INHERITANCE OF CLUSTERNESS, DESTALKNESS AND DEEP RED COLOUR IN CHILLI

[*Capsicum annuum* L.]

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree

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DECLARATION

I hereby declare that this thesis entitled "Inheritance of clusterness, destalkness and deep red colour in chilli (Capsicum annuum L.)" is a bona fide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or other similar title, of any other University or Society.

Vellanikkara,
15th November, 1985

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CERTIFICATE

Certified that this thesis entitled "Inheritance of clusterness, destalkness and deep red colour in chilli (*Capsicum annuum* L.)" is a record of research work done independently by Sri. T.R. Gopalakrishnan under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to him.

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Introduction

INTRODUCTION

Chilli (*Capsicum annuum* L.) is an indispensable spice-cum-vegetable crop grown throughout India. Originated in South America, the crop was introduced to India by Portuguese during the middle of seventeenth century. The wider ecological adaptability of this crop facilitated its spread in different parts of the country. India now ranks first in the world production of chilli with 52.8 lakh tonnes of dry chilli from an area of 7.92 lakh ha (1982-'83). Andhra Pradesh, Maharashtra, Karnataka, West Bengal, Gujarat, Bihar and Assam account for 96% of total area under chilli in India. The cultivation of chilli in Kerala, like any other vegetable crop, is limited to 1250 ha with an annual production of 1143 tonnes of dry chilli. The consumption of chilli in India is over 99% of our production. During 1982-'83 India exported 12,888 tonnes of dry chillies worth Rs 123 million. This accounts for 15% of total world chilli export, next to China (24%). The U.S.S.R., U.K., U.S.A., Arab and Gulf countries are the principal markets for Indian chillies.

The fruit is known for pungency, colour, aroma and taste it imparts to the food materials. Capsaicin, the pungency factor in chilli is an active counter irritant. The chilli oleoresin is used in pharmaceutical and cosmetic preparations. The colouring factor of chilli is ascribed to capsanthin, a carotenoid pigment. The large fruited and non-pungent capsicum or paprika, used principally as vegetable, is rich in carotene and vitamin C (1.8 and 103 mg/100 g respectively).

Variability in the available germplasm is an important pre-requisite for the success of crop improvement programmes. The biometrical approaches in plant breeding enable the breeder to determine the heritable and non-heritable components of phenotypic variation. Such an attempt was made in the chilli population maintained at the College of Horticulture, Kerala Agricultural University, Vellanikkara. Also efforts were made to exploit heterosis which has already been reported in chilli by many scientists (Rao et al., 1981; Sontakke, 1981; Murthy and Lakshmy, 1983; Uzo, 1984; Pious, 1985). The F_1 hybrids and their segregating generations developed from four diverse lines selected based on type of branching, fruiting habit, fruit orientation, fruit colour and yield were also utilized for the estimation of gene action in respect of particular characters.

The presence of non-additive gene action for most of the metric traits was reported in chilli. (Chung and Chang, 1979; Gill et al., 1980; Singh and Rai, 1981; Singh et al., 1982). In the non-additive gene action, the contribution of epistasis may be significant. Discarding of epistatic gene action would vitiate the estimate of genetic variance and breeding programmes. Hence the main gene effects and the magnitude and type of epistasis were also worked out in the present study.

The information on genetics and inheritance pattern of desirable characters is quite important in the improvement of chilli. Such information from inheritance studies enables the breeder to mainpulate the genes on a more scientific basis. Dichotomous/indeterminate growth habit, solitary fruit bearing habit, non-uniform fruit ripening and persistent calyx are certain undesirable traits in chilli for mechanical harvesting. Dichotomous growth pattern in the commercial varieties results in the production of a single fruit at each branching node, which has to be harvested one by one. This works out to nearly 20% of the cost of cultivation for harvesting of solitary fruits alone. According to Subramania (1983), transfer of multiple flower character to cultivated varieties would result in more concentrated fruit set, uniform maturity and reduced harvest cost. The multiple flower trait also has the potential for increased yield. The clustered accessions of chilli, CA 33 and CA 23 in the germplasm of the College of Horticulture are characterised by extensive axillary shoots terminating in clusters of fruits and maturing almost simultaneously. The fruits in these accessions are borne mainly on the periphery and are more suited for mechanical harvesting.

In the commercial chilli varieties, calyx persists tightly to the picked fruits. CA 33 has destalked fruit character where the calyx is loosely attached to the fruit, making harvesting less cumbersome. Due to this desirable trait it is also quite possible to get a high quality chilli powder without the contamination of calyx. Another essential requirement to get a high quality chilli powder is the shining deep red colour of the pericarp. Fruit colour was considered earlier as a qualitative character with monogenic inheritance (Deshpande, 1933). Later, after the standardization of procedures for quantitative estimation of colouring pigments, it is considered as a quantitative trait with polygenic control

The present investigation was mainly aimed to work out the inheritance of the above mentioned desirable traits viz., clusterness, destalkness and deep red colour using suitable cross combinations. All these attempts have an overall objective of improvement in chilli and the compiled information would greatly embellish the improvement programmes.

Review of Literature

REVIEW OF LITERATURE

The information on genetics and breeding of chilli are reviewed under the following heads:

A. Genetic variability and divergence in chilli

B. Combining ability analysis in chilli

C. Heterosis in chilli

D. Components of gene action through generation mean analysis in chilli

E. Inheritance of type of branching, fruiting habit, fruit orientation, destalkness and fruit colour in chilli

A. Genetic variability and divergence in chilli

1. Genetic variability, heritability and genetic advance in chilli

Heritability estimates indicated the effectiveness with which selection of a genotype could be based on the phenotypic performance (Table 1). But they do not necessarily mean a high genetic advance for a particular quantitative character. Heritability along with estimates of genetic advance should be considered more than heritability *per se* while making selections (Johnson *et al*. 1955).

In a study of 79 F_3 lines of a cross between Mexican chillies, 59 MC 5 x Line 159254, Legg and Lippert (1966) noted high heritability associated with high genetic advance for fruits/plant, fruit weight and carotene content. Ramanujam and Thirumalachar (1967) reported high heritability (0.90) for capsaicin content in a set of 12 chilli varieties.

Singh and Singh (1970) observed low heritability and expected genetic advance for plant height (0.30, 9.16), primary branches/plant (0.31, 16.79), fruits/plant (0.29, 32.1), fruit length (0.20, 13.06), fruit width (0.23, 1.04) and fruit yield/plant (0.18, 12.55) from a study involving 19 lines.

Nandpuri et al. (1971) evaluated 25 lines of red chilli. Days to flower, days to maturity, fruits/plant and fruit yield/plant recorded high heritability (broad sense). Estimates of expected genetic advance were high for fruits/plant (59.00), branches/plant (50.00), fruit yield/plant (26.95) and plant height (34.38). Singh et al. (1972) recorded maximum heritability and genetic advance for average fruit size. Coefficient of variation was high for primary and tertiary branches/plant, fruits/plant, fruit size, average fruit weight and yield.

Arya and Saini (1976) observed high genotypic coefficient of variation (92.61), phenotypic coefficient of variation (92.79), heritability (0.99) and genetic advance (190.47) for fruits/plant followed by fruit size in a set of seven lines. High heritability estimates were recorded for fruit yield/plant (0.99), leaf length (0.99) and branches/plant (0.98). The above characters had high variation and genetic advance. Awasthi _et al_. (1976) recorded high estimates of heritability and genetic advance for plant height (0.81, 33.14), fruit length (0.94, 28.36) and fruit yield/plant (0.76, 192.35) while evaluating 38 varieties. High heritability with low genetic advance was found for branches/plant (0.99, 14.53), fruit girth (0.94, 0.67) and average fruit weight (0.90, 2.41). Fruits/plant had moderate values of heritability and genetic advance.

In another experiment with 30 cultivars, Arya and Saini (1977) observed high heritability for fruit size (0.99) and branches/plant (0.99). The highest genotypic coefficient of variation was observed for rind thickness (223.33) and fruit size (129.89). Genetic advance was maximum for fruit yield/plant (605.13). Hussain (1977) recorded high values of heritability and genetic advance for fruits/plant and fruit weight. This is in confirmity with the results of Hiremath and Mathapati (1977). Singh and Singh (1977a) reported high heritability (narrow sense) value for branches/plant (0.76), plant height (0.88), days to maturity (0.96) and fruits/plant (0.84). Fruits/plant and yield/plant had the highest values of genetic advance (47.06 and 17.23 respectively).

In a population of chilli, estimates of variability and heritability were low for earliness, yield, plant height and capsaicin content (Abou-El-Fadl, 1979). Evaluation of 11 pickle types of chillies led Arya (1979) to observe high values of heritability and genetic advance for green fruit yield/plant (0.99 and 130.90 respectively) and fruits/plant (0.95 and 201.91 respectively). Dutta et al. (1979) found high coefficients of variation for fruit weight, fruits/plant, fruit yield/plant, branches/plant and plant height based on a study using 23 varieties. Heritability estimates were high for fruit weight (0.97) followed by days to flower (0.91), plant height (0.87) and fruits/plant (0.77).

In 12 varieties Ramakumar et al. (1981) observed moderate to high values of heritability and genetic advance for plant height (0.44, 11.1), fruits/plant (0.41, 30.64) and fruit girth (0.90, 40.5). While studying the F_1, F_2, BC_1 and BC_2 of Azamgarh Local x 6004, Singh and Rai (1981) noted moderate estimates of heritability and genetic advance for branches/plant (0.57, 63.95), fruit length (0.66, 58.26) and fruit girth (0.47, 33.11).

Based on evaluation of 25 chilli lines Bavaji and Murthy (1982) observed high heritability and genetic advance for branches/plant (0.85, 75.30), fruit length (0.95, 56.80) and average fruit weight (0.88, 57.50). In an experiment with 30 chilli lines, Elangovan et al. (1982) observed high heritability for fruit girth (0.97), fruit length (0.96), plant spread (0.89) and fruit weight (0.86). Fruits/plant and average fruit weight exhibited high genetic advance (72.79 and 70.29 respectively).

Working on 12 chilli lines, Amarchandra et al. (1983) noted high heritability and genetic advance for average fruit weight (0.97, 69.31) and fruit yield/ha (0.97, 72.00). Kshirsagar et al. (1983) reported high estimates of genotypic and phenotypic coefficients of variation, heritability and genetic advance for fruit length (32.33, 32.97, 0.97 and 65.85 respectively) and high to moderate values for fruits/plant (22.45, 37.46, 0.53 and 44.44 respectively). Based on evaluation of 14 varities at Coimbatore, Vadivel et al. (1983), reported that plant height, branches/plant, fresh fruit weight, fruit yield and fruit girth were highly affected by environment. Maximum heritability was observed for average fruit weight (0.83) followed by plant height (0.71) and the lowest for branches/plant (0.21).

Gupta and Yadav (1984) observed high coefficients of variation for fruit girth and branches/plant. Heritability in the broad sense was maximum for fruit girth while genetic advance was the highest for fruits/plant. From a study on 30 chilli varieties at the College of Agriculture, Vellayani Nair et al. (1984) reported the high environmental influence on primary branches/plant. High estimates of heritability and genetic advance were noticed for fruits/plant (0.99, 249.31), average fruit weight (0.99, 206.35), fruit girth (0.99, 140.87), fruit yield/plant (0.99, 222.75) and capsaicin content (0.99, 205.64). High heritability with low genetic advance for days to flower (0.98, 35.81) and plant height (0.96, 53.50) was indicative of non-additive gene action.

2. Genetic divergence in chilli

Forty five lines of chilli were subjected to D^2 analysis by Singh and Singh (1976a). The lines differed significantly for plant height, branches/plant, days to flower, days to maturity, fruit length, fruit thickness, fruits/plant and yield/plant. Branches/plant, fruit thickness, fruits/plant and fruit yield/plant contributed more towards the total divergence. The clustering pattern of lines did follow geographical distribution.

From a D^2 analysis on 27 varieties, Mehra and Peter (1980) reported that fruits/plant contributed the maximum towards diversity (88.03). Sundaram et al. (1980) could not observe any relationship between genetic and geographic diversity when they subjected 35 Indian and 15 foreign varieties of Capsicum frutescens L. to D^2 analysis. Branches/plant and fruits/plant were the important characters contributing to genetic divergence.

Table 1. Variability, heritability and genetic advance for polygenic characters in chilli

Characters	Authority
Plant height	
High estimates of variability, heritability and genetic advance	Singh (1958); Nandpuri et al. (1971) Awasthi et al. (1976); Hiremath and Mathapati (1977); Ramalingam and Rajendran (1977); Dutta et al. (1979); Raju (1980); Milkova and Popova (1981); Ramakumar et al. (1981); Singh and Rai (1981)
Low estimates of variability, heritability and genetic advance	Singh and Singh (1970); Abou-El-Fadl (1979); Rao et al. (1981); Vadivel et al. (1983)
High estimates of heritability and low estimates of genetic advance	Nair et al. (1984)

Table 1. (Contd.)

Characters	Authority
Branches/plant	
High estimates of variability, heritability and genetic advance	Nandpuri *et al.* (1971); Singh *et al.* (1972); Arya and Saini (1976, 1977); Hiremath and Methapati (1977); Ramalingam and Rajendran (1977); Dutta *et al.* (1979); Ramalingam (1979); Singh and Rai (1981); Bavaji and Murthy (1982); Gupta and Yadav (1984)
Low estimates of variability, heritability and genetic advance	Singh and Singh (1970); Al-Hamidi *et al.* (1977); Vadivel *et al.* (1983)
High estimates of heritability and low estimates of genetic advance	Awasthi *et al.* (1976)
Leaf length	
High estimates of variability, heritability and genetic advance	Arya and Saini (1976)
Fruit length	
High estimates of variability, and genetic advance	Nandpuri *et al.* (1970); Awasthi *et al.* (1976); Dutta *et al.* (1979); Ramalingam (1979); Raju (1980); Singh and Rai (1981); Bavaji and Murthy (1982); Elangovan *et al.* (1982); Kshirsagar *et al.* (1983)

Table 1. (Contd.)

Characters	Authority
Low estimates of heritability and genetic advance	Singh and Singh (1970)
Fruit girth	
High estimates of variability, heritability and genetic advance	Raju (1980); Ramakumar et al. (1981); Singh and Rai (1981); Elangovan et al. (1982); Gupta and Yadav (1984); Nair et al. (1984)
Low estimates of heritability and genetic advance	Singh and Singh (1970); Vadivel et al. (1983)
High estimates of heritability and low estimates of genetic advance	Awasthi et al. (1976)
Average fruit weight	
High estimates of variability, heritability and genetic advance	Legg and Lippert (1966); Nandpuri et al. (1970); Singh et al. (1972); Hiremath and Mathapati (1977); Ramalingam and Rajendran (1977); Singh and Singh (1977a); Dutta et al. (1979); Ramalingam (1979); Rao et al. (1981); Singh et al. (1981); Bavaji and Murthy (1982); Elangovan et al. (1982); Amarchandra et al. (1983); Vadivel et al. (1983); Nair et al. (1984)

Table 1. (Contd.)

Characters	Authority
High estimates of heritability and low estimates of genetic advance	Awasthi et al. (1976)
Fruit size	
High estimates of variability, heritability and genetic advance	Singh (1958); Singh et al. (1972); Arya and Saini (1976); Arya and Saini (1977); Amarchandra et al. (1983)
Fruits/plant	
High estimates of variability, heritability and genetic advance	Legg and Lippert (1966); Nandpuri et al. (1970, 1971); Singh et al. (1972); Arya and Saini (1976); Awasthi et al. (1976); Hussain (1977); Hiremath and Mathapati (1977); Singh and Singh (1977a); Arya (1979); Dutta et al. (1979); Ramalingam (1979); Ramakumar et al. (1981); Rao et al. (1981); Singh et al. (1981); Singh and Rai (1981); Bavaji and Murthy (1982); Elangovan et al. (1982); Kshirsagar et al. (1983); Gupta and Yadav (1984); Nair et al. (1984)
Low estimates of heritability and genetic advance	Singh and Singh (1970)

Table 1. (Contd.)

Characters	Authority
Fruit yield/plant	
High estimates of variability, heritability and genetic advance	Nandpuri et al. (1971); Singh et al. (1972); Arya and Saini (1976, 1977); Awasthi et al. (1976); Arya and Saini (1977); Hiremath and Mathapati (1977); Hussain (1977); Singh and Singh (1977a); Arya (1979); Dutta et al. (1979); Rao et al. (1981); Singh et al. (1981); Singh and Rai (1981); Amarchandra et al. (1983); Nair et al. (1984)
Low estimates of variability, heritability and genetic advance	Singh and Singh (1970); Abou-El-Fadl (1979); Vadivel et al. (1983)
Days to flower	
High estimates of heritability	Nandpuri et al. (1970); Singh and Singh (1977a); Dutta et al. (1979); Ramalingam (1979); Singh and Rai (1981)
Low estimates of variability and heritability	Abou-El-Fadl (1979)
High estimates of heritability and low estimates of genetic advance	Nair et al. (1984)

B. Combining ability analysis in chilli

Daskalov *et al*. (1973) observed high general combining ability for earliness in the lines 17 and 29 in crosses with Gold Medal. These lines were produced by inter-specific hybridization between *Capsicum annuum* L. and *Capsicum pendulum* Wild. From a study of 6 x 6 diallel cross, Gill *et al*. (1973) reported significant variances for general combining ability (g c a) and specific combining ability (s c a) for days to flower, fruit length and fruits/plant. In a unidirectional diallel cross consisting of eight parents and 28 F_1S, Betlach (1974) noted significant g c a and s c a effects for earliness and fruits/plant. Only g c a was significant for fruit yield/plant.

Milkova (1979) observed the highest estimate of g c a effect in the variety Gold Medal for plant height. Variances due to g c a and s c a were high for plant height, branches/plant, leaves/plant and fruit weight.

Pandey *et al*. (1981b) crossed 12 cultivars with three pollen parents. Among the female parents G-4 and G-5 had higher g c a effects for yield, fruits/plant, earliness, plant height and branches/plant. Among the males, Jwala and Pant C-2 had higher g c a effects. The estimates of s c a effects showed that the better combiners for yield were Kalyanpur Yellow x Pant C-2, CA 960 x Jwala, CA 63 x Sirhind and Patna Red x Sirhind. The crosses involving one or both parents with high g c a effects also exhibited high s c a effects.

Gomez and Cuartero (1982) and Singh (1982) observed greater magnitude of s c a variance for yield/plant. Variances due to g c a and s c a observed by Rao and Chhonkar (1984) in a 10 x 10 diallel were highly significant for yield/plant and average fruit weight. CA 960 and G-4 were good combiners for yield.

C. Heterosis in chilli

The first report on heterosis in chilli came from Deshpande (1933) who observed it for earliness, plant height, fruit girth, fruits/plant and yield/plant (Table 2). Later, Pal (1945) reported higher yield in hybrids when he crossed two Pusa types. The F_1 hybrids were found less stable.

Of the 34 F_1s made through crossing of 15 varieties and 3 hybrids, 18 combinations were earlier than the parents, one was later and the rest were on par with the parents (Michna, 1963). In crosses among the varieties, nine combinations exhibited relative heterosis for yield upto 85.7%. The hybrids were superior to parents especially during unfavourable conditions. In three years trials with 13 F_1 hybrids, Betlach (1965, 1967) observed that heterosis during favourable seasons was due to an increase in the fruit number rather than the fruit size. Under the most congenial growing condition the number as well as size of fruits contributed to yield.

Popova and Mihailov (1969) evaluated ten hybrids and their parents. The hybrids were intermediate for fruits/plant and average fruit weight. In a diallel cross involving six bell pepper varieties Silvetti and Giovanelli (1970) observed heterosis for earliness and yield.

According to Khrenova (1972) heterotic combinations from parents which were morphologically alike can be used in the second and subsequent generations, if selection for yield was practiced. Heterotic hybrids from crossing morphologically different varieties should be used only in the first generation. Evaluation of two heterotic intervarietal hybrids by Popova (1972) led him to observe lower yield in F_2 than in the F_1 but higher than the yield of the better parent.

Lee et al. (1973) observed heterosis for average fruit weight, yield, fruits/plant and carotenoid contents. Singh et al. (1973) noted heterobeltiosis for fruit length (45), fruits/plant (30), plant height (19) and yield/plant

(19). Six of the seven crosses showed heterosis for plant height and five for fruit length. Three crosses significantly outyielded their better parents and one cross exhibited heterosis for fruits/plant. None of the hybrids showed heterosis for days to flower.

Bak et al. (1975) observed heterosis for plant height, days to maturity, fruits/plant and fruit length. Yield was higher by 61% in the hybrids than in the parents. In a 9 x 9 diallel, Lippert (1975) noted significant heterosis for fruit length. F_1 hybrids had uniform maturity.

Mishra et al. (1976) made eight crosses using eight parental lines. Heterosis was maximum for fruit yield (84.35) followed by fruits/plant (68.33), branches/plant (61.49), fruit length (20.63), days to maturity (17.53) and days to flower (14.69). Three crosses exhibited heterosis for earliness and five crosses showed significant heterobeltiosis for fruits/plant and yield/plant. Heterosis for plant height and fruit girth was non-significant. Popova et al. (1976) estimated intermediate values for carotene content in the F_1. From a half diallel cross involving six varieties, Rochhetta et al. (1976) reported relative heterosis for yield in F_1. In the F_2, heterosis for yield was observed only in crosses involving a low yielding variety.

Pandian et al. (1978) studied eight hybrids, all of which showed negative heterosis for fruit length and fruit girth. Many of them showed negative heterosis for plant height. Relative heterosis to the extent of 32.8% for fruits/plant, and 55.9% for dry chilli yield/plant were manifested by the hybrids. Five crosses exhibited relative heterosis for yield/plant. Singh and Singh (1978) recorded heterosis for earliness, branches/plant, fruit length, fruit thickness, fruits/plant and yield in a diallel cross involving eight chilli lines.

Of the seven F_1 hybrids of bell peppers developed by crossing five varieties, Joshy and Singh (1980) observed three heterotic hybrids for plant height, one each for primary branches, fruit length, fruit weight and fruit girth, four for fruits/plant and one for fruit yield/plant. Park and Takatashi (1980) observed intermediate values of capsaicin in hybrids compared to parents.

Nowaczyk (1981) studied F_1 hybrids from sweet and two pungent varieties. Heterosis for average fruit weight was rare but was common for capsaicin content and every hybrids surpassed the better parent in capsaicin content. Pandey et al. (1981a) recorded heterobeltiosis for fruit yield and fruits/plant in a line x tester analysis involving 12 varieties. Sontakke (1981) reported heterobeltiosis to the extent of 61.4% for yield in a 9 x 9 diallel cross of chilli.

From a line x tester analysis involving 10 lines and three testers resulting in 30 hybrids, Balakrishnan *et al.* (1983) identified the hybrids, CA 247 x K-2, CA 385 x CA 380 and CA 63 x CA 380 as heterotic combinations for commercial exploitation. Murthy and Lakshmy (1983) studied a 8 x 8 diallel. Heterobeltiosis was observed for plant height (31.64) fruits/plant and dry fruit yield/plant. CA 197 x Santaka exhibited high heterosis (196.63) for yield/plant.

From interspecific hybrids between two *Capsicum annuum* lines (Jwala and K-2) and three *Capsicum frutescens* lines (White Kandhari, Chuna and Ornamental type) Krishnakumari (1984) reported significant heterosis for days to flower, plant height, fruits/plant and yield/plant. Heterobeltiosis for yield ranged from -35.8% to 62.9% and relative heterosis from -19.34% to 78.77%. No heterosis was observed for primary branches/plant. Uzo (1984) reported heterosis for plant height, fruits/plant and yield/plant in a study involving three Japanese varieties.

In crosses between K A U cluster and bell pepper varieties (Hungarian Wax, Early Cal Wonder, Hybrid Pepper Bell Boy) Pious (1985) noted heterosis for earliness, plant height, fruit length, fruit perimeter, average fruit weight and green fruit yield.

Table 2. Heterosis in chilli

Characters	Authority
Plant height	Deshpande (1933); Pal (1945); Singh et al. (1973); Alpatev and Khrenova (1975); Popova and Mihailov (1975, 1976); Gill and Ahmed (1977); Sharma and Saini (1977a); Pandian et al. (1978); Joshy and Singh (1980); Murthy and Lakshmy (1983); Krishnakumari (1984); Uzo (1984); Pious (1985)
Branches/plant	Mishra et al. (1976); Singh and Singh (1978); Joshy and Singh (1980); Sontakke (1981)
Shoot length	Popova and Mihailov (1976, 1978)
Leaf area	Studentsova (1973); Popova and Mihailov (1976)
Fruit length	Singh et al. (1973); Bak et al. (1975); Lippert (1975); Mishra et al. (1976); Pandian et al. (1978); Singh and Singh (1978); Rao et al. (1981); Pious (1985)
Fruit girth	Deshpande (1933); Pandian et al. (1978); Singh and Singh (1978); Joshy and Singh (1980); Pious (1985)
Average fruit weight	Betlach (1965, 1967); Popova and Mihailov (1969); Lee et al. (1973); Gill and Ahmed (1977); Murthy and Lakshmy (1983); Pious (1985)

Table 2. (Contd.)

Characters	Authority
Fruits/plant	Deshpande (1933); Pal (1945); Betlach (1965, 1967); Popova and Mihailov (1969); Lee et al. (1973); Singh et al. (1973); Bak et al. (1975); Lippert (1975); Mishra et al. (1976); Rochhetta et al. (1976); Pillai et al. (1977); Pandian et al. (1978); Singh and Singh (1978) Joshy and Singh (1980); Pandey et al. (1981a); Rao et al. (1981); Balakrishnan et al. (1983); Murthy and Lakshmy (1983); Krishnakumari (1984); Uzo (1984)
Fruit yield/plant	Deshpande (1933); Pal (1945); Michna (1963); Betlach (1965, 1967); Bazak et al. (1969); Silvetti and Giovanelli (1970); Nagaich et al. (1972); Popova (1972); Lee et al. (1973); Singh et al. (1973); Allah et al. (1975); Bak et al. (1975); Lippert (1975); Rochhetta et al. (1976); Singh and Singh (1976a); Sharma and Saini (1977a); Pandian et al. (1978); Singh and Singh (1978); Shifris and Sacks (1980); Nowaczyk (1981); Pandey et al. (1981a); Rao et al. (1981); Sontakke (1981); Balakrishnan et al. (1983); Murthy and Lakshmy (1983); Krishnakumari (1984); Uzo (1984); Pious (1985)

Table 2. (Contd.)

Characters	Authority
Earliness	Deshpande (1933); Pal (1945); Daskalov and Murthazov (1955); Michna (1963); Bazak et al. (1969); Silvetti and Giovanelli (1970); Popova and Mihailov (1972); Studentsova (1973); Alpatev and Khrenova (1975); Bak et al. (1975); Mishra et al. (1976); Soh et al. (1976); Soltanovskaya (1976) Singh and Singh (1978); Sontakke (1981); Krishnakumari (1984); Uzo (1984); Pious (1985)
Capsaicin content	Kvachadze (1976); Park and Takatashi (1980), Nowaczyk (1981)
Carotene content	Lee et al. (1973); Popova et al. (1976)

D. Components of gene action through generation mean analysis in chilli

Brauer (1962) studied inheritance of pungency and colour in chilli by crossing six varieties. Eventhough a few transgressive segregants were observed, the inheritance of capsaicin and beta carotene were generally intermediate. In a study of F_0, F_1, F_2, BC_1 and BC_2 of pungent x pungent and pungent x non-pungent crosses Ohta (1962) observed dominance of pungency over non-pungency (Table 3). Brauer (1963) reported epistasis in the inheritance of capsaicin.

Ramanujam and Thirumalachar (1966), Quagliotti and Ottaviano (1971) and Gill et al. (1973) suggested polygenic inheritance for this character.

Betlach and Vytopil (1969) observed that total yield was controlled by superdominance factors. Silvetti and Giovanelli (1970) reported polygenic inheritance for earliness and yield. According to Nagaich et al. (1972), small fruit size was dominant. Kvachadze (1973) observed intermediate inheritance for capsaicin.

In a diallel analysis involving ten inbred lines for two seasons Nandpuri and Kumar (1973) observed that complementary epistasis and overdominance relationships of alleles were involved in the inheritance of yield. About nine genes were found to control yield. High yield was dominant to low yield. The relative frequency of dominant and recessive genes was 4:1. Allah et al. (1975) crossed six inbreds in all possible combinations. Additive gene action effects were relatively high for the inheritance of fruit weight. For early yield, total yield and fruits/plant, additive effects were less important compared to non-additive effects and epistasis.

Popova and Mihailov (1976) reported overdominance for main stem length, plant height and leaf area in the F_1. Data on plant height, branches/plant, days to flower, fruit length, fruits/plant and yield/plant in the parental, F_1, F_2, BC_1 and BC_2 generations of three crosses revealed that prominant gene effects for all the characters were additive, dominant and epistatic (Singh and Singh, 1976b). Among the epistatic effects, dominance x dominance were the most important followed by additive x additive.

Al-Hamidi et al. (1977) reported that average fruit weight was controlled by fewer number of genes. Betlach (1977) reported that additive effects with a moderately positive dominance predominated in the inheritance of fruits/plant. Singh and Singh (1977b) reported additive effects for fruit length and additive and dominance effects for plant height, branches/plant and earliness. Overdominance was also observed for all the above characters.

Among 43 hybrids studied by Dikanev (1978) only in three, clear dominance of earliness was observed. Values of additive genetic variance was high for branches/plant, plant height, days to maturity, fruits/plant and yield/ plant. Estimates of minimum number of genes controlling each character indicated that observed characters were under polygenic control. Singh and Singh (1978) made 28 crosses among eight varieties. In heterotic hybrids dominance components were twice as great as the additive components for yield. Eighteen of the crosses showed duplicate epistasis for yield and the rest showed complementary epistasis.

In crosses between Yolo Wonder and Tatong, Chung and Chang (1979) observed that plant height was controlled by 3 genes and fruit length by two genes. In Yolo Wonder x Funnings Tender Twig, yield and flowers/plant were controlled each by two genes. Epistasis was significant for fruits/plant, yield/plant, days to fruit maturity, fruit weight, plant height and fruit length.

Singh et al. (1980) crossed NP 46 A and Hungarian Wax. Additive and dominance effects were significant for fruit length, fruit girth and fruit weight. Additive effects predominated for all the characters. Non-allelic interaction was important for flowering time, fruit length and fruit girth. Results from a 6 x 6 diallel cross by Thakur et al. (1980) indicated that fruit size was controlled by additive gene action, days to flower by dominance, and plant height, fruits/plant and yield/plant by over-dominance. Both additive and non-additive effects influenced early yield. Plant height, fruit size, early and total yields were controlled by 2, 5, 3 and 24 genes respectively.

Prudek (1981) reported that fruit yield was mainly controlled by overdominant gene action. From a study of parents, F_1, F_2, BC_1 and BC_2 of Azamgarh Local x PI 6004 for two seasons, Singh and Rai (1981) reported high proportion of additive x additive interaction components and marginal role of non-additive components in controlling the inheritance of plant height, days to flower, fruit length, branches/plant and fruits/plant.

After an evaluation of P_1, P_2, F_1, F_2, BC_1 and BC_2 of the cross between a pungent x non-pungent line, Ahmed et al. (1982) reported that pungency was dominant over non-pungency. The additive, dominance and dominance x dominance genetic components were significant for capsaicin content. Additive and dominance effectswere important for days to flower and plant height. But only additive x additive effect influenced average fruit weight, total yield, fruits/plant and fruit diameter.

Rao and Chhonkar (1983) crossed ten varieties of chilli in all possible combinations. Both additive and non-additive effects were important for fruit yield and fruits/plant. Additive genetic effects were significant for fruit circumference and ripe fruit yield/plant and non-additive effects for plant height, branches/plant and fruit length.

Table 3. Components of gene action controlling inheritance of polygenic characters in chilli

Characters	Authority
Plant height	
Additive	Singh and Singh (1977b); Soh *et al.* (1977)
Non-additive	Popova and Mihailov (1976); Sharma and Saini (1977a); Thakur *et al.* (1980); Rao and Chhonkar (1983)
Additive and non-additive	Milkova (1977); Singh and Singh (1977b); Ahmed *et al.* (1982)
Additive, dominance, and epistasis	Singh and Singh (1976b)
Dominance and epistasis	Singh and Rai (1981)
Epistasis	Chung and Chang (1979)
Branches/plant	
Additive	Sharma and Saini (1977a); Singh and Singh (1977b); Milkova (1979)
Non-additive	Rao and Chhonkar (1983)
Additive and non-additive	Singh and Singh (1977b)
Additive, dominance and epistasis	Singh and Singh (1978)
Dominance and epistasis	Singh and Rai (1981)
Main stem length	
Overdominance	Popova and Mihailov (1976)
Leaf area	
Overdominance	Popova and Mihailov (1976)

Table 3. (Contd.)

Characters	Authority
Fruit length	
Additive	Lippert (1975); Singh and Singh (1977b)
Non-additive	Mishra et al. (1976); Rao and Chhonkar (1983)
Additive and non-additive	Milkova (1979); Sethiamihardja (1983)
Additive, dominance and epistasis	Singh and Singh (1976b); Gill et al. (1980)
Dominance and epistasis	Singh and Rai (1981)
Epistasis	Chung and Chang (1979)
Fruit girth	
Additive	Lippert (1975); Ahmed et al. (1982); Rao and Chhonkar (1983)
Additive and non-additive	Milkova (1979); Gill et al (1980); Sethiamihardja (1983)
Additive, dominance and epistasis	Singh et al. (1982)
Average fruit weight	
Additive	Allah et al. (1975); Milkova (1979); Dikil and Anikeenko (1981); Ahmed et al. (1982)
Additive and non-additive	Gill et al. (1980)
Epistasis	Chung and Chang (1979)

Table 3. (Contd.)

Characters	Authority
Fruits/plant	
Additive	Allah *et al*. (1975); Singh and Singh (1977b); Ahmed *et al*. (1982)
Non-additive	Thakur *et al*. (1980)
Additive and non-additive	Rao and Chhonkar (1983)
Additive, dominance and epistasis	Singh and Singh (1977b)
Dominance and epistasis	Singh and Rai (1981)
Epistasis	Chung and Chang (1979)
Fruit yield/plant	
Additive	Allah *et al*. (1975); Lippert (1975); Singh and Singh (1977b); Ahmed *et al*. (1982)
Non-additive	Betlach and Vytopil (1969); Sharma and Saini (1977a); Thakur *et al*. (1980); Dikil and Anikeenko (1981)
Additive and non-additive	Silvetti and Grassia (1976); Rao and Chhonkar (1983)
Additive, dominance and epistasis	Singh and Singh (1976b)
Dominance and epistasis	Nandpuri and Kumar (1973); Singh and Singh (1978)

Table 3. (Contd.)

Characters	Authority
Epistasis	Scossiroli *et al.* (1974); Chung and Chang (1979)
Earliness	
Additive	Allah *et al.* (1975); Soh *et al.* (1976); Singh and Singh (1977b)
Non-additive	Dikanev (1978)
Additive and non-additive	Singh and Singh (1977b); Milkova (1979); Thakur *et al.* (1980); Ahmed *et al.* (1982)
Additive, dominance and epistasis	Singh and Singh (1976b)
Non-additive and epistasis	Singh and Rai (1981)
Epistasis	Chung and Chang (1979); Gill *et al.* (1980)
Capsaicin content	
Additive	Brauer (1962); Qugliotti and Ottaviano (1971); Kvachadze (1973); Sharma and Saini (1977b); Bajaj *et al.* (1980); Park and Takatashi (1980)
Additive, dominance and epistasis	Ahmed *et al.* (1982)
Epistasis	Brauer (1963)
Carotene content-additive	Lippert (1975)

E. Inheritance of type of branching, fruiting habit, fruit orientation, destalkness and fruit colour in chilli

1. Branching habit

Webber (1912) reported first the breeding behaviour of branching habit in chilli. Dale (1931) based on a cross between Coal Gem and Anaheim, reported that the determinate character is recessively inherited. Ferenc (1970) also observed the monogenic and recessive inheritance of determinate growth habit in chilli. Anjeli (1974) reported that the ornamental form Capsicum annuum var. fasciculatum could be used as a source of gene for determinate habit.

In intra and interspecific crosses of Capsicum chinese Jacq. with Capsicum frutescens L. and Capsicum baccatum L., Berg and Lippert (1975) indicated a monogenic and recessive basis for the inheritance of axillary shooting which was designated as 'compact' with a gene symbol 'ct'. Considerable environmental effect on the expression of axillary shooting was observed by them.

Shifris and Hakin (1977) crossed Santaka with Csokros Fellalo and Yolo Wonder Y. Santaka is a Japanese cultivar with many axillary shoots developing acropetally along the main stem. It has fasciculate bearing habit.

