high yield (163.63 g per plant), better fruit size (13.93 cm^2), high capsaicin (1.4%) and ascorbic acid (74.9 mg 100 g^{-1}) whereas CF 5 recorded the highest capsaicin content (1.57%). The afore mentioned accessions found promising for yield and quality attributes, after further refinement and multi environmental testing can be considered for large scale adoption.

Summary

SUMMARY

The present investigation, 'Genetic improvement of bird pepper (*Capsicum frutescens* L.) by selection' was undertaken at the Department of Olericulture, Kerala Agricultural University, Vellanikkara, during the period 1993 to 1997. The objectives of the investigation were estimation of variability and genetic diversity, study of floral biology, analysis of important chemical constituents in relation to quality, improvement of selected accessions through single plant and mass selection methods and morphological and biochemical characterization of bird pepper.

Results of these experiments are summarised below:

Eighty six accessions of bird pepper collected from different locations were characterized based on descriptor list of Capsicum prepared by IBPGR (1983). Significant differences were observed between 86 accessions for all the biometric characters studied. In the preliminary experiment, accession CF 36 was found superior with respect to fruit size and CF 19, CF 36 and CF 23 for yield.

The twenty five accessions selected from the first experiment based on fruit size and yield, were evaluated in a replicated trial for two seasons. Significant differences were observed among accessions for all the biometric characters studied. Accession CF 19 gave the earliest yield. CF 36 was found superior with respect to fruit size and fruit weight. The high yielding accessions were CF 103, CF 36, CF 23, CF 10 and CF 19.

High heritability in conjunction with high GCV and expected genetic advance was obtained for fruit size and fruit weight. High heritability coupled with low genetic advance was observed for dry chilli recovery, days to harvest, plant spread and number of harvests.

A significant positive association of yield with plant height, primary branches per plant, plant spread, number of harvests, mean fruit weight and fruit size was observed at genotypic and phenotypic levels. Fruit yield exhibited significant negative association with days to first harvest and crop duration.

Genetic divergence of the 25 selected accessions was estimated. The genotypes were grouped into six clusters.

Four white fruited accessions of bird pepper (CF 19, CF 23, CF 36 and CF 103) and two green fruited accessions (CF 5 and CF 10) which gave consistent high yield with better fruit size in the two seasons were advanced through single plant and mass selection for three generations.

The selection methods varied significantly to effect changes in fruit size, number of harvests and yield in three consecutive generations, single plant selection proved to be more efficient in improving these traits. Genetic gain was realised for fruit characters and yield under both methods of selection.

The study on the floral biology revealed that duration of flower opening was from 8 am to 1 pm with peak period from 9 am to 10 am. Anther dehiscence commenced at 8 am and continued up to 11 am with the peak between 9 am to 10 am. Maximum receptivity of stigma was observed 24 hours prior to and six hours after anthesis. The range for pollen characters like pollen size, fertility, viability and

production per anther were 37.11 μ to 42.11 μ, 83.9 to 88.3 per cent, 30.7 to 38.1 per cent and 1866.7 to 4560.0 respectively.

Heterostyly was observed in white fruited accession of bird pepper, CF 23 producing long styled (76%), medium styled (18%) and short styled (6%) flowers, while all the flowers in the green fruited accession (CF 10) were long styled.

Significant variation was observed among the 25 selected accessions for ascorbic acid, capsaicin, oleoresin and carotenoids. Ascorbic acid, oleoresin and carotenoids registered a significant increase with fruit ripening in all the accessions. Capsaicin content was high in red ripe compared to mature green fruits in all accessions except CF 5, CF 10, CF 23 and CF 153, where a slight decrease on ripening was observed.

The range of ascorbic acid, capsaicin, oleoresin and carotenoids respectively in mature green fruits were 21.0 to 77.6 mg in g^{-1}, 0.21 to 1.57 per cent, 4.5 to 14.25 per cent and 0.14 to 0.5 per cent. The corresponding values in ripe fruits were 31.5 to 135.75 mg per 100 gm, 0.43 to 1.7 per cent, 8.75 to 24.25 per cent and 0.26 to 0.69 per cent respectively. The highest content of ascorbic acid, capsaicin, oleoresin and carotenoids in mature fruits were registered in accessions CF 15 (77.6 mg 100 g^{-1}), CF 5 (1.57%), CF 23 (14.25%) and CF 138 (0.5%) respectively. In general, the green fruited accessions of *C. frutescens* had higher capsaicin content compared to white fruited types.

