INTERVARIETAL HETEROSIS IN *Capsicum annuum* L. AND EVALUATION OF A SET OF CLUSTERED BELL PEPPERS

By

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THESIS

submitted in partial fulfilment of
the requirement for the degree

Master of Science in Horticulture

Faculty of Agriculture
Kerala Agricultural University

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COLLEGE OF HORTICULTURE
Vellanikkara - Trichur

1987

D E C L A R A T I O N

I hereby declare that this thesis entitled 'Intervarietal heterosis in *Capsicum annuum* L. and evaluation of a set of clustered bell peppers' is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara,
1-7-1987.

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C E R T I F I C A T E

Certified that this thesis entitled 'Inter-varietal heterosis in *Capsicum annuum* L. and evaluation of a set of clustered bell peppers' is a record of research work done independently by Miss. T. Girijadevi under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Vellanikkara,
22/9/ 1987.

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C E R T I F I C A T E

We, the undersigned members of the Advisory Committee of Miss. T. Girijadevi, a candidate for the degree of Master of Science in Horticulture agree that the thesis entitled 'Intervarietal heterosis in *Capsicum annuum* L. and evaluation of a set of clustered bell peppers' may be submitted by Miss. T. Girijadevi, in partial fulfilment of the requirement for the degree.

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ACKNOWLEDGEMENT

I express my heartfelt gratitude and indebtedness to Dr. K.V. Peter, Professor and Head, Department of Olericulture, Chairman of my Advisory Committee for his constant encouragement, constructive suggestions, immense help, astute advice and keen interest at every stage of the investigation and preparation of the thesis.

I am greatly indebted to Dr. T.R. Gopalakrishnan, Assistant Professor, Department of Olericulture, for his sustained interest and valuable guidance during the period of work and in the preparation of the thesis. I consider it as my privilege to offer my gratitude to Dr. K.M.N. Namboodiri, Professor and Head, Department of Agricultural Botany, for his constructive criticisms and valuable suggestions rendered to me for the preparation of the thesis. I am extremely grateful to Sri. V.K.G. Unnithan, Professor, Department of Agricultural Statistics for the unstinted help and suggestions given during my statistical works.

I sincerely acknowledge my gratitude to the staff members of the Department of Olericulture for their sincere and timely help throughout the course of investigation. My sincere thanks are also due to all my fellow students and friends especially to Miss. Vshamani for the help and encouragement rendered at various stages of this investigation.

Profound thanks are due to Sri. Joy, K.A., and Sri. Lonan, K.J., for the care and interest they have taken in typing this manuscript.

It is with gratitude I remember the strenuous help and unfailing support of my brother which helped me a lot for the successful completion of the work.

Finally I wish to acknowledge the Indian Council of Agricultural Research for awarding the Junior Research Fellowship for the post-graduate programme.

T. GIRIJADEVI

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Introduction

INTRODUCTION

Chilli (Capsicum annuum L.) is an important vegetable-cum-spice crop grown in India. Believed to have been introduced by the Portuguese from West Indies and grown in Bombay as early as 1779 (Watt 1889), it has become an important commercial crop of India. Chilli is known for its prungency, colour, aroma and taste, it imparts to the food materials. Chilli oleo-resin is used in pharmaceutical and cosmetic preparations. Besides its indegenous uses, chilli has a very great export potential. Hot chilli is more and widespread in India compared to bell peppers. Usually the large fruited and non-prungent capsicums or bell peppers, used principally as vegetable, are rich in caretene (1.8 mg/100 g) and vitamin C (103 mg/100 g).

Bell pepper (Capsicum annuum L. var. grossum Sendt.) is a newly introduced crop in Kerala. Only a few relevant information are available on the suitability of this crop to the warm humid tropical conditions of Kerala. Eventhough the tropical and subtropical conditions are conducive for the growth of hot forms, bell peppers are grown only in relatively cool climatic conditions. Another limiting factor for cultivation of capsicum in warm humid tropics

is bacterial wilt caused by Pseudomonas solanacearum E.F. Smith. Hot forms of chilli like KAU Cluster (Capsicum annuum var. fasciculatum) and Pant C-1 (Capsicum annuum var. longum) are endowed with multiple disease resistance especially against bacterial wilt. The usefulness of KAU Cluster and Pant C-1 as sources of resistance to wilt can be exploited in growing bell peppers under the warm humid conditions of Kerala.

In chilli, heterosis was reported for many economically important characters. It can boost up yield, low at present. Report on intervarietal heterosis between Capsicum annuum var. grossum, Capsicum annuum var. longum and Capsicum annuum var. fasciculatum are rather limited.

Since most of the present day cultivars are solitary fruited nearly 20% of the total cost of cultivation is exclusively for harvesting of fruits alone (Pious 1985). So attempts have been made at Kerala Agricultural University to develop clustered bell peppers resulting from crosses between bell peppers like Hungarian Wax and Sweet Red Cherry Pickling with KAU Cluster (hot chilli). These clustered bell pepper lines developed at Kerala Agricultural University needed continuous evaluation.

Considering all the above factors, the present investigation was undertaken with the following objectives.

1. To estimate intervarietal F_1 heterosis in *Capsicum annuum* .

2. To estimate the combining ability effects in progenies of intervarietal crosses of *Capsicum annuum*.

3. To evaluate F_1 hybrids for reaction to bacterial wilt under field conditions.

4. To evaluate a set of clustered bell peppers for adaptability and to select elite plant types.

Review of Literature

REVIEW OF LITERATURE

The information on variability, adaptability, genetic divergence, heterosis, combining ability, resistance to bacterial wilt and clusterness in Capsicum annuum L. are presented.

A. Genetic variability, heritability and genetic advance in Capsicum annuum

Legg and Lippert (1966) observed a high phenotypic and genotypic variability in sweet pepper for plant height, fruits/plant and fruit yield/plant. They also noted high heritability associated with high genetic advance for carotene content, fruits/plant and fruit weight.

In a study involving 19 lines, Singh and Singh (1970) observed a 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).

Nandpuri et al. (1971) observed high heritability for days to flower, days to maturity, fruits/plant and fruit yield/plant. Estimate of expected genetic advance was high for fruits/plant (59.00), branches/plant (50.00),

fruit yield/plant (26.95) and plant height (34.38).

Arya and Saini (1976) recorded a high heritability estimate for leaf length, branches/plant and fruit yield/plant. They also observed a high genotypic and phenotypic coefficient of variation, heritability and genetic advance for fruits/plant.

While evaluating 38 varieties, Awasthi et al. (1976) observed a high estimate of heritability with low genetic advance for branches/plant, fruit girth and average fruit weight. Fruits/plant had moderate values of heritability and genetic advance. High estimates of heritability and genetic advance were found for plant height, fruit length and fruit yield/plant.

Evaluation of 23 varieties of chilli conducted by Dutta et al. (1979) led to observe a high coefficient of variation for plant height, branches/plant, fruit weight, fruits/plant and fruit yield/plant. Heritability estimate was high for fruit weight (0.97), days to flower (0.91), plant height (0.87) and fruits/plant (0.77).

Chandra et al. (1983), based on an evaluation of 12 chilli lines, reported 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 and high to moderate values for fruits/plant. Vadivel et al. (1983) reported that plant height, branches/plant, fresh fruit weight, fruit girth and fruit yield were highly influenced by environment.

Nair et al. (1984) reported environmental influence on primary branches/plant after evaluating 30 chilli varieties. High estimates of heritability and genetic advance were noted for fruits/plant (0.99, 249.31), average fruit weight (0.99, 206.35), fruit girth (0.99, 140.87) and fruit yield/plant (0.99, 222.75). High heritability with low genetic advance was found for days to flower (0.98, 35.81) and plant height (0.96, 53.50), indicating role of non-additive gene action.

Gopalakrishnan (1985) reported high estimate of heritability coupled with high genetic advance for main stem length and fruit length. High estimates of heritability along with low genetic advance were reported for days to flower, days to first fruit harvest and fruit girth.

B. Adaptability in bell peppers

Bell peppers grew well in a relatively cool climate of 15-25°C. (Thomas and Nair, 1961; Singh, 1963; Singh, 1976; Hosmani, 1982). The cultivation requirements of bell

peppers were given by Joshi and Singh (1975). They grow well in warm and humid climate, but dry weather is equally necessary during fruit maturity. A low humidity and high temperature at flowering and fruiting cause flower and immature fruit shedding. Cochran (1936) reported that air temperature at the time of bloom affects fruit set. The maximum set of bell peppers occured at a constant temperature of 11°C - 18°C, with temperature below 11°C and above 32°C, preventing fruit set. Pronounced effect of temperature on fruit set, fruit shape and fruit size in California Wonder was reported by Rylski and Halevy (1974). Low night temperature increased the percentage of fruit set and parthenocarpic fruit development. High day temperature (20°C - 24°C) and low light intensity (30% shade), mainly at early stages of flower development, promoted flower drop. High temperature during later stage of flower development was a pre-requisite for the formation of full shaped fruits. Although bell peppers grow satisfactorily over a wide range of soil types, well drained light loam soil is the best. Water logging over a short period is harmful. The ideal pH is 6.0 - 6.5 (Joshi and Singh, 1975) or 5.5 - 7.0 (Swarup, 1974).

Pious (1985) tested the adaptability of bell pepper lines and F_1 hybrids involving bell peppers and hot chillies. Hungarian wax, Cubanelle and Early Calwonder yielded fairly well under warm humid tropical conditions and were identified promising for Kerala.

C. Genetic divergence in chilli

Singh and Singh (1976a) evaluated 45 lines of chilli and conducted D^2 analysis for divergence. 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 of 27 chilli varieties, Mehra and Peter (1980) reported that fruits/plant contributed the maximum towards diversity (98.03%).

Sundaram et al. (1980) subjected 35 Indian and 15 exotic varieties of Capsium frutescens to D^2 analysis. They could not observe any relationship between genetic diversity and geographic diversity. Gopalakrishnan (1985) subjected 38 chilli lines to D^2 analysis and reported that main stem length (23.19%) contributed maximum towards total genetic divergence followed by fruit length (21.48%), fruit yield/plant (18.92%) and days to red chilli harvest (11.66%). Primary branches/plant had the lowest contribution to the total genetic divergence in chilli (2.46%).

D. Intervarietal heterosis in chilli

First report on heterosis in chillies was made by Deshpande (1933). He reported heterosis for plant vigour, height, earliness, fruit yield, fruit diameter and fruits/plant. Later Pal (1945) reported heterosis for plant height, earliness, fruits/plant and weight of dry chilli after studying Pusa strains of chilli for three seasons. Although heterosis was reported for the above characters, its expression was not sufficiently stable to justify their use for practical purposes.

By studying 34 hybrid combinations, Michna (1963) reported heterosis for fruit yield. Relative heterosis for yield upto 85.7% was recorded in crosses between varieties and upto 97.4% in crosses between varieties and F_1 hybrids. The superiority of the hybrids was more pronounced in unfavourable years than in favourable years. In a few of these crosses, the F_2 yield was lower than that of the F_1 and in two crosses between varieties and hybrids, it was higher by 21% and 36.7% respectively.

Betlach (1965, 1967) reported heterosis for fruits/plant and average fruit weight. Heterosis was manifested for total yield by an increase in the number, rather than fruit size in less favourable years. In an outstandingly favourable year for pepper, yield increment was the result of increase in both number and size of fruits.

Popova and Mihailov (1968) studied three pepper combinations and reported heterosis for average number of seeds/fruit. The F_1 hybrids were intermediate for fruits/plant, fruit weight, dry matter content in the fruits and 1000 seed weight.

From a study of seven hybrids Popova and Mihailov (1970) reported that hybrids had larger embryos than their respective parents. Relative heterosis for weight of embryos ranged from 104.7% to 119.9%.

Silvetti and Giovannelli (1970) conducted a diallel cross among six bell pepper varieties. Heterosis was observed for yield and earliness

Nagaich et al. (1972) reported heterosis for yield in chilli. Khrenova (1972) suggested that heterotic combinations from parents which are morphologically of the same type can be used in second and in subsequent generations, if selection for yield was practiced. Heterotic hybrids from morphologically contrasting varieties should be used only in the first generation. Marfutiana (1972) observed that the hybrids exceeded the parents by 6 to 28% for dry matter content and by 8 to 48% for sugar content. Most of the hybrids were 2-5 days earlier to parents.

Popova (1972) studied F_2 generations of two heterotic intervarietal hybrids. Total yields were lower in the F_2 than the F_1 but higher than the yield of the better parent .

Thicker pericarp, heavier fruits, higher yields, more fruits/plant and carotenoids were reported in F_1 hybrids than in the parents by Lee et al. (1973). Singh et al. (1973) studied seven F_1 hybrids along with their parents. They reported heterobeltiosis of 30% for fruits/plant, 19% for plant height, 45% for fruit length and 8% for fruit yield/plant. Out of seven crosses, three had significantly higher yield than their better parent . The highest yielding hybrid had significantly longer fruits than their better parent where as fruit thickness did not show heterosis in any of the crosses. Six crosses showed heterosis for plant height and five crosses for fruit length. Only one hybrid exhibited heterosis for fruits/plant. None of the hybrids showed heterosis for days to flower.

Forty eight Capsicum annuum F_1 hybrids and their parents were evaluated by Bak et al. (1975). They observed heterosis for earlines, fruits/plant and fruit length. Yield was higher by 61% in the hybrids compared with their parents. Dikši and Anikeenko (1975) reported standard

heterosis of 23 - 52% for early yield and 11 - 20% for total yield in multiple back crosses involving forms with cytoplasmic male sterility. Ilyushchenko (1975) studied carbohydrate content in seeds of F_1 hybrids and parents. For sugar content, the seeds of heterotic hybrids were superior to those of their parents, while the nonheterotic crosses were intermediate to their parents. Lippert (1975) reported significant heterosis for dry fruit weight/plant, fruit length and percentage of mature fruits at harvest.

Popova and Mihailov (1975) studied six F_1 hybrids. Heterosis was observed for whole plant weight, plant height, number of leaves, assimilation area, total root length and volume and embryo length.

Thakur and Theerth (1975) observed pronounced heterosis for uptake of N, P, Zn, Mn and Fe in hot peppers. Heterobeltiosis was observed for uptake of P.

Eight F_1S were evaluated by Mishra et al. (1976). Heterobeltiosis was present to the maximum extent of 84.35% for yield/plant, 68.33% for fruits/plant, 33.49% for primary branches/plant, 61.49% for secondary branches/plant, 20.63% for fruit length, 14.69% for days to flower and 17.53% for days to maturity. Out of eight F_1S, five gave significantly higher yield and fruits/plant over the better parent. Three

F_1S were observed earlier for flowering and maturity than the early parent. Heterosis was not significant for plant height and fruit girth. A positive association was observed among yield/plant, fruits/plant and primary branches/plant.

Rocchetta et al. (1976) measured ten characters associated with yield and maturity in the parents, F_1S and F_2S of a half diallel cross involving six capsicum varieties, which were high/intermediate/low yielding. Heterosis was observed in crosses between the yield types, high x intermediate, low x low and intermediate x intermediate. F_2 heterosis for yield was observed only in crosses involving the low yielding variety Topepo.

Singh and Singh (1976 a) studied F_1, F_2, BC_1 and BC_2 generations from a half diallel cross involving eight lines of Capsicum annuum from different agroclimatic regions. Heterosis was observed for branches/plant, days to flower, days to maturity, fruit length, fruit thickness, fruits/plant and yield/plant.

Singh and Singh (1976 b) observed significant heterosis for plant height, branches/plant, days to flower, days to maturity, fruit length, fruit thickness, fruits/plant and yield/plant in three experiments each with six genetic populations like P_1, P_2, F_1, F_2, B_1 and B_2.

Popova and Mihailov (1976) studied heterosis in red peppers. They reported heterosis for plant height, number of leaves/plant, leaf surface area, root length and shoot length. The embryos of the hybrid seeds were larger than those of parents showing that heterosis become apparent immediately after hybridization.

Sharma and Saini (1977) studied heterosis and combining ability in crosses involving four bell pepper varieties, Chinese Giant, California Wonder, Oshkosh and Yolo Wonder, two pickle types - Sweet Banana and Hungarian Wax and four pungent peppers - Waxy Globe, African Black, Solan Yellow and Hort Portugal. Considerable heterobeltiosis was observed for plant height and fruit yield. The top most heterotic crosses for yield were Yolo Wonder x Solan Yellow (55.4%), Solan Yellow x Hort Portugal (47.89%) and Waxy Globe x Hort Portugal (45.99%). The best yielding hybrid (202.5 gm/plant) was Hungarian Wax x Solan Yellow.

In interspecific F_1 hybrids involving Capsicum annuum, C. frutescens, C. baccatum, C. microcarpum and C. pendulum, Pillai et al. (1977) reported heterosis for plant height, duration of flowering, fruits/plant and percentage of fruit set.

Dikaanov (1978) studied 43 hybrids. Of these, three showed clear dominance of earliness and four hybrids out-yielded both their parents.