Csokros Fellalo is a Hungarian bush and clustered cultivar devoid of axillary shoots. Yolo Wonder Y has a few axillary shoots prior to first bifurcation. F_1 and F_2 from the Santaka x Csokros Fellalo cross progenies showed partial dominance of many over a few axillary shoots. F_1 and F_2 from Santaka x Yolo Wonder Y, had partial dominance of a few over many shoots. They concluded that prebifurcation though a quantitative character was controlled by relatively a few genes with different action and was modified by environment.

McCammon and Honma (1984) used three inbred lines, M S U 78-101, M S U 79-221 and M S U 74-230 to study inheritance of the "Umbrella branching" habit in peppers. M S U 78-101 is a dwarf clustered variety. M S U 79-221 has the fasciculate gene, 'fa'. Plants after attaining a height of approximately 15 cm, terminated into a cluster of 2-6 fruits followed by initiation of several lateral branches each of which terminated in a cluster of fruits which matured uniformely. Umbrella phenotype was designated to this habit. M S U 74-230 was an indeterminate variety. Genetic analysis suggested that the Umbrella phenotype was controlled by three major recessive genes, 'ct' and 'dt' determining plant habit and 'fa' determining fruit bearing habit. When the dominant alleles

'Dt' and 'Ct' were in the dominant homozygous or heterozygous condition an indeterminate genotype was produced. 'Su' a dominant supressor gene apparantly acted to supress the epistatic action of the 'Ct' gene. Modifiers were also involved in the control of branching in the Umbrella plants.

In all the above reports the indeterminate varieties had solitary fruits and determinate varieties, clustered fruits.

2. Fruiting habit

For the first time, Ikno (1913) reported that the umbel form of fruiting habit was recessive to non-umbel form and the inheritance was monogenic (Boswell, 1937). Deshpande (1944) suggested a monogenic recessive inheritance of clustered fruiting habit in chilli. This was supported by the later workers .Kormos and Kormos (1956), Murthy and Murthy (1962), Anjeli (1964), Ferenc (1970), Barrios and Mosokar (1972), Ludilov (1977), Voronima and Ilenko (1981), Meshram (1983), McCammon and Honma (1984) and Okitsu et al. (1984).

Rajamani and Nagaratnam (1962) reported a clustered pendulous chilli from Madurai district of Tamil Nadu which has 3-6 flowers/cluster. Lippert et al. (1965) coined the symbol 'fa' for fasciculate, compact, bushy plants with shortened internodes. Lippert et al. (1966) pointed out that flowers/node was one of the morphological distinguishing characters in Capsicum sp. with one in Capsicum annuum, 2-3 in Capsicum frutescens and 3-5 in Capsicum chinense.

Ohta (1969) noted a solitary variant among the G_2 generation of a graft of a fasciculate cultivar. According to him this might have arisen by mutation from recessive 'fa' to dominant 'fa^+'. In Hungary, Oromos and Zatyko (1971) described a clustered pepper variety, Gepi Konzerv (Machine Preserving). The fruits were erect which ripened uniformly and was suitable for mechanical harvesting. Christov and Popova (1974) from Bulgaria reported erect clustered variety, Buketen, suited for mechanical harvesting. Awasthi et al. (1977) described a pungent clustered chilli variety from Almora (Utter Pradesh) with 228.8 fruits/plant.

From crosses of two clustered varieties Buketen 3 (Clustered-3) and Gibrid 208 (Hybrid 208) with normal varieties, Ludilov (1977) observed that all the F_1 plants were normal. The F_2 segregated in normal, clustered and intermediate. When the intermediate forms were assigned to the cluster group the phenotypic ratio was

3:1 in hybrids with Buketen 3 and 5:1 with Gibrid 208. In a cross between solitary and clustered (2-3 flowers/node) plants, Saccardo and Sreeramalu (1977) obtained F_1 plants which had two flowers/node.

Ramalingam (1978) identified a clustered variety, MDU-1, with compact habit, from the gamma irriadiated K-1 chilli variety. Voronima and Ilenko (1981) reported another clustered variety, Vinnipukh. Meshram (1983) in Akola observed a tall and vigorous clustered plant from the M_2 generation of Jwala, after treatment with 10 Kr gamma rays.

In an interspecific hybridization programme at the University of Florida, Subramania (1983) crossed Delray Bell (Capsicum annuum) with PI 159236 (Capsicum chinense). Delray Bell had single flower at all nodes except at the first branching point where two flowers were borne in a few plants. PI 159236 produced mostly flowers and fruits in cluster of three with an occasional occurence of one or two flowers at a few nodes. This plant was considered by them as multiple flowered. The F_1 plants had two flowers/node. Data from F_2, F_3 and back cross generations for two seasons indicated that a few major genes controlled the production of two flowers/node while additional genes were needed for multiple flowered habit. The abnormal morphological characters observed in the segregating population led them to suggest that meiotic irregularities may be occuring and this resulted in highly variable and unstable results for the multiple flower character.

Pious (1985) worked out genetics of cluster bearing habit in chilli. Cluster bearing habit was governed by two genes with a specific dominant and recessive epistasis. The F_1s were solitary and F_2s segregated into 13 solitary and 3 clustered. He did not observe maternal effect in the inheritance of cluster bearing habit.

3. Fruit orientation

Earlier reports on inheritance of fruit orientation, indicated heterozygotes to be intermediate i.e. more or less horizontal (Halsted, 1909; Webber, 1912, Ikeno, 1913). Classification of segregates was complicated in many crosses by intra-plant variability and by apparent changes in orientation on pod maturity resulting in upright, intermediate or pendulous fruits. Classification of plants for these phenotypes was well accomplished by observing behaviour throughout the fruiting period (Ikeno, 1928).

The gene 'up' (originally designated as 'u' and 'p') for upright pedicel is recessive to its allele 'up^+' for pendulous condition (Shaw and Khan, 1928). Deshpande (1933) and Miller and Fineman (1937) suggested monogenic inheritance for fruit orientation (3 pendulous : one erect fruited plant in F_2). But marked variations occured when the factor for fruit position was in a heterozygous condition.

Kaiser (1935) presented evidence that the single gene inheritance of fruit orientation operated through genetic determination of a specific geotropic growth response. Singh and Roy (1945), Hagiwara and Oomura (1947) and Odland (1948) further corroborated the view that fruit orientation was governed by a single gene with upright being recessive to pendulous. Sahrigy and Seehy (1974) reported that the gene 'up' controls the form of pedicel by its influence on cortical growth. The dominant homozygote took effect at the early stage of pedicel development, but heterozygote much later. Gene 'up^+' was therefore, regarded as incompletely dominant by them.

The monogenic dominant inheritance of pendulous orientation in chilli was later supported by Sayed and Bagavandass (1980), Saccardo (1981) and Okitsu et al. (1984).

4. Destalkness of fruit

The first report on deciduous fruit character in chilli was by Halsted (1913) who crossed five persistent varieties to a deciduous variety, Birds Eye Pepper. All the F_1 plants were deciduous and in the F_2, deciduous character reappeared. He did not maintain adequate F_2 population to establish the inheritance of the character.

Smith (1951) established a monogenic and dominant inheritance for deciduous character in *Capsicum annuum* L. The dominant gene gets expressed only late in the fruit ripening process resulting in an easy separation of the fruit from the pedicel. This character was designated as "soft flesh". The destalked character was observed in one line each of *Capsicum chacoense* Hunz. and in several lines from *Capsicum pubescense* Ruiz and Pavon, *Capsicum frutescens* L. and *Capsicum pendulum* Wild.

Spasogevic and Webb (1971) reported that an incompletely dominant gene controlled the destalked habit in chilli. The gene differed from the "soft flesh" character reported by Smith (1951). In another study Spasogevic and Webb (1972) observed that easy detachability of fruits was controlled by a major gene, 'Ps' which had a variable expression depending up on the presence of two modifier genes. The number of genes and genotype of the hybrid affected degree of dominance.

Ludilov (1976) observed that the inheritance of force needed to separate the fruit, was intermediate or closer to the parent with easier fruit separation. They could not observe reciprocal differences. In 1977, Ludilov et al. described three destalked varieties of bell pepper Swallow, Moldavian, Gift and Drooping. An evaluation of 100 varieties led Ludilov (1978) to observe that the fruits of Mikhalev, Siberian First Borne, Swallow and Cece White Pepper were the easiest to separate from the pedicel. Highly promising hybrids with easy detachability were developed from crosses involving Mikhalev. Singh et al. (1978) reported a chilli line 5412-8 with destalked character. The mean force required for fruit separation in "easy pick" plants was 0.20 kg compared with 1.65 kg force for the hard pick varieties (Davis and Barry, 1979).

Fruit detachment force was controlled by additive gene action (Werner and Honma, 1980). Setiamihardja and Knavel (1982) also reported additive gene action with epistasis and a very small control over the expression for destalkness. There was no difference between the reciprocal crosses. Saccardo (1981) designated the gene 'S' for easy calyx removal in pepper.

Uzo (1984) crossed Nsukka Yellow with Nsukka Red and Enugu. Nsukka Yellow is destalked and Nsukka Red and Enugu are strongly stalked. The two F_1s had fleshy and strongly attached fruits. The F_2 and back cross generations segregated confirming monogenic inheritance, fleshy pedicel with strong attachment being dominant.

5. Mature fruit colour

Earlier works on the inheritance of mature fruit colours were limited to discrete colours like red, yellow, brown and green. Information on the inheritance of colour gradations are very much lackingin chilli.

Brown and green mature fruit colours were controlled by the recessive chlorophyll retainer gene 'cl' in combination with 'y^+' and 'y'. With 'cl' present, chlorophyll remains as the fruit matures. When 'cl' combined with 'y^+' (Red), a brown mature fruit colour (y^+y^+ clcl) resulted, where as with 'y' (yellow) a yellowish (yy cl^+cl^+) or olive green (yy clcl) colour was produced (Smith,1948, 1950; Kormos and Kormos, 1956).

Kormos (1954) observed that the levels of eigh pigments in the red fruited F_1 progengy of a cross between red x yellow types, exactly matched the pigment content of the red fruited parent. Similarly, pigments in the red and yellow F_2 segregants matched the respective parental types, suggesting total pigments to be controlled by the same factor.

More extensive studies with various colour shades from red to ivory indicated action of three gene pairs 'y' and 'y^+', 'C_1' and 'C_1^+' (originally 'C' and 'C^+'), and 'C_2' and 'C_2^+' (originally 'C_1' and 'C_1^+') (Kormos and Kormos, 1960; Kormos, 1962). The factors C_1 and C_2 reduced colours of 'y^+' and 'y' by inhibition of the beta carotene system with 'C_1' causing approximately $\frac{1}{10}$ reduction in red pigments. With 'C_2' present, red pigments occured only in traces. Colour development under this three gene pair system was postulated as follows:

y^+-	c_1^+-	Red
y^+-	$c_1\ c_1$	Salmon red
y^+-	$c_2\ c_2$	Pink
y y	c_1^+-	Orange
y y	$c_1\ c_1$	Lemon yellow
y y	$c_2\ c_2$	Ivory or white

Brauer (1962) analysed beta carotene in mature fruit and suggested the action of additive genes. He proposed the action of two genes, 'B' and 't' for high beta carotene content. Both 'B' and 't^+' were incompletely dominant with 'BB tt' producing high beta carotene (188 mg/100 g of dry powder), 'BB t^+t^+' intermediate levels (90-101 mg) and 'B^+B^+ t^+t^+' low levels (37-46 mg). The heterozygotic condition 't^+t' was stated to be completely epistatic to 'B^+B' but not to 'BB'.

The gene designation 'g' by Brauer (1962) was synonymous with 'cl' of Smith (1948). Laborde and Spurr (1973) suggested 'y^+' gene for increase in total carotenoid and red pigment contents in chilli.

Materials and Methods

MATERIALS AND METHODS

The studies were conducted at the College of Horticulture, Kerala Agricultural University, Vellanikkara during 1979-'83. The experimental farm is located at an altitude of 22.5 m above m s l and is situated between 70°32'N latitude and 76°16'E longitude. Geographically it falls in the warm humid tropical climatic zone. The soil type of experimental site is sandy loam with a pH of 5.1.

The experiments consisted of following:

A. Genetic variability and divergence in chilli
B. Combining ability analysis in chilli
C. Heterosis in chilli
D. Components of gene action through generation mean analysis in chilli
E. Inheritance of type of branching, fruiting habit, fruit orientation and destalkness in chilli

A. Genetic variability and divergence in chilli

1. Experimental materials

The chilli lines from the germplasm maintained at the Department of Olericulture, College of Horticulture, Vellanikkara were utilized for the preliminary evaluation.

Thirty eight lines divergent for earliness, plant type, fruiting habit etc. were grown in a randomised block design with three replications during July-November, 1979 to assess the extent of genetic variability and to select lines for further study. The thirty eight chilli lines along with an additional eight new lines were grown again during May-September, 1980 in a randomised block design with three replications. Plants were grown in ridges at a spacing of 60 x 45 cm. There were ten plants/genotype/replication. Crop management was done as per package of practices (Kerala Agricultural University, 1978).

The key morphological description of the 46 chilli lines are given below:

A Determinate growth habit, fruits in clusters

AB Fruits pendulous - CA 23

ABB Fruits upright

ABBC Corolla white with violet border - CA 56, CA 56-1

ABBCC Corolla white

ABBCCD Fruits stalked - CA 6, CA 6-1, CA 10-1, CA 19-1, CA 19-2, CA 19-3, CA 24-1, CA 24-2, CA 26-1, CA 30-1, CA 30-2, CA 32, CA 36, CA 36-1, CA 39-1, CA 43, CA 45, CA 47, CA 48, CA 52, CA 54, CA 54-1, CA 59

ABBCCDD Fruits destalked - CA 33

AA Indeterminate growth habit, fruits solitary

AAB Fruits pendulous

AABC Fruit surface crinkled - Jwala (CA 60), CA 60-1, NP 46-A (CA 68)

AABCC Fruit surface smooth

AABCCD Immature fruit cream white - CA 99

AABCCDD Immature fruit green

AABCCDDE Fruits slender - G-4 (CA 87)

AABCCDDEE Fruit base bulging

AABCCDDEEF Plants tall - CA 113

AABCCDDEEFF Plants medium tall - CA 69, K-2 (CA 94), CA 111, CA 120

AABB Fruits upright

AABBC Immature fruit purple - CA 110, CA 115, CA 118

AABBCC Immature fruit cream white - CA 3, CA 89

AABBCCC Immature fruit green

AABBCCCD Plants tall, spreading, leaf big and ovate - CA 112, CA 116, CA 119

AABBCCCDD Plants bush to medium tall, leaf small and ovate-lanceolate

AABBCCCDDE Flowering and fruiting at the same height - Pant C-1 (CA 53)

AABBCCCDDEE No uniformity in canopy - CA 12

2. Observations recorded

Five plants/genotype/replication were tagged randomly to take observations on the following quantitative characters:

a. Plant height (cm) - from base to the top of the plant
b. Main stem length - from base to the first fruiting point
c. Primary branches/plant
d. Fruit length (cm)
e. Fruit girth (cm) - diameter of the fruit
f. Average fruit weight (g)
g. Fruits/plant
h. Fruit yield/plant (g) - fresh weight
i. Days to flower
j. Days to red chilli harvest

3. Statistical analysis

a. Analysis of variance

The data were analysed for the analysis of variance as described by Ostle (1966) for a randomised block design.

Variability for different quantitative characters was estimated as suggested by Burton (1952). The formulae used in the estimation of variability at genotypic and phenotypic levels are:

i. Genotypic coefficient of variation (gcv) =

$$\frac{\text{genotypic standard deviation}}{\text{mean of the character}} \times 100$$

ii. Phenotypic coefficient of variation (pcv) =

$$\frac{\text{phenotypic standard deviation}}{\text{mean of the character}} \times 100$$

iii. Standard error of mean = $\frac{\text{environmental standard deviation}}{\sqrt{\text{replications}}}$

Environmental variance = mean square due to error

Genotypic variance =

$$\frac{\text{mean square due to genotype - mean square due to error}}{\text{replications}}$$

Phenotypic variance = genotypic variance + error variance

iv. Heritability in the broad sense was estimated by the formula suggested by Burton and Devane (1953).

$$h^2_{(b)} = \frac{\text{genotypic variance}}{\text{phenotypic variance}}$$

v. Expected genetic advance at 5% intensity of selection was calculated using the formula of Johnson *et al*. (1955).

$$GA = h^2 \times \sigma p \times i$$

where, h^2 = heritability

σp = phenotypic standard deviation

i = coefficient of intensity of selection (2.06 at p=0.05)

vi. Genetic advance (%) = $\frac{\text{genetic advance}}{\text{mean of the character}} \times 100$

b. Genetic divergence

The genetic distances among 38 chilli genotypes were calculated considering all the ten quantitative characters in the somatic analysis. The method suggested by Mahalanobis

(1928) was used to estimate the D^2 with $X_1, X_2, X_3, \ldots, X_{10}$ as the multiple measurements available on each genotype and $d_1, d_2, d_3, \ldots, d_{10}$ as $\bar{X}_1^1 - \bar{X}_1^2, \bar{X}_2^1 - \bar{X}_2^2, \bar{X}_3^1 - \bar{X}_3^2, \ldots, \bar{X}_{10}^1 - \bar{X}_{10}^2$ being the differences in the means of two genotypes where power denotes genotypes and suffix denotes the characters. Mahalanobis D^2 statistic is defined as follows:

$D^2 = b_1d_1 + b_2d_2 + b_3d_3 + \ldots + b_{10}d_{10}$. Here, the b_i values were estimated such that the ratio of variance between the genotypes to the variance within the genotypes was maximised.

$D_p^2 = \sum_i \sum_j W^{ij} (\bar{X}_i^1 - \bar{X}_i^2)(\bar{X}_j^1 - \bar{X}_j^2)$ where, W^{ij} is the i,j^{th} element of the inverse of estimated variance-covariance matrix.

Grouping of varieties to clusters was done by Tocher's method (Rao, 1952).

B. Combining ability analysis in chilli

1. Experimental materials

Based on evaluation of chilli lines for two seasons, four diverse parents viz., Jwala, Pant C-1, CA 33 and CA 23 (Plates I to IV) were selected to generate half diallel crosses. The four parents along with six F_1 hybrids were

Plate I. Jwala

Plate II. Pant C-1

Plate III. CA 33

Plate IV. CA 23

grown during May-September, 1981 in a completely randomised block design. All the plants in each line were used to take observations. The morphological description of the parental lines are given in Table 4.

2. Observations recorded

a. Plant height (cm)
b. Primary branches/plant
c. Leaf laminar length (cm)
d. Fruit length (cm)
e. Fruit girth (cm)
f. Average fruit weight (g)
g. Fruits/plant
h. Fruit yield/plant (g)
i. Days to flower

3. Statistical analysis

Analysis of variance was conducted to study the extent of differences among the chilli lines and hybrids.

a. Combining ability analysis

The procedure of Griffing (1956) for model 1, method 2 was followed for this study. The analysis of variance with the expected mean square is given in Table 5.

Table 4. Morphological description of four parental lines in chilli

Sl. No.	Characters	Parents			
		Jwala	Pant C-1	CA 33	CA 23
1.	Branching habit	indeterminate	indeterminate	determinate	determinate
2.	Fruiting habit	solitary	solitary	clustered	clustered
3.	Fruit orientation	pendulous	upright	upright	pendulous
4.	Fruit surface	crinkled	smooth	smooth	smooth
5.	Fruit length	long	medium	medium	medium
6.	Destalkness	stalked	stalked	destalked	stalked
7.	Fruit colour	light red	light red	deep red	light red

Table 5. Analysis of variance for combining ability

Source	df	SS	MS	Expected MS
g c a	$p-1$	S_g	M_g	$\sigma_e^2 + \sigma_s^2 + (p+2)\,\sigma_g^2$
s c a	$\frac{p(p-1)}{2}$	S_s	M_s	$\sigma_e^2 + \sigma_s^2$
error	m	S_e	M'_e	σ_e^2

where, $S_g = \frac{1}{p+2} \sum_i (Y_{i.} + Y_{ii})^2 - \frac{4}{p} Y_{..}^2$

$$S_s = \sum_{i \leq j} \sum Y_{ij}^2 - \frac{1}{p+2} \sum (Y_{i.} + Y_{ii})^2 + \frac{2}{(p+1)(p+2)} Y_{..}^2$$

p = number of parents involved (4)

$$M'_e = \frac{\text{expected error mean square}}{\text{number of plants/line}}$$

General combining ability effects, g_i and specific combining ability effects, s_{ij} were estimated as follows:

$$g_i = \frac{1}{p+2} \left[(Y_{i.} + Y_{ii}) - \frac{2}{p} Y_{..} \right]$$

$$s_{ij} = Y_{ij} - \frac{1}{p+2} (Y_{i.} + Y_{ii} + Y_{.j} + Y_{jj}) + \frac{2}{(p+1)(p+2)} Y_{..}$$

$$SE(g_i) = \left[\frac{(p-1)\,\sigma_e^2}{p(p+2)} \right]^{\frac{1}{2}}$$

$$SE(s_{ij}) = \left[\frac{(p^2 + p+2)\,\sigma_e^2}{(p+1)\ (p+2)} \right]^{\frac{1}{2}}$$

$$SE(g_i - g_j) = (2\sigma_e^2/n+2)^{\frac{1}{2}}$$

$$SE(s_{ij}-s_{ik}) = \left[\frac{2(n+1)\,\sigma e^2}{n+2}\right]^{\frac{1}{2}}$$

$$SE(s_{ij}-s_{kl}) = \left[\frac{2n\,\sigma e^2}{n+2}\right]^{\frac{1}{2}}$$

b. Graphic analysis

The graphic analysis proposed by Jinks and Hayman (1953) and Hayman (1954) was used to understand gene action from the diallel data.

The validity of the hypothesis was tested through regression (b) of covariance (Wr) on variance (Vr).

$$b = \frac{\text{Cov. (Wr,Vr)}}{\text{Var. Vr}}$$

$$SE(b) = \left[\frac{\text{Var. Wr-b Cov. (Wr Vr)}}{\text{Var. Vr x (p-2)}}\right]^{\frac{1}{2}}$$

where, Vr = the variance of the progeny means in the array of the r^{th} parent when the array is composed of parental means and mean values of all the crosses involving that parent.

Wr = covariance of the progeny means in the r^{th} parental array with the mean values of non-recurrent parent.

p = number of parents involved in the cross.

The significance of b from zero and unity were tested as $\frac{|b - 0|}{SE(b)}$ and $\frac{|1 - b|}{SE(b)}$. Both values were tested with table value of 't' at (p-2) degrees of freedom.

In the graph, Vr is taken along the X axis and Wr along the Y axis. Limits of Wr - Vr graph are marked by a parabolic curve with the equation

$$Wr = \sqrt{Vr \times V_0L_0} \text{ for each } Vr$$

where, V_0L_0 is the variance of parental mean.

The array values were represented by plotting points against their values of Vr and Wr in the graph.

C. Heterosis in chilli

The performance of parents and their six F_1 hybrids grown during May-September 1981 were considered for estimation of heterosis. Heterosis over mid-parent (relative heterosis) and better-parent (heterobeltiosis) were worked out as suggested by Briggle (1963) and Hayes et al. (1965). The significance of heterosis was tested by Students 't' test at (n-1) degrees of freedom.

D. Components of gene action through generation mean analysis in chilli

1. Experimental materials

Six F_1 hybrids developed by crossing four parents viz., Jwala, Pant C-1, CA 33 and CA 23 in a half diallel were selfed to generate corresponding F_2s. The F_1s were back crossed to either parents to develop back cross progenies. P_1, P_2, F_1, F_2, BC_1 and BC_2 from half diallel of above four parents were grown during May-September, 1983 in ridges and furrows at a spacing of 60 x 45 cm. There were about 50 plants under parental and F_1 generations and 350 plants under F_2 and back cross generations.

2. Observations recorded

a. Plant height (cm)
b. Main stem length (cm)
c. Primary branches/plant
d. Internodal length (cm)
e. Internodal girth (cm)
f. Leaf laminar length (cm)
g. Fruit length (cm)
h. Fruit girth (cm)
i. Average fruit weight (g)
j. Locules/fruit
k. Fruits/plant
l. Fruit yield/plant (g) (red chilli)
m. Days to flower
n. Capsaicin content (%). Capsaicin content was measured by following the procedure of Quagliotti (1971). Sun dried red ripe chillies were oven-dried, ground to a fine powder and analysed for their capsaicin content. The colour was developed with phospho-molybdic acid in acetone extracts of chilli powder and it turned turbid after one hour. The turbidity was removed by quick filteration and subsequent centrifuging. The absorbance of clear solution was measured at 650 nm. It was compared with standard curve drawn with pure capsaicin.
o. Total colouring matter (ppm). Sun dried ripe fruits

were oven-dried, ground to fine powder and used to estimate total carotenoid pigment. The colour pigment extracted in water saturated n-butyl alcohol was measured at 435.8 nm after quick filteration and was expressed as total carotenoid pigments in ppm (AOAC, 1980).

3. Statistical analysis

a. Scaling tests

Estimates of additive (D) and dominance (H) components of genetic variance were made using the means and variances of six populations - P_1, P_2, F_1, F_2, BC_1 and BC_2. Scaling tests suggested by Mather (1949) were carried out to detect the presence of non-allelic interaction.

$$A = 2\bar{B}_1 - \bar{P}_1 - \bar{F}_1$$

$$V(A) = 4V(\bar{B}_1) + V(\bar{P}_1) + V(\bar{F}_1)$$

$$B = 2\bar{B}_2 - \bar{P}_2 - \bar{F}_1$$

$$V(B) = 4V(\bar{B}_2) + V(\bar{P}_2) + V(\bar{F}_1)$$

$$C = 4\bar{F}_2 - 2\bar{F}_1 - \bar{P}_1 - \bar{P}_2$$

$$V(C) = 16V(\bar{F}_2) + 4V(\bar{F}_1) + V(\bar{P}_1) + V(\bar{P}_2)$$

$$D = 2\bar{F}_2 - \bar{B}_1 - \bar{B}_2$$

$$V(D) = 4V(\bar{F}_2) + V(\bar{B}_1) + V(\bar{B}_2)$$

The fitness of models depended on two conditions namely, additivity of gene effects and independence of heritable components from non-heritable components.

b. Generation mean analysis

i. Three parameter model

In the absence of non-allelic interaction, three parameter model as suggested by Jinks and Jones (1958) was used.

$$m = \frac{1}{2}\bar{P}_1 + \frac{1}{2}\bar{P}_2 + 4\bar{F}_2 - 2\bar{B}_1 - 2\bar{B}_2$$

$$V(m) = \frac{1}{4}V(\bar{P}_1) + \frac{1}{4}V(\bar{P}_2) + 16V(\bar{F}_2) + 4V(\bar{B}_1) + 4V(\bar{B}_2)$$

$$d = \frac{1}{2}\bar{P}_1 - \frac{1}{2}\bar{P}_2$$

$$V(d) = \frac{1}{4}V(\bar{P}_1) + \frac{1}{4}V(\bar{P}_2)$$

$$h = 6\bar{B}_1 + 6\bar{B}_2 - 8\bar{F}_2 - \bar{F}_1 - \frac{3}{2}\bar{P}_1 - \frac{3}{2}\bar{P}_2$$

$$V(h) = 36V(\bar{B}_1) + 36V(\bar{B}_2) + 64V(\bar{F}_2) + V(\bar{F}_1) + \frac{9}{4}V(\bar{P}_1) + \frac{9}{4}V(\bar{P}_2)$$

ii. Six parameter model

In the presence of non-allelic interaction as indicated by the significance of scaling tests, six parameter model was used as given by Hayman (1958).

$$m = \bar{F}_2$$

$$V(m) = V(\bar{F}_2)$$

$$d = \bar{B}_1 - \bar{B}_2$$

$$V(d) = V(\bar{B}_1) + V(\bar{B}_2)$$

$$h = \bar{F}_1 - 4\bar{F}_2 - \frac{1}{2}\bar{P}_1 - \frac{1}{2}\bar{P}_2 + 2\bar{B}_1 + 2\bar{B}_2$$

$$V(h) = V(\bar{F}_1) + 16V(\bar{F}_2) + \frac{1}{4}V(\bar{P}_1) + \frac{1}{4}V(\bar{P}_2) + 4V(\bar{B}_1) + 4V(\bar{B}_2)$$

$$i = 2\bar{B}_1 + 2\bar{B}_2 - 4\bar{F}_2$$

$$V(i) = 4V(\bar{B}_1) + 4V(\bar{B}_2) + 16V(\bar{F}_2)$$

$$j = \bar{B}_1 - \frac{1}{2}\bar{P}_1 - \bar{B}_2 + \frac{1}{2}\bar{P}_2$$

$$V(j) = V(\bar{B}_1) + \frac{1}{4}V(\bar{P}_1) + V(\bar{B}_2) + \frac{1}{4}V(\bar{P}_2)$$

$$l = \bar{P}_1 + \bar{P}_2 + 2\bar{F}_1 + 4\bar{F}_2 - 4\bar{B}_1 - 4\bar{B}_2$$

$$V(l) = V(\bar{P}_1) + V(\bar{P}_2) + 4V(\bar{F}_1) + 16V(\bar{F}_2) + 16V(\bar{B}_1) + 16V(\bar{B}_2)$$

Where,

m = mean

d = additive effect

h = dominance effect

i = additive x additive interaction

j = additive x dominance interaction

l = dominance x dominance interaction

The significance of the above genetic parameters were tested using 't' test.

c. Degree of dominance

Proportion between dominance and additive variances was calculated by solving the following equations:

$$V(F_2) = \frac{1}{2}D + \frac{1}{4}H + E$$

$$V(B_1) + V(B_2) = \frac{1}{2}D + \frac{1}{2}H + E$$

where,

$$E = \frac{V(P_1) + V(P_2) + V(F_1)}{3}$$

$$\text{Degree of dominance} = \sqrt{\frac{H}{D}}$$

d. Effective factors

The number of effective factors were calculated by the following formulae:

$$K_1 = \frac{\left[(\bar{P}_1 - \bar{P}_2)/2\right]^2}{D}$$

$$K_2 = \frac{\left[\bar{F}_1 - (\bar{P}_1 + \bar{P}_2)/2\right]^2}{H}$$

E. Inheritance of type of branching, fruiting habit, fruit orientation and destalkness in chilli

The six generations P_1, P_2, F_1, F_2, BC_1 and BC_2 of four diverse parents grown during May-September, 1983 were considered to derive the inheritance pattern of characters.

1. Experimental materials

a. Branching and fruiting habit

There were three sets of progenies

i) Set-1

P_1 - Jwala (indeterminate and solitary)
P_2 - CA 33 (determinate and clustered)
F_1 - Jwala x CA 33
F_2 - Jwala x CA 33
BC_1 - (Jwala x CA 33) x Jwala
BC_2 - (Jwala x CA 33) x CA 33

ii) Set-2

P_1 - Pant C-1 (indeterminate and solitary)
P_2 - CA 33 (determinate and clustered)
F_1 - Pant C-1 x CA 33
F_2 - Pant C-1 x CA 33
BC_1 - (Pant C-1 x CA 33) x Pant C-1
BC_2 - (Pant C-1 x CA 33) x CA 33

iii) Set-3

P_1 - Jwala (indeterminate and solitary)
P_2 - CA 23 (determinate and clustered)
F_1 - Jwala x CA 23
F_2 - Jwala x CA 23
BC_1 - (Jwala x CA 23) x Jwala
BC_2 - (Jwala x CA 23) x CA 23

b. Fruit orientation

There were three sets of progenies

i) Set-1

P_1 - Jwala (pendulous)
P_2 - Pant C-1 (upright)
F_1 - Jwala x Pant C-1
F_2 - Jwala x Pant C-1
BC_1 - (Jwala x Pant C-1) x Jwala
BC_2 - (Jwala x Pant C-1) x Pant C-1

ii) Set-2

P_1 - Jwala (pendulous)
P_2 - CA 33 (upright)
F_1 - Jwala x CA 33
F_2 - Jwala x CA 33
BC_1 - (Jwala x CA 33) x Jwala
BC_2 - (Jwala x CA 33) x Ca 33

iii) Set-3

P_1 - CA 33 (upright)
P_2 - CA 23 (pendulous
F_1 - CA 33 x CA 23
F_2 - CA 33 x CA 23
BC_1 - (CA 33 x CA 23) x CA 33
BC_2 - (CA 33 x CA 23) x CA 23

c. Destalkness

There were three sets of progenies

i) Set-1

P_1 - Jwala (stalked)
P_2 - CA 33 (destalked)
F_1 - Jwala x CA 33
F_2 - Jwala x CA 33
BC_1 - (Jwala x CA 33) x Jwala
BC_2 - (Jwala x CA 33) x CA 33

ii) Set-2

P_1 - Pant C-1 (stalked)
P_2 - CA 33 (destalked)
F_1 - Pant C-1 x CA 33
F_2 - Pant C-1 x CA 33
BC_1 - (Pant C-1 x CA 33) x Pant C-1
BC_2 - (Pant C-1 x CA 33) x CA 33

iii) Set-3

P_1 - CA 33 (destalked)
P_2 - CA 23 (stalked)
F_1 - CA 33 x CA 23
F_2 - CA 33 x CA 23
BC_1 - (CA 33 x CA 23) x CA 33
BC_2 - (CA 33 x CA 23) x CA 23

2. Qualitative characters studied

a. Branching habit - determinate/indeterminate

b. Fruiting habit - solitary/clustered

Those plants which bore more than two fruits at a node other than the first forking point were considered clustered.

c. Fruit orientation - pendulous/upright

d. Destalked nature of fruit - destalked/stalked

Plants which required less force to detach fruits from the pedicel were considered as destalked. The pedicel remained with the plant after the harvest of fruit. Since the expressivity of destalked character was not complete the method suggested by Avdeyev (1979) was used to calculate expected values.

3. Statistical analysis

The agreement of the observed values with the expected was tested by the χ^2 test of "goodness of fit" with (n-1) degrees of freedom, where, n is the number of classes (Panse and Sukhatme, 1954).

Results

RESULTS

The data from the present investigations were statistically analysed and are presented under the following heads:

A. Genetic variability and divergence in chilli

B. Combining ability analysis in chilli

C. Heterosis in chilli

D. Components of gene action through generation mean analysis in chilli

E. Inheritance of type of branching, fruiting habit, fruit orientation and destalkness in chilli

A. Genetic variability and divergence in chilli

1. Variability, heritability and genetic advance

General analysis of variance indicated significant differences among 38 chilli genotypes during the first season (Table 6). Forty six genotypes also had significant differences during second season except for primary branches/plant. The performance of 38 chilli genotypes during the first season and 46 genotypes during the second season are appended (Appendix-I).

Table 6. General analysis of variance for 10 quantitative characters in chilli

Source of variation	df	Mean squares									
		Plant height	Main stem length	Primary branches/ plant	Fruit length	Fruit girth	Average fruit weight	Fruits/ plant	Fruit yield/ plant	Days to flower	Days to red chilli harvest
Replications											
S-1	2	43.3	35.1	11.1	0.41	0.009	0.002	855.6	1201.1	23.6	18.5
S-2	2	4.7	43.6	15.9	0.08	0.004	0.004	3143.4	2515.8	21.2	2.2
Genotypes											
S-1	37	758.2**	1646.5**	15.2**	11.68**	0.025**	0.640**	8927.9**	12887.9**	102.8**	136.8**
S-2	45	1401.8**	2908.4**	7.8	22.89**	0.086**	0.680**	65767.6**	16409.9**	249.6**	390.2**
Error											
S-1	74	51.5	39.1	5.2	0.34	0.003	0.053	1970.6	2755.2	11.6	11.8
S-2	90	95.1	34.0	7.3	0.31	0.003	0.032	5079.5	1468.4	9.6	13.3

*Significant at $p = 0.05$; ** Significant at $p = 0.01$

The mean, range, coefficients of variation at genotypic and phenotypic levels, heritability and expected genetic advance of ten quantitative characters observed are given in Table 7.

a. Plant height

Plant height ranged from 48.90 cm in Pant C-1 to 130.50 cm in CA 89 during the first season with a general mean of 74.97 cm. During the second season the range was from 50.30 to 133.60 cm. CA 115 was the tallest during second season (133.60 cm), Jwala had a comparatively dwarf stature (52.40 cm). Heritable variation for plant height was higher than non-heritable variation as indicated by high heritability. Heritability was 0.82 with a higher genetic advance as per cent of mean (48.92).

b. Main stem length

Main stem length ranged from 34.70 to 127.50 cm with a general mean of 51.63 cm. There were significant differences for main stem length between determinate varieties (CA 33, 38.80 cm; CA 23, 36.50 cm) and indeterminate varieties (Jwala, 60.60 cm; NP 46 A, 60.30 cm). Heritable variation was much higher than the non-heritable variation (p c v, 46.42; g c v, 44.61) and it resulted in a high estimate of heritability (0.93). The genetic advance as per cent of mean was higher in both the seasons (88.92 in first season and 111.65 in second season).

