TRANSFER OF CLUSTERNESS TO BELL PEPPERS

[Capsicum annuum L. var. grossum Sendt.]

By

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THESIS

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To my Parents

DECLARATION

I hereby declare that this thesis entitled 'Transfer of clusterness to bell peppers (Capsicum annuum L. var. grossum Sendt.)' 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.

PIOUS THOMAS

VELLANIKKARA,

14-5-1985

CERTIFICATE

Certified that this thesis entitled 'Transfer of clusterness to bell peppers (*Capsicum annuum* L. var. *grossum* Sendt.)' is a record of research work done independently by Sri. Picus Thomas under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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We, the undersigned members of the Advisory Committee of Sri. Pious Thomas, a candidate for the degree of Master of Science in Horticulture agree that the thesis entitled 'Transfer of clusterness to bell peppers (*Capsicum annuum* L. var. *grossum* Sendt.)' may be submitted by Sri. Pious Thomas in partial fulfilment of the requirement for the degree.

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INTRODUCTION

Capsicums, peppers, or chillies (Capsicum annuum L.) are all members of the family Solanaceae with South American Centre of origin. Introduced to India by the Portuguese from West Indies and grown in Bombay as early as 1779 (Watt, 1889), chilli became a commercial crop of India. Chillies are rich sources of vitamins A, B, C and D and minerals calcium, phosphorus and iron. The hot forms are the sources of a digestive stimulant capsaicin. The intake of hot chilli per meal is generally low, while bell peppers are consumed in much larger quantity and so the latter has potential for nutritional improvement.

Bell pepper (Capsicum annuum L. var. grossum Sendt.) is a recently introduced crop to Kerala. It is treated generally as a sub-tropical vegetable due to its specific low temperature requirement for fruit set. Most of the available varieties are low temperature sensitive and suited only for September - October transplanting. No systematic work has been undertaken to select or breed type(s) suited to the warm humid tropical climate of Kerala.

Heterosis was reported for many economically important characters in hot and bell peppers. It can boost up the pepper yield, low at present. More seeds/fruit, higher natural out-crossing (Murthy and Murthy, 1962 b) and prominent role of

dominance are favourable factors for hybrid chilli production. The disadvantages with F_1 hybrids are high cost of F_1 seeds and the need for fresh seeds each time. It would be desirable, if the hybrids retain a good amount of vigour in the F_2 and the plants are homogeneous especially for fruit characteristics, so that the F_2 seeds could be profitably utilised.

The solitary bearing habit of bell peppers is a limiting factor in the total productivity mainly due to higher cost involved in manual harvesting. Transferring the cluster bearing habit to bell peppers might also result in determinate plant habit, more uniform fruit set, uniform plant type, shape, flowering and maturity, making mechanical harvesting possible (Subramanya, 1983). This character has potential for increased yield. At equal plant densities, cluster varieties yield lesser than normal types, but due to the compact form they can be planted at lesser spacings, resulting in higher yield per unit of land. Attempts to transfer cluster bearing character were made elsewhere, but with limited success. The availability of cluster fruiting habit in a closely related botanical variety, Capsicum annuum var. fasciculatum with multiple disease resistance and wide adaptability (Peter et al., 1984) opened new vistas in this direction.

Wilt, caused by Pseudomonas solanacearum E.F. Smith is a wide spread disease of chilli, especially in the acidic

soils, seriously hampering the cultivation of the crop in Kerala. It is necessary to evolve resistant varieties to wilt.

The present studies were undertaken with the following objectives.

1. Testing adaptability of selected bell pepper lines and F_1 hybrids involving bell peppers and hot chilli in the warm humid tropical climate of Kerala
2. Estimation of F_1 heterosis in intervarietal crosses involving bell peppers and hot chilli
3. Estimation of F_2 heterosis in intervarietal crosses
4. Studying the genetics of cluster bearing habit in intervarietal crosses involving Capsicum annuum var. grossum and Capsicum annuum var. fasciculatum
5. Identification of elite cluster bell peppers for further trials and
6. Assessing the extent of damage caused by bacterial wilt and selecting resistant line(s), if any.

REVIEW OF LITERATURE

A. Adaptability of bell peppers

Bell pepper being a newly introduced crop to Kerala, a few relevant information are only available on the suitability of this crop to the humid tropical climate of the state. The hot peppers are grown both under tropical and sub-tropical conditions. Bell peppers grow well in a relatively cool climate. They are suited for growing in hills during summer (Thomas and Nair, 1961; Singh, 1963; Singh, 1976; Hosmani, 1982).

Joshi and Singh (1975) describe the cultivation requirements of bell peppers. They grow well in warm and humid climate but dry weather is equally necessary during fruit maturity. Good seed germination occurs at soil temperatures of 4°C - 15°C. Low humidity and high temperature at flowering and fruiting cause flower and immature fruit shedding. According to Cochran (1936), air temperature at the time of bloom affects fruit set. The maximum set of bell peppers occured at constant temperatures of 11°C - 18°C, with temperatures below 11°C and above 32°C, preventing fruit set. Rylski and Halevy (1974) reported pronounced effect of temperature on fruit set, fruit shape and fruit size in California Wonder. Low night temperature increased the percentage of fruit set and parthenocarpic fruit development.

High day temperature (20-24°C) and low light intensity (30% shade), mainly at early stages of flower development, promoted flower drop. High temperature during later stages 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 even for a short period is harmful. The ideal soil pH is 6-6.5 (Joshi and Singh, 1975) or 5.5-7 (Swarup, 1974). Parasitic and non-parasitic diseases and pests cause serious limits to bell pepper cultivation in the warm humid regions. The parasitic diseases include anthracnose, leaf spot, bacterial wilt, fruit rot, powdery mildew, damping-off, leaf curl and mosaic. Blossom end rot and sunscald are the important non-parasitic diseases. The main damaging insects are the thrips and pepper maggot (Joshi and Singh, 1975).

According to Joshi and Singh (1975), a good crop yields 100-120 q/ha. Under the All India Co-ordinated Vegetable Improvement Project (AICVIP, 1978-'79, 1979-'80), observational trials were conducted on bell peppers at various centres (Table 1). At Katrain centre (Himachal Pradesh) four varieties were raised during April, 1978. Katrain Hybrid I recorded the maximum yield (152.56 q/ha) followed by Bharat F_1 Hybrid (130.64 q/ha), Katrain Hybrid II (122.43 q/ha) and California Wonder (82.8 q/ha).

Table 1. Performance of bell peppers in multilocational trials

Centre	Year	Varieties	Yield(q/ha)
Solan	1977-'78 &	Katrain Hybrid I	113.55
	1979-'80	Chinese Giant	98.55
		Katrain Hybrid II	85.77
		Vindale	84.72
		California Wonder	68.33
		Bharat F_1 Hybrid	63.66
Srinagar	1978-'79	Bullnose	114.76
		Bharat F_1 Hybrid	99.91
		California Wonder	88.30
		Katrain Hybrid II	70.38
		Selection 6	70.31
Hessarghata	1978-'79	Selection 13	147.72
		Selection 16	132.53
		Katrain Hybrid I	125.42
		Bharat F_1 Hybrid	117.11
		California Wonder	113.84
Almora	1977-'78 &	Katrain Hybrid I	123.80
	1978-'79	Katrain Hybrid II	110.25

In Dharwar District of Karnataka, the main bell pepper growing belt of the state, a varietal evaluation, comprising of 22 genotypes was conducted during January to April, 1980 (Veerappa et al., 1981). The genotypes differed significantly for days to flower, plant height, mean fruit weight and yield/plant. Chinese Giant, World Beater, and California Wonder yielded 286.1 g, 272.1 g and 252.3 g/plant respectively and were identified suited to Dharwar conditions.

B. Intervarietal F_1 heterosis

Deshpande (1933) was first in India to report on heterosis in chilli. He observed heterosis for earliness, plant height, fruit diameter, fruits/plant and yield.

Pal (1945) studied Pusa strains of chilli for three seasons. Although a slight heterosis was shown for earliness, plant height, fruits/plant and weight of dry produce, its expression was not sufficiently stable to justify their use for practical purpose.

Michna (1963) studied 34 hybrids among crosses involving 15 varieties and three hybrids. Nine hybrids were markedly superior for yield. Relative heterosis for yield to the extent of 85.7% was recorded in hybrids involving pure varieties and upto 97.4% in crosses between varieties and F_1 hybrids. The superiority of the hybrids were more marked during unfavourable years than in favourable years.

Setlach (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 the fruit size in less favourable or normal years. In an outstandingly favourable year for pepper, yield increments were the result of increase in both number and size of fruits. It was rare for heterosis to occur for fruit weight alone.

Silvetti and Giovanelli (1970) studied five components of earliness and eleven components of yield in a diallel cross involving six bell pepper varieties and observed heterosis for earliness and yield. Nagaich et al. (1972) reported heterosis for yield in chilli. Marfutina (1972) observed that the hybrids exceeded the parents by 6 to 28% for dry matter content and by 8 to 48% for sugar content.

Gill et al. (1973) studied combining ability of six bell pepper varieties. The gca and sca effects revealed the importance of non-additive type of gene action which could be exploited by hybrid seed production. Singh et al. (1973) reported heterobeltiosis for fruit length (45%), fruits/plant (30%), plant height (19%) and yield/plant (19%). Six of the seven crosses showed heterosis for plant height, and five for fruit length. Three crosses significantly outyielded their better parents and one cross exhibited heterosis for fruits/plant. None of the hybrids showed heterosis for days to flower.

Significant heterosis for percentage of mature fruits at harvest, fruit length and dry fruit yield/plant were reported by Lippert (1975). In South Korea, Bak et al. (1975) examined 48 hybrids and their parents. Heterosis was apparent for early maturity, fruit length and fruits/plant. Yield was higher by 61% on an average in the hybrids compared to their parents.

Thakur and Theerth (1975) observed pronounced relative heterosis for uptake of N, P, Zn, Mn and Fe in hot peppers whereas uptake of P exhibited heterobeltiosis.

Mishra et al. (1976) studied heterosis for eight components of yield in eight crosses. The manifestation of heterobeltiosis was to the maximum extent of 84.35% for yield/plant, 68.33% for fruits/plant, 61.49% for secondary branches plant, 33.49% for primary branches/plant, 20.63% for fruit length, 17.53% for days to maturity and 14.69% for days to flower. Five crosses showed significant heterobeltiosis for fruits/plant and yield/plant. Three crosses were earlier to flower and mature than their earlier parents. Heterosis was not significant for plant height and fruit girth.

Singh and Singh (1976 a) observed heterosis for days to flower, days to maturity, branches/plant, fruit length, fruit thickness, fruit number and yield in a diallel cross involving eight lines. They recommended recurrent selection to improve

yield. Singh and Singh (1976 b) reported significant heterosis for days to flower, days to maturity, plant height, branches/plant, fruit length, fruit thickness, fruits/plant and yield. Dominance, additive and epistatic types of gene action played a role, though dominant gene effects made preponderant contribution. According to them heterosis breeding or reciprocal recurrent selection would be an appropriate breeding methodology to cause quantitative improvement in chilli.

Singh and Singh (1977) worked out genetics of quantitative characters in chilli. Major contribution of dominance gene effects was observed for fruits/plant and dry yield, while both additive and dominance components were important for days to flower, days to maturity, branches/plant and plantheight. Over dominance was observed for all the characters except fruit thickness. They recommended reciprocal recurrent selection and/or heterosis breeding. Singh and Singh (1978 a) showed the importance of both gca and sca variances for plant height, fruit length, fruits/plant and yield/plant and recommended heterosis breeding for the improvement.

Sharma and Saini (1977) studied heterosis and combining ability in crosses involving four bell pepper varieties, Chinese Giant, California Wonder, Osh Kosh, 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 amount of heterobeltiosis was observed for plant height and fruit yield. The top most heterotic crosses for yield were Yelo Wonder x Solan Yellow (55.4%), Solan Yellow x Hot Portugal (47.89%) and Waxy Globe x Hot Portugal (45.99%). However, the best yielding hybrid (202.5 g/plant) was Hungarian Wax x Solan Yellow (41.36%). For plant height, Chinese Giant x Solan Yellow (54.49%) and Solan Yellow x Hot Portugal (47.9%) exhibited considerable heterosis. Heterosis for branches and leaf area/plant were negligible.

Gill and Ahmad (1977) reported relative heterosis for plant height and average fruit weight. Dikaanew (1978) studied 43 hybrids, of which three showed clear dominance for earliness and four hybrids outyielded both their parents. Singh and Singh (1978 b) studied 28 hybrids, all of which showed heterobeltiosis for yield. Dominance components were identified to be mainly responsible for heterosis for yield.

Pandian et al. (1978) studied eight hybrids, all of which showed negative heterosis for fruit length and fruit girth. Many of them showed negative heterosis for plant height and seeds/fruit. Relative heterosis to the extent of 33.3% for pericarp thickness, 35.5% for seed weight/fruit, 32.8% for fruits/plant and 55.9% for dry yield/plant were manifested by the hybrids. Five crosses gave higher fruit yield/plant, pericarp thickness and seed weight/fruit over midparents.

Joshi and Singh (1980) studied seven F_1 hybrids of bell peppers and observed heterobeltiosis for plant height, primary branches/plant, fruit length, fruits/plant and fruits/Kg. In a study involving crosses among four hot chillies viz. Perennial, Malgache, Malgache Yellow and S118 and three bell peppers viz. California Wonder, Javitte Cecei and Avelar, all hybrids yielded significantly more than the parents, except S118, which significantly outyielded all the other varieites. Relative heterosis varied from 193.9% to 284.9% and heterobeltiosis 96.3% to 160.0%. All the hybrids also yielded significantly higher than NP 46-A, and the standard heterosis ranged from 70.7% to 270.5%. None of the crosses exhibited heterosis for branches/plant, height, spread, fruit weight and fruit width (Singh, 1980-'81).

Somtakke (1981) studied a 9 x 9 full diallel cross. The mean percentage of F_1 heterosis over all the parents was maximum for yield (24.63%) followed by secondary branches/plant (24.42%), primary branches/plant (19.59%), days to flower (13.52%) and plant height (10.55%). The maximum heterobeltiosis was observed for ascorbic acid content (116.04%) and it was 61.4% for yield. In a line x tester cross involving 12 varieites and three pollen parents, Pandey et al. (1981) reported heterobeltiosis for fruit number and yield/plant. Nowaczyk (1981) observed heterosis for capsaicin yield but however, heterosis was rarely apparent for single fruit weight, flesh thickness, dry matter content and absorbic acid content.

Murthy and Lakshmi (1983) studied a 9 x 9 diallel. Maximum heterobeltiosis was observed for plant height (31.64%). None of the hybrids exhibited positive heterobeltiosis for fruit length, while 21 showed negative heterobeltiosis. Only three crosses showed significant heterosis for fruit weight and there is only little scope to improve this character through heterosis breeding. Heterosis to the extent of 198.77% was exhibited for fruits/plant and this character can be improved by heterosis breeding. Heterobeltiosis to the extent of 186.63% was observed for dry fruit yield.

Balakrishnan et al. (1983) investigated a 10 x 3 line x tester cross for combining ability and heterosis for earliness, branches/plant, fruit length, seeds/fruit, 1000 seed weight, fruits/plant and yield/plant. CA 247 x K-2 was the best yielding hybrid (207.5 g/plant). Hybrids exhibiting heterosis for yield also showed heterosis for more than one components of yield, but fruits/plant tended to be the most important contributing character. Uno (1984) reported highly significant heterotic effects for median harvest date, height, fruits/plant and yield/plant.

Reports on heterosis in interspecific crosses are scattered and rather limited. In successful crosses, involving five species, Capsicum annuum, C. frutescens, C. baccatum, C. pendulum and C. microcarpum, the F_1 hybrids exhibited heterosis for

flowering duration, percentage fruit set, branches/plant, leaves/plant, plant height, plant spread, and fruits/plant (Pillai et al., 1977)

In interspecific crosses involving two Capsicum annuum lines (Jwala and K-2) and three C. frutescens lines (White Kanthari, Chuna and Ornamental Type) Krishnakumari (1984) reported significant heterosis for days to flower, days to first harvest, days to fruit ripening, plant height, seeds/fruit, seed yield/plant, fruits/plant and yield/plant. No heterosis was observed for primary branches or dry fruit yield. Heterobeltiosis for yield ranged from -35.6% to 62.9% and relative heterosis from -19.34% to 78.77%.

