

**GENETIC ANALYSIS OF VARIABILITY IN
SEGREGATING MATERIAL DERIVED THROUGH
HYBRIDIZATION INVOLVING EXOTIC HYBRIDS
IN TOMATO (*Lycopersicon esculentum* Mill.)**

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**DEPARTMENT OF PLANT BREEDING AND GENETICS
UNIVERSITY OF AGRICULTURAL SCIENCES
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SUDHA K. J.

Thesis submitted to the
University of Agricultural Sciences, Bangalore
in partial fulfilment of the requirements
for the award of the degree of

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IN

PLANT GENETICS AND BREEDING

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JULY 1991

Affectionately Dedicated
to my
Loving Parents

DEPARTMENT OF PLANT GENETICS AND BREEDING
UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE

CERTIFICATE

This is to certify that the thesis entitled "GENETIC ANALYSIS OF VARIABILITY IN SEGREGATING MATERIAL DERIVED THROUGH HYBRIDIZATION INVOLVING EXOTIC HYBRIDS IN TOMATO (*Lycopersicon esculentum* Mill.)" submitted by Sudha, K.J. in partial fulfilment of the requirements for the degree of Master of Science (Agriculture) in Plant Genetics and Breeding to the University of Agricultural Sciences, Bangalore, is a record of research work done by her during her stay in the University under my guidance and supervision and that no part of the thesis has been submitted for the award of any other degree, diploma, associateship, fellowship or other similar titles.

Bangalore 1/8/91



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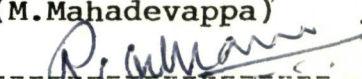
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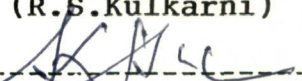
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INTRODUCTION

I INTRODUCTION

Tomato (Lycopersicon esculentum Mill.) is one of the most popular and widely grown vegetables in the world, ranking second in importance to potato in many countries. The fruits are eaten raw or cooked. Large quantities of tomato are used to produce canned products and it is a rich source of vitamin C.

Tomato, a member of the family Solanaceae, is a native of South America, Mexico in particular (Jenkins, 1948). Its cultivation extends from the tropics to a few degrees within the Arctic circle. World production of tomato is estimated to be 63.99 million tonnes from an area of 2.7 million hectares with an average yield of 23.98 tonnes per hectare (Anon., 1988). In India it occupies an area of 83,000 hectares and the average yield per hectare is about 9.58 tonnes (Anon., 1988).

Prior to 1920, tomato improvement depended largely upon selection of chance variants that originated as a result of mutation, spontaneous outcrossing or recombination of pre-existing genetic variation. Certain dominant characters can also be combined and heterosis has been exploited in F_1 hybrids in tomato to a great extent in the last fifty years, in developed countries like the U.S.A. and Japan. Heterosis breeding to develop F_1 hybrids in tomato is a recent development in India. Unlike in open pollinated varieties, desirable traits can be

combined in a short time, in F_1 hybrids. However, the high cost of seed production is a serious limitation in commercial use of hybrid tomatoes.

The success in a crop improvement programme depends, chiefly on the availability of genetic variability in the crop. As there are very few genotypes with desirable characteristics available for hybridization programme, recurrent utilization of the same genotypes results in limited variability. In such a situation, the introduction of exotic material with desirable characteristics offers a new alley in the crop improvement, owing to their diverse genetic background. Hence during the present study, attempts have been made to create greater variability in some of the characteristics of interest, utilizing two exotic F_1 hybrids and indigenously adapted varieties by involving them in hybridization. The variability generated thereby in the resulting segregating populations was estimated.

Prior to crossing, an attempt was made to introduce the hybrids directly by growing them under green house conditions. One of the hybrids, 'Beef Steak' failed to adapt well. The other hybrid 'Cherry Red' was comparatively better. Although the two hybrids are extremely high yielders in the U.S.A., their poor performance under Bangalore conditions is attributable to the change in environmental factors. Hence, the genes for high yielding traits present in those hybrids have to be transferred to the genetic background of locally adapted genotypes for their

better expression. Thus, it was sought to recombine the traits of the exotic hybrids and the indigenously adapted varieties and to select certain desirable genotypes from the segregating populations derived from the crosses.

With this in background, the present investigations were taken up with the following specific objectives :

1. to transfer desirable traits from exotic hybrids to indigenously adapted varieties, through hybridization and to select for transgressive segregants,
2. to estimate the spectrum and magnitude of genetic variability following hybridization between exotic hybrids and indigenously adapted varieties and
3. to study the correlations among various yield components in order to formulate appropriate selection criteria.

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

Tomato is an important vegetable crop grown in most parts of the world. It is a member of the family Solanaceae with a diploid chromosome number of 24.

Lycopersicon esculentum Mill. belongs to the subgenus Eulycopersicon of the genus Lycopersicon. Jenkins (1948) suggested that Mexico and not Peru was the source of cultivated tomatoes of the old world, and probably the only centre of domestication of the tomatoes, as there is a wide spread distribution of variety Cerasiformae in Mexico. The variety Cerasiformae bears greater genetic resemblance to the cultivated tomato than L. pimpinellifolium.

Tomato is an introduced crop to India. Its average productivity in India is about 9.58 tonnes per hectare which is much lower compared to a world average of 23.98 tonnes per hectare (Anon.,1988). The discrepancy indicates the need for an extensive crop improvement programme. Prior to 1920, tomato improvement depended largely on selection of chance variants that originated as a result of mutation, spontaneous out crossing or recombination of pre-existing genetic variation. However, in India several cultivars introduced from abroad particularly the U.S.A. have performed well. Among the various introduced varieties Sioux from the U.S.A. proved promising and gained popularity in most parts of India (Pal and Singh, 1951 and

Singh and Sikka, 1955). Other varieties like Marglobe, Best of All, Italian Red Pear and Roma performed well in other parts of India.

2.1 Sources of variability

Selection has played an important role in tomato improvement in India. Improved Meeruti was evolved at Indian Agricultural Research Institute, by selecting from an Indian cultivar at Meerut in Uttar Pradesh (Singh and Sikka, 1955). Pusa 120, a heavy yielder was selected from segregating material from Hawaii. Hybridization utilizing exotic cultivars as one of the parents was also attempted in evolving cultivars like Pusa Ruby and Pusa Early Dwarf. Pusa Ruby was obtained from the cross Sioux X Improved Meeruti and Pusa Early Dwarf, from Improved Meeruti X Red cloud.

Heterosis breeding has also been attempted for by many research workers by making inter-varietal crosses which included indigenous as well as exotic varieties (Chaudhary et al., 1965; Chaudhary and Khanna, 1972a and Bhutani et al., 1973).

Mittal et al. (1974), Rattan and Saini (1976) and Singh et al. (1978) have reported that desirable heterosis for yield appears to be due either to increased number of fruits per plant or fruit size and weight, which supports the fact that these characters are closely correlated with yield. Quinones (1957) stressed the desirability of using genetically diverse parents

for F_1 tomato hybrids which was earlier emphasised by Powers (1941). It was established that when large fruited varieties were crossed to small fruited ones, the resulting F_1 plants had fruits smaller in size than the average of the parents (Pillai, 1934 and Chaudhary and Khanna, 1972 a).

2.2 Variability studies

While breeding new varieties either by selection or hybridization, a knowledge of quantum of variability in the base population is a pre-requisite. Most of the studies in tomato on variability were rather confined to the evaluation of germplasm. But, studies on transgressive variability is indeed limited.

Yield being a complex character is a result of many components which are quantitatively inherited and quantitative characters are invariably influenced by environment. Mahmud and Kramer (1951) estimated environmental variances based only on variance among plants within the parent varieties.

As pointed out by Weber and Moorthy (1952), estimates of genotypic variance contain variance due to genotype-environment interaction effects as well. Genotypic coefficient of variation indicates the relative magnitude of genetic diversity present in the material.

Burton (1951) has suggested that a genotypic coefficient of variation together with heritability estimate would seem to give

the best picture of the amount of advance to be expected from selection. According to Johnson et al. (1955) this statistic seems to have considerable utility in facilitating the comparison of genetic variability in various populations and characters and in some cases may be useful in estimating genetic gain. The genetic gain can be expressed for a particular character through selection, as the product of its heritability and selection differential expressed in terms of phenotypic standard deviation (Lush, 1949).

Johnson et al. (1955) suggested that heritability and genetic advance when calculated together are more useful for predicting the resultant effect of selecting the best individual than heritability or genetic advance calculated alone.

2.3 Variability studies in tomato

The F_2 generation involving widely differing parents may throw wide variability which the germplasm repository may not possess. Hence the studies dealing with segregating generations can be promising, in deriving greater variability. (Bangaru et al., 1983 and Kumar et al., 1983).

A wide range of variation for plant height was observed (Prasad and Prasad, 1977 ; Nadar et al., 1980 and Sonone et al., 1986). Genotypic variance was highest for this trait (Nadar et al., 1980). Higher values of GCV and PCV have also been recorded for plant height (Kumar et al., 1980).

Prasad and Prasad (1977) and Nadar et al. (1980) observed wide range of variation for number of primary branches. High genotypic variance for this character was recorded by Sonone et al. (1986) and Singh et al. (1988).

Nandpuri et al. (1974) observed low variation for number of days taken for the maturity of first fruit.

Average fruit weight was found to be highly variable (Nandpuri et al., 1974 and Ahmed, 1987). Higher estimates of GCV and PCV were reported for average fruit weight as well as for fruit number per plant (Bangaru et al., 1983 ; Dudi et al., 1983 and Sonone et al., 1986). Saini and Sood (1971) reported high estimate of GCV for the latter. Kumar et al. (1980) observed high genotypic coefficient of variation for number of fruiting clusters per plant.

Total yield per plant was found to be the most variable character (Ahmed, 1987). High GCV was recorded for this character (Nandpuri et al., 1973 ; Kumar et al., 1980 ; Dudi et al., 1983 and Sonone et al., 1986). Nadar et al. (1980) observed wide range of variability for it. He noticed a wide difference between GCV and PCV which indicated the impact of high environmental influence for fruit yield.

Cobani and Merja (1986) found that number of locules and flesh thickness are least variable. Number of locules was found

to have low value of GCV (Kumar et al., 1980). Fruit length also was found to have a lower value of GCV (Prasad and Prasad, 1977).

2.4 Heritability studies

Higher values of heritability have been recorded for earliness (Tayel et al., 1959a and Nandpuri et al., 1973). Higher values of GA were also recorded for earliness (Nandpuri et al., 1973). Singh et al. (1973) and Sonone et al. (1986) observed high heritability for days to first flowering, but a low genetic advance was recorded by the latter, for the same.

Scosciroli et al. (1976) observed a high heritability for earliness while Li (1976) for earliness and growth stages. Similarly, Peter and Rai (1976) obtained high heritability estimate for days to fruit harvest.

Plant height was reported to have a high heritability (Tayel et al., 1959 b ; Singh et al., 1973 ; Nandpuri et al., 1977 and Kumar et al., 1980). Moderate values of heritability were also recorded for it (Prasad and Prasad, 1977 and Bangaru et al., 1983). In addition to high heritability values, Nadar et al. (1980) and Sonone et al. (1986) observed high genetic advance for plant height.

In a study of performance of indigenous and exotic varieties of tomato, Saini and Sood (1971). have reported high

heritability estimates and high genetic advance for number of flowers per plant.

While studying F_1 and F_2 populations of a cross, Tayel et al. (1960) estimated a high heritability for number of fruiting clusters per plant, while Kumar et al. (1980) arrived at a moderate heritability estimate for this trait.

Number of fruits per plant is considered as an important trait, as it is closely associated with yield. High heritability estimates have been observed for this character (Tayel et al., 1960 ; Saini and Sood, 1971 ; Singh et al., 1973 ; Nandpuri et al., 1973 and 1974 and Singh et al., 1974). Many others have also recorded high heritability estimates for this trait (Bangaru et al., 1983 ; Dudi et al., 1983 ; Khalil et al., 1986 and Yassin, 1988). Moderate heritability values were reported by Kumar et al. (1980) and Alvarez (1984) for number of fruits per plant.

Goldenberg (1967), while studying F_4 and F_5 generations of a cross reported a genetic gain of 37.7 per cent, for this trait. Though a high heritability estimate is not always accompanied by high estimates of genetic gain, there are reports of both the estimates being high for fruit number per plant (Nandpuri et al., 1973 and 1974 ; Singh et al., 1974 ; Peter and Rai, 1976 ; Nandpuri et al., 1977 ; Prasad and Prasad, 1977 ; Dudi et al., 1983 and Sonone et al., 1986). Bangaru et al. (1983) observed

highest estimate of genetic advance for this character. All these reports indicate that this trait has high heritability and high genetic advance.

Ibaria and Lambeth (1969 a) obtained a low broad-sense heritability estimate (29 per cent) in a tomato cross for average fruit weight.

Goldenberg (1967) reported a genetic advance of 24.17 per cent for the same. High estimates of heritability for this character however were reported by Nandpuri et al. (1973 and 1974), Alvarez (1984) and Khalil et al. (1986).

In addition to high heritability estimates, high genetic advance for average fruit weight was reported. (Nandpuri et al., 1973 ; Srivastava and Sachan, 1973 ; Nandpuri et al., 1977 ; Bangaru et al., 1983; Dudi et al., 1983 and Sonone et al., 1986).

Fruit yield is highly influenced by environment and is a complex character determined by several of its components and hence this is expected to be less heritable. Result of many investigations seems to support this view.

Pierce (1958) reported low estimates of heritability based on variance components (39 %) and also based on regression of F_3 means on parental performance (27 %). He attributed the difference to the bias caused by G X E interaction. Tayel et al. (1960) reported low heritability (44.2 %) in a tomato cross.

Goldenberg (1967) reported only 24.6 per cent genetic advance over population mean. Singh et al. (1973) recorded high heritability value for this character.

Singh et al. (1974), reported high estimates of heritability as well as genetic advance for yield. Supporting this, similar results have been observed (Nandpuri et al., 1977 ; Sonone et al., 1986 and Singh et al., 1988).

Nandpuri et al. (1973) and Dudi et al. (1983) reported high heritability and genetic advance for early yield and the former reported the same results for marketable yield also. Kumar et al. (1980) and Bangaru et al. (1983) observed moderate heritability estimates for early yield. Nadar et al. (1980) reported moderate estimates of heritability as well as genetic advance for early yield.

Chaudhary and Khanna (1972a), noticed variation in heritability value from 32.45 per cent to 72.18 per cent, in some crosses, for the number of locules, and also estimated a genetic advance of 43.72 per cent. High heritability for this character was reported by Singh et al. (1973 and 1974) and Peter and Rai (1976). Bangaru et al. (1983) and Sonone et al. (1986), reported a high heritability as well as genetic advance for number of locules.

Saini and Sood (1971) reported high heritability and high genetic advance for rind thickness.

Lower and Richard (1963) reported a range of 75 per cent to 91 per cent heritability estimate for soluble solids in their investigation. Stoner and Thompson (1966) while studying the inheritance of soluble solids in tomato recorded a heritability estimate of 74.9 per cent while Lower and Thompson (1967) recorded a genetic gain of 1.296 per cent for the same trait.

Ibaria and Lambeth (1969 b) and Srivasthava and Sachan (1973) reported a high heritability for soluble solids.

Bruyn et al. (1971) attributed variation in heritability values for sugar content in tomatoes in different studies to the changes in environment under which they were grown.

Sonone et al. (1986) reported a heritability estimate as high as 89.24 per cent and a medium genetic advance (27.7 per cent of mean) for soluble solids.

Prasad and Prasad (1977) reported a least genetic advance for fruit length (13.54 %). On the contrary Singh et al. (1974) observed a high heritability value accompanied by high genetic advance for width of the fruit.

Sonone et al. (1986) reported high heritability estimate and low genetic advance for fruit shape index.

2.5 Correlation studies and path analysis

Most of the breeding programmes require information on the

nature and magnitude of variation in the available material, association of characters with yield and among the characters themselves and the extent of environmental influence on these characters. This association is determined by the correlation coefficient. Further, correlation does not provide an exact picture of the relative importance of direct and indirect influence of each of the component characters towards yield. Path coefficient analysis proves itself useful in partitioning the correlation coefficient into direct and indirect effects. It was first described by Wright (1921). A summary of correlation studies done earlier in tomato has been given in Table 1.

Path analysis

Nadar et al. (1980) and Sonone et al. (1987) found number of lateral branches to have highest positive direct effect on yield. However, the latter also reported a higher degree of direct effect of plant height on fruit yield.

Path analysis by many investigators have shown the importance of number of fruits on yield which is accounted for by the higher direct effect of this character on yield. Srivasthava and Sachan (1973) found that the number of fruits per plant had maximum positive direct effect on yield. They also showed that positive association of fruits per bunch with yield was due to its indirect contribution through number of fruits per plant. Similarly, Dudi and Kalloo (1982), Gonzalez (1985 b) and Patil

Table 1. A summary of correlation studies done earlier in tomato.

Correlation between the characters	Positive Correlations	Negative Correlations	Authors.
Plant height Vs. yield.	*		Govinda Rasu <u>et al.</u> , 1980 ; Alvarez and Torres, 1983 and Ahmed <u>et al.</u> , 1988.
Plant height Vs. fruit weight.			Ahmed, 1987.
Number of laterals Vs. yield.			Govinda Rasu <u>et al.</u> , 1980 ; Singh and Singh, 1980; Alvarez and Torres, 1983 and Kumar and Muthukrishnan, 1983.
	**		Nadar <u>and et al.</u> , 1980 ; Sonone <u>et al.</u> , 1987.
Number of laterals Vs. number of fruits per plant.	*		Das and Chakraborty, 1987 ; Sonone <u>et al.</u> , 1987.
Earliness Vs. yield.			Kumar and Muthukrishnan, 1983.
Days to maturity Vs. number of fruits per plant			Singh and Singh, 1980.
Early yield Vs. total yield	**		Dudi and Kalloo, 1982.
Number of fruits per plant Vs. yield	**		Srivasthava and Sachan, 1973 ; Singh and Singh, 1980 ; Dudi and Kalloo, 1982 ; Alvarez and Torres, 1983 ; Patil, 1985 ; Gonzalez, 1985 b ; Rajadhan <u>et al.</u> , 1985 ; Munoz <u>et al.</u> , 1986 ; Yassin, 1986 ; Das and Chakraborty, 1987 ; Gomez, 1987 ; Sonone <u>et al.</u> , 1987 ; Ahmed <u>et al.</u> , 1988.
Number of trusses (fruiting branches) Vs. yield.	*		Alvarez and Torres, 1983.

Table 1. (Continued)

Average fruit weight Vs. yield.	*	Dudi and Kalloo, 1982 ; Kumar and Muthukrishnan, 1983 ; Patil, 1985 ; Munoz <u>et al.</u> , 1986 ; Ahmed, 1987 ; Sonone, <u>et al.</u> , 1987 and Ahmed <u>et al.</u> , 1988.
Number of fruits Vs. fruit weight	*	Srivasthava and Sachan, 1973 ; Kumar and Muthukrishnan, 1983 ; Alvarez and Torres, 1983 ; Patil, 1985 ; Das and Chakraborty, 1987 ; Gomez, 1987.
Fruit size Vs. yield.	*	Govinda Rasu <u>et al.</u> , 1980 ; Singh and Singh, 1980.
Fruit size Vs. number of fruits per plant.	*	Kohle, 1970 and Singh and Singh, 1980.
Yield per plant Vs. diameter of fruit.	*	Srivasthava and Sachan, 1973
Number of fruits per plant Vs. diameter, length and weight of fruit.	*	Alvarez and Torres, 1983.
Fruit weight Vs. equatorial diameter and polar diameter	**	Gonzalez and Alvarez, 1984 ; Gonzalez, 1985 a and 1985 c.
Number of locules Vs. fruit weight	*	Gonzalez and Alvarez, 1984 and Gonzalez, 1985 a.
Yield Vs. number of locules	*	Kumar and Muthukrishnan, 1983 and Patil, 1985.
Yield Vs. total soluble solids	*	Patil, 1985 and Patil and Bojappa, 1987.

** Highly significant correlations

* Significant correlations.

(1985) have also recorded a high positive direct effects of number of fruits per plant on yield. The character, fruit weight has also been shown to have higher direct effects on yield (Dudi and Kalloo, 1982 and Sonone et al., 1987). Equatorial and polar diameter of the fruits in turn exercised strongest direct influence on fruit weight (Gonzalez, 1985 a).

However, according to Srivasthava and Sachan (1973), fruit weight had negative direct effect on yield. They also found fruit diameter to be important in contributing to yield.

Patil (1985) reported pericarp thickness to have high positive direct effect on fruit yield.

Sonone et al. (1987) reported that days to first flowering and total soluble solids both had negative direct contribution and negative association with yield. He concluded that the character pairs days to first flowering and fruit yield as well as total soluble solids and fruit yield may be considered independent of one another.

Review of literature on genetic improvement studies in tomato indicated that there are limited reports on direct use of hybrid genotypes in the improvement of varieties. Hence, the present investigation was initiated to involve F_1 commercial hybrids from diverse source into three-way cross combinations in order to generate variability for various characters. This approach is also expected to provide a broad genetic base for the new

selections made from the segregating generations resulting from the three-way crosses.

MATERIAL AND METHODS

III MATERIAL AND METHODS

The experiment was carried out at Hebbal Farm, University of Agricultural Sciences, Bangalore, during Kharif 1990.