A comparison of the content of fixed oil, nucleic acid and protein, peroxidase and polyphenol oxidase enzyme activity, between accessions of *C. annuum* and *C. frutescens* (green and white) were done. The yield of fixed oil in

dry chilli seeds ranged from 11.0 to 21.5 per cent, with the highest in K-2, a cultivar of *C. annuum*. The acid value of chilli seed oil varied from 3.36 to 6.04, maximum for Ujwala.

Protein content was the highest in CF 10 (14.2 mg g^{-1}). Maximum activity of the peroxidase enzyme was in CF 5 (611.20 units per litre of enzyme extract) on 45th day after sowing. An increase in peroxidase activity with age of plants was noted.

The activity of the enzyme polyphenol oxidase in leaves of 60 days old seedlings was maximum in CF 36 (2.58 x 10^{-2} units). The specific enzyme activity (activity per minute per mg protein) was the highest in CF 103 (1.39 x 10^{-2} units)

The content of deoxyribonucleic acid and ribonucleic acid in seeds of six accessions in *Capsicum* sp. ranged from 1.62 to 2.26 mg g^{-1} and 3.02 to 5.4 mg g^{-1} respectively.

Analysis of flavour components in volatile oil from fresh and dehydrated fruits of *C. annuum* and *C. frutescens* (green and white) revealed variation in aroma bearing constituents between accessions.

Study of isozyme variation of enzyme peroxidase in six accessions belonging to *Capsicum* sp. revealed that there exists isozyme polymorphism in the genus *Capsicum*. The *C.* annuum and *C. frutescens* accessions had two bands with Rm values 0.395 and 0.465 common to them and one additional band with Rm value 0.581 exclusively in *C. annuum* cultivars.

Bird pepper accessions were identified for high yield, fruit size and quality parameters. Accession CF 19 was the best line with respect to earliness (134 days), yield (185.38 g per plant) and fruit size (24.26 cm^2) and had medium pungency (0.5%). CF 23 had good fruit size (14.76 cm^2), yield (148.15 g per plant), medium high pungency (0.9%) and high oleoresin (14.25%). Among the green fruited accessions CF 10 gave comparatively higher yield (163.63 g per plant), better fruit size (13.93 cm^2), high capsaicin (1.41%) and ascorbic acid (74.9 mg 100 g^{-1}) whereas CF 5 recorded the highest capsaicin content (1.57%).

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APPENDIX-I

Meteorological data during the cropping period (October 1993 to November 1997)

Year/ month	Temperature °C		Rainfall (mm)	Relative humidity (%)		Sunshine hours
	Maximum	Minimum		1	2	
1993						
October	30.7	23.4	519.0	91	74	4.8
November	31.5	23.6	76.6	82	64	5.8
December	31.6	23.1	18.0	76	55	7.5
1994						
January	32.9	22.6	19.4	74	42	9.1
February	34.8	23.1	1.7	79	38	8.7
March	36.2	23.7	21.0	79	38	9.3
April	34.9	24.4	165.2	88	59	8.0
May	33.6	24.7	124.2	88	61	8.0
June	28.9	22.9	955.1	96	83	2.1
July	28.6	22.4	1002.1	96	85	1.4
August	30.0	22.8	509.2	95	75	3.6
September	31.8	23.2	240.5	92	64	7.3
October	32.3	22.7	358.2	92	68	6.7
November	31.8	23.3	125.3	77	58	8.1
December	32.2	22.2	0.0	71	45	10.6
1995						
January	32.9	22.4	0.0	76	41	9.6
February	35.4	23.4	0.5	79	41	10.0
March	37.6	23.8	2.8	83	37	9.3
April	36.6	24.9	118.7	87	55	9.1
May	33.5	23.9	370.5	91	65	6.5
June	31.6	23.1	500.4	94	77	3.7
July	29.9	23.2	854.7	96	81	2.1
August	30.6	23.7	448.7	94	78	3.7
September	30.1	23.5	282.5	94	70	6.1
October	33.2	23.2	110.4	91	65	8.3
November	31.3	22.5	88.4	91	69	6.5
December	32.5	21.3	0.0	71	43	10.3
1996						
January	33.1	22.4	0.0	71	35	9.4
February	34.7	23.4	0.0	72	34	9.9
March	36.4	24.3	0.0	82	37	9.3
April	34.6	25.0	152.0	87	59	8.3

Contd.