The above information are summarised in Table 2.

Table 2. Characters in which F_1 hybrids showed heterosis

Characters	Authority
Earliness - general	Deshpande (1933); Silvetti and Giovanelle (1970); Narfutina (1972); Bak et al. (1975); Dikasnew (1978)
Days to flower	Mishra et al. (1976); Singh and Singh (1976 a, b); Soh et al. (1976); Sontakke (1981); Krishnakumari (1984)

Contd...

Table 2(Contd.)

Characters	Authority
Days to maturity	Mishra et al. (1976); Singh and Singh (1976 a, b); Krishnakumari (1984); Uso (1984)
General vigour	Deshpande (1933); Singh et al. (1973); Singh and Singh (1976 b); Gill and Ahmad (1977); Pillai et al. (1977); Sharma and Saini (1977); Joshi and Singh (1980); Sontakke (1981); Krishnakumari (1984)
Branches/plant	Singh and Singh (1976 a, b)
Primary branches/plant	Mishra et al. (1976); Joshi and Singh (1980); Sontakke (1981)
Secondary branches/plant	Mishra et al. (1976); Sontakke (1981)
Fruit length	Singh et al. (1973); Bak et al. (1975); Lippert (1975); Singh and Singh (1976 a, b); Joshi and Singh (1980); Singh (1980-'81)
Fruit thickness	Deshpande (1933); Singh and Singh (1976 a,b); Joshi and Singh (1980)

Contd.

Table 2. (Contd.)

Characters	Authority
Fruit pericarp thickness	Pandian et al. (1978)
Fruits/plant	Deshpande (1933); Betlach (1976, 1967); Singh et al. (1973); Bak et al. (1975); Mishra et al. (1976); Singh and Singh (1976 a,b); Pillai et al. (1977); Joshi and Singh (1980); Pandey et al.(1981); Murthy and Lakshmi (1983); Uzo (1984); Krishnakumari (1984)
Single fruit weight	Betlach (1965, 1967); Gill and Ahmad (1977); Murthy and Lakshmi (1983)
Fresh yield/plant	Michna (1963); Beltach (1965); Silvetti and Giovanelli (1970); Nagaich et al. (1972); Singh et al. (1973); Bak et al. (1975); Mishra et al. (1976); Singh and Singh (1976 a, b); Sharma and Saini (1977); Dikaanew (1978); Singh and Singh (1978 b); Joshi and Singh (1980); Singh (1980-'81); Sontakke (1981); Pandey et al. (1981); Murthy and Lakshmi (1983); Uzo (1984); Krishnakumari (1984)

Table 2. (Concl.)

Characters	Authority
Dry yield/plant	Deshpande (1933); Marfutina (1972); Lippert (1975); Pandian et al. (1978); Murthy and Lakshmi (1983)
Seeds/fruit	Krishnakumari (1984)
Seed yield	Pandian et al. (1978); Krishnakumari (1984)
Sugar content	Marfutina (1972)
Ascorbic acid content	Sontakke (1981)
Capsaicin content	Nowacsyk (1981)
Nutrient uptake	Thakur and Theerth (1975)

C. Intervarietal F_2 heterosis

Reports on expression of heterosis in the segregating population are scattered and rather limited. A comparison among three varieties, their F_1s and F_2 hybrids for yield showed that the F_2 progenies though inferior in yield to the F_1s were superior to the F_0 plants (Fuji et al., 1959). Michna (1963) studied 34 F_1 hybrids of which nine were markedly superior to the parents for yield. In six of these crosses,

the average yield of F_2 population was lower than that of F_1. in one it was equal to the F_1 and in two crosses it was higher than the F_1s by 21% and 36.7% respectively. Khrenova (1972) reported that heterotic combinations from parents, which were morphologically similar could be used in second and in subsequent generations if selection for yield was practised. Popova (1973) studied the F_2 generations of two heterotic intervarietal hybrids. Total yields were lower in the F_2 than in the F_1 but higher than the yields of the respective better parents.

Bocchetta et al. (1976) measured ten characters associated with yield and maturity in six bell peppers and their one way F_1s and F_2s. Heterosis for yield was observed in crosses between the yield types high x intermediate, intermediate x intermediate and low x low. In the F_2, heterosis for yield was observed in crosses involving the low yielding variety Topepo.

Singh and Singh (1976 b) reported significant inbreeding depression in F_2 for days to flower, days to maturity, plant height, branches/plant, fruit length, fruit thickness, fruits/plant and yield/plant. Days to flower and days to maturity had negative inbreeding depression. The degree of inbreeding depression depended upon the percentage contribution by the additive gene components. The characters governed by additive gene effect would show less inbreeding depression.

D. Clusterness in chillies

The first report on inheritance of clusterness in peppers seems to be of Ikeno (1913) (cf. Boswell, 1937). In a cross between non-umbel and umbel inflorescence forms, he obtained non-umbel forms in the F_1, which segregated into three non-umbel to one umbel in F_2 indicating monogenic recessive inheritance. Deshpande (1944) observed a bushy and compact bunch mutant in NP 46-A. Observations in F_1 and F_2 populations, involving this mutant and NP 46-A indicated monogenic difference between bunchy and normal plants, the former being necessive. The F_3 observations confirmed the F_2 results.

Rajamani and Nagaratnam (1962) observed a bunch chilli from Madurai in a bulk population of Samba variety. The plant possessed clusters of pedicels ranging from three to six, arising from a single axil and they bred true. In a study employing C-2 (pods-solitary) and C-21 (pods in clusters of four to eight/node) Murthy and Murthy (1962 a) established that solitary nature of pedicel was dominant to cluster habit, governed by a single gene pair.

In Bulgaria, Popova (1965) developed a few lines with a compact arrangement of fruits by hybridisation between Capsicum annuum and Capsicum annuum var. fasciculatum. The lines showed uniform ripening and were suitable for mechanised cultivation and harvesting.

Lippert et al. (1965) coined the gene symbol 'fa' for a fasciculate, compact, bushy plant, with shortened internodes. Kormos and Kormos (1966) reported F_2 plants in which the main axis was terminated by the inflorescence and no lateral shoots developed in cross between cluster and normal types.

Perenc (1970) developed two determinate varieties, Kalocsa D-601 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. In Hungary, Ormos and Zatyko (1971) described a bunched table pepper variety Gepi Konserv (Machine Preserving), 20-25 cm tall, with erect fruits borne at the same level which ripened uniformly and suited for mechanical harvesting. The fruits were white and non-pungent, 7 to 9 cm long, 5 to 6 cm wide having 3 to 4 mm thick flesh.

Based on inheritance studies using Capsicum frutescens, LR-1 (fruit pedicels mostly one or two and occasionally three/ node), Barrios and Mosokar (1972) established that cluster habit was recessive to normal, controlled by a single recessive gene. Angeli (1974) developed both vegetable and spice

varieties of determinate habit using the ornamental form, Capsicum annuum var. fasciculatum in Hungary.

Ludilov (1977) crossed two cluster forms, Buketen 3 (Clustered 3) and Girbrid 208 (Hybrid 208) with normal varieties. All the F_1s were normal. In the F_2 they segregated into normal, cluster and intermediate forms. When the intermediate forms were assaigned to the cluster group the phenotypic ratio of normal to cluster form was 3:1 in hybrids with Buketen 3, and 5:1 in those with Girbrid 208. The F_3 families were not stable. In case of hybrids between normal varieties and Girbrid 208, the progeny of F_2 cluster forms contained upto 27% normal forms. Meshram (1983) observed a clustered mutant in the M_2 of Jwala. Genetic analysis involving F_1, F_2 and F_3, from crosses between the mutant and Jwala indicated monogenic inheritance with normal (Cl) dominant to cluster (cl).

Subramanya (1982, 1983) attempted to transfer the genes for multiple flowers to Delray Bell (Capsicum annuum) from PI 159236 (Capsicum chinense). Delray Bell (P_1) had single flowers at all nodes, except at the first branching, where two flowers (or fruits) were borne in a few plants. The flowers/node in PI 159236 (P_2) was predominantly three with an occasional occurance of one, two or four flowers (or fruits) at a few nodes of the same plant. The P_2 parent was classified having multiple flowers. The measurements in the study were confined to first six nodes (two to seven positions) after

the first bifurcation. The F_1 plants were intermediate having predominantly two flowers/node. The F_1 performance indicated partial dominance towards increased flower number.

In the next season $P_1(9)$, $P_2(15)$, $B_1(70)$, $B_2(62)$ and $F_2(55)$ were used in the genetic analysis. Plants in the segregating populations were classified as single-, double-and multiple flower phenotypes. In the F_2 only two phenotypic groups, single - and double flower -, could be observed and the phenotypic ratio indicated that three dominant genes were involved in the control of double flower phenotype. According to this model, each gene independently would be capable of producing a double flower phenotype. The B_1 population segregated into single - and double flower types, but however, all individuals in the B_2 generation were classified as double flowered. Lack of recovery of P_2 phenotypes in the B_2 generation indicated that the multiple flower character was controlled by more than three genes. Studies with F_3 populations indicated that additional genes were involved in the control of multiple flower character. Absence of multiple flower type in the B_2 and F_2 generations were attributed to inadequate population size in the study.

In the above study, the expression of multiple flower character appeared to be highly variable and unstable. Appearance of single-, double- and multiple flower types in the same plant, made the classification very difficult.

E. Bacterial wilt resistance

Wilt caused by Pseudomonas solanacearum E.F. Smith is a wide spread disease of chilli, seriously limiting the cultivation of the crop especially in the acidic soils. Attempts have been made to screen out resistant varieties and identify sources of resistance. In Bulgaria, Mihov (1969) observed that peppers produced from crosses between Capsicum annuum and Capsicum fasciculatum were wilt resistant and of good quality.

Rahim and Samraj (1974) evaluated nine varieties for resistance to bacterial wilt in Kerala. The mean percentage of plants wilted in varieties Kandhari, Pungent Pride, Cherry Red, Vattal (a variety commonly available in the Kerala market), Dark Purple, Long Red, Hungarian Wax, Bhola and Chinese Giant were 0.85, 6.37, 10.25, 14.32, 16.28, 17.33, 35.2, 35.38 and 66.8 respectively. Kandhari was the most resistant variety. The varieties Hungarian Wax, Bhola and Chinese Giant, where the disease exceeded 20% were classified susceptible and the remaining classified resistant.

In a study of pepper cultivars for their reaction to eight race 1 isolates and one race 3 isolate of Pseudomonas solanacearum, cultivar KAU Cluster was resistant to four race 1 isolates and one race 3 isolate. White Kandhari was resistant to six of the race 1 isolates and Pant C-1, to three race 1 isolates and one race 3 isolate (Goth et al., 1983).

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 their reaction to nine isolates of *Pseudomonas solanacearum* (race 1 and race 2). No pepper lines tested were resistant to all nine isolates, K60, W82, W295, FF, A21, TEP12, TEP13, 126408-1 and Tifton 80-1. Only A21 isolate was pathogenic to all the pepper lines. The most resistant was Pant C-1 which showed resistance to K60, W82, W295 and FF isolates and moderate resistance to Tifton 80-1. KAU Cluster showed resistance to K60, W82, W295, FF and Tifton 80-1 isolates but it was highly susceptible to other isolates. All the U.S. Cultivars were highly susceptible to all, except the Philippine egg plant isolate, W 295. KAU Cluster was also resistant to *Phytophthora capsici* and *Meloidogyne incognita*.

MATERIALS AND METHODS

The present studies were conducted in three seasons during September to February, 1983-'84, April to August, 1984 and August to January, 1984-'85, at the Instructional Farm of College of Horticulture, Vellanikkara, Trichur. This research farm is located at an altitude of 22.5 m above mean sea level and 10°32' N latitude and 76°16' E longitude. The farm experiences a typical warm humid tropical climate. The soil type is well drained sandy loam with a pH, 5.1.

The meteorological data, during the period of experimentation are furnished in Appendix-I.

The experiments consisted mainly of six parts.

A. Testing adaptability of selected bell pepper lines and F_1 hybrids involving bell peppers and hot chilli

B. Estimation of F_1 heterosis in intervarietal crosses involving bell peppers and hot chilli

C. Estimation of F_2 heterosis, in intervarietal crosses

D. Studying the genetics of cluster bearing habit in intervarietal crosses involving Capsicum annuum var. grossum and Capsicum annuum var. fasciculatum

E. Identification of elite cluster types for further trials and

F. Assessing the extent of damage from bacterial wilt and selecting resistant line(s), if any

A. Testing adaptability or selected bell pepper lines and F_1 hybrids involving bell peppers and hot chilli.

1. Experimental materials

The materials for the study comprised of seven varieties of Capsicum annuum var. grossum, one variety of Capsicum annuum var. fasciculatum and six F_1 hybrids between Capsicum annuum var. grossum and Capsicum annuum var. fasciculatum as detailed below.

a. Capsicum annuum var. grossum:

(i) Yolo Wonder Improved (CAG-29)
(ii) Sweet Red Cherry Pickling (CAG-30)
(iii) Hybrid Pepper Bell Boy (CAG-31)
(iv) Early Calwonder (CAG-28)
(v) Cubanelle (CAG-32)
(vi) 672-Hungarian Wax (CAG-33)
(vii) Bharat F_1 Hybrid (CAG-1)

b. Capsicum annuum var. fasciculatum:

(i) KAU Cluster (CA-33)

c. F_1 hybrids:

(i) Yolo Wonder Improved x KAU Cluster

(ii) Sweet Red Cherry Pickling x KAU Cluster

(iii) Hybrid Pepper Bell Boy x KAU Cluster

(iv) Early Calwonder x KAU Cluster

(v) Cubanelle x KAU Cluster

(vi) 672-Hungarian Wax x KAU Cluster

d. Control:

(i) Pant C-1 (CA-53)

The key to identification of Capsicum annuum var. grossum genotypes is given below.

I. Fruits large, round and dark green

1. Fruits fasciated, tip sunken, less pungent

a. base lobate, longitudinal furrows prominent — Early Calwonder

b. base cordate, longitudinal furrows not prominent — Bharat F_1 Hybrid

2. Fruits fasciated, tip round, base cordate, longitudinal furrows prominent — Hybrid Pepper Bell Boy

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

II. Fruits long, light coloured

1. Fruits large, tip pointed, base truncate, yellowish, waxy coated, pungent	672-Hungarian Wax
2. Fruits large, tip blunt, base cordate or truncate, greenish yellow, cherry shaped, pungent.	Sweet Red Cherry Pickling
3. Fruits smaller, tip pointed, base truncate, light green, less pungent	Cubanelle

The six bell pepper varieties, used in crosses were selected based on compatibility with KAU Cluster. The F_1 hybrids between Capsicum annuum var. grossum and Capsicum annuum var. fasciculatum were produced through controlled pollination, during September to February, 1983-'84. In all crosses, KAU Cluster was used as the pollen parent.

2. Lay-out and experimental design

The seeds were sown on 1st April, 1984 and transplanted to the field on 15th May, 1984 in a Randomised Block Design,

with three replications at 60 x 45 cm spacing. There were 20 plants/genotype/replication. Five plants were randomly tagged from each replication in each genotype and the following observations were made.

a. Earliness:

(i) Days to first fruit set

(ii) Days to green fruit harvest

(iii) Days to fruit ripening

b. Vegetative characters:

(i) Plant height

(ii) Secondary branches/plant

(iii) Axillary shoots/plant

c. Productive characters:

(i) Pedicel length

(ii) Fruit length

(iii) Fruit perimeter

(iv) Fruits/plant

(v) Green fruit yield/plant

Vegetative characters were recorded at the second harvest stage. Four fruits were randomly selected from the second harvest, from each tagged plant to record fruit characters. Analysis of variance was performed, to test significance of differences among the genotypes.