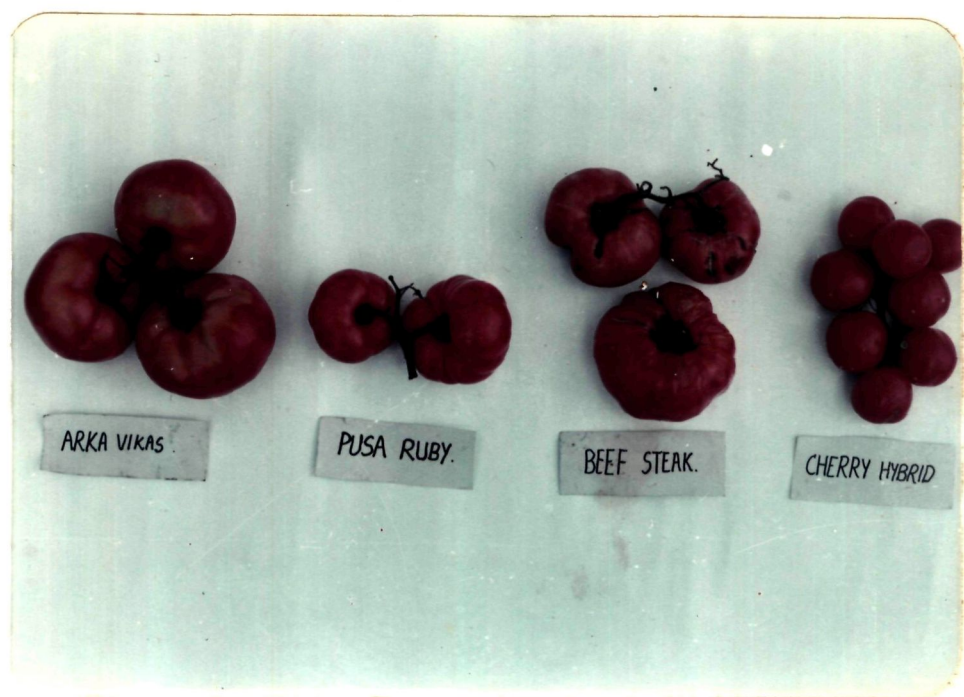
3.1 Experimental material

The experimental material comprised of two exotic commercial hybrids of tomato (Lycopersicon esculentum Mill.) obtained from the U.S.A., namely, Cherry Red hybrid and Beef Steak hybrid with contrasting characters and the two indigenously adapted varieties namely, Pusa Ruby and Arka Vikas (Plate 1). Since the two hybrids were commercial F_1 s, the parentage for them was not known.

The salient features of the four genotypes used in the study are as follows.

Pusa Ruby : It was developed from the cross Sioux X Improved Meeruti. It is an early cultivar. Fruits are slightly furrowed with uniform ripening and it is a heavy yielder. It has got an indeterminate growth habit and suitable for both growing in spring-summer and autumn-winter.

Arka Vikas : It is an improvement over the tomato variety Tip-top. It bears large oblate fruits each weighing about 80-85 gms. The fruits have an attractive deep red colour with uniform



1. The indigenous and exotic genotypes used in the hybridization programme.

ripening and it is a good yielder too. It has got a semi-determinate habit with a duration of 105-110 days.

Beef Steak hybrid : It was a commercial F_1 obtained from the U.S.A. The fruits are furrowed with a tendency for fruit cracking. Fruits are borne in bunches of 3 to 4 fruits. It has got a semi-determinate growth habit and did not perform well during the study though supposed to be a good yielder. In contrast to Cherry Red hybrid, it bears large fruits.

Cherry Red hybrid : This hybrid is also a commercial F_1 obtained from the U.S.A. Fruits are small, rounded and deep red in colour when completely ripe. The desirable features of the hybrid are that it is a heavy bearer with the fruits borne in a compact bunch of 8 to 9 fruits. It has got an indeterminate growth habit.

The genotypes were crossed in various combinations to get different segregating populations. The following are the segregating populations included in the investigation, along with the genotypes used as parents.

- | | | |
|--|---|-------------------|
| 1. The F_2 of Cherry Red (F_1 hybrid) | - | CR (F_2) |
| 2. Pusa Ruby X Beef Steak (F_1 hybrid) | - | PR X BS (F_1) |
| 3. Arka vikas X Beef Steak (F_1 hybrid) | - | AV X BS (F_1) |
| 4. Arka vikas X Cherry Red (F_1 hybrid) | - | AV X CR (F_1) |
| 5. Pusa Ruby X Cherry Red (F_1 hybrid) | - | PR X CR(F_1) |
| 6. Cherry Red (F_1 hybrid) X Pusa Ruby | - | CR(F_1) X PR |

The crosses are represented by the respective symbols given above in the succeeding chapters.

The seeds of the five crosses were obtained by hybridization in green house during Rabi 1989-90. Reciprocal crosses were tried in order to know the maternal effects. Sufficient crossed seeds could be obtained only for CR (F_1) X PR. Crossing was effected as suggested by Bhandari (1979).

Young buds were selected which were almost yellow in which anthesis would commence the following day. Such buds were emasculated by removing all the five anthers by picking stamens with forceps a little below the connective. Precaution was taken to avoid injury to stigma, as stamens form a cone around the style. The emasculated flowers were bagged and labelled. Yellow anthers from the male parents were collected, incised using a needle and pollen grains at the tip of the needle were transferred to the surface of stigma of the plant intended to be the female parent (with emasculated flowers). Then the pollinated flowers were bagged and labelled appropriately.

Since BS(F_1) had poor fruit set during the study, selfed seeds of only CR(F_1) were collected and CR(F_2) could be included in the experiment.

3.2 Experimental details

The experiment was carried out on sandy loam soil during

Kharif 1990. The seeds were sown on finely prepared raised nursery beds which were previously treated with 0.2 per cent Phytolon in the month of June, 1990. The seedlings which were 28 days old were transplanted to the main field. In the main field, the four genotypes used as parents namely the two hybrids and the two varieties along with five three-way crosses and the $CR(F_2)$ were considered as ten treatments and laid out in a randomised complete block design with three replications. The main field was prepared to a fine tilth and fertilizers and manures were applied as per the package of practices recommended by U.A.S., Bangalore. Furrows were opened at a spacing of 45cm and the seedlings were transplanted 30cm apart on the sides of the ridges and irrigated adequately, soon after planting.

There were two rows each of parents comprising of 16 plants (each row consisted of 8 plants), and 6 rows each of the three-way crosses and of the F_2 (each row consisted of 8 plants again).

Timely irrigation, plant protection measures and other operations were carried out. Incidence of leaf curl virus was observed three weeks after transplanting. To control white fly, which is the vector, 0.2 per cent Nuvacron was sprayed, at two weeks interval, until fruit setting stage:

3.3 Observations recorded

Observations were recorded on individual plant basis in the parents as well as in the segregating populations.

3.3.1 Vegetative characters

1. **Days to flowering :** The days taken from sowing to initiation of first flower was recorded.
2. **Plant height at flowering :** Plant height was recorded on the day of initiation of first flower in the plant and expressed in centimetres.
3. **Plant height at harvest :** Plant height was recorded on the day of first picking for each plant and expressed in centimetres.
4. **Number of primary branches :** The number of branches borne on the main stem with over 0.5cm thickness was recorded for each plant.

3.3.2 Reproductive characters

1. **Number of clusters :** Total number of inflorescences bearing fruits was recorded for each plant.
2. **Number of fruits per plant :** Total number of ripe fruits harvested from the plants was taken as the number of fruits per plant.
3. **Number of flowers per plant :** Total number of flowers produced by each plant was recorded.
4. **Number of flowers per inflorescence :** Three inflorescences were selected at different levels in each plant, number of

flowers in each inflorescence was counted and averaged to give the number of flowers per inflorescence.

5. **Fruit yield per plant :** Weight of fruits in different pickings from each plant was added separately to obtain the total yield per plant and expressed in Kilograms.

3.3.3 Fruit Characters

1. **Average fruit weight :** Weight of all the fruits in the first picking in each plant was recorded and divided by the number of fruits in that plant and expressed in grams.

2. **Equatorial diameter :** Five fruits were randomly selected from first picking and cut radially. The equatorial diameter was noted and averaged and expressed in centimetres.

3. **Polar diameter :** Five randomly selected fruits were cut longitudinally and the polar diameter recorded for all the fruits, averaged for each plant and expressed in centimetres.

4. **Rind thickness :** The rind thickness for the five fruits which were cut radially was recorded, the averages were worked out and expressed in millimetres.

5. **Number of locules :** In the same five fruits cut radially, number of locules were counted and averaged.

6. **Total soluble solids (%) :** Total soluble solids of three fruits selected from each plant at random in the first picking,

was measured using a Brix Refractometer and averages were worked out.

3.4 Statistical analysis of experimental data

Analysis of variance was done according to the method outlined by Panse and Sukhatme (1967), for all the fifteen characters. The means of the treatments were used for analysis.

Anova table was set up as follows.

Analysis of Variance (ANOVA)

	Source	d.f.	MS	F-Ratio
I	Replication	(r-1)	MS_r	MS_r/MS_e
II	Treatments	(t-1)	MS_t	MS_t/MS_e
	1) Non-segregating	(ns-1)	MS_{ns}	MS_{ns}/MS_e
	a) Variety	(v-1)	MS_v	MS_v/MS_e
	b) Hybrid	(h-1)	MS_h	MS_h/MS_e
	c) Variety Vs. hybrid	1	MS_{vh}	MS_{vh}/MS_e
	2) Segregating	(s-1)	MS_s	MS_s/MS_e
	a) Three-way cross	(tw-1)	MS_{tw}	MS_{tw}/MS_e
	b) Three-way cross Vs. F_2	1	MS_{twf}	MS_{twf}/MS_e
	3) Segregating Vs. non-segregating	1	MS_{sns}	MS_{sns}/MS_e
III	Error	(r-1)(t-1)	MS_e	--

Where, r = number of replications,
 t = number of treatments and
 MS_r, MS_t, MS_{ns} ---- are respective mean squares.

3.4.1 Variability studies

As the measures of variability, variances and genotypic and phenotypic coefficients of variation were computed as suggested by Burton and Devane (1953).

Phenotypic and genotypic components of variance were estimated with the help of formula suggested by Burton (1951),

$$\sigma_g^2 = \sigma_p^2 - \sigma_e^2$$

Where, σ_g^2 = Genotypic variance,
 σ_p^2 = Phenotypic variance and
 σ_e^2 = Environmental variance.

Environmental variance (σ_e^2) for the five three-way crosses was calculated by taking the average of non-segregating generations.

3.4.2 Frequency distribution

Frequency distribution for the fifteen characters was studied in the segregating populations included in the study.

3.4.3 Genetic parameters

Genetic parameters namely, genotypic coefficient of

variation, phenotypic coefficient of variation, heritability in broad sense, genetic advance and genetic advance as per cent of mean, were calculated for the characters studied for different three-way crosses using the formulae,

a. Genotypic coefficient of variation (GCV)

$$GCV = \frac{\sigma_g}{\bar{X}} \times 100$$

where, σ_g = genotypic standard deviation and
 $\bar{X}$ = mean of the character

b. Phenotypic coefficient of variation (PCV)

$$PCV = \frac{\sigma_p}{\bar{X}} \times 100$$

where, σ_p = phenotypic standard deviation and
 $\bar{X}$ = mean of the character

c. Heritability in broad sense (h^2)

$$h^2 = \frac{\text{Genotypic variance}}{\text{phenotypic variance}} \times 100$$

as suggested by Hanson et al. (1956).

d. Genetic advance (GA)

$$GA = h^2 \times K \times \sigma_p$$

where, h^2 = heritability in broad sense

K = selection differential which is
2.06 at 5 per cent selection
intensity

σ_p = phenotypic standard deviation

e. Genetic advance as per cent of mean (GA as % of mean)

$$GA \text{ as \% of mean} = \frac{GA}{\bar{X}} \times 100$$

where, GA = genetic advance

$\bar{X}$ = mean of the character,

as suggested by Johnson et al (1955).

3.4.4 Correlation and path analysis

The correlation coefficients were computed to determine the degree of association of characters with yield and also amongst themselves as outlined by Singh and Chaudhary (1977),

Correlation coefficient (r)

$$r_{xy} = \frac{\text{Cov}(x,y)}{\sqrt{V(x) \cdot V(y)}}$$

where, r_{xy} = correlation coefficient between x and y,

$Cov(x,y)$ = covariance of x and y,

$V_{(x)}$ = variance of x,

$V_{(y)}$ = variance of y.

Path analysis was done to know the direct and indirect effects of the yield components on yield as suggested by Wright (1921) and illustrated by Dewey and Lu (1957). Analysis was carried out using five independent characters with yield (dependent). The independent characters were,

- i) plant height at harvest,
- ii) number of primary branches,
- iii) number of clusters per plant,
- iv) number of fruits per plant and
- v) number of flowers per plant.

The computations of both correlation and path coefficients were done at the Computer centre, Gandhi Krishi Vignana Kendra, Bangalore, utilizing Regrel programme.

EXPERIMENTAL RESULTS

IV EXPERIMENTAL RESULTS

Improvement of any character in a crop demands that there is sufficient genetic variability available for it in the crop. The source of variability may be obtained using either indigenous or exotic genotypes. During the present study an attempt has been made to generate variability by crossing two exotic (F_1) hybrids, viz., Cherry Red hybrid - CR (F_1) and Beef Steak hybrid - BS (F_1), with contrasting characters, with the two indigenous varieties, viz., Arka Vikas-AV and Pusa Ruby -PR.

Different populations derived from the three-way crosses were raised along with parents and analysis of variance was carried out for the various morphological and fruit characteristics recorded during the study.

Various genetic parameters namely, genotypic and phenotypic coefficients of variation, heritability and genetic advance were estimated and comparison among different crosses was made (Tables 4.1 to 4.15).

The populations were also compared for their variability by studying the frequency distributions (Fig. 1 to 15).

Correlation studies and path analysis were carried out to know the extent of association among various characters studied and their relative contributions to yield.

The results of various aspects of study are presented in this chapter.

4.1 Analysis of variance

The results of analysis of variance for the fifteen characters studied are presented in Table 2.

Analysis of variance shows that variance due to treatment effects was highly significant for all the characters studied. Variance due to non-segregating populations was also highly significant for all the characters except for the total soluble solids. Variances due to segregating populations and due to three-way crosses for all the characters except days to flower, plant height at flowering and number of primary branches were significant.

Variances due to both varieties and hybrids were highly significant for all the characters except plant height at harvest, number of flowers per inflorescence, total soluble solids, number of locules and rind thickness. For total soluble solids variance due to both varieties and hybrids was non-significant.

Variance due to variety versus hybrid and due to three way crosses versus F_2 was significant for plant height at harvest, number of fruits per plant, number of flowers per plant, number

Table 2. A summary of the results of analysis of variance for various characters.

Source of variation	d.f.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Replication	2	2.75*	1.48	172.45	0.34	0.88	103.39	105.53	0.64	14.38	0.01	0.04	0.05	0.13	0.22	0.77**
Treatment	9	11.18**	10.03*	1110.14**	2.57**	82.52**	17344.21**	3752.48**	3.24**	348.42**	0.10**	0.29**	0.43**	3.59**	7.60**	0.53**
Non-segregating	3	29.59**	17.16**	2243.90**	5.38**	185.80**	14259.13**	8325.83**	4.93**	396.69**	0.252**	0.01	0.183**	3.81**	9.44**	0.16**
Variety	1	24.48**	27.86**	124.76	2.95**	17.99**	316.39**	450.84**	0.08	370.05**	0.04**	0.01	0.11**	0.25**	0.01	0.39**
Hybrid	1	56.43**	0.08**	2782.11**	12.9**	537.70**	10718.83**	22497.13**	1.50**	608.02**	0.71**	0.01	0.27**	10.24**	22.42**	0.06
Variety vs Hybrid	1	7.87	23.54	3824.90**	0.30	1.73	3223.91**	3829.54**	13.2**	212.02**	0.01	0.02	0.17**	0.94**	5.89**	0.03
Segregating	5	0.46	7.69	611.26**	0.17	36.88**	614.04**	1343.19**	2.86**	261.78**	0.03**	0.15*	0.40**	3.05**	5.96**	0.86**
3-way crosses	4	0.54	3.85	317.42*	0.22	45.95**	680.69**	1367.94**	1.43**	285.87**	0.03*	0.19**	0.42**	2.80**	5.59**	0.70**
3-way vs. F ₂	1	0.17	23.09**	1786.59**	0.0005	0.51	347.42**	1244.19**	8.57**	165.43**	0.02	0.0008	0.34	4.05**	7.42**	1.50**
Segregating vs. Non-segregating	1	9.49*	0.35	203.22	6.13**	0.84	14.87	278.88**	0.04	636.79**	0.04**	0.04	1.32**	5.65**	10.32**	0.005
Error	18	4.14	3.24	99.17	0.26	4.83	46.85	15.49	0.103	4.48	0.01	0.05	0.03	0.06	0.08	0.04
Index :																
1. Days to flower																
2. Plant height at flowering (cm)																
3. Plant height at harvest (cm)																
4. Number of primary branches																
5. Number of clusters																
6. Number of fruits																
7. Number of flowers																
8. Number of flowers per inflorescence																
9. Average fruit weight (g)																
10. Yield per plant (kg)																
11. Total soluble solids (%)																
12. Polar diameter (cm)																
13. Equatorial diameter (cm)																
14. Number of locules																
15. Rind thickness (mm)																

of flowers per inflorescence, average fruit weight, equatorial diameter and number of locules.

For days to flower, number of primary branches, number of flowers per plant, average fruit weight, yield per plant, polar diameter, equatorial diameter and number of locules, variance due to segregating versus non-segregating populations was highly significant.

4.2 Variability studies

4.2.1 Days to flower

The segregating populations did not differ significantly for days to flowering (Table 3).

Among parents, BS (F_1) took significantly more number of days (50 days) to flower than the other parents. The cross AV X BS (F_1) had the widest range (36 to 58 days) and highest variance (17.84) for this character. It had higher estimates of GCV (8.11%) and PCV (9.9%). The estimates of heritability and GA were 67.2 per cent and 13.64 per cent respectively. PR X BS (F_1) had the highest estimate of GCV (8.94) and a PCV estimate same as in AV X BS (F_1). The heritability (81.39%) and GA (16.6%) estimates were highest in PR X BS (F_1).

The values of the genetic parameters for different crosses have been presented in Table 4.1.

Table 3. Mean values for the fifteen characters studied in the crosses and parents.

Entries	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PR	42.21	16.96	61.89	5.46	14.45	38.75	57.46	5.1	0.652	49.04	4.11	3.21	5.36	5.45	3.35
AV	45.37	20.81	50.94	1.86	9.0	17.89	37.06	5.22	0.672	63.65	3.97	3.65	5.66	5.31	3.79
BS(F ₁)	50.0	16.00	68.33	3.27	3.67	10.67	20.86	6.73	0.438	57.53	4.11	3.73	6.2	5.87	3.53
CR(F ₁)	41.00	15.57	127.07	5.73	22.6	105.60	150.46	7.66	1.527	35.6	4.16	3.45	3.54	2.0	3.43
CR(F ₂)	42.74	35.56	102.36	5.26	13.43	47.43	89.98	7.71	0.903	36.11	4.08	2.75	3.2	2.36	2.53
PR X BS(F ₁)	42.47	15.38	68.04	5.43	9.08	19.38	45.79	5.18	0.686	51.25	4.15	3.4	5.39	5.09	4.02
AV X BS(F ₁)	42.68	17.86	64.65	6.09	8.61	19.61	40.73	5.75	1.56	55.91	4.46	3.68	6.14	5.5	4.29
AV X CR(F ₁)	43.35	17.94	89.78	5.23	14.59	47.59	75.97	6.71	0.804	33.63	4.78	3.18	4.06	2.76	3.53
PR X CR(F ₁)	43.01	18.74	74.78	6.16	14.97	46.97	88.12	6.4	0.862	38.63	4.13	2.76	3.67	2.84	3.11
CR(F ₁) X PR	43.58	16.80	77.1	5.13	18.1	52.11	77.91	6.41	0.950	37.52	4.55	2.87	3.62	2.62	3.22
F value	2.70	3.09	11.19	9.88	17.09	41.14	242.25	31.52	10.34	77.79	2.04	16.58	62.98	100	12.59
SEM	1.17	1.04	5.75	0.29	1.269	3.95	2.27	0.185	0.06	1.22	0.122	0.093	0.138	0.159	0.118
CD(5%)	3.476	3.09	17.08	0.875	3.77	11.74	6.745	0.55	0.171	3.63	0.364	0.277	0.409	0.473	0.352
CD(1%)	4.76	4.23	23.39	1.19	5.16	16.09	9.25	0.75	0.236	4.95	0.498	0.312	0.561	0.648	0.481

1) Days to flower						6) Number of fruits per plant						11) Total soluble solids (per cent)			
2) Plant height at flowering (cm)						7) Number of flowers per plant						12) Polar diameter (cm)			
3) Plant height at harvest (cm)						8) Number of flowers per inflorescence						13) Equatorial diameter (cm)			
4) Number of primary branches						9) Yield per plant (Kg)						14) Number of locules			
5) Number of clusters per plant						10) Average fruit weight (g)						15) Rind thickness (mm)			

Table 4.1. Estimates of genetic parameters in parents, F_2 and three-way crosses for days to flowering.

Entries	Mean $\pm$ S.E.	Range	Variance	GCV(%)	PCV(%)	Heritability (%)	GA	GA as % of mean
Non-segregating								
PR	42.21 $\pm$ 0.20	39-54	3.03					
AV	45.37 $\pm$ 0.30	42-57	8.18					
BS(F_1)	50.00 $\pm$ 0.20	36-48	3.57					
CR(F_1)	41.07 $\pm$ 0.26	45-59	6.20					
Segregating								
CR(F_2)	42.74 $\pm$ 0.30	39-54	10.27					
PRXBS(F_1)	42.47 $\pm$ 0.44	36-57	17.74	8.94	9.90	81.39	7.06	16.60
AVXBS(F_1)	42.68 $\pm$ 0.44	36-58	17.84	8.11	9.90	67.20	5.82	13.64
AVXCR(F_1)	43.35 $\pm$ 0.42	37-51	15.87	6.19	9.18	45.30	3.69	8.50
PRXCR(F_1)	43.01 $\pm$ 0.36	37-54	16.01	7.85	9.30	71.14	5.85	13.06
CR(F_1)XPR	43.58 $\pm$ 0.38	40-53	15.18	7.46	8.94	69.59	5.53	12.68

Note: Since the first four populations are homogenous the genetic parameters were not worked out for them.

4.2.2 Plant height at flowering

Among crosses, CR (F_2) had significantly higher plant height (35.56cm) than in CR (F_1) X PR and PR X BS (F_1) and in parents AV had significantly higher plant height than others (20.31cm).

The cross AV X CR (F_1) had the widest range (9.5 to 32cm) for this character with variance of 20.66, GCV 11.5 per cent, PCV 25.33 per cent, heritability 20.61 per cent and a GA of 10.98 per cent of mean. Variance was highest for the cross PR X CR (F_1) (90.64), in addition to higher estimates of GCV (48.78%), PCV (50.8%), heritability (85.51%) and GA (88.71 per cent of mean).