Table 7. Range, Mean genotypic (g c v) and phenotypic (p c v) coefficients of variation, heritability and expected genetic advance

Characters		Range	Mean ± sem	g c v	p c v	Heritability	Genetic advance	Genetic advance (%)
Plant height (cm)	S-1	48.90 - 130.50	74.97 ± 4.14	20.47	22.60	0.82	28.66	38.22
	S-2	50.30 - 133.60	79.54 ± 5.64	26.24	28.97	0.82	38.31	48.92
Main Stem length (cm)	S-1	34.70 - 127.50	51.63 ± 3.60	44.61	46.42	0.93	45.91	88.92
	S-2	31.00 - 129.70	56.38 ± 3.37	54.90	55.87	0.97	62.95	111.65
Primary branches/ plant	S-1	6.10 - 15.30	9.14 ± 1.32	19.91	31.94	0.38	2.28	24.95
	S-2	7.30 - 13.00	9.82 ± 1.56	4.18	27.80	0.02	0.11	1.12
Fruit length (cm)	S-1	2.90 - 10.50	4.60 ± 0.34	42.17	43.91	0.92	3.81	82.72
	S-2	1.90 - 13.80	4.73 ± 0.32	57.94	59.21	0.96	5.54	117.15
Fruit girth (cm)	S-1	0.62 - 0.97	0.79 ± 0.03	10.55	12.86	0.67	0.14	17.83
	S-2	0.32 - 0.94	0.76 ± 0.03	21.88	22.85	0.92	0.33	43.31
Average fruit weight (g)	S-1	1.09 - 2.68	1.49 ± 0.13	29.79	33.51	0.79	0.81	54.55
	S-2	0.18 - 2.74	1.21 ± 0.10	38.45	41.17	0.87	0.89	73.78
Fruits/plant	S-1	26.50 - 329.70	136.50 ± 25.63	35.28	47.98	0.54	72.94	53.44
	S-2	82.00 - 703.40	211.65 ± 41.15	67.20	75.16	0.80	261.95	123.76
Fruit yield/ plant (g)	S-1	59.40 - 390.20	179.86 ± 30.31	32.31	43.54	0.55	88.85	49.40
	S-2	97.20 - 444.60	172.92 ± 22.15	40.81	46.44	0.77	127.39	73.67
Days to flower	S-1	37.90 - 65.30	49.86 ± 1.97	11.07	13.00	0.72	9.62	19.29
	S-2	35.20 - 69.70	47.91 ± 1.79	18.68	19.75	0.89	17.35	36.21
Days to red chilli harvest	S-1	74.30 - 102.20	88.58 ± 1.99	7.52	8.51	0.78	11.76	13.70
	S-2	73.90 - 113.00	84.45 ± 2.11	13.27	13.96	0.90	21.86	25.89

S-1 = July - November, 1979; S-2 = May - September, 1980.

c. Primary branches/plant

Primary branches/plant ranged narrowly from 6.10 to 15.30 with a mean of 9.14 during the first season. The environmental effect was high as evidenced by low g c v (19.91) compared to p c v (31.94). Heritability (0.38) and expected genetic advance as per cent of mean (24.95) were also low for this character.

d. Fruit length

Significant variation among genotypes was observed for fruit length (range, 2.90 to 10.50 cm). CA 60-1, a selection from Jwala had the longest fruits (13.80 cm) followed closely by Jwala (13.20 cm) and NP 46 A (12.80 cm). A few chilli genotypes evaluated during the second season had only small fruits (CA 110 and CA 118, 1.90 cm each). The phenotypic differences among the lines were mainly genetical (p c v, 43.91; g c v, 42.17), as indicated by high estimate of heritability (0.92). The expected genetic advance as per cent of mean was also very high during the second season (117.15).

e. Fruit girth

Fruit girth averaged 0.79 cm during the first season and 0.76 cm during the second season. Fruit thickness was maximum in CA 19-2 (0.97 cm) closely followed by K-2 (0.94 cm). Fruit girth had only a very low estimate of heritability (0.67) and genetic advance (17.83%) during the first season. During the second season, heritability for this character was 0.92.

f. Average fruit weight

Average fruit weight ranged from 1.09 g in CA 56 to 2.68 g in K-2 during the first season and 0.18 g in CA 118 to 2.74 g in CA 60-1 during the second season with a mean of 1.49 and 1.21 g respectively. Fruit weight in Jwala and NP 46 A were also above 2 g.

The contribution of genotype in the total expression of fruit weight was moderately high as indicated by a fairly high estimate of heritability (0.87). The expected genetic advance as per cent of mean was medium to high for this character (54.55 during first season and 73.78 during second season).

g. Fruits/plant

Fruits/plant ranged from 26.50 in CA 47 to 329.70 in CA 3 with a general mean of 136.50 during the first season. During the second season fruits/plant ranged widely (82.00 to 703.3). Maximum fruits were harvested from the genotype CA 3 (329.7) followed by CA 48 (253.30), CA 45 (202.80), CA 89 (180.70) and Pant C-1 (178.10) during the first season and CA 112 (703.40), CA 118 (597.60), CA 110 (558.30) and CA 119 (551.30) during the second season. Fruits/plant recorded maximum variation in the second season (g c v, 67.20;

p c v, 75.16). The heritability though moderate in the first season (0.54) was high in the second season (0.80). Maximum genetic advance as per cent of mean was also recorded in this character during the second season (123.76).

h. Fruit yield/plant

Yield of red ripe chillies ranged from 59.40 g/plant in CA 47 to 390.20 g in CA 3. The average yield of 38 chilli lines was 179.86 g/plant while that of 46 varieties was 172.92 g/plant. During the first season, CA 3 was followed by CA 48 (328.9 g), CA 53 (281.4 g), CA 36-1 (268.4 g), CA 52 (263.9 g), Jwala (260.6 g), CA 54-1 (232.0 g), CA 60-1 (224.0 g), NP 46 A (217.1 g), CA 45 (211.3 g) and CA 33 (195.6 g). During the second season yield/plant ranged from 97.20 g in CA 59 to 444.60 g in CA 30-2, followed by CA 119 (333.8 g) and CA 113 (294.9 g).

Medium values of phenotypic and genotypic coefficients of variation (43.54 and 32.31 respectively) were observed during the first season with a heritability of 0.55. The expected genetic advance as per cent of mean was also low to medium (49.4). The extent of variability, heritability and genetic advance were comparatively higher during the second season (p c v, 46.44; heritability, 0.77; genetic advance (%), 73.67).

i. Days to flower

CA 99 was the earliest (37.9 days) to flower closely followed by Jwala (39.5 days), CA 60-1 (39.8 days), CA 69 (40.8 days) and NP 46 A (42.9 days). CA 3 flowered last and took 65.3 days to flower. Many of the clustered lines were late to flower (CA 33, 54.1 days; CA 23, 53.8 days). During the second season, Jwala flowered earlier (35.2 days after planting). CA 116 took 69.7 days to flower.

The extent of variation among chilli genotypes was very low (g c v, 11.07; p c v, 13.00). Even though heritability estimate was moderately high (0.72) the expected genetic advance was very low during both the seasons.

j. Days to red chilli harvest

Fruits of CA 99, Jwala and CA 60-1 became red enough to harvest within 75 days after planting. This was followed by CA 56-1 (77.1 days), Pant C-1 (77.5 days), CA 59 (77.6 days) and NP 46 A (78.7 days) during the first season. The white immature fruits of CA 3 became red for harvest only 102.2 days after planting. During the second season, CA 115 took 113.0 days to first red chilli harvest, followed by CA 116 (111.9 days), CA 119 (111.4 days) and CA 3 (102.2 days). On an average, the chilli genotypes were ready to harvest by 86 days after planting.

The variation among varieties for this character was also low (p c v, 13.96; g c v, 13.27). Heritability though moderately high (0.78 during first season and 0.90 in second season), expected genetic advance as per cent of mean was very low (13.70) for this character.

2. Genetic divergence among 38 chilli genotypes

The D^2 values computed for 703 pairs of chilli genotypes ranged from 3.09 (between genotypes CA 12 and CA 54-1) to 360.98 (between genotypes CA 3 and Bhagyalakshmy). Following Tocher's method, 38 lines were grouped into five clusters. Data relating to the number of clusters formed and the number of genotypes/cluster are given in Table 8.

Table 8. Clustering pattern in chilli

Cluster number	No.of genotypes in each cluster	Varieties/genotypes
I	29	CA 6, CA 6-1, CA 10-1, CA 12, CA 19-1, CA 19-2, CA 19-3, CA 23, CA 24-1, CA 24-2, CA 26-1, CA 30-1, CA 30-2, CA 32, CA 33, CA 36, CA 36-1, CA 39-1, CA 43, CA 45, CA 47, CA 48, CA 52, Pant C-1, CA 54, CA 54-1, CA 56, CA 56-1, CA 59.
II	6	Jwala, CA 60-1, NP 46-A, CA 89, K-2, CA 99
III	1	Bhagyalakshmy
IV	1	CA 89
V	1	CA 3

Cluster I was the largest having 29 genotypes followed by cluster II with six genotypes and cluster III, cluster IV and cluster V with one genotype each. CA 23, CA 33 and Pant C-1 were in the Ist Cluster, Jwala and NP 46 A in the IInd Cluster, Bhagyalakshmy, in the IIIrd Cluster, CA 89, a vigorously growing local chilli strain in the IVth Cluster and CA 3 (White Kandhari) in the Vth Cluster.

The intra and inter-cluster genetic distances are given in Table 9.

Table 9. Intra and inter-cluster average D^2 values

Clusters	I	II	III	IV	V
I	36.92	172.95	271.68	293.07	218.67
II		57.66	152.24	276.41	257.83
III			0.00	142.56	360.98
IV				0.00	180.19
V					0.00

The intra-cluster distance was the highest in cluster II (57.66) followed by cluster I (36.92). Inter-cluster distance was maximum between clusters III and V (360.98) followed by I and IV (293.07), II and IV (276.41) and II and V (257.83). The lowest genetic distance was between clusters II and III (152.24).

The genetic distance among the four chilli lines/varieties selected for generation mean analysis and inheritance studies are given in Table 10.

Table 10. Genetic distance among four chilli lines

Genotypes	D^2 values
Jwala and Pant C-1	108.59
Jwala and CA 33	145.20
Jwala and CA 23	167.17
Pant C-1 and CA 33	70.57
Pant C-1 and CA 23	60.48
CA 33 and CA 23	8.45

Main stem length contributed maximum (23.19%) towards total genetic divergence followed by fruit length (21.48%), fruit yield/plant (18.92%) and days to red chilli harvest (11.66%) (Table 11). Primary branches/plant had the lowest contribution to the total genetic divergence in chilli (2.46%).

Table 11. Relative contribution of ten characters to total genetic divergence

Characters	Contribution (%)
Plant height	8.39
Main stem length	23.19
Primary branches/plant	2.46
Fruit length	21.48
Fruit girth	5.69
Average fruit weight	2.42
Fruits/plant	3.27
Fruit yield/plant	18.92
Days to flower	2.52
Days to red chilli harvest	11.66

B. Combining ability analysis in chilli

Combining ability analysis indicated that variance due to general combining ability effect was highly significant ($p = 0.01$) for all the nine characters studied (Table 12). Estimates of general and specific combining ability effects are presented in Tables 13 and 14 respectively.

1. Plant height

Mean square due to general as well as specific combining ability effects were significant for plant height. Variance

Table 12. Analysis of variance for combining ability in a 4 x 4 diallel in chilli

Sources of variation	df	Mean squares								
		Plant height	Primary branches/ plant	Leaf laminar length	Fruit length	Fruit girth	Average fruit weight	Fruits/ plant	Fruit yield/ plant	Days to flower
g c a	3	66.49**	0.38*	14.93**	9.42**	0.002*	0.28**	3.89**	3.78**	73.69**
s c a	6	14.43**	0.31*	0.15*	0.65**	0.001	0.01	0.55	0.88	15.46**
Error	70	3.49	0.11	0.55	0.08	0.001	0.01	0.25	0.39	1.18

* Significant at p = 0.05; ** Significant p = 0.01

Table 13. Estimates of general combining ability effects of four chilli lines

Parental lines	Plant height (cm)	Primary branches/ plant	Leaf laminar length (cm)	Fruit length (cm)	Fruit girth (cm)	Average fruit weight (g)	Fruits/ plant	Fruit yield/ plant (g)	Days to flower
Jwala	-2.59	0.26	-0.69	1.85	0.006	0.32	-0.32	0.49	-3.48
Pant C-1	-3.16	-0.32	-0.41	-0.40	-0.02	-0.16	1.16	0.82	-2.50
CA 33	2.90	0.12	0.62	-0.52	-0.023	-0.04	-0.14	-0.41	2.44
CA 23	2.85	-0.05	0.47	-0.94	-0.009	-0.12	-0.69	-0.90	3.54
SE (g_i)	0.66	0.12	0.08	0.10	0.008	0.03	0.18	0.22	0.38
SE ($g_i - g_j$)	1.08	0.19	0.13	0.16	0.01	0.05	0.29	0.36	0.63

Table 14. Estimates of specific combining ability effects of six F_1 hybrids

F_1 hybrids	Plant height (cm)	Primary branches/ plant	Leaf laminar length (cm)	Fruit length (cm)	Fruit girth (cm)	Average fruit weight (g)	Fruits/ plant	Fruit yield/ plant (g)	Days to flower
Jwala x Pant C-1	-1.68	0.15	0.18	-1.32	0.03	-0.05	0.91	1.04	1.63
Jwala x CA 33	5.16	0.59	-0.46	0.66	0.02	0.06	-0.59	-0.80	-4.56
Jwala x CA 23	2.33	-0.37	-0.42	0.10	-0.01	-0.10	0.79	0.94	-1.54
Pant C-1 x CA 33	-1.70	-0.70	-0.19	0.35	-0.01	0.07	0.04	0.29	-5.67
Pant C-1 x CA 23	4.41	0.84	0.08	-0.43	-0.002	0.08	0.57	0.40	-0.02
CA 33 x CA 23	0.97	0.15	0.47	0.51	-0.01	0.01	0.41	-0.21	0.07
SE (s_{ij})	1.60	0.29	0.19	0.24	0.02	0.07	0.43	0.53	0.93
SE ($s_{ij}-s_{ik}$)	2.41	0.43	0.18	0.36	0.03	0.11	0.65	0.81	1.40
SE ($s_{ij}-s_{kl}$)	2.16	0.39	0.26	0.32	0.63	0.10	0.58	0.72	1.25

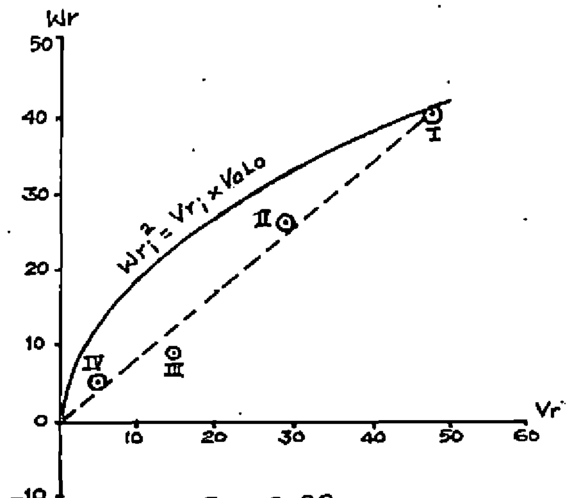
due to general combining ability effects was nearly five times that due to specific combining ability effects. Positive values of general and specific combining ability effects indicated increase in height and negative values indicated decrease in height. CA 33 had the maximum value of general combining ability effect (2.90) followed by CA 23 (2.85) and the lowest by Pant C-1 (-3.16). The crosses Jwala x CA 33 and Pant C-1 x CA 23 had maximum values of specific combining ability effect (5.16 and 4.41 respectively). Pant C-1 x CA 33 had the lowest s c a effect (-1.70).

Wr - Vr graph for plant height is presented in Fig.1. Position of Y intercept 'a' and observed regression line below the origin indicated the presence of overdominance. The 'b' value is significantly greater than zero. CA 23 contained maximum number of dominant genes while Jwala had more of recessive genes.

2. Primary branches/plant

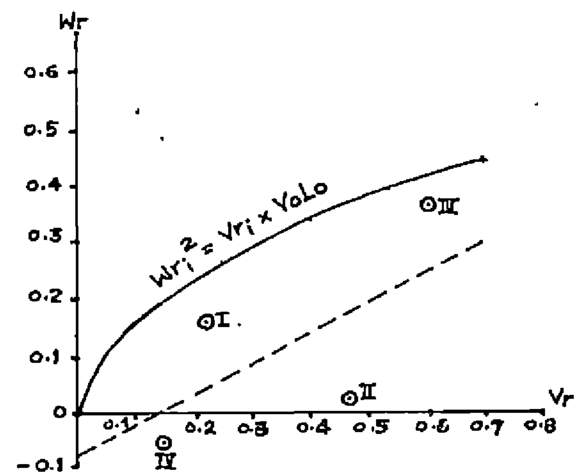
Variances due to general and specific combining ability effects were of same magnitude and were significant only at $p = 0.05$. Jwala and CA 33 had positive values of general combining ability effects (0.26 and 0.12 respectively) and Pant C-1 and CA 23 had negative values (-0.32 and -0.05 respectively). Out of six crosses, only Jwala x CA 23 and

Fig-1. Wr-Vr GRAPH FOR PLANT HEIGHT



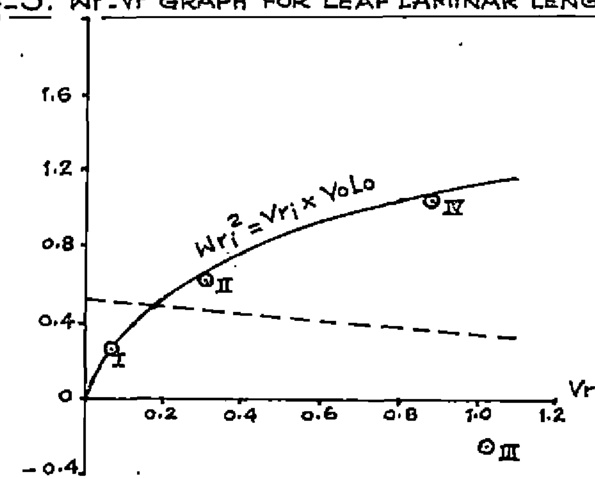
a = 0.82
b = 0.88 ± 0.09
VoLo = 35.31

Fig-2. Wr-Vr GRAPH FOR PRIMARY BRANCHES/PLANT



a = 0.09
b = 0.59 ± 0.46
VoLo = 0.28

Fig-3. Wr-Vr GRAPH FOR LEAF LAMINAR LENGTH



a = 0.52
b = 0.18 ± 0.90
VoLo = 1.43

I. JWALA
II. PANT C-1
III. CA 33
IV. CA 23

Pant C-1 x CA 33 had negative values of specific combining ability effects (-0.37 and -0.70 respectively). Maximum value of specific combining ability effect was shown by Pant C-1 x CA 23 (0.81) followed by Jwala x CA 33 (0.59).

Fig. 2 is the Wr - Vr graph for primary branches/plant. The position of Y intercept 'a' and the observed regression line indicated that the character was controlled by epistatic genes. This is substantiated by the wide dispersion of array points much below the observed regression line. The parents have wide genetic diversity.

3. Leaf laminar length

Variance due to specific combining ability effect, though significant had only low magnitude compared to variance due to general combining ability effect. CA 33 (0.62) and CA 23 (0.47) were the best general combiners for leaf laminar length. Jwala and Pant C-1 had negative g c a effects (-0.69, and -0.41 respectively). The leaf laminar length increased only in CA 33 x CA 23 (s c a 0.47) where as other hybrids had either negative or very low specific combining ability effects.

The Wr - Vr graph for leaf laminar length is given in Fig. 3. The position of regression line and Y intercept 'a' above origin indicated the presence of partial dominance. But the value of 'b' and scattered position of varieties below the regression line suggested epistasis.

4. Fruit length

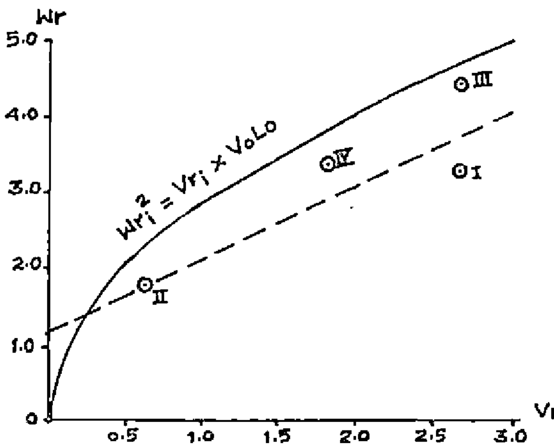
Both variances due to general and specific combining ability effects were significant for fruit length. The former was 15 times higher than the later. Jwala had high positive value of general combining ability effect (1.85). All the other three lines had negative effects for fruit length. Jwala x CA 33 and CA 33 x CA 23 exhibited maximum increase in fruit length as indicated by their high values of specific combining ability effects (0.66 and 0.51 respectively). All the hybrids other than Jwala x Pant C-1 and Pant C-1 x CA 23 had positive values of specific combining ability effects.

Wr - Vr graph for fruit length is given in Fig. 4. The positions of Y intercept 'a' and the position of observed regression line suggested partial dominance. This was substantiated by the value of 'b' higher than zero. The array points were scattered indicating wide genetic diversity in the parents for this character.

5. Fruit girth

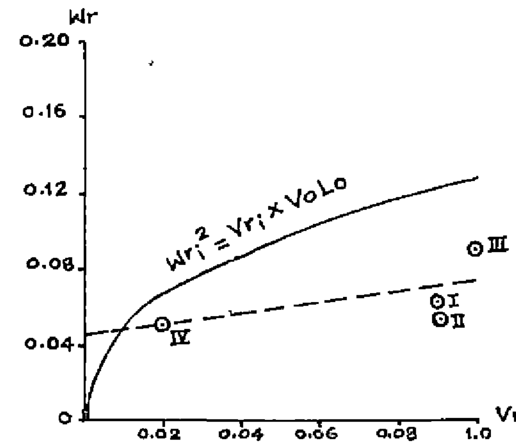
The variance due to general combining ability effect was significant for fruit girth. The general combining ability effect was positive only for Jwala (0.006). All other varieties were poor combiners. Two crosses involving

Fig-4. Wr-Vr GRAPH FOR FRUIT LENGTH



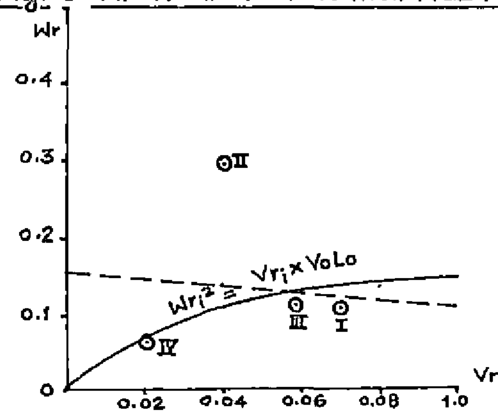
a = 1.06
b = 1.06 ± 0.13
VoLo = 7.61

Fig-5. Wr-Vr GRAPH FOR FRUIT GIRTH



a = 0.04
b = 0.26 ± 0.29
VoLo = 0.16

Fig-6. Wr-Vr GRAPH FOR AVERAGE FRUIT WEIGHT



a = 0.16
b = 0.16 ± 3.00
VoLo = 0.22

I. JWALA
II. PANT C-1
III. CA 33
IV. CA 23

Jwala showed positive specific combining ability effects (Jwala x Pant C-1, 0.03; Jwala x CA 23, 0.02).

Fig. 5 is the Wr - Vr graph for fruit girth. The position of regression line and Y intercept 'a' clearly revealed partial dominance in the expression of the trait. The closeness of CA 23 to origin indicated presence of more of dominant genes in the variety. CA 33 carried more of recessive genes.

6. Average fruit weight

The mean square due to specific combining ability was not significant for fruit weight. The variety Jwala had positive value of general combining ability effect (0.32). The lowest g c a effect was observed in Pant C-1 (-0.16). Majority of the crosses had positive values of specific combining ability effects.

The Wr - Vr graph (Fig.6) also indicated the importance of additive genes in the inheritance of this character. The position of regression line and Y intercept 'a' well above the origin, indicated partial dominance.

7. Fruits/plant

Analysis of variance revealed additive gene action in the inheritance of fruits/plant. Pant C-1 had the highest value of g c a effect (1.16). Jwala, CA 33 and CA 23 had negative values of g c a effects (-0.32, -0.14 and -0.69 respectively).

All the crosses other than Jwala x CA 33 (-0.59) had positive s c a effects. Jwala x Pant C-1 had the highest s c a effect (0.91) followed by Jwala x CA 23 (0.79) and Pant C-1 x CA 23 (0.57).

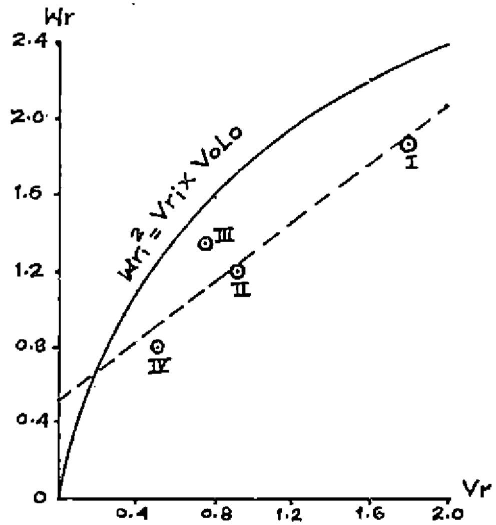
Wr - Vr graph (Fig.7) suggested partial dominance in the inheritance of fruits/plant. The position of observed regression line and Y intercept 'a' clearly indicated partial dominance. The regression of Wr on Vr was greater than zero substantiating a case of partial dominance. Jwala had more of recessive genes.

8. Fruit yield/plant

The analysis of variance showed the significance of g c a effect. Pant C-1 had the highest g c a effect (0.82) followed by Jwala (0.49). CA 33 and CA 23 were not good general combiners for yield/plant as observed by their negative values (-0.41 and -0.90 respectively). Jwala x Pant C-1 had the maximum s c a effect (1.04) followed by Jwala x CA 23 (0.94) and Pant C-1 x CA 23 (0.40). Jwala x CA 33 and CA 33 x CA 23 had negative values.

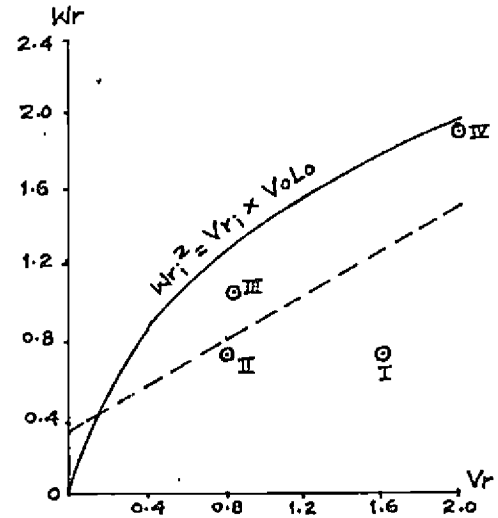
The position of Y intercept 'a' and the position of regression line indicated that fruit yield was controlled by partial dominance (Fig.8). Pant C-1 carried more of dominant genes while CA 23 carried more of recessive genes. Jwala and CA 33 were intermediate.

Fig-7. Wr-Vr GRAPH FOR FRUITS/PLANT



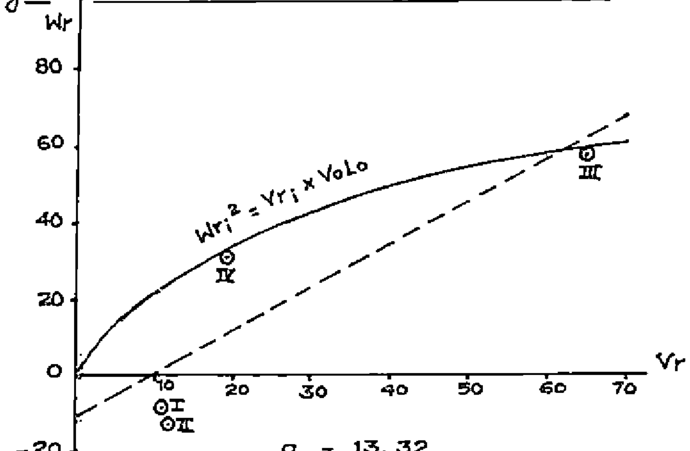
a = 0.56
b = 0.73 ± 0.19
VoLo = 2.89

Fig-8. Wr-Vr GRAPH FOR FRUIT YIELD/PLANT



a = 0.36
b = 0.56 ± 0.50
VoLo = 1.96

Fig-9. Wr-Vr GRAPH FOR DAYS TO FLOWER



a = 13.32
b = 1.16 ± 0.42
VoLo = 54.95

I . JWALA
II . PANT C-1
III . CA 33
IV . CA 23

9. Days to flower

The variance due to both g c a and s c a were significant for days to flower. Jwala (-3.48) and Pant C-1 (-2.50) had negative values of g c a effects which favoured earliness, while positive effects of CA 33 (2.44) and CA 23 (3.54) contributed to lateness. Of the six crosses, Pant C-1 x CA 33 (-5.67), Jwala x CA 33 (-4.56), Jwala x CA 23 (-1.54) and Pant C-1 x CA 23 (-0.02) had negative values of s c a effects and were early. Jwala x Pant C-1 and CA 33 x CA 23 had positive values of s c a effects (1.63 and 0.07 respectively).

The position of regression line and the position of Y intercept 'a' below the origin suggested that the character was governed by over-dominance (Fig.9). The closeness of Jwala and Pant C-1 to the origin also indicated the presence of more of dominant genes for days to flower in the above varieties.

C. Heterosis in chilli

The analysis of variance for the four parents and hybrids indicated highly significant differences among parents and hybrids (Table 15). Differences among the parents were significant for plant height, primary branches/plant, leaf laminar length, fruit length, fruit girth, average fruit weight,

Table 15. General analysis of variance for four parents and six F_1 hybrids in chilli

Sources of variation	df	Mean squares								
		Plant height	Primary branches/ plant	Leaf laminar length	Fruit length	Fruit girth	Average fruit weight	Fruits/ plant	Fruit yield/ plant	Days to flower
Genotypes	9	217.87**	2.67**	7.46**	28.59**	0.009*	0.78**	4.92*	8.52**	251.95**
Parents	3	282.55**	2.25	11.40**	60.88**	0.013*	1.77**	7.73*	15.68**	439.56**
Hybrids	5	217.42**	15.85**	6.33**	14.93**	0.007	0.35**	2.26	5.71	172.04**
Parents Vs Hybrids	1	26.03	1.41	1.27	0.06	0.003	0.007	9.84*	1.07	88.68**
Error	70	27.94	0.91	0.40	0.62	0.004	0.054	2.02	3.13	9.46

*Significant at $p = 0.05$; **Significant at $p = 0.01$

fruits/plant, fruit yield/plant and days to flower. The hybrids differed significantly only for plant height, primary branches/plant, leaf laminar length, fruit length, average fruit weight and days to flower. The mean squares due to parents Vs hybrids were significant for fruits/plant and days to flower.

1. Plant height

The F_1 hybrids Jwala x CA 33, Jwala x CA 23, Pant C-1 x CA 23 and CA 33 x CA 23 had significant relative heterosis for plant height (16.08%, 12.41%, 13.95% and 7.68% respectively) (Table 16). None of the hybrids showed significant heterobeltiosis. The hybrids CA 33 x CA 23 exceeded better parent by 5.82% with a height of 56.94 cm. In general, hybrids were taller than the parents.

2. Primary branches/plant

Four F_1 hybrids had more primary branches/plant than their mid-parents. The percentage of increase ranged from 6.66 in CA 33 x CA 23 to 25.36 in Pant C-1 x CA 23. Jwala x CA 23 and Pant C-1 x CA 33 had lower number of branches than the mid-parents. Pant C-1 x CA 23 and Jwala x CA 33 exceeded their better parent for primary branches/plant, but the increases were non-significant (20.00% and 12.20% respectively).

Table 16. Mean performance of parents and F_1 hybrids and extent of relative heterosis (RH) and heterobeltiosis (HB) in chilli

Genotypes	Plant height			Primary branches/plant			Leaf laminar length		
	Mean performance(cm)	R.H. (%)	H.B. (%)	Mean performance (cm)	R.H. (%)	H.B. (%)	Mean performance (cm)	R.H. (%)	H.B. (%)
Parents									
Jwala	42.14			5.13			5.70		
Pant C-1	43.38			4.00			5.87		
CA 33	53.81			5.00			5.09		
CA 23	51.94			4.38			7.60		
Hybrids									
Jwala x Pant C-1	42.79	0.07	1.35	4.88	6.84	-4.98	5.80	0.26	-1.21
Jwala x CA 33	55.69	16.08*	3.48	5.75	13.57	12.20	6.20	-9.86*	-23.02**
Jwala x CA 23	52.88	12.41**	1.81	4.63	-2.63	-9.76	6.08	-8.50*	-19.94**
Pant C-1 x CA 33	48.25	-0.71	-10.34	3.88	-13.89	-22.50	6.74	-3.20	-16.30*
Pant C-1 x CA 23	54.31	13.95*	4.56	5.25	25.36	20.00	6.86	1.92	-9.67
CA 33 x CA 23	56.94	7.68*	5.82	5.00	6.66	0.00	8.28	5.81	2.34
Mean of parents	47.82			4.63			6.06		
Mean of hybrids	51.81			4.90			6.66		
CD ($p=0.05$)	5.29			0.95			0.63		
sem	1.87			0.34			0.22		

Table 16. (Contd.).

Genotypes	Fruit length			Fruit girth			Average fruit weight		
	Mean performance (cm)	R.H. (%)	H.B. (%)	Mean performance (cm)	R.H. (%)	H.B. (%)	Mean performance (g)	R.H. (%)	H.B. (%)
Parents									
Jwala	9.89			0.80			2.30		
Pant C-1	5.83			0.76			1.25		
CA 33	4.12			0.86			1.48		
CA 23	3.96			0.80			1.40		
Hybrids									
Jwala x Pant C-1	6.07	-22.85**	-38.68**	0.83	10.13	7.38	1.73	-2.59	-24.80**
Jwala x CA 33	7.92	13.0	-19.94**	0.86	7.12	3.62	1.96	3.26	-14.53*
Jwala x CA 23	6.94	0.22	-29.83**	0.79	-1.12	-1.37	1.72	-6.74	-24.98**
Pant C-1 x CA 33	5.36	-0.14	-7.99	0.80	-1.17	-6.77	1.49	9.23	0.74
Pant C-1 x CA 23	4.16	-15.01*	-28.61**	0.78	3.33	0.50	1.42	7.33	1.57
CA 33 x CA 23	4.98	23.24*	20.78*	0.81	1.08	-1.98	1.48	2.64	-0.14
Mean of parents	5.95			0.81			1.61		
Mean of hybrids	5.91			0.81			1.63		
CD (p=0.05)	0.79			0.07			0.23		
sem	0.28			0.02			0.08		

Table 16. (Contd.)

Genotypes	Fruits/plant			Fruit yield/plant			Days to flower		
	Mean performance	R.H. (%)	H.B. (%)	Mean performance (g)	R.H. (%)	H.B. (%)	Mean performance	R.H. (%)	H.B. (%)
Parents									
Jwala	65.63			152.88			42.50		
Pant C-1	130.25			161.55			44.25		
CA 33	85.50			132.75			57.13		
CA 23	58.50			90.88			55.00		
Hybrids									
Jwala x Pant C-1	121.38	23.93	-6.81	201.13	27.93	24.50	42.88	-1.15	0.89
Jwala x CA 33	68.63	-10.73	-16.60	127.50	-9.18	-19.73	41.63	-16.08**	-2.05
Jwala x CA 23	84.13	35.55	28.19	160.25	31.48	4.82	45.75	-6.15	7.65*
Pant C-1 x CA 33	106.88	-0.93	-17.94	153.75	7.20	-2.35	41.50	-18.13**	-6.22
Pant C-1 x CA 23	88.13	22.11	-4.59	154.13	12.44	-10.30	48.25	-2.78	0.04
CA 33 x CA 23	62.63	-12.88	-16.85	110.38	14.76	-3.36	53.38	-4.80	-2.95
Mean of parents	84.97			134.52			49.72		
Mean of hybrids	88.63			151.19			45.57		
CD (p=0.05)	26.18			48.50			3.08		
sem	9.26			17.15			1.09		

3. Leaf laminar length

Jwala x CA 33, Jwala x CA 23 and Pant C-1 x CA 33 exhibited significant negative heterosis (heterobeltiosis -23.02%, -19.94% and -16.30% respectively). In majority of the hybrids, there was significant reduction in leaf laminar length compared to better parents. Positive heterobeltiosis though nonsignificant was shown only by CA 33 x CA 23 (2.34%).