Three bell pepper lines, Early Calwonder, 672-Hungarian Wax, and Bharat F_1 Hybrid and two hot peppers, KAU Cluster and Jwala were raised along with the two F_1 hybrids viz. Early Calwonder x KAU Cluster and 672-Hungarian Wax x KAU Cluster, in a Randomised Block Design, during August 1984 to January 1985. There were three replications with 12 plants/genotype/replication spaced at 60x45 cm. Observations were made on plant height, plant spread, fruits/plant, fruit weight and green fruit yield/plant.

B. Estimation of F_1 heterosis in intervarietal crosses involving bell peppers and hot chilli

1. Experimental materials

a. Parents:

(i) Yolo Wonder Improved

(ii) Sweet Red Cherry Pickling

(iii) Hybrid Pepper Bell Boy

(iv) Early Calwonder

(v) Cubanelle

(vi) 672-Hungarian Wax

b. F_1 hybrids:

(i) Yolo Wonder Improved x KAU Cluster

(ii) Sweet Red Cherry Pickling x KAU Cluster

(iii) Hybrid Pepper Bell Boy x KAU Cluster

(iv) Cubanelle x KAU Cluster

(v) Early Calwonder x KAU Cluster

(vi) 672-Hungarian Wax x KAU Cluster

c. Controls:

(i) Bharat F_1 Hybrid

(ii) Pant C-1

2. Lay-out and experimental design

The experiment was laid out during April to August, 1984, in a Randomised Block Design with three replications. There were 20 plants/genotype/replication. The spacing given was 60 x 45 cm. Five plants were randomly tagged in each genotype/block and observations were made on

a) Days to first fruit set

b) Days to green fruit harvest

c) Days to fruit ripening

d) Plant height

e) Secondary branches/plant

f) Axillary shoots/plant

g) Pedicel length

h) Fruit length

i) Fruit perimeter

j) Fruits/plant

k) Green fruit yield/plant.

Analysis of variance was performed to test the significance of differences among the genotypes.

Heterosis over better parent (heterobeltiosis), mid-parent (relative heterosis) and the check parent (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 $\bar{F}_1$, $\overline{BP}$, $\overline{MP}$ and $\overline{SV}$ are the mean performance of F_1 hybrid, better parent, mid-parent and standard variety respectively

Equality of variances was tested using 'F' test, ahead to testing the significance of heterosis. When the variances were homogeneous, significance of heterosis was tested using Student 't' test with $n_1 + n_2 - 2$ degrees of freedom.

$$\text{i.e. } t = \frac{/\bar{F}_1 - \bar{P}/}{\sqrt{\frac{s_1^2(n_1-1) + s_2^2(n_2-1)}{n_1 + n_2 - 2}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

where $\bar{F}_1$ and $\bar{P}$ are the mean performance of hybrid and parent or standard variety respectively, s_1^2 and s_2^2 are the sample mean squares for hybrid and

parent or standard variety respectively and n_1 and n_2 are the number of plants of hybrid and parent or standard variety respectively.

When the variances were not homogeneous Cochrans Approximate test (Snedecor and Cochran, 1937) was employed.

$$\text{i.e. } t = \frac{/\bar{F}_1 - \bar{P}/}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

The calculated value of t was tested against t'

$$t' = \frac{n_2 s_1^2 t_1 + n_1 s_2^2 t_2}{n_2 s_1^2 + n_1 s_2^2}$$

where t_1 and t_2 are the table values of t for n_1-1 and n_2-1 degrees of freedom respectively, at 5% level.

To test the significance of relative heterosis

$$t = \frac{/\bar{F}_1 - \bar{MP}/}{\sqrt{\frac{s_1^2}{n_1} + \frac{1}{4}\left(\frac{s_2^2}{n_2} + \frac{s_3^2}{n_3}\right)}}$$

where s_1^2, s_2^2 and s_3^2 are sample mean squares for the hybrid, maternal parent and paternal parent respectively and n_1, n_2 and n_3 are the number of plants in hybrids, maternal parent and paternal parent respectively.

The calculated value of t was tested against t"

$$t'' = \frac{s_1^2 t_1 n_2 n_3 + s_2^2 t_2 n_1 n_3 + s_3^2 t_3 n_1 n_2}{s_1^2 n_2 n_3 + s_2^2 n_1 n_3 + s_3^2 n_1 n_2}$$

where t_1, t_2 and t_3 are table values of t for n_1-1, n_2-1 and n_3-1 degrees of freedom respectively, at 5% level.

C. Estimation of F_2 heterosis in intervarietal crosses

1. Experimental materials

a) Parents:

(i) Sweet Red Cherry Pickling

(ii) Hybrid Pepper Bell Boy

(iii) Cubanelle

(iv) KAU Cluster

b) F_2 hybrids:

(i) Sweet Red Cherry Pickling x KAU Cluster

(ii) Hybrid Pepper Bell Boy x KAU Cluster

(iii) Cubanelle x KAU Cluster

Check varieties were Bharat F_1 Hybrid and Pant C-1.

2. Lay-out and experimental design

Seeds produced at Vegetable Laboratory, Horticultural Science Institute, BARC-W, Beltsville, U.S.A. were used for the study. The study was conducted during September, 1983 to February, 1984 in a Randomised block design with three

replications. There were 20 plants/replication for parents and check varieties, and 40 plants/replication for F_2s, spaced at 60 x 45 cm. Five plants/parent or check variety/replication were tagged randomly. In F_2, all plants excluding border plants were used to take observations on the following

a) Days to first fruit set
b) Days to green fruit harvest
c) Days to fruit ripening
d) Plant height
e) Branches/plant
f) Pedicel length
g) Fruit length
h) Fruit perimeter
i) Fruits/plant
j) Green fruit yield/plant
k) Dry fruit yield/plant

The data were statistically analysed first and F_2 heterosis was calculated. Heterobeltiosis, relative heterosis and standard heterosis were calculated as suggested by Briggle (1963) and Hayes et al. (1965).

The formulae used were

$$F_2 \text{ heterobeltiosis} = \frac{F_2 - \overline{BP}}{\overline{BP}} \times 100$$

$$F_2 \text{ relative heterosis} = \frac{F_2 - \overline{MP}}{\overline{MP}} \times 100$$

$$F_2 \text{ standard heterosis} = \frac{\bar{F}_2 - \bar{SV}}{\bar{SV}} \times 100$$

where $\bar{F}_2$, $\bar{BP}$, $\bar{MP}$ and $\bar{SV}$ are the mean performance of F_2 hybrid, better parent, mid-parent and standard variety respectively.

Significance of F_2 heterosis was tested after testing the significance of variances. Same procedure and formulae, except the fact that F_2s were evaluated, as employed in the previous experiment (B) were used here.

D. Studying the genetics of cluster bearing habit in intervarietal crosses involving Capsicum annuum var. grossum and Capsicum annuum var. fasciculatum

1. Experimental materials

a. Parents:

(i) Early Calwonder

(ii) 672-Hungarian Wax

(iii) Sweet Red Cherry Pickling

(iv) Hybrid Pepper Bell Boy

(v) KAU Cluster

b. F_1s:

(i) Early Calwonder x KAU Cluster

(ii) KAU Cluster x Early Calwonder

(iii) 672-Hungarian Wax x KAU Cluster

(iv) KAU Cluster x 672-Hungarian Wax

(v) Sweet Red Cherry Pickling x KAU Cluster

(vi) Hybrid Pepper Bell Boy x KAU Cluster

c. F_2s:

(i) Early Calwonder x KAU Cluster

(ii) 672-Hungarian Wax x KAU Cluster

(iii) Sweet Red Cherry Pickling x KAU Cluster

(iv) Hybrid Pepper Bell Boy x KAU Cluster

d. BC_1s:

(Early Calwonder x KAU Cluster) x Early Calwonder

(672-Hungarian Wax x KAU Cluster) x 672-Hungarian Wax

e. BC_2s:

(Early Calwonder x KAU Cluster) x KAU Cluster

(672-Hungarian Wax x KAU Cluster) x KAU Cluster

f. Half-sibs:

(672-Hungarian Wax x KAU Cluster) x

(Early Calwonder x KAU Cluster)

2. Lay-out and experimental design

The seeds were produced by hand pollination during April to August, 1984 and the experiments were conducted during August, 1984 to January, 1985.

The parents, F_1s, F_2s, BC_1s, BC_2s and the half-sib were raised in a uniformly fertile land, providing equal opportunity to each and every plant to express its genetic potential.

There were 30 plants/F_1s and the parents, Early Calwonder, 672-Hungarian Wax and KAU Cluster, 20 plants/Sweet Red Cherry Pickling and 15 plants/Hybrid Pepper Bell Boy. There were 70 and 120 plants respectively of F_2s of Sweet Red Cherry Pickling x KAU Cluster and Hybrid Pepper Bell Boy x KAU Cluster and 500 plants each/F_2, BC_1 and BC_2 of Early Calwonder x KAU Cluster and 672-Hungarian Wax x KAU Cluster. There were 120 plants of half-sib, (672-Hungarian Wax x KAU Cluster) x (Early Calwonder x KAU Cluster).

The plant populations were examined critically and classified into solitary and cluster fruit bearing groups. A plant was classified as cluster even if it possessed one cluster of a minimum number of two flowers (or fruits)/node, except at the first forking point.

The agreement of the observed frequencies with the expected frequencies was tested by the X^2 test of 'goodness of fit' with (n-1) degrees of freedom, where n = number of classes (Panse and Sukhatme, 1978).

The formula used was $X^2 = \sum \frac{(O-E)^2}{E}$

where O = observed frequency

E = expected frequency

Within the cluster group, based on proportion of fruits produced in clusters to the total fruits produced in the plant further classification was made to true cluster, occasional solitary and occasional cluster groups. The true cluster group produced all the flowers and fruits in clusters. The occasional solitary plants had majority of their flowers and fruits in clusters, but there were occasional solitary flowers and fruits which were not due to shedding. The occasional cluster group had most of their flowers or fruits solitary but for a few clusters in the plant.

The cluster population was further classified based on fruits developed/cluster. For this purpose, five clusters were selected at random from each plant and counts were made on fruits in each cluster. Frequency classes were made keeping a class interval of 0.5.

E. Identification of elite cluster bell peppers for further trials

The F_2 populations in the third experiment and the segregating populations in the fourth experiment were keenly observed for elite cluster types. Selection was practised based on cluster habit, fruits/plant, fruit size, plant height and general plant form. The identified lines were selfed and progressed through pure line selection.

F. Assessing the extent of damage from bacterial wilt and selecting resistant line(s), if any

The materials in the first experiment were observed for incidence of bacterial wilt. Bacterial ooze test was done to confirm wilt. Per cent incidence of wilt at the first harvest stage and at 100 days from transplanting were recorded. Analysis of variance was done to test the significance of differences among various genotypes. The genotypes were scored according to Maw and Ho (1976).

R - Resistant $< 20\%$ plants wilted

MR - Moderately resistant $> 20 < 40\%$ plants wilted

MS - Moderately susceptible $> 40 < 60\%$ plants wilted

S - Susceptible $> 60\%$ plants wilted

Results

RESULTS

The data were statistically analysed and the results are presented under the following heads.

A. Testing adaptability of selected bell pepper lines and F_1 hybrids involving bell peppers and hot chilli

B. Estimation of F_1 heterosis in intervarietal crosses involving bell peppers and hot chilli

C. Estimation of F_2 heterosis in intervarietal crosses

D. Genetics of clustered bearing habit in intervarietal crosses involving Capsicum annuum var. grossum and Capsicum annuum var. fasciculatum

E. Identification of elite cluster types for further trials and

F. Assessing the extent of damage from bacterial wilt and selecting resistant line(s), if any.

A. Testing adaptability of selected bell pepper lines and F_1 hybrids involving bell peppers and hot chilli

Seven bell pepper lines and two hot chilli lines were evaluated along with six F_1 hybrids during March to August, 1984 (Table 3). The varieties Sweet Red Cherry Pickling,

Hybrid Pepper Bell Boy, Yolo Wonder Improved and Bharat F_1 Hybrid, were susceptible to bacterial wilt.

Analyses of variances revealed significant differences among the genotypes for days to green fruit harvest, days to fruit ripening, plant height, secondary branches/plant, axillary shoots/plant, fruit length, fruit perimeter, fruits/plant, fruit weight and yield/plant. The genotypes were not significantly different for days to flower and pedicel length.

Days to flower ranged from 77 days in Cubanelle x KAU Cluster to 91 days in Cubanelle. Early Calwonder x KAU Cluster gave early green fruit harvest (100 days). Cubanelle took 117 days for first harvest. 672-Hungarian Wax took only 113 days to obtain first ripe fruits followed by 672-Hungarian Wax x KAU Cluster (114 days). KAU Cluster took the maximum duration of 125 days to first harvest of ripened fruits.

Early Calwonder was the dwarfest (34.1 cm) followed by 672-Hungarian Wax (38.9 cm), while the F_1, Hybrid Pepper Bell Boy x KAU Cluster was the tallest (67.8 cm). KAU Cluster had the maximum number of secondary branches (25.0) and axillary shoots (11.0). Next to KAU Cluster, the F_1 hybrid Cubanelle x KAU Cluster ranked with 12.7 secondary branches/ plant. 672-Hungarian Wax had the minimum number of secondary branches (4.4) and axillary shoots (0.8).

672-Hungarian Wax had the maximum fruit length (12.6 cm). The F_1 hybrids were identical for fruit length, and it ranged from 7.8 cm to 9.1 cm. For fruit perimeter, the F_1 hybrids Cubanelle x KAU Cluster, 672-Hungarian Wax x KAU Cluster and Sweet Red Cherry Pickling x KAU Cluster (average fruit perimeter, 5.2 cm) were on par and Yolo Wonder Improved x KAU Cluster, Hybrid Pepper Bell Boy x KAU Cluster and Early Calwonder x KAU Cluster (average fruit perimeter, 6.8 cm) were also on par.

Early Calwonder with an average fruit weight of 61.7 g ranked superior to all other genotypes. All the F_1s were on par for fruit weight, which ranged from 4.5 g in Cubanelle x KAU Cluster to 8.3 g in Early Calwonder x KAU Cluster. Fruit weight in 672-Hungarian Wax, Cubanelle and KAU Cluster were 28.3g, 10.7g and 1.5 g respectively.

The genotypes differed significantly for fruits/plant and yield/plant. Early Calwonder had the lowest fruits/plant (1.9) and yield/plant (117.2 g). Pant C-1 had the highest number of fruits/plant (146.4), yielding 192.7 g/plant. Ranked next was KAU Cluster with 122.9 fruits/plant which weighed 189.4 g. The F_1 hybrids were intermediate to their parents for fruits/plant. Except for the F_1 hybrid Yolo Wonder Improved x KAU Cluster, which yielded 196.8 g other hybrids were superior to all the parents studied. The highest yielding hybrid was

Table 3. Mean performance of bell peppers, hot chillies and F_1 hybrids

Lines	Days to flower	Days to green fruit harvest	Days to fruit ripening	Plant height (cm)
Bell peppers:				
Sweet Red Cherry Pickling	77.6			
Early Calwonder	78.8		84.	34.1
Cubanelle	90.9	116.7	123.1	51.5
672-Hungarian Wax	77.3	103.3	113.3	38.9
Hot chillies:				
KAU Cluster	87.5	115.9	124.8	50.7
Pant Col	81.0	114.4	123.1	57.2
F_1 hybrids:				
Yolo Wonder Improved x KAU Cluster	78.5	109.1	121.1	49.5
Sweet Red Cherry Pickling x KAU Cluster	81.1	104.7	114.9	61.2
Hybrid Pepper Bell Boy x KAU Cluster	77.7	105.8	117.7	67.8
Early Calwonder x KAU Cluster	79.7	100.4	121.5	56.5
Cubanelle x KAU Cluster	77.2	111.2	122.2	58.5
672-Hungarian Wax x KAU Cluster	82.3	106.6	113.8	56.5
Sem.±	3.3	3.5	2.5	3.2
CD (P = 0.05)	9.8	10.3	7.5	9.3

Table 3. (Contd.)