PR X BS (F_1), had a heritability estimate (26.7%) higher than that in the cross AV X BS (F_1) (17.1%), though the variance was higher in the latter (Table 4.2). This was because of the higher environmental influence in case of the latter. GA was also higher in PR X BS (F_1) (10.53%). The variance in parents for this character was almost as high as in the crosses (Table 4.2).

4.2.3 Plant height at harvest

CR (F_1) had significantly higher plant height over others among parents (127.07cm). Among crosses, AV X BS (F_1) and CR (F_2) were on par for plant height and the former had significantly higher plant height than others (Table 3).

Table 4.2. Estimates of genetic parameters in parents, F_2 and three-way crosses for plant height at flowering.

Entries	Mean $\pm$ S.E	Range	Variance	GCV(%)	PCV(%)	Heritability (%)	GA	GA as % of mean
Non-segregating								
PR	16.96 $\pm$ 0.29	12.0-29.5	8.02					
AV	20.81 $\pm$ 0.40	17.0-30.0	14.57					
BS(F_1)	16.00 $\pm$ 0.46	12.0-24.5	19.10					
CR(F_1)	15.57 $\pm$ 0.45	12.0-25.0	18.23					
Segregating								
CR(F_2)	35.56 $\pm$ 0.68	12.0-32.0	29.34					
PRXBS(F_1)	15.38 $\pm$ 0.30	9.5-24.5	18.50	14.45	27.96	26.70	2.39	15.55
AVXBS(F_1)	17.86 $\pm$ 0.47	10.0-29.5	20.31	10.44	25.23	17.10	1.58	8.85
AVXCR(F_1)	17.94 $\pm$ 0.48	9.5-32.0	20.66	11.50	25.33	20.61	1.97	10.98
PRXCR(F_1)	18.74 $\pm$ 0.85	9.5-29.5	90.64	48.78	50.80	85.51	16.67	88.71
CR(F_1)XPR	16.80 $\pm$ 0.55	11.5-33.0	24.40	19.98	29.40	46.21	4.68	27.86

Note: Since the first four populations are homogenous the genetic parameters were not worked out for them.

The over all range for this character was 37cm to 152cm. Among segregating populations, CR (F_2) had the highest variance (595.69), where as AV X BS (F_1) had the highest estimates of heritability (76.93%) and GA as per cent of mean (37.32%).

4.2.4 Number of primary branches

Among parents PR and CR (F_1) were on par for number of primary branches, but, had a significantly more number of primary branches per plant over the other two. Among segregating populations none of them differed significantly for this character.

All the crosses except CR (F_1) X PR and AV X CR (F_1) had a similar range for this character (Table 4.4). In the parents the over all range was 1 to 8. The cross, AV X BS (F_1) had the highest estimates of variance (7.89), GCV (40.38%), heritability (76.68%) and GA (72.21%). In the cross PR X CR (F_1), though the variance is higher (4.33) than in AV X CR (F_1) (2.58), heritability was higher in the latter (59.68%). However GA estimate was higher in PR X CR (F_1) (38.31% of mean) as compared to AV X CR (F_1) (37.47%).

4.2.5 Number of clusters per plant

All the parents were significantly different for number of clusters per plant, CR (F_1) had significantly more number of clusters (22.6) than other parents (Table 3). Among crosses CR

Table 4.3. Estimates of genetic parameters in parents, F_2 and three-way crosses for plant height at harvest.

Entries	Mean $\pm$ S.E	Range	Variance	GCV(%)	PCV(%)	Heritability (%)	GA	GA as % of mean
Non-segregating								
PR	61.89 $\pm$ 0.74	37-79	48.86					
AV	50.94 $\pm$ 0.36	39-65	12.01					
BS(F_1)	68.33 $\pm$ 1.04	38-64	97.61					
CR(F_1)	127.07 $\pm$ 1.46	109-152	195.21					
Segregating								
CR(F_2)	102.36 $\pm$ 2.98	37-151	595.69					
PRXBS(F_1)	68.04 $\pm$ 1.56	37-123	220.72	17.80	21.80	66.80	20.20	29.68
AVXBS(F_1)	64.65 $\pm$ 0.87	37-121	237.57	13.52	23.84	76.93	24.13	37.32
AVXCR(F_1)	89.78 $\pm$ 2.02	51-150	367.50	18.09	21.35	71.80	28.04	31.23
PRXCR(F_1)	74.78 $\pm$ 1.85	39-151	308.03	18.23	23.47	60.38	21.69	29.00
CR(F_1)XPR	77.10 $\pm$ 1.79	54-117	218.28	12.72	19.16	44.09	13.39	17.37

Note: Since the first four populations are homogenous the genetic parameters were not worked out for them.

Table 4.4. Estimates of genetic parameters in parents, F_2 and three-way crosses for number of primary branches per plant.

Entries	Mean $\pm$ S.E	Range	Variance	GCV(%)	PCV(%)	Heritability (%)	GA	GA as % of mean
Non-segregating								
PR	5.46 $\pm$ 0.12	3 - 8	2.28					
AV	3.86 $\pm$ 0.13	2 - 6	1.44					
BS(F_1)	3.27 $\pm$ 0.14	1 - 5	2.24					
CR(F_1)	6.73 $\pm$ 0.13	3 - 8	1.64					
Segregating								
CR(F_2)	5.26 $\pm$ 0.17	1 - 9	2.09					
PRXBS(F_1)	5.43 $\pm$ 0.15	1 - 9	2.54	9.76	46.78	11.02	0.36	6.65
AVXBS(F_1)	6.09 $\pm$ 0.29	2 - 10	7.89	40.38	46.12	76.68	4.39	72.21
AVXCR(F_1)	5.23 $\pm$ 0.19	1 - 8	2.58	23.72	30.71	59.68	1.96	37.47
PRXCR(F_1)	6.16 $\pm$ 0.22	1 - 9	4.33	22.72	33.78	54.73	2.36	38.31
CR(F_1)XPR	5.13 $\pm$ 0.19	1 - 7	2.67	16.43	31.85	26.59	0.875	17.06

Note: Since the first four populations are homogenous the genetic parameters were not worked out for them.

(F₁) X PR had significantly higher number of clusters than PR X BS (F₁), AV X CR (F₁) and CR (F₂).

CR (F₁) X PR had the widest range (5 to 37) and highest variance (82.09) for this character. PR X CR (F₁), AV X CR (F₁) and CR (F₂) had similar range. PR X CR (F₁) had highest estimate of heritability (75.97%) as well as GA (78.08%). It had a GCV of 44.07 per cent and a PCV of 50.56 per cent. AV X CR (F₁) also had higher estimates of heritability (73.86%) as well as GA (71.55%). It had a GCV of 40.35 per cent and a PCV of 46.95 per cent.

4.2.6 Number of fruits per plant

CR (F₁) had a significantly higher number of fruits (95.07) than other parents. Among crosses, all except PR X CR (F₁) and AV X BS (F₁), were on par with one another for number of fruits per plant.

The overall range for this character, was 4 to 127, and the cross AV X CR (F₁) had the widest range (4 to 121) with a variance of 573.36. PR X BS (F₁), though had a variance as low as 282.55, had the highest estimates of GCV (70.83%) and PCV (86.66%) because of its low mean value (19.38) and low environmental influence. It had a high heritability (67.24%) and high genetic advance (119.71%). PR X CR (F₁) had the highest estimates of variance (1048.75), heritability (86.49%) and GA (122.12%). CR (F₁) X PR also had higher estimates of variance

Table 4.5. Estimates of genetic parameters in parents, F_2 and three-way crosses for number of clusters per plant.

Entries	Mean $\pm$ S.E	Range	Variance	GCV(%)	PCV(%)	Heritability (%)	GA	GA as % of mean
Non-segregating								
PR	14.45 $\pm$ 0.40	6 - 22	17.98					
AV	9.00 $\pm$ 0.40	2 - 18	14.97					
BS(F_1)	3.67 $\pm$ 0.36	2 - 10	11.39					
CR(F_1)	22.60 $\pm$ 0.33	14 - 32	9.55					
Segregating								
CR(F_2)	13.43 $\pm$ 0.59	2 - 30	28.54					
PRXBS(F_1)	9.08 $\pm$ 0.54	2 - 22	26.71	38.18	56.93	45.02	4.79	52.75
AVXBS(F_1)	8.61 $\pm$ 0.46	2 - 18	19.00	28.01	50.63	30.63	2.78	32.28
AVXCR(F_1)	14.59 $\pm$ 0.72	2 - 30	46.91	40.35	46.95	73.85	10.44	71.55
PRXCR(F_1)	14.97 $\pm$ 0.68	2 - 30	57.28	44.07	50.56	75.97	11.69	78.08
CR(F_1)XPR	18.01 $\pm$ 0.97	5 - 37	82.09	45.67	50.05	83.24	15.49	85.58

Note: Since the first four populations are homogenous the genetic parameters were not worked out for them.

Table 4.6. Estimates of genetic parameters in parents, F_2 and three-way crosses for number of fruits per plant.

Entries	Mean $\pm$ S.E	Range	Variance	GCV(%)	PCV(%)	Heritability (%)	GA	GA as % of mean
Non-segregating								
PR	38.75 $\pm$ 0.97	4 - 56	100.67					
AV	17.89 $\pm$ 1.47	4 - 43	184.49					
BS(F_1)	10.67 $\pm$ 1.11	4 - 30	84.46					
CR(F_1)	105.60 $\pm$ 1.60	95 - 127	182.60					
Segregating								
CR(F_2)	47.43 $\pm$ 1.93	4 - 108	466.78					
PRXBS(F_1)	19.38 $\pm$ 1.00	4 - 43	282.55	70.83	86.66	67.24	23.20	119.71
AVXBS(F_1)	19.61 $\pm$ 1.71	4 - 56	262.18	58.16	83.32	48.70	16.00	81.59
AVXCR(F_1)	47.59 $\pm$ 2.29	4 - 121	573.37	41.81	50.72	67.99	33.54	70.48
PRXCR(F_1)	46.97 $\pm$ 1.89	4 - 108	1048.75	64.85	69.74	86.49	57.36	122.12
CR(F_1)XPR	52.11 $\pm$ 2.06	9 - 113	1018.36	56.82	61.24	86.09	56.53	108.49

Note: Since the first four populations are homogenous the genetic parameters were not worked out for them.

(1018.36), heritability (86.09%) and GA (108.49%) as per cent of mean.

4.2.7 Number of flowers per plant

CR (F_1) had significantly higher number of flowers (150.46) than other parents and crosses. Among segregating populations CR (F_2) had the highest mean value (89.98) (Table 3).

The over all range for this character was 13 to 238. Among segregating generations the over all range was 13 to 188. PR X CR (F_1) had the widest range (13 to 188) with a variance of 1064.03. CR (F_1) X PR showed the highest variance (1409.28). However, AV X CR (F_1) had the highest estimates of GCV (39.9%), heritability (85.81%) and genetic advance (76.31%). PR X CR (F_1) also had higher values of variance (1064.03), GCV (32.87%), heritability (78.87%) and GA (60.24%). In CR (F_2), variability estimate was 1165.61.

4.2.8 Number of flowers per inflorescence

BS (F_1) and CR (F_1) had significantly higher number of flowers per inflorescence than PR and AV (Table 3).

Among the segregating populations CR (F_2) had significantly higher number of flowers per inflorescence than others.

The over all range for this character was 3 to 9. The crosses PR X BS (F_1), PR X CR (F_1) and AV X CR (F_1) were on par

for the range. AV X BS (F_1) had the highest estimates of variance (1.7), heritability (68.8%) and GA (32.17%). PR X BS (F_1) also had higher values of variance (1.56), heritability (61.54%) and GA as per cent of mean (30.8). The GCV (18.91%) and PCV (24.11%) estimates were highest in this cross. PR X CR (F_1) and AV X CR (F_1) had moderate values of heritability (55.28% and 55.9% respectively) and GA (19.68% and 18.03% respectively).

4.2.9 Average fruit weight

Among parents, all were significantly different from one another for the average fruit weight (Table 3). AV had the highest mean value of average fruit weight (63.73 g). Among crosses, PR X BS (F_1) and AV X BS (F_1) had significantly higher values, than the other populations.

The over all range for this character was 27 to 71 g. Among crosses PR X BS (F_1) had the widest range (32 to 62 g). Variance was highest for CR (F_2) (39.65). AV X BS (F_1) also had a high variance (35.5) accompanied by the highest estimates of heritability (71.18%) and GA (15.65%). In AV X CR (F_1) though variance was moderate (18.72), it had the highest GCV (9.79%) and PCV (12.87%) estimates. However heritability was 57.9 per cent and GA was 15.37 per cent here. PR X BS (F_1) had a high variance of 20.74 and heritability and GA estimates of 58.0 per cent and 10.6 per cent respectively.

Table 4.7. Estimates of genetic parameters in parents, F_2 and three-way crosses for number of flowers per plant.

Entries	Mean $\pm$ S.E	Range	Variance	GCV(%)	PCV(%)	Heritability (%)	GA	GA as % of mean
Non-segregating								
PR	57.46 $\pm$ 1.74	13 - 88	272.42					
AV	37.06 $\pm$ 1.18	15 - 63	126.60					
BS(F_1)	20.96 $\pm$ 1.39	13 - 63	174.99					
CR(F_1)	150.46 $\pm$ 1.40	88 - 238	177.16					
Segregating								
CR(F_2)	89.98 $\pm$ 2.94	15 - 168	1165.61					
PRXBS(F_1)	45.79 $\pm$ 2.12	13 - 88	506.85	36.75	49.16	55.86	25.90	56.56
AVXBS(F_1)	40.73 $\pm$ 2.09	13 - 113	196.77	16.61	34.42	23.36	6.65	16.33
AVXCR(F_1)	75.97 $\pm$ 2.13	13 - 163	1070.95	39.90	43.07	85.81	57.97	76.31
PRXCR(F_1)	88.12 $\pm$ 2.50	13 - 188	1064.03	32.87	37.02	78.87	53.08	60.24
CR(F_1)XPR	77.91 $\pm$ 2.78	31 - 146	1409.28	44.17	48.18	84.05	64.96	83.38

Note: Since the first four populations are homogenous the genetic parameters were not worked out for them.

Table 4.8. Estimates of genetic parameters in parents, F_2 and three-way crosses for number of flowers per inflorescence.

Entries	Mean $\pm$ S.E	Range	Variance	GCV(%)	PCV(%)	Heritability (%)	GA	GA as % of mean
Non-segregating								
PR	5.10 $\pm$ 0.07	4 - 6	0.440					
AV	5.22 $\pm$ 0.05	4 - 6	0.300					
BS(F_1)	6.73 $\pm$ 0.09	5 - 8	0.770					
CR(F_1)	7.99 $\pm$ 0.09	6 - 9	0.670					
Segregating								
CR(F_2)	7.77 $\pm$ 0.26	6 - 9	0.687					
PRXBS(F_1)	5.18 $\pm$ 0.13	3 - 7	1.560	18.91	24.11	61.54	1.597	30.80
AVXBS(F_1)	5.75 $\pm$ 0.13	4 - 6	1.700	18.81	22.67	68.80	1.850	32.17
AVXCR(F_1)	6.71 $\pm$ 0.11	5 - 9	1.100	11.73	15.63	55.10	1.210	18.03
PRXCR(F_1)	6.40 $\pm$ 0.12	4 - 8	1.230	12.88	17.33	55.28	1.260	19.68
CR(F_1)XPR	6.41 $\pm$ 0.25	5 - 8	0.649	4.78	12.56	14.48	0.230	3.62

Note: Since the first four populations are homogenous the genetic parameters were not worked out for them.

Table 4.9. Estimates of genetic parameters in parents, F_2 and three-way crosses for average fruit weight.

Entries	Mean $\pm$ S.E	Range	Variance	GCV(%)	PCV(%)	Heritability (%)	GA	GA as % of mean
Non-segregating								
PR	49.04 $\pm$ 0.29	37 - 57	7.75					
AV	63.65 $\pm$ 0.34	47 - 67	10.79					
BS(F_1)	57.53 $\pm$ 0.33	52 - 67	9.67					
CR(F_1)	35.60 $\pm$ 0.23	32 - 42	4.97					
Segregating								
CR(F_2)	36.11 $\pm$ 0.78	27 - 42	39.65					
PRXBS(F_1)	51.25 $\pm$ 0.29	32 - 62	20.74	6.77	8.88	58.00	5.44	10.60
AVXBS(F_1)	55.91 $\pm$ 0.62	42 - 71	35.50	8.90	10.66	71.18	8.74	15.63
AVXCR(F_1)	33.63 $\pm$ 0.46	27 - 42	18.72	9.79	12.87	57.90	5.17	15.37
PRXCR(F_1)	38.63 $\pm$ 0.42	27 - 52	15.97	4.66	10.34	20.35	1.64	4.20
CR(F_1)XPR	37.52 $\pm$ 0.41	30 - 49	16.52	8.49	10.83	61.50	5.15	13.72

Note: Since the first four populations are homogenous the genetic parameters were not worked out for them.

4.2.10 Yield per plant

Among parents CR (F_1) had significantly higher yield per plant (1.527kg) than others. Among crosses CR (F_1) X PR had the highest value of yield per plant (0.950kg), but on par with CR (F_2) (0.903kg).

The over all range for this character was 0.198 to 2.491 kg. CR (F_1) X PR had the widest range of variation (0.349 to 2.491 kg) with a variance of 0.275. It had a GCV of 40.56%, PCV (55.2%), heritability (54%) and GA (61.52%). PR X CR (F_1) had the highest variance (0.295) accompanied by the highest estimates of GCV (47.83%), heritability (57.28%) and GA (73.08%). PR X BS (F_1) and AV X CR (F_1) were on par for variance (Table 4.10).

4.2.11 Total soluble solids

All the parents were on par for total soluble solids, with one another; among crosses, AV X CR (F_1) had the highest mean value (4.78) which is significantly higher than all others except AV X BS (F_1) and CR (F_1) X PR.

It had an overall range of 3 to 5. All the crosses had a similar range except CR (F_1) X PR (Table 4.11). Variance was highest for the cross CR (F_1) X PR (4.59). It also had the highest estimates of GCV (36.66%), PCV (38.6%), heritability (98.9%) and GA (36.94%). PR X BS (F_1) had low values of GCV (7.21%) and PCV (8.13%). Since the difference between GCV and

Table 4.10. Estimates of genetic parameters in parents, F_2 and three-way crosses for yield per plant.

Entries	Mean $\pm$ S.E	Range	Variance	GCV(%)	PCV(%)	Heritability (%)	GA	GA as % of mean
Non-segregating								
PR	0.652 $\pm$ 0.04	0.200-1.548	0.152					
AV	0.672 $\pm$ 0.04	0.205-1.098	0.155					
BS(F_1)	0.438 $\pm$ 0.03	0.203-0.873	0.113					
CR(F_1)	1.527 $\pm$ 0.03	0.873-2.223	0.101					
Segregating								
CR(F_2)	0.903 $\pm$ 0.54	0.202-1.998	0.120					
PRXBS(F_1)	0.686 $\pm$ 0.05	0.198-1.323	0.188	35.70	63.20	29.50	0.259	35.75
AVXBS(F_1)	1.560 $\pm$ 0.05	0.201-1.548	0.240	20.87	31.40	44.16	0.440	28.20
AVXCR(F_1)	0.804 $\pm$ 0.05	0.198-1.998	0.183	29.00	53.20	30.05	0.264	32.83
PRXCR(F_1)	0.862 $\pm$ 0.06	0.200-2.723	0.295	47.83	63.00	57.28	0.630	73.08
CR(F_1)XPR	0.950 $\pm$ 0.07	0.349-2.491	0.275	40.56	55.20	54.00	0.580	61.52

Note: Since the first four populations are homogenous the genetic parameters were not worked out for them.

PCV was narrow which can be attributed to low environmental influence, heritability estimate was high (78.07%). AV X BS (F_1) had moderate values of GCV (11.34%) and PCV (12.66%), with higher estimates of heritability (80.4%) and genetic advance (20.63%).

Both PR X CR (F_1) and AV X CR (F_1) had moderate heritability (68.35% and 69.8% respectively) and GA estimates (18.28% and 16.95 respectively).

4.2.12 Polar diameter

Among parents BS (F_1) had a significantly higher polar diameter (3.73 cm) than others.

Among segregating populations, PR X CR (F_1), CR (F_1) X PR and CR (F_2) were on par with one another and the other three populations, differed significantly with one another for polar diameter. The over all range of variability for this character was 1.9 to 5.9 cm. AV X BS(F_1) recorded the widest range (1.9 to 5.9 cm).

Highest estimates of variance (0.398), GCV (14.24%) PCV (17.14%), heritability (68.98%) and GA (24.18%) were recorded for AV X BS (F_1). The crosses PR X BS (F_1) and PR X CR (F_1) had moderate estimates of heritability (55.85% and 51.08% respectively) and GA (16.87% and 16.44% respectively).

Table 4.11. Estimates of genetic parameters in parents, F_2 and three-way crosses for total soluble solids.

Entries	Mean $\pm$ S.E	Range	Variance	GCV(%)	PCV(%)	Heritability (%)	GA	GA as % of mean
Non-segregating								
PR	4.11 $\pm$ 0.01	3.5 - 4.5	0.020					
AV	3.97 $\pm$ 0.03	3.5 - 4.7	0.096					
BS(F_1)	4.11 $\pm$ 0.02	3.5 - 4.9	0.029					
CR(F_1)	4.16 $\pm$ 0.04	3.5 - 5.0	0.180					
Segregating								
CR(F_2)	4.08 $\pm$ 0.05	3.0 - 5.0	0.312					
PRXBS(F_1)	4.15 $\pm$ 0.03	3.0 - 5.0	0.115	7.21	8.13	78.07	0.55	13.25
AVXBS(F_1)	4.46 $\pm$ 0.06	3.0 - 5.0	0.319	11.34	12.66	80.40	0.93	20.63
AVXCR(F_1)	4.78 $\pm$ 0.07	3.0 - 5.0	0.457	9.77	11.70	69.80	0.98	16.95
PRXCR(F_1)	4.13 $\pm$ 0.06	3.0 - 5.0	0.316	11.25	13.60	68.35	0.78	18.88
CR(F_1)XPR	4.55 $\pm$ 0.09	3.5 - 5.0	4.590	36.66	38.60	98.90	2.05	36.94

Note: Since the first four populations are homogenous the genetic parameters were not worked out for them.

Table 4.12. Estimates of genetic parameters in parents, F_2 and three-way crosses for polar diameter.