Appendix I. Continued

Year/ month	Temperature °C		Rainfall (mm)	Relative humidity (%)		Sunshine hours
	Maximum	Minimum		1	2	
May	32.8	25.2	95.4	91	63	7.7
June	30.5	23.8	400.3	94	75	4.7
July	28.8	23.1	588.7	96	83	2.7
August	29.1	23.6	310.0	95	78	3.7
September	29.2	23.7	391.6	94	74	4.3
October	30.1	22.9	219.3	93	70	6.0
November	31.5	23.6	22.1	84	59	7.1
December	30.5	21.8	60.4	80	55	6.8
1997						
January	32.0	22.9	0.0	78	45	9.6
February	33.9	21.8	0.0	82	39	9.3
March	35.7	24.0	0.0	82	37	9.6
April	35.2	24.5	8.2	83	50	9.6
May	34.4	24.5	63.0	87	57	6.7
June	31.2	23.0	720.5	93	71	5.9
July	28.6	21.8	979.2	95	84	1.9
August	29.0	22.8	636.8	95	78	3.4
September	30.6	23.4	164.0	93	71	6.8
October	32.2	23.6	194.7	88	65	7.3
November	31.6	23.2	209.7	88	67	5.3

APPENDIX-II

Preparation of Folin-Dennis reagent for estimation of capsaicin

* Reflux 750 ml distilled water, 100 g sodium tungstate, 20 g phosphomolybdic acid and 50 ml phosphoric acid for two hours

* Cool and dilute to 1000 ml with distilled water

APPENDIX-III

Preparation of reagent for estimation of fatty acid

Neutral solvent

Mix 25 ml ether and 25 ml 95% alcohol. Add a drop of phenophthalein indicator and neutralize with N/10 alkali.

APPENDIX-IV

Preparation of reagents for estimation of nucleic acid

1.Diphenylamine Reagent

The diphenylamine reagent was prepared by dissolving 1.5 g of diphenyl amine in 100 ml of glacial acetic acid and adding 1.5 ml of concentrated H_2SO_4. Stored the reagent in ambre coloured bottles in the dark. On the day the reagent was used, added 0.1 ml of aqueous acetaldehyde (16 mg per ml) for each 20 ml of the reagent used.

2. Orcinol Reagent

2.1 Reagent A

Dissolved 1 g Orcinol and 375 mg $FeCl_3.6H_2O$ in distilled water and made up volume to 25 ml. Cooled in an ice bath at 4°C.

2.2 Reagent B

Added 500 ml of concentrated HCl to 100 ml of water.

Added 475 ml of HCl reagent B to reagent A. Stored in ambre coloured bottles in dark till use.

APPENDIX-V

Preparation of reagents for estimation of protein

1. Extraction buffer (Tris buffer, pH 7.0)

Tris	- 21.19 g
Citric acid	- 2.63 g
Vitamin C	- 0.538 g
Cysteine HCl	- 0.527 g
Water	- 500 ml
pH	- 7.0

2. Folin-Ciocalteu reagent

Reflux gently for 10 hrs, 100 g sodium tungstate, 25 g sodium molybdate, 700 ml water, 50 ml 85% phosphoric acid and 100 ml conc. HCl. Add 150 g lithium sulphate, 50 ml water and a few drops of Bromine water. Boil the mixture for 15 minutes to remove excess bromine. Cool, dilute to 1 litre and filter.