4. Fruit length

Out of six hybrids, three exceeded their mid-parents for fruit length. CA 33 x CA 23 exhibited maximum heterosis for fruit length (relative heterosis 23.24% and heterobeltiosis 20.78%). Fruits of Jwala x Pant C-1, Jwala x CA 23, Jwala x CA 33 and Pant C-1 x CA 23 were significantly smaller than their respective better parents. In general, fruit length in hybrids were lesser than the parents (5.91 and 5.95 cm respectively).

5. Fruit girth

Jwala x Pant C-1 exhibited maximum relative heterosis (10.13%). The hybrids Jwala x Pant C-1 and Jwala x CA 33 had more fruit girth than their better parent, Jwala (heterobeltiosis 7.38% and 3.62% respectively).

6. Average fruit weight

Jwala x CA 33 had the highest fruit weight (1.96 g) among the hybrids. This was 3.26% more than the mid-parent. Relative heterosis was high in Pant C-1 x CA 33 (9.23%) followed by Pant C-1 x CA 23 (7.33%) though both were non-significant. Average fruit weight in Pant C-1 x CA 23 was (1.57%) more than the better parent. In crosses involving Jwala, there was significant reduction in average fruit weight. This was indicated by significant negative heterobeltiosis in Jwala x Pant C-1 (-24.80%), Jwala x CA 33 (-14.53%) and Jwala x CA 23 (-24.98%).

7. Fruits/plant

Hybrids had more fruits than the parents (Table 16). Jwala x Pant C-1 produced the maximum number of fruits/plant (121.38) but it was 6.81% lower than its better parent, Pant C-1. Relative heterosis was more in Jwala x CA 23 (35.55%) followed by Jwala x Pant C-1 (23.93%) and Pant C-1 x CA 23 (22.11%). The fruits/plant ranged from 68.63 to 121.38. The cross Jwala x CA 23 exceeded its better parent by 28.19%. All the other combinations had negative heterobeltiosis.

8. Fruit yield/plant

The mean yield of hybrids was 151.19 g compared to

134.52 g in the parents. Relative heterosis ranged from -9.18% in Jwala x CA 33 to 31.48% in Jwala x CA 23. All the hybrids except Jwala x CA 33 performed better than the mid-parents. Jwala x Pant C-1 (Plate V) and Jwala x CA 23 (Plate VI) exceeded their better parents (24.50% and 4.82% respectively). Jwala x Pant C-1 yielded maximum (201.13 g/plant). The remaining four hybrids had only negative values of heterobeltiosis.

9. Days to flower

The hybrids were earlier to the parents by 4.15 days. Relative heterosis ranged from -18.13% in Pant C-1 x CA 33 to -1.15% in Jwala x Pant C-1. All the hybrids were earlier to mid-parents. Jwala x CA 23 and Pant C-1 x CA 23 were later than the later parents (heterobeltiosis 7.65% and 0.04% respectively). Jwala x CA 33, Pant C-1 x CA 33 and CA 33 x CA 23 though earlier than the earlier parents, were not significant.

D. Components of gene action through generation mean analysis in chilli

The performance of four chilli lines viz., Jwala, Pant C-1, CA 33 and CA 23, their F_1s, F_2s and back cross generations are presented in Appendix II.

The presence and type of non-allelic interactions were determined by A, B, C and D scaling tests (Table 17).

Plate V. F_1 hybrid, Jwala x Pant C-1

Plate VI. F_1 hybrid, Jwala x CA 23

Table 17. Scaling tests for non-allelic interaction in a 4 x 4 diallel for 15 characters in chilli

Characters		Combinations					
		P_1xP_2	P_1xP_3	P_1xP_4	P_2xP_3	P_2xP_4	P_3xP_4
Plant height	A	+	NS	+	+	++	NS
	B	++	NS	+	NS	NS	NS
	C	NS	NS	NS	NS	NS	++
	D	NS	NS	NS	++	NS	++
Main stem length	A	+	NS	++	NS	NS	++
	B	NS	NS	+	+	NS	++
	C	+	++	++	+	++	++
	D	NS	NS	NS	NS	++	++
Primary branches/plant	A	++	++	+	++	+	+
	B	NS	+	NS	+	+	+
	C	NS	NS	+	++	NS	+
	D	NS	NS	+	++	NS	NS
Internodal length	A	++	NS	++	NS	++	NS
	B	NS	NS	NS	++	NS	NS
	C	NS	NS	NS	++	++	NS
	D	++	NS	NS	++	++	NS

Table 17. (Contd.)

Characters		Combinations					
		P_1xP_2	P_1xP_3	P_1xP_4	P_2xP_3	P_2xP_4	P_3xP_4
Internodal girth	A	NS	NS	NS	++	+	NS
	B	NS	NS	NS	++	NS	NS
	C	NS	NS	NS	NS	+	++
	D	NS	NS	NS	++	++	++
Leaf laminar length	A	NS	NS	NS	NS	++	NS
	B	NS	NS	NS	NS	NS	NS
	C	NS	NS	NS	NS	NS	NS
	D	NS	NS	NS	NS	NS	NS
Fruit length	A	NS	+	+	+	NS	NS
	B	NS	NS	++	NS	NS	NS
	C	++	NS	NS	NS	++	NS
	D	++	NS	NS	NS	++	NS
Fruit girth	A	NS	NS	NS	NS	NS	NS
	B	NS	NS	++	NS	NS	++
	C	NS	NS	+	+	NS	+
	D	NS	NS	++	NS	NS	++

Table 17. (Contd.)

Characters		Combinations					
		P_1xP_2	P_1xP_3	P_1xP_4	P_2xP_3	P_2xP_4	P_3xP_4
Average fruit weight	A	NS	NS	NS	NS	NS	++
	B	NS	+	NS	+	NS	++
	C	NS	NS	NS	NS	+	NS
	D	NS	NS	NS	NS	NS	NS
Locules/fruit	A	+	NS	NS	+	NS	NS
	B	NS	NS	NS	+	NS	NS
	C	NS	NS	NS	NS	NS	NS
	D	NS	NS	NS	NS	NS	NS
Fruits/plant	A	NS	NS	NS	++	NS	NS
	B	NS	NS	NS	NS	NS	++
	C	NS	NS	++	++	++	NS
	D	NS	NS	++	++	NS	NS
Fruit yield/ plant	A	NS	NS	NS	NS	NS	NS
	B	++	NS	NS	NS	NS	NS
	C	++	NS	NS	++	+	NS
	D	NS	NS	NS	++	+	NS

Table 17. (Contd.)

Characters		Combinations					
		P_1xP_2	P_1xP_3	P_1xP_4	P_2xP_3	P_2xP_4	P_3xP_4
Days to flower	A	NS	NS	NS	NS	NS	NS
	B	NS	NS	NS	+	NS	NS
	C	NS	NS	NS	NS	NS	NS
	D	NS	NS	+	NS	NS	NS
Capsaicin content	A		NS		NS		
	B		+		++		
	C		NS		NS		
	D		++		+		
Total Colouring matter	A		NS		++		
	B		NS		+		
	C		NS		NS		
	D		NS		NS		

+ Significant at p=0.05; ++ Significant at p=0.01

NS Non-significant

P_1 Jwala; P_2 Pant C-1; P_3 CA 33; P_4 CA 23

The mean effect (m), components of genetic effects like additive effect (d), dominance effect (h), additive x additive effect (i), additive x dominance effect (j) and dominance x dominance effect (l), components of genetic variance, degree of dominance, estimates of heritability and number of effective factors for 15 quantitative characters are presented in Tables 18-47.

1. Plant height

In all the combinations except Jwala x CA 33, the presence of non-allelic interactions were detected. The proportion of dominance effect was higher than additive effect (Table 18). Additive effect was significant only in Jwala x CA 33 (-3.85). Dominance effect was significant in four out of six crosses, of which Jwala x CA 23 had negative effect (-27.30). Significant additive x additive and dominance x dominance interactions were noted in Jwala x CA 23, Pant C-1 x CA 33, Pant C-1 x CA 23 and CA 33 x CA 23.

Jwala x Pant C-1 had the highest additive variance (73.4) (Table 19). Pant C-1 x CA 33 combination had high additive variance (60.6), followed by Pant C-1 x CA 23 (44.2). CA 33 x CA 23 had a dominance variance of 231.88. The degree of dominance for plant height was 0.36 in Jwala x CA 23 combination.

Table 18. Components of total genetic effect for plant height (cm) in chilli

Combinations	Genetic parameters					
	m	d	h	i	j	l
$P_1 \times P_2$	$40.20 \pm 1.97^{**}$	3.70 ± 2.02	12.70 ± 9.01	12.20 ± 8.86	2.00 ± 2.22	$-37.00 \pm 11.76^{*}$
$P_1 \times P_3$	$51.35 \pm 8.87^{**}$	$-3.85 \pm 0.97^{**}$	-21.15 ± 21.49			
$P_1 \times P_4$	$45.00 \pm 1.83^{**}$	1.11 ± 2.30	$-27.30 \pm 8.77^{*}$	$-25.40 \pm 8.63^{*}$	3.45 ± 2.51	$30.40 \pm 2.50^{*}$
$P_2 \times P_3$	$36.70 \pm 1.91^{**}$	1.70 ± 2.06	$28.65 \pm 9.03^{*}$	$30.20 \pm 8.67^{**}$	$34.05 \pm 2.29^{**}$	$-50.50 \pm 12.30^{**}$
$P_2 \times P_4$	$30.90 \pm 1.85^{**}$	-1.80 ± 2.15	$37.95 \pm 7.88^{**}$	$42.00 \pm 8.54^{**}$	2.25 ± 2.38	$-59.10 \pm 11.84^{**}$
$P_3 \times P_4$	$39.30 \pm 1.39^{**}$	-1.90 ± 3.11	$36.70 \pm 8.49^{**}$	$36.20 \pm 8.34^{**}$	-3.40 ± 3.29	$-49.80 \pm 13.98^{**}$

*Significant at $p = 0.05$; **Significant at $p = 0.01$

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

Table 19. Components of genetic variance, degree of dominance, heritability estimates and number of effective factors for plant height in chilli

Combinations	D	H	Degree of dominance $\sqrt{\frac{H}{D}}$	$h^2_{(n)}$ (%)	$h^2_{(b)}$ (%)	K_1	K_2
$P_1 \times P_2$	73.40	-61.08	$\sqrt{-0.83}$	0.95	0.55	0.04	-0.004
$P_1 \times P_3$	-13.40	51.80	$\sqrt{-3.87}$	-0.21	0.20	-1.11	0.530
$P_1 \times P_4$	28.20	3.60	0.36	0.42	0.45	0.20	1.000
$P_2 \times P_3$	60.60	-97.72	$\sqrt{-1.61}$	0.83	0.16	0.51	-0.030
$P_2 \times P_4$	44.20	-33.88	$\sqrt{-0.77}$	0.65	0.40	0.37	-0.480
$P_3 \times P_4$	-116.40	231.88	$\sqrt{-1.99}$	-3.02	-0.01	-0.02	0.001

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

Estimate of heritability in narrow sense was the highest in Jwala x Pant C-1 (0.95) followed by Pant C-1 x CA 33 (0.83) and Pant C-1 x CA 23 (0.65). Maximum heritability in the broad sense was also observed in Jwala x Pant C-1 (0.55). The estimates of number of effective factors showed that K_1 was lesser than one in all the combinations while in Jwala x CA 23, K_2 was one.

2. Main stem length

In all the six combinations, the scaling tests were significant. Estimates of additive effects were significant in three out of six combinations (Table 20). Generations involving Jwala x CA 23, Pant C-1 x CA 23 and CA 33 x CA 23 had significant additive genetic effects. Jwala x CA 23 exhibited negative additive effect. The magnitude of dominance effect was significant only in CA 33 x CA 23 (20.93). Relative magnitude of dominance effect was approximately three times the additive effect.

Additive x additive interaction was significant in generations of Pant C-1 x CA 23 and CA 33 x CA 23. Both additive x dominant and dominant x dominant interactions were significant in Jwala x CA 23.

All the generations except Jwala x Pant C-1 had positive additive variances (Table 21). Additive variance was maximum in CA 33 x CA 23 (57.0). Two generations

Table 20. Components of total genetic effect for main stem length (cm) in chilli

Combinations	Genetic parameters					
	m	d	h	i	j	l
$P_1 \times P_2$	24.31 ± 0.95**	0.10 ± 1.67	-11.45 ± 5.26	1.76 ± 5.08	1.83 ± 1.86	9.99 ± 8.16
$P_1 \times P_3$	23.60 ± 1.74**	2.65 ± 2.53	-9.45 ± 8.65	3.50 ± 8.59	2.55 ± 2.65	16.70 ± 12.44
$P_1 \times P_4$	23.42 ± 1.47**	-4.10 ± 1.60*	-13.98 ± 6.88	-5.40 ± 6.70	-6.83 ± 1.86**	33.55 ± 9.24**
$P_2 \times P_3$	24.50 ± 1.36**	1.55 ± 1.72	-3.33 ± 6.65	7.50 ± 6.64	3.38 ± 1.94	1.65 ± 9.40
$P_2 \times P_4$	21.30 ± 0.97**	3.05 ± 1.23*	9.95 ± 4.80	17.90 ± 4.60**	2.25 ± 1.60	-10.50 ± 6.85
$P_3 \times P_4$	21.43 ± 1.47**	3.45 ± 1.80*	20.93 ± 6.44**	23.51 ± 6.28**	0.83 ± 1.55	-4.65 ± 8.01

*Significant at $p = 0.05$; **Significant at $p = 0.01$

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

Table 21. Components of genetic variance, degree of dominance, heritability estimates and number of effective factors for main stem length in chilli

Combinations	D	H	Degree of dominance $\sqrt{\frac{H}{D}}$	$h^2_{(n)}$ (%)	$h^2_{(b)}$ (%)	K_1	K_2
$P_1 \times P_2$	-18.80	23.32	$\sqrt{-1.24}$	-1.02	-0.39	-0.20	7.22
$P_1 \times P_3$	12.84	55.12	2.07	0.21	0.67	0.001	3.04
$P_1 \times P_4$	35.80	-53.72	$\sqrt{-1.50}$	0.82	0.20	0.21	-1.38
$P_2 \times P_3$	14.20	-23.72	$\sqrt{-1.67}$	0.39	0.06	0.24	4.94
$P_2 \times P_4$	7.20	-43.60	$\sqrt{-6.06}$	0.38	-0.78	0.09	-1.34
$P_3 \times P_4$	57.00	-96.80	$\sqrt{-1.70}$	1.34	0.20	0.12	-0.07

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

involving Jwala x Pant C-1 (23.22) and Jwala x CA 33 (55.12) only exhibited positive dominance variance. The degree of dominance in Jwala x CA 33 was 2.07. Heritability estimate (narrow sense) ranged from 0.21 to 1.34. The generations involving Jwala x CA 23 had high heritability (0.82). K_1 value was very low in all the cases. The estimate of K_2 was the highest in Jwala x Pant C-1 (7.22) followed by Pant C-1 x CA 33 (4.94) and Jwala x CA 33 (3.04).

3. Primary branches/plant

Significance of A, B, C and D scaling tests indicated presence of non-allelic interaction for primary branches/ plant. Additive genetic effect was significant in Jwala x Pant C-1 (-1.7) and Jwala x CA 33 (1.4) (Table 22). Dominance effect was maximum in Pant C-1 x CA 33 (7.25) followed by Jwala x CA 23 (3.30) and were significant. In general, dominance effects were higher than additive effects.

In Jwala x Pant C-1 and Jwala x CA 33, additive x dominance epistasis was observed. In Jwala x CA 23 both additive x additive and additive x dominance interactions were significant. Pant C-1 x CA 33 manifested significance in both additive x additive and dominance x dominance interactions. Dominance x dominance gene interaction was significant in Pant C-1 x CA 23. In all generations except Pant C-1 x CA 23 and CA 33 x CA 23 epistasis was of duplicate type.

Table 22. Components of total genetic effect for primary brances/plant in chilli

Combinations	Genetic parameters					
	m	d	h	i	j	l
$P_1 \times P_2$	3.80 ± 0.32**	-1.70 ± 0.39**	-0.50 ± 1.56	-0.60 ± 1.51	-2.10 ± 0.42**	3.00 ± 2.16
$P_1 \times P_3$	3.90 ± 0.26**	1.40 ± 0.42**	-1.25 ± 1.37	-0.80 ± 1.34	1.15 ± 0.45*	2.50 ± 2.08
$P_1 \times P_4$	3.00 ± 0.05**	-0.60 ± 0.40	3.30 ± 1.23*	3.60 ± 1.19*	-1.20 ± 0.43*	-3.80 ± 1.92
$P_2 \times P_3$	3.30 ± 0.18**	0.50 ± 0.41	7.25 ± 1.15**	7.80 ± 1.08**	0.65 ± 0.44	-14.10 ± 1.94**
$P_2 \times P_4$	3.60 ± 0.38**	0.00 ± 0.44	-0.10 ± 1.78	3.60 ± 1.75	-0.20 ± 0.47	-7.40 ± 2.41*
$P_3 \times P_4$	5.30 ± 0.62**	-0.10 ± 0.82	-0.95 ± 1.41	-0.60 ± 2.96	-0.45 ± 0.83	-5.70 ± 4.19

*Significant at $p = 0.05$; **Significant at $p = 0.01$

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

All the generations except CA 33 x CA 23, had negative values of either additive or dominance variance (Table 23). Positive values of dominance variance ranged from 2.56 in Jwala x CA 33 to 9.57 in CA 33 x CA 23. Degree of dominance estimated in CA 33 x CA 23 was 2.22. Heritability in the narrow sense ranged from 0.25 in CA 33 x CA 23 to 1.42 in Pant C-1 x CA 33. Jwala x Pant C-1 had moderate value of heritability (0.59). Both K_1 and K_2 estimated in all the six different generations were lesser than one.

4. Internodal length

In all generations, except Jwala x CA 33 and CA 33 x CA 23, the non-allelic interaction affected the expression of internodal length. Additive genetic effects were significant in five out of six generations (Table 24). In cases where non-allelic interaction was present additive genetic effect was also significant. Out of six generations dominance effect was significant in three - Jwala x Pant C-1 (1.98), Pant C-1 x CA 33 (2.25) and Pant C-1 x CA 23 (4.67). Magnitude of dominance effect was higher than additive effect. All the three types of epistasis were detected in Jwala x Pant C-1 and Pant C-1 x CA 23. In Jwala x CA 23, the epistasis was mainly of additive x dominance type while in Pant C-1 x CA 33 it was both additive x additive and additive x dominance. In all the crosses the internodal length was controlled by duplicate epistasis.

Table 23. Components of genetic variance, degree of dominance, heritability estimates and number of effective factors for primary branches/plant in chilli

Combinations	D	H	Degree of dominance $\sqrt{\frac{H}{D}}$	$h^2_{(n)}$ (%)	$h^2_{(b)}$ (%)	K_1	K_2
$P_1 \times P_2$	-1.24	-1.44	$\sqrt{-1.16}$	0.59	0.25	0.13	-0.01
$P_1 \times P_3$	-0.92	2.56	$\sqrt{-2.78}$	-0.69	0.27	-0.07	0.08
$P_1 \times P_4$	-1.24	2.59	$\sqrt{-2.09}$	-0.13	0.06	-0.29	0.04
$P_2 \times P_3$	1.90	-4.41	$\sqrt{-2.32}$	1.42	-0.23	0.01	-0.07
$P_2 \times P_4$	1.96	-1.01	$\sqrt{-0.58}$	0.68	0.50	0.02	-0.01
$P_3 \times P_4$	1.94	9.57	2.22	0.25	0.88	0.06	0.01

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

Table 24. Components of total genetic effect for internodal length (cm) in chilli

Combi-nations	Genetic parameters					
	m	d	h	i	j	l
$P_1 \times P_2$	2.41 ± 0.12**	0.99 ± 0.11**	1.98 ± 0.55**	2.78 ± 0.53**	1.14 ± 0.16**	-4.6 ± 0.74**
$P_1 \times P_3$	-1.39 ± 1.09	-0.35 ± 0.12**	0.50 ± 2.81			
$P_1 \times P_4$	3.25 ± 0.21**	-1.64 ± 0.44**	-0.80 ± 1.26	-1.08 ± 1.22	-1.44 ± 0.29	2.12 ± 2.06
$P_2 \times P_3$	2.24 ± 0.17**	0.88 ± 0.28*	2.25 ± 0.90*	2.96 ± 0.87**	1.08 ± 0.31**	-2.70 ± 1.37
$P_2 \times P_4$	2.40 ± 0.16**	0.68 ± 0.27*	4.67 ± 0.85**	5.16 ± 0.83**	0.73 ± 0.31*	-7.90 ± 1.29**
$P_3 \times P_4$	1.55 ± 1.24	0.15 ± 0.12	3.72 ± 2.87			

* Significant at $p = 0.05$; ** Significant at $p = 0.01$

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

Three generations had additive variance ranging from 0.30 in Jwala x Pant C-1 to 0.88 in Jwala x CA 23 for internodal length (Table 25). The remaining three combinations had negative values of additive variance. Jwala x CA 33 had the highest positive dominance variance (3.83) followed by Pant C-1 x CA 23 (0.89). High estimates of heritability (narrow sense) were observed in Jwala x Pant C-1 (1.07) and Jwala x CA 23 (1.00). CA 33 x CA 23 had moderate values of heritability (0.57). K_1 factor ranged from -0.09 in Pant C-1 x CA 33 to 0.11 in CA 33 x CA 23. All the generations except Jwala x Pant C-1 had positive values of K_2. The estimate of K_2 in CA 33 x CA 23 was 3.11.

5. Internodal girth

Out of six generations, Pant C-1 x CA 33, Pant C-1 x CA 23 and CA 33 x CA 23 had significant values in scaling tests. All the above three generations recorded significant positive dominance effect (Table 26). CA 33 x CA 23 had maximum dominance effect (0.45) and remaining two crosses were <u>on par</u> (0.34 and 0.35 respectively). Significant additive x additive and dominance x dominance type of duplicate epistasis prevailed in Pant C-1 x CA 33, Pant C-1 x CA 23 and CA 33 x CA 23.

The degree of dominance for internodal girth was 0.78

Table 25. Components of genetic variance, degree of dominance, heritability estimates and number of effective factors for internodal length in chilli

Combinations	D	H	Degree of dominance $\sqrt{\frac{H}{D}}$	$h^2_{(n)}$ (%)	$h^2_{(b)}$ (%)	K_1	K_2
$P_1 \times P_2$	0.30	-0.92	$\sqrt{-3.07}$	1.07	-0.57	0.08	-0.70
$P_1 \times P_3$	-1.66	3.83	$\sqrt{-2.31}$	-2.37	0.36	-0.07	0.23
$P_1 \times P_4$	0.88	-1.85	$\sqrt{-2.11}$	1.00	-0.05	0.05	0.04
$P_2 \times P_3$	-0.44	0.56	$\sqrt{-1.27}$	-0.79	-0.29	-0.09	0.90
$P_2 \times P_4$	-0.48	0.89	$\sqrt{-1.86}$	-0.96	-0.68	-0.01	0.27
$P_3 \times P_4$	0.80	-0.07	$\sqrt{-0.09}$	0.57	0.55	0.11	3.11

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

Table 26. Components of total genetic effect for internodal girth (cm) in chilli

Combinations	Genetic parameters					
	m	d	h	i	j	l
$P_1 \times P_2$	$0.90 \pm 0.13^{**}$	0.03 ± 0.02	-0.28 ± 0.31			
$P_1 \times P_3$	$0.86 \pm 0.12^{**}$	0.01 ± 0.01	-0.45 ± 0.28			
$P_1 \times P_4$	0.90 ± 0.16	0.02 ± 0.02	-0.52 ± 0.32			
$P_2 \times P_3$	$0.67 \pm 0.03^{**}$	0.03 ± 0.03	$0.34 \pm 0.12^{*}$	$0.56 \pm 0.12^{**}$	0.05 ± 0.04	$-1.26 \pm 0.18^{**}$
$P_2 \times P_4$	$0.61 \pm 0.02^{**}$	0.03 ± 0.04	$0.35 \pm 0.12^{*}$	$0.51 \pm 0.12^{**}$	0.38 ± 0.46	$-0.81 \pm 0.19^{**}$
$P_3 \times P_4$	$0.63 \pm 0.02^{**}$	-0.04 ± 0.04	$0.45 \pm 0.11^{**}$	$0.52 \pm 0.10^{**}$	-0.05 ± 0.04	$-0.66 \pm 0.18^{**}$

*Significant at $p = 0.05$; **Significant at $p = 0.01$

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

in Jwala x Pant C-1 (Table 27). The magnitude of both additive and dominance variances were low in all the combinations. Heritability in narrow sense was high only in Jwala x CA 23 (0.92). Jwala x Pant C-1 and Pant C-1 x CA 33 had very low estimates (0.14 and 0.17 respectively). Estimate of K_1 was the highest in Jwala x Pant C-1 (0.45) while K_2 estimate was the highest in Jwala x CA 23 (2.07) followed by Jwala x Pant C-1 (1.20).

6. Leaf laminar length

Only in Pant C-1 x CA 23 based generations, non-allelic interaction was observed. Of the six combinations, Jwala x CA 33, Jwala x CA 23, Pant C-1 x CA 33 and Pant C-1 x CA 23 had significant additive effect (1.00, -0.97, -1.86, -0.93 respectively) (Table 28). None of the combinations had significant dominance effect for leaf laminar length. Complementary epistasis was observed in Pant C-1 x CA 23.

Jwala x CA 33, Jwala x CA 23 and Pant C-1 x CA 23 had additive variances of 8.66, 3.20 and 0.38 respectively (Table 29). Dominant variances were estimated in Jwala x Pant C-1 (24.13), Pant C-1 x CA 33 (27.96) and Pant C-1 x CA 23 (0.73). Degree of dominance was 1.39 in Pant C-1 x CA 23. It was 0.83 in CA 33 x CA 23. The highest value of heritability in narrow sense was observed in Jwala x CA 33 (1.61), followed by Jwala x CA 23 (0.94). Estimates of K_1 and K_2 were 2.11 and 1.46 respectively in Pant C-1 x CA 23.

Table 27. Components of genetic variance, degree of dominance, heritability estimates and number of effective factors of internodal girth in chilli

Combinations	D	H	Degree of dominance $\sqrt{\frac{H}{D}}$	$h^2_{(n)}$ (%)	$h^2_{(b)}$ (%)	K_1	K_2
$P_1 \times P_2$	0.002	0.001	0.78	0.14	0.19	0.45	1.20
$P_1 \times P_3$	-0.006	0.015	$\sqrt{-2.47}$	-0.60	0.14	-0.18	2.07
$P_1 \times P_4$	0.022	-0.017	$\sqrt{-0.78}$	0.92	0.56	0.01	-1.10
$P_2 \times P_3$	0.002	-0.009	$\sqrt{-4.60}$	0.17	-0.22	0.20	-5.50
$P_2 \times P_4$	-0.018	0.031	$\sqrt{-1.71}$	-2.25	-0.33	-0.01	0.81
$P_3 \times P_4$	-0.018	0.024	$\sqrt{-1.33}$	-3.00	-1.00	-0.003	0.22

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

Table 28. Components of total genetic effect for leaf laminar length (cm) in chilli

Combinations	Genetic parameters					
	m	d	h	i	j	l
$P_1 \times P_2$	$8.33 \pm 2.31^{**}$	-0.08 ± 0.25	-5.42 ± 6.34			
$P_1 \times P_3$	4.46 ± 2.19	$1.00 \pm 0.26^{**}$	5.62 ± 4.69			
$P_1 \times P_4$	$4.50 \pm 1.88^{*}$	$-0.97 \pm 0.17^{**}$	4.98 ± 4.26			
$P_2 \times P_3$	1.17 ± 2.90	$-0.93 \pm 0.19^{**}$	11.70 ± 7.47			
$P_2 \times P_4$	$6.17 \pm 0.36^{**}$	$-1.86 \pm 0.49^{**}$	2.48 ± 1.75	1.44 ± 1.72	-0.97 ± 0.54	0.17 ± 2.48
$P_3 \times P_4$	$7.32 \pm 1.27^{**}$	0.03 ± 0.25	-0.99 ± 3.18			

*Significant at $p = 0.05$; **Significant at $p = 0.01$

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

Table 29. Components of genetic variance, degree of dominance, heritability estimates and number of effective factors for leaf laminar length

Combinations	D	H	Degree of dominance $\sqrt{\frac{H}{D}}$	$h^2_{(n)}$ (%)	$h^2_{(b)}$ (%)	K_1	K_2
$P_1 \times P_2$	-11.48	24.13	$\sqrt{-2.10}$	-3.36	0.17	-0.01	0.02
$P_1 \times P_3$	8.66	-14.22	$\sqrt{-1.64}$	1.61	0.22	0.12	-0.05
$P_1 \times P_4$	3.20	-4.60	$\sqrt{-1.44}$	0.94	0.26	0.29	-0.08
$P_2 \times P_3$	-11.92	27.96	$\sqrt{-2.35}$	-2.41	0.42	-0.07	-0.15
$P_2 \times P_4$	0.38	0.73	1.39	0.15	0.29	2.11	1.46
$P_3 \times P_4$	-0.94	-0.64	0.83	-0.82	-1.10	-0.001	-0.03

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

7. Fruit length

Scaling tests were significant for fruit length in all the combinations except CA 33 x CA 23. Additive effect was significant in Jwala x CA 33 (0.90). Dominance effect was 7.99 in Jwala x Pant C-1 and -3.12 in Pant C-1 x CA 23 (Table 30). The combinations with additive x additive and dominance x dominance type of gene interactions were Jwala x Pant C-1 and Pant C-1 x CA 23. Jwala x CA 23 and Pant C-1 x CA 33 had additive x dominance type of epistasis. All the combinations had duplicate type of epistasis.

Degree of dominance for fruit length was 4.75 in CA 33 x CA 23 (Table 31). All the combinations involving Jwala had positive additive variances ranging from 1.50 in Jwala x CA 33 to 5.32 in Jwala x Pant C-1. Pant C-1 x CA 33 and Pant C-1 x CA 23 had only low estimate of dominance variance (0.92 and 0.52 respectively). Heritability in the narrow sense was 1.41 in Jwala x CA 23, followed by Jwala x Pant C-1 (1.37) and Jwala x CA 33 (0.65). The estimate of K_1 was 1.50 in Jwala x CA 33. Estimate of K_1 ranged from 0.03 in Jwala x Pant C-1 to 1.50 in Jwala x CA 33. The estimate of K_2 ranged from 0.24 in Pant C-1 x CA 33 to 0.85 in Pant C-1 x CA 23.

8. Fruit girth

The magnitude of dominance effect was higher than

Table 30. Components of total genetic effect for fruit length (cm) in chilli

Combi-nations	Genetic parameters					
	m	d	h	i	j	l
P_1 x P_2	3.80 ± 0.44**	0.60 ± 0.35	7.99 ± 1.91**	7.20 ± 1.90**	-0.57 ± 0.39	-5.57 ± 2.30*
P_1 x P_3	5.21 ± 0.34**	0.90 ± 0.39*	-1.05 ± 1.59	-1.60 ± 1.57	-0.60 ± 0.43	3.98 ± 2.15
P_1 x P_4	6.00 ± 0.42**	-0.48 ± 0.34	-0.06 ± 1.83	-1.32 ± 1.80	-2.12 ± 0.38**	1.72 ± 2.24
P_2 x P_3	3.69 ± 0.13**	-0.44 ± 0.28	-0.67 ± 0.81	-0.20 ± 0.76	-0.78 ± 0.31*	1.17 ± 1.34
P_2 x P_4	5.30 ± 0.08**	0.07 ± 0.25	-3.12 ± 0.66**	-3.78 ± 0.59**	-0.41 ± 0.28	3.59 ± 1.21*
P_3 x P_4	2.48 ± 0.56**	0.14 ± 0.13	2.02 ± 1.35			

*Significant at p = 0.05; **Significant at p = 0.01

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

Table 31. Components of genetic variance, degree of dominance, heritability estimates and number of effective factors for fruit length in chilli

Combinations	D	H	Degree of dominance $\sqrt{\frac{H}{D}}$	$h^2_{(n)}$ (%)	$h^2_{(b)}$ (%)	K_1	K_2
$P_1 \times P_2$	5.32	-4.79	$\sqrt{-0.90}$	1.37	0.75	0.03	-0.27
$P_1 \times P_3$	1.50	-0.53	$\sqrt{-0.36}$	0.65	0.54	1.50	-0.57
$P_1 \times P_4$	5.31	-5.79	$\sqrt{-1.09}$	1.41	0.64	0.51	-0.27
$P_2 \times P_3$	-0.88	0.92	$\sqrt{-1.04}$	-2.59	-1.24	-0.13	0.24
$P_2 \times P_4$	-1.02	0.52	$\sqrt{-0.51}$	-8.50	-6.33	-0.22	0.85
$P_3 \times P_4$	-0.02	-0.45	4.75	-0.08	-1.03	-0.98	-0.26

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

additive effect in majority of the combinations (Table 32). Jwala x CA 33, Pant C-1 x CA 23 and CA 33 x CA 23 had significant additive effect (-0.06, -0.06 and 0.07 respectively). All the combinations had negative values of dominance effect, of which the values of Jwala x CA 23 (-0.51), Pant C-1 x CA 33 (-0.20) and CA 33 x CA 23 (-0.57) were significant.

All the three types of non-allelic interactions were observed in Jwala x CA 23. In CA 33 x CA 23, additive x additive and dominance x dominance types of epistasis were significant. The magnitudes of both additive and dominance variances for fruit girth were low in all the combinations (Table 33). Heritability in narrow sense was very high in Pant C-1 x CA 23 (3.55) followed by Jwala x CA 33 (1.75) and Jwala x CA 23 (1.71). CA 33 x CA 23 had moderate value of heritability ($h^2_{(n)}$= 0.44). Estimates of K_1 and K_2 were lesser than one.

9. Average fruit weight

Non-allelic interaction was not detected in Jwala x Pant C-1 and Jwala x CA 23. All combinations with Jwala and Pant C-1 x CA 33 had significant additive effect (Table 34). Additive x additive type of epistasis was observed in Pant C-1 x CA 33. Dominance x dominance type of epistasis was observed in CA 33 x CA 23.

Table 32. Components of total genetic effect for fruit girth (cm) in chilli

Combinations	Genetic parameters					
	m	d	h	i	j	l
$P_1 \times P_2$	0.87 ± 0.14**	0.02 ± 0.01	-0.04 ± 0.35			
$P_1 \times P_3$	0.88 ± 0.11**	-0.06 ± 0.02**	-0.02 ± 0.30			
$P_1 \times P_4$	1.05 ± 0.04**	0.07 ± 0.05	-0.51 ± 0.18*	-0.67 ± 0.18**	0.12 ± 0.05*	0.90 ± 0.26**
$P_2 \times P_3$	0.90 ± 0.01**	-0.06 ± 0.03	-0.20 ± 0.09*	-0.15 ± 0.09	0.02 ± 0.04	0.08 ± 0.15
$P_2 \times P_4$	0.85 ± 0.21**	-0.06 ± 0.01**	-0.15 ± 0.57			
$P_3 \times P_4$	1.04 ± 0.03**	0.07 ± 0.02**	-0.57 ± 0.15**	-2.38 ± 0.14**	0.05 ± 0.04	0.87 ± 0.20**

*Significant at $p = 0.05$; **Significant at $p = 0.01$

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

Table 33. Components of genetic variance, degree of dominance, heritability estimates and number of effective factors for fruit girth in chilli

Combinations	D	H	Degree of dominance $\sqrt{\frac{H}{D}}$	$h^2_{(n)}$ (%)	$h^2_{(b)}$ (%)	K_1	K_2
$P_1 \times P_2$	-0.02	0.02	$\sqrt{-1.20}$	-1.67	-0.67	0.02	0.93
$P_1 \times P_3$	0.04	-0.06	$\sqrt{-1.43}$	1.75	0.50	0.08	-0.04
$P_1 \times P_4$	0.05	-0.08	$\sqrt{-1.58}$	1.71	0.36	0.04	-0.32
$P_2 \times P_3$	-0.01	0.02	$\sqrt{-1.33}$	-3.00	1.00	-0.48	0.14
$P_2 \times P_4$	0.08	-0.03	$\sqrt{-0.41}$	3.55	0.64	0.05	-0.08
$P_3 \times P_4$	0.01	-0.003	$\sqrt{-0.35}$	0.44	0.37	0.03	-0.69

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

Table 34. Components of total genetic effect for average fruit weight (g) in chilli

Combinations	Genetic parameters					
	m	d	h	i	j	l
$P_1 \times P_2$	1.20 ± 0.78	-0.73 ± 0.05**	0.43 ± 1.68			
$P_1 \times P_3$	1.43 ± 0.13**	0.39 ± 0.15*	0.74 ± 0.63	0.59 ± 0.61	0.17 ± 0.17	0.02 ± 0.84
$P_1 \times P_4$	2.22 ± 0.71*	0.19 ± 0.07*	1.73 ± 1.54			
$P_2 \times P_3$	1.37 ± 0.12**	-0.49 ± 0.17*	-0.66 ± 0.62	-0.56 ± 0.60	-0.49 ± 0.19*	1.42 ± 0.89
$P_2 \times P_4$	1.13 ± 0.13**	-0.10 ± 0.12	0.57 ± 0.65	0.47 ± 0.59	-0.07 ± 0.15	0.81 ± 0.90
$P_3 \times P_4$	1.35 ± 0.17**	0.06 ± 0.06	-1.19 ± 0.70	-1.14 ± 0.69	0.08 ± 0.10	2.90 ± 0.77**

*Significant at p = 0.05; **Significant at p = 0.01

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

Combinations except Pant C-1 x CA 33 had positive additive variance and negative dominance variance (Table 35). The magnitude of additive variance ranged from 0.28 in Jwala x CA 23 to 1.08 in CA 33 x CA 23. The magnitude of heritability was very high in all the cases except Pant C-1 x CA 33. The highest heritability (narrow sense) was recorded in CA 33 x CA 23 (1.86) followed by Jwala x Pant C-1 (1.42), Jwala x CA 23 (1.41) and Pant C-1 x CA 23 (1.17). The number of effective factors did not exceed one in any of the combinations.