Lines	Secondary branches/ plant	Axillary shoots/ plant	Pedicel length (cm)	Fruit length (cm)
Bell peppers:				
Early Calwonder	4.7	1.7		
Cubanelle	7.0	1.7	3.4	3.2
672-Hungarian Wax	4.4	0.8	3.1	12.6
Hot chillies:				
KAU Cluster	25.0	11.0	3.2	5.0
Pant C-1	8.1	5.7	3.1	5.7
F_1 hybrids:				
Yolo Wonder Improved x KAU Cluster	6.8	2.7	3.3	7.8
Sweet Red Cherry Pickling x KAU Cluster	7.7	4.4	3.4	9.1
Hybrid Pepper Bell Boy x KAU Cluster	6.5	2.8	3.7	7.9
Early Calwonder x KAU Cluster	7.5	3.7	3.7	8.7
Cubanelle x KAU Cluster	12.7	6.1	3.4	8.2
672-Hungarian Wax x KAU Cluster	7.2	2.9	3.3	9.1
Sem. ±	1.7	0.5	0.1	0.4
CD (P = 0.05)	5.0	1.5	0.4	1.2

Table 3. (Concl.)

Lines	Fruit perimeter (cm)	Fruits/ plant	Fruit weight (g)	Yield/ Plant (g)
Bell Peppers:				
Early Calwonder	--	1.9	61.7	117.2
Cubanelle	8.4	12.1	10.7	129.3
672-Hungarian Wax	8.9	11.1	20.3	226.1
Hot chillies:				
KAU Cluster	3.6	122.9	1.5	189.4
Pant C-1	3.5	146.4	1.3	192.7
F_1 hybrids:				
Yolo Wonder Improved x KAU Cluster	6.6	30.4	6.5	196.8
Sweet Red Cherry Pickling x KAU Cluster	5.3	58.8	5.6	329.5
Hybrid Pepper Bell Boy x KAU Cluster	6.7	64.9	7.2	464.9
Early Calwonder x KAU Cluster	7.2	47.9	8.3	396.6
Cubanelle x KAU Cluster	5.0	70.2	4.5	318.2
672-Hungarian Wax x KAU Cluster	5.3	71.4	5.6	401.5
Sem. ±	0.2	7.5	4.5	41.0
CD(P = 0.05)	0.7	22.1	13.2	121.1

Hybrid Pepper Bell Boy x KAU Cluster (464.8 g/plant). 672-Hungarian Wax x KAU Cluster, Early Calwonder x KAU Cluster, Sweet Red Cherry Pickling x KAU Cluster and Cubanelle x KAU Cluster yielded 401.5 g, 396.6 g, 329.5 g and 318.2 g/plant respectively. The fruits/plant in the above hybrids were 71.4, 47.9, 58.8 and 70.2 respectively. 672-Hungarian Wax produced 11.1 fruits/plant, which weighed 226.1 g.

Seven genotypes, Early Calwonder, 672-Hungarian Wax, Bharat F_1 Hybrid, KAU Cluster, Jwala, Early Calwonder x KAU Cluster (F_1) and 672-Hungarian Wax x KAU Cluster (F_1) were further evaluated during August to January, 1984-'85. Significant differences were observed among the genotypes for days to harvest, plant height, plant spread, fruit length, fruit weight, fruits/plant and yield/plant (Table 4).

Early Calwonder, 672-Hungarian Wax, Early Calwonder x KAU Cluster and 672-Hungarian Wax x KAU Cluster were early (101 to 103 days from sowing to first harvest). KAU Cluster took 119 days to first harvest.

Plant height ranged from 39.3 cm (Bharat F_1 Hybrid) to 64.9 cm (Early Calwonder x KAU Cluster). Plant spread was the maximum (0.34 m^2) in 672-Hungarian Wax x KAU Cluster, followed by Early Calwonder x KAU Cluster (0.32 m2) and Jwala (0.31 m^2) and it was the minimum in Bharat F_1 Hybrid (0.09m^2).

Table 4. Mean performance of bell peppers, hot chillies and F_1 hybrids

Lines	Days to harvest	Plant height (cm)	Plant spread (m^2)	Fruit length (cm)	Fruit weight (g)	Fruits/ plant	Yield/ Plant (g)
Bell peppers:							
Early Calwonder	103.3	44.5	0.15	10.6	68.1	8.1	551.7
672-Hungarian Wax	100.5	52.4	0.18	14.1	29.9	18.2	589.9
Bharat F_1 Hybrid	112.3	39.3	0.09	10.4	66.5	5.2	345.7
Hot chillies:							
KAU Cluster	119.0	47.6	0.14	5.1	1.7	97.4	168.6
Jwala	113.0	56.6	0.31	12.2	2.9	105.1	305.3
F_1 Hybrids:							
Early Calwonder x KAU Cluster	100.8	64.9	0.32	8.2	8.9	58.8	520.0
672-Hungarian Wax x KAU Cluster	100.7	61.5	0.34	8.6	5.8	92.3	533.0
Sem ±	2.0	2.5	0.04	0.4	1.9	7.1	78.6
CD (P = 0.05)	6.0	7.5	0.11	1.4	5.7	21.5	238.3

672-Hungarian Wax had the longest fruits (14.1 cm.) followed by Jwala (12.2 cm). Fruit length was the lowest (5.1 cm) in KAU Cluster. The hybrids had fruit weights of 5.8 g in 672-Hungarian Wax x KAU Cluster and 8.9 g in Early Calwonder x KAU Cluster.

Jwala had the maximum fruits/plant (105.1) followed by KAU Cluster (97.4). Early Calwonder and 672-Hungarian Wax produced 8.1 and 19.7 fruits/plant respectively. The hybrids were intermediate to their parents. 672-Hungarian Wax out-yielded all the other genotypes (589.9 g/plant). KAU Cluster (168.6 g/plant) was the lowest yielding. Early Calwonder, Bharat F_1 Hybrid and Jwala yielded 531.7 g, 345.7 g and 305.3 g respectively. The F_1s were intermediate to their parents, yielding 520 g (Early Calwonder x KAU Cluster) and 533 g (672-Hungarian Wax x KAU Cluster).

B. Estimation of F_1 heterosis in intervarietal crosses involving bell peppers and hot chilli

Bell pepper varieties, Yolo Wonder Improved, Sweet Red Cherry Pickling and Hybrid Pepper Bell Boy did not perform well and as such heterobeltiosis and relative heterosis were not calculated in comparison to them in F_1 crosses. Extent of heterosis over KAU Cluster was calculated in allthe crosses. Since the check variety Bharat F_1 Hybrid also did not perform well, standard heterosis was calculated with reference to Pant C-1 only.

Mean performance of parents and F_1s and extent of heterosis over KAU Cluster, heterobeltiosis, relative heterosis and standard heterosis over Pant C-1 observed for various characters are presented in Table 5.

1. Days to flower

All the F_1 hybrids were earlier than the common parent KAU Cluster (88 days) by 6 to 11 days and exhibited significant negative heterosis. The F_1 hybrid Cubanelle x KAU Cluster which flowered after 77 days of sowing was the earliest and exhibited significant heterobeltiosis and relative heterosis.

2. Days to green fruit harvest

The F_1 hybrid Early Calwonder x KAU Cluster took only 100 days for the first harvest of green fruits. All the hybrids were earlier to KAU Cluster (116 days) and Pant C-1 (114 days). Heterosis observed over KAU Cluster ranged from -4.0% to -13.4% and that over Pant C-1 ranged from -2.8% to -12.2%. Heterobeltiosis and relative heterosis were not significant.

3. Days to fruit ripening

The hybrid, 672-Hungarian Wax x KAU Cluster took only 114 days to fruit ripening. This was 11 days earlier than KAU Cluster and 9 days earlier than Pant C-1. All the F_1 hybrids matured earlier than KAU Cluster and Pant C-1.

4. Plant height

All the F_1 hybrids were taller than their bell pepper parents. Five of the six hybrids were taller than their common parent KAU Cluster and three were taller than Pant C-1. The tallest hybrid was Hybrid Pepper Bell Boy x KAU Cluster (67.8 cm) which was 33.7% more than KAU Cluster and 18.5% more than Pant C-1.

5. Secondary branches/plant

KAU Cluster had the maximum number of secondary branches (25.0). The hybrids were intermediate to their parents for this character. Cubanelle x KAU Cluster ranked first among the hybrids (12.6 branches). This was 49.7% lesser than KAU Cluster and 54.4% more than Pant C-1. Secondary branches in the other hybrids ranged from 6.4 to 7.6.

6. Axillary shoots/plant

KAU Cluster had the maximum axillary shoots/plant (11.0). Among the F_1 hybrids, Cubanelle x KAU Cluster had the maximum number of axillary shoots (6.1). This was 44.5% lesser than KAU Cluster but 7% more than Pant C-1.

7. Pedicel length

All hybrids showed significant positive heterosis over Pant C-1 and the heterotic increase ranged from 6.4% to 19.3% and four hybrids showed significant increase over KAU Cluster.

8. Fruit length

All the F_1 hybrids showed significant increase over KAU Cluster and Pant C-1 for fruit length. Among the F_1 Hybrids, 672-Hungarian Wax x KAU Cluster had the maximum fruit length (9.1 cm) which was more than KAU Cluster and Pant C-1 to an extent of 78.4% and 59.6% respectively. It was 27.7% lower than the better parent, 672-Hungarian Wax.

9. Fruit perimeter

All the F_1 hybrids expressed significant positive heterosis over KAU Cluster (3.6 cm) and Pant C-1 (3.5 cm). The fruit permieter in the hybrids ranged from 5 cm. (Cubanelle x KAU Cluster) to 7.1 cm (Early Calwonder x KAU Cluster). Significant negative heterobeltiosis and relative heterosis were exhibited by the hybrids, Cubanelle x KAU Cluster and 672-Hungarian Wax x KAU Cluster.

10. Fruit weight

Among the hybrids, Early Calwonder x KAU Cluster had the maximum fruit weight (8.3 g). This was about five times the fruit weight of KAU Cluster and six times that of Pant C-1. Heterosis in this cross was observed to the extent of 453.3% over KAU Cluster, 538.4% over Pant C-1, -86.5% over Early Calwonder and -73.7% over mid-parent. Fruit weight in all the hybrids were intermediate to their parents.

Table 5. Mean performance of parents and F_1s, and extent of heterosis over KAU Cluster (CP), heterobeltiosis (BP), relative heterosis (MP) and standard heterosis (SV)

Lines	Days to flower					Days to green fruit harvest				
	Mean performance	CP(%)	BP(%)	MP(%)	SV(%)	Mean performance	CP(%)	BP(%)	MP(%)	SV(%)
Parents:										
Pant C-1	81.0					114.4				
KAU Cluster	87.5					115.9				
Sweet Red Cherry Pickling	77.6					—				
Early Calwonder	78.8					[illegible]				
Cubanelle	90.9					116.7				
672-Hungarian Wax	77.3					103.3				
F_1 hybrids:										
Yelo Wonder Improved x KAU Cluster	78.5	-10.3**			-3.1	109.1	-5.8**			-4.6**
Sweet Red Cherry Pickling x KAU Cluster	81.1	-7.3**	+4.3	-1.8	+0.1	104.7	-9.6**			-8.4**
Hybrid Pepper Bell Boy x KAU Cluster	77.7	-11.2**			-4.0	105.8	-8.7**			-7.5*
Early Calwonder x KAU Cluster	79.7	-8.9**	+1.1	-4.2	-1.6	100.4	-13.4**			-12.2**
Cubanelle x KAU Cluster	77.2	-11.7**	-11.7**	-13.4**	-4.7	111.2	-4.0	-4.0	-4.4	-2.8
672-Hungarian Wax x KAU Cluster	82.3	-5.9**	+6.4	-0.1	+1.6	106.0	-8.5**	+2.9	-3.4	-7.3**

* and ** - significant at 5% and 1% levels, respectively

Table 5. (Contd.)

Lines	Days to fruit ripening					Plant height				
	Mean performance	CP(%)	BP(%)	MP(%)	SV(%)	Mean performance (cm)	CP(%)	BP(%)	MP(%)	SV(%)
Parents:										
Pant C-1	123.1					57.2				
KAU Cluster	124.8					50.7				
Early Calwonder	—					34.1				
Cubanelle	123.1					51.5				
672-Hungarian Wax	113.3					38.9				
F_1 hybrids:										
Solo Wonder Improved x KAU Cluster	121.1	-2.9			-1.6	49.5	-2.3			-13.5**
Sweet Red Cherry Pickling x KAU Cluster	114.9	-7.9**			-6.8**	61.2	+20.7**			+6.9
Hybrid Pepper Bell Boy x KAU Cluster	117.7	-5.6**			-4.4**	67.8	+33.7**			+18.5**
Early Calwonder x KAU Cluster	121.5	-2.6	—	—	-1.3	56.5	+11.4	+11.4	+33.2**	-1.2
Cubanelle x KAU Cluster	122.2	-2.2	-0.9	-1.6	-0.9	58.5	+15.4	+13.6	+14.9	+2.6
672-Hungarian Wax x KAU Cluster	113.8	-8.8**	+0.4	-4.4**	-7.3*	56.5	+11.4	+11.4	+26.1**	-1.2

Table 5. (Contd.)

Lines	Secondary branches/plant					Axillary shoots/plant				
	Mean performance	CP(%)	BP(%)	MP(%)	SV(%)	Mean performance	CP(%)	BP(%)	MP(%)	SV(%)
Parents:										
Pant C-1	8.1					5.7				
KAU Cluster	25.0					11.0				
Early Calwonder	4.6					1.7				
Cubanelle	7.0					1.7				
672-Hungarian Wax	4.4					0.8				
F_1 hybrids:										
Yolo Wonder Improved x KAU Cluster	6.7	-73.2**			-17.2	2.7	-75.4**			-52.6**
Sweet Red Cherry Pickling x KAU Cluster	7.6	-69.6**			-6.2	4.4	-60.0**			-22.8**
Hybrid Pepper Bell Boy x KAU Cluster	6.4	-74.4**			-20.9*	2.8	-74.5**			-50.8**
Early Calwonder x KAU Cluster	7.5	-70.0**	-70.0**	-49.4*	-7.4	3.7	-66.3**	-66.1**	-41.4**	-35.0**
Cubanelle x KAU Cluster	12.6	-49.8**	-49.7**	-21.5	+54.4**	6.1	-44.5**	-44.5**	-3.9	+7.0
672-Hungarian Wax x KAU Cluster	7.2	-71.2**	-71.2**	-55.3**	-11.1	2.9	-73.3**	-73.3**	-50.6**	-49.1**

Table 5. (Contd.

Lines	Pedicel length					Fruit length				
	Mean performance (cm)	CP (%)	BP (%)	MP (%)	SV (%)	Mean performance (cm)	CP (%)	BP (%)	MP (%)	SV (%)
Parents:										
Pant C-1	3.1					5.7				
KAU Cluster	3.2					5.1				
Cubanelle	3.4					8.2				
672-Hungarian Wax	3.1					12.6				
F_1 hybrids:										
Yolo Wonder Improved x KAU Cluster	3.3	+3.1			+6.4**	7.8	+52.9**			+36.7**
Sweet Red Cherry Pickling x KAU Cluster	3.4	+6.2**			+9.6**	9.1	+78.4**			+59.6
Hybrid Pepper Bell Boy x KAU Cluster	3.7	+15.6**			+19.3**	7.9	+54.9**			+38.5**
Early Calwonder x KAU Cluster	3.7	+15.6**			+19.3**	8.7	+70.5**			+52.6**
Cubanelle x KAU Cluster	3.4	+6.2**	0	+2.4	+9.6**	8.2	+60.7**	0	+24.7**	+43.8**
672-Hungarian Wax x KAU Cluster	3.3	+3.1	+3.1	+5.4	+6.4**	9.1	+78.4**	-27.7**	+3.8	+59.6**

Table 5. (Contd.)