Entries	Mean $\pm$ S.E	Range	Variance	GCV(%)	PCV(%)	Heritability (%)	GA	GA as % of mean
Non-segregating								
PR	3.52 $\pm$ 0.04	1.9 - 4.4	0.103					
AV	3.65 $\pm$ 0.04	1.9 - 4.9	0.131					
BS(F_1)	3.73 $\pm$ 0.04	2.4 - 4.9	0.116					
CR(F_1)	3.45 $\pm$ 0.03	2.9 - 5.4	0.080					
Segregating								
CR(F_2)	2.75 $\pm$ 0.05	1.9 - 3.9	0.183					
PRXBS(F_1)	3.40 $\pm$ 0.05	2.9 - 4.9	0.298	10.95	14.64	55.85	0.57	16.87
AVXBS(F_1)	3.68 $\pm$ 0.06	1.9 - 5.9	0.398	14.24	17.14	68.96	0.89	24.18
AVXCR(F_1)	3.18 $\pm$ 0.04	1.9 - 4.4	0.154	6.96	12.34	31.49	0.25	8.01
PRXCR(F_1)	2.76 $\pm$ 0.04	1.9 - 3.9	0.186	11.34	15.63	51.08	0.45	16.44
CR(F_1)XPR	2.87 $\pm$ 0.04	2.2 - 3.6	0.138	7.50	12.94	34.06	0.26	9.09

Note: Since the first four populations are homogenous the genetic parameters were not worked out for them.

4.2.13 Equatorial diameter

Among parents BS (F_1) had significantly higher equatorial diameter than others. PR and AV were on par. Among segregating populations, significantly lower values were recorded for CR (F_2), PR X CR (F_1) and CR (F_1) X PR, than the other three populations (Table 2).

An overall range of 2.4 to 7.8 cm was recorded for this character. AV X BS (F_1) had the widest range (3.0 to 7.8 cm). Variance was highest for the cross AV X BS (F_1) (2.14). It also had higher values of GCV (22.15%) and PCV (23.82%) though the highest estimates were recorded for PR X CR (F_1) (32.58% and 37.36% respectively). PR X CR (F_1) also had the highest estimate of GA (58.58%) along with a heritability of 70.06 per cent. However, heritability was highest for AV X BS (F_1) (86.2%). PR X BS (F_1) had a moderate heritability estimate (59.0%) and GA (24.11%) though GCV and PCV values were the least (Table 4.13).

4.2.14 Number of locules

Among parents, CR (F_1) had the least number of locules (2.0). Among crosses, AV X BS (F_1) and PR X BS (F_1) had significantly higher number of locules than others (Table 2). The over all range was 2 to 8. In the segregating populations, PR X BS (F_1) and AV X BS (F_1) had wider range (Table 4.14).

Table 4.13. Estimates of genetic parameters in parents, F_2 and three-way crosses for equatorial diameters.

Entries	Mean $\pm$ S.E	Range	Variance	GCV(%)	PCV(%)	Heritability (%)	GA	GA as % of mean
Non-segregating								
PR	5.36 $\pm$ 0.05	3.0 - 6.0	0.710					
AV	5.66 $\pm$ 0.10	4.2 - 6.6	0.900					
BS(F_1)	6.20 $\pm$ 0.05	4.2 - 6.6	0.210					
CR(F_1)	3.54 $\pm$ 0.04	2.4 - 4.8	0.178					
Segregating								
CR(F_2)	3.20 $\pm$ 0.16	2.4 - 4.2	0.910					
PRXBS(F_1)	5.39 $\pm$ 0.01	3.6 - 7.2	1.140	15.29	19.81	59.00	1.30	24.11
AVXBS(F_1)	6.14 $\pm$ 0.11	3.0 - 7.8	2.140	22.15	23.82	86.20	2.59	42.18
AVXCR(F_1)	4.06 $\pm$ 0.12	3.0 - 4.8	1.147	19.23	26.38	52.92	1.97	28.81
PRXCR(F_1)	3.17 $\pm$ 0.14	2.4 - 5.4	1.880	32.58	37.36	76.06	2.15	58.58
CR(F_1)XPR	3.62 $\pm$ 0.18	2.5 - 4.5	0.812	16.75	24.89	45.32	0.84	23.08

Note: Since the first four populations are homogenous the genetic parameters were not worked out for them.

For this character variance was virtually zero in case of CR (F_1). Among the crosses AV X BS (F_1) recorded the highest variance (0.77) and heritability estimate (73.9%). However, GCV and PCV estimates were highest in case of AV X CR (F_1) (18.79% and 21.86% respectively). It also had higher heritability and GA estimates (73.9% and 32.97% respectively). PR X BS (F_1) and PR X CR (F_1) had moderate values of heritability (66.66% and 65.71% respectively) and genetic advance (28.16% and 27.75% respectively).

4.2.15 Rind thickness

All the parents were on par with one another for rind thickness except for AV (3.79mm). CR (F_2) had a significantly low thickness (2.53mm) than other crosses. PR X BS (F_1) and AV X BS (F_1) were on par (Table 3).

The over all range for this character was 1.5 to 6.0 mm. PR X BS (F_1) and AV X BS (F_1) had the widest range (Table 4.15). Variance was highest for the cross AV X BS (F_1) (0.834). It also recorded high GCV (18.04%), heritability (71.82%) and GA (31.57%).

Variance was also high for the crosses PR X BS (F_1) (0.590), PR X CR (F_1) (0.465) and CR (F_1) X PR (0.452). PR X BS (F_1) had a GCV of 14.61 per cent where as PR X CR (F_1) and CR (F_1) X PR had GCV estimates of 16.24 per cent and 15.28 per cent

Table 4.14. Estimates of genetic parameters in parents, F_2 and three-way crosses for number of locules.

Entries	Mean $\pm$ S.E	Range	Variance	GCV(%)	PCV(%)	Heritability (%)	GA	GA as % of mean
Non-segregating								
PR	5.45 $\pm$ 0.04	4 - 7	0.240					
AV	5.31 $\pm$ 0.05	4 - 7	0.190					
BS(F_1)	5.87 $\pm$ 0.05	5 - 7	0.220					
CR(F_1)	2.00 $\pm$ 0.00	0	0.000					
Segregating								
CR(F_2)	2.36 $\pm$ 0.05	2 - 3	0.257					
PRXBS(F_1)	5.09 $\pm$ 0.08	3 - 7	0.690	13.32	16.32	66.66	1.13	22.20
AVXBS(F_1)	5.50 $\pm$ 0.09	4 - 8	0.770	13.73	15.95	74.02	0.80	28.16
AVXCR(F_1)	2.76 $\pm$ 0.06	2 - 4	0.365	18.79	21.86	73.90	0.91	32.97
PRXCR(F_1)	2.84 $\pm$ 0.06	2 - 5	0.350	16.89	20.83	65.71	0.80	28.16
CR(F_1)XPR	2.62 $\pm$ 0.05	2 - 4	0.324	17.24	21.76	62.29	0.73	27.75

Note: Since the first four populations are homogenous the genetic parameters were not worked out for them.

respectively. Heritability and GA estimates were moderate for the three crosses (Table 4.15).

4.3 Frequency distribution

Frequency distributions have been plotted for the various characters studied to know the nature of distribution (Fig. 1 to 15) for different populations and for different characters. Class intervals have been formed as suggested by Sundar Raj et al. (1972).

4.4 Correlation studies

In crop improvement, while selecting, association of characters play an important role. Yield being a complex character, cannot be selected for as such and its relation with its components and the relation among components themselves is very important. Hence the phenotypic correlations were worked out for the various characters considered during the study, for different segregating populations (Appendices 1 to 6).

The correlations among the important yield components and with yield are summarised in Table 5.

4.4.1 Association of days to flower with yield

In the crosses AV X CR (F_1), CR (F_1) X PR and CR (F_2), this character was negatively associated with yield, indicating that earliness resulted in increased yield. However, the other three

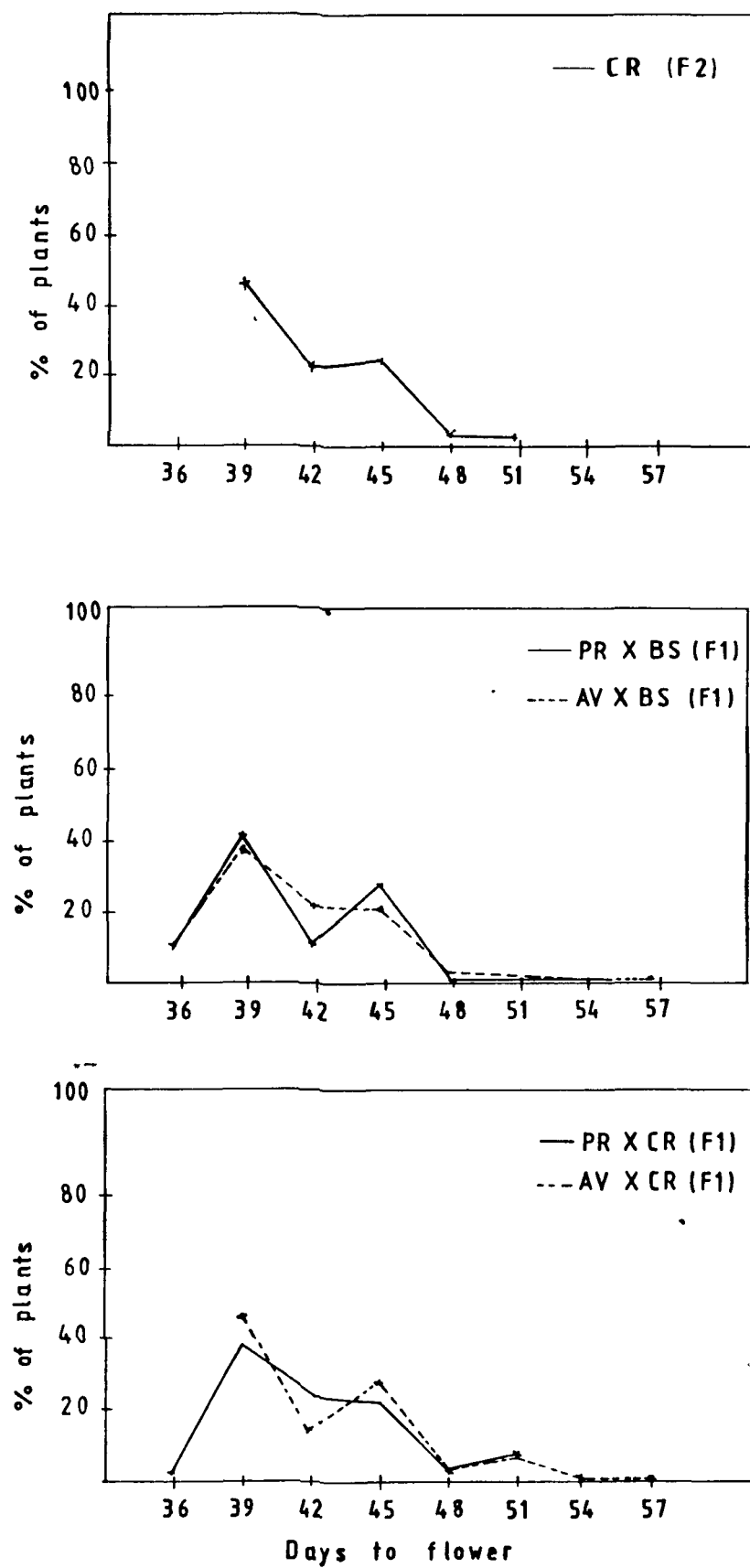


FIG1. Frequency Distribution of Different Segregating Populations for Days to Flowering.

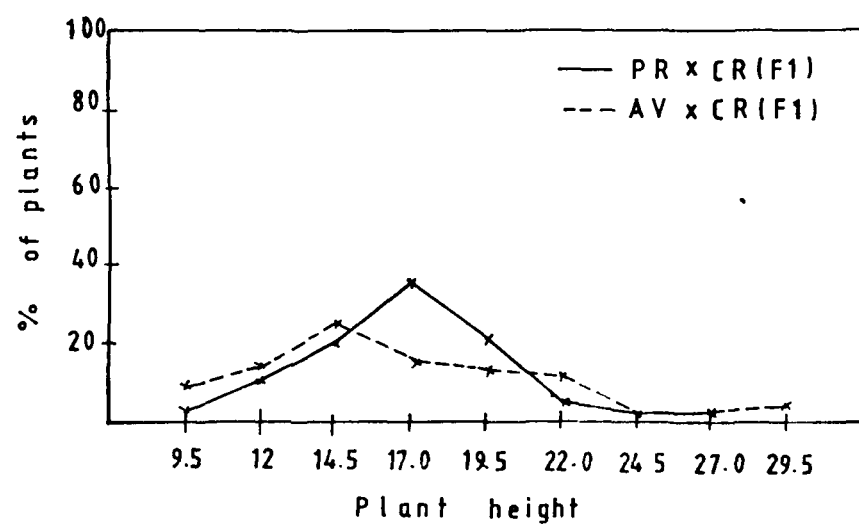
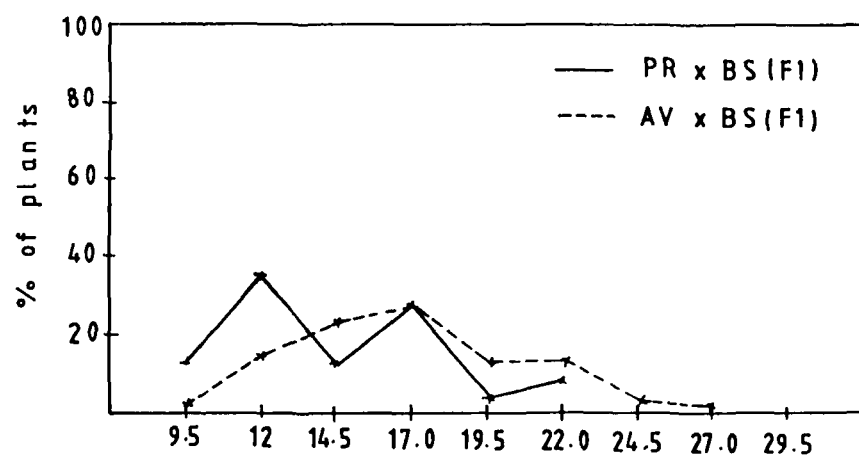
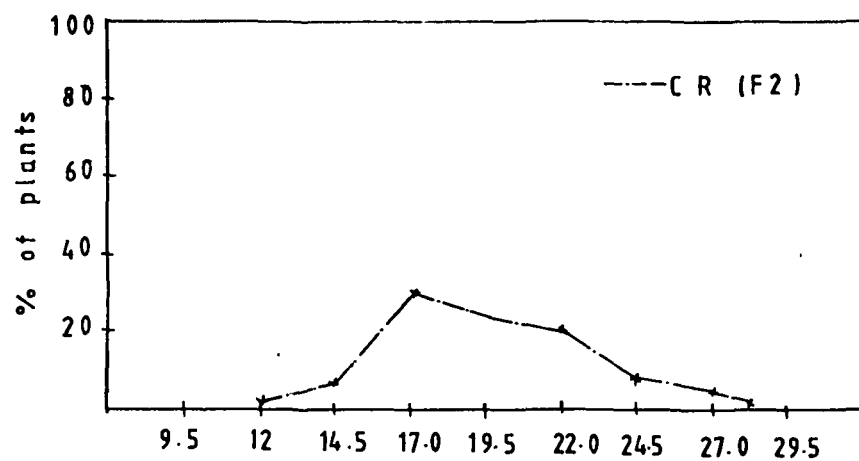


FIG 2. Frequency Distribution of Different Segregating Populations for Plant Height at Flowering

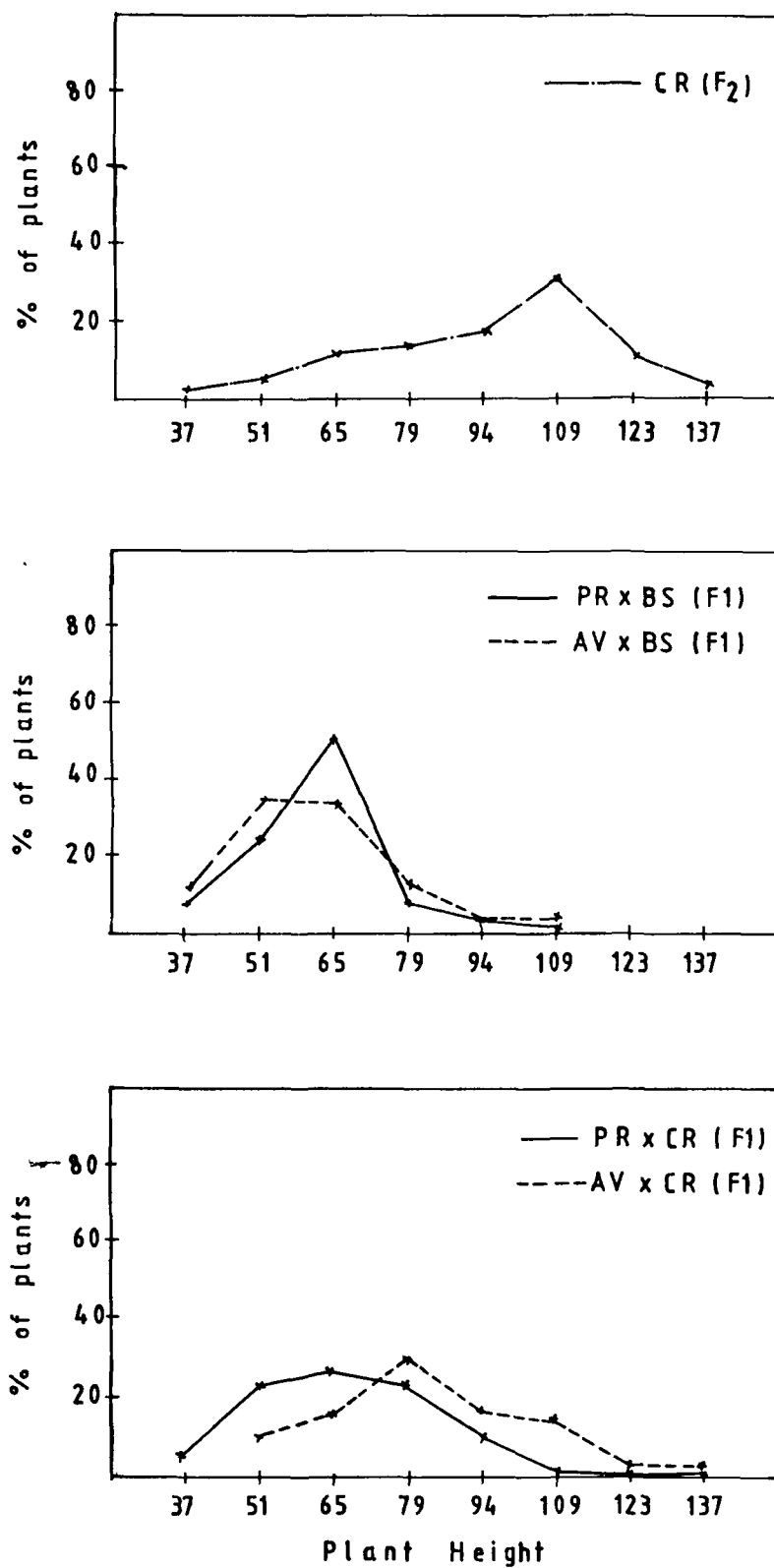


FIG 3. Frequency Distribution of Different Segregating Populations for Plant Height at Harvest

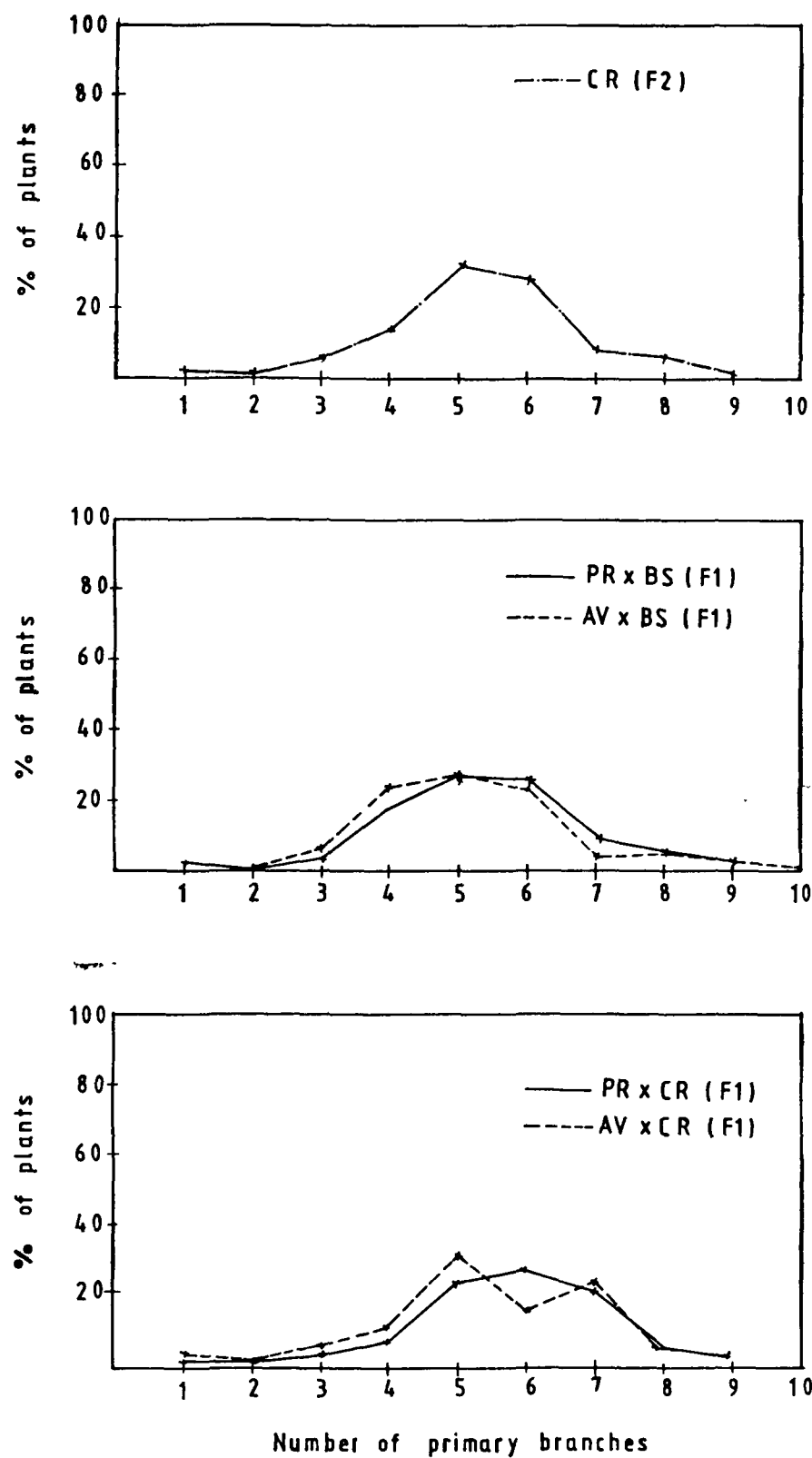


FIG 4. Frequency Distribution of Different Segregating Populations for Number of Primary Branches