10. Locules/fruit

A simple additive-dominance model fitted for locules/fruit in all the combinations except Jwala x Pant C-1 and Pant C-1 x CA 33. Additive effect was significant in Jwala x Pant C-1 and Jwala x CA 23 (Table 36). Dominance x dominance type of epistasis was detected in Pant C-1 x CA 23.

The magnitude of variances for locules/fruit was low in all the combinations (Table 37). Four out of six combinations had high estimates of heritability. CA 33 x CA 23 had the highest estimate of heritability in narrow sense (5.38) followed by Pant C-1 x CA 23 (1.61) and Pant C-1 x CA 33 (1.16). In all the combinations, number of effective factors were lesser than one.

Table 35. Components of genetic variance, degree of dominance, heritability estimates and number of effective factors for average fruit weight in chilli

Combinations	D	H	Degree of dominance $\sqrt{\frac{H}{D}}$	$h^2_{(n)}$ (%)	$h^2_{(b)}$ (%)	K_1	K_2
$P_1 \times P_2$	0.96	-1.03	$\sqrt{-1.07}$	1.42	0.66	0.05	-0.01
$P_1 \times P_3$	0.28	-0.29	$\sqrt{-1.04}$	0.78	0.37	0.17	-0.01
$P_1 \times P_4$	0.76	-0.92	$\sqrt{-1.21}$	1.41	0.56	0.05	-0.02
$P_2 \times P_3$	-0.02	0.16	$\sqrt{-8.00}$	-0.07	0.27	-0.003	0.06
$P_2 \times P_4$	0.42	-1.36	$\sqrt{-3.24}$	1.17	-0.72	0.003	-0.01
$P_3 \times P_4$	1.08	-1.47	$\sqrt{-1.40}$	1.86	0.60	0.001	-0.001

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

Table 36. Components of total genetic effect for locules/fruit in chilli

Combi-nations	Genetic parameters					
	m	d	h	i	j	l
$P_1 \times P_2$	$2.02 \pm 0.02^{**}$	$0.60 \pm 0.05^{**}$	0.19 ± 0.13	0.16 ± 0.12	0.11 ± 0.05	0.22 ± 2.22
$P_1 \times P_3$	$2.31 \pm 0.29^{**}$	-0.09 ± 0.04	-0.53 ± 0.65			
$P_1 \times P_4$	$2.27 \pm 0.53^{**}$	$-0.09 \pm 0.04^{*}$	-0.33 ± 1.43			
$P_2 \times P_3$	$2.12 \pm 0.05^{**}$	0.04 ± 0.04	-0.34 ± 0.23	-0.32 ± 0.22	0.08 ± 0.06	$0.76 \pm 0.29^{*}$
$P_2 \times P_4$	1.33 ± 0.92	-0.04 ± 0.04	$+0.20 \pm 1.94$			
$P_3 \times P_4$	$2.28 \pm 0.33^{**}$	0.00 ± 0.05	-0.22 ± 0.79			

*Significant at $p = 0.05$; **Significant at $p = 0.01$

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

Table 37. Components of genetic variance, degree of dominance, heritability estimates and number of effective factors for locules/fruit in chilli

Combinations	D	H	Degree of dominance $\sqrt{\frac{H}{D}}$	$h^2_{(n)}$ (%)	$h^2_{(b)}$ (%)	K_1	K_2
$P_1 \times P_2$	-0.03	0.04	$\sqrt{-1.25}$	-4.00	-1.50	-0.08	0.003
$P_1 \times P_3$	0.08	-0.13	$\sqrt{-1.74}$	0.95	0.13	0.11	-0.02
$P_1 \times P_4$	-0.66	1.44	$\sqrt{-2.18}$	-5.35	0.47	-0.01	0.002
$P_2 \times P_3$	0.18	-0.20	$\sqrt{-1.14}$	1.16	0.50	0.01	-0.002
$P_2 \times P_4$	1.55	-1.32	$\sqrt{-0.85}$	1.61	0.93	0.001	0.00
$P_3 \times P_4$	-0.28	0.25	$\sqrt{-0.90}$	5.38	2.96	0.00	0.01

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

11. Fruits/plant

Scaling tests indicated the absence of non-allelic interaction in Jwala x Pant C-1 and Jwala x CA 33. Additive effect ranged from -9.17 in CA 33 x CA 23 to 32.95 in Pant C-1 x CA 33 (Table 38). Additive effect was significant in Jwala x Pant C-1 (-8.55), Jwala x CA 23 (10.77), Pant C-1 x CA 33 (32.95), Pant C-1 x CA 23 (30.94) and CA 33 x CA 23. Dominance effect was significant only in Jwala x CA 23 (57.61) and Pant C-1 x CA 33 (83.03). Both additive x additive and dominance x dominance interactions were significant in Jwala x CA 23. All the three types of epistasis were found in Pant C-1 x CA 33. Additive x additive type of epistasis was detected in Pant C-1 x CA 23. Additive x dominance and dominance x dominance types of interactions were observed in CA 33 x CA 23.

High estimates of additive variances were observed in Jwala x CA 33 (526.60), Pant C-1 x CA 33 (505.80) and CA 33 x CA 23 (580.80) (Table 39). Generations involving the remaining combinations, Jwala x Pant C-1, Jwala x CA 23 and Pant C-1 x CA 23 had high dominance variances (651.48), 100.92 and 318.12 respectively). Heritability in narrow sense was very high in three out of six combinations. The K_1 was 0.24 in Pant C-1 x CA 33. The K_2 was 0.31 in Pant C-1 x CA 23.

Table 38. Components of total genetic effect for fruits/plant in chilli

Combinations	Genetic parameters					
	m	d	h	i	j	l
$P_1 \times P_2$	73.35 ± 23.23*	-8.55 ± 2.01**	-20.04 ± 55.63			
$P_1 \times P_3$	62.94 ± 18.47**	2.45 ± 2.02	-68.88 ± 39.99			
$P_1 \times P_4$	49.23 ± 2.71**	10.77 ± 4.29*	57.61 ± 14.27**	58.74 ± 13.81**	6.77 ± 4.75	-69.24 ± 21.51*
$P_2 \times P_3$	63.14 ± 4.63**	32.95 ± 4.20**	83.03 ± 20.71**	79.18 ± 20.35**	21.95 ± 4.72**	-112.42 ± 26.20**
$P_2 \times P_4$	79.24 ± 3.48**	30.94 ± 5.30**	-3.90 ± 17.80	4.80 ± 17.50	18.39 ± 5.70*	-64.16 ± 26.16
$P_3 \times P_4$	59.27 ± 4.48**	-9.17 ± 3.32*	24.16 ± 19.55	32.38 ± 19.11	-10.52 ± 3.95*	-76.08 ± 23.78*

*Significant at p = 0.05; **Significant at p = 0.01

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

Table 39. Components of genetic variance, degree of dominance, heritability estimates and number of effective factors for fruits/plant in chilli

Combinations	D	H	Degree of dominance $\sqrt{\frac{H}{D}}$	$h^2_{(n)}$ (%)	$h^2_{(b)}$ (%)	K_1	K_2
$P_1 \times P_2$	-27.2	651.48	$\sqrt{-23.95}$	-0.12	0.68	-2.69	0.03
$P_1 \times P_3$	526.6	-581.48	$\sqrt{-1.10}$	2.86	0.64	0.01	-0.05
$P_1 \times P_4$	-74.2	100.92	$\sqrt{-1.36}$	-0.51	-0.16	-0.22	0.07
$P_2 \times P_3$	505.80	-519.92	$\sqrt{-1.03}$	1.18	0.57	0.24	-0.03
$P_2 \times P_4$	-75.8	318.12	$\sqrt{-4.20}$	-0.31	0.34	-2.08	0.31
$P_3 \times P_4$	580.8	-382.20	$\sqrt{-0.66}$	1.45	0.50	0.004	-0.04

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

12. Fruit yield/plant

Significant non-allelic interaction was observed in three out of six combinations. The magnitude of dominance effect was higher than additive effect for fruit yield/plant (Table 40). Additive effect was significant in all the combinations except CA 33 x CA 23. It varied from -25.09 in Pant C-1 x CA 33 to 19.66 in Pant C-1 x CA 23. Significant dominance effects were detected in Jwala x Pant C-1 (27.03), Pant C-1 x CA 33 (84.13) and Pant C-1 x CA 23 (41.09). Both additive x additive and dominance x dominance types of interactions were detected in Pant C-1 x CA 33 and Pant C-1 x CA 23. Additive x dominance type of interaction was observed in Jwala x Pant C-1. In Pant C-1 x CA 23, epistasis was of duplicate type. In the remaining two combinations, it was complementary type.

(Pant C-1 x CA 33) x Pant C-1 yielded maximum among the F_2 and back cross generations (Plate VII). Clustered segregants in (Jwala x CA 33) x CA 33 (Plate VIII) and (Pant C-1 x CA 33) x CA 33 (Plate IX) were also found promising.

The magnitude of additive and dominance variances were very high (Table 41). Additive variances ranged from 32.6 in Jwala x Pant C-1 to 1896.8 in Jwala x CA 23. Dominance variance was the highest in Pant C-1 x CA 23 (633.08) followed by CA 33 x CA 23 (350.40). The degree of dominance

Plate VII. (Pant C-1 x CA 33) x Pant C-1

Plate VIII. (Jwala x CA 33) x CA 33

Plate IX. (Pant C-1 x CA 33) x CA 33

Plate X. Intensity of red colour in CA 33, Jwala and Pant C-1

Table 40. Components of total genetic effect for fruit yield/plant (g) in chilli

Combinations	Genetic parameters					
	m	d	h	i	j	l
$P_1 \times P_2$	101.45 ± 3.58**	-11.97 ± 4.90*	27.03 ± 7.59**	15.06 ± 17.37	18.14 ± 5.27*	46.86 ± 25.38
$P_1 \times P_3$	77.64 ± 22.80**	5.56 ± 1.80*	29.31 ± 48.76			
$P_1 \times P_4$	57.81 ± 39.62	12.64 ± 2.26**	54.72 ± 96.50			
$P_2 \times P_3$	81.34 ± 5.67**	-25.09 ± 4.03**	84.13 ± 24.82**	89.86 ± 22.69**	9.72 ± 4.51	131.08 ± 30.35**
$P_2 \times P_4$	86.43 ± 2.99**	19.66 ± 5.84**	41.09 ± 17.01*	53.00 ± 16.70*	0.86 ± 6.32	-67.41 ± 27.01*
$P_3 \times P_4$	89.17 ± 22.39**	3.44 ± 2.33	-34.22 ± 54.57			

*Significant at p = 0.05; **Significant at p = 0.01

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

Table 41. Components of genetic variance, degree of dominance, heritability estimates and number of effective factors for fruit yield/plant in chilli

Combinations	D	H	Degree of dominance $\sqrt{\frac{H}{D}}$	$h^2_{(n)}$ (%)	$h^2_{(b)}$ (%)	K_1	K_2
$P_1 \times P_2$	32.6	120.68	1.92	0.13	0.36	1.17	1.19
$P_1 \times P_3$	893.8	-1007.77	$\sqrt{-1.13}$	1.54	0.67	0.09	-0.01
$P_1 \times P_4$	1896.8	-495.32	$\sqrt{-0.26}$	0.99	0.86	0.08	-0.02
$P_2 \times P_3$	961.8	-1284.12	$\sqrt{-1.34}$	1.49	0.50	0.25	-0.03
$P_2 \times P_4$	-324.6	633.08	$\sqrt{-1.95}$	-1.82	-0.05	-1.09	0.23
$P_3 \times P_4$	-133.2	350.4	$\sqrt{-2.63}$	-0.34	0.11	-0.09	0.46

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

was 1.92 in Jwala x Pant C-1. Heritability in the narrow sense for yield was very high in Jwala x CA 33 (1.54), Jwala x CA 23 (0.99) and Pant C-1 x CA 33 (1.49). In all the combinations except Jwala x Pant C-1, number of effective factors were less than one. In Jwala x Pant C-1 the estimate of K_1 and K_2 were 1.17 and 1.19 respectively.

13. Days to flower

Non-allelic interaction was detected in Jwala x CA 23 and Pant C-1 x CA 33. Significant additive effects were observed in Jwala x CA 33 (-5.90) and Pant C-1 x CA 23 (-3.2) (Table 42). Out of six combinations five exhibited negative dominance effects. Duplicate type of epistasis was observed in Jwala x CA 23 and Pant C-1 x CA 33. Jwala x CA 23 exhibited additive x dominance type of interaction for days to flower.

Additive variances ranged from 11.20 to 66.00 in five of six combinations (Table 43). In all the combinations except Jwala x Pant C-1 additive variance was positive and dominance variance negative. Jwala x CA 33 had a moderately high value of heritability ($h^2_{(n)}$ = 0.78). All the other combinations had very low heritability for days to flower. Jwala x CA 33, Jwala x CA 23 and Pant C-1 x CA 33 had K_1 estimate above one. In five out of six combinations K_2 had negative values.

Table 42. Components of total genetic effect for days to flower in chilli

Combinations	Genetic parameters					
	m	d	h	i	j	l
$P_1 \times P_2$	-32.15 ± 4.69**	-0.85 ± 0.51	-20.05 ± 12.33			
$P_1 \times P_3$	59.48 ± 6.68**	-5.90 ± 0.80**	-38.44 ± 15.32*			
$P_1 \times P_4$	46.20 ± 1.34**	2.00 ± 2.13	-21.45 ± 6.61**	-16.0 ± 9.85	6.05 ± 1.93*	18.10 ± 9.40
$P_2 \times P_3$	45.90 ± 1.19**	-1.40 ± 0.92	-13.55 ± 5.77*	-8.4 ± 5.65	3.65 ± 1.68	15.50 ± 8.07
$P_2 \times P_4$	47.18 ± 7.29**	-3.20 ± 0.76**	6.16 ± 16.18			
$P_3 \times P_4$	0.90 ± 6.02	0.03 ± 0.98	-0.28 ± 13.95			

*Significant at $p = 0.05$; **Significant at $p = 0.01$

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

Table 43. Components of genetic variance, degree of dominance, heritability estimates and number of effective factors for days to flower in chilli

Combinations	D	H	Degree of dominance $\sqrt{\frac{H}{D}}$	$h^2_{(n)}$ (%)	$h^2_{(b)}$ (%)	K_1	K_2
$P_1 \times P_2$	-39.2	85.60	$\sqrt{-2.37}$	-3.38	10.31	-0.02	0.0003
$P_1 \times P_3$	33.0	-35.48	$\sqrt{-1.08}$	0.78	0.36	1.05	-2.44
$P_1 \times P_4$	11.2	-14.40	$\sqrt{-1.29}$	0.31	0.11	1.46	-2.06
$P_2 \times P_3$	11.2	-4.920	$\sqrt{-0.44}$	0.39	0.31	2.28	-5.39
$P_2 \times P_4$	66.0	-88.80	$\sqrt{-1.35}$	1.20	0.39	0.16	-0.12
$P_3 \times P_4$	24.0	-61.48	$\sqrt{-2.56}$	-0.72	-0.20	0.14	-0.001

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

14. Capsaicin content

Significance of scaling tests indicated non-allelic interaction for capsaicin content. In Jwala x CA 33 both additive and dominance effects were significant (-0.10 and -0.27 respectively). Only additive effect was significant in Pant C-1 x CA 33 (-0.11) (Table 44). In both the combinations additive x additive and dominance x dominance interactions affected capsaicin content of fruits. Duplicate type of epistasis dominated in the expression of this character.

Additive variance in both the cases, Jwala x CA 33 and Pant C-1 x CA 33 was 0.01 (Table 45). Dominance variance in both combinations were negative. Estimate of heritability in narrow sense was moderately high (0.75 in Pant C-1 x CA 33 and 0.77 in Jwala x CA 33). K_1 was 2.40 in Jwala x CA 33 and it was 3.83 in Pant C-1 x CA 33.

15. Total colouring matter.

Total colouring matter in chilli fruits expressed as total carotenoid pigments was the highest in CA 33 (2107.10 ppm) (Plate X). Total carotenoid contents in Jwala and Pant C-1 did not differ markedly (1209.3 and 1391.5 ppm respectively). The normal distribution of red colour in parents, F_1, F_2 and back cross generations indicated quantitative inheritance.

Table 44. Components of total genetic effect for capsaicin content (%) in chilli fruits

Combinations	Genetic parameters					
	m	d	h	i	j	l
$P_1 \times P_3$	$0.54 \pm 0.02^{**}$	$-0.10 \pm 0.02^{**}$	$-0.27 \pm 0.10^{**}$	$-0.24 \pm 0.09^{**}$	0.02 ± 0.02	$0.42 \pm 0.13^{**}$
$P_2 \times P_3$	$0.53 \pm 0.02^{**}$	$-0.11 \pm 0.02^{**}$	-0.17 ± 0.10	$-0.23 \pm 0.09^{*}$	0.05 ± 0.03	$0.44 \pm 0.13^{**}$

Table 45. Components of genetic variance, degree of dominance, heritability estimates and number of effective factors for capsaicin content in chilli fruits

Combinations	D	H	Degree of dominance $\sqrt{H/D}$	$h^2_{(n)}$ (%)	$h^2_{(b)}$ (%)	K_1	K_2
$P_1 \times P_3$	0.01	-0.01	$\sqrt{-1.40}$	0.77	0.23	2.40	-0.10
$P_2 \times P_3$	0.01	-0.03	$\sqrt{-4.67}$	0.75	-1.00	3.83	-0.11

*Significant at p = 0.05; **Significant at p = 0.01

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

Non-allelic interaction was observed in Pant C-1 x CA 33 (Table 46). In Jwala x CA 33 and Pant C-1 x CA 33, additive effect was only significant (-448.90, -319.65 respectively). In Pant C-1 x CA 33, dominance x dominance interaction was observed and the expression of total colouring matter in chilli fruits was controlled by duplicate type of epistasis.

The magnitude of additive variance was high in Jwala x CA 33 (216129.5) and in Pant C-1 x CA 23 (6956.20) (Table 47). Negative dominance variances were noted in the above two combinations. Heritability (narrow sense) for total colouring matter in Jwala x CA 33 and Pant C-1 x CA 33 were 1.23 and 0.18 respectively. The estimate of K_1 for Pant C-1 x CA 33 was 18.40 while in Jwala x CA 33 it was only 0.93.

E. Inheritance of type of branching, fruiting habit, fruit orientation and destalkness in chilli

1. Type of branching and fruiting habit

Four chilli lines viz., Jwala, Pant C-1, CA 33 and CA 23 were used to generate F_1s, F_2s, BC_1s and BC_2s to study the genetics of type of branching and fruiting habit (Table 48). In indeterminate varieties the main stem continued to grow to a particular height, terminated in a solitary flower and bifurcated. Each branch after a few

Table 46. Components of total genetic effect for total colouring matter (ppm) in chilli fruits

Combi-nations	Genetic parameters					
	m	d	h	i	j	l
$P_1 \times P_3$	1399.20±276.58**	-448.9±30.36**	241.83±678.09			
$P_2 \times P_3$	1669.74± 44.13**	-319.65±59.56**	-48.26±234.65	-124.46±212.96	38.15±66.89	719.56±356.04*

Table 47. Components of genetic variance, degree of dominance, heritability estimates and number of effective factors for total colouring matter in chilli fruits.

Combinations	D	H	Degree of dominance $\sqrt{H/D}$	$h^2_{(n)}$ (%)	$h^2_{(b)}$ (%)	K_1	K_2
$P_1 \times P_3$	216129.5	-317278.80	$\sqrt{-1.47}$	1.23	0.33	0.93	-0.0002
$P_2 \times P_3$	6956.2	-102572.52	$\sqrt{-4.75}$	0.18	-1.14	18.40	-0.0570

* Significant at p = 0.05; ** Significant at p = 0.01

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

nodes terminated in a flower and again bifurcated and this type of branching continued. Jwala and Pant C-1 had indeterminate growth habit with solitary fruits. In CA 33 and CA 23 the main stem after growing to a height of about 30 cm terminated in a cluster of flowers. This was followed by development of a number of primary branches acro petally from the main stem which in turn resulted in a number of clusters. All the determinate plants had flowers and fruits in clusters. In F_1, F_2, BC_1 and BC_2 generations involving the above parents, determinate growth and cluster bearing habit were found pleiotropic. Not a single plant with indeterminate growth habit was clustered fruited during the entire study.

All the 47 plants in Jwala x CA 33, 37 plants in Pant C-1 x CA 33 and 26 plants in Jwala x CA 23 were solitary. This indicated dominance of solitary over clustered habit.

The plants in the segregating generations - F_2s, BC_1s and BC_2s - were classified into solitary and clustered.

a. Jwala x CA 33

Three hundred and twenty one plants in the F_2 generation segregated into 244 solitary and 77 clustered which fitted a 3:1 ratio ($\chi^2 = 0.18$, $p = 0.5 - 0.7$). In

Table 48. Inheritance of clusterness in chilli

Set No.	Cross/ generations	Observed number of plants			Expected genetic ratio	χ^2	Probability
		Solitary	Clustered	Total			
1.	Jwala x CA 33						
	P_1	38	0	38			
	P_2	0	46	46			
	F_1	47	0	47			
	F_2	244	77	321	3 : 1	0.18	0.50-0.70
	BC_1	232	3	235	1 : 0	1.76*	0.05-0.10
	BC_2	150	121	271	1 : 1	3.10	0.05-0.10
2.	Pant C-1 x CA 33						
	P_1	42	0	42			
	P_2	0	46	46			
	F_1	37	0	37			
	F_2	188	59	247	3 : 1	0.11	0.70-0.80
	BC_1	291	0	291	1 : 0	0.00*	1.00
	BC_2	162	169	331	1 : 1	0.73	0.30-0.50
3.	Jwala x CA 23						
	P_1	38	0	38			
	P_2	0	26	26			
	F_1	26	0	26			
	F_2	225	51	276	13 : 3	0.01	0.90-0.95
	BC_1	232	5	237	1 : 0	2.25*	0.02-0.05
	BC_2	147	78	225	1 : 1	21.16	Below 0.001

* 't' value

BC_1 generation, 232 out of 235 plants were solitary and the rest clustered. This fitted an expected ratio of 1:0 (t= 1.76, p = 0.05 - 0.1). In the BC_2 generation, out of 271 plants 150 were solitary and the remaining 121 were clustered. The observed values also fitted to a 1:1 genetic ratio (X^2 = 3.10, p = 0.05 - 0.1).

b. Pant C-1 x CA 33

Out of 247 F_2 plants 188 were solitary and 59 clustered. This fitted to a 3:1 ratio (X^2 = 0.11, p = 0.7 - 0.8). In the BC_1 generation, all the 291 plants were solitary fitting a 1:0 ratio (t= 0, p = 1). The BC_2 also fitted to an expected 1:1 ratio (X^2 = 0.73, p = 0.3 - 0.5).

c. Jwala x CA 23

The 276 F_2 plants segregated into a 13:3 ratio (X^2 = 0.01, p = 0.9 - 0.95). The 225 plants were solitary and 51 clustered. BC_1 segregation did not agree to a 1:0 ratio with five clustered out of 237 plants. The BC_2 had 147 solitary and 78 clustered plants. This BC_2 segregation also did not fit to an expected 1:1 ratio (X^2 = 21.16, p = 0.02 - 0.05).

2. Fruit orientation

Two pendulous fruited lines, Jwala and CA 23 and two upright fruited lines, Pant C-1 and CA 33 were used to generate F_1, F_2, BC_1 and BC_2 generations to study the genetics of fruit orientation (Table 49).

All the 42 plants in Jwala x Pant C-1, 47 plants in Jwala x CA 33 and 35 plants in CA 33 x CA 23 had pendulous fruits indicating dominance of pendulous over erect fruit orientation.

Plants in the segregating generations F_2s, BC_1s and BC_2s were classified into pendulous and upright fruited.

a. Jwala x Pant C-1

In the F_2 generation, 360 plants segregated into 286 pendulous and 74 erect fruited plants. This fitted well to a genetic ratio of 13:3 (X^2 = 0.77, p = 0.30 - 0.50). In BC_1, there was only a rare occurence of two upright fruited plants out of 262. This observed frequency fitted to the expected 1:0 ratio (X^2 = 0.99, p = 0.01 - 0.2). The digenic recessive inheritance of upright fruit orientation was further confirmed in the BC_2 generation where the 192 plants segregated into 84 pendulous and 108 upright giving a 1:1 ratio (X^2 = 3.00, p = 0.05 - 0.1).

The Jwala x Pant C-1 cross clearly indicated the digenic dominant inheritance of pendulous fruit orientation over erect.

Table 49. Inheritance of fruit orientation in chilli

Set No.	Cross/ generations	Observed number of plants: Pendulous	Upright	Total	Expected genetic ratio	χ^2	Probability
1.	Jwala x Pant C-1						
	P_1	38	0	38			
	P_2	0	42	42			
	F_1	42	0	42			
	F_2	286	74	360	13 : 3	0.77	0.30-0.50
	BC_1	260	2	262	1 : 0	0.99*	0.10-0.20
	BC_2	84	108	192	1 : 1	3.00	0.05-0.10
2.	Jwala x CA 33						
	P_1	38	0	38			
	P_2	0	46	46			
	F_1	47	0	47			
	F_2	254	67	321	13 : 3	0.95	0.30-0.50
	BC_1	232	3	235	1 : 0	1.76*	0.05-0.10
	BC_2	151	120	271	1 : 1	3.55	0.05-0.10
3.	CA 33 x CA 23						
	P_1	0	46	46			
	P_2	26	0	26			
	F_1	35	0	35			
	F_2	264	70	334	13 : 3	1.07	0.30-0.50
	BC_1	112	89	201	1 : 1	2.24	0.02-0.05
	BC_2	269	5	274	1 : 0	2.64*	0.01-0.001

* 't' value

b. Jwala x CA 33

In the F_2 generation, the 321 plants segregated into an expected 13:3 ratio (χ^2 = 0.95, p = 0.30 - 0.50). The two hundred and fifty four plants were pendulous and 67 upright fruited. The back cross generations also agreed to a digenic inheritance. In the BC_1, out of 235 plants only three were erect fruited fitting a 1:0 ratio (t = 1.76, p = 0.05 - 0.10). In BC_2, 271 plants segregated into 151 pendulous and 120 upright fruited plants fitting an expected 1:1 ratio (χ^2 = 3.55, p = 0.05 - 0.10).

c. CA 33 x CA 23

The F_2 of CA 33 x CA 23 segregated as in previous two sets. Three hundred and thirty four F_2 plants segregated into 264 pendulous and 70 upright fruited plants fitting a digenic 13:3 ratio (χ^2 = 1.0, p = 0.30 - 0.50). In BC_1 the observed frequency fitted fairly to an expected genetic ratio of 1:1 (χ^2 = 2.24, p = 0.02 - 0.05). BC_2 generation also agreed to a 1:0 ratio of pendulous to upright fruited plants.

3. Destalkness

The destalked line CA 33 was crossed to stalked genotypes Jwala, Pant C-1 and CA 23 to generate F_1, F_2, BC_1, and BC_2 (Table 50). The expressivity of destalkness in CA 33 was not complete as evidenced by 32 stalked plants out of 46 plants in the parental line.

Table 50. Inheritance of destalked nature of fruits in chilli

Set No.	Cross/ generations	Observed number of plants			Expected number considering expressivity		Expected genetic ratio #	χ^2	Probability
		Stalked	Destalked	Total	Stalked	Destalked			
1.	Jwala x CA 33								
	P_1	38	0	38					
	P_2	32	14	46					
	F_1	47	0	47					
	F_2	295	26	321	296.58	24.42	3.696:0.304	0.11	0.70-0.80
	BC_1	235	0	235	235.00	0.00	1 : 0	0.00*	1.00
	BC_2	223	48	271	229.76	41.24	1.696:0.304	1.31	0.20-0.30
2.	Pant C-1 x CA 33								
	P_1	42	0	42					
	P_2	32	14	46					
	F_1	37	0	37					
	F_2	223	24	247	228.21	18.79	3.696:0.304	1.56	0.20-0.30
	BC_1	291	0	291	291.00	0.00	1 : 0	0.00*	1.00
	BC_2	186	29	231	195.85	35.15	1.696:0.304	3.26	0.05-0.10

Table 50. (Contd.)

Set No.	Cross/ generations	Observed number of plants			Expected number considering expressivity		Expected genetic ratio #	χ^2	Probability
		Stalked	Destalked	Total	Stalked	Destalked			
3.	CA 33 x CA 23								
	P_1	32	14	46					
	P_2	26	0	26					
	F_1	35	0	35					
	F_2	324	10	334	327.65	6.35	15.696:0.304	2.14	0.10-0.30
	BC_1	183	18	201	185.71	15.28	3.696:0.304	0.52	0.50-0.30
	BC_2	274	0	274	274.0	0.00	1 : 0	0.00*	1.0

The expected ratio has been derived from classical ratios considering expressivity.

* 't' value

The F_1 hybrids Jwala x CA 33, Pant C-1 x CA 33 and CA 33 x CA 23 were stalked indicating dominance of stalked character over destalked. The plants in the segregating generations - F_2, BC_1 and BC_2 - were classified into stalked and destalked.

a. Jwala x CA 33

In the F_2, 321 plants segregated into 295 stalked and 26 destalked. Considering the low expressivity of destalkness in the parental line, the expected ratio for a 3:1 in the F_2 was modified to 3.696:0.304 (Expected frequency 296.58 stalked and 24.42 destalked). Observed values fitted to the expected genetic 3:1 ratio suggesting a single factor recessive inheritance for destalkness (X^2 = 0.11, p = 0.7 - 0.8). All the 235 BC_1 plants had stalked character. Two hundred and seventy one BC_2 plants segregated into 223 stalked and 48 destalked plants in an expected 1.696:0.304 ratio (X^2 = 1.31, p = 0.20 - 0.30).

b. Pant C-1 x CA 33

Two hundred and forty seven F_2 plants segregated into 223 stalked and 24 destalked plants fitting a 3.696:0.304 ratio (X^2 = 1.56, p = 0.20 - 0.30). All the 291 BC_1 plants were stalked. BC_2 segregation also agreed to a single factor inheritance of destalked nature. A total of

231 BC_2 plants segregated into 186 stalked and 29 destalked plants which fitted a 1.696:0.304 ratio (X^2 = 3.26, p = 0.05 - 0.10).

c. CA 33 x CA 23

A total of 334 F_2 plants segregated into 324 stalked and 10 destalked plants, which fitted a 15.696:0.304 ratio (X^2 = 2.14, p = 0.10 - 0.30). The BC_1 segregated into 3.696:0.304 expected ratio. All the BC_2 plants were stalked.

Discussion

DISCUSSION

Chilli is an indispensable spice-cum-vegetable crop grown all over the world. Apart from its pungency, the crop is a rich source of carotene and vitamin C (6.6 and 96 mg/100 g respectively). It also imparts colour, taste and aroma to food materials.

The leading commercial chilli varieties, Jwala, NP 46 A, Pant C-1, K-2 and Bhagyalakshmy are solitary fruited and stalked. Nearly 20% of the total cost of production is for harvesting of fruits alone (Pious, 1985). Additional labour is also involved to remove the persistent calyx from the harvested fruits during processing. Attempts are made at the Kerala Agricultural University to develop clustered and destalked chillies to minimise the cost involved in harvesting and processing. The present investigation was mainly aimed to unravel the genetics of clusterness, destalkness and fruit colour in chilli.

A. Variability in chilli

Success of any breeding programme depends primarily on the extent of variability in the base population. Evaluation and estimation of genetic variability, heritability, expected genetic advance etc. are primary pre-requisites for all the crop improvement programmes. High heritability coupled with high genetic advance would be a better estimate for selection rather than heritability alone (Johnson et al., 1955).

Considerable variation was observed in chilli populations resulting from natural outcrossing aided by heterostyly and protogyny Lippert et al. (1966). In the present investigation, the contribution of genotype in the phenotypic expression was studied to realise the performance of chilli genotypes.

The thirty eight chilli lines showed significant differences for plant height, main stem length, primary branches/plant, fruit length, fruit girth, average fruit weight, fruits/plant, fruit yield/plant, days to flower and days to red chilli harvest. The forty six lines raised during the second season also differed for all the above characters except primary branches/plant. The observed high variation, quite rational in an often cross pollinated crop like chilli was reported by Dutta et al. (1979), Ramalingam (1979), Bavaji and Murthy (1982), Kshirsagar et al (1983) and Nair et al. (1984).

Fruit yield/plant and fruits/plant were maximum in CA 3 (390 g and 330 respectively). CA 3 was late to flower and took 65 days compared to 38 days in the earliest accession CA 99. CA 3 was ready for harvest 102 days after planting while CA 99 and Jwala were harvested within 75 days. Maximum number of fruits was borne by CA 112 during the second season (703/plant).

Phenotypic coefficient of variation (p c v) was maximum for fruits/plant (75.16) during season II and 47.98 during season I (Fig.10). This was followed by fruit length (59.21 during season II and 43.91 during season I) and main stem length (55.87 during season II and 46.42 during season I). High estimates of phenotypic coefficient of variation were reported earlier for fruits/plant by Hiremath and Mathapati (1977), Dutta _et al_. (1979) and Kshirsagar _et al_. (1983), Ramalingam (1979) and Kshirsagar _et al_. (1983) observed high values of p c v for fruit length in chilli.

Moderate values of p c v were observed for fruit yield/plant (43.54 during season I and 46.44 during season II) and average fruit weight (33.51 during season I and 41.17 during season II) which could be exploited by suitable breeding procedures (Dutta _et al_., 1979; Rao _et al_., 1981 and Vadivel _et al_., 1983).

The lowest p c v was recorded for maturity period, measured by days to red chilli harvest (8.51 during season I and 13.96 during season II). Singh and Singh (1977a) and Ramalingam (1979) also observed low estimates of variation for days to flower and days to red chilli harvest. In the

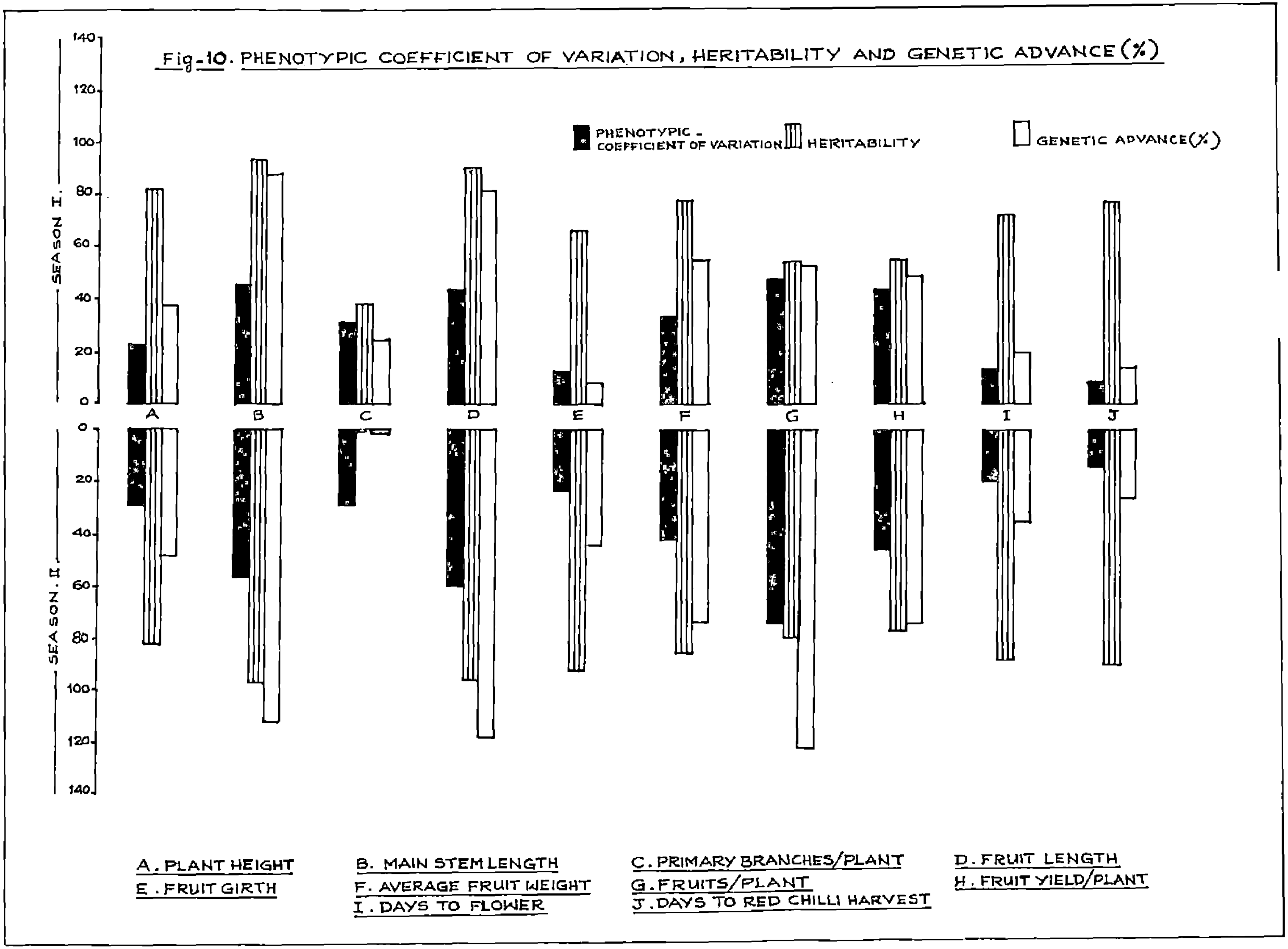


Fig-10. PHENOTYPIC COEFFICIENT OF VARIATION, HERITABILITY AND GENETIC ADVANCE (%)
PHENOTYPIC - COEFFICIENT OF VARIATION
HERITABILITY
GENETIC ADVANCE (%)
SEASON I.
SEASON. II
140
120
100
80
60
40
20
0
A
B
C
D
E
F
G
H
I
J
A. PLANT HEIGHT
B. MAIN STEM LENGTH
C. PRIMARY BRANCHES/PLANT
D. FRUIT LENGTH
E. FRUIT GIRTH
F. AVERAGE FRUIT WEIGHT
G. FRUITS/PLANT
H. FRUIT YIELD/PLANT
I. DAYS TO FLOWER
J. DAYS TO RED CHILLI HARVEST

present investigation, a narrow range of variation was observed for fruit girth, primary branches/plant and plant height.