Gopalakrishnan (1985) developed six F_1 hybrids using four chilli genotypes. Out of six hybrids, four exhibited significant relative heterosis for plant height. Three F_1 hybrids had larger fruits than their mid-parents and three F_1 hybrids manifested relative heterosis and one hetero-beltiosis for fruit/plant. All the hybrids were earlier than early parent .

Pious (1985) reported heterosis in the intervarietal crosses between bell peppers and the hot chilli (KAU Cluster) for days to flower, days to green fruit harvest, days to fruit ripening, plant height, pedicel length, fruit length, fruit perimeter, fruit weight and green fruit yield/plant. F_2 heterosis was observed for days to green fruit harvest, days to fruit ripening, plant height, fruit length and green fruit yield/plant. The information on heterosis are summarised (Table 1).

Table 1. Heterosis in *Capsicum annuum*

Characters	Reported by
General vigour	Deshpande (1933), Singh *et al.* (1973), Singh and Singh (1976 b), Pillai *et al.* (1977), Sharma and Saini (1977)

Plant height	Deshpande (1933), Pal (1945), Singh et al. (1973), Popova and Mihailov (1975, 1976), Sharma and Saini (1977), Gopalakrishnan (1985), Pious (1985)
Branches/plant	Singh and Singh (1976 a, b), Mishra et al. (1976)
Shoot length	Popova and Mihailov (1976)
Total root length	Popova and Mihailov (1975, 1976)
Earliness	Deshpande (1933), Pal (1945), Michna (1963), Silvetti and Giovanelle (1970), Marfutiana (1972), Bak et al. (1975), Dikii and Anikeenko (1975), Mishra et al. (1976), Singh and Singh (1976 a, b), Dikaanev (1978), Gopalakrishnan (1985), Pious (1985)
Fruit set	Pillai et al. (1977)
Fruit length	Singh et al.(1973), Bak et al. (1975), Lippert (1975), Mishra et al. (1976), Singh and Singh (1976 a, b), Gopalakrishnan (1985), Pious (1985)
Fruit girth	Deshpande (1933), Singh and Singh (1976 a, b), Gopalakrishnan (1985), Pious (1985)
Fruits/plant	Deshpande (1933); Pal (1945); Betlach (1965, 1967); Popova and Mihailov (1968); Lee et al. (1973); Singh et al. (1973); Bak et al. (1975); Lippert (1975); Mishra et al. (1976); Rocchetta et al. (1976); Singh and Singh (1976 a, b); Pillai et al. (1977); Gopalakrishnan (1985)
Fresh fruit yield/plant	Michna (1963); Betlach (1965); Silvetti and Giovanelli (1970); Singh et al. (1973); Bak et al. (1975); Lippert (1975);

	Rocchetta et al. (1976); Mishra et al. (1976); Singh and Singh (1976 a, b); Sharma and Saini (1977); Dikkaanev (1978); Gopalakrishnan (1985); Pious (1985)
Dry fruit yield/plant	Deshpande (1933); Pal (1945); Marfutiana (1972); Lippert (1975)
Average fruit weight	Betlach (1965, 1967); Popova and Mihailov (1968); Lee et al. (1973); Gopalakrishnan (1985); Pious (1985)
Seeds/fruit	Popova and Mihailov (1968)
Embryo size	Popova and Mihailov (1970, 1975)
Sugar content	Marfutiana (1972); Ilyushchenko (1975)
Carotenoid content	Lee et al. (1973)
Nutrient uptake	Thakur and Theerth (1975)

E. Combining ability analysis in chilli

Gill et al. (1973) reported significant variances for general combining ability effects (gca) and specific combining ability effects (sca) for days to flower, fruit length and fruits/plant by studying a 6 x 6 diallel. Betlach (1974) reported significant gca and sca effects for earliness and fruits/plant in an unidirectional diallel cross consisting of eight parents and 28 F_1s. Only gca was significant for fruit yield/plant.

Singh and Singh (1978) from a line x tester analysis

noted high variance for specific combining ability in all the characters studied except fresh fruit yield/plant indicating predominance of non additive gene action for fruit yield/plant. Parental lines possessed high gca effects for yield and its components in F_1 and F_2.

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

Pandey et al. (1981) crossed 12 cultivars with three pollen parents. The estimates of sca effects showed that the better combiners for yield were those crosses which involved one or both parents with high gca effects. Gomez and Cuartero (1982) and Singh (1982) observed a greater magnitude of sca variance for yield/plant.

Rao and Chhonkar (1984) studied a 10 x 10 diallel. They observed that variances due to gca and sca were highly significant for yield/plant and average fruit weight.

Gopalakrishnan (1985) from a half diallel cross involving four diverse parents reported a highly significant variance due to general combining ability effects for plant height, primary branches/plant, leaf laminar length, fruit length, fruit girth, average fruit weight, fruits/plant, fruit yield/plant and days to flower.

F. Evaluation for field resistance to bacterial wilt

Pseudomonas solanacearum E.F. Smith, which causes wilt, limits the cultivation of the crop especially in warm humid tropics. Attempts were made to screen out resistant varieties and identify sources of resistance.

Rahim and Samraj (1974) evaluated nine chilli varieties for resistance to bacterial wilt. The mean percentage of plants wilted in varieties Kandhari, Pungent Pride, Cherry Red, Vattal, Dark Purple, Long Red, Hungarian Wax, Bhola and Chinese Giant were 0.85, 6.37, 10.25, 14.32, 16.28, 17.33, 35.20, 35.38 and 66.80 respectively.

Goth et al. (1983) reported that KAU Cluster was resistant to four race 1 isolates and one race 3 isolate of Pseudomonas solanacearum, Peter et al. (1984) evaluated four hot peppers, Pant C-1, KAU Cluster (Capsicum annuum), White Kandhari and Chuna (Capsicum frutescens) along with six U.S. cultivars, Yolo Wonder Improved, Hybrid Pepper Bell Boy, Sweet Red Cherry Pickling, California Wonder, 672-Hungarian Wax and Cubanelle 78 V 2860 for reaction to nine isolates of Pseudomonas solanacearum (race 1 and race 3). No pepper lines tested were resistant to all nine isolates, K-60, W 82, W 295, FF, A 21, TEP 12, TEP 13, 126408-1 and Tifton 80-1. Only A 21 isolate was pathogenic to all the pepper lines. The most resistant was Pant C-1 which showed

resistance to K 60, W 82, W 295 and FF isolates and moderate resistance to Tifton 80-1. KAU Cluster had resistance to K 60, W 82, W 295, FF and Tifton 80-1 isolates but was highly susceptible to all other isolates used. KAU Cluster was also resistant to Phytophthora capsici and Meloidogyne incognita. Pious (1985) also observed that the line KAU Cluster was resistant to bacterial wilt.

G. Clusterness in Chilli

Deshpande (1944) observed a bushy and compact bunch mutant in NP-46 A. Murthy and Murthy (1962) established that solitary nature of pedicel was dominant to cluster habit, governed by a single gene pair, from a study involving G-2 (Pods-solitary) and C-21 (Pods-Clusters of four to eight/node). A bunch type chilli was observed in a bulk population of Samba variety in Madurai of Tamil Nadu. The plant possessed clusterness of pedicels ranging from three to six arising from a single axil and they bred true (Rajamani and Nagaratnam, 1962).

Popova (1965) from Bulgaria developed a few lines with compact arrangement of fruits by hybridization between Capsicum annuum and Capsicum annuum var. fasciculatum. The lines showed uniformripening and were suitable for mechanised cultivation and harvesting. In the F_2 generation

of a cross between cluster and normal types Kormos and Kormos (1966) reported plants in which the main axis was terminated by the inflorescence and no lateral shoots developed.

Ferenc (1970) developed two determinate varieties Kalocsa D-160 and Kalocsa D-621; bearing fruits in erect bunches from crosses involving indeterminate varieties and Capsicum annuum var. fasciculatum. Genetic studies showed that determinate (bunched) character was recessive and monogenic. At equal plant densities, the bunched varieties yielded lesser than normal types, but when planted at twice the density they were superior in yield under irrigation but not superior under unirrigated condition. Ormos and Zatyko (1971) described a bunched table pepper variety Gepi Konzerv (Machine Preserving) with erect fruits borne at the same level which ripened uniformly and suited for mechanical harvesting. In Bulgaria, an erect clustered variety Buketen, suited for mechanical harvesting was reported (Christov and Popova, 1974). Awasthi et al. (1977) reported a pungent clustered chilli variety from Almora in U.P.

Ramalingam (1978) reported a clustered variety, MDU-1, with compact habit, from the γ irriadiated K-1 chilli variety. Vinnipukh another clustered variety was reported by Voronina and Ilenko (1981). Meshram (1983) in

Akola observed a tall vigorous clustered plant from the M_2 generation of Jwala, after treatment with 10 Kr γ rays.

Subramanya (1983) crossed Delray Bell Capsicum annuum (having single flower/node) with PI 159236 - Capsicum chinense (multiple flowered). The F_1 plants had two flowers/node. Data from F_2, F_3 and back cross generations indicated that the expression of the multiple flower character was highly variable and unstable. Gopalakrishnan (1985) observed that the clustered fruiting habit was governed by a single gene and was recessive.

Pious (1985) observed that the cluster bearing habit was governed by two genes with a specific dominant and recessive epistasis in the same gene interaction from a study involving F_1, F_2, BC_1 and BC_2 generations of Hungarian Wax x KAU Cluster.

Materials & Methods

MATERIALS AND METHODS

The present studies were conducted at the College of Horticulture, Vellanikkara, Trichur during July - December, 1985-86. The experimental farm is located at an altitude of 22.5 m above MSL and lies between 10° 32' N latitude and 76° 16' E longitude. The farm experiences a typical warm humid tropical climate. The soil type is a well drained sandy loam with pH 5.1.

Experimental materials

The materials for the study comprised of five varieties of Capsicum annuum var. grossum, one variety each of Capsicum annuum var. longum and Capsicum annuum var. fasciculatum and their ten F_1 hybrids as detailed below:

a) Capsicum annuum var. grossum

i) Hungarian Wax

ii) Sweet Red Cherry Pickling

iii) Early Calwonder

iv) Cubanelle

v) Yolo Wonder Improved

b) Capsicum annuum var. fasciculatum

KAU Cluster

c) Capsicum annuum Var. longum

Pant C-1

d) F_1 hybrids

i) Hungarian Wax x KAU Cluster

ii) Hungarian Wax x Pant C-1

iii) Sweet Red Cherry Pickling x KAU Cluster

iv) Sweet Red Cherry Pickling x Pant C-1

v) Early Calwonder x KAU Cluster

vi) Cubanelle x KAU Cluster

vii) Early Calwonder x Pant C-1

viii) Cubanelle x Pant C-1

ix) Yolo Wonder Improved x KAU Cluster

x) Yolo Wonder Improved x Pant C-1

The F_1 hybrids were developed through hand emasculation and pollination during July to November, 1985.

The key morphological description of different varieties of Capsicum annuum L. used are given below.

A. Fruits less prungent and less seeded

B. Fruits round and dark green

c. Fruits fasciated, tip sunken, base lobate, longitudinal furrows prominent - Early Calwonder

cc. Fruits not fasciated tip round base cordate, longitudinal furrows not prominent - Yolo Wonder Improved.

BB. Fruits long, light green

c. Fruits tip pointed, yellowish, waxy coated - Hungarian Wax

cc. Fruits tip blunt, greenish yellow, cherry shaped - Sweet Red Cherry Pickling

ccc. Fruits tip pointed, light green - Cubanelle

AA. Fruits highly pungent and more seeded

B. Fruits in clusters - KAU Cluster

BB. Fruits solitary - Pant C-1

Lay out and experimental design

The experiment was laid out during December-April 1985-86 and August-December 1986, in a Randomised Block Design, with three replications. There were 30 plants/ genotype/replication. The spacing was 60 cm x 45 cm. During the first season, all plants except KAU Cluster wilted in replication 1. Observations were then taken only from two replications. Five plants were tagged randomly in each genotype/replication and observations were recorded on these plants. The quantitative characters observed were plant height (cm), primary branches/plant, tap root length (cm),

primary roots/plant, days to flower, days to first green fruit harvest, days to fruit ripening, fruit length (cm), fruit perimeter (cm), fruits/plant and green fruit yield/plant (g). Observations on tap root length, primary roots/plant, days to fruit ripening, fruit length and fruit perimeter were taken only during August-December 1986. Analysis of variance was done to test the significance of differences among genotypes.

Statistical analysis

a) Analysis of variance

Data recorded in each season were analysed character wise as described by Ostle (1966).

$$Yij = \mu + ti + bj + eij \qquad \begin{matrix} i = 1 \ \ldots \ t \\ j = 1 \ \ldots \ r \end{matrix}$$

where

yij = Performance of i^{th} variety in j^{th} block

μ = General mean

ti = True effect of i^{th} variety

bj = True effect of j^{th} block and

eij = Random error

The actual break up of the total variance into variance due to replications, varieties and error and their expectations are given in Table 2.

Table 2. General analysis of variance

Sources	df	Mean squares	
		Observed	Expected
Total	tr-1		
Between replications	r-1	M_1	
Between genotypes	t-1	M_2	Error variance + (number of replications x genotypic variance)
Error	(t-1)(r-1)	M_3	Error variance

b) Estimation of variability

Variability for quantitative characters were estimated as suggested by Burton (1952)

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 =

$$\frac{\text{Environmental standard deviation}}{\sqrt{\text{replications}}}$$

iv) Coefficient of variation =

$$\frac{\text{Standard deviation}}{\text{Mean of the character}} \times 100$$

v) Genotypic variance =

$$\frac{\text{(Mean square due to genotypes - mean square due to error)}}{\text{Number of replications}}$$

vi) Phenotypic variance =

Genotypic variance + Error variance

vii) Error variance = Mean square due to error

viii) Heritability in the broad sense

$$h^2(b) = \frac{\text{Genotypic variance}}{\text{Phenotypic variance}}$$

ix) 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)

x) Genetic advance (%) = $\frac{\text{Genetic advance}}{\text{Mean of the character}} \times 100$

c) i) Estimation of genetic divergence

The genetic divergences existing among parental Chilli and Capsicum genotypes were measured by Mahalanobis D^2 statistics (Murthy and Arunachalam 1967).

Treating D as the generalised statistical distance, all populations were grouped into a number of clusters using a computer oriented iterative algorithm for formation of clusters as suggested by Suresh (1986).

ii) Correlation (r) between genetic distance and F_1 performance

Simple correlations (r) were worked out between genetic distance and F_1 performance for yield.

d) Estimation of heterosis

Heterosis over better parent (heterobeltiosis), mid parent (relative heterosis) and standard variety (standard heterosis) were calculated (Briggle 1963, Hayes et al. 1965). The formulae used were

$$\text{Heterobeltiosis} = \frac{\bar{F}_1 - \overline{BP}}{\overline{BP}} \times 100$$

$$\text{Relative heterosis} = \frac{\bar{F}_1 - \overline{MP}}{\overline{MP}} \times 100$$

$$\text{Standard heterosis} = \frac{\bar{F}_1 - \overline{SV}}{\overline{SV}} \times 100$$

where

$\overline{F_1}$, $\overline{BP}$, $\overline{MP}$ and $\overline{SV}$ were the mean performance of F_1 hybrid, better parent, midparent and standard variety respectively. Significance of heterosis was tested using student 't' test.

e) Estimation of combining ability effects

General combining ability (gca) and specific combining ability (sca) effects were estimated as in a line x tester analysis. General combining ability effects of different parents and specific combining ability effects of hybrids were worked out based on the methods suggested by Kempthorne (1957). The analysis of variance and mean square expectations are detailed below (Singh and Choudhary, 1979).

Table 3. Analysis of variance for line x tester analysis

Sources	df	MS	E(MS)
Replications	(r-1)	MS_r	
Crosses	(fm-1)		
Lines	(f-1)	Mf	$\sigma^2_e + r\sigma^2_{fm} + mr\sigma^2_f$
Testers	(m-1)	Mm	$\sigma^2_e + r\sigma^2_{fm} + fr\sigma^2_m$
Lines x Testers	(f-1) (m-1)	Mfm	$\sigma^2_e + r\sigma^2_{fm}$
Error	(r-1) (fm-1)	Me	σ^2_e

where

m = Number of testers (2), f = Number of lines (5)
r = Number of replications (3)

The following statisitcal model was used to estimate gca and sca effects.

Xij = μ + gi + gj + sij + eijk where μ = population mean, gi = gca effect of i^{th} line, gj = gca effect of j^{th} tester. Sij = sca effect of ij^{th} combination, eijk = Error associated with ijk^{th} observation, i = Number of lines; j = Number of testers; K = Number of replications;

i = 1, ..., f

j = 1, ..., m

k = 1, ..., r

The individual effects were estimated as indicated below:

a) $gi = \frac{Xi..}{mr} - \frac{X...}{fmr}$ where Xi.. is the total of i^{th} line, over all replications and testers. X... is the sum of all the (ij) hybrid combinations overall the replications.

b) $gj = \frac{X.j.}{mr} - \frac{X...}{fmr}$ where X.j. is the total of j^{th} tester overall replications and lines.

c) $Sij = \frac{X(ij).}{r} - \frac{X.i.}{fr} - \frac{X.j.}{mr} + \frac{X...}{fmr}$ where X(ij) is the ij^{th} combination total of the hybrid between the i^{th} line and j^{th} tester overall replications.