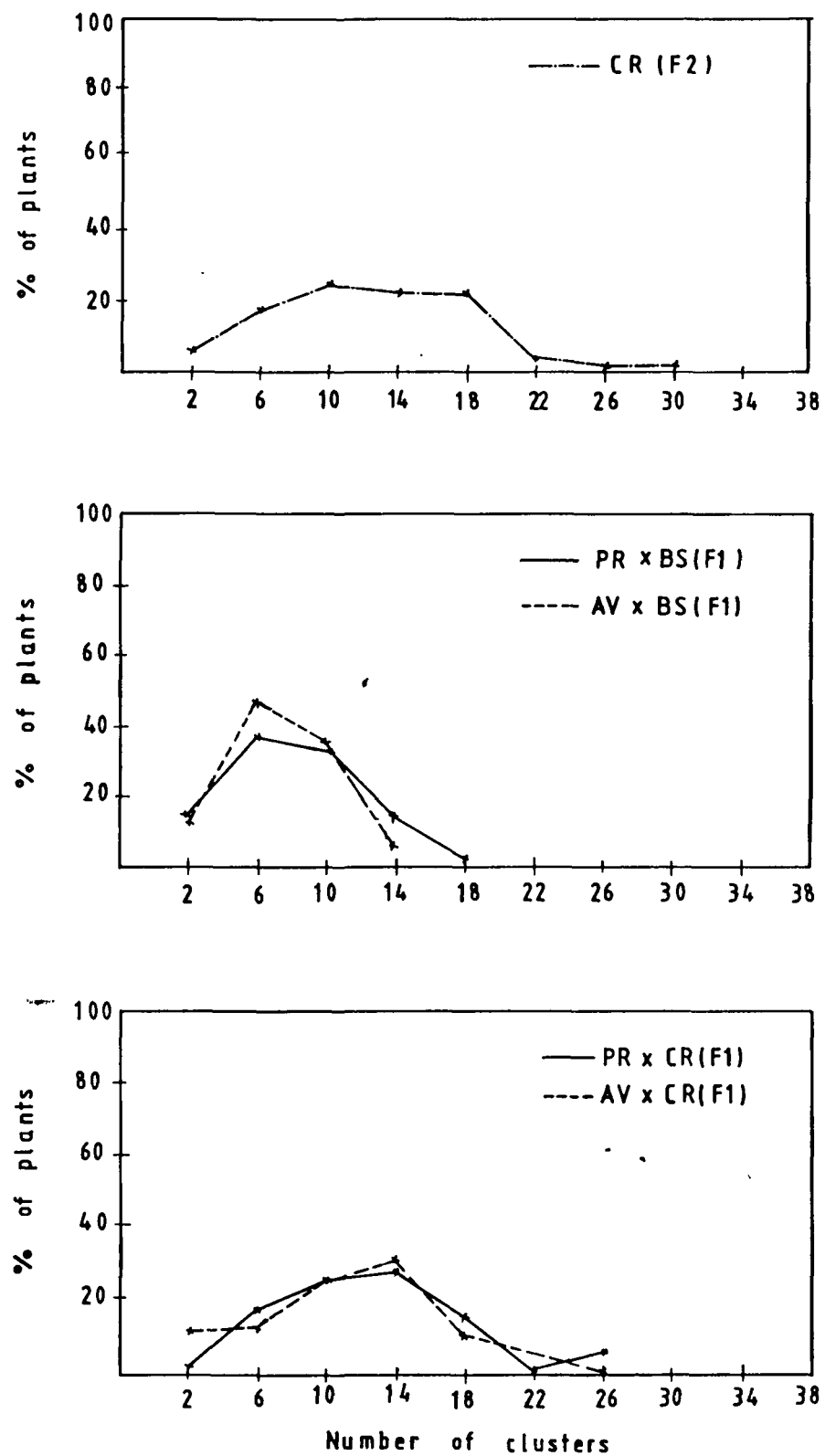


FIG 5. Frequency Distribution of Different Segregating Populations for Number of Clusters per Plant

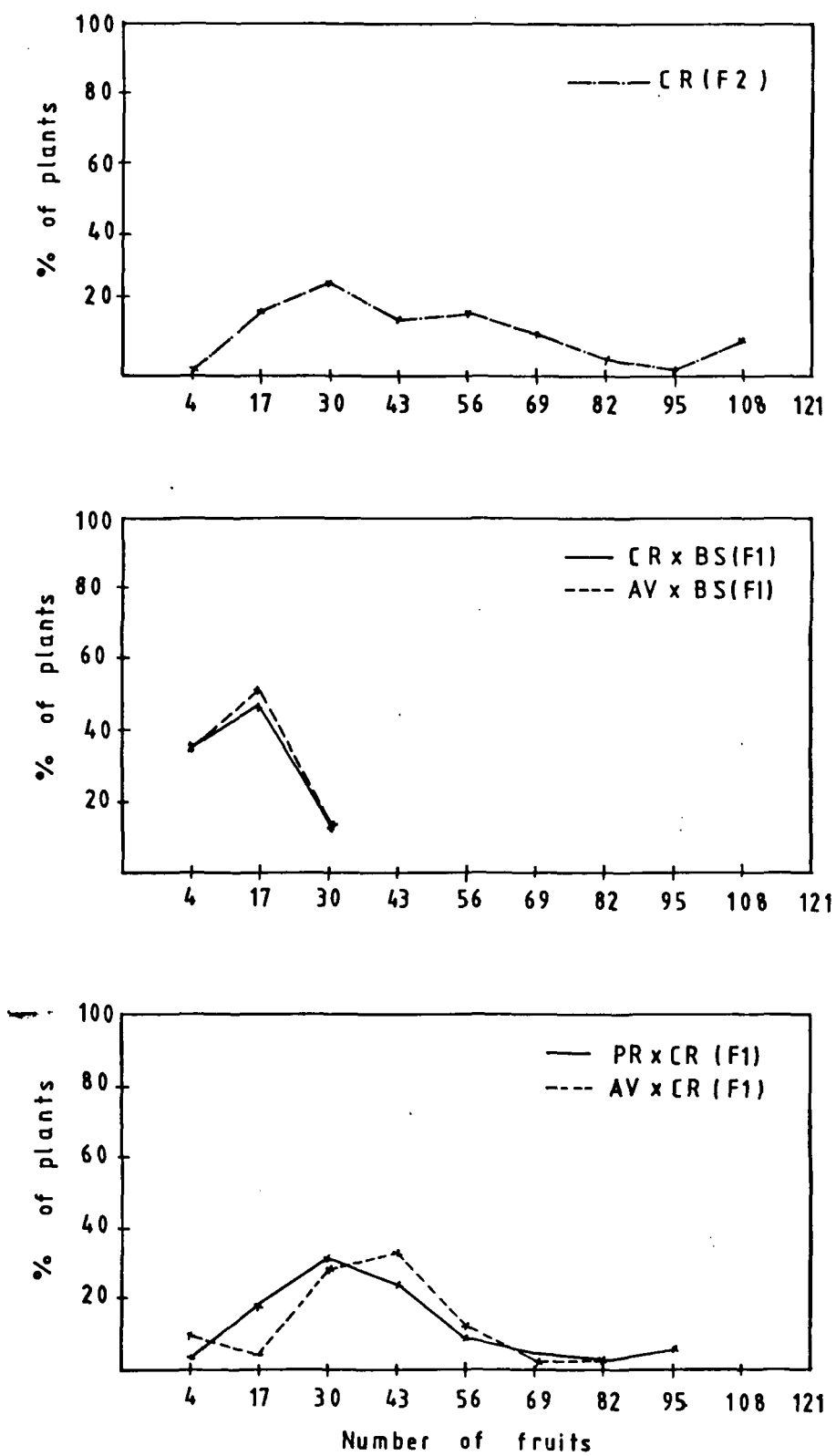


FIG 6. Frequency Distribution of Different Segregating Populations for Number of Fruits per Plant

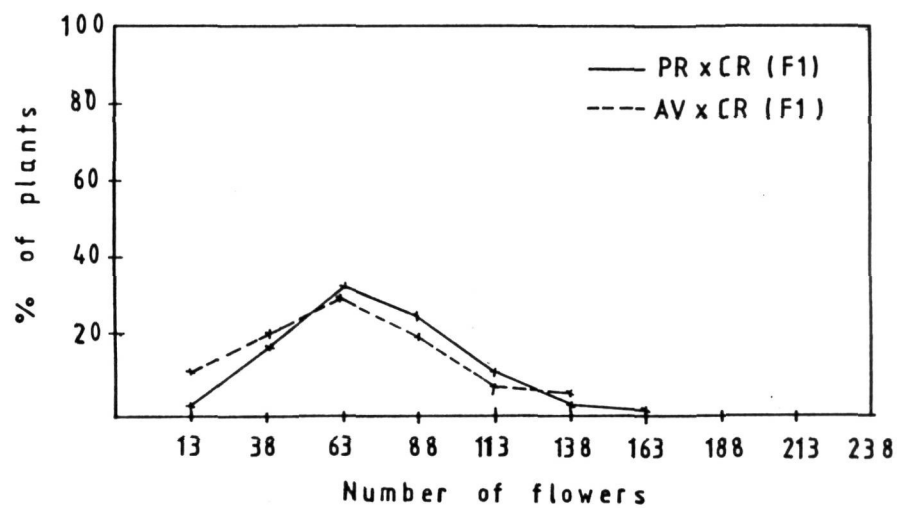
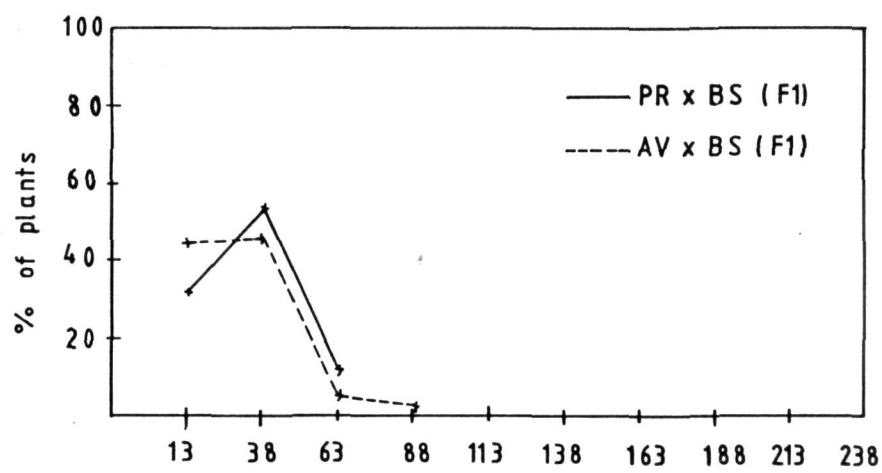
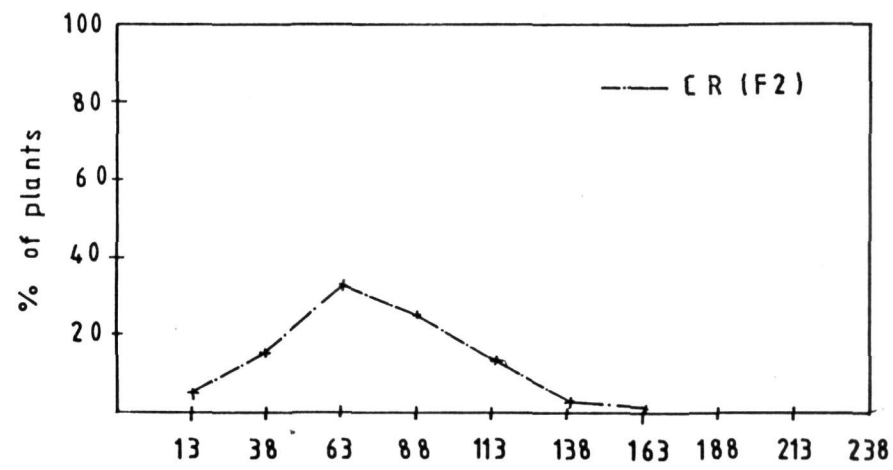


FIG 7. Frequency Distribution of Different Segregating Populations for Number of Flowers per Plant

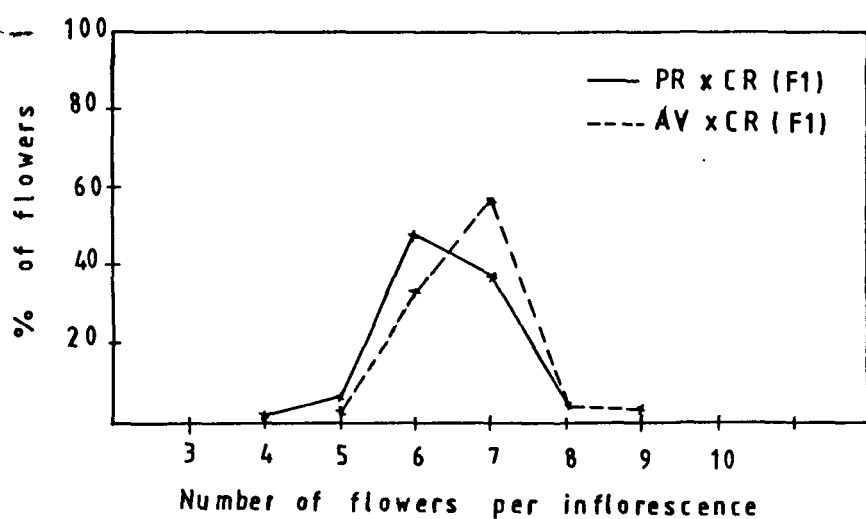
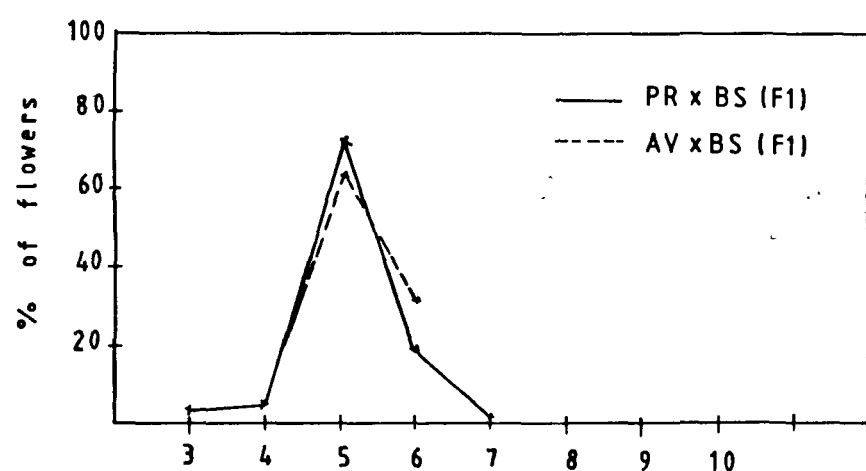
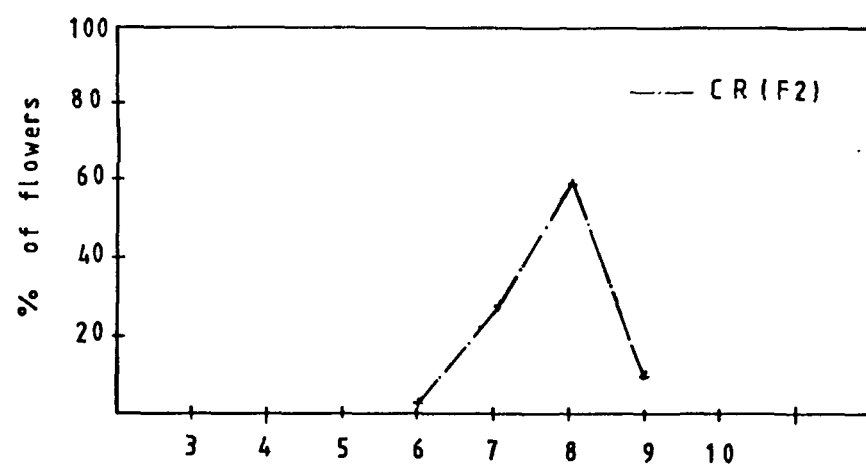


FIG 8. Frequency Distribution of Different Segregating Populations for Number of Flowers per Inflorescence

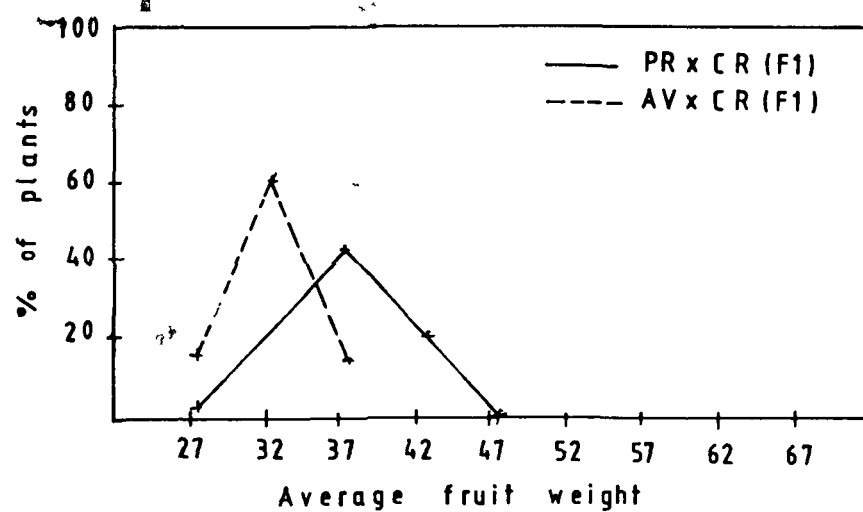
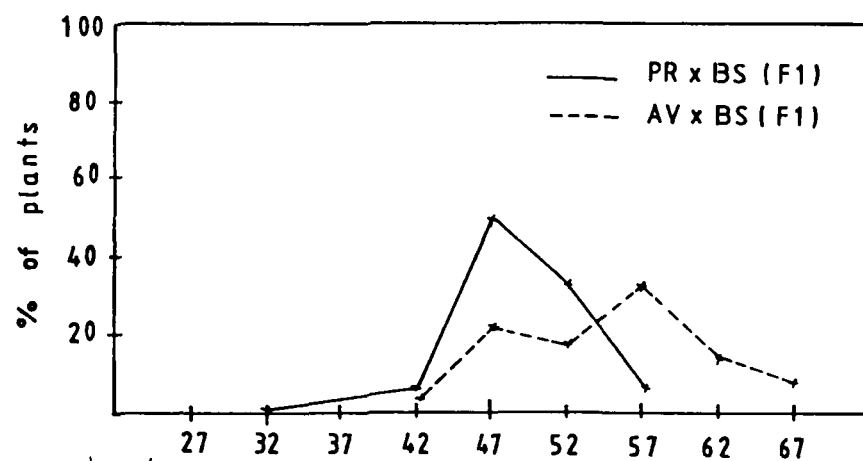
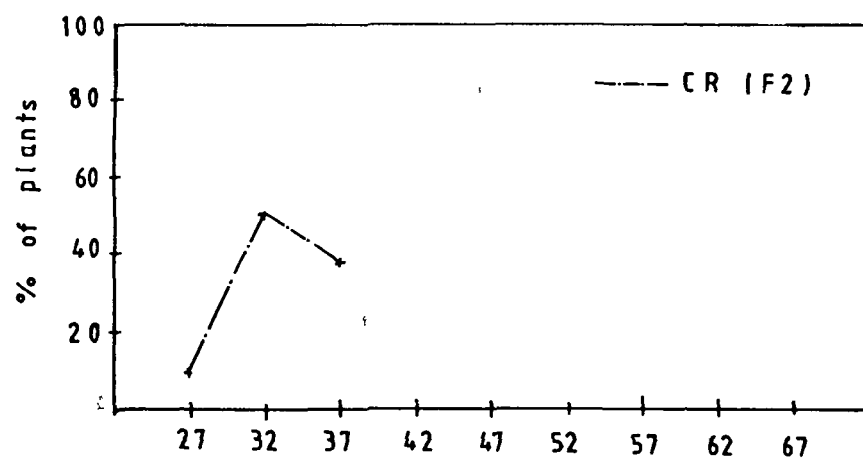


FIG 9. Frequency Distribution of Different Segregating Populations for Average Fruit Weight