High heritability, resulting from high g c v was observed for main stem length, fruit length, days to red chilli harvest, days to flower, plant height, fruit girth and average fruit weight. The impact of environment on primary branches/plant was very high as indicated by low g c v. A low estimate of heritability and expected genetic advance were observed for this character. The high influence of environment on primary branches/plant was earlier reported by Al-Hamidi _et al_. (1977) and Vadivel _et al_. (1983).

Heritability values give an indication of the effectiveness of selection on the basis of phenotypic performance. It does not necessarily mean a high genetic advance for a particular quantitative character. Heritability along with estimates of expected genetic advance should be considered more than heritability _per se_ while making selections. High heritability coupled with high estimates of expected genetic advance was observed for fruit length and main stem length. The high estimates of g c v also revealed that variations in the above two characters were mainly genetic. Fruits/plant also had moderately high estimates of heritability and expected genetic advance. This was substantiated by the reports of Singh and Rai (1981), Bavaji and Murthy (1982) and Kshirsagar et al. (1983). High estimates of heritability and expected genetic advance for the above three characters indicated that they could be improved through appropriate selection methods.

Days to flower, days to first harvest and fruit girth though having high heritability, the expected genetic advance was very low. Eventhough these characters may be genetically determined as indicated by high g c v and heritability, the environmental and interaction influence would be quite significant especially in the flowering and fruit maturity periods. This may be the reason for low expected genetic advance for these characters (Awasthi et al., 1976). Singh and Singh (1977a) Dutta et al. (1979) and Singh and Rai (1981) reported earlier high heritability for days to flower.

B. Combining ability, gene action and heterosis in chilli

Information on gene action and combining ability would facilitate the choice of suitable parents in hybridization programmes and in isolating promising F_1 hybrids for further exploitation. The diallel crosses are helpful in determining both general (g c a) and specific combining ability (s c a) of parents and hybrid combinations respectively. General and specific combining ability could be attributed to additive and non-additive gene action respectively (Sprague and Tatum, 1942).

From the 46 chilli lines, four lines viz., Jwala, Pant C-1, CA 33 and CA 23 were selected based on type of branching, fruiting habit, fruit orientation, fruit colour, destalkness, earliness and yield. They were crossed in all possible combinations without reciprocals. Combining ability analysis revealed that variances due to general combining ability were significant for all the nine characters studied (Table 51). The significance of variances due to both g c a and s c a for plant height, primary branches/plant, leaf laminar length, fruit length and days to flower indicated the role of both additive and non-additive gene actions for the control of above characters. Recurrent selection could be used for the improvement of such characters. Milkova (1977, 1979) observed additive and non-additive gene action for plant height, primary branches/plant, fruit length and earliness.

Variance due to g c a alone was significant for fruit girth, average fruit weight, fruits/plant and fruit yield/plant disclosing importance of additive genes for the expression. Since there was preponderance of additive gene action, significant advancement could be achieved in the segregating

Table 51. Components of total genetic variance for nine quantitative characters in chilli

Characters	Gene action	
Plant height	Additive	Non-additive
Primary branches/plant	Additive	Non-additive
Leaf laminar length	Additive	Non-additive
Fruit length	Additive	Non-additive
Fruit girth	Additive	--
Average fruit weight	Additive	--
Fruits/plant	Additive	--
Fruit yield/plant	Additive	--
Days to flower	Additive	Non-additive

generations using simple selection procedures as pedigree, bulk method etc. (Lippert, 1975; Soh et al., 1977; Milkova, 1979; and Ahmed et al., 1982).

In the 4 x 4 diallel, five hybrids exhibited relative heterosis (RH) for plant height, of which four were significant (Table 52 and 53). The hybrid CA 33 x CA 23 was the tallest (57 cm) and had significant relative heterosis (7.68%). The s c a effect of the above cross, in which two good general combiners involved was only 0.97. This indicated that hybrids with high per se performance may not necessarily have a high s c a effect. In the Wr - Vr graphical analysis for plant height position of Y intercept 'a' and the observed regression line below origin suggested over-dominance. Heterosis for plant height may be the function of over-dominance as reported by Joshy and Singh (1980), Murthy and Lakshmy (1983), Krishnakumari (1984), Uzo (1984) and Pious (1985).

Three F_1 hybrids exhibited relative heterosis for fruit length. The hybrid CA 33 x CA 23 had maximum heterobeltiosis and high s c a effect (0.51). The per se performance was lower (5.0 cm) which may be ascribed to the involvement of two poor combiners in the cross. The combining ability effects of the parents were more related to per se performance than the s c a effects of their hybrids. Fruit length was the highest in Jwala x CA 33 (7.9 cm). This hybrid

Table 52. Number of heterotic F_1 hybrids in a 4 x 4 diallel in chilli

Character	Relatively heterotic hybrids	Heterobeltiotic hybrids
Plant height	5(4)	5(0)
Primary branches/plant	4(0)	2(0)
Leaf laminar length	4(0)	1(0)
Fruit length	3(1)	1(1)
Fruit girth	4(0)	3(0)
Average fruit weight	4(0)	2(0)
Fruits/plant	3(0)	1(0)
Fruit yield/plant	5(0)	2(0)
Days to flower	6(2)	3(0)

(Data within parenthesis indicate number of significant hybrids)

Table 53. Performance of salient intervarietal F_1 hybrids and their specific combining ability effects

Character	Hybrids	*per se* performance	sca effect	Heterobeltiosis	Relative heterosis
Plant height	CA 33 x CA 23	56.94 cm	0.97	5.82	7.68
	Jwala x CA 33	55.69 cm	5.16	3.48	16.08
Primary branches/plant	Jwala x CA 33	5.75	0.59	12.20	13.57
	Pant C-1 x CA 23	5.25	0.84	20.00	25.36
Leaf laminar length	CA 33 x CA 23	8.28 cm	0.47	2.34	5.81
Fruit length	Jwala x CA 33	7.92 cm	0.66	-19.94	13.00
	CA 33 x CA 23	4.98 cm	0.51	20.78	23.24
Fruit girth	Jwala x CA 33	0.86 cm	0.02	3.62	7.12
	Jwala x Pant C-1	0.83 cm	0.03	7.38	10.13
Average fruit weight	Jwala x CA 33	1.96 g	0.06	-14.53	3.26
	Jwala x Pant C-1	1.73 g	-0.05	-24.80	-2.59
Fruits/plant	Jwala x Pant C-1	121.38	0.91	-6.81	23.93
	Pant C-1 x CA 33	106.88	0.04	-17.94	-0.93
Fruit yield/plant	Jwala x Pant C-1	201.13 g	1.04	24.50	27.93
	Jwala x CA 23	160.25 g	0.94	4.82	31.48
Days to flower	Pant C-1 x CA 33	41.50	-5.67	-6.22	-18.13
	Jwala x CA 33	41.63	-4.56	-2.05	-16.08

had the maximum s c a effect. But the magnitude of heterosis was low. The position of Y intercept 'a' and observed regression line also confirmed partial dominance for fruit length.

Two F_1 hybrids Pant C-1 x CA 33 and Pant C-1 x CA 23 though exceeded their better parent for average fruit weight by 0.74% and 1.57% respectively, the *per se* performance was not promising. The parents involved in the above crosses were poor combiners. Fruit weight was maximum in Jwala x CA 33 (2.0 g) followed by Jwala x Pant C-1 (1.7 g) but had only low s c a effect. The higher *per se* performance of the above two hybrids was contributed by the involvement of the best general combiner, Jwala, in the above two crosses. The preponderance of additive gene action may be responsible for the low magnitude of heterosis for average fruit weight as reported by Gill and Ahmed (1977) and Murthy and Lakshmy (1983).

Out of six F_1 hybrids, three exhibited relative heterosis and one heterobeltiosis for fruits/plant; but the estimates were non-significant. Jwala x Pant C-1 had maximum fruits/plant (121). Relative heterosis (23.93%) and s c a effect (0.91) were also high in this combination. Eventhough Jwala and Pant C-1 were genetically divergent and placed under two separate clusters, the estimated D^2

value in general was low (108.59). The low D^2 values among the varieties may be responsible for non-significant heterosis observed in the hybrids. The hybrid Pant C-1 x CA 33 also performed better (107 fruits/plant). The high *per se* performance of the hybrid may be due to the involvement of Pant C-1 which had maximum g c a effect. Magnitude of heterosis was maximum in Jwala x CA 23 (RH 35.85%; HB 28.19%) involving the most divergent parents (D^2 167.17). Varying extent of heterosis for fruits/plant was observed by Pandey *et al.* (1981a), Balakrishnan *et al.* (1983), Murthy and Lakshmy (1983), Krishnakumari (1984) and Uzo (1984). Combining ability analysis and Wr - Vr graphic analysis indicated predominance of additive genes and partial dominance for the control of fruits/plant (Allah *et al.*, 1975; Betlach, 1965; Singh and Singh, 1977b and Ahmed *et al.*, 1982).

Four hybrids exceeded the mid-parents and of which two of them exceeded the better-parents for fruit yield/plant. Jwala x Pant C-1 yielded the maximum (201 g/plant) and had the highest heterosis (RH 27.93%). The above hybrid had high s c a effect (1.04), good *per se* performance and its parents were good general combiners. Taking into account *per se* performance (160 g/plant), s c a effect and heterosis, Jwala x CA 23 was the second best combination. In the above two heterotic hybrids the parents belonged to two different clusters. Varying extent of heterosis for yield was earlier reported by Pandey et al. (1981a), Rao et al. (1981), Sontakke (1981), Balakrishnan et al. (1983), Murthy and Lakshmy (1983), Uzo (1984) and Pious (1985). In the present study, the observed low magnitude of heterosis for yield/plant may be due to the involvement of parents separated by comparatively narrow genetic distances.

All the hybrids were earlier than the mid-parents and three exhibited heterobeltiosis. The position of Y intercept 'a' below the origin indicated overdominance for days to flower. Pant C-1 x CA 33 was the earliest (41.5 days and had the maximum negative value of s c a effect (-5.67), relative heterosis (-18.13%) and heterobeltiosis (-6.22%). This was closely followed by Jwala x CA 33 (42 days) with a high negative s c a effect (-4.56), relative heterosis (-16.08) and heterobeltiosis (-2.05). The present result concures with Sontakke (1981), Krishnakumari (1984), Uzo (1984) and Pious (1985). Involvement of considerable non-additive gene action for earliness suggests that once early lines are isolated, further improvement could be achieved through hybridization programmes.

The diallel analysis revealed the type of gene action governing quantitative characters. Formulation of breeding programmes based on main gene effects and neglecting the possible epistasis would be misleading and would vitiate effectiveness of breeding efforts. Using means and variances of P_1, P_2, F_1, F_2, BC_1 and BC_2 generations of crosses involving four parents - Jwala, Pant C-1, CA 33 and CA 23 - components of genetic variances were estimated as suggested by Mather (1949). The genetic effects were partitioned into additive, dominance and epistatic effects to examine whether epistatic effects existed in the material under study. The magnitude and type of epistasis were also estimated along with the main effects. Fixable heritability ($h^2_{(n)}$) and number of units of polygenes (K) governing each of quantitative character were also worked out.

The dominance effects were higher than additive effects for plant height. Three out of six combinations had significant positive dominance effects. In all the combinations except Jwala x CA 33 the, A B C & D scaling tests were significant indicating the inadequacy of simple additive - dominance model to explain plant height. Epistasis for plant height was earlier reported by Chung and Chang (1979) and Singh and Rai (1981). In five out of six crosses the opposite sign (+ve and -ve) of two components, dominance (h) and dominance x dominance (l) suggested the presence of duplicate epistasis. Estimates of fixable heritability were generally high (Jwala x Pant C-1, 0.95; Pant C-1 x CA 33, 0.83). The degree of dominance in Jwala x CA 23 was 0.36 indicating partial dominance.

The number of effective factors for plant height was one in Jwala x CA 23, but this estimate would be highly biased because of presence of epistatic gene action.

Though additive effects were significant, the magnitude of dominance effect was approximately three times the additive effect for main stem length. The presence of epistasis was detected in all the six combinations as indicated by the significance of scaling tests. The -ve sign of h and +ve sign of l or +ve sign of h and -ve sign of l in four combinations revealed the presence of duplicate epistasis. The degree of dominance in Jwala x CA 33 was 2.07 indicating overdominance. Popova and Mihailov (1976) also observed overdominance for main stem length. The combinations Pant C-1 x CA 23 and CA 33 x CA 23 had significant estimates of additive effect as well as additive x additive effect. The magnitude of K_2 indicated that 7, 3 and 4 units of polygenes governed the main stem length in Jwala x Pant C-1, Jwala x CA 33 and Pant C-1 x CA 33 respectively.

As reported by Singh and Rai (1981), the magnitude of dominance component was higher than additive component for primary branches/plant. In all the six combinations, non-allelic interaction was significant of which two had complementary and the remaining four had duplicate epistasis for primary branches/plant.

The dominance variances and effects were higher than additive variances and effects for internodal length and girth. Scaling tests were significant in four combinations for internodal length and in three combinations for internodal girth indicating the presence of non-allelic interaction and in all the above cases, the epistasis was of duplicate type. The non-genetic factors influenced both the characters as evidenced by the non-significance of any of the genetic parameters in CA 33 x CA 23 for internodal length and in Jwala x Pant C-1, Jwala x CA 33 and Jwala x CA 23 for internodal girth. This was further confirmed by negative values of degree of dominance in all the combinations.

The simple additive-dominance model was adequate in all the combinations except Pant C-1 x CA 23 for leaf laminar length. The magnitude of additive effect was higher than dominance effect. His estimate of heritability and higher values of K_1 compared to K_2 indicated additive gene action for leaf laminar length.

Simple additive-dominance model was adequate only in the generations involving CA 33 x CA 23 to explain gene action for fruit length. The differences in signs of dominance effect and dominance x dominance effect in the remaining five cases revealed duplicate epistasis. In Jwala x Pant C-1 significant positive dominance effect points to increased fruit length. Simple additive dominance model fitted well to the inheritance of fruit girth in Jwala x Pant C-1, Jwala x CA 33 and Pant C-1 x CA 23. In the remaining three combinations, duplicate epistasis operated for the control of fruit girth as reported by Singh et al. (1982).

In all the combinations except Pant C-1 x CA 33 and CA 33 x CA 23 dominance effect was positive for average fruit weight. Non-allelic interaction was detected in four combinations, of which two showed complementary epistasis and the remaining two duplicate epistasis. Chung and Chang (1979) also reported epistasis for fruit weight in chilli.

The proportion of additive effect was higher than dominance effect for locules/fruit. Additive effects were significant in Jwala x Pant C-1 and Jwala x CA 23. The additive type of inheritance for locules/fruit was further confirmed by high estimate of heritability and low degree of dominance.

In three out of six combinations, dominance effects were positive indicating dominance towards more number of fruits/plant. Scaling tests were significant in all the combinations except Jwala x Pant C-1 and Jwala x CA 33. This explains non-allelic interaction in four cases.

Duplicate epistasis was observed in Jwala x CA 23, Pant C-1 x CA 33 and CA 33 x CA 23, while in Pant C-1 x CA 23 epistasis was of complementary type.

Among the F_1 hybrids maximum yield/plant was recorded in Jwala x Pant C-1 during May - September 1983 (127 g/plant). It had a significant additive effect, dominance effect as well as additive x dominance interaction effect. The dominance variance was higher than additive variance. High value of potence ratio (1.92) and low value of heritability in the above combaination also indicated over-dominant gene action for fruit yield/plant. This was in agreement with observation of Singh and Singh (1976b). The dominance effects in all the combinations were positive revealing greater possibilities of increasing yield by hybridization. But the significance of additive effects in four hybrid generations also points out the role of additive gene action. Positive value of dominance effect opposite to negative value of dominance x dominance effect in Pant C-1 x CA 23 suggested duplicate epistasis while in Jwala x Pant C-1 and Pant C-1 x CA 33 epistasis was of complementary type. Scossiroli et al. (1974) and Chung and Chang (1979) stressed the influence of epistasis on fruit yield in chilli.

The importance of dominance gene action for days to flower was indicated by high magnitudes of dominance effect and dominance variance. Negative dominance effect in all the combinations except Pant C-1 x CA 23 indicated earliness.

Dikanev (1978) found non-additive gene action for earliness in chilli. The non-allelic interactions in Jwala x CA 23 and Pant C-1 x CA 33 were mainly of duplicate type. More than one gene governed the inheritance of days to flower in Jwala x CA 33, Jwala x CA 23 and Pant C-1 x CA 33.

The pungent principle in chilli is capsaicin, a substituted benzylamine derivative. The mean value of capsaicin in F_1 was more or less equal to mid-parental value which indicated partial dominance of high pungency over low pungency. The scaling tests were significant indicating presence of non-allelic interaction. Brauer (1962) observed epistasis in the inheritance of pungency. Significance of additive, dominance, additive x additive and dominance x dominance effects indicated the importance of additive, dominance and epistatic components in Jwala x CA 33. In Pant C-1 x CA 23 additive, additive x additive and dominance x dominance effects were significant suggesting the prominent role of additive and epistatic components. The difference in signs of dominance and dominance x dominance effects suggested duplicate epistasis. The significance of additive effects in both combinations revealed the importance of additive gene action for capsaicin content. High value of heritability and low potence ratio also indicated additive gene action. The importance of fixable genetic effect was earlier reported by Quagliotti and Ottaviano (1971), Kvachadze (1973), Sharma and Saini (1977b), Park and Takatashi (1980) and Bajaj et al. (1980). The number of effective genes governing capsaicin content was 2.40 and 3.83 in Jwala x CA 33 and Pant C-1 x CA 33 respectively.

Quality of dried chilli is evaluated by its colour and pungency, shining deep red colour is preferred in the market. The colour of chilli is ascribed mainly to capsanthin constituting about 35% of the total carotenoid pigments. The colouring matter expressed as total carotenoid pigments was high in CA 33 (2107.10 ppm). Jwala and Pant C-1 did not differ markedly (1209.30 and 1391.5 ppm respectively). F_1, BC_1 and BC_2 means for colouring matter in Jwala x CA 33 and Pant C-1 x CA 33 being intermediate suggested partial dominant type of inheritance. Further, the back cross progeny means showed skewness towards the recurrent parents used indicating that this character was governed by additive genes. The F_1 hybrids equalled mid-parental values which indicated partial dominance of intense red colour over light red colour. Simple additive dominance model fitted only in Jwala x CA 33. The additive effect was significant in both hybrid generations. All these estimates of gene effects revealed that additive gene action controlled total colouring matter. Brauer (1962) also reported additive genes for red colour in chilli.

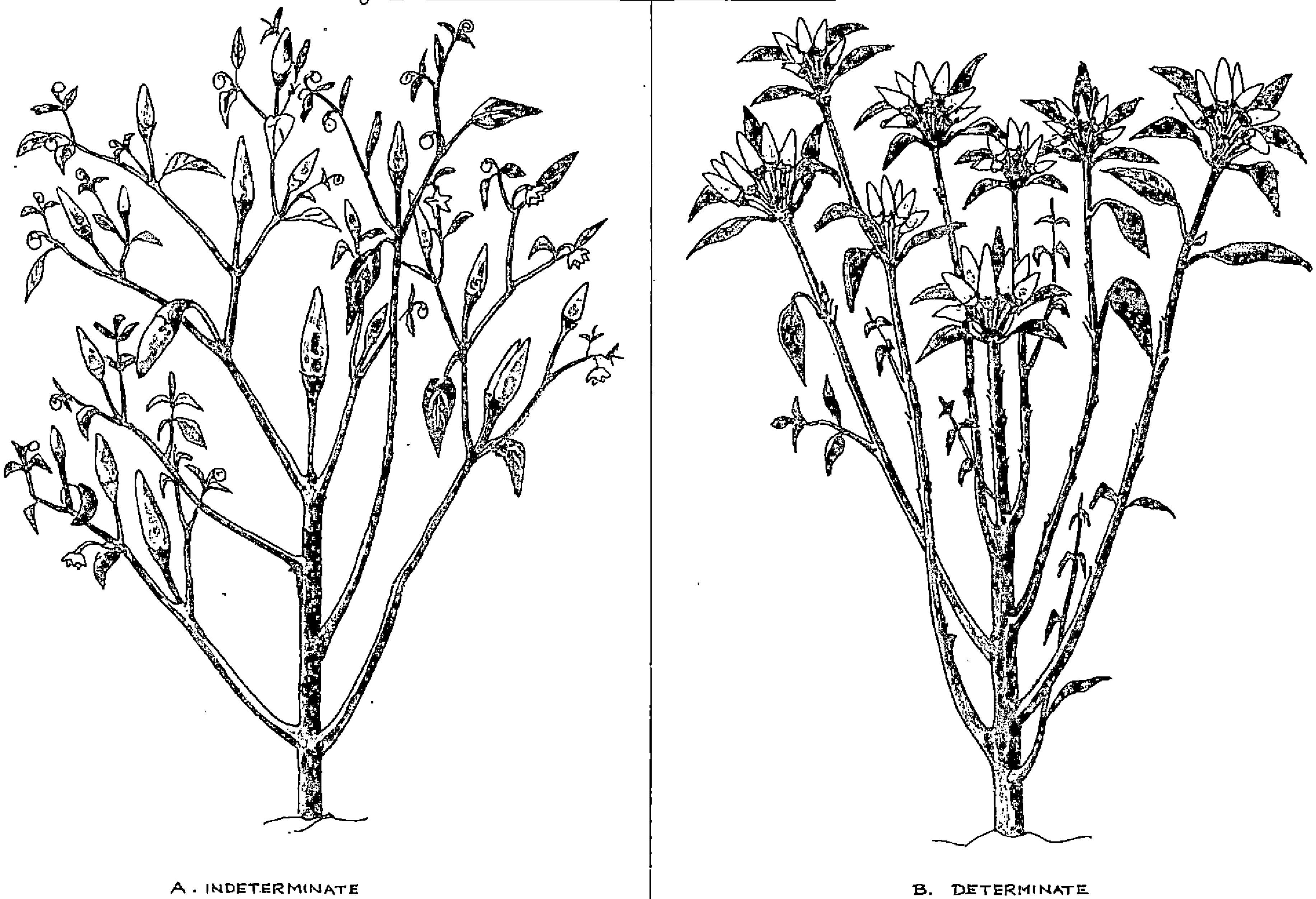
C. Inheritance studies in chilli

Commercial chilli cultivars in India are solitary fruited with an indeterminate growth habit. The seedlings grow straight as single stem. After reaching a specific height determined by genetic constitution in conjunction with its specific environment, the stem normally bifurcates and then keeps bifurcating. Solitary fruits are borne in the leaf axils. Jwala and Pant C-1 have this type of branching and fruiting habit. The solitary bearing habit limits mechanical harvesting and makes harvesting process labour intensive. Nearly 20 per cent of the cost of chilli cultivation is for the harvesting of fruits alone.

Attempts are now in progress to develop clustered chilli varieties for mechanical harvesting. The seedlings of two clustered lines, CA 33 and CA 23 terminated in a cluster of flowers after growing to a height of 30 to 40 cm. This was followed by initiation of several lateral branches each bearing a terminal cluster of fruits. McCammon and Honma (1984) designated this habit as 'Umbrella phenotype'.

Dale (1931), Shifris and Hakin (1977) and McCammon and Honma (1984) pointed out that clustered habit is seen only in determinate plants. In the present study also all the clustered plants were determinate. This showed that determinate habit is pleiotropic to clustered fruiting habit (Fig.11).

Fig-11. TYPE OF BRANCHING IN CHILLI



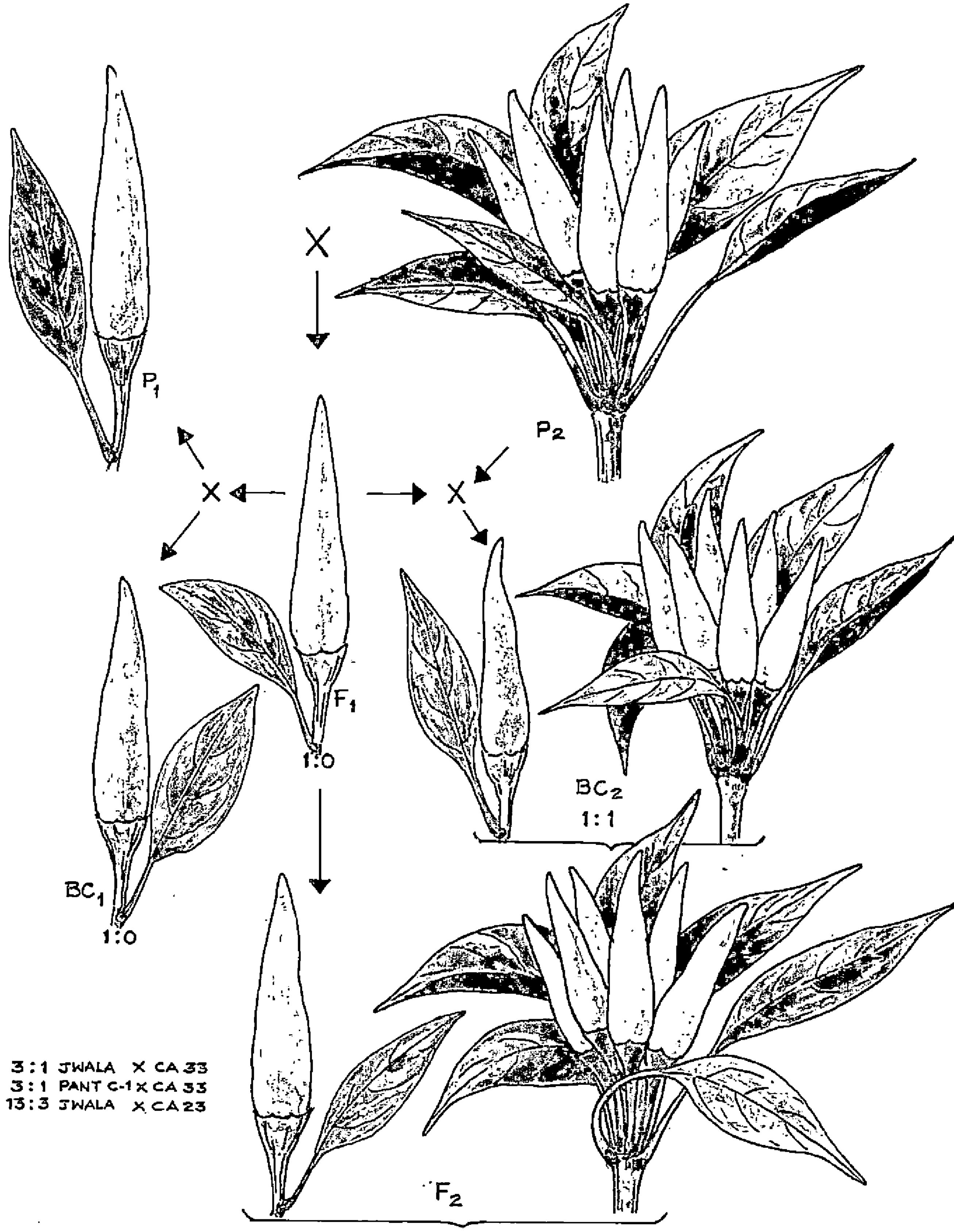
The F_1s Jwala x CA 33 and Pant C-1 x CA 33 were solitary fruited with an indeterminate growth habit indicating dominance of solitary fruiting habit over clustered fruiting habit. The F_2s of both the above hybrids fitted to a 3 solitary : 1 cluster suggesting a single gene difference between the parents (Fig.12). The BC_1s and BC_2s of the hybrids confirmed monogenic and recessive inheritance of clusterness in chilli which is in agreement with the earlier reports by Deshpande (1944), Kormos and Kormos (1956), Murthy and Murthy (1962), Anjeli (1964), Ferenc (1970), Barrios and Mosokar (1972), Ludilov (1977), Voronima and Ilenko (1981), Meshram (1983), McCammon and Honma (1984) and Okitsu et al. (1984).

The genotypes of the above three parents are postulated as follows:

Jwala	Cl_1 Cl_1
Pant C-1	Cl_1 Cl_1
CA 33	cl_1 cl_1

In crosses involving CA 23 also, the dominance of solitary to clustered habit was observed. But a deviation from the reported monogenic inheritance was noted. The F_2 fitted a 13 : 3 ratio ($p = 0.90 - 0.95$). The back cross generations failed to substantiate expected ratios. This necessitates further study for deriving the genotype of CA 23.

Fig-12. INHERITANCE OF CLUSTERNESS IN CHILLI



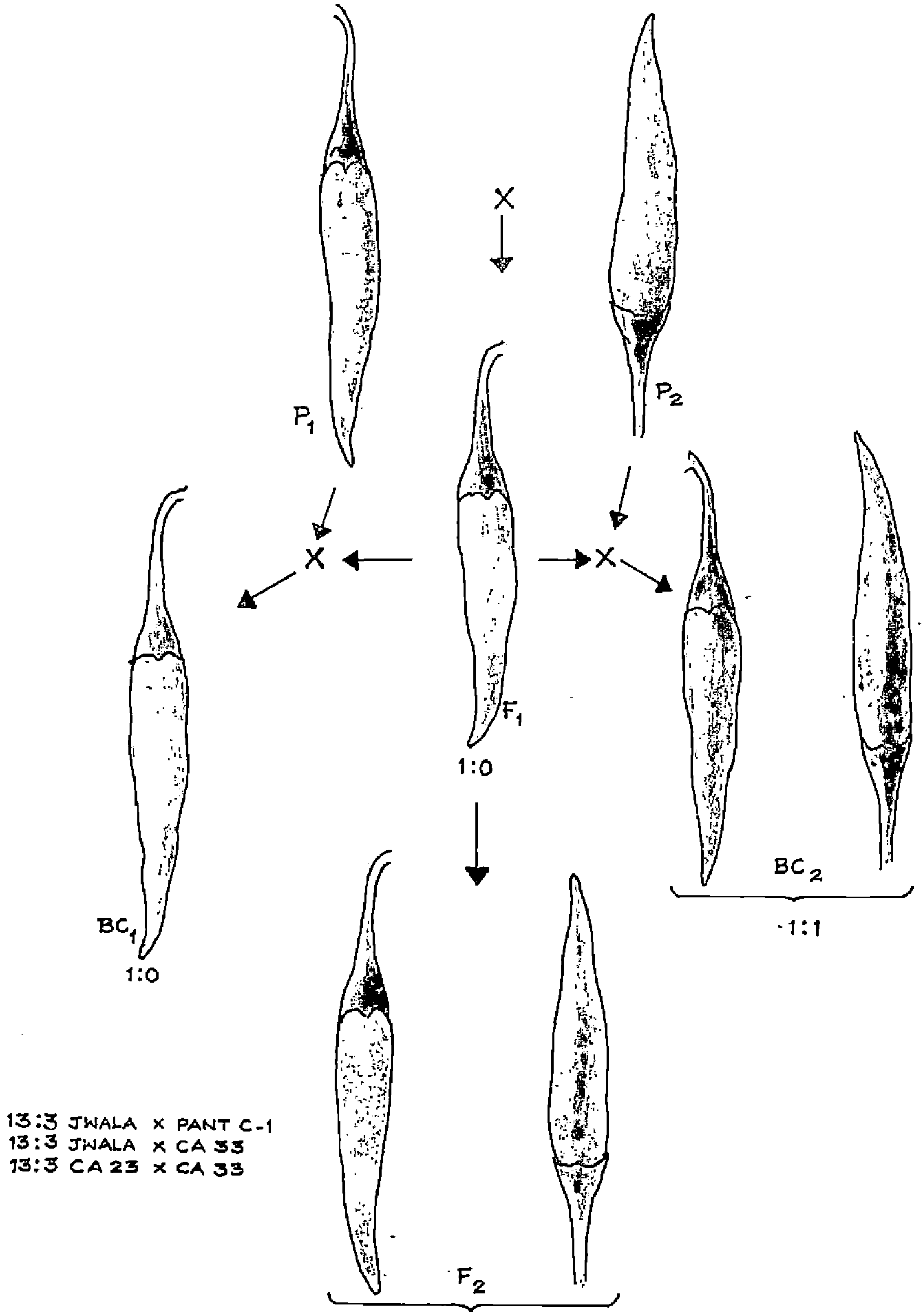
From the inheritance studies it can be concluded that clusterness is recessive and the difference of CA 33 with Jwala and Pant C-1 is only for a single gene 'cl_1'.