Standard errors pertaining to gca effects of lines and testers and sca effects of different hybrids were calculated as follows:

$$SE\ (gca\ line) = \left[\frac{Me}{rm}\right]^{\frac{1}{2}}$$

$$SE\ (gca\ tester) = \left[\frac{Me}{fr}\right]^{\frac{1}{2}}$$

$$SE\ (sca\ effects) = \left[\frac{Me}{r}\right]^{\frac{1}{2}}$$

$$SE(gi-gj)\ line = \left[\frac{2Me}{mr}\right]^{\frac{1}{2}}$$

$$SE\ (gi-gj)\ tester = \left[\frac{2Me}{fr}\right]^{\frac{1}{2}}$$

$$SE\ (Sij-Skl) = \left[\frac{2Me}{r}\right]^{\frac{1}{2}}$$

Variance due to gca ($\sigma^2 g$) and sca ($\sigma^2 s$) and the ratio of additive to total genotypic variance (Rg) were estimated as follows:

$$\sigma^2 g = \frac{1}{r(2fm-f-m)} \left[\frac{(f-1)\ (Mf) + (m-1)\ (Mm)}{f + m - 2} - Mf.m\right]$$

$$\sigma^2 s = \frac{Mf.m - Me}{r}$$

$$Rg = \frac{2\sigma^2 g}{2\sigma^2 g + \sigma^2 s}$$

ii) Association between <u>per se</u> performance and general combining ability effects

Simple correlations (r) were worked out between the <u>per se</u> performance of parental lines and general combining ability effects.

f) Evaluation of the F_1 hybrids for field resistance to bacterial wilt.

The ten F_1 hybrids in the first experiment along with KAU Cluster and Pant C-1 were spot planted with a known suscept (Hungarian Wax) to study the host reaction to the bacteria. Ooze test was done to confirm bacterial wilt. Observations were recorded on number of healthy plants where Hungarian Wax wilted. The genotypes were scored according to Mew and Ho (1976), R - Resistant <20% wilted, MR - moderately resistant > 20 <40% plants wilted, MS - moderately susceptible > 40 < 60% plants wilted, S - susceptible > 60% plants wilted.

g) Evaluation of a set of clustered bell peppers for yield and their components and selection of elite line(s).

Segregating generations (F4 and F5) of Sweet Red Cherry Pickling x KAU Cluster and Hungarian Wax x KAU Cluster, which were developed at Kerala Agricultural University were made use for this study. Selected clustered lines (two in F4 and 17 in F5) were grown in a compact homogeneous block without replications. The materials were evaluated for variability in plant height (cm), days to first picking,

clusters/plant, fruits/plant and fruit yield/plant (g). Observations were also made on reaction to bacterial wilt. Elite plant(s) in each family were progressed.

h) Correlation between yield and root characteristics

Simple correlations (r) were worked out between root characters, tap root length and primary roots/plant with fruit yield, primary branches/plant and plant height.

Results

RESULTS

The data recorded in the present study were analysed and the results are presented under the following heads.

A. Genetic variability, heritability and genetic advance in Capsicum annuum L.

B. Genetic divergence in Capsicum annuum

C. Intervarietal heterosis in Capsicum annuum

D. Combining ability analysis in Capsicum annuum

E. Evaluation of the F_1 hybrids for field resistance to bacterial wilt

F. Evaluation of a set of clustered bell peppers

G. Association between root characters and fruit yield, primary branches/plant and plant height

A. Genetic variability, heritability and genetic advance in Capsicum annuum

General analysis of variance indicated significant differences among the lines for all the characters studied (Table 4).

The extent of variability for yield and its components in chillies, capsicums and chilli x capsicum crosses were measured in terms of range, mean, coefficient of

Table 4. General analysis of variance for yield and its components in *Capsicum annuum*

Sources of variation		Mean squares										
		Plant height (cm)	Primary branches/ plant	Taproot length (cm)	Primary roots/ plant	Days to flower	Days to first green fruit harvest	Days to fruit ripening	Fruit length (cm)	Fruit perimeter (cm)	Fruit/plant	Green fruit yield/plant (g)
Replication												
	E_1	23.16	0.96	NA	NA	66.29	15.58	NA	NA	NA	6.38	1562.02
	E_2	20.37	1.22	20.67	111.02	15.09	1.47	49.05	0.12	0.13	15.74	1632.51
Treatments												
	E_1	66.98**	14.75**	NA	NA	87.28*	193.25**	NA	NA	NA	3475.46**	15001.56**
	E_2	154.59**	18.92**	37.87**	614.85**	349.62**	288.99**	120.29**	13.83**	6.12**	2585.95**	14475.26**
Error												
	E_1	7.41	0.58	NA	NA	4.05	13.41	NA	NA	NA	9.73	376.25
	E_2	7.24	0.81	3.07	56.64	12.24	15.33	9.45	1.07	1.04	13.51	349.72

* p = 0.05
** p = 0.01

E_1 = December 1985 - April 1986
E_2 = August - December 1986
NA = Not available

variation at genotypic, phenotypic and environmental levels (Table 5). The range for plant height was 35.35 cm in Early Calwonder to 58.60 cm in Sweet Red Cherry Pickling x KAU Cluster, primary branches/plant 3.17 (Hungarian Wax) to 16.62 (KAU Cluster); tap root length 8.30 cm (Early Calwonder x KAU Cluster) to 18.94 cm (Yolo Wonder Improved x KAU Cluster); primary roots/plant 45.12 (Pant C-1) to 109.53 (Hungarian Wax x KAU Cluster), days to flower 56.17 (Hungarian Wax x KAU Cluster) to 91.52 (KAU Cluster), days to first green fruit harvest 79.15 (Sweet Red Cherry Pickling x KAU Cluster) to 119.00 (Pant C-1); days to fruit ripening 101.17 (Sweet Red Cherry Pickling x Pant C-1) to 125.61 (KAU Cluster); fruit length 4.27 cm (KAU Cluster) to 13.37 cm (Hungarian Wax); fruit perimeter 2.86 cm (Pant C-1) to 7.77 cm (Early Calwonder); fruits/plant 3.90 (Early Calwonder) to 149.13 (Pant C1) and green fruit yield 129.80 g (Early Calwonder) to 482.80 g (Hungarian Wax x KAU Cluster). The highest estimate of genotypic coefficient of variation (gcv) was observed for fruits/plant (60.86) followed by primary branches/plant (40.49) and green fruit yield/plant (30.36). The genotypic coefficient of variation (gcv) was the lowest for days to fruit ripening (5.46). The contribution of genotype in total expression of character was maximum in the case of fruits/plant (h^2 0.99) followed by green fruit yield/plant (h^2 0.95). The expected genetic advance as per cent of mean

Table 5. Range, mean, phenotypic (pcv), genotypic (gcv) and environmental (ecv) coefficients of variation, heritability (h^2), genetic advance, genetic advance (% of mean) for yield and its components in chilli, capsicum and capsicum chilli crosses

Components of variation			Plant height (cm)	Primary branches/ plant	Tip root length (cm)	Primary roots/plant	Days to flower
Range	E_1	Ch	44.41 - 46.28	7.15 - 16.62	NA	NA	86.96 - 91.52
		Ca	35.35 - 54.45	3.85 - 7.44	NA	NA	86.12 - 96.31
		Cr	39.86 - 54.09	5.52 - 8.11	NA	NA	68.79 - 78.59
	E_2	Ch	39.25 - 50.09	6.19 - 14.41	10.45 - 11.61	45.12 - 51.39	78.30 - 87.06
		Ca	37.36 - 52.74	3.17 - 5.40	8.65 - 15.12	54.29 - 66.36	71.57 - 87.85
		Cr	52.19 - 58.60	4.33 - 8.11	8.30 - 18.94	60.44 -109.53	56.17 - 61.63
Mean	E_1	Ch	45.34 ± 1.92	12.02 ± 0.53	NA	NA	89.24 ± 1.33
		Ca	45.30 ± 1.92	5.32 ± 0.53	NA	NA	74.74 ± 1.33
		Cr	49.48 ± 1.92	6.51 ± 0.53	NA	NA	74.49 ± 1.33
	E_2	Ch	44.67 ± 15.50	10.30 ± 0.46	11.03 ± 1.01	51.26 ± 4.34	83.09 ± 2.02
		Ca	53.07 ± 1.55	4.39 ± 0.46	11.13 ± 1.01	59.66 ± 4.34	76.72 ± 2.02
		Cr	56.23 ± 1.55	6.08 ± 0.46	12.43 ± 1.01	73.41 ± 4.34	58.94 ± 2.02
gcv	E_1		11.43	39.81	NA	NA	8.51
	E_2		23.46	40.49	28.54	20.44	15.83
pcv	E_1		12.77	41.31	NA	NA	8.95
	E_2		24.03	43.13	32.09	23.34	16.67
ecv	E_1		5.69	11.03	NA	NA	2.46
	E_2		5.20	14.83	14.68	11.27	5.22
Heritability	E_1		0.80	0.93	NA	NA	0.92
	E_2		0.95	0.88	0.79	0.77	0.90
Genetic advance	E_1		10.06	5.37	NA	NA	12.85
	E_2		24.41	4.75	6.24	24.60	20.75
Genetic advance (% of mean)	E_1		21.06	79.03	NA	NA	16.83
	E_2		47.17	78.32	52.28	36.96	30.99

NA - Not available
E_1 - December 1985 - April 1985
E_2 - August - December 1986
Ch - Chilli
Ca - Capsicum
Cr - Capsicum x Chilli crosses

(contd...)

Table 5. (contd...)

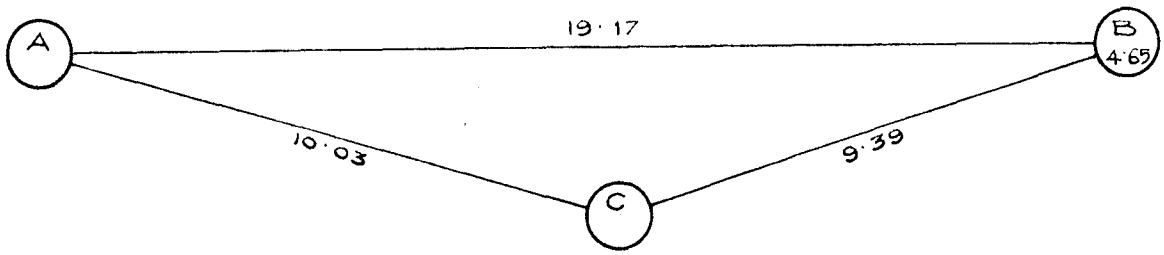
Components of variation			Days to first green fruit harvest	Days to fruit ripening	Fruit length (cm)	Fruit peri-meter (cm)	Fruits/plant	Green fruit yield/plant (g)
Range	E_1	Ch	117.10 - 119.00	NA	NA	NA	113.50 - 141.00	181.60 - [illegible]
		Ca	90.25 - 101.79	NA	NA	NA	3.00 - 17.00	129.99 - [illegible]
		Cr	90.64 - 112.10	NA	NA	NA	43.68 - 76.00	279.75 - [illegible]
	E_2	Ch	106.06 - 113.96	117.55 - 125.61	4.27 - 5.19	2.86 - 2.94	142.13 - 118.25	199.43 - [illegible]
		Ca	99.00 - 110.36	107.41 - 121.33	5.55 - 13.37	6.48 - 7.77	6.00 - 37.92	239.50 - [illegible]
		Cr	79.15 - 96.79	101.17 - 115.91	6.66 - 9.99	4.53 - 7.12	51.26 - 91.78	330.50 - [illegible]
Mean	E_1	Ch	118.05 ± 2.51	NA	NA	NA	127.25 ± 2.39	184.75 ± [illegible]
		Ca	97.48 ± 2.51	NA	NA	NA	11.50 ± 2.39	177.46 ± [illegible]
		Cr	99.13 ± 2.51	NA	NA	NA	57.82 ± 2.39	332.26 ± [illegible]
	E_2	Ch	110.01 ± 1.59	121.58 ± 1.78	4.73 ± 0.59	2.90 ± 0.58	113.69 ± 9.55	191.07 ± [illegible]
		Ca	103.03 ± 1.59	112.98 ± 1.78	8.55 ± 0.59	7.02 ± 0.58	22.51 ± 9.55	300.60 ± [illegible]
		Cr	88.95 ± 1.59	109.29 ± 1.78	8.31 ± 0.59	5.48 ± 0.58	71.79 ± 9.55	395.43 ± [illegible]
gcv	E_1		8.43	6.27	NA	NA	60.96	[illegible]
	E_2		17.55	5.46	20.03	23.47	56.74	[illegible]
pcv	E_1		9.13	7.23	NA	NA	61.14	[illegible]
	E_2		17.79	6.12	29.12	29.81	57.04	[illegible]
ecv	E_1		3.51	3.61	NA	NA	5.86	[illegible]
	E_2		2.89	2.76	13.07	18.37	5.82	5.49
Herit-ability	E_1		0.85	0.75	NA	NA	0.99	[illegible]
	E_2		0.94	0.79	0.79	0.62	0.98	[illegible]
Genetic advance	E_1		16.25	13.29	NA	NA	72.17	171.79
	E_2		34.09	11.17	3.79	2.11	73.49	169.97
Genetic advance (% of mean)	E_1		82.67	11.19	NA	NA	124.79	61.00
	E_2		35.67	10.04	47.91	35.08	116.28	[illegible]

was the highest for fruits/plant (124.79). The phenotypic differences among the lines were mainly genetical as indicated by high estimates of heritability in the case of fruits/plant and green fruit yield/plant. Environmental factors influenced the extent of variation for tap root length, primary roots/plant, fruit perimeter and fruit length.

B. Genetic divergence in Capsicum annuum

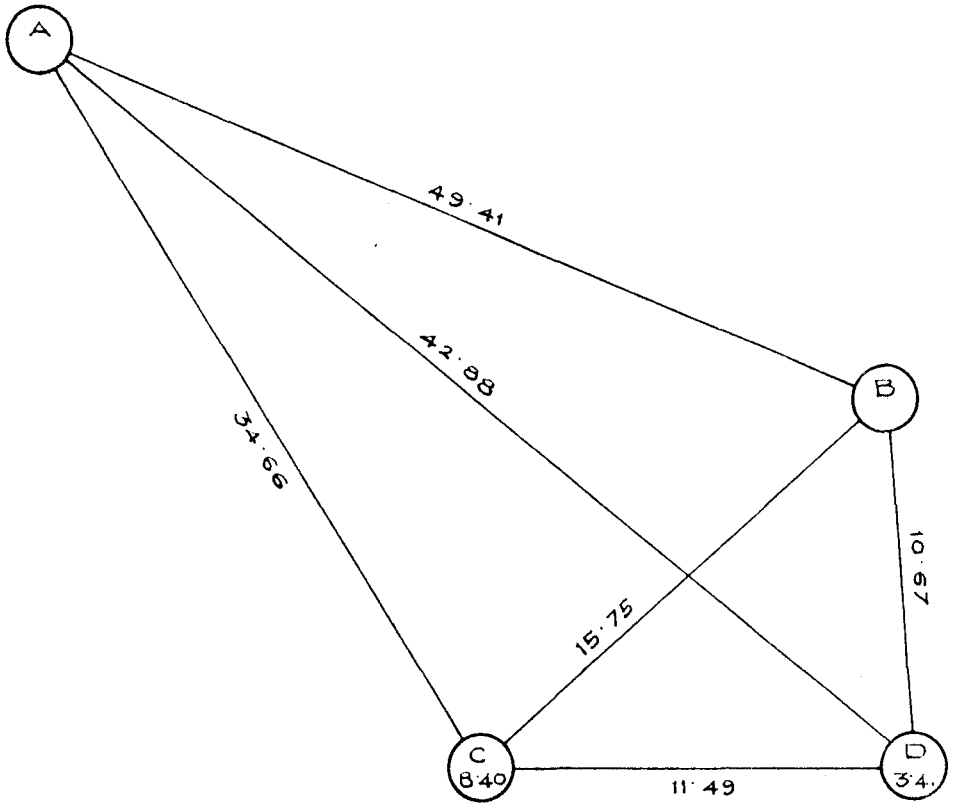
Genetic divergence among parental lines were estimated utilising Mahalanobis D^2 statistics. For this analysis six characters recorded during December 1985 - April 1986 and nine characters recorded during August - December 1986 were utilised. During December 1985 - April 1986, five lines were classified into three clusters A, B and C. Cluster B was the largest with three lines. This was followed by A and C (Fig.1). During August - December 1986, there were four clusters A, B, C and D. Cluster C was the largest with tWro lines followed by Cluster D with two lines. Clusters A and B have one line each (Fig. 2).