Lines	Fruit perimeter					Fruit weight				
	Mean performance(cm)	CP(%)	BP(%)	MP(%)	SV(%)	Mean performance (g)	CP(%)	BP(%)	MP(%)	SV(%)
Parents:										
Pant C-1	3.5					1.3				
KAU Cluster	3.6					1.5				
Early Calwonder	--					61.7				
Cubanelle	8.4					10.7				
672-Hungarian Wax	8.9					20.3				
F_1 hybrids:										
Yolo Wonder Improved x KAU Cluster	6.6	+83.0**			+88.5**	6.5	+330.4**			
Sweet Red Cherry Pickling x KAU Cluster	5.3	+47.2**			+51.4**	5.6	+270.8**			+330.7**
Hybrid Pepper Bell Boy x KAU Cluster	6.8	+88.8**			+94.2**	7.2	+380.0**			+453.8**
Early Calwonder x KAU Cluster	7.1	+97.2**			+102.8**	8.3	+453.3**	-86.5**	-73.7**	+538.4**
Cubanelle x KAU Cluster	5.0	+38.8**	-40.4**	-16.3	+42.8**	4.5	+200.0**	-57.9**	-36.0*	+246.1**
672-Hungarian Wax x KAU Cluster	5.3	+47.2**	-40.4**	-15.9**	+51.4**	5.6	+273.3**	-72.4**	-48.6**	+330.7**

Table 5. (Concl.)

Lines	Fruits/plant					Green fruit yield/plant				
	Mean performance	CP(%)	BP(%)	MP(%)	SV(%)	Mean performance (g)	CP(%)	BP(%)	MP(%)	SV(%)
Parents:										
Pant C-1	146.4					192.7				
KAU Cluster	122.9					189.4				
Early Calwonder	1.9					117.2				
Cubanelle	12.1					129.3				
672-Hungarian Wax	11.1					226.1				
F_1 hybrids:										
Yolo Wonder Improved x KAU Cluster	30.4	-75.2**			-79.2**	196.8	+3.9			+2.1
Sweet Red Cherry Pickling x KAU Cluster	58.8	-52.1**			-59.8**	329.5	+73.9**			+70.9**
Hybrid Pepper Bell Boy x KAU Cluster	64.8	-47.2**			-53.7**	464.9	+145.4**			+141.2**
Early Calwonder x KAU Cluster	47.9	-61.0**	-61.0**	-23.1**	-67.2**	396.6	+109.4**	+109.4**	+158.6**	+105.8**
Cubanelle x KAU Cluster	70.2	-42.9**	-42.9**	+3.9	-52.0**	318.2	+68.0**	+68.0**	+99.6**	+65.1**
672-Hungarian Wax x KAU Cluster	71.4	-41.9**	-41.9**	+6.5	-51.2**	401.5	+111.9**	+77.5**	+93.2**	+108.3**

11. Fruits/plant

The F_1 hybrids did not show positive heterosis over the common parent KAU Cluster. The hybrid, 672-Hungarian Wax x KAU Cluster had 71.4 fruits/plant. All the F_1 hybrids exceeded the bell pepper parents for fruits/plant. The bell pepper parents had fruits/plant ranging from 1.9 (Early Calwonder) to 12.1 (Cubanelle). The F_1 hybrids ranged from 30.4 fruits/plant (Yolo Wonder Improved x KAU Cluster) to 71.4 fruits (672-Hungarian Wax x KAU Cluster).

12. Green fruit yield/plant

Five of the six F_1 hybrids exhibited significant heterosis over KAU Cluster and Pant C-1. Three hybrids showed significant heterobeltiosis and relative heterosis. The best yielding hybrid was Hybrid Pepper Bell Boy x KAU Cluster which yielded 464.9 g/plant. This was more to the extent of 145.4% over KAU Cluster (189.4 g/plant) and 141.2% over Pant C-1 (192.7 g/plant). Early Calwonder x KAU Cluster yielded 396.6 g and exhibited heterobeltiosis of 109.4% and relative heterosis of 158.6%. 672-Hungarian Wax x KAU Cluster yielded (401.5 g/plant), nearly double its better parent, 672-Hungarian Wax (226.1 g).

C. Estimation of F_2 heterosis in intervarietal crosses

Analysis of variances revealed significant differences among the parental and F_2 populations for days to green fruit harvest, days to fruit ripening, secondary branches/plant,

pedicel length, fruit length, fruit perimeter, fruits/plant, and dry fruit yield/plant. The populations were not significantly different for days to flower, plant height and green fruit yield/plant. Mean performance of parents and F_2s and extent of F_2 heterosis explained further as heterobeltiosis, relative heterosis and standard heterosis estimates over Bharat F_1 Hybrid and Pant C-1 for various characters are presented in Table 6.

1. Days to flower

The F_2 populations took 37 to 38 days to flower from transplanting. The F_2s of Sweet Red Cherry Pickling x KAU Cluster and Cubanelle x KAU Cluster took more time than their respective parents, whereas Hybrid Pepper Bell Boy x KAU Cluster was intermediate to its parents. They were earlier to Bharat F_1 hybrid (40 days) by 2 to 3 days and by 4 to 5 days to Pant C-1 (42 days). Significant standard heterosis over Pant C-1 to the extent of -11.8% was shown by the segregating populations.

2. Days to green fruit harvest

Sweet Red Cherry Pickling x KAU Cluster F_2 took 60 days for the first harvest of green fruits. The F_2s of Hybrid Pepper Bell Boy x KAU Cluster and Cubanelle x KAU Cluster took 61 and 62 days respectively. All F_2s were earlier to

Pant C-1 (66 days) by 4 to 6 days but gave delayed harvesting compared to Bharat F_1 Hybrid (54 days) by 6 to 8 days.

3. Days to fruit ripening

Hybrid Pepper Bell Boy x KAU Cluster F_2 took 77 days to fruit ripening. It was 4 days earlier to Hybrid Pepper Bell Boy and one day earlier to KAU Cluster. Cubanelle x KAU Cluster showed delayed ripening (79 days) compared to both the parents. Sweet Red Cherry Pickling x KAU Cluster F_2 took 77 days to fruit ripening and it was 15.6% more than its early parent, Sweet Red Cherry Pickling (66 days).

4. Plant height

The F_2s of Sweet Red Cherry Pickling x KAU Cluster (57.2 cm) and Cubanelle x KAU Cluster (52.1 cm) were taller than their better parents, Sweet Red Cherry Pickling (51.6cm) and KAU Cluster (49.8 cm) respectively. Sweet Red Cherry Pickling x KAU Cluster F_2 showed a heterobeltiosis of 10.8%, relative heterosis of 12.8% and standard heterosis of 35.2% over Bharat F_1 Hybrid (42.3 cm).

5. Secondary branches/plant

KAU Cluster had the maximum secondary branches/plant (11.3) followed by Pant C-1 (9.1). All the F_2 populations were intermediate to their parents, with 6.1 to 6.6 branches/plant and they exhibited significant negative heterobeltiosis

(-41.6% to -46%), relative heterosis (13.4% to -25.1%), standard heterosis over Pant C-1 (-27.5% to -32.9%) and positive standard heterosis over Bharat F_1 Hybrid (56.4% to 69.2%)

6. Pedicel length

The F_2 hybrids were intermediate to their parents and their pedicel length varied from 3.1 cm (Cubanelle x KAU Cluster) to 3.3 cm (Sweet Red Cherry Pickling x KAU Cluster). All the F_2s exhibited significant heterobeltiosis (-13.2% to -18.4%), standard heterosis over Bharat F_1 Hybrid (-15.4% to -20.5%) and standard heterosis over Pant C-1 (6.8% to 13.8%).

7. Fruit length

Average fruit length in the F_2 population of Hybrid Pepper Bell Boy x KAU Cluster, Cubanelle x KAU Cluster and Sweet Red Cherry Pickling x KAU Cluster were 8 cm, 8.2 cm and 9.1 cm respectively. Fruits in the F_2 of Hybrid Pepper Bell Boy x KAU Cluster were longer than both of its parents whereas in Cubanelle x KAU Cluster and Sweet Red Cherry Pickling x KAU Cluster, it was significantly shorter than their better parents, Cubanelle (10.1 cm) and Sweet Red Cherry Pickling (12.2 cm) respectively. The F_2s exhibited significant positive heterosis over Bharat F_1 Hybrid ranging from 12.7% to 28.5% and 29% to 46.7% over Pant C-1.

8. Fruit Perimeter

The F_2s showed significant negative heterosis over their better parents, mid-parents and the check variety, Bharat F_1 Hybrid and significant positive heterosis over Pant C-1. The fruit perimeter in bell pepper parents ranged from 9.9cm (Sweet Red Cherry Pickling) to 16.3 (Hybrid Pepper Bell Boy). In the F_2 hybrids it ranged from 5.5 cm to 6.4 cm.

9. Fruits/plant

KAU Cluster had the maximum fruits/plant (140.5), followed by Pant C-1 (130.6) and in bell pepper lines, it ranged from 6.3 in Hybrid Pepper Bell Boy to 11.2 in Sweet Red Cherry Pickling. The F_2s were intermediate to their parents, where the fruits/plant ranged from 29.9 to 36.7 and they all exhibited significantly negative heterobeltiosis, relative heterosis and standard heterosis over Pant C-1.

10. Green fruit yield/plant

Average fruit yield in the F_2 of Sweet Red Cherry Pickling x KAU Cluster (224.7 g/plant), Cubanelle x KAU Cluster (195.6 g/plant) and Hybrid Pepper Bell Boy x KAU Cluster (189.8 g/plant) were more than their common parent KAU Cluster (180.8 g/plant) but lesser than their respective bell pepper parents. The bell pepper parents had yield/plant ranging from 217.5 g (Hybrid Pepper Bell Boy) to 281 g (Sweet Red Cherry Pickling) and the hterobeltiosis ranged from -12.7% to -20.0% but it was significant in no case.

Table 6. Mean performance of parents and F_2s and extent of heterobeltiosis (BP), relative heterosis (MP) and standard heterosis (SV) over Bharat F_1 Hybrid and Pant C-1.

Lines	Days to flower					Days to green fruit harvest				
	Mean performance	BP(%)	MP(%)	SV(%)		Mean performance	BP(%)	MP(%)	SV(%)	
				Bharat F_1 Hybrid	Pant C-1				Bharat F_1 Hybrid	Pant C-1
Parents:										
Bharat F_1 Hybrid	39.7					54.4				
Pant C-1	42.1					65.7				
KAU Cluster	36.1					59.1				
Sweet Red Cherry Pickling	35.5					49.1				
Hybrid Pepper Bell Boy	41.7					63.0				
Cubanelle	36.5					51.5				
F_2 hybrids:										
Sweet Red Cherry Pickling x KAU Cluster	37.1	+4.5	+3.5	-6.5	-11.8*	59.8	+21.7**	-10.4**	+9.9*	-8.9*
Hybrid Pepper Bell Boy x KAU Cluster	37.1	+2.7	-1.0	-6.5	-11.8*	60.6	+2.5	-0.6	+11.4*	-7.6**
Cubanelle x KAU Cluster	37.5	+3.9	+4.5	-5.5	-10.9*	62.1	+20.6**	+12.2**	+14.0*	-5.4

* and ** significant at 5% and 1% levels respectively

Table 6. (Contd.)

Lines	Days to fruit ripening					Plant height				
	Mean performance	BP(%)	MP(%)	SV(%)		Mean performance (cm)	BP(%)	MP(%)	SV(%)	
				Bharat F_1 Hybrid	Pant C-1				Bharat F_1 Hybrid	Pant C-1
Parents:										
Bharat F_1 Hybrid	82.9					42.3				
Pant C-1	81.6					58.1				
KAU Cluster	77.9					49.8				
Sweet Red Cherry Pickling	66.3					51.6				
Hybrid Pepper Bell Boy	81.2					38.1				
Cubanelle	74.8					47.9				
F_2 hybrids:										
Sweet Red Cherry Pickling x KAU Cluster	76.6	+15.6**	+6.3*	-7.8*	-6.0**	57.2	+10.8	+12.8*	+35.2**	-1.5
Hybrid Pepper Bell Boy x KAU Cluster	76.5	-1.8	-3.8	-7.7	-6.1	47.8	-4.0	+8.8	+13.0	-17.7
Cubanelle x KAU Cluster	78.6	+5.1	+2.9	-5.2	-3.6	52.1	+4.6	+6.6	+23.1**	-10.3

Table 6.(Contd.)

Lines	Secondary branches/plant					Pedicel length				
	Mean performance	BP(%)	MP(%)	SV(%)		Mean performance (cm)	BP(%)	MP(%)	SV(%)	
				Bharat F_1 Hybrid	Pant C-1				Bharat F_1 Hybrid	Pant C-1
Parents:										
Bharat F_1 Hybrid	3.9					3.9				
Pant C-1	9.1					2.9				
KAU Cluster	11.3					2.8				
Sweet Red Cherry Pickling	5.1					3.9				
Hybrid pepper Bell Boy	3.9					3.8				
Cubanelle	4.9					3.8				
F_2 hybrids:										
Sweet Red Cherry Pickling x KAU Cluster	6.1	-46.0**	-25.1**	+56.4**	-32.9**	3.2	-17.9**	-4.9	-17.9**	+10.3*
Hybrid Pepper Bell Boy x KAU Cluster	6.6	-41.6**	-13.4**	+69.2**	-27.5**	3.3	-13.2**	-0.5	-15.4**	+13.8*
Cubanelle x KAU Cluster	6.1	-46.0**	-23.8**	+56.4**	-32.9**	3.1	-18.4**	-6.6	-20.5**	+6.8*

Table 6. (Contd.)

Lines	Fruit length					Fruit perimeter				
	Mean performance (cm)	BP(%)	MP(%)	SV(%)		Mean performance (cm)	BP(%)	MP(%)	SV(%)	
				Bharat F_1 Hybrid	Pant C-1				Bharat F_1 Hybrid	Pant C-1
Parents:										
Bharat F_1 Hybrid	7.1					19.1				
Pant C-1	6.2					3.4				
KAU Cluster	5.3					3.4				
Sweet Red Cherry Pickling	12.2					9.9				
Hybrid Pepper Bell Boy	6.4					16.3				
Cubanelle	10.1					10.5				
F_2 hybrids:										
Sweet Red Cherry Pickling x KAU Cluster	9.1	-25.4**	+4.5	+28.5**	+46.7**	5.5	-44.4**	-17.1**	-71.2**	+61.7**
Hybrid Pepper Bell Boy x KAU Cluster	8.0	+25.0**	+37.4**	+12.7**	+29.0**	6.4	-60.8**	-34.9**	-66.5**	+88.2**
Cubanelle x KAU Cluster	8.2	-18.8**	+6.4	+15.5**	+32.2**	5.5	-47.6**	-20.0**	-71.2**	+61.7**

Table 6.(Contd.)

Lines	Fruits/plant					Green fruit yield/plant				
	Mean performance	BP(%)	MP(%)	SV(%)		Mean performance (g)	BP(%)	MP(%)	SV(%)	
				Bharat F_1 Hybrid	Pant C-1				Bharat F_1 Hybrid	Pant C-1
Parents:										
Bharat F_1 Hybrids	4.4					233.0				
Pant C-1	130.6					174.0				
KAU Cluster	140.5					180.8				
Sweet Red Cherry Pickling	11.2					281.0				
Hybrid Pepper Bell Boy	6.3					217.5				
Cubanelle	10.3					229.3				
F_2 hybrids:										
Sweet Red Cherry Pickling x KAU Cluster	36.7	-73.8**	-51.5**	+734.1**	-71.8**	224.7	-20.0	-2.7	-3.6	+29.1*
Hybrid Pepper Bell Boy x KAU Cluster	29.9	-78.7**	-59.2**	+579.5**	-77.1**	189.8	-12.7	-4.6	-18.5	+9.1
Cubanelle x KAU Cluster	36.1	-74.3**	-52.1**	+720.4**	-72.3**	195.6	-14.6	-4.5	-16.0	+12.4*

Table 6. (Concl.)