Shaw and Khan (1928) designated the gene 'up' for upright or erect fruit orientation. The earlier reports by Deshpande (1933), Kaiser (1935), Miller and Fineman (1937), Singh and Roy (1945), Hagiwara and Oomura (1947), Odland (1948) Murthy and Murthy (1962), Sayed and Bagavandass (1980), Saccardo (1981) and Okitsu et al. (1984) suggested a monogenic inheritance for fruit orientation, pendulous being dominant over upright. In the present study also dominance of pendulous over upright orientation of fruits was confirmed (Fig.13). The F_2 generation of Jwala x Pant C-1, Jwala x CA 33 and CA 33 x CA 23 segregated into 13 pendulous : 3 upright fruited plants suggesting a digenic inheritance with specific dominant and recessive epistasis, 'up_1' epistastic over 'up_2^+'. The genotypes of the four parents for fruit orientation are proposed as follows:

Jwala	$up_1^+ up_1^+ \; up_2 \, up_2$
CA 23	$up_1^+ up_1^+ \; up_2 \, up_2$
Pant C-1	$up_1 \, up_1 \; up_2^+ up_2^+$
CA 33	$up_1 \, up_1 \; up_2^+ up_2^+$

In the stalked genotypes of chilli the pedicel persists to the fruit during harvesting and the persistent calyx will be a serious constraint for mechanical harvesting and

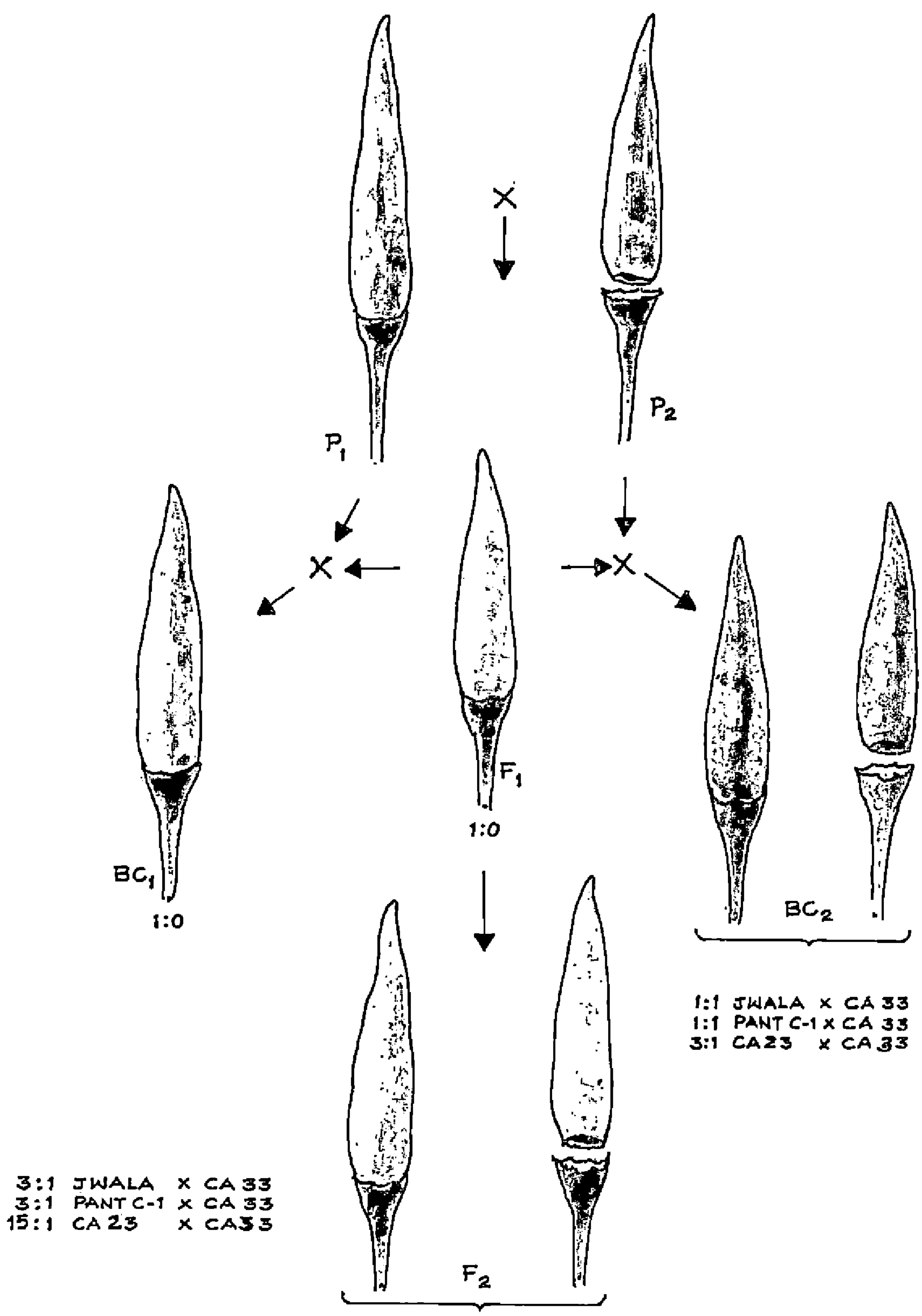
Fig-13. INHERITANCE OF FRUIT ORIENTATION IN CHILLI



processing of chillies. In CA 33 destalked character did not express completely. Based on values of expressivity the expected ratios were modified in the subsequent generations of crosses with Jwala, Pant C-1 and CA 23. In CA 33 x CA 23 all the F_1s were completely stalked and the fruit portion adhered strongly to the pedicel. This indicated dominance of stalked over destalked character (Fig.14). The F_2 segregated into 15 stalked : 1 destalked suggesting the involvement of two genes with duplicate factor interaction, ds_1ds_1 ds_2ds_2 producing destalked character. The duplicate factor interaction was further confirmed by a 3 : 1 segregation in the BC_1 generation. In the remaining two combinations Jwala x CA 33 and Pant C-1 x CA 33, the F_2s fitted to a 3 stalked : 1 destalked ratio revealing the difference at one locus between the parents. This was further confirmed in back cross generations. The same results were observed by Uzo (1984).

Inheritance studies suggested that destalked character was recessive and digenic. The difference of CA 33 with Jwala and Pant C-1 was only at a single locus while with CA 23 at two loci. The genotypes of the four parents are proposed as follows:

Fig-14. INHERITANCE OF DESTALKNESS IN CHILLI



Jwala	$ds_1^+ds_1^+$	$ds_2\ ds_2$
Pant C-1	$ds_1^+ds_1^+$	$ds_2\ ds_2$
CA 33	$ds_1\ ds_1$	$ds_2\ ds_2$
CA 23	$ds_1^+ds_1^+$	$ds_2^+ds_2^+$

The present sets of investigations comprising estimation of variability, combining ability, gene action and inheritance of characters were undertaken as a first step for the overall improvement of chilli. Corroborating the earlier reports, we found enough variability in the germplasm and also heterosis for different quantitative characters. Testing of combining ability and gene action were ambly rewarding in determining the suitable combiners and in deciding the magnitude of each type of gene action involved in desirable traits. The investigation has paved the way for understanding the genetics of clusterness destalkness and fruit orientation in chilli using suitable cross combinations.

Summary

SUMMARY

The present investigation "Inheritance of clusterness, destalkness and deep red colour in chilli (Capsicum annuum L.)" was conducted at the College of Horticulture, Kerala Agricultural University, Vellanikkara during July-November, 1979; May-September, 1980; May-September, 1981 and May-September, 1983. The magnitude of genetic variability in chilli germplasm maintained at the College of Horticulture, Vellanikkara was assessed. The F_1 heterosis in intervarietal crosses was estimated for commercial exploitation of hybrid vigour in chilli. The gene action and type of epistasis governing quantitative characters were studied. The genetics of type of branching, fruiting habit, fruit orientation and destalkness were also worked out.

Variability studies showed significant differences for plant height, main stem length, fruit length, fruit girth, average fruit weight, fruits/plant, fruit yield/plant, days to flower and days to red chilli harvest. Phenotypic coefficient of variation was maximum for fruits/plant (75.16) followed by fruit length (59.21) and main stem length (55.87). Fruit yield/plant recorded only moderate value of pcv. High heritability coupled with high genetic advance was observed for fruit length and main stem length.

Fruits/plant had moderately high estimates of heritability and expected genetic advance. Days to flower, days to first harvest and fruit girth having high heritability had very low expected genetic advance.

Four chilli genotypes - Jwala, Pant C-1, CA 33 and CA 23 - selected based on type of branching, fruiting habit, fruit orientation, ripe fruit colour, destalkness, earliness and yield were crossed in all possible combinations without reciprocals and heterosis was estimated. Out of six hybrids, four exhibited significant relative heterosis for plant height. The hybrid CA 33 x CA 23 was the tallest (57 cm). Three F_1 hybrids had longer fruits than their mid-parents and length of fruit was maximum in Jwala x CA 33 (7.9 cm) among the hybrids. The average fruit weight was also maximum in Jwala x CA 33 (2 g.). Three F_1 hybrids manifested relative heterosis and one, heterobeltiosis for fruits/plant. Though the magnitude of heterosis was maximum in Jwala x CA 33 (RH 35.85%) Jwala x Pant C-1 had maximum fruits/plant (121). Taking into consideration of <u>per se</u> performance and heterosis, Jwala x Pant C-1 was the best hybrid yielding 201g/plant followed by Jwala x CA 23 (160g/plant). All the hybrids were earlier than the mid-parents of which three were earlier than early parents. Pant C-1 x CA 33 flowered 41 days after planting. The magnitude of observed heterosis was not appreciable because the genetic distances of parents involved in the crosses were comparatively narrow.

Combining ability analysis and graphic analysis revealed the presence of both additive and non-additive gene action for the control of plant height in chilli. Generation mean analysis disclosed the importance of dominance effect over additive effect. Duplicate epistasis affected the main gene effects for the control of plant height in five out of six combinations. The magnitude of dominance effect was higher than additive effect for main stem length, primary branches/plant and days to flower. Preponderance of additive effect was noted for leaf laminar length. In majority of the cases interaction effects, especially duplicate type, influenced the main gene effects. Fruit length was governed by both additive and non-additive gene action with involvement of epistasis. Locules/fruit in chilli was obviously an additive character. Combining ability analysis showed predominance of additive gene action for fruit girth, average fruit weight, fruits/plant and fruit yield/plant. For all the above characters the type of interaction varied with combinations of parents and all the three types viz., additive x additive, additive x dominance and dominance x dominance were observed. In most cases epistasis was of duplicate type. Capsaicin content and carotenoid pigments were observed as polygenic characters and both were governed by additive gene action. The colouring matter expressed as total carotenoid pigments was maximum in CA 33 (2107.10 ppm). Jwala and Pant C-1 did not differ markedly (1209.30 and 1391.5 ppm respectively).

Clusterness in chilli was recessive and monogenic. The clustered accession CA 33 differed with solitary varieties Jwala and Pant C-1 only for a single gene 'cl_1'. The genotype of clustered accession CA 33 was postulated as cl_1cl_1. Determinate growth habit was pleiotropic to clustered fruiting habit.

The upright fruit orientation was observed as recessive and digenic. Two genes 'up_1' and 'up_2' operated with a specific dominant and recessive epistasis for the control of upright fruit orientation.

Expressivity of destalked character in CA 33 was not complete. Stalked character was dominant over destalked. Difference of destalked genotype CA 33 with stalked varieties Jwala and Pant C-1 was only at a single locus 'ds_1'. CA 23 differed from CA 33 at two loci 'ds_1' and 'ds_2' with duplicate gene action. The genotype of CA 33 for destalked habit was postulated as ds_1ds_1 ds_2ds_2.

References

REFERENCES

Abou-El-Fadl, I.A. 1979. Improvement of some economical characters in chilli pepper (Capsicum minimum Roxb.). (Abstr.) Alexandria J. Agric. Res. 27 : 471.

Ahmed, N., Singh, J. and Virk, D.S. 1982. Inheritance of some quantitative characters in chilli pepper (Capsicum annuum L.) II. Earliness, seed number, fruit weight and plant height. Capsicum Newsletter 1 : 31.

Al-Hamidi, A., El-Gengaihi, S.E. and Shalaby, A.S. 1977. Variability and heritability studies on major agronomic characters of Capsicum frutescens grown in Egypt. Acta Agron. (Acad. Sci. Hung.) 26 : 412-419.

Allah, A.M.K., Abdel, A.Z.E. and Gad, A.A. 1975. Inheritance and gene action for yield in peppers (Capsicum annuum L.). Egyptian J. Genet. Cyt. 4 : 287-296.

*Alpatev, A.V. and Khrenova, V.V. 1975. The manifestation of some characters in first generation hybrids of sweet pepper. Selekt. i Semenorodstva Ovoschch 2 : 12-18.

Amarchandra, Shrivastava, S.K. and Nair, P.K.K. 1983. Variation in productivity parameters in Capsicum genotypes. (In) Muthukrishnan, C.R., Muthuswamy, S. and Arumugam, R. (Ed.) Natl. Sem. Prod. Tech. Tomato Chillies Proc. Tamil Nadu Agric. Univ., Coimbatore pp. 128-130.

*Anjeli, L. 1964. Breeding bunched peppers. Kertsoz. Szolesz Foikal Kozl. 28 : 66-79.

*Anjeli, L. 1974. The use of fasciculate form (determinate habit) in the breeding of new Hungarian pepper varieties. Rept. Hort. Res. Inst., Budapest pp. 151-155.

A.O.A.C. 1980. Official Methods of Analysis of the Association of Official Analytical Chemists. 13th Ed. Association of Official Analytical Chemists, Washington pp. 218.

Arya, P.S. 1979. Genetic variability, heritability and genetic advance in pickle type chillies (Capsicum annuum L.). Indian cocoa Arecanut spices J. 11 : 82-85.

Arya, P.S. and Saini, S.S. 1976. Genetic variability and correlation studies in bell pepper. Indian J. Agric. Res. 10 : 223-228.

Arya, P.S. and Saini, S.S. 1977. Variability studies in pepper (Capsicum annuum L.) varieties. Indian J. Hort. 34 : 415-421.

Avdeyev, Y.I. 1979. Inheritance of resistance to concentric cracking. Tomato Genet. Co-op. Rept. 29 : 20-21.

Awasthi, D.N., Joshi, S. and Ghildiyal, P.C. 1976. Studies on genetic variability, heritability and genetic advance in chilli (Capsicum annuum L.). Progr. Hort. 8(3) : 37-40.

Awasthi, D.N., Joshy, S. and Ghildiyal, P.C. 1977. A new clustered variety of chilli (Capsicum annuum L.). Progr. Hort. 9 : 33-35.

Bajaj, K.L., Kaur, G.D. and Sooch, B.S. 1980. Varietal variation in some important chemical constituents in chilli (Capsicum annuum L.) fruits. Veg. Sci. 7 : 48-54.

Bak, S.K., Yu, I.Y. and Choic, D.I. 1975. Study on the characterestics of red pepper hybrids. Res. Rept. Rural Dev. Hort. Agric. Engg. South Korea 17 : 43-47.

Balakrishnan, P., Muthukrishnan, C.R. and Irulappan, I. 1983. Heterosis and combining ability in chilli (Capsicum annuum L.). (In) Muthukrishnan, C.R., Muthuswami, S. and Arumugam, R.(Ed.). Natl. Sem. Prod. Tech. Tomato Chillies Proc. Tamil Nadu Agric. Univ. Coimbatore pp. 142-146.

Barrios, E.P. and Mosokar, H.I. 1972. The inheritance of pod colour and bearing habit in Capsicum frutescens L. J. Amer. Soc. Hort. Sci. 97 : 65-66.

Bavaji, J.N. and Murthy, N. 1982. Selection indices for yield components in chilli (Capsicum annuum L.). South Indian Hort. 30 : 17-21.

*Bazak, E., Chyla, F. and Picklowska, M. 1969. Yield and nutritive value of some hybrid varieties of red pepper in the environment of lower Silesia. Biol. Warzyw. 9 : 285-298.

Berg, B.O. and Lippert, L.F. 1975. Inheritance of axillary shooting in Capsicum. Bot. Gaz. 136 : 141-145.

*Betlach, J. 1965. The effect of productivity factors on the total fruit yield of F_1 hybrid peppers. Vyzk. Ust. Zelim. Bull. 9 : 19-31.

*Betlach, J. 1967. Some results of heterosis breeding of sweet pepper (Capsicum annuum L.). J. Genet. Slecht. 3 : 239-252.

*Betlach, J. 1974. Combining ability (general and specific) of some quantitative characters of sweet pepper. Veg. Res. Inst. Rept. Olomoue, Czechoslovakia pp. 211-217

*Betlach, J. 1977. The inheritance of number of fruits/plant in red pepper. Vyzk. Ust. Zelim. Bull. 19 : 47-50.

*Betlach, J. and Vytopil, J. 1969. Analysis of a diallel cross involving some quantitative characters of sweet pepper (Capsicum annuum L.). Genet. i Slecht. 5 : 7-16.

Boswell, V.R. 1937. Improvement and genetics of tomatoes, peppers and egg plants. U.S. Dept. Agric. Year Bk. pp. 176-206.

*Brauer, H.O. 1962. Investigation on quality characters in F_1 hybrids of red pepper. Z. Pflanzenz. 48 : 259-276.

Brauer, H.O. 1963. Influence of progenitors on the quality of F_1 hybrid of chilli (Capsicum annuum L.). Caribean Region Amer. Soc. Hort. Sci. XI Ann. meet. Proc. pp. 41-46.

Briggle, L.W. 1963. Heterosis in wheat - a review. Crop Sci. 3 : 407-412.

Burton, G.W. 1952. Quantitative inheritance in grasses. 6th Int. Grassld. Cong. Proc. 1 : 277-283.

Burton, G.W. and Devane, E.H. 1953. Estimating heritability in tall fescue from replicated clonal material. Agron. J. 45 : 478-481.

*Christov, S. and Popova, D. 1974. Trends and results in breeding of pepper (Capsicum annuum L.) in Bulgaria. Rept. Inst. Veg. Crops Bulgaria pp. 335-339.

Chung, W.J. and Chang, W.N. 1979. Studies on genetic behaviour and breeding of sweet pepper. V. Number of effective genes and gene action for quantitative characters. J. Agric. Forestry 28 : 51-60.

Dale, E.E. 1931. Inheritance of 'dwarf' in Capsicum. Michi. Acad. Sci. Arts Lett. 13 : 1-4.

Daskalov, K.H. and Murtazov, T. 1955. New heterotic red pepper varieties for cultivation under glass or outdoor production. Theor. Appl. Genet. 38 : 370-372.

*Daskalov, K.H. Rusenova, I. and Milkova, L. 1973. Results from the combined use of interspecific hybridization and heterosis in pepper (Capsicum annuum L.). Rept. Inst. Genet. Bulgaria pp. 15-24.

Davis, G.J. and Barry, R. 1979. Difference between tabasco pepper selections in mechanically induced fruit abscission. HortScience 14 : 121.

Deshpande, R.B. 1933. Studies in Indian chillies (3) : The inheritance of some characters in Capsicum annuum L. Indian J. Agric. Sci. 3 : 219-300.

Deshpande, R.B. 1944. Inheritance of bunchy habit in chilli. Indian J. Genet. 4 : 54-55.

*Dikanev, G.P. 1978. Manifestation of heterosis in intervarietal pepper hybrids. Vsesoyuznogo ordena Lenina i ordena Druzhley Narodev Inst. Bull. Rastemievodstva, Imeni 80 : 49-52.

*Dikil, S.P. and Anikeenko, V.S. 1981. Inheritance of some economically useful characters in hot pepper hybrids obtained using male sterility. Trudy. po. Prikladnoi Bot. Genet. i Selekt. 69 : 22-28.

Dutta, M., Dasgupta, P.K., Chattergee, S.D. and Majundar, M.K. 1979. Variability, interrelationship and path coefficient analysis for some quantitative characters in chilli (Capsicum annuum L.). Indian Agric. 23 : 95-102.

Elangovan, M., Pandian, I.R.S. and Sayed, S. 1982. Genetic variability in certain metric traits of Capsicum annuum L. South Indian Hort. 29 : 224-225.

*Ferenc, M. 1970. The production of bunched spice type red peppers with determinate growth with regard to the requirements for machine picking. Duna-Tisza Kozl. Mezogaz dasagi kiserleti Intezet. Bull. 5 : 75-94.

Gill, H.S. and Ahmed, M.G. 1977. Heterotic development of plant characters in Capsicum species. J. Agric. Res., Pakistan 15 : 393-400.

Gill, C.R., Singh, J.R. and Ghai, B.S. 1980. Inheritance of some quantitative characters in chillies (Capsicum annuum L.). Crop Improv. 7 : 54-59.

Gill, H.S., Thakur, P.C. and Thakur, T.C. 1973. Combining ability in sweet pepper (Capsicum annuum Var. grossum Sendt.). Indian J. Agric. Sci. 43 : 918-921.

Gomez, G.M.L. and Cuartero, J. 1982. Method of g c a evaluation. Capsicum Newsletter 1 : 33.

Griffing, B. 1956. Concepts of general and specific combining ability in relation to diallel crossing systems. Aust. J. Biol. Sci. 9 : 463-493.

Gupta, C.R. and Yadav, R.D.S. 1984. Genetic variability and path analysis in chilli (Capsicum annuum L.). Genet. Agric. 38 : 425-432.

Hagiwara, T.K. and Oomura, Y. 1947. On linkage in Capsicum annuum L. Japan J. Genet. Suppl. 1 : 87-96.

Halsted, B.D. 1909. Experiments with peppers. New Jersey St. Agric. Expt. Sta. Ann. Rept. pp. 308-317.

Halsted, B.D. 1913. Experiments with peppers. New Jersey St. Agric. Expt. Sta. 33rd Ann. Rept. pp. 365-386.

Hayes, J.K., Immer, F.R. and Smith, D.C. 1965. Methods of Plant Breeding. McGraw Hill Book Company, Inc. New York. 2nd Ed. pp. 329-332.

Hayman, B.I. 1954. The theory and analysis of diallel crosses. Genetics 39 : 789-809.

Hayman, B.I. 1958. The separation of epistasis from additive and dominance variation in generation means. Heredity 12 : 371-390.

Hiremath, K.G. and Mathapati, S.N. 1977. Genetic variability and correlation studies in Capsicum annuum L. Madras Agric. J. 64 : 170-173.

Hussain, J.S. 1977. Studies on the productivity in chilli (Capsicum annuum L.). M.Sc. (Ag.) thesis. Tamil Nadu Agric. Univ., Coimbatore pp. 49-65.

*Ikeno, S. 1913. Studies uber die Bastarde Van paprika (Capsicum annuum L.). Zeitschr. Ind. Abstr. 10 : 99-114.

Ikeno, S. 1928. Change of dominance in a cross of two strains of Capsicum annuum. Imp. Acad. Tokyo Proc. 4 : 400-403.

Jinks, J.L. and Hayman, B.I. 1953. The analysis of diallel crosses. Maize Genet. Co-op. Newsletter 27 : 48-54.

Jinks, J.L. and Jones, R.M. 1958. Estimation of the components of heterosis. Genetics 43 : 223-234.

Johnson, H.W., Robinson, H.F. and Comstock, R.E. 1955. Estimates of genetic and environmental variability in soy beans. Agron. J. 47 : 314-318.

Joshy, S. and Singh, B. 1980. A note on hybrid vigour in sweet pepper (Capsicum annuum L.). Haryana J. Hort. Sci. 9 : 90-92.

Kaiser, S. 1935. The inheritance of geotropic response in Capsicum fruits. Torrey Bot. Club Bull. 62 : 75-80.

Kerala Agricultural University 1978. Package of Practices Recommendations. Director of Extension, Kerala Agrl. Univ., Vellanikkara pp. 137-138.

*Khrenova, V.V. 1972. A study of second and third generation sweet pepper hybrids. Tr. VNII Selekt. i Semenorodstva Ovoschch. 3 : 110-113.

*Kormos, J. 1954. Inheritance of carotenoid pigment. Inst. Biol. Tihany Ann. Rept. 22 : 235-252.

*Kormos, J. 1962. Enige Bermerkungen uber die Karotenfarben derpaprika frucht. Acta Bot. (Acad. Sci. Hung.) 8 : 279-281.

*Kormos, J. and Kormos, J. 1956. Determinate growth in red pepper. Noventytermeles 5 : 1-10.

*Kormos, J. and Kormos, J. 1960. Die Genetischen typen der carotenoid systeme der paprika frucht. Acta Bot. (Acad. Sci. Hung.) 6 : 305-319.

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

Kshirsagar, A.K., Kale, P.B. and Wankhade, R.V. 1983. Variation and correlation studies in chillies (Capsicum annuum L.). (In) Muthukrishnan, C.R., Muthuswamy, S. and Arumugam, R. (Ed.). Natl. Sem. Prod. Tech. Tomato Chillies Proc. Tamil Nadu Agric. Univ., Coimbatore pp. 131-133.

*Kvachadze, M.B. 1973. Genetics of certain characters in sweet pepper (Capsicum annuum L.). Soobshch AN Gruz S.S.R. 70 : 697-700.

Kvachadze, M.V. 1976. The heredity of some quantitative characters in Capsicum annuum L. Acad. Sci. Georgean S.S.R. Bull. 82 : 169-172.

Laborde, J.A. and Spurr, A.R. 1973. Chromoplast ultrastructure as effected by genes controlling grana retention and carotenoids in fruits of C. annuum L. Amer. J. Bot. 60 : 736-744.

Lee, S.W., Kim, K.S., Lee, S.S. and Jo, Y.K. 1973. Studies on fruit characters and chemical components in several varieties of pepper. J. Korean Soc. Hort. Sci. 13 : 27-34.

Legg, P.D. and Lippert, L.F. 1966. Estimates of variation in environmental variability in a cross between two strains of pepper (Capsicum annuum L.). Proc. Amer. Soc. Hort. Sci. 89 : 443-448.

Lippert, L.F. 1975. Heterosis and combining ability in chilli and peppers by diallel analysis. Crop Sci. 15 : 323-325.

Lippert, L.F., Berg, B.O. and Smith, P.G. 1965. Gene list for the peppers. J. Hered. 56 : 30-34.

Lippert, L.F., Smith, P.G. and Berg, B.O. 1966. Cytogenetics of the vegetable crops. Garden pepper, Capsicum sp. Bot. Rev. 32 : 24-25.

*Ludilov, V.A. 1976. Fruit attachment strength in different sweet pepper varieties and its effect on crop quality with mechanical harvesting. Nauch. Tr. NII Ovoshch Kh-Va. 6 : 206-212.

*Ludilov, V.A. 1977. Inheritance of the character 'Clustered fruit arrangement' in red peppers. Tsitologiya i Genet. 11 : 426-429.

*Ludilov, V.A. 1978. Evaluation of collection of sweet pepper variety for firmness for fruit attachment. (In) Pl. Breed. Abstr. 50 : 8102.

*Ludilov V.A., Lysenko, N.M. and Formin, V.U. 1977. Features of the mechanical harvesting of Sweet pepper. Kartofel i Ovoschi 12 : 25-27.

Mahalanobis, P.C. 1928. A statistical study at chinese head measurement. J. Asiatic Soc. Bengal 25 : 301-377.

Mather, K. 1949. Biometrical Genetics. Chapman and Hall Ltd. London pp. 90-118.

McCammon, K.R. and Honma, S. 1984. Genetics of the 'Umbrella' branching habit in Capsicum annuum L. Theor. Appl. Genet. 68 : 541-545.

Mehra, C.S. and Peter, K.V. 1980. Genetic divergence in chilli. Indian J. Agric. Sci. 50 : 477-481.

Meshram, L.D. 1983. Clustered mutant in chilli (Capsicum annuum L). J. Nuclear Agric. Biol. 12 : 50-51.

*Michna, M. 1963. The phenomenon of heterosis and duration of its effect in Capsicum annuum. Hodowla Roslim Aklimatylz Nascennectwo 7 : 531-581.

*Milkova, L. 1977. Combining ability in a diallel cross of pepper (Capsicum annuum L.). Genet. i Selekt. 12 : 62-67.

*Milkova, L. 1979. General and specific combining ability for plant height in a diallel cross of Capsicum annuum L. Genet. i Selekt. 10 : 324-328.

Milkova, L. and Popova, D. 1981. Inheritance of some quantitative characters in pepper (Capsicum annuum L.). Genet. i Selekt. 14 : 35-40.

Miller, J.C. and Fineman, Z.M. 1937. A genetic study of some qualitative and quantitative characters of the genus Capsicum. Proc. Amer. Soc. Hort. Sci. 35 : 544-550.

Mishra, S.P., Singh, H.N. and Singh, A. 1976. Note on heterosis in chilli (Capsicum annuum L.). Progr. Hort. 8 : 61-64.

Murthy, N.S.R. and Lakshmi, N. 1983. Studies on heterosis in chilli (Capsicum annuum L.). (In) Muthukrishnan, C.R. Muthuswamy, S. and Arumugam, R. (Ed.). Natl. Sem. Prod. Tech. Tomato Chillies Proc. Tamil Nadu Agric. Univ., Coimbatore pp. 139-141.

Murthy, N.S.R. and Murthy, B.S. 1962. Inheritance studies in chillies. Andhra Agric. J. 9 : 140-144.

Nagaich, B.B., Sethi, J. and Chaubey, I.P. 1972. Inheritance of characters and heterosis in Capsicum sp. Haryana J. Hort. Sci. 1 : 69-75.

Nair, P.M., Mary, M.K. and Nair, V.G. 1984. Estimation of variability and genetic parameters in chillies. Indian Cocoa Arecanut Spices J. 7 : 115-117.

Nandpuri, K.S., Gupta, P.S. and Thakur, P.C. 1970. Correlation studies in chilli. J. Res. Punjab Agric. Univ. 7 : 501-503.

Nandpuri, K.S., Gupta, P.S. and Thakur, P.C. 1971. Variability studies in chillies. J. Res. Punjab Agric. Univ. 8 : 311-315.

Nandpuri, K.S. and Kumar, J.C. 1973. Inheritance of fruit characters in chilli. I. Yield. J. Res. Punjab Agric. Univ. 10 : 49-52.

Nowaczyk, P. 1981. Heterosis effect in F_1 hybrids of red pepper (C. annuum L.). under forcing and delaying cultivation in green house and plastic tunnel. Genet. Polonica 22 : 85-89.

Odland, M.L. 1948. Inheritance studies in the pepper Capsicum frutescens. Minnesota Agric. Expt. Sta. Tech. Bull. 179 : 1-32.

Ohta, Y. 1962. Physiological and genetical studies on pungency in red pepper. V. Genetics of pungency. Japan. J. Genet. 37 : 169-175.

Ohta, V. 1969. A variant found in the progeny from grafting in Capsicum annuum. Natl. Inst. Genet. Japan Ann. Rept. pp. 34-35.

*Okitsu, S., Honda, F., Yamato, M., Niiuchi, K., I to, K. and Ota, S. 1984. Breeding of new cultivars of hot pepper (Capsicum annuum L.). Tachiyatsubusa, Karayatsubusa and Hosoyatsubusa. Veg. Ornamental Crops Res. Sta., C. Kurume Bull. 7 : 25-33.

*Oromos, I.N. and Zatyko, L. 1971. Production and breeding of table peppers with regard to the requirements of the canning industry. Agrartudomanyi Kozl. 30 : 601-606.

Ostle, B. 1966. Statistics in Research. I.B.H., Oxford pp. 363-370.

Pal, B.P. 1945. Studies in hybrid 1. Note on manifestation of hybrid vigour in gram, sesamum, chilli and maize. Indian J. Genet. 5 : 106-121.

Pandey, S.C., Pandita, M.L. and Dixit J. 1981 a. Studies on heterosis in chilli (Capsicum annuum L.). Haryana J. Hort. Sci. 10 : 116-121.

Pandey, S.C., Pandita, M.L. and Dixit, J. 1981 b. Line x tester analysis for the study of combining ability in chilli (C. annuum L.). Haryana Agric. Univ. J. Res. 11 : 206-212.

Pandian, I.R.S., SivaSubramanian, V. and Rengaswamy, P. 1978. Hybrid vigour in chilli (Capsicum annuum L.). South Indian Hort. 26 : 191-192.

Panse, V.G. and Sukhatme, P.V. 1954. Statistical Methods for Agricultural Workers. 3rd Ed. I.C.A.R., New Delhi pp. 70-73.

Park, J.B. and Takatashi, K. 1980. Expression of heterosis and combining ability for capsaicin content in red pepper. J. Japan. Soc. Hort. Sci. 49 : 189-196.

Pillai, E.R.S., George, M.K. and Mercy, S.T. 1977. Studies on interspecific hybrids of five species of Capsicum with special reference to its qualitative and quantitative characters. Agric. Res. J. Kerala 15 : 1-5.

Pious, T. 1985. Transfer of clusterness to bell peppers (Capsicum annuum L. Var. grossum Sendt.). M.Sc. thesis, Kerala Agric. Univ., Vellanikkara 97 pp.

*Popova, D. 1972. Use of the second hybrid generation of pepper. Priroda Bulgaria 22 : 57-58.

*Popova, D., Daskalov, S., Milkova, L. and Markova, M. 1976. A study of heterosis in red pepper in Bulgaria. AZSSR 5 : 37-39.

*Popova, D. and Mihailov, L. 1969. A study of the manifestation of heterosis in tomato and pepper. Genet. i Selekt. 2 : 249-264.

*Popova, D. and Mihailov, L. 1972. Effect of some factors in the manifestation of heterosis in sweet pepper. Priroda Bulgaria 22 : 71-74.

*Popova, P.G. and Mihailov, L. 1975. A contribution to the study of some manifestations of heterosis in sweet pepper (C. annuum L.). Genet. i Slecht. 11 : 125-126.

*Popova, D. and Mihailov, L. 1976. Inheritance of some quantitative characters in heterotic combinations of pepper (Capsicum annuum L.). Genet. Agric. 30 : 399-406.

Popova, D. and Mihailov, L. 1978. Biological basis of the hybrid seed production in peppers. Acta Hort. 8 : 83-87.

*Prudek, M. 1981. Genetic analysis of fruit yield and its components in sweet pepper. Informacni Zprovodaj 14 : 28.

Quagliotti, L. 1971. Effects of soil moisture and nitrogen levels on the pungency of berries of Capsicum annuum L. Hort. Res. 11 : 93-97.

Quagliotti, L. and Ottaviano, E. 1971. Genetic analysis of the variability in capsaicin content in two pepper varieties. Genet. Agric. 25 : 56-66.

Rajamani, T.S. and Nagaratnam, A.K. 1962. Advances in farm research : Chilli. Indian Fmg 12(7) : 5.

Raju, D.N.N. 1980. Correlation and path coefficient analysis in Capsicum annuum L. Var. grossum Sendt. (Abstr.) Mysore J. Agric. Sci. 14 : 278-279.

Ramakumar, P.V., Murthy, S.R.N. and Durgaprasad, M.M.K. 1981. Genetic variability, correlation and discriminant function in chilli. Indian J. Agric. Sci. 51 : 723-725.

Ramalingam, R.S. 1978. Madhurai-1, An improved chilli variety. Madras Agric. J. 65 : 84-86.

Ramalingam, R.S. 1979. Studies on genetic variability for yield and its components in chillies. Andhra Agric. J. 26 : 92-94.

Ramalingam, R.S. and Rajendran, M.C. 1977. Variability studies in chillies. Madras Agric. J. 64 : 675-676.

Ramanujam, S. and Thirumalachar, D.K. 1966. Component analysis of capsaicin content in chilli. Indian J. Genet. 26 : 227-229.

Ramanujam, S. and Thirumalachar, D.K. 1967. Genetic variability of certain characters in red pepper (Capsicum annuum L.). Mysore J. Agric. Sci. 1 : 30-36.

Rao, C.R. 1952. Advanced Statistical Methods in Biometric Research. John Wiley and Sons Inc. New York pp. 28-56.

Rao, P.V. and Chhonkar, V.S. 1983. Components of genetic variances for five quantitative characters in chilli. South Indian Hort. 31 : 15-19.

Rao, P.V. and Chhonkar, V.S. 1984. Combining ability analysis for yield components in chilli. Indian J. Agric. Sci. 54 : 1038-1044.

Rao, R.V.V., Jaiswani, B.G. and Msawa, B.M. 1981. Factor analysis in chilli. Indian J. Agric. Sci. 51 : 225-228.

Rochhetta, G.I., Giorgi, O. and Giovanelli, G. 1976. Correlation analysis between morphological traits and productivity in cultivated capsicum for an understanding of heterosis phenomenon. Genet. Agric. 30 : 355-374.

Saccardo, F. 1981. The latest on breeding peppers for processing. (Abstr.) Informat. Agric. 37 : 18287-18290.

Saccardo, F. and Sreeramalu, K. 1977. Cytological investigation on the genus Capsicum. EUCARPIA 3rd Meet. France Proc. pp. 51-60.

Sahrigy, M.A. and Seehy, M.A. 1974. Cytogenetical studies in the genus Capsicum. II A. morphogenetic study C. Pedicels. Egyptian J. Genet. Cyt. 3 : 299-300.

Sayed, S. and Bagavandass, M. 1980. Inheritance studies in chilli (C. annuum L.). South Indian Hort. 28 : 31.

Scossirolli, R.E., Silvetti, E. and Giovanelli, G. 1974. Genetics of production traits in Capsicum. Inst. Genet. Italy Rept. pp. 181-191.

Setiamihardja, R. 1983. Inheritance and association of certain fruit and pedicel characters in Capsicum annuum L. relative to the fruit detachment force. (Abstr.) Diss. Abstr. Int. B. 43 : 3805 B.

Setiamihardja, R. and Knavel, D.E. 1982. Inheritance of certain fruit detachment force. (Abstr.) Hort. Science 17 : 477.

Sharma, P.P. and Saini, S.S. 1977a. Heterosis and combining ability for yield and agronomic characters in pepper (Capsicum annuum L.). Veg. Sci. 4 : 43-48.

Sharma, P.P. and Saini, S.S. 1977b. Inheritance of capsaicin content in Capsicum annuum L. Veg. Sci 4 : 81-85.

Shaw, F.J.F. and Khan, S.A.R.K. 1928. Studies on Indian chillies (1) The type of Capsicum. Mem. Dept. Agric. Indian Ser. 6 : 59-82.

Shifris, C. and Hakin, Y. 1977. Segregation of prebifurcation shooting, stem length and leaf number of main stem in two crosses of Capsicum annuum L. Euphytica 26 : 491-495.

Shifris, C. and Sacks, J.M. 1980. The effect of distance between parents on the yield of sweet pepper and hot pepper hybrids. (Capsicum annuum L.). in a single harvest. Theor. Appl. Genet. 58 : 253-256.

Silvetti, E. and Giovanelli, G. 1970. Analysis of a diallel cross among some sweet pepper varieties and their F_1 progeny. Genet. Agric. 24 : 269-279.

Silvetti, E. and Grassia, A. 1976. Genetic researches on Capsicum. Genet. Agric. 30 : 375-397.

Singh, K. 1958. Genetic variability in chillies. M.Sc. thesis. IARI, New Delhi pp. 69-82.

Singh, R.P. 1982. Combining ability in relation to chilli breeding. Madras Agric. J. 69 : 81-85.