APPENDIX-VI

Gel mixture preparation (Isozyme analysis)

Stock solutions	Separating (7.5%) (ml)	Stacking (2.5%) (ml)
Acrylamide (30:0.8)	2.50	1.25
Separating gel buffer stock	1.25	-
Stacking gel buffer stock	-	2.50
Ammonium persulphate (1.5%)	0.50	-
Riboflavin (0.004%)	-	1.25
Water	5.75	5.00
TEMED	0.005	0.008
Total	10.00	10.00

APPENDIX-VII

General analysis of variance of biometric characters in 86 bird pepper accessions

Source of variation	df	Mean squares							
		Plant height	Plant spread	Fruit length	Pedicel length	Fruit pedicel ratio	Fruit girth	Fruit size	Yield
Genotypes	85	966.98**	519.767**	4.083**	0.844**	0.580**	1.832**	81.154**	6844.621**
Error	344	92.601	87.779	0.074	0.071	0.028	0.042	1.285	197.408

**Significant at 1% level

APPENDIX-VIII

General analysis of variance of biometric characters of 25 selected accessions of bird pepper

Source of variance	df	Plant height	Plant spread	Primary branches per plant	No. of harvests	Days to first harvest	Days to last harvest	Mean fruit weight	Fruit girth	Fruit length	Pedicel length	Fruit/ pedicel ratio	Fruit size	Driage	Yield
Genotypes															
		**	**	**	**	**	**	**	**	**	**	**	**	**	**
S_1	24	276.21	29.58	1.47	0.47	149.16	158.29	0.25	0.58	1.38	0.44	0.20	29.63	5.19	639.24
		*	**	**	**	**	**	**	**	**	**	**	**	**	
S_2	24	338.12	61.85	2.27	0.52	140.30	100.29	0.27	0.67	1.67	0.53	0.18	43.65	4.33	881.58
Error															
S_1	25	20.64	10.57	0.32	0.06	6.47	9.67	0.02	0.01	0.01	0.01	0.01	0.36	0.08	10.42
S_2	25	17.14	8.40	0.24	0.05	7.47	9.71	0.01	0.01	0.01	0.02	0.01	0.36	0.08	21.81

** Significant at 1% level

* Significant at 5% level

APPENDIX-IX

General analysis of variance for morphological and economic characters in three generations of selection

Source	df	Plant height			Pr. branches			Days to harvest			Fruit length			Pedicel length			Fruit girth		
		G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3
A	1	1.972	12.241	20.981*	0.327**	0.167	0.042	108.375**	18.375	322.667**	0.170**	0.120**	0.220**	0.096**	0.053*	0.470**	0.056**	0.014	0.213**
B	5	62.957**	33.683	68.922**	3.433**	0.391*	0.019	35.742*	28.142	63.867**	3.364**	2.788**	2.714**	0.434**	0.390**	0.335**	0.840**	0.818**	1.226**
AB	5	32.566*	38.441	2.562	0.273	0.075	0.038	1.275	11.275*	9.867	0.020	0.012	0.034	0.021**	0.008	0.012	0.006	0.014	0.016
Error	11	9.132	15.431	4.086	0.540	0.096	0.022	9.769	5.223	8.303	0.007	0.007	0.002	0.003	0.007	0.019	0.003	0.005	0.004

Acc. No.		Fruit weight			Fruit size			Crop duration			Number of harvest			Yield per plant		
		G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3
A	1	0.011	0.015*	0.062**	6.484**	3.267**	14.882**	198.375**	51.042*	3.375	0.667**	0.375**	1.042**	1203.033**	989.322**	2431.705**
B	5	3.228**	0.557**	0.741**	107.414**	86.28**	119.786**	382.742**	197.342**	576.875**	0.599**	0.083	0.411**	513.436**	300.722**	1385.748**
AB	5	0.009	0.001	0.022	0.658	0.771	0.828	34.075	3.942	40.275**	0.075	0.043	0.054	25.412	27.176	106.643
Error	11	0.045	0.002	0.001	0.146	0.125	0.115	13.102	6.042	49.769	0.013	0.034	0.026	36.167	25.873	24.612