The inter and intra cluster average D values are presented in Tables 6 and 7. During December - April, 1985-86, the distance was maximum between clusters A and B (19.17) and minimum between clusters B and C (9.39). During



CLUSTER	VARIETIES
A.	PANT C-1
B.	CUBANELLE, HUNGARIAN WAX, EARLY CALWONDER.
C.	KAU CLUSTER

FIG. 1. INTER AND INTRA CLUSTER GENETIC DISTANCE (D) AMONG TWO LINES OF CHILLIES AND THREE LINES OF CAPSICUMS DURING DECEMBER - APRIL 1985 - '86



CLUSTER	VARIETIES
A.	PANT C-1.
B.	EARLY CALWONDER.
C.	SWEET RED CHERRY PICKLING, HUNGARIAN WAX.
D.	KAU CLUSTER, CUBANELLE

FIG. 2. INTER AND INTRA CLUSTER GENETIC DISTANCE (D) AMONG TWO LINES OF CHILLIES AND FOUR LINES OF CAPSICUMS DURING AUGUST - DECEMBER 1986.

Table 6. Intra and inter cluster genetic distance (D) among two chilli and three capsicum lines during December, 1985 - April, 1986

Name of cluster	Lines within cluster	Intra and inter-cluster distances		
		A	B	C
A	Pant C-1	<u>0.00</u>		
B	Cubanelle, Hungarian Wax, Early Calwonder	19.17	<u>4.65</u>	
C	KAU Cluster	10.03	9.39	<u>0.00</u>

The underlined values indicate the intra-cluster distances

Table 7. Intra and inter-cluster genetic distance (D) among two chilli and four capsicum lines during August-December, 1986

Name of cluster	Lines within cluster	Intra and inter-cluster distances			
		A	B	C	D
A	Pant C-1	<u>0.00</u>			
B	Early Calwonder	49:41	<u>0.00</u>		
C	Sweet Red Cherry Pickling, Hungarian Wax	34.66	15.75	<u>8.40</u>	
D	KAU Cluster Cubanelle	42.98	10.69	11.49	<u>3.41</u>

The underlined values indicate the intracluster distances.

August - December 1986, the maximum intercluster average D value (49.41) was observed between clusters A and B having only one line each. It was minimum between B and D (10.69).

Simple correlations (r) were worked out between genetic distance of parents and F_1 performance for yield. Positive correlation was observed between genetic distance and F_1 yield. But this association was not significant. The estimate of correlation coefficient (r) was 0.58 during December - April 1986 and 0.69 during August - December '86.

C. Intervarietal heterosis in Capsicum annuum

Bell pepper varieties Early Calwonder, Sweet Red Cherry Pickling and Yolo Wonder Improved did not perform well during December - April 1986. Performance of Yolo Wonder improved was also poor during August - December 1986. Heterobeltiosis and relative heterosis were not calculated in comparison to them. Extent of heterosis over KAU Cluster and Pant C-1 were calculated in all the crosses. Mean performance of parents and F_1s and extent of heterosis over KAU Cluster, over better parent, relative heterosis, and over Pant C-1 observed are presented in Table 8.

1. Plant height

All hybrids were taller than their parents during August - December 1986. All hybrids except four showed

Table 8. Mean performance of two chilli and five capsicum lines and their F_1 hybrids and extent of heterosis

Lines	Plant height (cm)									
	December 1985 - April 1986					August - December 1986				
	Mean	% over KAU Cluster	% over BP	% over MP	% over Pant C-1	Mean	% over KAU Cluster	% over BP	% over MP	% over Pant C-1
Chilli										
KAU Cluster	44.41					39.25				
Pant C-1	46.28					50.09				
Capsicum										
Hungarian Wax	49.99					42.00				
Sweet Red Cherry Pickling	45.90					51.48				
Early Calwonder	35.35					37.36				
Cubanelle	54.45					52.74				
Yolo Wonder Improved	40.82					44.50				
F_1 hybrids										
Hungarian Wax x KAU Cluster	54.09	21.79**	8.19*	14.59**	16.88*	53.01	35.06**	26.21**	30.49**	5.83
Hungarian Wax x Pant C-1	45.96	3.49	-8.06	-4.52	-0.01	58.43	48.87**	16.65**	26.89**	16.65**
Sweet Red Cherry Picking x KAU Cluster	39.86	-10.25	-13.16*	-11.73*	-13.87*	58.60	49.29**	13.83**	29.17**	16.99**
Sweet Red Cherry Pickling x Pant C-1	53.13	19.64**	14.80*	15.27**	14.80*	64.11	63.34**	24.53**	26.24**	27.99**
Early Calwonder x KAU Cluster	44.99	1.31	1.31	12.81*	-2.79	55.58	41.61**	41.61**	45.10**	10.96**
Early Calwonder x Pant C-1	44.82	0.01	-3.15	9.81	-3.15	54.16	37.98**	8.13	23.88	8.13
Cubanelle x KAU Cluster	54.38	22.45**	-0.01	10.01	17.50**	54.33	38.42**	3.01	18.22**	8.46*
Cubanelle x Pant C-1	51.82	16.69*	-4.82	2.89	11.97*	55.23	40.71**	4.72	7.42	10.26*
Yolo Wonder Improved x KAU Cluster	54.22	22.09**	22.09**	27.23**	17.16*	56.68	44.41**	13.16**	35.36**	13.16**
Yolo Wonder Improved x Pant C-1	51.50	15.96*	11.28	18.25*	11.28	52.19	32.97**	4.19	10.35*	4.19

* p = 0.05 ** p = 0.01 NA = Not Available MP = Mid Parent BP = Better Parent

Table 8. (contd...)

Lines	Primary branches/plant									
	December 1985 - April 1986					August - December 1986				
	Mean	% over KAU Cluster	% over BP	% over MP	% over Pant C-1	Mean	% over KAU Cluster	% over BP	% over MP	% over Pant C-1
Chilli										
KAU Cluster	16.62					14.42				
Pant C-1	7.15					6.19				
Capsicum										
Hungarian Wax	5.94					3.17				
Sweet Red Cherry Pickling	5.11					4.57				
Early Calwonder	3.85					4.50				
Cubanelle	7.44					5.40				
Yolo Wonder Improved	4.24					4.29				
F_1 hybrids										
Hungarian Wax x KAU Cluster	6.64	-60.05**	-60.05**	-41.13**	-7.13	5.68	-60.06**	-60.06**	-35.38**	-7.15
Hungarian Wax x Pant C-1	6.41	-61.43**	-10.35	2.06	-10.35	5.83	-59.57**	-5.82	24.57	-5.82
Sweet Red Cherry Pickling x KAU Cluster	6.87	-58.66**	-58.66**	-36.77**	-3.92	6.99	-51.53**	-51.53**	-25.99**	12.92
Sweet Red Cherry Pickling x Pant C-1	5.52	-66.78**	-22.79*	-9.95	-22.79*	5.25	-63.59**	-15.19	-2.42	-15.19
Early Calwonder x KAU Cluster	6.49	-60.95**	-60.95**	-36.59**	-9.23	5.32	-63.11**	-63.11**	-43.76**	-14.05
Early Calwonder x Pant C-1	5.65	-66.00**	-20.98	-2.73	-20.98	5.00	-65.33**	-19.92	6.45	-19.22
Cubenelle x KAU Cluster	8.11	-51.20	-51.20	-32.58**	13.43	8.03	-44.31**	-44.31**	-18.97**	29.73*
Cubanelle x Pant C-1	6.93	-58.30	-6.85	-5.00	-3.08	8.13	-43.62**	31.34*	40.29**	31.34*
Yolo Wonder Improved x KAU Cluster	6.19	-62.76**	-62.76**	-40.65**	-13.43	6.05	-58.04**	-58.04**	-35.33*	-2.26
Yolo Wonder Improved x Pant C-1	6.31	-62.03**	-11.75	-10.79	-11.75	4.33	-69.97**	-30.05**	-17.37	-30.05**

Table 5. (contd...)

Lines	August - December 1986									
	Tap root length (cm)					Primary roots/plant				
	Mean	% over KAU Cluster	% over BP	% over MF	% over Pant C-1	Mean	% over KAU Cluster	% over BP	% over MF	% over Pant C-1
Chilli										
KAU Cluster	10.45					57.39				
Pant C-1	11.61					45.12				
Capsicum										
Hungarian Wax	9.81					66.36				
Sweet Red Cherry Pickling	8.65					58.33				
Early Calwonder	15.62					55.25				
Cubanelle	10.44					63.91				
Yolo Wonder Improved	NA					NA				
F_1 hybrids										
Hungarian Wax x KAU Cluster	12.27	17.42	17.42	21.13	5.68	109.54	90.87**	65.07**	77.03**	142.77**
Hungarian Wax x Pant C-1	8.47	-18.95	-27.05*	-20.92	-27.05*	85.23	48.51**	28.43**	52.91**	88.89**
Sweet Red Cherry Pickling x KAU Cluster	12.89	23.35**	23.35**	34.97*	11.02	67.23	18.23	16.32	17.27	50.38**
Sweet Red Cherry Pickling x Pant C-1	18.24	74.55**	57.11**	80.06**	57.11	71.82	25.14*	23.13*	38.85*	59.18**
Early Calwonder x KAU Cluster	8.30	-20.57	-46.86**	-36.33**	-28.57*	76.72	33.68**	33.68**	36.22**	70.04**
Early Calwonder x Pant C-1	8.19	-21.63	-47.57**	-39.74**	-27.13*	60.44	5.31	9.39	20.43	33.96*
Yolo Wonder Improved x KAU Cluster	18.94	81.24**	NA	NA	63.14**	67.15	17.01	NA	NA	48.83**
Yolo Wonder Improved x Pant C-1	16.09	53.97**	NA	NA	38.59**	66.36	15.62	NA	NA	47.07**

Table 8. (cont'd...)

Lines	Days to flower									
	December 1985 - April 1986					August - December 1986				
	Mean	% over K&U Cluster	% over B	% over M	% over Pant C-1	Mean	% over K&U Cluster	% over B	% over M	% over Pant C-1
Chilis										
K&U Cluster	91.52					87.85				
Pant C-1	86.96					78.30				
Cantaloup										
Hungarian Wax	66.21					75.51				
Sweet Red Cherry Pickling	74.45					75.93				
Early Calwonder	71.86					72.64				
Cubanelle	86.71					87.86				
Yolo Wonder Improved	74.86					75.11				
F_1 hybrids										
Hungarian Wax x K&U Cluster	70.81	-22.63**	6.95*	-10.21**	-18.57**	56.18	-36.05**	-21.44**	-29.49**	-28.25**
Hungarian Wax x Pant C-1	69.79	-24.84**	3.89	-10.18**	-20.89**	57.55	-34.49**	-19.52**	-23.17**	-26.50**
Sweet Red Cherry Pickling x K&U Cluster	77.16	-15.69**	3.64	-7.02**	-11.27**	59.81	-31.92**	-21.03**	-26.92**	-23.61**
Sweet Red Cherry Pickling x Pant C-1	77.56	-15.25**	4.18	-3.89	-10.81	60.15	-31.53**	-20.68**	-21.95**	-23.18*
Early Calwonder x K&U Cluster	74.79	-18.28**	4.08	-8.44*	-13.99**	58.14	-33.82**	-19.97**	-25.91**	-25.75**
Early Calwonder x Pant C-1	78.59	-14.13**	9.37**	-1.03	-9.63**	59.45	-32.33**	-18.16**	-21.22**	-24.07*
Cubanelle x K&U Cluster	76.74	-16.26**	-11.20**	-13.81*	-11.87**	59.23	-32.58**	-32.58**	-32.58**	-24.35**
Cubanelle x Pant C-1	75.77	-17.21**	-12.21**	12.54	-12.87**	59.62	-32.13**	-23.86**	-29.24**	-23.85**
Yolo Wonder Improved x K&U Cluster	71.17	-22.24**	-4.93	-14.45**	-18.16	61.63	-29.85**	-17.95**	-24.36**	-21.29**
Yolo Wonder Improved x Pant C-1	73.72	-19.45**	-1.52	-8.89**	-15.23**	57.71	-34.31**	-23.17**	-24.76**	-26.29**

Table 8. (contd...)

Lines	Days to green fruit harvest									
	December 1985 - April 1986					August - December 1986				
	Mean	% over KAU Cluster	% over BP	% over MP	% over Pant C-1	Mean	% over KAU Cluster	% over BP	% over MP	% over Pant C-1
Chilli										
KAU Cluster	117.10					113.96				
Pant C-1	119.00					106.06				
Capsicum										
Hungarian Wax	90.25					104.27				
Sweet Red Cherry Pickling	NA					99.00				
Early Calwonder	101;79					99.85				
Cubanelle	100.00					110.44				
Yolo Wonder Improved	NA					NA				
F_1-hybrids										
Hungarian Wax x KAU Cluster	99.56	-14.97**	10.31*	-3.96	-16.33**	93.25	-18.17**	-10.57**	-14.54**	-12.01*
Hungarian Wax x Pant C-1	95.10	-18.78*	-5.37	-9.10	-20.08*	85.42	-28.04**	-18.08**	-18.77**	-19.46**
Sweet Red Cherry Pickling x KAU Cluster	112.06	-4.30	NA	NA	-5.83	79.15	-30.55**	-20.05	-25.66*	-25.38*
Sweet Red Cherry Pickling x Pant C-1	102.79	-12.22**	NA	NA	-13.62*	85.45	-25.09*	-13.69	-16.66	-19.64
Early Calwonder x KAU Cluster	101.54	-13.29**	-0.01	-7.22	-14.67**	92.81	-18.56*	-7.05*	-13.19*	-12.49*
Early Calwonder x Pant C-1	91.25	-22.07**	-10.35*	-17.31**	-23.31**	91.72	-19.52*	-8.14*	-10.92*	-13.52*
Cubanelle x KAU Cluster	90.64	-22.59*	-9.36	-16.49	-23.83*	85.23	-25.21*	-22.83**	-24.04**	-19.64**
Cubanelle x Pant C-1	95.12	-18.77**	-4.88	-13.13	-20.07*	96.79	-15.07**	-8.74**	-10.59**	-8.74**
Yolo Wonder Improved x KAU Cluster	99.29	-15.21**	NA	NA	-16.56**	94.92	-16.71**	NA	NA	-10.51**
Yolo Wonder Improved x Pant C-1	104.00	-11.18**	NA	NA	-12.61**	84.75	-25.63*	NA	NA	-20.09**

Table 8. (contd...)

Lines	Days to fruit ripening				
	August - December 1986				
	Mean	% over KAU Cluster	% over BP	% over MP	% over Pant C-1
Chilli					
KAU Cluster	125.61				
Pant C-1	117.55				
Capsicum					
Hungarian Wax	114.83				
Sweet Red Cherry Pickling	111.33				
Early Calwonder	107.41				
Cubanelle	121.33				
Yolo Wonder Improved	NA				
F_1 hybrids					
Hungarian Wax x KAU Cluster	111.76	-11.03**	-2.67	-7.04**	-4.93*
Hungarian Wax x Pant C-1	102.05	-18.75**	-11.13**	-12.17**	-13.19**
Sweet Red Cherry Pickling x KAU Cluster	108.83	-13.36*	-2.24	-8.79**	-7.39**
Sweet Red Cherry Pickling x Pant C-1	101.17	-19.46**	-9.13**	-11.59**	-13.93**
Early Calwonder x KAU Cluster	112.17	-10.69**	4.43	3.73	-4.58*
Early Calwonder x Pant C-1	108.67	-13.49**	1.17	3.39	-7.55**
Cubanelle x KAU Cluster	107.83	-14.75**	-11.13**	-12.67**	-8.27**
Cubanelle x Pant C-1	115.91	-7.72**	-1.39	-2.96	-1.39
Yolo Wonder Improved x KAU Cluster	106.89	-14.90**	NA	NA	-9.07**
Yolo Wonder Improved x Pant C-1	107.72	-14.24**	NA	NA	-8.36*

Table 8. (contd...)

Lines	Fruit Length (cm)					Fruit Perimeter (cm)				
	December 1985 - April 1986					August - December 1986				
	Mean	% over KAU Cluster	% over BP	% over MP	% over Pant C-1	Mean	% over KAU Cluster	% over BP	% over MP	% over Pant C-1
Chilli										
KAU Cluster	4.27					2.94				
Pant C-1	5.19					2.87				
Capsicum										
Hangarian Wax	13.39					7.22				
Sweet Red Cherry Pickling	8.55					6.61				
Early Calwonder	6.71					6.49				
Cubanelle	5.55					7.77				
Yolo Wonder Improved	NA					NA				
F_1 hybrids										
Hungarian Wax x KAU Cluster	8.50	99.06**	-36.52*	-3.74	63.78**	4.86	65.31*	-32.69**	-4.33	69.34*
Hungarian Wax x Pant C-1	9.99	133.96**	-25.39**	7.53	92.49**	4.53	54.08	-37.26**	-10.21	57.84
Sweet Red Cherry Pickling x KAU Cluster	9.95	113.02**	16.37	55.23**	91.71**	5.18	76.19*	-21.63	8.48	80.49**
Sweet Red Cherry Pickling x Pant C-1	8.99	110.54**	5.15	30.86*	73.22**	5.41	84.01**	-18.15	14.14	88.50**
Early Calwonder x KAU Cluster	6.66	55.97**	-0.74	21.31	28.32	5.23	77.89*	-19.41	10.92	82.23**
Early Calwonder x Pant C-1	7.78	82.20**	15.95	30.76**	49.90*	7.12	142.18**	9.71	52.14**	148.08**
Cubenelle x KAU Cluster	7.67	79.63**	38.19**	56.21**	47.78*	5.14	74.83*	-33.85**	-3.38	79.09*
Cubanelle x Pant C-1	7.36	72.36**	32.61**	37.06*	41.81*	4.85	65.31*	-37.45**	-8.65	69.33**
Yolo Wonder Improved x KAU Cluster	7.89	84.78*	NA	NA	52.02**	5.54	88.43**	NA	NA	93.03**
Yolo Wonder Improved x Pant C-1	8.28	93.91**	NA	NA	59.54**	6.96	136.73**	NA	NA	142.51**

Table 8. (contd...)