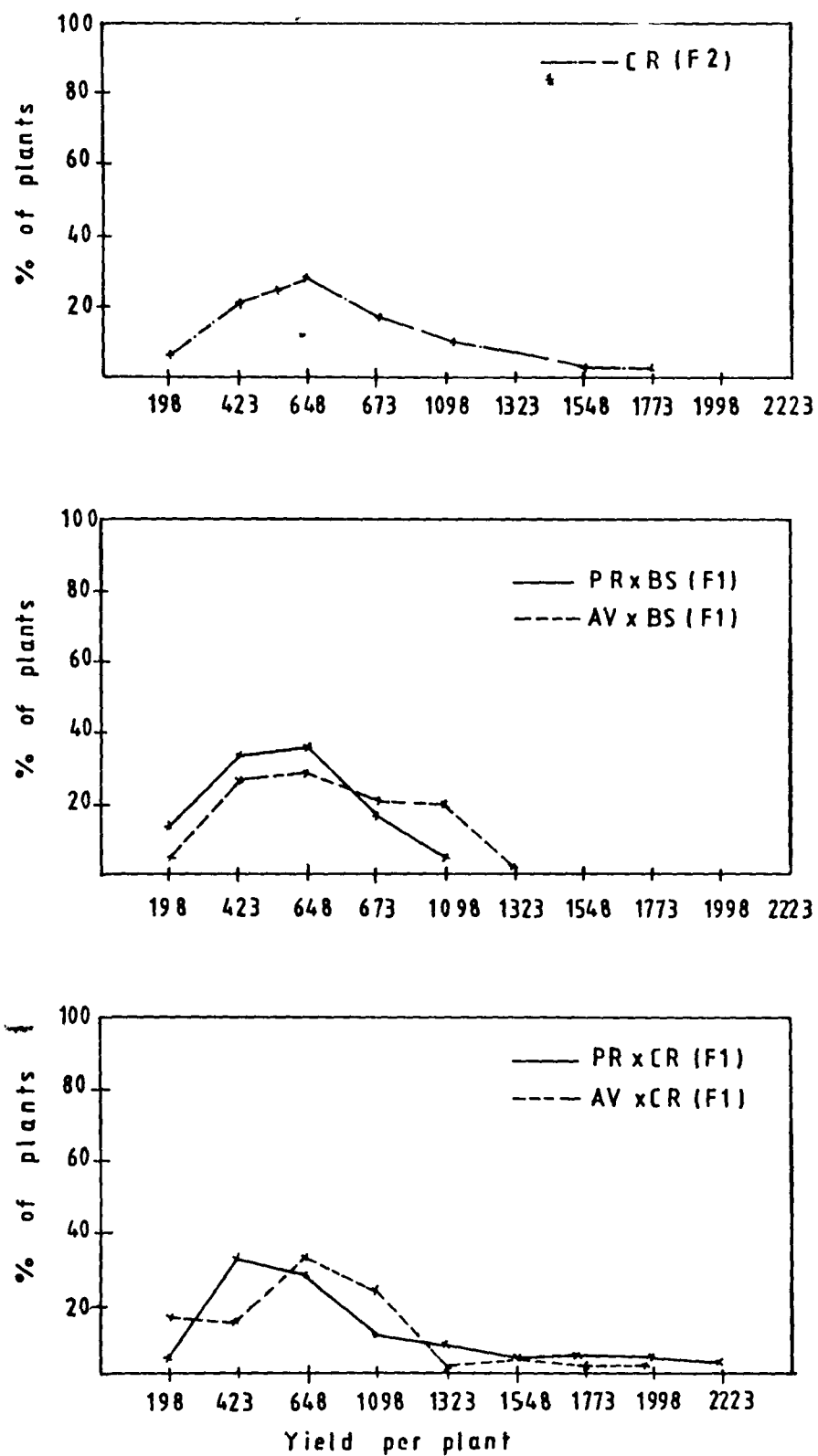


FIG 10. Frequency Distribution of Different Segregating Populations for Yield per Plant

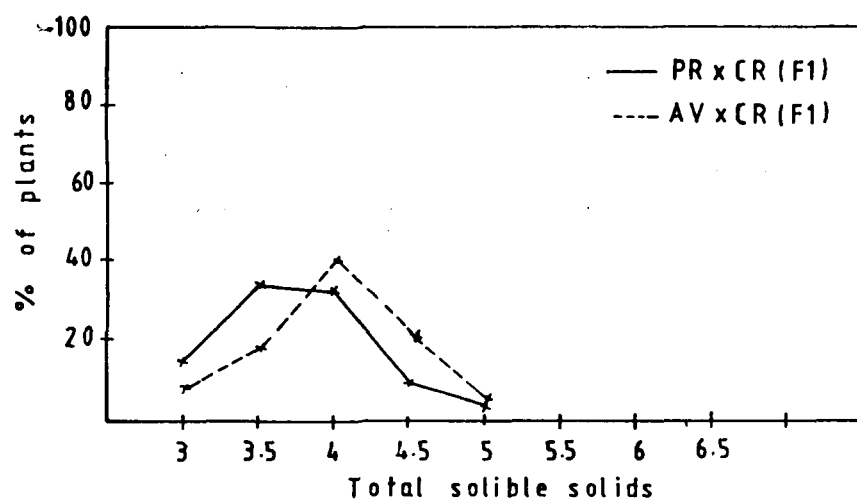
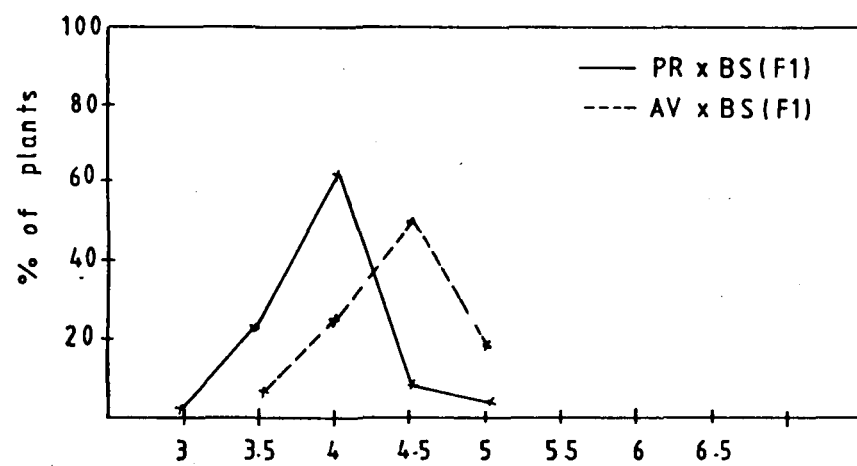
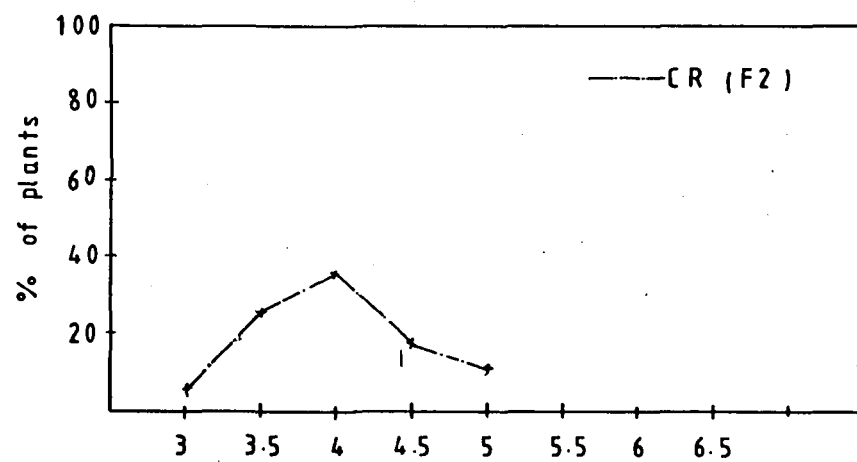


FIG 11. Frequency Distribution of Different Segregating Populations for Total Soluble Solids

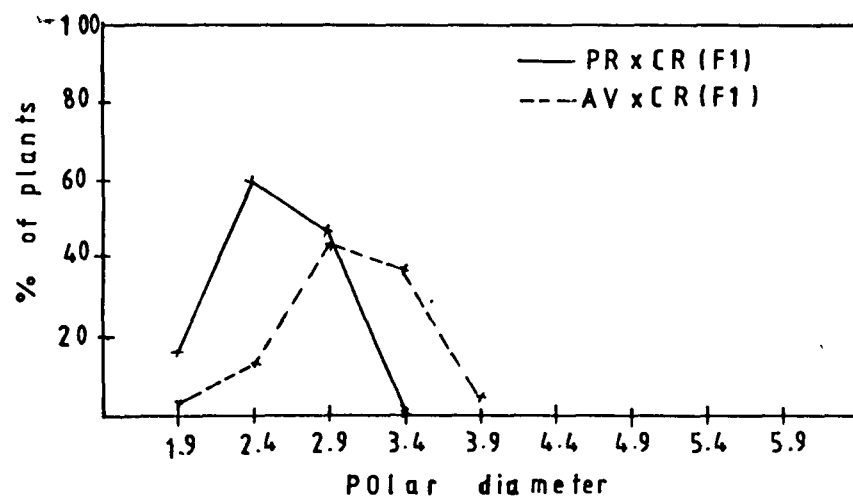
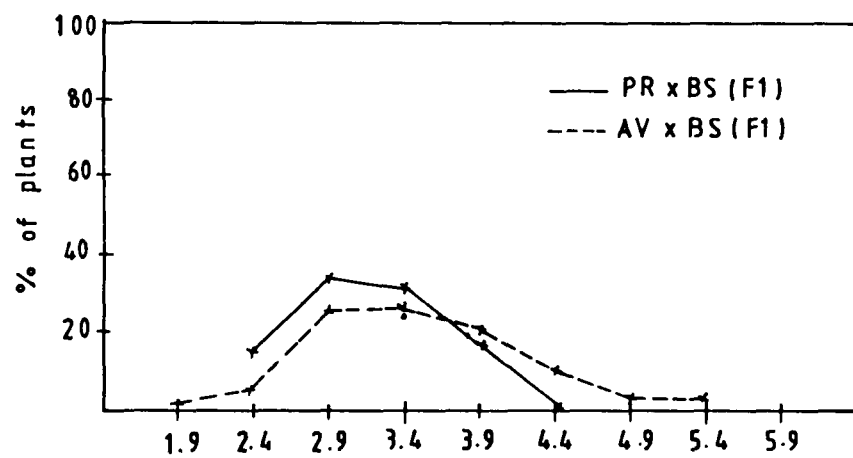
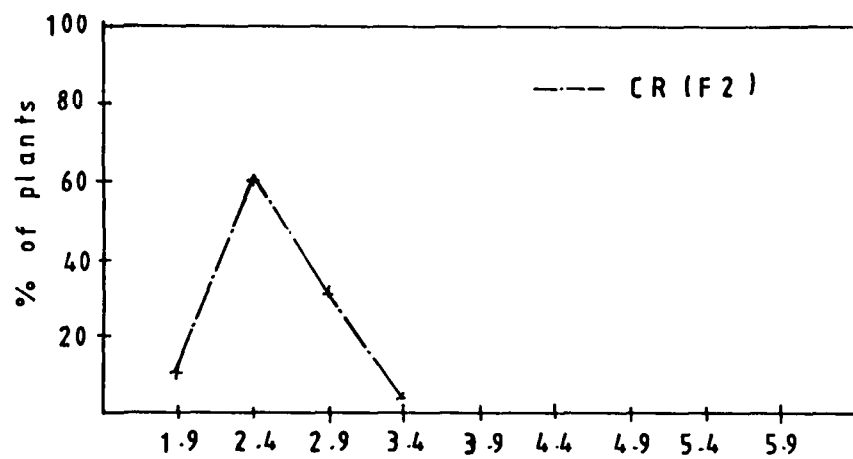


FIG 12. Frequency Distribution of Different Segregating Populations for Polar Diameter

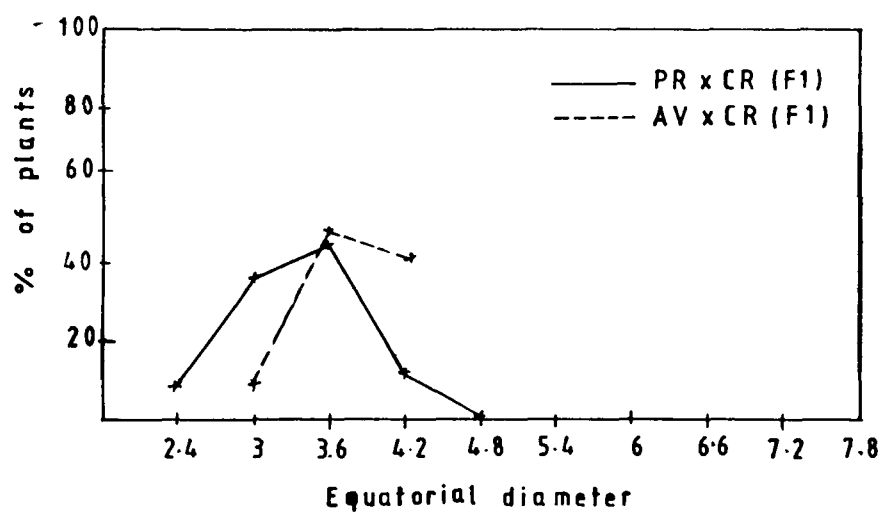
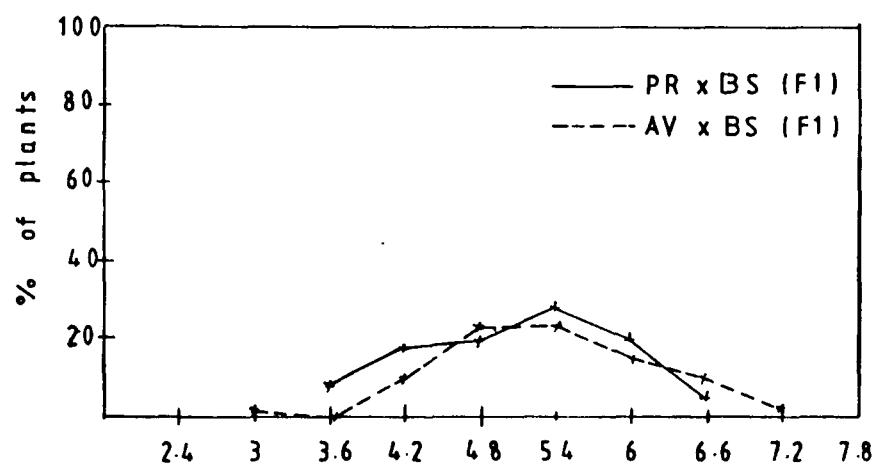
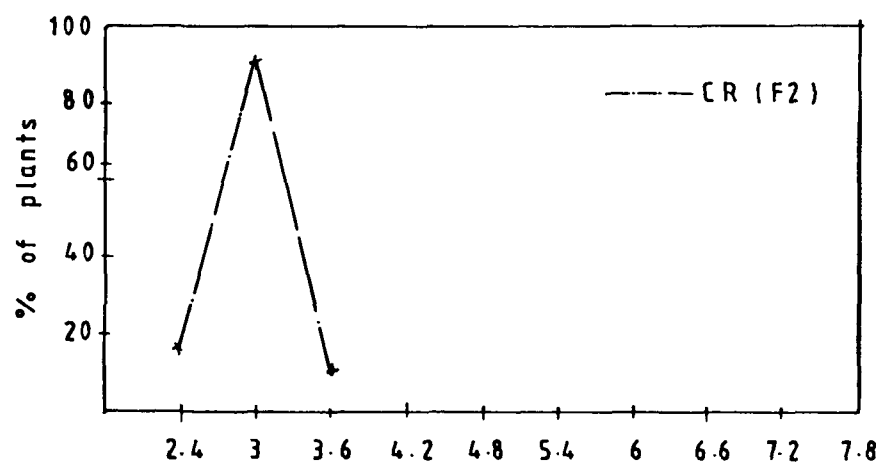


FIG 13. Frequency Distribution of Different Segregating Populations for Equatorial Diameter.

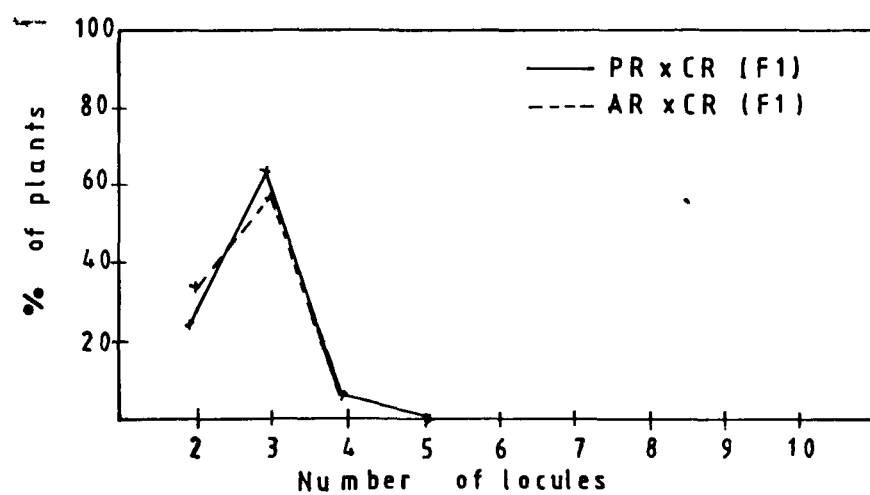
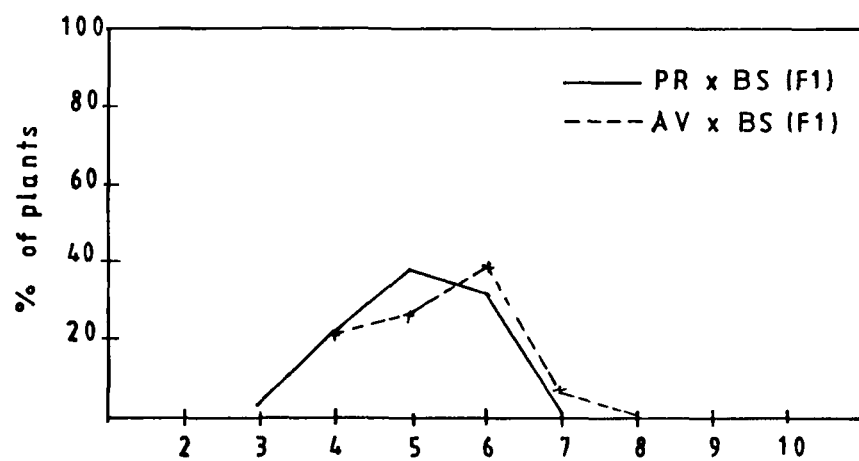
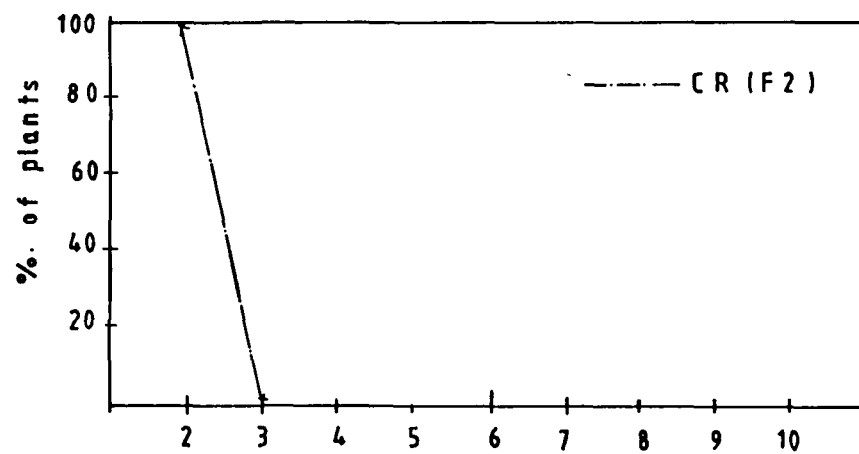


FIG 14. Frequency Distribution of Different Segregating Populations for Number of Locules.

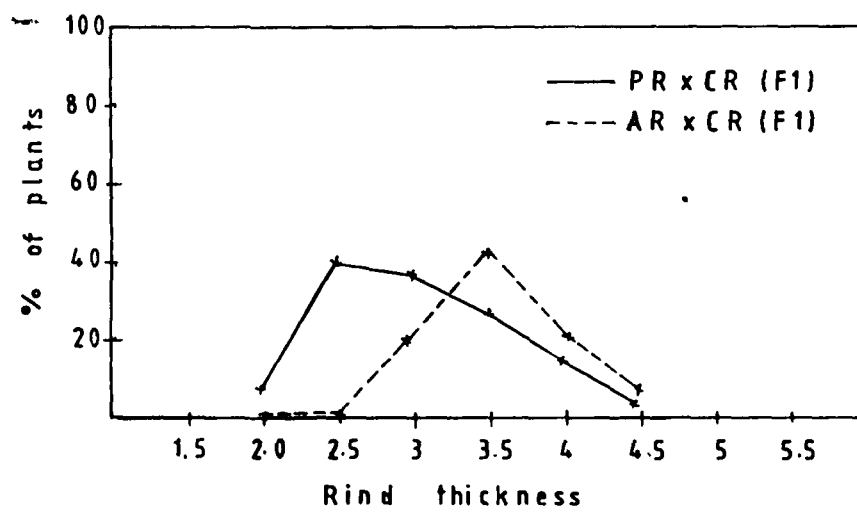
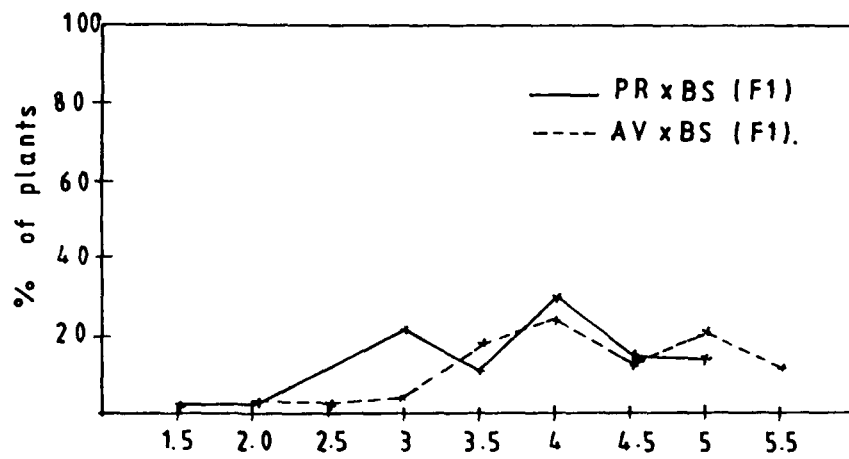
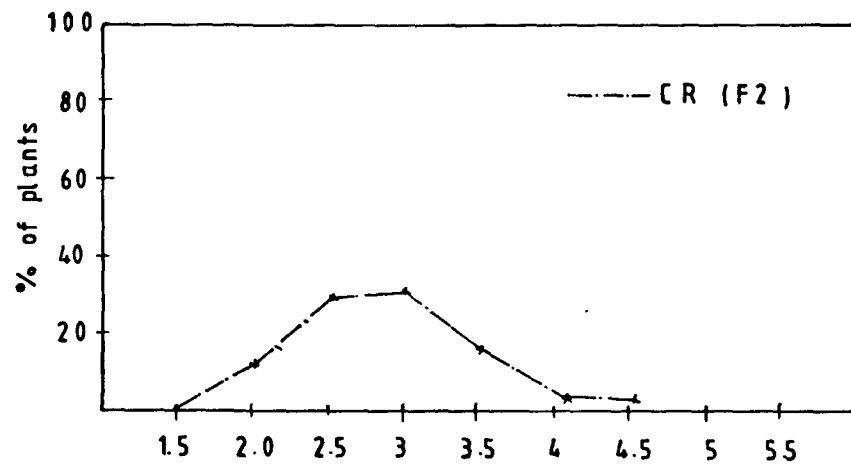


FIG 15. Frequency Distribution of Different Segregating Populations for Rind Thickness

Table 4.15. Estimates of genetic parameters in parents, F₂ and three-way crosses for rind thickness.