A - Methods of selection, B - Genotypes, G - Generation ** P = 0.01, * P = 0.05

APPENDIX-X

General analysis of variance of pollen characters in bird pepper

Source of variation	df	Mean squares			
		Pollen size	Pollen fertility	Pollen germination	Pollen output per anther
Genotypes	5	10.751 ^{NS}	13.905 ^{NS}	28.345 ^{NS}	2342115.556**
Error	12	4.646	4.932	48.888	16711.111

** Significant at 1% level

APPENDIX-XI

General analysis of variance of chemical constituents at two stages of maturity

Sources of variation	df	Mean squares							
		Ascorbic acid		Capsaicin		Oleoresin		Carotenoids	
		Mature	Ripe	Mature	Ripe	Mature	Ripe	Mature	Ripe
Genotypes	24	564.161**	1198.839**	0.235**	0.289**	24.129**	40.722**	0.023**	0.030**
Error	25	28.067	21.182	0.014	0.019	4.785	9.646	0.002	0.002

**Significant at 1% level

APPENDIX-XII

General analysis of variance of changes in chemical constituents with maturity

Sources of variation	df	Mean squares			
		Ascorbic acid (Ripe-Mature)	Capsaicin (Ripe-Mature)	Oleoresin (Ripe- Mature)	Carotenoids (Ripe-Mature)
Genotypes	24	723.673**	0.276**	32.244**	0.027**
Error	25	26.816	0.027	8.145	0.003

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** Significant at 1% level

APPENDIX-XIII

General analysis of variance of nucleic acid, protein and fatty acid content of six accessions in *Capsicum* sp.

Source of variation	df	Mean squares				
		DNA	RNA	Soluble protein	Seed oil	Acid value seed oil
Genotypes	5	0.327**	2.767**	28.424**	41.135**	4.478**
Error	18	0.049	0.155	0.389	0.468	0.531

**Significant at 1% level

GENETIC IMPROVEMENT OF BIRD PEPPER (*Capsicum frutescens* L.) BY SELECTION

By
K. B. SHEELA

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the
requirements for the degree

Doctor of Philosophy in Horticulture

Faculty of Agriculture
Kerala Agricultural University

Department of Olericulture
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VELLANIKKARA, THRISSUR
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1998

ABSTRACT

Investigation on 'Genetic improvement of bird pepper (*Capsicum frutescens* L.) by selection' was undertaken at the Department of Olericulture, Kerala Agricultural University, Vellanikkara, during 1993-97. The main objectives of the study were estimation of variability and genetic diversity, study of floral biology, improvement of the selected lines through single plant and mass selection methods, analysis of biochemical constituents and morphological and biochemical characterization of bird pepper.

Eighty six accessions of bird pepper collected from different locations were characterized based on IBPGR descriptor list for *Capsicum*. Wide variability was observed for morphological and biometric characters.

Twenty five selected accessions were further evaluated for two seasons for quantitative characters. Variability, heritability, genetic diversity and association of various characters was studied.

Accessions CF 5, CF 10, CF 19, CF 23, CF 36 and CF 103 having consistent high yield and better fruit size were advanced by single plant and mass selection for three generations. Single plant selection was more effective in improving fruit size and yield. Genetic gain was realised for fruit characters and yield under both the methods of selection.

The peak period of anthesis and anther dehiscence in bird pepper was between 9 am to 10 am. Stigma was receptive 24 hours before and after anthesis.

Significant variation was observed among 25 selected accessions for ascorbic acid, capsaicin, oleoresin and carotenoid content. The highest content of ascorbic acid, capsaicin, oleoresin and carotenoids in mature fruits were registered in accessions CF 15 (77.6 mg 100 g^{-1}), CF 5 (1.57%), CF 23 (14.25%) and CF 138 (0.5%) respectively. These constituents registered a significant increase with ripening.

A comparison of *C. frutescens* and *C. annuum* accessions with respect to fatty acid, nucleic acid and protein content, enzyme activities and flavour components were made. Biochemical characterization of *C. frutescens* was done by studying the electrophoretic pattern of the enzyme peroxidase.

Accession CF 19 with high yield (185.38 g per plant) and better fruit size (24.26 cm^2) and CF 5 and CF 10 with high capsaicin content (1.57 and 1.41% respectively) were identified for further improvement.