Lines	Fruits/plant									
	December 1985 - April 1986					August - December 1986				
	Mean	% over KAU Cluster	% over BP	% over MP	% over Pant C-1	Mean	% over KAU Cluster	% over BP	% over MP	% over Pant C-1
Chilli										
KAU Cluster	113.50					118.25				
Pant C-1	141.00					149.13				
Capsicum										
Hungarian Wax	13.60					17.00				
Sweet Red Cherry Pickling	NA					37.92				
Early Calwonder	3.90					6.60				
Cubanelle	17.00					28.50				
Yolo Wonder Improved	NA					NA				
F_1 hybrid										
Hungarian Wax x KAU Cluster	76.00	-33.04**	-33.04**	-19.59	-46.09**	91.78	-22.38**	-22.38**	35.72**	-38.45**
Hungarian Wax x Pant C-1	68.07	-40.03**	-51.72**	-11.94**	-51.72**	86.00	-27.27**	-42.33**	3.53	-42.33**
Sweet Red Cherry Pickling x KAU Cluster	59.88	-47.25**	NA	NA	-57.53**	78.50	-33.62*	-33.62*	-0.01	-47.36**
Sweet Red Cherry Pickling x Pant C-1	56.50	-50.22**	NA	NA	-59.92**	75.70	-35.98**	-49.24**	-19.06**	-49.24**
Early Calwonder x KAU Cluster	46.00	-59.47**	-67.38**	-21.64**	-67.38**	58.25	-50.74**	-50.74**	-6.69	-60.94**
Early Calwonder x Pant C-1	43.08	-62.05**	-69.45**	-40.54**	-69.45**	51.26	-56.67**	-65.63**	-34.17**	-65.63**
Cubanelle x KAU Cluster	64.50	-43.17**	-54.26**	-1.15	-54.26**	71.75	-39.33**	-39.33**	-2.21	-51.89**
Cubanelle x Pant C-1	55.42	-51.13**	-60.59**	-23.85**	60.59**	65.42	-44.68**	-56.13**	-26.34**	-56.13**
Yolo Wonder Improved x KAU Cluster	56.60	-50.13**	NA	NA	-59.86**	70.63	-40.25**	NA	NA	-52.63**
Yolo Wonder Improved x Pant C-1	52.13	-54.07**	NA	NA	-63.03**	68.60	-41.99**	NA	NA	-53.99**

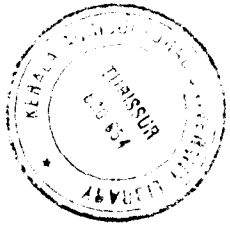


Table 8. (Contd...)

Lines	Green fruit yield/plant (g)									
	December 1985 - April 1986					August - December 1986				
	Mean	% over KAU Cluster	% over BP	% over MP	% over Pant C-1	Mean	% over KAU Cluster	% over BP	% over MP	% over Pant C-1
Chilli										
KAU Cluster	181.60					198.43				
Pant C-1	197.90					194.90				
Capsicum										
Hungarian Wax	264.90					385.65				
Sweet Red Cherry Pickling	NA					291.75				
Early Calwonder	129.98					239.50				
Cubanelle	137.49					285.50				
Yolo Wonder Improved	NA					NA				
F_1 hybrid										
Hungarian Wax x KAU Cluster	400.50	120.53**	51.19*	79.39**	113.81**	482.80	156.22**	25.19	68.19**	147.72**
Hungarian Wax x Pant C-1	385.50	112.28**	45.33*	70.27**	105.16**	415.87	120.70**	7.84	43.27*	113.38**
Sweet Red Cherry Pickling x KAU Cluster	342.00	88.33**	NA	NA	82.01**	425.40	125.76**	45.81*	77.18**	118.27**
Sweet Red Cherry Pickling x Pant C-1	303.75	67.26**	NA	NA	61.66*	410.60	117.91**	40.74*	68.74**	110.67**
Early Calwonder x KAU Cluster	278.75	53.49*	53.49*	78.93**	48.35*	356.50	89.19**	48.85*	66.61**	82.91**
Early Calwonder x Pant C-1	292.40	61.01**	55.61*	83.97**	55.61*	351.25	86.41**	46.66*	61.72*	80.22**
Cubanelle x KAU Cluster	346.25	90.67**	90.67**	117.02**	84.27**	394.38	109.29**	38.14	66.43**	102.35**
Cubanelle x Pant C-1	291.65	60.32**	54.95*	78.95**	54.95*	330.50	75.45**	15.76	37.51*	69.51**
Yolo Wonder Improved x KAU Cluster	370.00	103.74**	NA	NA	96.91**	398.00	111.22**	NA	NA	104.21**
Yolo Wonder Improved x Pant C-1	311.75	71.67**	NA	NA	65.91**	389.50	106.71**	NA	NA	99.85**

significant positive heterobeltiosis. The tallest hybrid was Sweet Red Cherry Pickling x KAU Cluster (58.68 cm) which was 44.41% more than KAU Cluster and 13.16% more than Pant C-1. In general, hybrids were taller than the parents. During December'85- April 1986, the tallest hybrid was Cubanelle x KAU Cluster (54.38 cm) which was taller to the extent of 22.45% over KAU Cluster and 17.50% over Pant C-1.

2. Primary branches/plant

KAU Cluster had the maximum number of primary branches/plant (16.62 and 14.42 respectively during December'85- April 1986 and August - December 1986). The hybrids were intermediate to their parents for this characters. Cubanelle x KAU Cluster (8.11) and Cubanelle x Pant C-1 (8.13) ranked first among the hybrids during first and second seasons. This was 51.20% and 43.62% lesser than KAU Cluster and 13.43% and 31.43% more than Pant C-1. Primary branches/plant ranged from 5.52 - 6.93 in other hybrids during first season and 4.33 - 8.03 during second season.

3. Tap root length

Out of 10 hybrids, four showed significant positive heterosis over KAU Cluster. All hybrids except three showed positive heterosis over Pant C-1 for this character.

4. Primary roots/plant

All hybrids exhibited significant positive heterosis over Pant C-1. Out of 10 hybrids only four showed significant positive heterosis over KAU Cluster. The heterotic increase ranged from 5.31% to 90.87% over KAU Cluster and 33.96% to 142.77% over Pant C-1. The highest value of primary roots/plant was observed in Hungarian Wax x KAU Cluster (109.54).

5. Days to flower

During both the seasons, all hybrids were earlier than the common parents KAU Cluster and Pant C-1 and exhibited significant negative heterosis. During December - April 1985-'86, Hungarian Wax x Pant C-1 was the earliest (68.79). Whereas Hungarian Wax x KAU Cluster flowered in 56.18 days during August - December 1986 and showed significant relative heterosis (-29.49%) and heterobeltiosis (-21.44%).

6. Days to green fruit harvest

All the F_1 hybrids were earlier to common parents KAU Cluster (117.1) and Pant C-1 (119.00) during both the seasons. Heterosis observed over KAU Cluster ranged from -4.30 to -22.59%. Cubanelle x KAU Cluster was the earliest which took 91 days to green fruit harvest (December 1985 - April 1986).

During second season, Yolo Wonder Improved x Pant C-1 was the earliest which took 85 days for green fruit harvest. All hybrids exhibited significant negative heterosis over KAU Cluster and Pant C-1.

7. Days to fruit ripening

The hybrid Sweet Red Cherry Pickling x Pant C-1 was the earliest which took 101 days for fruit ripening followed by Hungarian wax x Pant C-1 (102 days). All hybrids showed signficant negative heterosis over Pant C-1 and KAU Cluster. Out of 10 hybrids, only three showed significant heterobeltiosis.

8. Fruit length

All the hybrids showed positive heterosis over KAU Cluster and Pant C-1. Among the hybrids Hungarian Wax x Pant C-1 had the maximum fruit length (9.99 cm) which was more than KAU Cluster and Pant C-1, to the extent of 133.96% and 92.49% respectively. It was 25.39% lower than the better parent Hungarian Wax.

9. Fruit perimeter

All hybrids exhibited positive significant heterosis over KAU Cluster (2.94 cm) and Pant C-1 (2.87 cm). Significant negative heterobeltiosis was expressed by Cubanelle x Pant C-1. Cubanelle x KAU Cluster, Hungarian Wax x KAU Cluster and Hungarian Wax x Pant C-1.

10. Fruits/plant

The F_1 hybrids did not show positive heterosis over the common parents KAU Cluster and Pant C-1. The hybrid, Hungarian Wax x KAU Cluster had 92 fruits/plant. All the F_1 hybrids exceeded the bell pepper parents for fruits/plant. The bell pepper parents had fruits/plant ranging from 3.90 (Early Calwonder) to 37.92 (Sweet Red Cherry Pickling). The F_1 hybrids ranged from 43 fruits/plant (Early Calwonder x Pant C-1) to 92 fruits (Hungarian Wax x KAU Cluster).

11. Green fruit yield/plant

During December - April 1986, all hybrids exhibited significant heterosis over KAU Cluster and Pant C-1. All hybrids showed significant heterobeltiosis and significant relative heterosis. The best yielding hybrid was Hungarian Wax x KAU cluster (400.5 g/plant). During August - December, 1986 also, all hybrids exhibited significant heterosis over KAU Cluster and Pant C-1. The highest yielding hybrid was Hungarian Wax x KAU Cluster (482.5 g/plant). This was more to the extent of 156.22% over KAU Cluster (188.43 g/plant) and 147.72% over Pant C-1 (194.90 g/plant).

D. Combining ability analysis in Chilli

Line x tester analysis was conducted to find out general combining ability (gca) effects and specific

combining ability effects (sca). Analysis of variance for line x tester is presented in Table 9. A comparison of parents Vs. hybrids revealed highly significant differences between parents and hybrids for most the characters studied. The differences among the testers were non-significant for all characters except for primary roots/plant, fruits/plant and green fruit yield/plant during August - December '86. Variance due to hybrids were significant for all the characters studied except for primary branches/plant and days to green fruit harvest during December - April 1986. Partioning of variation due to hybrids revealed that the differences between the crosses due to the differences among the female parent is highly significant for most of the characters studied. Estimates of general and specific combining ability effects are presented in Table 10 and 11 respectively.

1. Plant height

Variance due to specific combining ability effects (σ^2 sca) was larger than variance due to general combining ability effects (σ^2gca) during both the seasons. A significant positive estimate of gca effect was observed in Sweet Red Cherry Pickling (5.12) and Yolo Wonder Improved (3.38) and Cubanelle (3.63). Plant height increased in Sweet Red Cherry Pickling x Pant C-1 during both the seasons and in Yolo Wonder Improved x KAU Cluster

Table 9. Analysis of variance for line x tester analysis in *Capsium annum*

Components of variation		Mean squares										
		Plant height (cm)	Primary branches/ plant	Taproot length (cm)	Primary roots/ plant	Days to flower	Days to first green fruit harvest	Days to fruit ripening	Fruit length (cm)	Fruit perimeter (cm)	Fruits/ plant	Green fruit yield/ plant (g)
Replications	E_1	23.16	0.96	NA	NA	66.28	15.58	NA	NA	NA	6.38	1562.02
	E_2	20.37	1.22	20.67	111.02	15.09	1.47	49.05	0.12	0.13	15.74	1632.51
Genotypes	E_1	66.98**	14.75**	NA	NA	87.28*	193.25**	NA	NA	NA	3475.46**	15001.56**
	E_2	154.59**	18.92**	37.87**	614.85**	349.62**	288.99**	120.29**	13.83**	6.12**	2585.95**	14475.26**
Parents	E_1	75.67**	36.35*	NA	NA	175.27**	294.55**	NA	NA	NA	8277.90**	5790.91**
	E_2	113.81**	43.42**	104.77**	166.97*	138.48**	92.59**	126.99**	33.42**	13.61**	1751.55**	139696.65**
Parents Vs. Crosses	E_1	142.83**	4.86**	NA	NA	149.23**	564.40**	NA	NA	NA	6.29	185417.24**
	E_2	1464.46**	2.19	20.19*	3261.10**	4697.08**	3197.07**	629.62**	8.86**	3.31*	27393.94**	154443.20**
Crosses	E_1	52.77**	1.05	NA	NA	21.73**	37.99	NA	NA	NA	332.15**	918.94**
	E_2	36.24**	4.62**	9.74**	637.95**	7.34*	96.79**	59.23**	3.49**	2.27*	293.06**	939.21*
Lines	E_1	54.72	1.37	NA	NA	42.39**	22.06*	NA	NA	NA	752.57*	1552.07*
	E_2	50.51	8.32*	122.55**	1101.93**	9.28	90.53	46.57	8.18	3.90	834.36**	1558.28*
Testers	E_1	0.07	2.42	NA	NA	2.19	35.21	NA	NA	NA	135.95	1162.05
	E_2	10.50	3.46	1.03	517.73**	0.08	0.44	42.95	0.87	2.53	114.77*	1269.78*
Lines x Testers	E_1	63.99**	0.39	NA	NA	5.77	55.30*	NA	NA	NA	9.82	225.03
	E_2	28.41*	1.22	30.49**	204.04**	7.20	127.14**	75.95	2.02	2.07	6.56	237.50
Error	E_1	7.41	0.58	NA	NA	4.05	13.41	NA	NA	NA	9.73	376.25
	E_2	7.24	0.81	3.07	56.64	12.24	15.33	9.45	1.07	1.04	13.51	349.72

* p = 0.05

** p = 0.01

E_1 = December 1985 - April 1986

E_2 = August - December 1986

NA = Not available

Table 10. General combining ability effects for yield and its components in Capsicum annuum

		Plant height (cm)	Primary branches/ plant	Taproot length (cm)	Primary roots/ plant	Days to flower	Days to green fruit harvest	Days to fruit maturity	Fruit length (cm)	Fruit perimeter (cm)	Fruits/ plant	Green fruit yield/ plant (g)
Lines												
Hungarian Wax	E_1	0.55	0.01	NA	NA	-4.71	-0.90	NA	NA	NA	7.11	30.37*
	E_2	-0.51	-0.32	-2.06**	23.97**	-2.08	0.38	-1.39	0.94	-0.79	17.09	26.92*
Sweet Red Cherry Pickling	E_1	-2.98*	-0.31	NA	NA	2.87	4.14	NA	NA	NA	0.19	-4.69
	E_2	5.12**	0.04	3.13**	-3.58	1.03	-6.65**	-3.29*	1.16*	-0.19	5.31	11.26
Early Calwonder	E_1	-4.57**	-0.44	NA	NA	2.19	-1.37	NA	NA	NA	-6.64*	-23.34*
	E_2	-1.36	-0.92	-4.19**	-4.83	- 0.15	3.31	2.12	-1.09*	0.69	-17.08**	-20.80*
Cubanelle	E_1	3.63*	1.01*	NA	NA	1.71	-3.31	NA	NA	NA	1.07	-6.65
	E_2	-1.45	1.99*	-1.97*	-8.91**	0.48	2.06	3.57**	-0.78	-0.48	-3.21	-16.52
Yolo Wonder Improved	E_1	3.38*	-0.26	NA	NA	-2.05	1.26	NA	NA	NA	-1.73	4.71
	E_2	-1.79	-0.80	5.08**	-6.65*	0.72	0.89	-0.99	-0.22	0.76	-2.16	-0.87
Testers												
KAU Cluster	E_1	0.03	-0.35	NA	NA	-0.38	0.74	NA	NA	NA	1.39	7.62
	E_2	-0.59	0.34	-0.19	4.15*	0.05	0.12	1.19	-0.17	-0.29	2.39	7.97
Pant C-1	E_1	-0.03	0.35	NA	NA	0.38	-0.74	NA	NA	NA	-1.39	-7.62
	E_2	0.59	-0.34	0.19	-4.15*	-0.05	-0.12	-1.19	0.17	0.29	-2.39	-7.62
SE (gi) lines	E_1	1.36	0.38	NA	NA	1.01	1.83	NA	NA	NA	3.12	9.69
	E_2	1.09	0.51	0.72	3.07	1.42	1.59	1.26	0.42	0.45	1.84	9.35
SE(gj) Testers	E_1	0.86	0.24	NA	NA	0.64	1.49	NA	NA	NA	3.02	6.13
	E_2	0.69	0.32	0.45	1.94	0.90	1.01	0.79	0.27	1.96	1.16	5.91
SE(gi-gj) lines	E_1	1.92	0.54	NA	NA	1.42	2.59	NA	NA	NA	2.39	13.72
	E_2	1.55	0.52	1.01	4.35	2.01	2.25	1.77	0.60	0.59	2.59	13.22
SE (gi-gj) testers	E_1	1.22	0.34	NA	NA	0.89	2.11	NA	NA	NA	1.51	8.67
	E_2	0.98	0.40	0.64	2.75	1.28	1.43	1.12	0.39	0.37	1.84	8.36