Entries	Mean $\pm$ S.E	Range	Variance	GCV(%)	PCV(%)	Heritability (%)	GA	GA as % of mean
Non-segregating								
PR	3.35 $\pm$ 0.05	2.0 - 5.5	0.280					
AV	3.79 $\pm$ 0.06	3.0 - 5.5	0.260					
BS(F ₁)	3.53 $\pm$ 0.06	2.5 - 5.5	0.210					
CR(F ₁)	3.43 $\pm$ 0.04	3.0 - 4.5	0.140					
Segregating								
CR(F ₂)	2.53 $\pm$ 0.06	1.5 - 5.0	0.359					
PRXBS(F ₁)	4.02 $\pm$ 0.08	1.5 - 5.4	0.590	14.61	19.11	58.47	0.92	22.83
AVXBS(F ₁)	4.29 $\pm$ 0.09	2.0 - 6.0	0.834	18.04	21.29	71.82	1.35	31.57
AVXCR(F ₁)	3.53 $\pm$ 0.06	2.0 - 5.0	0.398	12.61	17.87	49.75	0.65	18.29
PRXCR(F ₁)	3.11 $\pm$ 0.06	2.0 - 5.0	0.465	16.24	21.93	54.84	0.77	24.77
CR(F ₁)XPR	3.22 $\pm$ 0.07	2.0 - 4.5	0.452	15.28	20.88	53.54	0.74	23.03

Note: Since the first four populations are homogenous the genetic parameters were not worked out for them.

Table 5. A summary of important correlations for various traits in different segregating populations.

Character Pairs	CR(F2)	PR X BS(FL)	AV X BS(FL)	AV X CR(FL)	PR X CR(FL)	CR(FL) X PR
X ₁ and X ₈	-0.264**	-0.212 (NS)	0.009 (NS)	-0.338*	-0.063 (NS)	-0.345**
X ₂ and X ₃	0.277**	0.366**	-0.282**	0.487**	0.54 (NS)	0.144 (NS)
X ₂ and X ₄	0.310**	0.657**	0.210*	0.536**	0.398**	0.489**
X ₂ and X ₅	0.215*	0.494**	0.016 (NS)	0.615**	0.213 (NS)	0.531**
X ₂ and X ₈	0.157 (NS)	0.591**	-0.321**	0.621**	0.552**	0.543**
X ₃ and X ₈	0.520**	0.336*	-0.653**	0.458**	0.034 (NS)	0.254**
X ₄ and X ₈	0.839**	0.659**	-0.135 (NS)	0.883**	0.647**	0.919**
X ₅ and X ₈	0.938**	0.741**	-0.069 (NS)	0.978**	0.549**	0.974**
X ₆ and X ₈	0.711**	0.586**	-0.102 (NS)	0.638**	0.714**	0.879**
X ₇ and X ₈	0.159 (NS)	0.105 (NS)	-0.653**	-0.069 (NS)	0.351**	0.154 (NS)

NS	:	Non - significant	X ₁	:	Days to flower	X ₅	:	Number of fruits
*	:	Significant at 5% level	X ₂	:	Plant height at harvest	X ₆	:	Number of flowers
**	:	Significant at 1% level	X ₃	:	Number of branches	X ₇	:	Average fruit weight
			X ₄	:	Number of clusters	X ₈	:	Fruit yield per plant

populations (PR X BS (F_1), AV X BS (F_1) and PR X CR (F_1)) did not show significant correlations though found negative in two of them (Table 5).

4.4.2 Association of plant height at harvest with number of primary branches

The two characters had positive association in all the populations except AV X BS (F_1) (-0.282). However, correlations were not significant in the two crosses PR X CR (F_1) and CR (F_1) X PR. This association indicated that the plants with greater vigour had more number of primary branches.

4.4.3 Association of plant height at harvest with number of clusters

The association between the two characters was consistently significant and positive in all the crosses, indicating that the plant height contributes to yield through number of clusters.

4.4.4 Association of plant height at harvest with number of fruits per plant

Except in the crosses, AV X BS (F_1) and PR X CR (F_1), these two characters were positively correlated, with high correlation values in three crosses PR X BS (F_1), AV X CR (F_1) and CR (F_1) X PR (0.494, 0.615 and 0.531 respectively). This shows that the contribution of plant height to yield is high via number of fruits.

4.4.5 Association of plant height at harvest with yield per plant

Plant height at harvest being an important yield component had positive significant correlation with yield, in all the crosses except AV X BS (F_1) and CR (F_2).

In AV X BS (F_1), however the association was negative and in CR (F_2), non-significant.

4.4.6 Association of number of primary branches with yield

In all the crosses except two (AV X BS (F_1) and PR X CR (F_1), the characters were positively correlated. The populations AV X CR (F_1) and CR (F_2) had high correlation coefficient values (0.458 and 0.520 respectively).

4.4.7 Association of number of clusters with yield per plant

The two characters were found to have consistent positive association in all the crosses except AV X BS (F_1) where it was negative (-0.135). All the values of correlation coefficient were high. This shows that number of clusters is an important yield attributing character.

4.4.8 Association of number of fruits with yield per plant

It has been established that the number of fruits per plant is the most important yield component. In the present study, all the crosses except AV X BS (F_1) had high positive correlation between the two characters.

4.4.9 Association of number of flowers with yield per plant

Highly significant, positive association was also observed between number of flowers per plant and yield per plant in all the crosses except AV XBS (F_1). It was negative though non-significant in AV X BS (F_1) (-0.102).

4.4.10 Association between Average fruit weight and yield per plant

In the cross AV X BS (F_1), a high negative correlation was recorded between average fruit weight and yield per plant. However, in four of the populations the association was non-significant. In PR X CR (F_1) the correlation was significantly positive.

4.5 Path analysis

Path analysis was carried out to know the relative contribution of different characters to yield, which can be direct or indirect and this is not evident from simple correlation coefficients alone. The results of path analysis are presented in Tables 6.1 to 6.6. Path analysis includes six out of the fifteen characters studied.

4.5.1 Pusa Ruby X Cherry Red (F_1 hybrid)

Plant height at harvest had contributed directly to the yield to a considerable extent (0.300). But number of branches had a negative direct effect in this cross (-0.0204). Though number of

Table 6.1. Phenotypic path coefficients of five yield components in the Cross PR X CR (F_1).

Character	x_1	x_2	x_3	x_4	x_5	Correlation with yield
x_1	<u>0.3000</u>	-0.0011	0.0820	0.0426	0.1283	0.552
x_2	0.0162	<u>0.0204</u>	0.0025	0.0068	0.0425	0.034
x_3	0.1195	-0.0002	<u>0.2060</u>	0.0883	0.2333	0.647
x_4	0.0639	0.0007	0.0913	<u>0.1993</u>	0.1937	0.549
x_5	0.0942	-0.0021	0.1177	0.0944	<u>0.4086</u>	0.713
Residual = 0.0547						
x_1	Plant height at harvest (cm)					
x_2	Number of primary branches					
x_3	Number of clusters per plant					
x_4	Number of fruits per plant					
x_5	Number of flowers per plant					
Note	: Underlined values are the direct effects of those characters on yield.					

clusters per plant had a correlation as high as 0.644, its direct effect was only 0.2060. But, its influence via number of flowers per plant was 0.2333. Number of flowers per plant had a high correlation with yield (0.713) as well as high direct effect (0.4086).

4.5.2 Cherry Red (F_1 hybrid) X Pusa Ruby

In CR (F_1) X PR, plant height inspite of its high correlation with yield (0.543) had only a meagre direct effect (0.0339), but its effect via number of fruits per plant was considerable (0.4992). Here, the number of clusters per plant had a correlation of 0.919 with yield, with a negative direct effect of -0.0009. But its indirect effect via number of fruits per plant was 0.8865.

Number of fruits per plant had a high correlation (0.974) with yield as well as highest direct effect (0.941) on yield, where as number of flowers per plant though was highly correlated with yield (0.879) had a direct effect of only (0.012), but its influence via number of fruits per plant was very high (0.8423). Residual effect for this cross was 0.0497.

4.5.3 Arka Vikas X Beef Steak (F_1 hybrid)

In this cross all the correlations with yield except the one with number of branches are contradictory to the correlations seen in other crosses. The character plant height had a

Table 6.2. Phenotypic path coefficients of five yield components in the Cross CR(F₁) x PR.

Character	<u>X₁</u>	X ₂	X ₃	X ₄	X ₅	Correlation with yield
X ₁	<u>0.0339</u>	0.0037	0.0004	0.4992	0.0067	0.543
X ₂	0.0049	<u>0.0254</u>	-0.0002	0.2209	0.0031	0.254
X ₃	0.0166	0.0069	<u>-0.0009</u>	0.8865	0.0099	0.919
X ₄	0.0179	0.0059	-0.0008	<u>0.9411</u>	0.0108	0.974
X ₅	0.0188	-0.0065	-0.0007	0.8423	<u>0.1206</u>	0.879
Residual = 0.0497						
X ₁	Plant height at harvest (cm)					
X ₂	Number of primary branches					
X ₃	Number of clusters per plant					
X ₄	Number of fruits per plant					
X ₅	Number of flowers per plant					
Note	: Underlined values are the direct effects of those characters on yield.					

correlation of -0.3205. However, its direct effect was very low (-0.0374). It had contributed more via the number of primary branches (-0.2736). The character, number of branches had a high positive correlation (0.9853) as well as high direct effect (0.9699). The correlation of number of clusters, number of fruits and number of flowers per plant were all non-significant and negative, so also their direct effects. Residual influence was 0.022.

4.5.4 Arka Vikas X Cherry Red (F_1 hybrid)

Here, plant height had a significant correlation with yield. Though the direct effect of this character was only 0.0238, it contributed significantly through number of fruits per plant (0.6333). Number of primary branches had a negative direct effect on yield inspite of its positive significant correlation with yield (0.458). Nevertheless, it contributed indirectly through number of fruits per plant (0.489). Number of clusters per plant also contributed indirectly through number of fruits per plant (0.9466) though its direct effect was negative (-0.1056). Here, number of fruits per plant had the highest correlation with yield (0.978) and most of it was due to its high direct influence (0.9129). Number of flowers per plant also contributed through number of fruits per plant (0.6325), its direct effect being non significant (0.0587). It had a residual effect of 0.0388.

Table 6.3. Phenotypic path coefficients of five yield components in the Cross AV X BS(F_1).

Character	X_1	X_2	X_3	X_4	X_5	Correlation with yield
X_1	<u>-0.0374</u>	-0.2736	-0.0108	0.0007	0.0006	-0.321
X_2	0.0105	<u>0.9699</u>	-0.0417	-0.0017	0.0023	0.985
X_3	-0.0078	-0.0786	<u>-0.0515</u>	0.0346	0.0315	-0.135
X_4	-0.0006	-0.0385	-0.0413	<u>0.0432</u>	-0.0318	0.069
X_5	0.0004	-0.0365	-0.0262	0.0222	<u>-0.0619</u>	-0.102
Residual = 0.022						
X_1	Plant height at harvest (cm)					
X_2	Number of primary branches					
X_3	Number of clusters per plant					
X_4	Number of fruits per plant					
X_5	Number of flowers per plant					
Note	: Underlined values are the direct effects of those characters on yield.					

Table 6.4. Phenotypic path coefficients of five yield components in the Cross AV x CR(F₁).

Character	<u>x₁</u>	x ₂	x ₃	x ₄	x ₅	Correlation with yield
x ₁	<u>0.0238</u>	-0.0048	-0.0566	0.6333	0.0256	0.621
x ₂	0.0116	<u>-0.0098</u>	-0.0510	0.4891	0.0178	0.458
x ₃	0.0127	-0.0047	<u>-0.1055</u>	0.9466	0.0336	0.883
x ₄	0.1335	-0.0046	-0.0971	<u>0.9103</u>	0.0361	0.978
x ₅	0.010	-0.0029	-0.0603	0.6325	<u>0.0587</u>	0.6384
Residual = 0.0388						
x ₁ :	Plant height at harvest (cm)					
x ₂ :	Number of primary branches					
x ₃ :	Number of clusters per plant					
x ₄ :	Number of fruits per plant					
x ₅ :	Number of flowers per plant					
Note	: Underlined values are the direct effects of those characters on yield.					

4.5.5 Pusa Ruby X Beef Steak (F_1 hybrid)

Here, plant height at harvest had a positive correlation of 0.591 on yield and its direct effect on yield was 0.2107. Its indirect effect via number of fruits per plant was high (0.3270). Even number of primary branches contributed indirectly via number of fruits per plant (0.1482), though its direct effect was low (0.0951).

Number of clusters per plant had a negative direct effect (-0.1588) inspite of its high correlation with yield (0.659), but it contributed indirectly via number of ^{fruits} per plant (0.5331). The high correlation of number of fruits per plant was mainly due to high direct effect (0.6616). Number of flowers per plant also contributed indirectly via number of fruits per plant (0.3149), its direct effect being low (0.1821). Residual effect was 0.3511, here.

4.5.6 Cherry Red (F_2)

Here, plant height at harvest did not have significant correlation with yield. Number of primary branches had a high positive correlation (0.520) with yield which was mainly due to its indirect effect via number of fruits per plant (0.4671), as its indirect effect was very low (0.0403). Number of clusters per plant and number of flowers per plant also contributed indirectly via number of fruits per plant (0.7790 and 0.6700 respectively). They had positive significant correlation with

Table 6.5. Phenotypic path coefficients of five yield components in the Cross PR X BS(F_1).

Character	x_1	x_2	x_3	x_4	x_5	Correlation with yield
x_1	<u>0.2107</u>	0.0348	-0.1043	0.3268	0.1229	0.591
x_2	0.0771	<u>0.0951</u>	-0.0465	0.1482	0.0621	0.336
x_3	0.1385	0.0279	<u>-0.1588</u>	0.5331	0.0983	0.659
x_4	0.1041	0.0213	-0.1327	<u>0.6616</u>	0.0867	0.741
x_5	0.1422	0.0324	-0.0857	0.3149	<u>0.1821</u>	0.586
Residual = 0.351						
x_1	Plant height at harvest (cm)					
x_2	Number of primary branches					
x_3	Number of clusters per plant					
x_4	Number of fruits per plant					
x_5	Number of flowers per plant					
Note	: Underlined values are the direct effects of those characters on yield.					

yield (0.839 and 0.711 respectively). Even here, the number of fruits per plant had the highest correlation with yield (0.938), which was mainly due to its high direct effect (0.879).

4.6 Identification of transgressive segregants

Based on frequency distribution, an attempt has been made to classify the plants into different groups for some of the characters, for the segregating populations and to identify the extreme types (Table 7). It was observed that for fruit size, wherever the parent CR (F_1) is involved, the plants fell into small and medium fruit types (Plate 3a). On the contrary when, BS (F_1) was involved, they fell into medium and big fruited types (Plates 3a and 3b). But in CR (F_2), there was no segregation for fruit size and all the plants were small fruited ones (Plate 2).

For average fruit weight, when CR (F_1) was one of the parents, most of the plants fell into the category with low and medium fruit weight and in CR (F_2) all the plants were with low average fruit weight. When BS (F_1) was one of the parents the fruits had medium and high average fruit weight (Table 7).

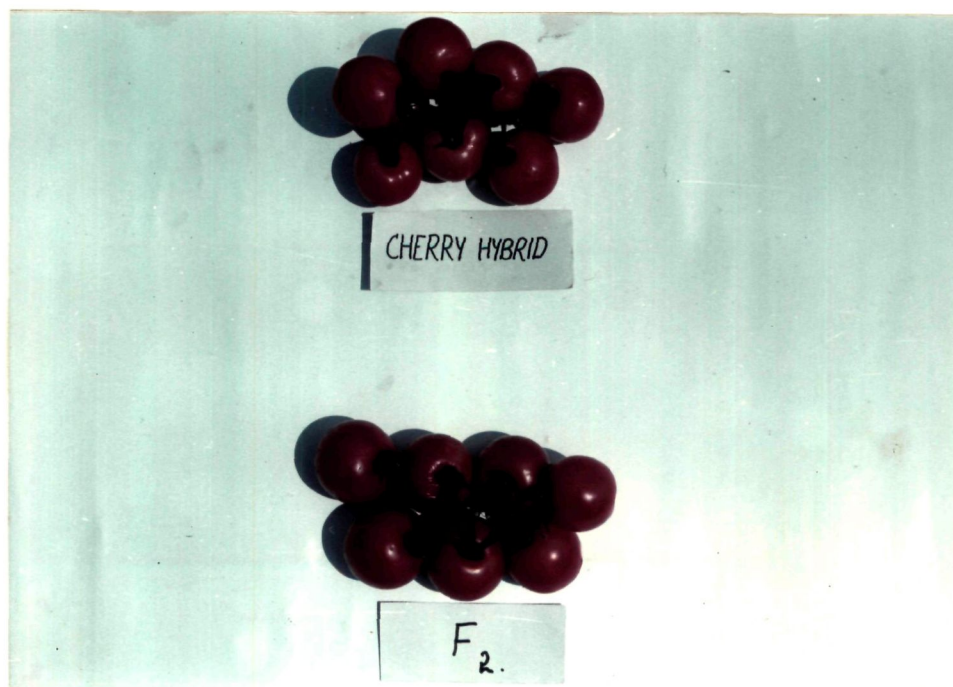
For yield per plant, in the crosses AV X BS (F_1) and PR X BS (F_1) there were no plants falling into high yield category. In AV X CR (F_1) and CR (F_2) the frequency of plants with high yield was 4 and 6 per cent respectively, where as in PR X CR (F_1), the percentage was 10 (Table 7).

Table 6.6. Phenotypic path coefficients of five yield components in CR(F₂).

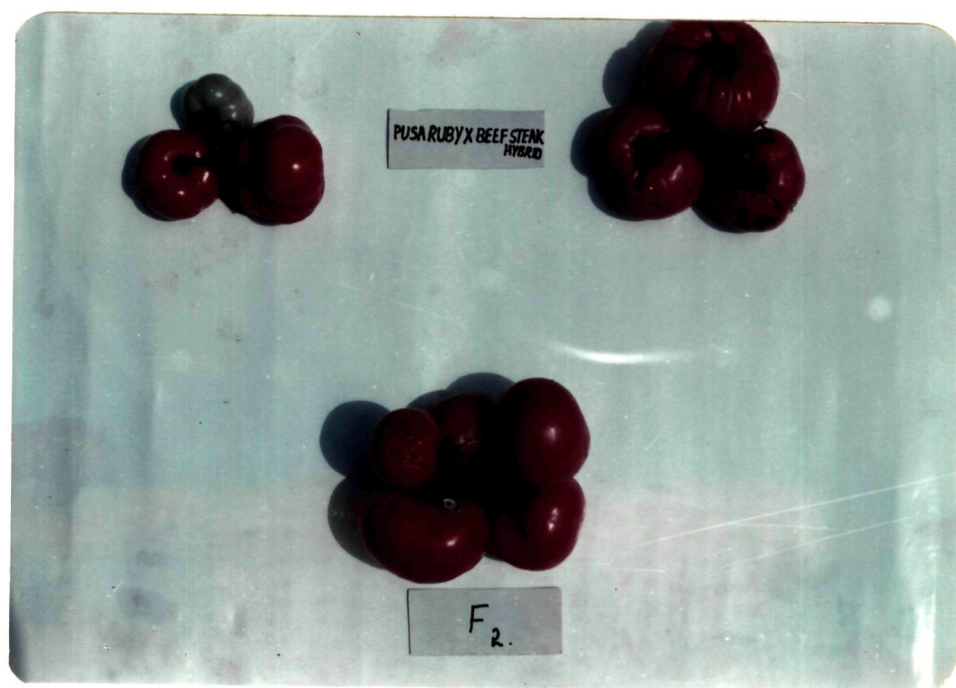
Character	x_1	x_2	x_3	x_4	x_5	Correlation with yield
x_1	<u>-0.0607</u>	0.0112	0.0195	0.1891	-0.0021	0.157
x_2	-0.0168	<u>0.0403</u>	0.0329	0.4671	-0.0036	0.520
x_3	-0.0188	0.0211	<u>0.0630</u>	0.7794	-0.0057	0.839
x_4	-0.0131	0.0214	0.0558	<u>0.8797</u>	-0.0059	0.938
x_5	-0.0165	0.0186	0.0463	0.6704	<u>-0.0078</u>	0.711
Residual = 0.116						
x_1	Plant height at harvest (cm)					
x_2	Number of primary branches					
x_3	Number of clusters per plant					
x_4	Number of fruits per plant					
x_5	Number of flowers per plant					
Note	: Underlined values are the direct effects of those characters on yield.					

Table 7. Frequency of different categories as observed for different crosses for five characters.