Lines	Dry fruit yield/plant				
	Mean Performance (g)	BP(%)	MP(%)	SV(%)	
				Bharat F_1 Hybrid	Pant C-1
Parents:					
Bharat F_1 Hybrid	22.0				
Pant C-1	33.5				
KAU Cluster	41.9				
Sweet Red Cherry Pickling	29.5				
Hybrid Pepper Bell Boy	18.7				
Cubanelle	23.9				
F_1 hybrids:					
Sweet Red Cherry Pickling x KAU Cluster	33.9	-19.1	-4.9	+54.1*	+1.2
Hybrid Pepper Bell Boy x KAU Cluster	28.4	-32.2**	-6.2	+29.1*	-15.1
Cubanelle x KAU Cluster	29.3	-30.1*	-11.04	+33.1*	-12.5

11. Dry fruit yield/plant

KAU Cluster had the maximum dry fruit yield/plant (41.9g) The F_2 hybrids did not show positive heterosis over the better parent or mid-parent. All the F_2 hybrids exceeded their bell pepper parents and Bharat F_1 Hybrid. The dry fruit yield/plant in bell pepper parents ranged from 18.7 g (Hybrid Pepper Bell Boy) to 29.5 g (Sweet Red Cherry Pickling). The F_2 hybrids ranged from 28.4g/plant in Hybrid Pepper Bell Boy x KAU Cluster to 33.9 g in Sweet Red Cherry Pickling x KAU Cluster.

D. Genetics of cluster bearing habit in intervarietal crosses involving Capsicum annuum var. grossum and Capsicum annuum var. fasciculatum

The parents, F_1s and segregating populations (F_2, BC_1 and BC_2) were critically observed for solitary and cluster bearing types.

1. Parents

A total of 30 plants each in KAU Cluster, Early Calwonder and 672-Hungarian wax, 20 plants in Sweet Red Cherry Pickling and 15 plants in Hybrid Pepper Bell Boy were observed for the bearing habit. Early Calwonder, 672-Hungarian wax, Sweet Red Cherry Pickling and Hybrid Pepper Bell Boy showed predominantly solitary flowering and fruiting habits. There were two flowers at the main forking point, which developed into solitary fruits or no fruits at all.

KAU Cluster, the source for cluster bearing habit, was a predominantly cluster type producing flowers and fruits in clusters. In this line the main shoot terminated in an inflorescence. The vegetative growth continued rarely by the development of one or two side branches, which again terminated in inflorescences. Further growth was mainly through axillary shoots developing from the main stem and sub-axillary shoots developing from axillary shoots. All the axillary and sub-axillary shoots again terminated in inforescences. On an average there were 13.1 axillary shoots within a range of 8 to 16.

Shedding of flowers and immature fruits is a serious disorder in KAU Cluster. Five flower clusters were randomly selected in each of the 26 plants of KAU Cluster to study flower and fruit formation in clusters (Table 7). Flowers/cluster ranged from 4.5 to 12.3 with an average of 7.4. On an average 5.4 fruits were developed/cluster and it ranged from 2.8 to 8.5. The flowers observed were normal, either long styled or medium styled. Although KAU Cluster showed a predominantly cluster flowering and fruiting habit, occasional solitary fruits were also observed towards the end of the crop in a few plants.

2. F_1 hybrids

Thirty plants each were observed in F_1 hybrids. Early

Table 7. Flower and fruit formation in the clustered bearing line, KAU Cluster

Plant No.	Flowers/ cluster	Fruits/ cluster	Fruits over flowers/ cluster (%)
1.	7.8	6.0	76.9
2	7.5	4.8	64.0
3	6.4	3.8	59.4
4	6.0	4.5	75.0
5	4.5	2.8	62.2
6	7.3	4.5	61.6
7	7.4	5.4	73.0
8	6.5	5.0	76.9
9	7.3	5.8	79.4
10	6.6	5.8	87.9
11	5.8	4.0	68.9
12	6.4	3.6	56.3
13	7.6	5.4	71.1
14	6.3	4.5	71.4
15	7.2	6.0	83.3
16	8.2	5.4	65.8
17	7.4	5.4	73.0
18	6.4	4.6	71.9
19	8.0	6.5	81.3
20	7.0	5.6	80.0
21	11.0	8.5	77.3
22	7.4	6.2	83.8
23	7.2	6.4	88.9
24	9.3	7.0	75.3
25	7.2	5.8	80.5
26	12.3	7.8	63.4
Mean	7.4	5.4	73.4

Calwonder x KAU Cluster, KAU Cluster x Early Calwonder, 672-Hungarian Wax x KAU Cluster, KAU Cluster x 672-Hungarian Wax, Sweet Red Cherry Pickling x KAU Cluster and Hybrid Pepper Bell Boy x KAU Cluster. All the F_1 hybrids had solitary flowering and fruiting habits. The direct and reciprocal crosses did not differ for the bearing habit.

3. Segregating populations

a. Early Calwonder x KAU Cluster

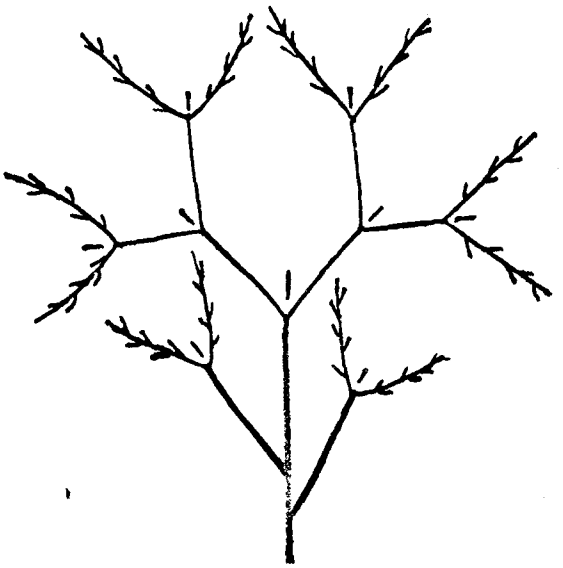
Early Calwonder, KAU Cluster, their F_1s, F_2s, BC_1s and BC_2s were classified cluster and solitary (Table 8). There were 388 solitary and 104 cluster types among the 492 F_2 plants examined. The segregation in F_2 fitted a 13:3 ratio ($\chi^2 = 1.841$, $0.2 > P > 0.1$). The back cross generation (BC_1) had all the 457 plants solitary. This fitted well to the expected 1:0 ratio ($\chi^2 = 0$, $P = 1$). In the BC_2 generation, 207 plants were solitary and 203 cluster, which fitted a 1:1 ratio ($\chi^2 = 0.039$, $0.9 > P > 0.8$).

The cluster types in the segregating populations (F_2 and BC_2) were further classified into true cluster, occasional solitary and occasional cluster groups (Fig. 1, Table 9).

Table 8. Genetics of clusterness in hybrids involving Early Calwonder and KAU Cluster.

Generations	No. of plants			Expected phenotypic ratio	X^2	P
	Solitary	Cluster	Total			
Parents:						
Early Calwonder	30	—	30			
KAU Cluster	—	30	30			
F_1s:						
Early Calwonder x KAU Cluster	30	—	30			
KAU Cluster x Early Calwonder	30	—	30			
F_2:						
Early Calwonder x KAU Cluster	388	104	492	13:3	1.841	0.1–0.2
BC_1:						
(Early Calwonder x KAU Cluster) x Early Calwonder	457	—	457	1:0	0	1.0
BC_2:						
(Early Calwonder x KAU Cluster) x KAU Cluster	207	203	410	1:1	0.039	0.8–0.9

Fig : 1



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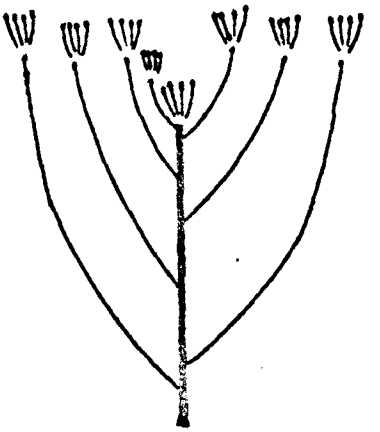

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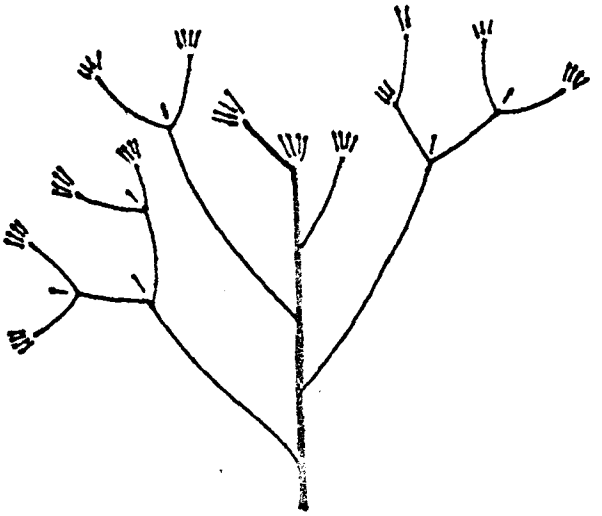

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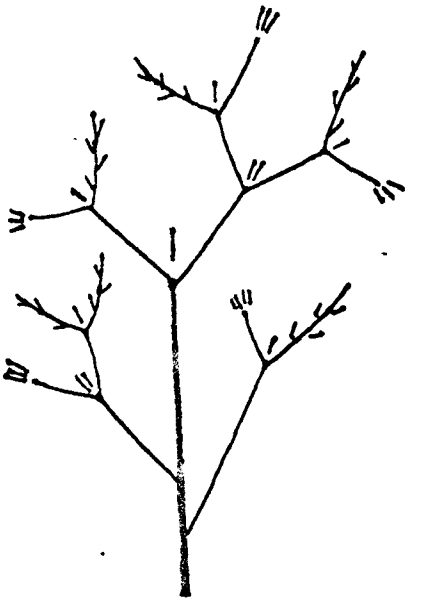

d

Table 9. Number of true cluster, occasional solitary and occasional cluster plants in the F_2 and BC_2 populations of Early Calwonder x KAU Cluster

Generations	True cluster	Occasional solitary	Occasional cluster	Total
F_2	32	36	32	100
BC_2	123	58	17	198

The cluster plants in the F_2 and BC_2 populations were further classified based on average fruits/cluster. Flower clusters were randomly tagged and counts were made on fruits developed/cluster. It ranged from 0.5 to 5.9 fruits/cluster in F_2 population with an average of 2.6 fruits/cluster. In the BC_2 population there wer 3.6 fruits/cluster on an average within a range of 1.0 to 9.4.

A frequency distribution of plants based on fruits/cluster was attempted with a class interval of 0.5 (Table 10). Ninety six cluster plants in the F_2 population were grouped into 11 classes. Eighteen plants fell in the 1.5-1.9 class, 23 in the 2.0-2.4 class, 15 in the 2.5-2.9 class and 12 in the 3.0-3.4 class. In the BC_2 generation 186 cluster plants were grouped into 17 classes. The class with 5.0-5.4 fruits/cluster was the median class, 38 plants fell in the class 3.0-3.4 and 35 in the 4.0-4.4 class.

Table 10. Frequency distribution of clustered plants in F_2 and BC_2 generations of Early Calwonder x KAU Cluster

Classes	F_2		BC_2	
	fre-quency	Percentage of plants	fre-quency	Percentage of plants
0.5 - 0.9	3	3.1		
1.0 - 1.4	7	7.3	6	3.2
1.5 - 1.9	18	18.8	8	4.3
2.0 - 2.4	23	23.9	16	8.6
2.5 - 2.9	15	15.6	26	14.0
3.0 - 3.4	12	12.5	38	20.4
3.5 - 3.9	7	7.3	19	10.2
4.0 - 4.4	4	4.2	35	18.8
4.5 - 4.9	4	4.2	13	7.0
5.0 - 5.4	2	2.1	11	5.9
5.5 - 5.9	1	1.0	3	1.6
6.0 - 6.4			5	2.7
6.5 - 6.9			1	0.5
7.0 - 7.4			2	1.1
7.5 - 7.9			0	—
8.0 - 8.4			2	1.1
8.5 - 8.9			0	—
9.0 - 9.4			1	0.5
Total	96		186	

b. 672-Hungarian Wax x KAU Cluster

672-Hungarian Wax, KAU Cluster, their F_1s, F_2s, BC_1s, and BC_2s were classified into solitary and cluster groups (Table 11). Out of the 462 plants observed in the F_2, 356 were solitary and 106 were cluster and this was in agreement with a 3:1 ratio (χ^2 = 1.0417, $0.5 > P > 0.3$). All the 441 plants in the BC_1 population were solitary. This fitted well to the expected 1:0 ratio (χ^2 = 0, P = 1). There were 261 solitary and 212 cluster types among the 473 plants examined in BC_2, which fitted a 1:1 ratio (χ^2 = 5.076, $0.05 > P > 0.02$)

Based on the proportion of fruits produced in clusters to the total fruits produced in a plant, the cluster types in the segregating populations (F_2 and BC_2) were further classified into true cluster, occasional solitary and occasional cluster groups (Table 12).

Table 12. Number of true cluster, occasional solitary and occasional cluster plants in the F_2 and BC_2 populations of 672-Hungarian Wax x KAU Cluster

Generations	True cluster	Occasional solitary	Occasional cluster	Total
F_2	42	43	14	99
BC_2	134	54	3	193

Table 11. Genetics of clusterness in hybrids involving 672-Hungarian wax and KAU Cluster

Generations	No. of plants			Expected phenotypic ratio	χ^2	P
	Solitary	Cluster	Total			
Parents:						
672-Hungarian wax	30	—	30			
KAU Cluster	—	30	30			
F_1s:						
672-Hungarian wax x KAU Cluster	30	—	30			
KAU Cluster x 672-Hungarian wax	30	—	30			
F_2:						
672-Hungarian wax x KAU Cluster	356	106	462	3:1	1.0417	0.3-0.5
BC_1:						
(672-Hungarian wax x KAU Cluster) x 672-Hungarian wax	441	—	441	1:0	0	1.0
BC_2:						
(672-Hungarian wax x KAU Cluster) x KAU Cluster	261	212	473	1:1	5.076*	0.02-0.05

* Significant at P 0.05.

The cluster plants in the F_2 and BC_2 populations were further classified based on average fruits/cluster. In the F_2 population, fruits/cluster ranged from 1.0 to 6.5 with an average of 2.9. In the BC_2 population, there were 3.7 fruits/cluster within a range of 0.7 to 7.0.

A frequency distribution was attempted with a class interval of 0.5 (Table 13). The 99 F_2 plants with cluster bearing habit were grouped into 12 classes. Twenty one plants were in the class 2.0-2.4 fruits/cluster, 9 in the 2.5-2.9 class, and 26 in the 3.0-3.4 class. In the BC_2 generation 193 plants were grouped into 14 classes. There were 41 plants in the class 3.0-3.4, 25 in 3.5-3.9 class and 38 in 4.0-4.4 class.

c. Sweet Red Cherry Pickling x KAU Cluster

Classification into solitary and cluster bearing groups were made in the parental, F_1 and F_2 populations (Table 14). Out of the 45 plants observed in the F_2, 39 were solitary and 6 cluster. This was in agreement with a 13:3 ratio ($\chi^2 = 0.869$, $0.5 > P > 0.3$). No true cluster types were observed in the F_2 population.

d. Hybrid Pepper Bell Boy x KAU Cluster

The breeding behaviour of Hybrid Pepper Bell Boy, KAU Cluster, its F_1 and F_2 populations are given in Table 14.