Singh, J., Ahmed N. and Virk, D.S. 1982. Inheritance of some quantitative characters in chilli pepper (Capsicum annuum L.). (1) Fruit yield, number and size. Capsicum Newsletter 1 : 30.

Singh, A., Bajpaye, N.K. and Sharma, V.K. 1981. Genetic studies in chillies. Progr. Hort. 13(3-4) : 9 - 13.

Singh, R.P. and Rai, J.N. 1981. Note on the heritability and genetic advance in chilli (Capsicum annuum L.). Progr. Hort. 13 : 89-92.

Singh, M.P. and Roy, R.S. 1945. Inheritance of fruit position in chilli cross. Curr. Sci. 14 : 133.

Singh, N.B. and Singh, B. 1970. Interrelationship, heritability estimate and genetic advance in yield and other characters in chillies (Capsicum annuum L.). Madras Agric. J. 57 : 369-373.

Singh, A. and Singh, H.N. 1976a. Genetic divergence in chilli. Indian J. Genet. 36 : 425-430.

Singh, A. and Singh, H.N. 1976b. Components of variance and degree of dominance for yield contributing traits in chilli. Indian J. Agric. Sci. 46 : 376-381.

Singh, A. and Singh, H.N. 1977a. Note on heritability, genetic advance and minimum number of genes in chilli. Indian J. Agric. Sci. 47 : 260-262.

Singh, A. and Singh, H.N. 1977b. Genetic components for yield and its contributing traits in chilli (*Capsicum annuum* L.). Haryana J. Hort. Sci. 6 : 155-160.

Singh, A. and Singh, H.N. 1978. Heterosis and its components for yield in chilli. Indian J. Agric. Sci. 48 : 387-389.

Singh A., Singh, H.N. and Bajpaye, N.K. 1978. A new strai of chilli with loose calyx. Indian Hort. 28 : 13.

Singh, G.H., Singh, J.R. and Ghai, B.S. 1980. Inheritance of some quantitative characters in chillies (*Capsicum annuum* L.). Crop Improv. 7 : 54-59.

Singh, K., Singh, B., Kalloo and Mehrotra, N. 1972. Variability and correlation studies in chillies. J. Res. Haryana Agric. Univ. 11 : 13-18.

Singh, A., Singh, H.N. and Mital, R.K. 1973. Heterosis in chillies. Indian J. Genet. 33 : 398-400.

Smith, P.G. 1948. Brown mature fruit colour in pepper (*Capsicum frutescens*). Science 107 : 345-346.

Smith, P.G. 1950. Inheritance of brown and green mature fruit colour in peppers. J. Hered. 41 : 138-140.

Smith, P.G. 1951. Deciduous ripe fruit character in peppers. Proc. Amer. Soc. Hort. Sci. 57 : 343-344.

Soh, A.C., Yap, T.C. and Graham, K.M. 1976. Heterosis and Combining ability in diallel cross of chilli (*Capsicum annuum* L.). J. Agric. Sci. 87 : 447-449.

Soh, A.C., Yap, T.C. and Graham, K.M. 1977. Diallel analysis in chilli for horticultural characteristics and resistance to pepper veinal mottle virus. SABRAO J. 9 : 127-134.

*Soltanovskaya, G., 1976. Heterosis in sweet pepper (Capsicum annuum L.). (In) Pl. Breed. Abstr. 49 : 9449.

Sontakke, M.B. 1981. Genetical studies in chillies (Capsicum annuum L.). M.Sc. thesis, Univ. of Agric. Sci., Bangalore pp. 50-69.

*Spasojevic, V. and Webb, R.E. 1971. Inheritance of the abscission of ripe pepper from its calyx. Arhiv. Biol. Nanka. 23 : 115-119.

Spasojevic, V., and Webb, R.E. 1972. Inheritance of abscission of ripe pepper fruit from its calyx. Sci. Bull. 19 : 17.

Sprague, G.F. and Tatum, L.A. 1942. General Vs specific combining ability in single cross corn. J. Amer. Soc. Agron. 34 : 923-932.

*Studentsova, L.I. 1973. Some morphological and physiological features of red pepper hybrids. Trudy po Prikladnoi Bot. Genet. i Selekt. 50 : 30-33.

Subramanya, R. 1983. Transfer of genes for multiple flowers from Capsicum chinense to Capsicum annuum L. HoftScience 18 : 747-749.

Sundaram, A., Ramakrishnan, A., Renganathan, C.R. and Ramalingam, S. 1980. Genetic divergence in chilli. Indian J. Agric. Sci. 50 : 391-393.

Thakur, P.C., Gill, H.S. and Bhagchandani, P.M. 1980. Diallel analysis of some quantitative traits in sweet pepper. Indian J. Agric. Sci. 50 : 811-817.

Uzo, J.O. 1984. Hybrid vigour and gene action of two qualitative traits of flavour peppers in Nigeria. Sci. Hort. 22 : 321-326.

Vadivel, E., Vadivel, B., Arumugam, R. and Muthuswamy, S. 1983. Variability studies in pungent chillies (Capsicum annuum L.). (In) Muthukrishnan, C.R., Muthuswamy, S. and Arumugam, R. (Ed.) Natl. Sem. Prod. Tech. Tomato Chillies Proc. Tamil Nadu Agric. Univ., Coimbatore pp. 134-136.

*Voronima, M.V. and Ilenko, T.S. 1981. Promising dwarf lines of sweet pepper for cultivation under cover. Trudy po prickladoni Bot. Genet. i Selekt. 69 : 123-126.

Webber, H.J. 1912. Preliminary notes on pepper hybrids. Amer. Breeders Assoc. Ann. Rept. 7 : 188-199.

Werner, D.J. and Honma, S. 1980. Inheritance of fruit detachment force in pepper. J. Amer. Soc. Hort. Sci. 105 : 805-807.

*Original not seen

Appendices

Appendix-I. Mean performance of chilli genotypes for 10 characters during two seasons

Accession number		Plant height (cm)	Main stem length (cm)	Primary branches/ plant(cm)	Fruit length (cm)	Fruit girth (cm)	Average fruit weight	Fruits/ plant	Fruit yield/ plant (g)	Days to flower	Days to red chilli harvest
CA 3	S-1	123.4	94.9	14.2	4.0	0.82	1.39	329.7	390.2	65.3	102.2
	S-2	111.6	80.2	9.2	4.1	0.82	1.11	238.5	312.3	67.3	109.7
CA 6	S-1	69.7	38.3	8.7	3.3	0.89	1.40	119.1	156.6	52.4	90.8
	S-2	73.1	35.3	9.3	4.2	0.82	1.38	98.6	118.1	46.4	76.0
CA 6-1	S-1	74.7	38.8	8.1	3.4	0.76	1.15	142.1	152.5	52.5	88.9
	S-2	68.4	36.7	7.7	3.8	0.82	1.16	164.8	120.3	49.7	74.0
CA 10-1	S-1	82.5	36.1	8.3	3.8	0.73	1.30	134.7	165.3	53.7	91.7
	S-2	72.7	34.1	9.4	3.7	0.82	0.93	160.9	132.3	47.9	85.7
CA 12	S-1	70.5	38.2	10.8	3.0	0.80	1.22	108.3	198.8	52.1	89.8
	S-2	67.4	35.2	10.9	3.9	0.77	1.43	99.3	118.5	43.7	83.3
CA 19-1	S-1	79.3	37.8	9.3	3.9	0.79	1.32	132.3	162.5	51.1	85.4
	S-2	77.5	38.7	8.7	3.9	0.84	1.35	111.9	124.1	43.3	80.1
CA 19-2	S-1	74.6	36.7	9.7	2.9	0.97	1.55	135.9	136.8	51.3	88.8
	S-2	58.7	32.6	8.7	3.9	0.81	1.31	117.3	169.7	43.4	85.7
CA 19-3	S-1	76.5	38.4	9.3	5.1	0.74	1.59	131.0	164.3	52.6	83.9
	S-2	62.2	36.2	9.6	3.8	0.82	1.34	112.3	123.2	44.1	88.0
CA 23	S-1	65.8	36.5	9.3	3.3	0.82	1.47	151.3	163.3	53.8	87.3
	S-2	65.5	31.0	12.1	4.8	0.82	1.20	146.6	143.5	45.3	86.3

Appendix-I. (Contd.)

Accession number		Plant height (cm)	Main stem length (cm)	Primary branch-es/ plant (cm)	Fruit length (cm)	Fruit girth (cm)	Aver-age fruit weight (g)	Fruits/ plant	Fruit yield/ plant (g)	Days to flower	Days to red chilli harvest
CA 24-1	S-1	70.5	35.0	8.6	3.3	0.82	1.24	148.8	140.9	49.4	84.0
	S-2	69.6	33.6	10.9	3.8	0.73	1.57	173.9	192.7	45.3	82.1
CA 24-2	S-1	82.2	37.3	7.3	4.3	0.78	1.40	159.3	176.4	53.0	90.9
	S-2	64.8	35.1	11.3	3.4	0.83	1.16	137.4	146.3	45.2	82.7
CA 26-1	S-1	76.7	39.7	9.6	5.0	0.83	1.47	130.7	172.3	47.3	84.9
	S-2	51.1	32.7	9.3	3.9	0.76	1.08	123.8	142.3	43.3	85.3
CA 30-1	S-1	82.6	42.1	9.0	3.0	0.87	1.27	140.1	147.3	51.6	86.4
	S-2	69.5	36.3	9.4	3.8	0.86	1.29	132.7	139.7	42.7	86.3
CA 30-2	S-1	86.0	43.2	9.0	4.2	0.77	1.26	133.1	128.7	53.2	88.9
	S-2	77.4	38.1	8.6	3.8	0.89	1.21	125.9	444.6	42.6	85.4
CA 32	S-1	70.8	42.3	6.5	3.9	0.79	1.36	107.3	152.2	50.6	88.5
	S-2	65.4	33.1	10.3	3.8	0.78	1.52	127.7	153.9	47.6	78.5
CA 33	S-1	71.8	38.8	7.7	4.0	0.85	1.48	147.6	195.6	54.1	91.7
	S-2	87.1	38.3	8.7	3.9	0.83	1.36	151.1	205.4	48.8	76.3
CA 36	S-1	70.4	37.5	7.5	3.2	0.81	1.26	89.1	115.1	46.6	84.3
	S-2	72.5	40.7	8.7	4.0	0.80	1.35	111.7	124.0	44.6	82.0
CA 36-1	S-1	58.3	38.0	10.3	3.6	0.80	1.35	201.3	268.4	49.6	86.4

Appendix-I. (Contd.)

Accession number		Plant height (cm)	Main stem length (cm)	Primary branches/ plant (cm)	Fruit length (cm)	Fruit girth (cm)	Average fruit weight (g)	Fruits/ plant	Fruit yield/ plant (g)	Days to flower	Days to red chilli harvest
CA 39-1	S-1	64.4	37.7	9.1	3.5	0.76	1.29	91.7	128.9	52.1	91.9
	S-2	73.1	37.9	8.1	3.4	0.78	1.21	115.6	109.0	47.3	78.3
CA 43	S-1	58.5	41.5	6.8	3.8	0.78	1.29	112.3	158.6	46.3	84.5
	S-2	71.2	36.5	7.3	3.3	0.89	1.22	88.8	97.7	42.6	79.3
CA 45	S-1	70.8	45.8	15.1	3.9	0.83	1.19	202.8	211.3	48.2	87.1
	S-2	68.4	35.7	10.1	4.0	0.83	1.18	112.7	113.0	46.0	79.3
CA 47	S-1	70.6	35.6	10.8	4.3	0.76	1.13	26.5	59.4	53.0	85.9
	S-2	88.7	44.3	13.0	3.5	0.79	1.08	124.3	133.0	45.8	76.1
CA 48	S-1	65.3	40.6	9.3	4.6	0.82	1.26	253.3	328.9	51.9	89.3
	S-2	63.1	38.0	9.3	3.7	0.81	1.25	100.3	121.3	43.6	82.7
CA 52	S-1	77.4	43.4	9.2	3.3	0.71	1.74	189.7	263.9	50.3	88.6
	S-2	68.6	32.7	10.0	5.3	0.74	1.05	124.1	118.0	39.3	77.1
CA 53	S-1	48.9	42.3	6.1	4.6	0.82	1.23	178.1	281.4	46.9	77.5
(Pant C-1)	S-2	59.0	37.7	12.3	4.8	0.79	0.97	319.8	269.5	37.7	77.4
CA 54	S-1	76.9	76.3	6.3	2.9	0.77	1.21	132.5	173.4	54.5	91.6
	S-2	74.5	39.3	7.4	2.8	0.81	1.18	126.3	116.2	40.6	82.1
CA 54-1	S-1	69.0	37.1	11.7	3.0	0.85	1.23	155.6	232.0	50.7	88.7
	S-2	72.4	38.6	11.7	3.0	0.89	1.38	122.7	116.0	41.6	86.7

Appendix-I. (Contd.)

Accession number		Plant height (cm)	Main stem length (cm)	Primary branch-es/ plant (cm)	Fruit length (cm)	Fruit girth (cm)	Aver-age fruit weight (g)	Fruits/ plant	Fruit yield/ plant (g)	Days to flower	Days to red chilli harvest
CA 56	S-1	64.8	34.7	8.7	4.0	0.84	1.09	88.3	96.4	48.5	88.9
	S-2	57.3	31.7	7.3	4.0	0.86	1.36	140.3	116.3	50.3	83.3
CA 56-1	S-1	59.6	42.1	10.1	3.7	0.75	1.10	111.7	130.9	50.9	77.1
	S-2	68.9	32.9	12.2	3.7	0.82	1.18	124.0	119.2	48.6	84.1
CA 59	S-1	67.4	39.1	9.2	4.3	0.75	1.21	101.0	144.1	50.2	77.6
	S-2	71.4	37.5	9.0	4.2	0.76	1.35	121.3	97.2	48.6	85.3
CA 60 (Jwala)	S-1	60.7	60.6	7.3	9.8	0.71	2.29	133.8	260.6	39.5	74.7
	S-2	52.4	39.7	8.0	13.2	0.83	2.13	134.7	228.3	35.2	74.8
CA 60-1	S-1	76.5	76.7	7.4	10.5	0.70	2.11	114.5	224.0	39.8	74.9
	S-2	50.3	37.3	7.7	13.8	0.87	2.74	132.7	270.1	36.6	73.9
CA 68 (NP 46-A)	S-1	70.9	70.5	6.2	6.9	0.80	2.10	114.3	217.1	42.9	78.7
	S-2	60.7	60.3	8.6	12.8	0.93	1.97	108.2	146.5	38.7	75.9
CA 69	S-1	71.4	70.3	9.3	9.2	0.74	1.89	78.4	163.2	40.8	78.7
	S-2	74.1	66.7	10.3	8.9	0.73	1.96	123.7	115.1	41.5	80.0
CA 87 (Bhagya lakshmy)	S-1	101.6	101.5	9.2	6.5	0.62	1.85	31.67	77.8	44.8	79.7
	S-2	85.7	85.7	9.7	6.5	0.72	1.21	93.64	152.1	41.5	84.4

Appendix-I. (Contd.)

Accession number		Plant height (cm)	Main stem length (cm)	Primary branches/ plant (cm)	Fruit length (cm)	Fruit girth (cm)	Average fruit weight (g)	Fruits/ plant	Fruit yield/ plant (g)	Days to flower	Days to red chilli harvest
CA 89	S-1	130.5	127.5	15.3	4.3	0.80	1.26	180.7	146.4	65.0	102.0
	S-2	101.7	98.6	11.2	4.2	0.86	1.08	282.3	341.3	64.7	106.3
CA 94 (K-2)	S-1	94.5	91.5	6.4	8.3	0.92	2.68	78.3	162.3	40.3	77.5
	S-2	94.6	86.3	8.0	7.5	0.94	2.36	82.0	173.7	37.5	77.4
CA 99	S-1	94.9	94.8	10.0	7.3	0.78	2.17	115.4	193.8	37.9	74.3
	S-2	92.6	91.3	8.3	8.6	0.90	1.96	174.4	256.3	43.6	84.5
CA 110	S-2	129.3	121.7	12.0	1.9	0.32	0.25	558.3	170.7	67.0	107.0
CA 111	S-2	65.6	54.6	12.1	6.6	0.84	1.37	121.0	237.1	45.9	81.3
CA 112	S-2	111.3	105.3	9.1	2.2	0.36	0.22	703.4	147.3	65.9	106.9
CA 113	S-2	129.0	122.7	12.9	4.1	0.83	0.84	302.7	294.9	50.3	86.3
CA 115	S-2	133.6	129.7	10.7	1.9	0.41	0.41	338.2	196.7	65.0	113.0
CA 116	S-2	112.7	107.2	11.7	2.2	0.34	0.25	439.5	195.9	69.7	111.9
CA 118	S-2	112.3	104.7	11.0	1.9	0.35	0.18	597.6	192.6	64.0	108.6
CA 119	S-2	110.6	111.7	11.3	2.1	0.32	0.22	551.3	333.8	64.1	111.4
CA 120	S-2	96.8	90.3	8.9	6.9	0.89	1.57	218.6	404.4	48.7	83.9

Appendix-I. (Contd.)

Accession number	Plant height (cm)	Main stem length (cm)	Primary branches/ plant (cm)	Fruit length (cm)	Fruit girth (cm)	Average fruit weight (g)	Fruits/ plant	Fruit yield/ plant (g)	Days to flower	Days to red chilli harvest
CD(p=0.05)S-1	11.8	1.2	3.7	0.9	0.10	0.37	72.7	85.9	5.4	5.5
S-2	15.8	9.4	4.4	0.9	0.08	0.29	115.5	62.1	5.0	5.9

S-1 = July-November, 1979; S-2 = May-September, 1980.

Appendix II. Generation means for 15 quantitative characters in chilli

Generations	$P_1 \times P_2$	$P_1 \times P_3$	$P_1 \times P_4$	$P_2 \times P_3$	$P_2 \times P_4$	$P_3 \times P_4$
Plant height (cm)						
P_1	38.5 ± 1.27	38.5 ± 1.27	38.5 ± 1.27	35.1 ± 1.33	35.1 ± 1.33	46.2 ± 1.46
B_1	45.1 ± 1.60	40.5 ± 1.84	39.2 ± 1.36	43.4 ± 1.62	40.5 ± 1.29	47.4 ± 1.72
F_1	37.3 ± 1.35	37.1 ± 1.94	38.95 + 1.19	39.1 + 2.30	35.1 ± 1.38	45.2 + 1.12
F_2	40.2 ± 1.97	42.5 ± 1.77	45.00 ± 1.83	36.7 ± 1.91	30.9 ± 1.85	39.3 ± 1.39
B_2	41.4 ± 1.23	40.0 ± 1.88	38.1 ± 1.85	45.1 ± 1.28	42.3 ± 1.71	49.3 ± 2.59
P_2	35.1 ± 1.33	46.2 ± 1.46	43.2 ± 1.58	46.2 ± 1.46	43.2 ± 1.58	43.2 ± 1.58
Main stem length (cm)						
P_1	36.1 ± 1.03	36.1 ± 1.03	36.1 ± 1.03	32.25 ± 1.27	32.25 ± 1.27	35.9 ± 1.23
B_1	24.8 ± 1.20	25.8 ± 1.62	20.0 ± 1.15	27.15 ± 1.21	27.3 ± 0.51	29.0 ± 0.52
F_1	21.2 ± 1.08	23.05 ± 0.65	24.8 ± 1.24	23.25 ± 1.44	23.8 ± 0.92	30.7 ± 1.00
F_2	24.31 ± 0.96	23.6 ± 1.74	23.4 ± 1.47	24.5 ± 1.36	21.3 ± 0.97	21.4 ± 1.46
B_2	24.7 ± 1.16	23.15 ± 1.94	24.1 ± 1.11	25.6 ± 1.23	24.25 ± 1.12	25.55 ± 1.06
P_2	32.25 ± 1.27	35.9 ± 1.23	30.65 ± 1.60	35.9 ± 1.23	30.65 ± 1.60	30.65 ± 1.60

Appendix II (Contd.)

Generations	$P_1 \times P_2$	$P_1 \times P_3$	$P_1 \times P_4$	$P_2 \times P_3$	$P_2 \times P_4$	$P_3 \times P_4$
Primary branches/plant						
P_1	4.60 ± 0.19	4.60 ± 0.19	4.60 ± 0.19	3.80 ± 0.28	3.80 ± 0.28	4.10 ± 0.21
B_1	2.80 ± 0.24	4.60 ± 0.41	3.60 ± 0.35	5.50 ± 0.16	4.50 ± 0.26	5.10 ± 0.41
F_1	4.30 ± 0.35	3.90 ± 0.26	3.70 ± 0.25	3.40 ± 0.35	3.50 ± 0.29	3.40 ± 0.21
F_2	3.80 ± 0.32	3.90 ± 0.26	3.00 ± 0.22	3.30 ± 0.18	3.60 ± 0.38	5.30 ± 0.62
B_2	4.50 ± 0.30	3.00 ± 0.13	4.20 ± 0.19	5.00 ± 0.37	4.50 ± 0.35	5.20 ± 0.70
P_2	3.80 ± 0.28	4.10 ± 0.21	3.40 ± 0.22	4.10 ± 0.21	3.40 ± 0.22	3.40 ± 0.22
Internodal length (cm)						
P_1	2.90 ± 0.15	2.90 ± 0.15	2.90 ± 0.15	3.20 ± 0.23	3.20 ± 0.23	3.60 ± 0.18
B_1	3.60 ± 0.08	2.30 ± 0.19	2.16 ± 0.16	3.42 ± 0.27	4.03 ± 0.20	3.38 ± 0.23
F_1	2.25 ± 0.12	2.31 ± 0.11	3.38 ± 0.30	2.69 ± 0.16	2.76 ± 0.03	2.99 ± 0.19
F_2	2.41 ± 0.12	2.36 ± 0.19	3.25 ± 0.21	2.24 ± 0.17	2.40 ± 0.16	2.84 ± 0.26
B_2	2.61 ± 0.08	2.94 ± 0.34	3.80 ± 0.41	2.54 ± 0.05	3.35 ± 0.19	3.25 ± 0.22
P_2	3.20 ± 0.23	3.60 ± 0.18	3.30 ± 0.17	3.60 ± 0.18	3.30 ± 0.17	3.30 ± 0.17

Appendix II (Contd.)

Generations	$P_1 \times P_2$	$P_1 \times P_3$	$P_1 \times P_4$	$P_2 \times P_3$	$P_2 \times P_4$	$P_3 \times P_4$
Internodal girth (cm)						
P_1	0.79 ± 0.02	0.79 ± 0.02	0.79 ± 0.02	0.73 ± 0.03	0.73 ± 0.03	0.77 ± 0.02
B_1	0.75 ± 0.02	0.68 ± 0.03	0.65 ± 0.02	0.83 ± 0.02	0.75 ± 0.03	0.73 ± 0.03
F_1	0.72 ± 0.03	0.60 ± 0.03	0.63 ± 0.02	0.52 ± 0.04	0.58 ± 0.01	0.69 ± 0.03
F_2	0.78 ± 0.03	0.68 ± 0.02	0.70 ± 0.04	0.67 ± 0.03	0.61 ± 0.02	0.63 ± 0.02
B_2	0.74 ± 0.03	0.64 ± 0.02	0.69 ± 0.03	0.70 ± 0.03	0.72 ± 0.03	0.78 ± 0.03
P_2	0.73 ± 0.03	0.77 ± 0.02	0.75 ± 0.03	0.77 ± 0.02	0.75 ± 0.03	0.75 ± 0.03
Leaf laminar length (cm)						
P_1	5.37 ± 0.35	5.37 ± 0.35	5.37 ± 0.35	5.52 ± 0.36	5.52 ± 0.36	7.37 ± 0.38
B_1	5.83 ± 0.38	7.15 ± 0.21	6.46 ± 0.27	6.08 ± 0.48	5.60 ± 0.39	6.91 ± 0.25
F_1	6.14 ± 0.41	7.24 ± 0.60	6.96 ± 0.38	7.09 ± 0.40	7.45 ± 0.17	7.47 ± 0.32
F_2	6.42 ± 0.32	6.56 ± 0.52	6.36 ± 0.41	5.57 ± 0.50	6.17 ± 0.36	7.11 ± 0.24
B_2	5.57 ± 0.88	6.93 ± 0.25	7.18 ± 0.33	7.70 ± 0.93	7.46 ± 0.29	7.32 ± 0.32
P_2	5.52 ± 0.36	7.37 ± 0.38	7.31 ± 0.34	7.37 ± 0.38	7.31 ± 0.34	7.31 ± 0.34

Appendix II (Contd.)

Generations	$P_1 \times P_2$	$P_1 \times P_3$	$P_1 \times P_4$	$P_2 \times P_3$	$P_2 \times P_4$	$P_3 \times P_4$
Fruit length (cm)						
P_1	6.78 ± 0.30	6.78 ± 0.30	6.78 ± 0.30	4.45 ± 0.17	4.45 ± 0.17	3.78 ± 0.18
B_1	5.90 ± 0.32	5.26 ± 0.35	5.43 ± 0.31	3.42 ± 0.22	4.39 ± 0.14	3.36 ± 0.10
F_1	6.40 ± 0.15	5.83 ± 0.20	6.40 ± 0.29	3.65 ± 0.23	4.64 ± 0.27	3.30 ± 0.10
F_2	3.80 ± 0.44	5.21 ± 0.34	6.00 ± 0.42	3.69 ± 0.13	5.30 ± 0.08	3.19 ± 0.11
B_2	5.30 ± 0.13	4.36 ± 0.18	5.91 ± 0.13	3.86 ± 0.17	4.32 ± 0.21	3.60 ± 0.13
P_2	4.45 ± 0.17	3.78 ± 0.18	3.50 ± 0.17	3.78 ± 0.18	3.50 ± 0.17	3.50 ± 0.17
Fruit girth (cm)						
P_1	0.83 ± 0.02	0.83 ± 0.02	0.83 ± 0.02	0.79 ± 0.02	0.79 ± 0.02	0.94 ± 0.02
B_1	0.92 ± 0.03	0.88 ± 0.01	0.93 ± 0.04	0.83 ± 0.03	0.85 ± 0.02	0.92 ± 0.03
F_1	0.96 ± 0.05	0.94 ± 0.02	1.02 ± 0.04	0.82 ± 0.02	0.90 ± 0.03	0.97 ± 0.03
F_2	0.88 ± 0.02	0.89 ± 0.03	1.06 ± 0.04	0.90 ± 0.01	0.83 ± 0.03	1.04 ± 0.03
B_2	0.81 ± 0.04	0.90 ± 0.01	0.85 ± 0.02	0.89 ± 0.01	0.80 ± 0.08	0.85 ± 0.02
P_2	0.79 ± 0.02	0.94 ± 0.02	0.91 ± 0.01	0.94 ± 0.02	0.91 ± 0.01	0.91 ± 0.01

Appendix II (Contd.)

Generations	$P_1 \times P_2$	$P_1 \times P_3$	$P_1 \times P_4$	$P_2 \times P_3$	$P_2 \times P_4$	$P_3 \times P_4$
Average fruit weight (g)						
P_1	1.93 ± 0.12	1.93 ± 0.12	1.93 ± 0.12	1.48 ± 0.01	1.48 ± 0.11	1.50 ± 0.05
B_1	1.72 ± 0.11	1.77 ± 0.14	1.53 ± 0.10	0.98 ± 0.15	1.20 ± 0.08	1.09 ± 0.05
F_1	1.62 ± 0.07	1.75 ± 0.11	1.62 ± 0.04	1.39 ± 0.12	1.62 ± 0.25	1.48 ± 0.09
F_2	1.41 ± 0.18	1.43 ± 0.13	1.63 ± 0.16	1.37 ± 0.12	1.13 ± 0.13	1.35 ± 0.17
B_2	1.36 ± 0.08	1.39 ± 0.05	1.50 ± 0.08	1.47 ± 0.09	1.30 ± 0.09	1.04 ± 0.03
P_2	1.48 ± 0.11	1.50 ± 0.08	1.53 ± 0.14	1.50 ± 0.08	1.55 ± 0.14	1.55 ± 0.14
Locules/fruit						
P_1	2.02 ± 0.02	2.02 ± 0.02	2.02 ± 0.02	2.12 ± 0.04	2.12 ± 0.04	2.20 ± 0.08
B_1	2.10 ± 0.04	2.06 ± 0.04	2.06 ± 0.04	2.06 ± 0.03	2.04 ± 0.02	2.22 ± 0.08
F_1	2.06 ± 0.03	2.16 ± 0.06	2.16 ± 0.07	2.14 ± 0.06	2.16 ± 0.06	2.26 ± 0.06
F_2	2.02 ± 0.02	2.14 ± 0.06	2.16 ± 0.08	2.12 ± 0.05	2.00 ± 0.22	2.22 ± 0.07
B_2	2.04 ± 0.02	2.12 ± 0.05	2.18 ± 0.02	2.02 ± 0.02	2.10 ± 0.13	2.18 ± 0.05
P_2	2.21 ± 0.04	2.20 ± 0.08	2.20 ± 0.07	2.20 ± 0.08	2.20 ± 0.07	2.20 ± 0.07

Appendix II (Contd.)

Generations	$P_1 \times P_2$	$P_1 \times P_3$	$P_1 \times P_4$	$P_2 \times P_3$	$P_2 \times P_4$	$P_3 \times P_4$
Fruits/plant						
P_1	66.60 ± 2.75	66.60 ± 2.75	66.60 ± 2.75	83.70 ± 2.94	83.70 ± 2.94	61.70 ± 2.96
B_1	66.31 ± 4.21	59.26 ± 1.20	69.30 ± 2.21	99.41 ± 3.63	96.21 ± 4.41	62.68 ± 2.58
F_1	79.40 ± 2.30	58.75 ± 1.89	59.98 ± 2.94	76.55 ± 3.28	61.25 ± 2.44	52.33 ± 3.50
F_2	71.99 ± 4.70	66.83 ± 4.29	49.23 ± 2.71	63.14 ± 4.63	79.24 ± 3.48	59.27 ± 4.48
B_2	78.57 ± 5.27	60.24 ± 3.01	58.53 ± 3.67	66.46 ± 2.12	65.27 ± 2.93	71.85 ± 2.12
P_2	83.70 ± 2.94	61.70 ± 2.96	59.60 ± 3.06	61.70 ± 2.96	58.60 ± 3.06	58.60 ± 3.06
Fruit yield/plant						
P_1	108.54 ± 2.41	108.54 ± 2.41	108.54 ± 2.41	120.88 ± 2.99	120.88 ± 2.99	90.14 ± 2.68
B_1	111.20 ± 3.40	101.26 ± 3.06	96.85 ± 2.95	116.35 ± 2.26	109.51 ± 2.64	82.56 ± 6.02
F_1	126.68 ± 3.14	95.93 ± 3.93	92.83 ± 4.83	99.78 ± 5.70	90.08 ± 2.13	74.00 ± 5.53
F_2	101.45 ± 3.58	89.54 ± 5.38	80.24 ± 9.78	81.34 ± 5.67	86.43 ± 2.99	76.82 ± 4.42
B_2	99.23 ± 3.53	88.67 ± 1.98	82.68 ± 9.37	91.26 ± 3.34	89.85 ± 5.21	69.85 ± 3.08
P_2	120.88 ± 2.99	90.14 ± 2.68	83.27 ± 3.81	90.14 ± 2.68	83.27 ± 3.81	83.27 ± 3.81

Appendix II (Contd.)

Generations	P_1 x P_2	P_1 x P_3	P_1 x P_4	P_2 x P_3	P_2 x P_4	P_3 x P_4
Days to flower						
P_1	41.40 ± 0.86	41.40 ± 0.86	41.40 ± 0.86	43.10 ± 0.54	43.10 ± 0.54	53.20 ± 1.34
B_1	41.70 ± 1.41	40.61 ± 1.09	43.20 ± 1.22	43.10 ± 0.71	44.80 ± 1.20	49.50 ± 1.15
F_1	42.30 ± 0.41	38.00 ± 1.22	40.00 ± 1.42	43.00 ± 0.93	43.10 ± 1.63	51.60 ± 1.48
F_2	44.00 ± 0.76	44.50 ± 1.45	46.20 ± 1.34	45.90 ± 1.19	44.20 ± 1.66	50.60 ± 1.29
B_2	41.80 ± 1.06	42.30 ± 1.17	41.20 ± 1.25	44.50 ± 1.34	44.00 ± 0.86	50.13 ± 0.90
P_2	43.10 ± 0.54	53.20 ± 1.34	49.50 ± 1.43	53.20 ± 1.34	49.50 ± 1.42	49.50 ± 1.43

Appendix II (Contd.)

Generations	$P_1 \times P_3$	$P_2 \times P_3$
Capsaicin content (%)		
P_1	0.413 ± 0.006	0.35 ± 0.01
B_1	0.43 ± 0.01	0.43 ± 0.01
F_1	0.50 ± 0.03	0.56 ± 0.02
F_2	0.54 ± 0.02	0.53 ± 0.02
B_2	0.52 ± 0.02	0.53 ± 0.02
P_2	0.65 ± 0.01	0.65 ± 0.04
Total colouring matter (ppm)		
P_1	1209.30 ± 29.61	1391.50 ± 29.94
B_1	1450.46 ± 63.03	1478.80 ± 37.16
F_1	1665.10 ± 118.48	1825.50 ± 93.73
F_2	1526.44 ± 55.08	1669.74 ± 44.13
B_2	1731.92 ± 52.78	1798.45 ± 46.55
P_2	2107.10 ± 53.02	2107.10 ± 53.02

P_1 - Jwala, P_2 - Pant C-1, P_3 - CA 33, P_4 - CA 23

INHERITANCE OF CLUSTERNESS, DESTALKNESS AND DEEP RED COLOUR IN CHILLI

[*Capsicum annuum* L.]

By

T. R. GOPALAKRISHNAN

ABSTRACT OF A THESIS

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ABSTRACT

The research project "Inheritance of clusterness, destalkness and deep red colour in chilli (*Capsicum annuum* L.)" was carried out at the College of Horticulture, Kerala Agricultural University, Vellanikkara, Trichur from July 1979 to September 1983. Preliminary evaluation of 38 chilli lines during 1979 and 46 lines during 1980 revealed considerable variation for most of the economic characters. Phenotypic coefficient of variation was the maximum for fruits/plant followed by fruit length and main stem length. High heritability coupled with high expected genetic advance was observed for fruit length and main stem length. Earliness measured as days to flower and days to red chilli harvest, though having high heritability, had only a very low expected genetic advance.

Six F_1 hybrids developed by crossing four specific chilli lines - Jwala, Pant C-1, CA 33 and CA 23 - exhibited heterosis for earliness. Four F_1 hybrids manifested relative heterosis for plant height. Among the hybrids Jwala x CA 33 had the longest fruits (7.9 cm) with the maximum average fruit weight (2 g). Taking into consideration of the yield in terms of the number and weight of fruits and the extent of heterosis, Jwala x Pant C-1 was the best hybrid yielding 201 g/plant (fruits/plant, 121) followed by Jwala x CA 23.

Combining ability analysis and generation mean analysis revealed the gene action of economic characters. Combining ability analysis stressed the importance of additive gene action for fruit girth, average fruit weight, fruits/plant and fruit yield/plant. Preponderance of additive gene action for leaf laminar length, locules/ fruit, capsaicin content and colouring matter of fruits expressed as total carotenoid contents was indicated in the generation mean analysis. The dominance effect was higher than additive effect for main stem length, primary branches/plant and days to flower. The type of gene interaction governing expression of characters varied with specific parental combinations. All the three types of interactions - additive x additive, additive x dominance and dominance x dominance - were observed. In most cases epistasis was of duplicate type.

The parental lines Jwala, Pant C-1, CA 33 and CA 23, along with their F_1s, F_2s, BC_1s and BC_2s were grown during May-September 1983 to study the inheritance of clusterness, fruit orientation and destalkness. The transfer of clusterness to cultivated varieties would reduce the cost of harvesting of fruits and offers possibility for mechanical harvesting. Clustered fruiting habit was recessive and monogenic. The genotypes of clustered accession CA 33 and solitary varieties Jwala and Pant C-1 were proposed as cl_1cl_1, Cl_1Cl_1 and Cl_1Cl_1 respectively. Determinate type of branching was pleiotropic to clustered fruiting habit. The pendulous fruit was dominant to upright and two genes 'up_1' and 'up_2' operated with a specific dominant and recessive epistasis for the control of upright fruit orientation in chilli. The genotype of pendulous lines Jwala and CA 23 for fruit orientation was postulated as $up_1^+up_1^+$ up_2up_2 while that of erect fruited lines Pant C-1 and CA 33 was up_1up_1 $up_2^+up_2^+$. Destalkness in chilli was recessive and digenic. Destalked genotype CA 33 differed from stalked varieties Jwala and Pant C-1 at at single locus 'ds_1' while it differed from CA 23, a stalked line, at two loci 'ds_1' and 'ds_2' with duplicate gene action. The genotype of CA 33 was proposed as ds_1ds_1 ds_2ds_2.

The study resulted in the development of destalked, clustered and deep red chilli lines which are under advanced trials.