* p = 0.05
** p = 0.01

E_1 - December 1985 - April 1986
E_2 - August - December 1986

NA - Not available

Table 11. Specific combining ability effects for yield and its components in Capsicum x chilli crosses

Hybrids		Plant height (cm)	Primary branches/ plant	Tap-root length (cm)	Pri-mary roots/ plant	Days to flow-er	Days to first green fruit harvest	Days to fruit ripen-ing	Fruit length (cm)	Fruit peri-meter (cm)	Fruits/ plant	Green fruit yield/ plant (g)
Hungarian Wax x KAU Cluster	E_1	+2.01	-0.12	NA	NA	0.69	0.37	NA	NA	NA	0.65	-3.62
	E_2	-2.12	-0.40	2.08*	+7.99	-0.73	3.79	3.66*	-0.57	0.46	0.49	8.77
Hungarian Wax x Pant C-1	E_1	-2.01	0.12	NA	NA	-0.69	-0.37	NA	NA	NA	-0.65	3.62
	E_2	2.12	0.40	-2.08*	-7.99	0.73	-3.79	-3.66*	0.57	-0.46	-0.49	-8.77
Sweet Red Cherry Pickling x KAU Cluster	E_1	-3.33	+0.16	NA	NA	0.09	1.58	NA	NA	NA	2.14	1.94
	E_2	-2.16	0.53	-2.49*	-6.14	-0.22	-3.27	2.63	0.65	0.18	-0.99	-4.27
Sweet Red Cherry Pickling x Pant C-1	E_1	3.33	-0.16	NA	NA	-0.99	-1.58	NA	NA	NA	-2.14	-1.94
	E_2	2.16	-0.53	+2.49*	6.14	0.22	3.27	-2.63	-0.65	-0.18	0.99	4.27
Early Calwonder x KAU Cluster	E_1	0.03	0.04	NA	NA	-0.76	1.83	NA	NA	NA	-0.61	-11.04
	E_2	1.30	-0.18	0.24	3.98	-0.71	0.42	0.55	-0.38	-0.65	1.02	-6.66
Early Calwonder x Pant C-1	E_1	-0.03	-0.04	NA	NA	0.76	-1.83	NA	NA	NA	0.61	11.04
	E_2	-1.30	0.18	-0.24	-3.98	0.71	-0.42	-0.55	0.388	+0.65	-1.02	6.66
Cubanelle x KAU Cluster	E_1	0.62	0.12	NA	NA	0.41	-1.88	NA	NA	NA	0.68	6.03
	E_2	0.13	-0.38	-1.44	-2.08	-0.25	-5.90*	-5.24**	-0.33	-0.43	-0.77	-8.00
Cubanelle x Pant C-1	E_1	-0.62	-0.12	NA	NA	-0.41	1.88	NA	NA	NA	-0.68	-6.03
	E_2	-0.14	0.38	1.44	2.08	0.25	5.90*	5.24**	-0.33	-0.43	-0.77	-8.00
Yolo Wonder Improved x KAU Cluster	E_1	0.66	-0.20	NA	NA	-0.45	-1.92	NA	NA	NA	4.64	6.94
	E_2	2.84	0.44	1.61	-3.76	1.93	4.98*	-1.61	-0.02	0.42	-1.37	-5.84
Yolo Wonder Improved x Pant C-1	E_1	-0.66	0.20	NA	NA	0.45	1.92	NA	NA	NA	-4.64	-6.94
	E_2	-2.84	-0.44	-1.61	3.76	-1.93	-4.98*	1.61	0.02	-0.42	1.37	5.84
SE (ij)	E_1	1.92	0.54	NA	NA	1.42	2.58	NA	NA	NA	2.21	13.82
	E_2	1.55	0.52	1.01	4.34	2.02	2.26	1.77	0.59	0.58	2.59	13.22
SE (Sij-Skl)	E_1	2.72	0.75	NA	NA	2.01	3.66	NA	NA	NA	3.39	19.39
	E_2	2.19	0.73	1.43	6.14	2.86	10.22	2.51	0.85	0.83	3.68	18.70

* p = 0.05
** p = 0.01
E_1 = December 1985 - April 1986
E_2 = August - December 1986
NA = Not available

and Hungarian Wax x Pant C-1 during August - December'86. Whereas other hybrids had either negative or very low sca effects.

2. Primary branches/plant

A significant positive estimate of gca effect was noted in Cubanelle (1.01 and 1.99 respectively during E_1 and E_2). The highest estimate of sca effect was observed in Sweet Red Cherry Pickling x KAU Cluster (0.53) followed by Yolo Wonder Improved x KAU Cluster (0.44).

3. Tap root length

Highly significant positive estimate of gca effect was noted in Yolo Wonder Improved (5.08) and Sweet Red Cherry Pickling (3.13). Hungarian Wax, Cubanelle and Early Calwonder had significantly negative estimates of gca. Significantly positive estimates of sca were observed in Sweet Red Cherry Pickling x Pant C-1 (2.49) and Hungarian Wax x KAU Cluster (2.08).

4. Primary roots/plant

Positively significant gca effect was noted in Hungarian Wax (23.97) and KAU Cluster (4.15). Out of 10 hybrids, only five had positive values of specific combining ability effects. Maximum value of specific combining ability effect was noted in Sweet Red Cherry Pickling x Pant C-1 (6.14).

5. Days to flower

Hungarian Wax had the lowest value of gca effect during both the seasons (-4.71, -2.08 respectively during E_1 and E_2) which favoured earliness. Cubanelle and Sweet Red Cherry Pickling had positive values during both the seasons. Out of 10 hybrids, five had negative estimates of sca effect during December to April 1986 and the lowest estimate was noted in Early Calwonder x KAU Cluster (-0.76). During August to December 1986 the lowest sca effect was noted in Yolo Wonder Improved x Pant C-1 (-1.93).

6. Days to first green fruit harvest

A negative estimate of gca effect was noted only for Hungarian Wax, Early Calwonder, Cubanelle and Pant C-1 during December to April 1986. During August to December 1986 period, only Hungarian Wax, Sweet Red Cherry Pickling and Pant C-1 had negative values of gca effect. All others had positive values of gca effect. The lowest value of gca effect was noticed in Sweet Red Cherry Pickling (-6.65). Yolo Wonder Improved x Pant C-1 and Cubanelle x KAU Cluster had significantly negative values of sca effects (-4.98 and -5.90 respectively).

7. Days to fruit ripening

Gca effects were negative only for Sweet Red Cherry Pickling, Hungarian Wax, Yolo Wonder Improved and

Pant C-1. All others had positive values of gca effect for this character. Significantly negative values of sca effect were observed in Hungarian Wax x Pant C-1 (-3.66) and Cubanelle x KAU Cluster (-5.24).

8. Fruit length

Except Cubanelle, Early Calwonder, Yolo Wonder Improved and KAU Cluster all others had positive values of gca effect. Of these, Sweet Red Cherry Pickling had significantly positive value of gca effect for fruit length (1.16). Sweet Red Cherry Pickling x KAU Cluster and Hungarian Wax x Pant C-1 had maximum fruit length as indicated by high values of sca effects (0.65 and 0.57 respectively).

9. Fruit perimeter

The gca effect was positive only for Early Calwonder (0.69), Yolo Wonder Improved (0.76) and Pant C-1 (0.29). Out of 10 hybrids five had positive sca effects. The highest sca effect was observed in Early Calwonder x Pant C-1 (0.65).

10. Fruits/plant

Hungarian Wax had the highest value of gca effect in both seasons (7.11 and 17.09 respectively during E_1 and E_2) followed by Cubanelle (1.07 in E_1) and Sweet Red Cherry

Pickling (5.31 in E_2). Out of 10 hybrids evaluated, only five showed positive sca effects during both the seasons. The highest sca effect was noticed in Yolo Wonder Improved x KAU Cluster (4.64 during E_1) followed by Sweet Red Cherry Pickling x KAU Cluster (2.14).

11. Green fruit yield/plant

Among the parents Hungarian Wax had the highest gca effect (30.37 and 26.92 respectively during E_1 and E_2) for this character. Positive values of gca effect were noticed in the case of KAU Cluster (during both seasons) Sweet Red Cherry Pickling (during E_2), Yolo Wonder Improved (during E_1) All others showed negative estimates of gca effect. Maximum sca effect was noticed in Early Calwonder x Pant C-1 (11.04 during E_1) followed by Hungarian Wax x KAU Cluster 8.77 (during E_2).

Components of variance due to gca and sca effects and R_g values.

The estimates of variance due to gca and sca effects were made (Table 12). Higher estimates of σ^2 sca were observed for plant height, tap root length, primary roots/ plant, days to maturity, days to green fruit harvest, fruit length and fruit perimeter during both seasons. The high values of σ^2 sca indicated presence of overdominance for these characters.

Table 12. Estimates of variance components of general combining ability (σ^2g) specific combining ability (σ^2s) and Rg value

Characters		σ^2s	σ^2g	Rg
Plant height (cm)	E_1	28.29	5.96	0.29
	E_2	7.05	0.54	0.13
Primary branches/plant	E_1	-0.06	0.05	3.24
	E_2	0.14	0.72	0.91
Tap root length (cm)	E_1	NA	NA	NA
	E_2	9.14	3.08	0.40
Primary roots/plant	E_1	NA	NA	NA
	E_2	49.13	30.04	0.28
Days to flower	E_1	0.86	1.10	0.72
	E_2	-1.68	1.61	+2.09
Days to green fruit harvest	E_1	20.95	-4.81	-0.85
	E_2	37.27	0.59	-0.03
Days to fruit ripening	E_1	NA	NA	NA
	E_2	22.17	-1.16	-0.12
Fruit length (cm)	E_1	NA	NA	NA
	E_2	0.32	0.22	0.58
Fruit perimeter (cm)	E_1	NA	NA	NA
	E_2	0.34	0.07	0.30
Fruits/plant	E_1	0.05	38.36	0.49
	E_2	-3.47	32.39	0.53
Green fruit yield/plant(g)	E_1	-75.61	48.05	4.68
	E_2	-56.11	48.61	2.36

E_1 - December 1985 - April 1986

E_2 - August - December 1986

NA - Not available

The Rg values was the highest for fruit yield/ plant (4.68) followed by Primary branches/plant (3.24).

Association between *per se* performance and general combining ability effects.

Correlation between gca effects and *per se* performance of parents for various quantitative characters was calculated (Table 13).

No significant correlations were observed between gca effects and *per se* performance of parents for yield and any of the yield contributing characters. A negative correlation was observed between gca effects and *per se* performance of parents for primary branches/plant (-0.16) and days to first green fruit harvest (-0.20) during E_1 and tap root length during E_2 (-0.74). All others showed a positive correlation.

E. Evaluation of F_1 hybrids for field resistance to bacterial wilt

The 10 F_1 hybrids along with Pant C-1 and KAU Cluster were evaluated for bacterial wilt reaction under field conditions along with the susceptible check Hungarian Wax during December - April 1986 and August-December 1986 (Table 14). KAU Cluster was found resistant to bacterial wilt during both the seasons. During December - April 1986

Table 13. Association between general combining ability effects and per se performance of parents

Characters		r value
Plant height (cm)	E_1	0.17
	E_2	0.32
Primary branches/plant	E_1	-0.16
	E_2	0.07
Taproot length (cm)	E_1	NA
	E_2	-0.74
Primary roots/plant	E_1	NA
	E_2	0.47
Days to flower	E_1	0.42
	E_2	0.52
Days to first green fruit harvest	E_1	-0.20
	E_2	0.29
Days to fruit ripening	E_1	NA
	E_2	0.10
Fruit length (cm)	E_1	NA
	E_2	0.08
Fruit perimeter (cm)	E_1	NA
	E_2	0.06
Fruits/plant	E_1	0.07
	E_2	0.03
Green fruit yield/plant (g)	E_1	0.69
	E_2	0.56

NA - Not available

E_1 - December, 1985 - April 1986

E_2 - August, 1986 - December 1986

Table 14. Bacterial wilt incidence as observed in spot planting

Lines	Wilt incidence during December 1985 - April '86		Wilt incidence during August-December, 1986	
	%	Score	%	Score
KAU Cluster	14.17	R	8.33	R
Pant C-1	83.33	S	51.60	MS
Hungarian Wax x KAU Cluster	95.83	S	53.30	MS
Hungarian Wax x Pant C-1	100.00	S	90.00	S
Sweet Red Cherry Pickling x KAU Cluster	90.00	S	49.80	MS
Sweet Red Cherry Pickling x Pant C-1	100.00	S	100.00	S
Early Calwonder x KAU Cluster	54.54	MS	41.60	MS
Early Calwonder x Pant C-1	87.50	S	83.20	S
Cubanelle x KAU Cluster	91.66	S	85.00	S
Cubanelle x Pant C-1	90.80	S	90.00	S
Yolo Wonder Improved x KAU Cluster	52.50	MS	33.30	MR
Yolo Wonder Improved x Pant C-1	91.66	S	95.00	S

except the lines Early Calwonder x KAU Cluster (54.54%) and Yolo Wonder Improved x KAU Cluster (52.50%), all were highly susceptible to bacterial wilt. During August - December 1986, the line Yolo Wonder Improved x KAU Cluster (33.30%) was moderately resistant to wilt. The lines Pant C-1 (51.6%), Hungarian Wax x KAU Cluster (53.30%), Sweet Red Cherry Pickling x KAU Cluster (49.80%), Early Calwonder x KAU Cluster (41.60%) were moderately susceptible to bacterial wilt. The susceptible check Hungarian Wax showed 100% wilt incidence.

F. Evaluation of a set of clustered bell peppers

F_4 and F_5 generations of Sweet Red Cherry Pickling x KAU Cluster and Hungarian Wax x KAU Cluster were raised during December - April 1986 and August - December 1986 respectively. These were evaluated for variability for yield and its components.

1. F_4 generation

The mean, range, coefficient of variation for five quantitative characters in F_4 generations of Hungarian Wax x KAU Cluster and Sweet Red Cherry Pickling x KAU Cluster are given in Table 15.

The range for plant height was 14.50 cm (HW x KAU) to 38.00 cm (SR x KAU); days to first green fruit harvest

Table 15. Mean, range and coefficient of variation (cv) for yield and its components in F_4 generations of Hungarian Wax x KAU Cluster and Sweet Red Cherry Pickling x KAU Cluster crosses

		Plant height (cm)	Days to first green fruit harvest	Clusters/plant	Fruits/plant	Yield/plant (g)
Mean	HW x KAU	23.42 ± 1.62	83.17 ± 2.42	8.14 ± 1.04	38.75 ± 8.02	146.25 ± 41.56
	SR x KAU	24.95 ± 2.37	97.42 ± 1.18	9.28 ± 1.72	20.57 ± 2.43	137.71 ± 21.85
Range	HW x KAU	14.50 - 33.00	76.00 - 90.00	7.00 - 14.00	17.00 - 59.00	95.00 - 283.00
	SR x KAU	15.50 - 38.00	96.00 - 105.00	2.30 - 14.00	13.00 - 32.00	90.00 - 270.00
cv	HW x KAU	24.95	7.13	33.75	41.39	56.85
	SR x KAU	30.04	3.19	58.76	31.28	41.98

HW x KAU - Hungarian Wax x KAU Cluster

SR x KAU - Swet Red Cherry Pickling x KAU Cluster

76.00 (HW x KAU) to 105.00 (SR x KAU); Clusters/plant 2.30 (SR x KAU) to 24.00 (HW x KAU); fruits/plant 13.00 (SR x KAU) to 59.00 (HW x KAU) and yield/plant 90.00 g (SR x KAU) to 283.00 g (HW x KAU). The highest estimate of coefficient of variation was observed for clusters/plant (58.76) followed by yield/plant (56.85).

2. F_5 generations

2.1 Hungarian Wax x KAU Cluster

Nine selected lines of F_5 generation of the cross Hungarian Wax x KAU Cluster were evaluated (Table 16).

Plant height ranged from 11.00 cm (2-2 and 2-5) to 46.00 cm (4-6). The highest coefficient of variation for plant height was observed in the line 23 (33.88). Days to green fruit harvest ranged from 80 days (4-5) to 110 days (3-1). The coefficient of variation was maximum in the case of 26 (13.98). Considerable variation among the genotypes was observed for clusters/plant. It ranges from 1.00 - 12.00. The cv was highest in the case of 2-5 (67.06). Fruits/plant ranged from 4.00 to 50.00. The highest estimate of cv was observed in the case of 2-2 (66.82).

The yield/plant ranged from 20.00 g (39) to 235.00 g (23). The highest estimate of cv was in 2-5 (73.96). The lowest estimate was observed in 3-1 (42.31).