Table 13. Frequency distribution of clustered plants in F_2 and BC_2 generations of 672-Hungarian Wax x KAU Cluster

Classes	F_2		BC_2	
	frequency	Percentage of plants	frequency	Percentage of plants
0.5 - 0.9	-	-	1	0.5
1.0 - 1.4	7	7.1	2	1.0
1.5 - 1.9	11	11.1	1	0.5
2.0 - 2.4	21	21.2	22	11.4
2.5 - 2.9	9	9.1	18	9.3
3.0 - 3.4	26	26.3	41	21.2
3.5 - 3.9	9	9.1	25	13.0
4.0 - 4.4	9	9.1	38	19.7
4.5 - 4.9	1	1.0	17	8.8
5.0 - 5.4	3	3.0	17	8.8
5.5 - 5.9	1	1.0	5	2.6
6.0 - 6.4	1	1.0	3	1.5
6.5 - 6.9	1	1.0	2	1.0
7.0 - 7.4	-	-	1	0.5
Total	99		193	

Table 14. Genetics of clusterness in Sweet Red Cherry Pickling x KAU Cluster and Hybrid Pepper Bell Boy x KAU Cluster

Generations	No. of plants			Expected phenotypic ratio	χ^2	P
	Solitary	Cluster	Total			
Parents:						
Sweet Red Cherry Pickling	20	—	20			
Hybrid Pepper Bell Boy	15	—	15			
KAU Cluster	—	30	30			
F_1s:						
Sweet Red Cherry Pickling x KAU Cluster	30	—	30			
Hybrid Pepper Bell Boy x KAU Cluster	30	—	30			
F_2s:						
Sweet Red Cherry Pickling x KAU Cluster	39	6	45	13:3	0.869	0.3-0.5
Hybrid Pepper Bell Boy x KAU Cluster	153	25	178	13:3	2.586	0.1-0.2

There were 153 solitary and 25 cluster types among the 178 F_2 plants observed which showed agreement to a 13:3 ratio (X^2 = 2.586, $0.2 > P > 0.1$). In the F_2 population there were true cluster, occasional solitary and occasional cluster types within the cluster group.

e. Half-sibs: (672-Hungarian Wax x KAU Cluster) x (Early Calwonder x KAU Cluster)

In this segregating population 122 plants were examined. There were 84 solitary and 28 cluster plants (Table 15). The segregation showed a good fit to the expected 3:1 ratio. (X^2 = 0, P = 1)

E. Identification of elite cluster types for further trials

The F_2 population of Early Calwonder x KAU Cluster, 672-Hungarian Wax x KAU Cluster, Sweet Red Cherry Pickling x KAU Cluster and Hybrid Pepper Bell Boy x KAU Cluster were critically examined and elite cluster types were identified and progressed through pure line selection. The description of the selected lines are given in Appendix-II.

From Early Calwonder x KAU Cluster F_2, 23 lines were selected. Forty four lines were selected from the F_2 of 672-Hungarian Wax x KAU Cluster. Only one promising line was found in

Table 15. Genetics of clusterness in Early Calwonder x KAU Cluster and 672-Hungarian Wax x KAU Cluster and the half-sib involving them

Generations	No. of plants			Expected Phenotypic ratio	χ^2	P
	Solitary	Cluster	Total			
Parents:						
Early Calwonder	30	—	30			
672-Hungarian Wax	30	—	30			
KAU Cluster	—	30	30			
F_1s:						
Early Calwonder x KAU Cluster	30	—	30			
KAU Cluster x Early Calwonder	30	—	30			
672-Hungarian Wax x KAU Cluster	30	—	30			
KAU Cluster x 672-Hungarian Wax	30	—	30			
F_2s:						
Early Calwonder x KAU Cluster	388	104	492	13:3	1.841	0.1-0.2
672-Hungarian Wax x KAU Cluster	356	106	462	3 :1	1.0417	0.3-0.5
Half-sibs:						
(672-Hungarian Wax x KAU Cluster) x (Early Calwonder x KAU Cluster)	84	28	122	3:1	0	1.0

Sweet Red Cherry Pickling x KAU Cluster F_2. Seven lines were selected from Hybrid Pepper Bell Boy x KAU Cluster F_2.

F. Assessing the extent of damage from bacterial wilt and selecting resistant line(s), if any

Percent wilt incidence based on plants established in the field at first harvest stage and at 100 days from transplanting, are presented in Table 16.

1. Wilt incidence at first harvest stage.

Disease incidence in KAU Cluster, 672-Hungarian wax, Hybrid Pepper Bell Boy, Early Calwonder and Cubanelle were 3.7%, 7.5%, 15%, 15.5% and 18.9% respectively. The F_1 hybrids, Hybrid Pepper Bell Boy x KAU Cluster, Early Calwonder x KAU Cluster and Cubanelle x KAU Cluster also showed lesser than 20% disease incidence. Pant C-1, Bharat F_1 Hybrid and the F_1s, Sweet Red Cherry Pickling x KAU Cluster and 672-Hungarian Wax x KAU Cluster were moderately resistant. Yolo Wonder Improved (61.1%) was susceptible to bacterial wilt.

2. Wilt incidence at 100 days from transplanting

KAU Cluster showed a wilt incidence of only 14.4%. Early Calwonder (30.8%), 672-Hungarian Wax (33.3%), Cubanelle (36.9%) and the F_1 hybrids, Early Calwonder x KAU Cluster

Table 16. Bacterial wilt incidence in bell peppers, hot chillies and crosses among them

Lines	Wilt incidence at first harvest stage		Wilt incidence at 100 days from transplanting	
	(%)	Scoring as per Mew and Ho (1976)	(%)	Scoring as per Mew and Ho (1976)
Hot Chillies:				
Pant C-1	25.0	MR	49.4	MS
KAU Cluster	3.7	R	14.4	R
Bell Peppers:				
Bharat F_1 Hybrid	31.0	MR	78.2	S
Yolo Wonder Improved	61.1	S	72.2	S
Sweet Red Cherry Pickling	53.1	MS	80.2	S
Hybrid Pepper Bell Boy	15.0	R	60.0	S
Early Calwonder	15.5	R	30.8	MR
Cubanelle	18.9	R	36.9	MR
672-Hungarian Wax	7.5	R	33.3	MR
F_1 hybrids:				
Yolo Wonder Improved x KAU Cluster	48.5	MS	78.5	S
Sweet Red Cherry Pickling x KAU Cluster	29.4	MR	47.8	MS
Hybrid Pepper Bell Boy x KAU Cluster	15.7	R	39.1	MR
Early Calwonder x KAU Cluster	18.4	R	21.9	MR
Cubanelle x KAU Cluster	15.0	R	41.9	MS
672-Hungarian Wax x KAU Cluster	23.6	MR	44.0	MS
Sem. ±	9.6		10.7	
CD (P = 0.05)	27.9		31.1	

(21.9%) and Hybrid Pepper Bell Boy x KAU Cluster (39.1%) were moderately resistant. Hybrid Pepper Bell Boy, Yolo Wonder Improved, Bharat F_1 Hybrid, Sweet Red Cherry Pickling, and the F_1 hybrid, Yolo Wonder Improved x KAU Cluster were susceptible to the extent of 60%, 72.2%, 78.2%, 80.2% and 78.2% respectively.

DISCUSSION

Bell pepper, Capsicum annuum var. grossum is a recently introduced crop to Kerala. It grows well in a relatively cool climate and is suited for growing in hills during summer (Hosmani, 1982). Dry weather is necessary during fruit maturity of the crop. The ideal temperature for fruit set ranges from 11°C to 18°C (Cochran, 1936). High day temperature (20°C to 24°C) and low light intensity (30% shade) promote flower drop (Rylski and Halevy, 1974). Joshi and Singh (1975) report that water logging even for a short period is harmful to the crop. The ideal soil pH is 6 to 6.5. The above requirements of bell peppers make it a difficult crop to be grown under the warm humid and tropical conditions of Kerala, especially in the coastal tracts and mid-lands. September to February months would only be the possible season for the crop. Unlike bell peppers, hot chillies are grown throughout the year under high warm humid and tropical conditions. The hot chillies set fruits even at a high temperature of 35°C to 37°C. The variety KAU Cluster (Fig.2) is grown under high temperature and high humid conditions. Any attempt to transfer the adaptable and hot-set genes to bell peppers would largely be welcomed. Peter et al. (1984) reported multiple disease resistance in KAU Cluster, especially against Pseudomonas solanacearum, Phytophthora capsici and Meloidogyne incognita. The usefulness of involving the line KAU Cluster in hybrid breeding programmes is thus obviously explicit.

Heterosis is being commercially exploited in bell peppers. The Bharat F_1 Hybrid has become recently popular in India. Any attempt on heterosis breeding in bell peppers making use of the adaptable local lines would be a desirable step. The high cost of F_1 hybrids has always been a limiting factor in the growing of hybrid bell peppers by the marginal chilli farmers. Information on retentivity of heterosis in F_2 generations assumes importance in this context.

It has been worked out that 20% of the total cost of cultivation is exclusively for harvesting fruits. Therefore development of cluster bell peppers assumes importance. The concept of cluster bell peppers has been lauded as revolutionary (Webb, 1984 and Van den berg, 1985 Personal communications). Considerable increase in yield levels, in the cluster plant types is quite evident. Information on genetics of clusterness has to be gathered a priori to any effective breeding programme. The present studies were designed to draw information on the above aspects, making use of six newly introduced bell pepper lines from the Vegetable Laboratory, Horticultural Science Institute, BARC-W, Beltsville, U.S.A. and the line KAU Cluster, identified at Kerala Agricultural University.

Among the seven bell pepper lines evaluated, the varieties Sweet Red Cherry Pickling, Hybrid Pepper Bell Boy, Yolo Wonder Improved and Bharat F_1 Hybrid saccumbed to bacterial

wilt. The above four varieties are not suited to wilt prone areas. The varieties 672-Hungarian Wax (Fig.3), Early Calwonder (Fig.4) and Cubanelle were found promising. The line 672-Hungarian Wax yielded 226.1 g/plant during April to August, 1984, compared to 117.2 g in Early Calwonder, 129.3 g in Cubanelle and 189.4 g in KAU Cluster. During August to January, 1984-'85, 672-Hungarian Wax, Early Calwonder and KAU Cluster yielded 589.9 g, 551.7 g and 168.6 g/plant respectively. The stability in performance of these lines needs to be studied further.

The F_1 hybrids were better in yield and earlier to flower compared to the common parent, KAU Cluster. The higher yield coupled with earliness in F_1 hybrids enhances crop profitability. The green fruit harvest is also earlier in the F_1 hybrids. The phenomenon of heterosis was conspicuously evident in the hybrids developed in the present study (Table 17). The hybrid, 672-Hungarian Wax x KAU Cluster (Fig. 5) with desirable plant and fruit characteristics was the most promising.

The retentivity of heterosis in F_2 generation was also studied (Table 18). The F_2 hybrids would evidently yield more than the parents and could be grown for general purpose marketing. The agronomic uniformity of the plants and the physical uniformity of the produce need to be practically assessed.

Table 17. Number of F_1 hybrids exhibiting desirable heterosis over Pant C-1

	Economic characters			
	Days to harvest	Fruits/plant	Fruit weight	Yield/plant
Number of F_1 hybrids with desirables heterosis	5	Nil	6	5
Name of the most outstanding hybrid	Early Calwonder x KAU Cluster	---	Early Calwonder x KAU Cluster	Hybrid Pepper Bell Boy x KAU Cluster

Table 18. Number of F_2 hybrids exhibiting desirable heterosis over Panc C-1.

	Economic characters		
	Days to harvest	Fruits/plant	Green fruit yield/plant
Number of F_2 hybrids with desirable heterosis.	2	Nil	2
Name of the most outstanding F_2 hybrid	Sweet Red Cherry Pickling x KAU Cluster	--	Sweet Red Cherry Pickling x KAU Cluster

The genetics of clusterness revealed definite information. The F_1s showed the dominance of solitary bearing habit. Cluster habit is controlled by two genes with a dominant and recessive epistatic gene action. This is proved through a 13 solitary : 3 cluster ratio in the F_2s of Early Calwonder x KAU Cluster, Sweet Red Cherry Pickling x KAU Cluster and Hybrid Pepper Bell Boy x KAU Cluster and a 1:0 (solitary:cluster) ratio in BC_1 and 1:1 (solitary: cluster) ratio in BC_2 of Early Calwonder x KAU Cluster. The F_2 segregation in 672-Hungarian Wax x KAU Cluster indicated a 3 solitary : 1 cluster ratio. This ratio is expected considering dominant homozygosity at both loci in 672-Hungarian Wax. This further confirmed the dijenic inheritance for clusterness. The direct and reciprocal F_1 crosses did not differ for the bearing habit suggesting the absence of cytoplasmic effect.

The genes responsible for the bearing habit are tentatively named Cl_1 - cl_1 and Cl_2 - cl_2, with a dominant and recessive epistasis in the same gene action. Cl_2 is epistatic over Cl_1 and cl_1 (dominant epistasis) and cl_1 is epistatic over Cl_2 and cl_2 (recessive epistasis) in the same gene interaction. The genotypes are thus worked out as

KAU Cluster	$Cl_1Cl_1cl_2cl_2$	-	Cluster
Early Calwonder	$cl_1cl_1Cl_2Cl_2$	-	Solitary
Sweet Red Cherry Pickling	$cl_1cl_1Cl_2Cl_2$	-	Solitary

Hybrid Pepper Bell $Cl_1Cl_1Cl_2Cl_2$ - Solitary Boy

672-Hungarian Wax $Cl_1Cl_1Cl_2Cl_2$ - Solitary

The ratios obtained in the half-sib (672-Hungarian Wax x KAU Cluster) x (Early Calwonder x KAU Cluster) progenies also confirmed the digenic inheritance (Table 19).

Clusterness in cluster plants seem to show a continuous variation. The frequency distribution based on fruits/cluster in cluster types indicated a normal distribution. But the genetic analysis of polygenic inheritance of this character indicated the major role of environment in the expression of this character, as there was more variance among the parents compared to the F_2s. This aspect needs to be studied further. The three classes in the cluster group have also resulted more through reasons of environment rather than genetic. This matter of instability has still to be perused.

Cluster bell peppers with desirable characters were identified and progressed (Figs. 6-9). The line KAU Cluster was observed resistant to bacterial wilt confirming the earlier reports by Peter et al. (1984).

Table 19. Genetics of clusterness and genotypes of bell peppers and KAU Cluster

	Early Calwonder x KAU Cluster		672-Hungarian Wax x KAU Cluster	
	$(cl_1cl_1Cl_2Cl_2)$	$(Cl_1Cl_1cl_2cl_2)$	$(Cl_1Cl_1Cl_2Cl_2)$	$(Cl_1Cl_1cl_2cl_2)$
F_1	$Cl_1cl_1Cl_2cl_2$	X	$Cl_1Cl_1Cl_2cl_2$	
		Half-sib 3:1		
F_2	13:3		3:1	
BC_1	1:0		1:0	
BC_2	1:1		1:1	

Hybrid Pepper Bell Boy x KAU Cluster			Sweet Red Cherry Pickling x KAU Cluster	
$(cl_1cl_1Cl_2Cl_2)$	$(Cl_1Cl_1cl_2cl_2)$		$(cl_1cl_1Cl_2Cl_2)$	$Cl_1Cl_1cl_2Cl_2)$
F_1	$Cl_1cl_1Cl_2cl_2$		$Cl_1cl_1Cl_2cl_2$	
F_2	13:3		13:3	

Fig. 2. Cluster bearing line, KAU Cluster (x 0.19)

Fig. 3. Bell pepper line, 672-Hungarian Wax (x 0.17)

Fig. 2

Fig. 3

Fig. 4. Bell pepper line, Early Calwonder (x 0.21)

Fig. 5. F_1 hybrid, 672-Hungarian Wax x KAU Cluster (x 0.16)

Fig. 4

Fig. 5

Fig. 6. Early Calwonder x KAU Cluster - 308 (x 0.22)

Fig. 7. Early Calwonder x KAU Cluster - 486 (x 0.21)

Fig. 6

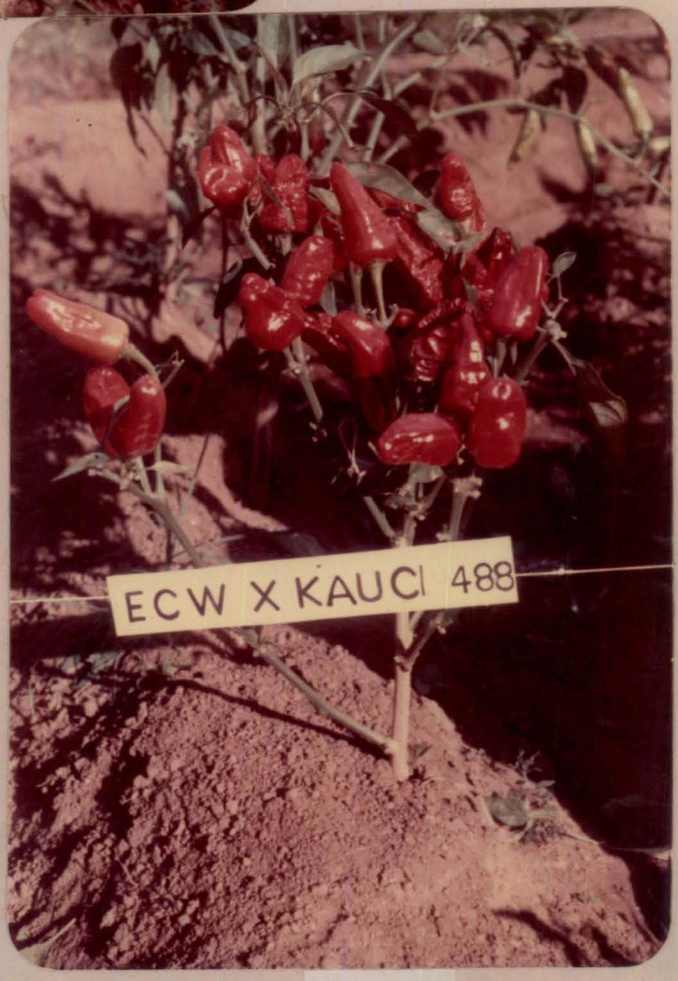

Fig. 7

Fig. 8. 672-Hungarian Wax x KAU Cluster - 406 (x0.25)

Fig. 9. 672-Hungarian Wax x KAU Cluster - 423 (x0.26)

Fig. 8

Fig. 9

January

SUMMARY

The present studies, 'Transfer of clusterness to bell peppers (*Capsicum annuum* L. var. *grossum* Sendt.)' were conducted in three seasons during September to February, 1983-'84, April to August, 1984 and August to January, 1984-'85, at the Instructional Farm of College of Horticulture, Vellanikkara, Trichur. The experiments consisted of six parts.

A. Testing the adaptability of selected bell pepper lines and F_1 hybrids involving bell peppers and hot chilli

B. Estimation of F_1 heterosis in intervarietal crosses involving bell peppers and hot chilli

C. Estimation of F_2 heterosis in intervarietal crosses

D. Studying the genetics of cluster bearing habit in inter-varietal crosses involving *Capsicum annuum* var. *grossum* and *Capsicum annuum* var. *fasciculatum*

E. Identification of elite cluster types for further trials and

F. Assessing the extent of damage from bacterial wilt and selecting resistant line(s), if any

The experimental materials comprised mainly of seven varieties of sweet peppers and two varieties of hot chillies.

2. The bell pepper varieties, Sweet Red Cherry Pickling, Hybrid Pepper Bell Boy, Yolo Wonder Improved and Bharat

F_1 Hybrid were highly susceptible to bacterial wilt. 672-Hungarian Wax, Cubanelle and Early Calwonder yielded fairly well under the warm humid tropic conditions. 672-Hungarian Wax took 113 days for first ripened fruit. It had the maximum fruit length (12.6 cm). Early Calwonder was the dwarfest (34.1 cm). 672-Hungarian Wax, Early Calwonder and Cubanelle are prospective varieties for Kerala.

3. Heterosis was observed in the intervarietal crosses 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. Hybrid Pepper Bell Boy x KAU Cluster yielded the highest (464.9 g/plant) during April to August, 1984, followed by 672-Hungarian Wax x KAU Cluster (410.5 g/plant) and Early Calwonder x KAU Cluster (396.6 g/plant). During August to January, 1984-'85, 672-Hungarian Wax x KAU Cluster yielded the highest (533 g/plant) followed by Early Calwonder x KAU Cluster (520 g/plant). The hybrid, 672-Hungarian Wax x KAU Cluster is found promising.

4. The F_2 heterosis was observed for days to green fruit harvest, days to fruit ripening, plant height, fruit length and green fruit yield/plant. F_2 heterosis was not significant for dry fruit yield/plant.

5. The cluster bearing habit is governed by two genes with a specific dominant and recessive epistasis in the same

gene interaction. The F_1s showed dominance of solitary bearing habit. No maternal effect was observed in the inheritance of this character. The F_2 segregations fitted well to a 13 (solitary) : 3 (cluster) ratio. The digenic inheritance of clusterness was confirmed by segregations in BC_1 and BC_2 generations. The genotypes of KAU Cluster ($Cl_1Cl_1cl_2cl_2$), Early Calwonder, ($cl_1cl_1Cl_2Cl_2$), Hybrid Pepper Bell Boy ($cl_1cl_1Cl_2Cl_2$), Sweet Red Cherry Pickling ($cl_1cl_1Cl_2Cl_2$) and 672-Hungarian Wax ($Cl_1Cl_1Cl_2Cl_2$) were worked out. The above segregation ratio was further confirmed through progenies of half-sib, (672-Hungarian Wax x KAU Cluster) x (Early Calwonder x KAU Cluster).

6. Cluster bell peppers with desirable characters are identified and progressed. The line, KAU Cluster was observed resistant to bacterial wilt.

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* Originals not seen

Appendices

Appendix - 1. Meteorological data during the period of experimentation

Year	Month	Temperature (°C)			RH (%)	Rainfall	
		Average Maximum	Average Minimum	Highest Maximum		Total (mm)	Rainy days
1983	September	29.5	23.4	31.0	84.0	494.6	24
1983	October	31.2	23.1	33.0	77.0	149.8	6
1983	November	31.8	22.3	33.5	71.0	60.2	3
1983	December	31.2	23.9	33.0	63.0	24.4	3
1984	January	32.4	23.3	34.5	58.0	0	0
1984	February	34.3	24.2	36.6	56.0	27.0	3
1984	March	35.2	24.3	39.8	67.0	18.9	2
1984	April	34.5	24.9	39.5	72.6	109.2	9
1984	May	34.5	25.8	37.0	71.0	40.6	6
1984	June	29.0	22.7	33.0	87.0	853.1	28
1984	July	28.6	22.9	30.8	87.0	730.4	24
1984	August	29.3	22.2	30.5	83.5	260.2	21
1984	September	30.4	23.2	32.6	68.2	158.6	7
1984	October	29.9	22.1	33.0	67.5	323.7	12
1984	November	32.1	23.1	33.8	54.4	7.8	1
1984	December	31.9	20.8	35.0	46.0	16.4	1

Source: Meteorological observatory, Vellanikkara.

Appendix-II. Description of the selected lines.

Pedigree	Line	Plant height (cm)	Cluster group	Flowers/ Cluster	Fruits/ cluster	Fruits/ plant	Solitary fruits	Fruit length (cm)	Fruit perimeter (cm)	Fruit orientation	Plant form
Early Calwonder/ KAU Cluster -	22	28	TC*	6.0	4.8	20	-	6.3	6.0	erect	compact
	25	16	TC	6.0	3.8	16	-	6.4	8.0	erect	compact
	81	43	TC	7.0	3.0	24	-	6.2	6.2	erect	compact
	91	37	TC	5.2	1.7	14	-	9.4	8.4	drooping	compact
	131	56	OS**	6.8	4.3	26	2	7.5	7.2	erect	spreading
	182	60	TC	5.3	2.0	35	-	6.0	10.0	drooping	spreading
	191	46	TC	6.3	4.3	32	-	5.7	7.5	erect	semi-compact
	195	60	OS	3.4	2.8	26	5	7.5	7.4	erect	spreading
	212	61	OS	4.0	1.6	19	4	7.5	14.0	erect	spreading
	218	33	TC	6.0	3.3	22	-	7.2	8.0	erect	compact
	225	39	TC	3.6	2.8	29	-	6.7	5.2	erect	compact
	286	42	OS	3.8	2.8	34	7	7.7	5.4	erect	semi-compact
	289	35	TC	3.4	3.0	20	-	6.5	7.0	erect	compact
	295	38	TC	6.5	3.0	6	-	6.0	7.6	erect	compact
	308	31	TC	7.4	5.2	55	-	4.9	6.6	erect	compact
	309	38	OS	5.2	3.2	43	6	7.2	6.1	erect	compact
	343	28	TC	3.2	2.4	26	-	7.6	6.0	erect	compact
	354	36	OS	5.3	4.3	21	4	7.8	10.0	drooping	semi-compact
	410	45	TC	4.4	3.0	39	-	5.0	6.6	erect	compact
	458	32	TC	4.6	3.6	21	-	9.5	6.7	drooping	compact
	477	52	TC	2.8	2.8	28	-	8.3	5.4	erect	spreading
	482	42	OS	3.8	3.4	34	4	8.3	8.3	erect	spreading
	488	36	OS	4.4	2.8	34	5	6.1	8.0	erect	semi-compact

TC* true cluster
OS** occasional solitary

Appendix-II. (Contd.)

Pedigree	Line	Plant height (cm)	Cluster group	Flowers/ Cluster	Fruits/ cluster	Fruits/ plant	Solitary fruits	Fruit length (cm)	Fruit perimeter (cm)	Fruit ofientation	Plant form
672-	9	18	TC	4.0	2.4	11	-	8.7	5.3	erect	compact
Hungarian	22	18	TC	7.0	5.7	7	-	6.5	6.4	erect	compact
Wax/KAU	37	40	TC	3.4	2.0	20	-	7.7	5.2	erect	semi-compact
Cluster -	38	48	TC	4.8	2.6	15	-	8.9	4.3	erect	compact
	49	44	TC	6.0	3.2	32	-	6.5	4.2	erect	semi-compact
	74	50	TC	5.2	3.8	38	-	7.6	6.7	erect	semi-compact
	78	33	OS	5.4	3.0	54	3	7.5	6.0	erect	semi-compact
	86	35	OS	3.5	1.5	15	3	8.1	4.1	erect	compact
	88	25	OS	4.3	3.0	42	3	9.9	4.5	erect	compact
	89	35	OS	4.8	3.2	48	3	8.0	4.0	erect	compact
	103	39	OS	6.3	3.3	18	2	7.4	5.4	erect	compact
	106	38	TC	5.4	3.6	25	-	8.5	5.0	erect	compact
	114	36	OS	4.6	3.2	26	3	9.0	5.2	erect	compact
	133	20	TC	4.8	2.4	24	-	7.5	6.5	erect	compact
	142	36	OS	5.4	5.2	48	2	8.4	6.7	erect	compact
	167	18	OS	4.2	3.4	16	2	8.2	4.2	erect	compact
	169	42	OS	5.0	3.2	18	1	10.7	6.4	erect	compact
	172	31	OS	5.6	3.2	36	3	10.3	6.0	erect	compact
	188	29	TC	3.8	1.8	9	-	9.8	5.4	erect	compact
	203	27	TC	3.4	3.0	30	-	9.6	4.8	erect	compact
	218	41	TC	7.6	6.4	38	-	8.3	5.2	erect	semi-compact
	228	42	OS	4.6	2.0	35	3	7.7	6.7	erect	semi-compact
	253	32	OS	4.8	4.6	29	2	8.9	6.3	erect	compact
	254	31	OS	3.3	3.0	23	4	10.0	4.8	erect	compact
	258	32	OS	3.6	3.4	33	4	8.0	5.9	erect	compact
	264	58	TC	5.8	3.8	32	-	9.2	5.4	erect	spreading
	269	20	TC	3.0	1.8	9	-	9.0	7.2	erect	compact

Appendix-II (Contd.)

Pedigree	Line	Plant height (cm)	Cluster group	Flowers/ cluster	Fruits/ cluster	Fruits/ plant	Solitary fruits	Fruit length (cm)	Fruit perimeter (cm)	Fruit orientation	Plant form
672-	272	43	OS	4.8	4.4	37	3	7.0	5.5	erect	compact
Hungarian	275	37	OS	4.8	2.8	20	2	6.5	7.5	erect	semi-compact
Wax/KAU	284	27	TC	5.2	3.2	18	-	10.3	4.8	erect	compact
Cluster -	288	51	TC	5.0	4.0	22	-	7.6	6.2	erect	semi-compact
	299	42	OS	5.8	3.0	39	3	9.4	5.2	erect	compact
	301	10	TC	3.2	1.0	4	-	8.1	5.1	erect	compact
	303	47	OS	3.2	2.0	44	2	8.7	6.2	erect	compact
	324	29	OS	3.8	2.0	17	2	11.0	6.6	erect	compact
	326	34	OS	6.4	4.4	41	4	8.1	5.0	erect	compact
	363	20	OS	3.0	2.6	16	1	9.5	7.0	erect	compact
	392	8	TC	4.2	2.0	12	-	5.5	6.0	erect	compact
	397	33	TC	5.2	2.8	22	-	6.4	6.3	erect	compact
	406	44	TC	5.2	4.2	33	-	6.5	5.6	erect	semi-compact
	423	31	TC	5.8	4.0	20	-	7.6	6.2	erect	compact
	428	43	TC	7.6	5.0	31	-	6.4	5.4	erect	compact
	447	36	OS	4.8	3.0	32	5	8.0	5.0	erect	compact
	472	34	TC	3.4	1.6	16	-	9.8	6.6	erect	compact
Sweet Red Cherry Pickling/ KAU											
Cluster -	30	29	OS	-	-	21	-	7.0	4.7	drooping	compact

Appendix-II. (concl.)

Pedigree	Line	Plant height (cm)	Cluster group	Flowers/ Cluster	Fruits/ cluster	Fruits/ plant	Solitary fruits	Fruit length (cm)	Fruit perimeter (cm)	Fruit orientation	Plant form
Hybrid Pepper Bell Boy/KAU Cluster	2	35	OS	-	-	30	4	11.5	5.0	drooping	compact
	11	43	PC	-	-	37	-	10.5	6.2	drooping	spreading
	36	26	OS	-	-	15	2	8.0	5.8	drooping	compact
	60	20	PC	-	-	8	-	10.4	10.0	drooping	compact
	79	26	OS	-	-	7	1	6.4	6.8	drooping	compact
	105	26	PC	-	-	20	-	7.3	6.8	drooping	compact
	134	24	PC	-	-	12	-	9.0	8.0	drooping	compact

TRANSFER OF CLUSTERNESS TO BELL PEPPERS

[Capsicum annuum L. var. grossum Sendt.]

By

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ABSTRACT OF A THESIS

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ABSTRACT

The present studies 'Transfer of clusterness to bell peppers (*Capsicum annuum* L. var. *grossum* Sendt.) were conducted during September to February, 1983-'84, April to August, 1984 and August to January, 1984-'85. Three bell pepper varieties, 672-Hungarian Wax, Early Calwonder and Cubanelle were found suitable to the warm humid tropical condition of Kerala. The F_1 hybrids involving bell peppers and the hot cluster chilli were also found suitable to the tract. All the hybrids yielded more than their better parents. The F_1 hybrids showed desirable heterosis for days to flower, days to green fruit harvest, days to fruit ripening, plant height, pedicel length, fruit length, fruit perimeter, fruit weight and yield/plant. 672-Hungarian Wax x KAU Cluster F_1 hybrid was the most promising with desirable plant and fruit characteristics. The F_2 heterosis was not significant for exploitation.

The solitary bearing habit was dominant over cluster habit. No maternal effect was observed in the inheritance of this character. The bearing habit was controlled by two genes with a specific dominant and recessive epistatic gene action. This was clearly proved through a 13 (solitary) : 3 (cluster) ratio in the F_2s of Early Calwonder x KAU Cluster,

Sweet Red Cherry Pickling x KAU Cluster and Hybrid Pepper Bell Boy x KAU Cluster. It was further confirmed through test crosses and half-sib crosses. The 3:1 (solitary:cluster) ratio obtained in 672-Hungarian Wax x KAU Cluster F_2 was attributed to homozygous dominant condition of both the genes in 672-Hungarian Wax. The genes for clusterness were tentatively named Cl_1-cl_1 and Cl_2-cl_2 with epistatic gene actions by Cl_2 and cl_1. The genotypes were thus worked out as KAU Cluster-$Cl_1Cl_1cl_2cl_2$, Early Calwonder - $cl_1cl_1Cl_2Cl_2$, Sweet Red Cherry Pickling - $cl_1cl_1Cl_2Cl_2$, Hybrid Pepper Bell Boy - $cl_1cl_1Cl_2Cl_2$ and 672-Hungarian Wax - $Cl_1Cl_1Cl_2Cl_2$. Fruits/cluster showed a continuous variation but the genetic analysis revealed a major role of environment in the expression of the character. Elite cluster bell pepper lines were identified and progressed. The line, KAU Cluster was observed resistant to bacterial wilt.