Table 16. Mean, range and coefficient of variation (cv) for yield and yield contributing characters in F_5 generations of Hungarian Wax x KAU Cluster

Pedigree number		Plant height (cm)	Days to first green fruit harvest	Clusters/plant	Fruits/plant	Yield/plant (g)
1		2	3	4	5	6
	Mean	18.25 ± 1.08	84.33 ± 1.43	5.50 ± 1.09	14.75 ± 1.75	88.25 ± 19.12
1 - 5	Range	15.00 - 21.00	80.00 - 90.00	3.00 - 9.00	9.00 - 18.00	40.00 - 143.00
	cv	11.86	4.15	39.62	23.67	43.22
	Mean	21.42 ± 1.42	77.80 ± 1.49	3.95 ± 0.43	16.53 ± 3.33	93.38 ± 14.84
2 - 2	Range	11.00 - 40.00	69.00 - 85.00	2.00 - 8.00	7.00 - 42.00	41.00 - 223.00
	cv	33.11	7.41	47.56	66.82	63.56
	Mean	19.17 ± 1.06	82.75 ± 0.97	4.00 ± 0.79	9.2 ± 1.73	46.80 ± 9.67
2 - 3	Range	16.00 - 24.00	80.00 - 86.00	1.00 - 6.00	4.00 - 14.00	25.00 - 85.00
	cv	13.53	2.62	0.45	42.04	46.27
	Mean	14.10 ± 0.78	73.80 ± 3.18	2.60 ± 0.78	16.00 ± 6.83	65.00 ± 21.50
2 - 5	Range	11.00 - 17.00	61.00 - 83.00	1.00 - 6.00	6.00 - 46.00	40.00 - 155.00
	cv	13.53	9.63	67.06	6.54	73.96

contd...

Table 16. (contd...)

1		2	3	4	5	6
	Mean	27.09 ± 1.23	87.40 ± 1.74	4.70 ± 0.86	22.00 ± 4.16	106.18 ± 13.54
3 - 1	Range	18.00 - 30.00	83.00 - 110.00	1.00 - 10.00	6.00 - 50.00	41.00 - 181.00
	cv	16.92	6.29	57.91	62.68	42.31
4 - 6	Mean	24.31 ± 1.22	75.10 ± 0.79	4.63 ± 0.31	19.55 ± 1.43	106.74 ± 9.56
	Range	15.00 - 46.00	60.00 - 82.00	1.00 - 9.00	11.00 - 40.00	57.00 - 215.00
	cv	29.66	9.01	39.52	32.73	39.06
	Mean	23.09 ± 1.11	80.64 ± 1.29	5.38 ± 0.29	21.68 ± 1.32	116.24 ± 7.88
23	Range	12.00 - 34.00	64.00 - 88.00	2.00 - 11.00	8.00 - 42.00	55.00 - 235.00
	cv	33.88	9.18	37.71	40.46	45.99
	Mean	17.38 ± 1.08	75.83 ± 4.33	2.63 ± 0.30	17.60 ± 4.02	113.36 ± 31.20
26	Range	13.00 - 22.00	64.00 - 87.00	1.00 - 4.00	6.00 - 28.00	30.00 - 195.00
	cv	17.95	13.98	32.65	50.89	61.38
	Mean	24.26 ± 0.85	84.25 ± 1.55	4.88 ± 0.65	16.58 ± 2.68	85.23 ± 12.74
39	Range	18.00 - 30.00	75.00 - 88.00	2.00 - 12.00	6.00 - 33.00	20.00 - 155.00
	cv	14.45	6.36	53.23	56.05	53.89

2.2 Sweet Red Cherry Pickling x KAU Cluster

The extent of variability present for yield and its components were measured in terms of range, mean and coefficient of variation. The results obtained are presented in Table 17.

Plant height ranged from 12.5 cm to 53 cm with a general mean of 20 cm (11-2), 18.68 cm (II-8), 16.40 cm (III-6), 22.05 cm (III-7), 18.5 cm (1), 32.64 cm (2), 26.91 cm (27) and 30.64 cm (28).

Days to first green fruit harvest ranged from 75.00 (II-2) to 99.00 (III-6). The highest estimate of cv was observed in 28 (5.57). Clusters/plant ranged from 1.00 - 15.00. The estimate of cv was highest in the case of II-2 (74.71). Considerable variation among the genotypes were observed for fruits/plant. The range for fruits/plant was 6.00 to 70.00. Highest cv for this character was observed in II-2 (47.02). The yield of green fruit/plant ranged from 40.00 g to 372.00 g. The highest cv was observed in 2 (53.74).

Considerable variability for fruit clusters/plant was observed in F_5 generations of Hungarian Wax x KAU Cluster and Sweet Red Cherry Pickling x KAU Cluster. The frequency distribution of clustered plants are appended (Appendix I & II).

Table 17. Mean, range and coefficient of variation (cv) for yield and its components in F_5 generations of Sweet Red Cherry Pickling x KAU Cluster

Pedigree number		Plant height (cm)	Days to first green fruit harvest	Clusters/ Plant	Fruits/Plant	Yield/Plant (g)
1		2	3	4	5	6
	Mean	20.00 ± 1.18	80.80 ± 0.86	3.90 ± 0.92	14.09 ± 1.99	83.00 ± 10.89
IL-2	Range	16.00 - 30.00	75.00 - 83.00	1.00 - 12.00	6.00 - 28.00	45.00 - 163.00
	cv	19.54	3.40	74.71	47.02	47.30
	Mean	18.68 ± 0.75	82.10 ± 0.41	3.50 ± 0.49	11.72 ± 1.03	69.64 ± 5.47
IL-8	Range	12.50 - 21.00	79.00 - 83.00	1.00 - 8.00	6.00 - 15.00	45.00 - 94.00
	cv	15.03	1.58	52.62	29.11	26.04
	Mean	16.40 ± 5.95	92.40 ± 2.15	5.40 ± 0.66	20.20 ± 1.87	105.40 ± 9.42
IIL-6	Range	25.00 - 35.00	84.00 - 99.00	4.00 - 6.00	14.00 - 27.00	80.00 - 140.00
	cv	81.11	5.19	27.71	20.63	19.98
	Mean	22.05 ± 1.30	80.30 ± 0.59	2.36 ± 0.39	16.14 ± 2.21	92.13 ± 15.44
IIL-7	Range	18.00 - 28.00	78.00 - 83.00	1.00 - 6.00	8.00 - 29.00	55.00 - 197.00
	cv	18.68	2.69	54.93	38.78	47.41

contd...

Table 17. (contd...)

1	2	3	4	5	6
1	Mean	18.50 ± 1.33	79.00 ± 1.46	3.80 ± 0.72	14.25 ± 1.75	110.75 ± 15.01
	Range	15.00 - 24.00	77.00 - 84.00	2.00 - 6.00	10.00 - 19.00	85.00 - 160.00
	cv	16.03	3.69	42.11	24.49	27.11
2	Mean	32.64 ± 2.23	84.00 ± 0.68	5.57 ± 0.58	13.00 ± 1.68	69.58 ± 10.79
	Range	23.00 - 46.00	81.00 - 84.00	1.00 - 9.00	7.00 - 25.00	40.00 - 145.00
	cv	25.54	3.03	38.80	40.70	53.74
27	Mean	26.91 + 1.73	87.45 ± 0.47	4.94 ± 0.68	29.62 ± 3.45	179.16 ± 21.36
	Range	15.50 - 41.00	86.00 - 89.00	1.00 - 13.00	6.00 - 55.00	50.00 - 300.00
	cv	26.49	1.78	58.62	42.07	41.31
28	Mean	30.64 ± 2.57	83.92 ± 1.35	8.08 ± 1.15	47.80 ± 4.88	346.70 ± 28.31
	Range	26.00 - 53.00	77.00 - 88.00	3.00 - 15.00	18.00 - 70.00	103.00 - 372.00
	cv	31.41	5.57	51.50	32.26	25.81

Mean, medium and variance for clusterness in F_5 generation of Hungarian Wax x KAU Cluster and Sweet Red Cherry Pickling x KAU Cluster are given in Table 18. Hungarian Wax x KAU Cluster has a mean of 4.29 with medium 6.50 and variance 11.13. Sweet Red Cherry Pickling x KAU Cluster has a mean value of 4.49, a median 8.00 and variance 17.50.

Evaluation for wilt resistance

Selected clustered bell pepper lines were evaluated under field condition for resistance to bacterial wilt. The lowest percentage of wilt was observed in II-1 of F_5 generation of Hungarian Wax x KAU Cluster (21.43%) and was moderately resistant (Table 19). I-5, II-2, II-5, II-6, 23 and 26 were also recorded as moderately resistant. F_4 generation of Sweet Red Cherry Pickling x KAU Cluster was susceptible to wilt. The description of the selected clustered bell peppers is appended in Appendix III.

G. Association between root characters and fruit yield, primary branches/plant and plant height

Significant positive correlation was observed between primary roots/plant and fruit yield (0.65). Correlation (r) between primary roots/plant and plant height and primary branches/plant; root length and yield/plant, plant height and primary branches/plant were not significant (Table 20).

Table 18. Mean, median and variance for clusterness in F_5 generation of Hungarian Wax x KAU Cluster and Sweet Red Cherry Pickling x KAU Cluster

	Mean	Median	Variance
Hungarian Wax x KAU Cluster	4.29 ± 0.84	6.50	11.13
Sweet Red Cherry Pickling x KAU Cluster	4.49 ± 1.12	8.00	17.50

Table 19. Bacterial wilt incidence in F_4 and F_5 generations of Hungarian Wax x KAU Cluster and Sweet Red Cherry Pickling x KAU Cluster

Pedigree	Wilt incidence	
	%	Score
F_4		
Hungarian Wax x KAU Cluster	60.00	MS
Sweet Red Cherry Pickling x KAU Cluster	65.71	S
F_5		
Sweet Red Cherry Pickling x KAU Cluster		
II-2	43.00	MS
II-8	48.00	MS
III-7	23.38	MR
III-6	26.60	MR
1	26.80	MR
2	53.33	MS
28	56.36	MS
27	55.71	MS
Hungarian Wax x KAU Cluster		
I-5	28.57	MR
II-1	21.43	MR
II-2	34.28	MR
II-5	35.71	MR
III-1	40.00	MS
IV-6	22.50	MR
23	38.33	MR
26	30.00	MR
39	45.45	MS

Table 20. Correlation between root characters and plant height, primary branches/plant and fruit yield

Characters	Tap root length	Primary roots/ plant
Fruit yield	0.23	0.65**
Plant height	0.14	0.41
Primary branches/plant	-0.08	-0.10

** p = 0.01

Discussion

DISCUSSION

Bell peppers (*Capsicum annuum* L. var. *grossum* Sendt.) are important fruit vegetables used in many forms of cookery. Being a newly introduced crop to Kerala, a few relevant information are only available on the suitability of this crop to the warm humid tropical climate of the State. It grows well in a relatively cool climate and is suited for growing in hills during summer months (Hosmani, 1982). Dry weather is necessary during fruit maturity of the crop. The maximum set of peppers occur at a temperature of 11°C - 18°C (Cochran, 1936). High day temperature (20-24°C) and low light intensity (30% shade) enhance flower drop (Rylski and Halevy 1974). The ideal soil pH is 6.0 to 6.5. The above requirements of bell peppers make it a difficult crop to be grown under the warm humid tropical conditions of Kerala. September-February months would be the possible growing season for the crop. Many of the bell peppers are susceptible to bacterial wilt. Unlike bell peppers, hot chillies are grown throughout the year in Kerala. The hot chillies set fruits at a high temperature of 35°C to 37°C. The varieties KAU Cluster and Pant C-1 are grown under high temperature and high humid conditions. Peter *et al*. (1984) reported resistance in KAU Cluster and Pant C-1 against *Pseudomonas solanacearum* E.F. Smith. Wilt resistance in KAU Cluster was again confirmed

by Pious (1985). KAU Cluster and Pant C-1 as sources of resistance to bacterial wilt can be exploited in growing bell peppers under the warm humid conditions of Kerala. Any attempt on heterosis breeding in bell peppers making use of the adaptable local lines like KAU Cluster and Pant C-1 would be largely welcomed.

Success of any breeding programme depends primarily on the extent of variability in the base population. Evaluation and estimation of genetic variability, heritability and expected genetic advance are pre-requisites for any crop improvement programme. In the present investigation, the contribution of genotype to the phenotypic expression of different characters was studied. The extent of genetic variability was estimated in a set of two chilli lines, five capsicum lines and 10 capsicum x chilli F_1 crosses.

Phenotypic coefficient of variation (pcv) was maximum for fruits/plant (61.14 and 57.04 during E_1 and E_2 respectively) followed by primary branches/plant. The high estimate of phenotypic coefficient of variation (pcv) for fruits/plant was earlier reported by Hiremath and Mathapati (1977), Kshirsagar et al. (1983) and Gopalakrishnan (1985). The lowest pcv was recorded for days to fruit ripening (7.23 in E_1 and 6.12 in E_2). Singh and Singh (1977), Ramalingam (1979) and Gopalakrishnan (1985) also observed a low estimate

of phenotypic variation for days to red chilli harvest. High heritability was observed for primary branches/plant, plant height, days to flower, days to first green fruit harvest, fruits/plant and green fruit yield/plant.

Heritability values give an indication of the effectiveness of selection on the basis of phenotypic performance. Heritability along with estimates of expected genetic advance should be considered more than heritability per se while making selections. Higher heritability coupled with high estimates of expected genetic advance for plant height, days to flower, days to green fruit harvest, fruits/plant and fruit yield/plant reveal the involvement of additive gene action. Similar observations were also made by Kshirsagar et al. (1983) and Arya and Saini (1976). Moderately high estimate of heritability and expected genetic advance was observed for primary roots/plant and days to fruit ripening. High estimate of heritability and expected genetic advance for these characters indicated that they could be improved through appropriate selection methods. Fruit length and fruit perimeter had a low heritability and a low expected genetic advance. This shows the impact of environment on fruit perimeter. The high influence of environment on fruit perimeter was earlier reported by Singh and Singh (1970) and Vadivel et al. (1983). Primary branches/plant has high heritability value but the expected

genetic advance was low. This indicates the involvement of non-additive gene action for this character. This was substantiated by the reports of Awasthi et al. (1976).

Heterosis breeding was extensively explored and utilised for boosting up yield in a number of economically important crops. The prevalence of heterosis has practical implication only if heterosis is explored on a rather extensive scale and highly heterotic crosses were easily and quickly separated out. Information on genetic divergence of the materials and combining ability would facilitate the choice of parents for hybridization and in isolating promising F_1 hybrids for further exploitation. The line x tester analysis helps to determine both general (gca) and specific (sca) combining ability of parents and hybrids respectively. General and specific combining ability could be attributed to additive and non-additive type of gene actions respectively (Sprague and Tatum, 1942).

A comparison of parents Vs hybrids (Table 9) revealed highly significant differences between parents and hybrids for all the characters. This could be expected because the lines and testers were genetically divergent and placed under separate clusters. The varietal association in different clusters was slightly disturbed with changes in seasons. There was shifting of varieties from one cluster to another. It is likely, because these estimates are

obtained from quantitative characters which are affected by genotype x environment interactions. Eventhough a positive correlation was observed between the genetic distance of parents and F_1 performance for yield it was not significant. This may be due to the fact that only a lower number of genotypes (6) were taken for the estimation.

Combining ability analysis revealed the importance of non-additive gene action as indicated by high σ^2 sca for all characters except primary branches/plant, days to flower, fruits/plant and green fruit yield/plant. High σ^2 gca along with high Rg value for the above four characters indicated involvement of additive gene action for the control of these characters. Preponderance of additive gene action for these characters was observed by Lippert (1975), Milkova (1979) and Gopalakrishnan (1985). Since there was preponderance of additive gene action for the above characters, significant advancement could be achieved in the segregating generations using simple selection procedures. Comparatively equal values of variance due to both gca and sca for fruit length indicated the role of both additive and non-additive gene action for the control of the above character. Recurrent selection could be used for improvement of such characters. Milkova (1977, 1979) observed additive and non-additive gene action for fruit length.

The F_1 hybrids were better in yield and earlier to flower compared to the common parents KAU Cluster and Pant C-1.

The phenomenon of heterosis is conspicuously evident in the hybrids developed in the study (Tables 22 and 23). Out of 10 hybrids, Sweet Red Cherry Pickling x Pant C-1 was the tallest (64.11 cm) and had significant relative heterosis (26.24%) and heterobeltiosis (24.53%). This hybrid resulted from a cross between two good general combiners. The sca effect of the above cross in which two good general combiners involved was only 2.16. This indicated that hybrids with high per se performance may not necessarily have a high sca effect. Primary branches/plant was maximum in Cubanelle x Pant C-1 (8.13) exhibiting a significant heterobeltiosis (31.34%) and relative heterosis (40.29%). But the sca effect was maximum in Sweet Red Cherry Pickling x KAU Cluster (0.16 and 0.53 respectively during E_1 and E_2). The per se performance of this hybrid was lower which may be ascribed to the involvement of a poor combiner. Out of 10 hybrids, four showed relative heterosis and seven showed heterobeltiosis for tap root length. The hybrid Yolo Wonder Improved x KAU Cluster had the maximum tap root length (18.94 cm). Popova and Mihailov(1975, 1976) reported heterosis for root length. Four hybrids showed heterobeltiosis and relative heterosis for primary roots/plant. Hungarian Wax x KAU Cluster had the maximum primary roots/plant, and had the highest relative heterosis (65.07). The above hybrid had high sca effect (7.99) and its parents were good general combiners.

Table 21. Number of F_1 hybrids exhibiting desirable heterosis over Pant C-1 and KAU Cluster during December, 1985 - April 1986

	Economic characters		
	Days to harvest	Fruits/plant	Green fruit yield/plant
Number of F_1 hybrids with desirable heterosis	9 (9)	NIL	10 (10)
Name of the most outstanding hybrid	Cubanelle x KAU Cluster	-	Hungarian Wax x KAU Cluster
	(Cubanelle x KAU Cluster)	-	(Hungarian Wax x KAU Cluster)

Figures in parenthesis indicates hybrids exhibiting desirable heterosis over KAU Cluster

Table 22. Number of F_1 hybrids exhibiting desirable heterosis over Pant C-1 and KAU Cluster during August - December 1986

	Economic Characters		
	Days to harvest	Fruit/plant	Green fruit yield/plant
Number of F_1 hybrids with desirable heterosis	10 (10)	NIL	10 (10)
Name of the most outstanding hybrid	Sweet Red Cherry Pickling x KAU Cluster (Sweet Red Cherry Pickling x KAU Cluster)	-	Hungarian Wax x KAU Cluster (Hungarian Wax x KAU Cluster)

Figures in parenthesis indicates hybrids exhibiting desirable heterosis over KAU Cluster

All the hybrids were earlier than the common parents KAU Cluster and Pant C-1 for days to green fruit harvest. Yolo Wonder Improved x Pant C-1 was the earliest among all the hybrids. The hybrid Cubanelle x KAU Cluster had maximum negative value of sca effect (-5.70) and heterobeltiosis. The per se performance of this hybrid was lower which may be ascribed to the involvement of two poor combiners in the cross. Out of 10 hybrids, three showed significant negative heterobeltiosis and five exhibited significant relative heterosis. Fruit perimeter was maximum in the case of Early Calwonder x Pant C-1 (7.12 cm). This hybrid had the maximum sca effect.

Hungarian Wax x KAU Cluster produced maximum fruits/plant (76 and 92 during E_1 and E_2 respectively) which may be due to the involvement of two good general combiners. Varying extent of heterosis for fruits/plant was observed by Pandey et al. (1981), Murthy and Lakshmi (1983), Gopalakrishnan (1985). All hybrids exceeded the mid-parent for fruit yield/plant. Hungarian Wax x KAU Cluster yielded the maximum (400.5 g/plant in E_1 and 482.8 g/plant in E_2) (Fig.3). The high yield in above cross is resulted from increase in the number and size of fruits/plant. This hybrid had relative heterosis of 79.39% in E_1 and 68.19% in E_2. Taking into account per se performance (425.4 gm/plant) and heterosis, Sweet Red Cherry Pickling x KAU Cluster was the second best combination (Fig.4). During December'85 - April'86

period Hungarian Wax x Pant C-1 was the second best combination (415.87 g/plant) (Fig.5). In the above heterotic hybrids the patents belonged to different clusters. Varying extent of heterosis for yield was earlier reported by Pandey et al. (1981). Murthy and Lakshmi (1983), Gopalakrishnan (1985), Pious (1985).

The performance of all the hybrids were better during August - December '86 compared to December '85 to April '86 period. This is due to the favourable environmental condition prevailing during August to December '86. All the F_1 hybrids were solitary fruited and were pungent.

Commercial cultivars of chillies and capsicums are solitary fruited. The solitary bearing habit limits mechanical harvesting and makes harvesting process labour intensive. Nearly 20 per cent of the cost of cultivation of chilli is for harvesting of fruits alone. The concept of clustered bell peppers assumes importance in this context. Attempts are made at Kerala Agricultural University to develop clustered bell pepper lines, adapted to Kerala conditions. Pious (1985) developed a set of clustered bell peppers by crossing bell peppers like Hungarian Wax, Sweet Red Cherry Pickling with hot chilli - KAU Cluster. These lines needed continuous evaluation. The present investigation was mainly undertaken to study the variability present in the segregating populations of clustered bell

peppers and to select elite plants. Considerable variations was observed in the population for all the characters studied. There is scope for further selection. Clustered bell peppers with desirable characters were identified and progressed (Fig. 6 to 9).

Evaluation for wilt resistance showed that the line KAU Cluster (Fig.10) was resistant to wilt confirming the earlier reports of Peter et al. (1984) and Pious (1985). During December - April period all F_1 hybrids except Early Calwonder x KAU Cluster and Yolo Wonder Improved x KAU Cluster were susceptible to wilt. These two hybrids were moderately susceptible. During August - December period Yolo Wonder Improved x KAU Cluster was moderately resistant to wilt. Evaluation of segregating generations of Hungarian Wax x KAU Cluster and Sweet Red Cherry Pickling x KAU Cluster for wilt resistance showed that out of 19 lines 10 were moderately resistant to wilt. Others were either susceptible or moderately susceptible to wilt. The line Pant C-1 was found susceptible to wilt under Vellanikkara conditions.

The present investigation was mainly under taken to make the bell peppers adaptable to warm humid tropical climatic conditions of Kerala by using adaptable local lines. As per the earlier reports pronounced heterosis

was found for different quantitative characters. Hungarian Wax x KAU Cluster was found to be the most promising hybrid, followed by Sweet Red Cherry Pickling x KAU Cluster . These promising hybrid combinations can be used further for selecting desirable segregants in subsequent generations. Evaluation of clustered bell peppers resulted in selection of elite plants and these selected clustered plants were progressed for further evaluation. The development of clustered bell peppers dwarfer in stature and adaptabile to warm humid conditions carrying resistance to bacterial wilt is a longterm breeding objective. A part of the present work aimed at progression of the above lines and identifying such elite plants. To this limited objective, substantial progress has been made.

Fig. 3. F_1 hybrid, Hungarian Wax x KAU Cluster

Fig. 4. F_1 hybrid, Sweet Red Cherry Pickling x KAU Cluster


672-HW X KAU-C

Fig. 5. F_1 hybrids, Hungarian Wax x Pant C-1

Fig. 6. Hungarian Wax x KAU Cluster I-5-3

Fig.7. Hungarian Wax x KAU Cluster I-5-4

Fig.8. Hungarian Wax x KAU Cluster 23-24

Fig.9. Hungarian Wax x KAU Cluster 23-20

Fig.10. Spot planting with the suscept wilted

Summary

SUMMARY

The present studies were conducted at the College of Horticulture, Kerala Agricultural University, Vellanikkara during July to December 1985-86. The materials for the study comprised of five lines of bell pepper, two lines of hot chillies and their F_1 hybrids. The magnitude of variability in the materials was assessed. The F_1 heterosis in intervarietal crosses was estimated for exploitation of hybrid vigour. Line x tester analysis was done to estimate the combining ability effects. The F_1 hybrids along with hot chillies were evaluated for wilt resistance by spot planting. A set of clustered bell peppers was evaluated for yield and its components. The association between root characters tap root length and primary roots/plant with yield was also observed.

The genotypes differed significantly for plant height, primary branches/plant, tap root length, primary roots/plant, days to flower, days to green fruit harvest, days to fruit ripening, fruit length, fruit perimeter, fruits/plant and green fruit yield/plant. Phenotypic coefficient of variation was maximum for fruits/plant (61.14 and 57.04 respectively in E_1 and E_2). High heritability coupled with high magnitude of genetic advance was observed for fruits/plant. Plant height, days to fruit ripening, fruit length and fruit perimeter having moderately

high heritability had only a low expected genetic advance. The parental genotypes were classified into three and four clusters during first and second seasons respectively.

All hybrids except two showed significant positive heterobeltiosis for plant height during August - December 1986. The tallest hybrid was Sweet Red Cherry Pickling x KAU Cluster (58.6 cm). All hybrids showed negative heterobeltiosis for primary branches/plant. Maximum number of primary branches was observed in Cubanelle x KAU Cluster (8.11) and Cubanelle x Pant C-1 (8.13) during first and second seasons, respectively. Out of 10 hybrids, four showed positive heterosis for primary roots/plant. Primary roots/plant was maximum in Hungarian Wax x KAU Cluster (109.54). All the hybrids were earlier than the common parents KAU Cluster and Pant C-1. Among the hybrids, fruit length was maximum in Hungarian Wax x Pant C-1. Out of 10 hybrids, six showed positively significant heterobeltiosis for fruit perimeter. The F_1 hybrids did not show positive heterosis over the common parents KAU Cluster and Pant C-1 for fruits/plant. All the F_1 hybrids exceeded the bell pepper parents for fruits/plant. Hungarian Wax x KAU Cluster had maximum fruits/plant (91.78). Taking into consideration per se performance and heterosis, Hungarian Wax x KAU Cluster was the best hybrid yielding 400.5 g/plant and 482.5 g/plant respectively during first and second seasons. No clear cut

relationship could be established between the extent of genetic distance between the parents and the performances of the F_1 hybrid combinations.

Combining ability analysis revealed the presence of non-additive gene action for all characters studied except primary branches/plant, days to flower, fruits/plant and green fruit yield/plant. A preponderance of additive gene action was observed for the above characters.

The spot planting of susceptible with lines under evaluation indicated that only the line KAU Cluster was resistant to bacterial wilt.

In segregating generations of Hungarian Wax x KAU Cluster and Sweet Red Cherry Pickling x KAU Cluster considerable variation was observed for all the characters studied. In F_4 generation coefficient of variation was maximum in Hungarian Wax x KAU Cluster for yield/plant (56.85). In F_5 generation it was for Hungarian Wax x KAU Cluster 2-5 (73.96) followed by Hungarian Wax x KAU Cluster 2-2 (63.56). There was no line which was resistant to wilt.

A significant positive correlation was observed between fruit yield/plant and primary roots/plant.

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Appendices

Appendix - I. Frequency distribution of clustered plants in F_5 generation of Hungarian Wax x KAU Cluster

Classes	Frequency	Percentage of plants
1.0 - 2.0	20	12.57
2.0 - 3.0	31	19.49
3.0 - 4.0	29	18.24
4.0 - 5.0	31	19.49
5.0 - 6.0	19	11.95
6.0 - 7.0	11	6.92
7.0 - 8.0	6	3.77
8.0 - 9.0	6	3.77
9.0 - 10.0	3	1.89
10.0 - 11.0	2	1.26
11.0 - 12.0	1	0.63

Appendix - II. Frequency distribution of clustered plants in F_5 generations of Sweet Red Cherry Pickling x KAU Cluster

Classes	Frequency	Percentage of plants
1.0 - 2.0	22	24.72
2.0 - 3.0	12	13.48
3.0 - 4.0	16	17.98
4.0 - 5.0	15	16.85
5.0 - 6.0	6	6.74
6.0 - 7.0	0	0
7.0 - 8.0	5	5.62
8.0 - 9.0	3	3.37
9.0 - 10.0	3	3.37
10.0 - 11.0	0	0
11.0 - 12.0	2	2.25
12.0 - 13.0	3	3.37
13.0 - 14.0	1	1.12
14.0 - 15.0	1	1.12
Total	89	

Appendix - III. Description of the selected clustered lines

Pedigree	Number	Plant height (cm)	Clusters/ plant	Fruits/ Cluster	Fruits/ Plant	Fruit yield/ plant (g)	Fruit orient-ation	Cluster group
1	2	3	4	5	6	7	8	9
Hungarian Wax x KAU Cluster								
IV-6	4	20	5	3.0	15	98	erect	OS
	5	25	9	2.1	14	62	erect	OS
	24	30	8	2.5	30	115	erect	TC
	28	22	6	2.8	10	53	erect	OS
	29	18	5	3.0	20	112	erect	OS
	39	15	3	2.0	18	103	erect	OS
I-5	3	18	5	4.5	15	85	erect	TC
	4	19	5	4.0	17	105.5	erect	TC
	5	15	3	5.0	18	90	erect	TC
	12	21	4	2.0	11	50	erect	TC

contd...

Appendix-III (contd...)

1	2	3	4	5	6	7	8	9
Hungarian Wax x KAU Cluster								
IL-2	1	24	3	1.3	10	60	erect7	OS
	2	29	3	3.0	12	62	erect	TC
	7	26	3	3.5	34	115	erect	OS
	9	18	7	3.2	29	169	erect	OC
	11	15	6	2.0	13	55	erect	-
	15	19	4	2.5	26	125	erect	OC
	18	30	6	3.0	11	65	erect	OS
III-1	4	21	7	2.5	24	120	erect	OS
	44	27	7	2.0	20	121	erect	OC
	50	28	4	2.5	30	151	erect	OC
III-5	17	27	6	3.2	12	80	erect	OS
23	11	18	3	2.0	36	119	erect	OS
	20	20	8	2.4	38	210	erect	OS
	24	23	5	4.0	22	125	erect	OS
	39	22	4	2.8	23	158	erect	OS
	47	30	9	2.3	38	131	erect	OC
	48	24	6	2.9	23	166	erect	OC
	74	21	4	2.5	19	108.5	erect	OS
	79	32	5	2.5	30	195	erect	OC
	83	17	8	2.0	20	80	erect	TC
	88	22	4	2.0	8	49.5	erect	OS
	93	30	7	2.7	13	80. 8	erect	OS

contd...

Appendix-III (contd...)

1	2	3	4	5	6	7	8	9
Hungarian Wax x KAU Cluster								
III-23	103	25	7	-	20	150	erect	OC
	107	27	3	-	12	63	erect	OS
	115	26	12	2.0	26	165	erect	OC
Sweet Red Cherry Pickling x KAU Cluster	4	24	3	2.0	12	105	drooping	OS
II-2	15	19	4	2.5	26	145	drooping	OS
II-8	10							
III-6	1	30	4	-	20	105	drooping	OS
	2	35	6	-	21	114	drooping	OC
11	6	35	5	2.0	8	50	drooping	OS
	14	24	5	4.0	12	61	drooping	OS
27	8	30	8	3.0	37	183	drooping	OC
28	3	30	4	2.0	32	140	drooping	OC
	11	31	14	2.0	46	201	drooping	OC
	13	39	15	2.5	68	241	drooping	OC
	22	30	13	2.5	70	272	drooping	OC
	23	29	14	3	38	115	drooping	OS
	34	28	6	2.0	18	103	drooping	OC
	35	33	59	3.8	55	28	drooping	OC
	46	26	10	2.4	42	242	drooping	OC

TC - True Clustered OS - Occasional Solitary OC - Occasional Clustered

INTERVARIETAL HETEROSIS IN *Capsicum annuum* L. AND EVALUATION OF A SET OF CLUSTERED BELL PEPPERS

By

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ABSTRACT OF THESIS

submitted in partial fulfilment of
the requirement for the degree

Master of Science in Horticulture

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Vellanikkara - Trichur

1987

ABSTRACT

The present studies 'Intervarietal heterosis in *Capsicum annuum* L. and evaluation of a set of clustered bell peppers' were conducted at the College of Horticulture, Kerala Agricultural University, Vellanikkara during July 1985 - December 1986. The materials for the study comprised of five bell pepper varieties, two hot chillies and their 10 F_1 hybrids. Evaluation of these materials revealed considerable variation for most of the economic characters. Phenotypic coefficient of variation was maximum for fruits/plant. High heritability coupled with high genetic advance was also observed for fruits/plant.

The F_1 hybrids involving bell peppers and hot chillies were found suitable for warm humid tropical conditions of Kerala. All the F_1 hybrids yielded more than the better parent. The F_1 hybrids showed desirable heterosis for plant height, primary branches/plant, tap root length, primary roots/plant, days to flower, days to green fruit harvest, days to fruit ripening, fruit length, fruit perimeter and green fruit yield/plant. The F_1 hybrid Hungarian Wax x KAU Cluster was the most promising yielding 482.8 g/plant (fruits/plant - 92) followed by Sweet Red Cherry Pickling x KAU Cluster and Hungarian Wax x Pant C-1.

Combining ability analysis revealed the preponderance of additive gene action for primary branches/plant, days to flower, fruits/plant and green fruit yield/plant. A preponderance of non-additive gene action was observed for plant height, tap root length, primary roots/plant and days to green fruit harvest, days to fruit ripening and fruit perimeter. Preponderance of additive and non-additive gene action was observed for fruit length.

The parental lines were grouped into three and four clusters during first and second seasons respectively, based on Mahalanobis D^2 statistics.

The line KAU Cluster was found resistant to bacterial wilt. Primary roots/plant was positively correlated with yield. In segregating generations of Hungarian Wax x KAU Cluster and Sweet Red Cherry Pickling x KAU Cluster considerable variation was observed for all the characters studied. Elite clustered bell pepper lines were identified and progressed.