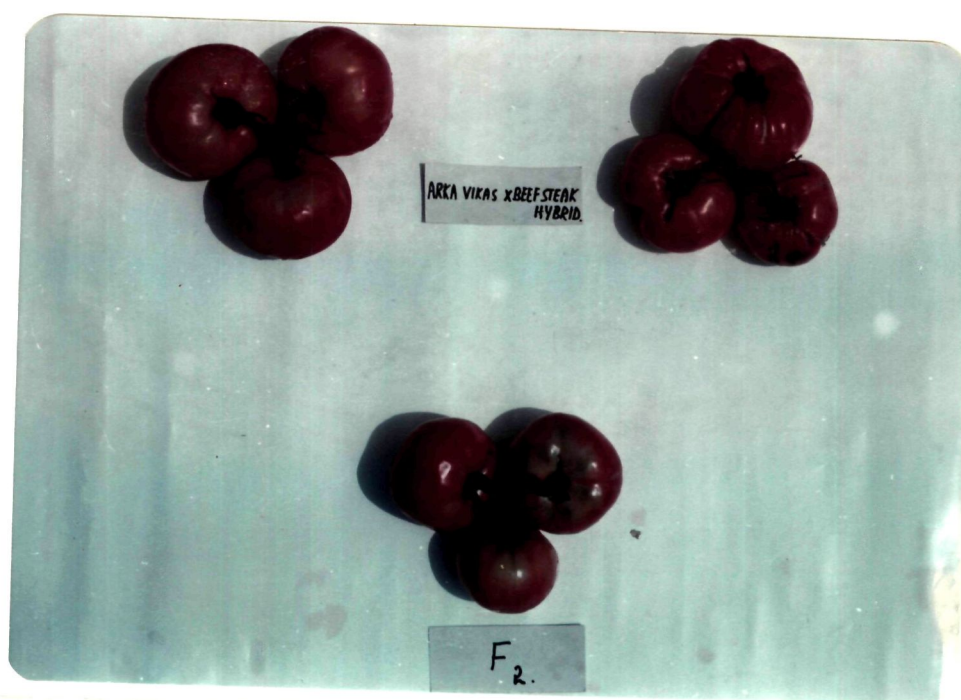
Crosses	Fruit size (% of plants)			Average fruit weight (% of plants)			Yield per plant (% of plants)			Number of fruits per plant (% of plants)			Bunch type (% of plants)	
	Small	Medium	Big	Low	Medium	High	Low	Medium	High	Low	Medium	High	Bunch of 6-9 fruits	Bunch of 3-5 fruits
CR(F ₂)	100	--	--	100	--	--	55	39	6	46	52	2	100	--
PR X BS(F ₁)	-	73	27	2	92	6	80	20	--	100	--	-	--	100
AV X BS(F ₁)	2	64	34		44	56	57	43	--	98	2	-	--	100
AV X CR(F ₁)	58	42	--	83	17	--	64	32	4	43	51	6	100	--
PR X CR(F ₁)	88	12	--	77	23	--	64	24	10	54	41	5	100	--



2. A segregant in F_2 generation derived from Cherry Red (F_1 hybrid) showing characteristic bearing of fruits in bunches of eight.



3a. Fruits of the three-way cross Pusa Ruby X Beef Steak (F_1 hybrid) showing increase in size of fruits.



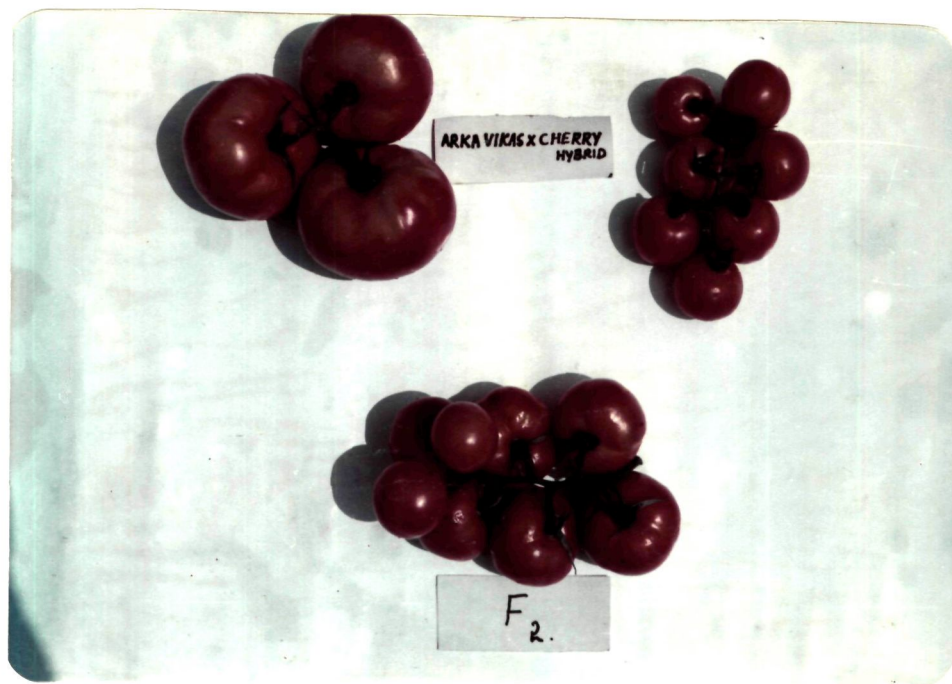
3b. Fruits of the three-way cross Arka Vikas X Beef Steak (F_1 hybrid) showing resemblance to fruits of Arka Vikas.

Similarly, for number of fruits per plant, AV X BS (F_1) and PR X BS (F_1) did not have plants in high category. AV X CR (F_1) and PR X CR (F_1) had 6 and 5 per cent of plants respectively in high fruit number category. In CR (F_2) it was 2 per cent (Table 7). For bunch type, when the parent, CR (F_1) was involved, all the plants (100%) were with bunches of 6 to 9 fruits (Plates 4a and 4b) and when BS (F_1) was involved they fell into the category with 3 to 5 fruited bunches (Plates 3a and 3b).

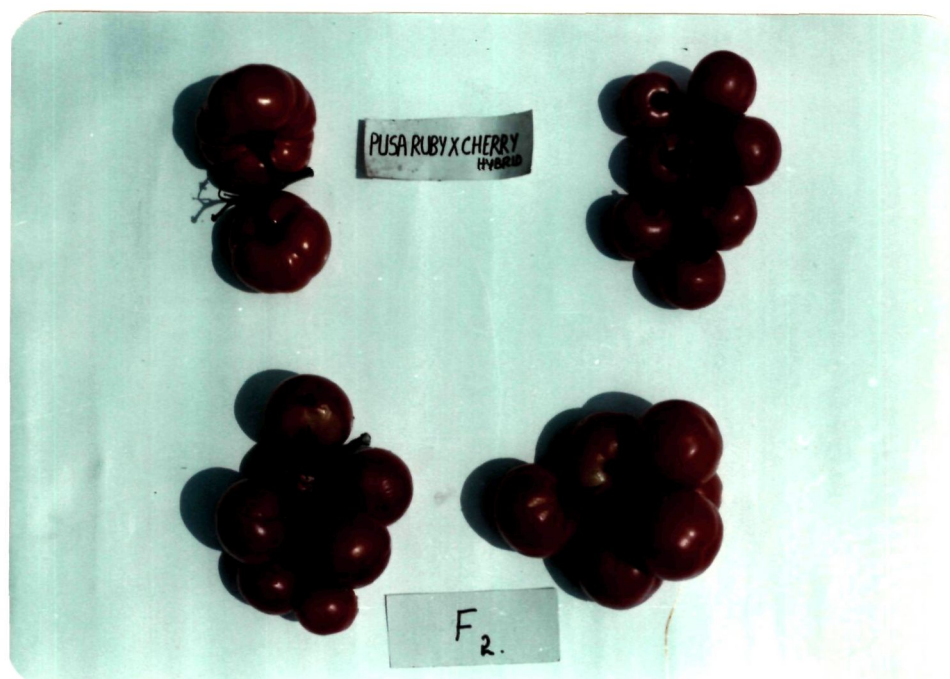
The percentages of transgressive segregants for 9 out of the 15 characters studied are given in the Table 8. The percentage of plants exceeding the better parent was noted for the three-way crosses. For CR (F_2), the percentage of plants exceeding the CR (F_1) was noted.

For plant height at harvest all the crosses showed transgressive segregants and in the cross AV X BS (F_1) the percentage of transgressive segregants was highest (21.0%). For number of primary branches all except AV X CR (F_1) showed transgressive segregants and in AV X BS (F_1), the percentage was 40.15. For number of clusters per plant, only PR X CR (F_1) had transgressive segregants, whereas for number of fruits per plant, none of the crosses had any.

For the characters number of flowers per plant, average fruit weight, yield per plant, total soluble solids and equatorial diameter, AV X BS (F_1) showed transgressive segregants



4a. Fruits of the three-way cross Arka Vikas X Cherry Red (F_1 hybrid) inheriting the bunch characteristics of the hybrid.



4b. Fruits of the three-way cross Pusa Ruby X Cherry Red (F_1 hybrid) with intermediate fruit size and bunches resembling that of the hybrid parent.

consistently ; PR X CR (F_1) and AV X CR (F_1) had none, for these characters (Table 8).

4.7 Selection of genotypes

Some of the outstanding genotypes which could be of value for further multiplication were selected based on number and size of the fruits and bunch characteristics (Table 9). Preliminary observations have been recorded for the genotypes and yields have been noted.

Table 8. Transgressive segregants percentage for nine characters in the segregating populations.

Trait	Crosses					
	PR X BS(F ₁)	AV X BS(F ₁)	PR X CR(F ₁)	AV X CR(F ₁)	CR (F ₂)	
1. Plant height at harvest	a	14.4	21.0	4.5	3.1	4.3
	b	68.33	68.33	127.07	127.07	127.07
2. Number of primary branches	a	10.2	40.15	8.0	-	6.0
	b	5.46	3.86	6.73	6.73	6.73
3. Number of clusters per plant	a	-	-	8.0	-	4.6
	b	14.45	9.0	22.6	22.6	22.6
4. Number of fruits per plant	a	-	-	-	-	-
	b	38.75	17.89	105.6	105.6	105.6
5. Number of flowers per plant	a	-	10.2	-	-	8.5
	b	57.46	37.06	150.46	150.46	150.46
6. Average fruit weight	a	-	8.3	-	-	-
	b	57.53	63.65	49.04	63.65	35.6
7. Yield per plant	a	-	24.5	-	-	5.5
	b	0.652	0.672	1.527	1.527	1.527
8. Total soluble solids	a	4.2	19.5	-	-	13.1
	b	4.11	4.11	4.16	4.16	4.16
9. Equatorial diameter	a	-	16.2	-	-	-
	b	6.2	6.2	5.36	5.66	3.54

a - Percentage of transgressive segregants ; b - Mean of the better parent.

Table 9. Important features of the genotypes selected from segregating populations.

Selection number	Selection from the crosses	Important features of the selections
1	Pusa Ruby X Cherry Red (F_1 hybrid)	It was a heavy bearer with a fruit yield of 1.985 Kg per plant. As Cherry Red hybrid (small fruited) is one of the parents and Pusa Ruby is big fruited, this genotype had medium expression for fruit size. Fruits were borne in bunches of 6-9 fruits which were deep red in colour (Cherry Red hybrid character).
2	Pusa Ruby X Cherry Red (F_1 hybrid)	This was also a heavy bearer with a fruit yield of 1.790 Kg per plant and had medium to big fruits. It has inherited the character of bunches of 6-9 fruits from Cherry Red hybrid which seems to be dominant. Fruits were deep red coloured as the hybrid parent.
3	Pusa Ruby X Cherry Red (F_1 hybrid)	Heavy bearing with a yield of 1.960 Kg per plant. The fruits were again medium to big in size with bunches of 6-9 fruits and deep red coloured.
4	Pusa Ruby X Cherry Red (F_1 hybrid)	It gave a fruit yield of 1.675 Kg per plant. The fruits were slightly smaller in size and round. As Cherry Red hybrid was one of the parents it had bunches of 6-9 fruits with deep red colour.
5	Pusa Ruby X Cherry Red (F_1 hybrid)	Heavy bearer with a fruit yield of 1.930 Kg per plant. Fruits were small to medium in size and bunches were again with 6-9 fruits with deep red colour.
6	Pusa Ruby X Cherry Red (F_1 hybrid)	This genotype was also a heavy bearer giving an yield of 1.765 Kg per plant with slightly small, round fruits and it has also inherited the bunch character of Cherry Red hybrid (with 6-9 fruits) and fruits were deep red coloured.

Table 9. (Continued)

7	Cherry Red (F_1 hybrid) X Pusa Ruby	Heavy bearer which had an yield of 1.570 Kg per plant, had medium expression for fruit size. As Cherry Red hybrid is involved in the cross, it had bunches of 6-9 fruits which were deep red coloured.
8	Arka Vikas X Cherry Red (F_1 hybrid)	It was a heavy bearer with a fruit yield of 1.690 Kg per plant. Fruits were medium size and with bunches of 6-9 fruits (Cherry Red hybrid character). Here also fruits were deep red coloured.
9	Arka Vikas X Cherry Red (F_1 hybrid)	Heavy bearing with an yield of 1.775 Kg per plant. Fruits were medium size and bunches were with 6-9 fruits as in Cherry Red (F_1 hybrid). Fruits were also deep red coloured as in Cherry Red hybrid.
10	Pusa Ruby X Beef Steak (F_1 hybrid)	Good bearing with an yield of 1.865 Kg per plant. Fruits were bigger as in Beef Steak (F_1 hybrid). Fruits borne in bunches of 3-5 fruits as in the Beef Steak (F_1 hybrid) and the fruits were with medium-deep red colour.
11	Arka Vikas X Beef Steak (F_1 hybrid)	Good bearer and had a fruit yield of 1.735 Kg per plant. Fruits were again borne in bunches of 3-5 fruits (character inherited from Beef Steak hybrid) ; medium-deep red coloured fruits.
12	Cherry Red (F_2)	It was a heavy bearer with an yield of 1.550 Kg per plant. Fruits were small and rounded (as in Cherry Red hybrid) and fruits were borne in bunches of 6-9 fruits. Fruits had deep red colour.

DISCUSSION

V DISCUSSION

Most of the earlier crop improvement programmes in tomato consisted of either evaluation of germplasm or hybridization using the indigenous varieties. But utilization of the similar varieties in different combinations for hybridization fails to create additional variability for crop improvement programme. Hence, introduction of exotic material with desirable characteristics offers a new alley in the crop improvement.

During the present study, an attempt was made to introduce two exotic hybrids from the U.S.A. namely, Beef Steak hybrid and Cherry Red hybrid, as each of the two hybrids possessed many desirable characteristics. The Cherry Red hybrid seemed to adapt well as the pollen fertility, fruit setting and seed setting were normal, in green house and in field conditions as well. But, the other hybrid Beef Steak did not perform well when first tried to grow in green house conditions. The number of flowers borne was very less. Fruit setting percentage was also very low. Flower and fruit drop was observed. Hence, it was sought to recombine the desirable traits of exotic hybrids with the locally adapted varieties with an objective of creating novel genetic variability and provide broad genetic base. It was expected to get a wide range of recombinants with desirable fruit size, growth habit and so on, and transgressive segregants for yield, fruit number, fruit size and other characters in the resulting three-way crosses.

The essential features of the study were as follows:

- i). Comparison of the variabilities in the different segregating populations derived from hybridization between exotic hybrids and indigenous varieties.
- ii). To screen the segregating populations for transgressive segregants combining many desirable traits.
- iii). To study the correlations between various yield components and work out the direct and indirect effects of each component to the total fruit yield.

5.1. Comparison of means

The mean values of the parent CR (F_1) was the highest for the characters plant height at harvest, number of primary branches, number of clusters, number of fruits, number of flowers per plant and number of flowers per inflorescence.

For the character days to flowering, BS (F_1) had the highest mean value that is, it took more days to flowering, where as for plant height at flowering CR (F_2) had the highest mean value. For the character yield per plant the cross AV X BS (F_1) had the least mean value.

For the total soluble solids most of the crosses had higher mean values compared to parents which may be due to dominant as well as additive gene effect. Rama Rao and Chaudhary (1974) reported quantitative mode of inheritance with transgressive

segregation in F_2 and Kalloo et al. (1974) reported dominant gene action for this character. For polar diameter all the crosses involving CR (F_1) as a parent had a lower polar diameter than that of the parent CR (F_1) (which had a lower value than the other parent). This shows that smaller fruit size (as indicated by smaller polar diameter) is controlled by dominant genes. This is evident by the study of Pillai (1934) and Chaudhary and Khanna (1972b) who reported that the fruit size of the F_1 s was smaller compared to the average of the parents. Similarly all the crosses involving CR (F_1) except AV X CR (F_1) had a lower equatorial diameter ; a similar explanation could be given for this. For number of locules, CR (F_1) had the least number of locules (2) and all the crosses involving CR (F_1) as a parent, including CR (F_2) had a mean value lower than 3.0 which is lower compared to that of other crosses. This showed that less number of locules is controlled by dominant gene action. This character must be controlled by few genes, since there was virtually zero variance for this character in the parent CR (F_1) i.e., environmental variance was minimum. Powers (1939 and 1941) has reported complete or almost complete dominance of small number of locules over multi locules. Similarly, Fogle and Currence (1950) and Ahuja (1968) have reported partial dominance of few locules over the higher number. For rind thickness, the means of the crosses involving CR (F_1) and PR in addition to CR (F_2) had a value lower than that in CR (F_1). However, it has been reported that thick pericarp is partially dominant to thin pericarp and

additive gene action controls inheritance of this character (Nandpuri and Tyagi, 1976).

5.2 Variability studies

5.2.1 Vegetative characters

Among vegetative characters, for days to flowering, there was no much difference in variance among different crosses. Though PR X BS (F_1) and AV X BS (F_1) had relatively higher variance values and GCV and PCV estimates, the genetic advance was low for this character. This was because genotypic variance as such for this character was low. Hence, inspite of heritability estimate as high as 89.39 per cent (PR X BS (F_1)) the GA was only 16.6 per cent of mean. Even when the heritability estimate is 100 per cent, one may not achieve a higher GA, because GA value depends on the genotypic variance also (Allard, 1960).

For the character plant height at flowering, the variance in the parents is almost as high as that in the crosses, indicating a greater degree of environmental influence. However, PR X CR (F_1) had higher variance, GCV, PCV and also higher heritability and GA estimates.

For plant height at harvest CR (F_2) had the highest variance and mean. The other two crosses PR X CR (F_1) and AV X CR (F_1) also had higher variance and GCV estimates. Heritability estimate was high in all the crosses except CR (F_1) X PR,

indicating the greater proportion of genotypic variance, out of the total variance. GA estimates were also high for all those crosses.

For number of primary branches AV X BS (F_1) had high variance and also higher mean suggesting that the selection from that population will be of use for further breeding programme. This possibility was further strengthened by the higher estimates of heritability and GA of the character.

5.2.2 Reproductive characters

The crosses PR X CR (F_1), AV X CR (F_1) and CR (F_1) X PR had higher variances for the characters like number of flowers, number of clusters and number of fruits per plant accompanied with higher mean values. The GCV estimates were also high for these crosses. Few other crosses, inspite of their lower variances had high GCV estimates owing to the lesser influence of environment. Heritability and GA estimates were also high for the just mentioned crosses. This consistency of the crosses PR X CR (F_1), AV X CR (F_1) and CR (F_1) X PR tells about the worthiness of these crosses for selecting genotypes with desirable degree of these reproductive attributes.

Previous studies have also revealed higher estimates of heritability and genetic advance for number of fruiting clusters per plant (Tayel et al., 1960a and Kumar et al., 1980), number of fruits per plant (Nandpuri et al., 1973 and 1974 ; Singh et al.,

1974 ; Peter and Rai, 1976 ; Nandpuri et al., 1977 ; Prasad and Prasad 1977 ; Bangaru et al., 1983 ; Dudi et al., 1983 and Sonone et al., 1986) and number of flowers per plant (Saini and Sood, 1971). The result of innumerable studies reveal that number of fruits per plant is the most important yield attribute and can be selected for, if one wants to improve yield. High genetic advance for this character suggests that additive gene action is predominant here (Conti, 1974 ; Kalloo et al., 1974 and Maggiore et al., 1976).

For number of flowers per inflorescence, the crosses PR X BS (F_1) and AV X BS (F_1) had higher estimates of GCV and PCV, and also heritability and GA estimates. The heritability estimate of a character depends on the population studied, the generation studied, unit of measurement, method used and the genotype environment interaction (Jones, 1986). Hence the differences in heritability estimates, can be attributed to any of these factors.

Yield is the character of interest in most of the breeding programmes. All the crosses had considerable variation for this character. PR X CR (F_1) and CR (F_1) X PR had the higher estimates of variance as measured through estimates of GCV and PCV. Heritability and genetic advance were highest for these two crosses. But the heritability as such for the character yield per plant was moderate (less than 60 per cent). Heritability was classified as high (greater than 60%), moderate (40% - 60%) and

low (less than 40%) (Jones, 1986). These lower values of heritability for yield is because of the higher proportion of environmental influence for this character. Genetic advance was also low for this character.

These results suggest that yield cannot be selected for as such owing to the higher level of environmental influence. This was also attributed by many workers to the non-additive gene action (Khalf-Allah, 1970 and Conti, 1974). Low and moderate values of heritability have been reported earlier (Pierce, 1958 ; Kumar et al., 1980 and Bangaru et al., 1983). Low and moderate values of GA have been reported by Goldenberg (1967) and Nadar et al. (1980). However high heritability and GA estimates have also been reported (Singh et al., 1974 ; Nandpuri et al., 1973 and 1977 ; Sonone et al., 1986 and Singh et al., 1988).

5.2.3 Fruit characters

Genotypic variances were comparatively lower for average fruit weight, total soluble solids, polar diameter, number of locules and rind thickness, as evident by the values of GCV. However, some crosses had higher values of GCV for the just mentioned characters owing to the higher values of mean and genotypic variance. The difference between the genotypic and phenotypic coefficients of variation for these characters was narrow indicating a lesser influence of environment. Earlier studies have also revealed a low value of GCV for fruit length

(Prasad and Prasad, 1977) and locule number (Kumar et al., 1980). However, higher estimates of GCV and PCV have been recorded for average fruit weight (Bangaru et al., 1983 ; Dudi et al., 1983 and Sonone et al., 1986). The characters average fruit weight, total soluble solids, polar diameter, number of locules and rind thickness had high heritability estimates owing to the narrow difference between the genotypic and phenotypic coefficients of variability. However, there were considerable differences among the values of heritability recorded for different crosses, for these characters. For average fruit weight, all the crosses except PR X CR (F_1) had relatively higher estimates of GCV, heritability and genetic advance. For total soluble solids, the cross CR (F_1) X PR possessed the maximum amount of genetic variability. It also recorded the highest heritability and GA estimates. These results indicate that the above mentioned crosses have a value for selecting genotypes with good average fruit weight and total soluble solids content.

For the character equatorial diameter the crosses AV X BS (F_1) and PR X CR (F_1) had higher variance and also higher estimates of GCV, heritability and genetic advance.

5.3 Frequency distribution

The frequency distribution of any polygenic character in the segregating population is expected to show a smooth, normal, bell shaped curve (Allard, 1960). In the present study except for

days to flowering, number of flowers per plant and number of locules in segregating populations, other characters showed nearly normal distribution (Fig 1-15). In case of plant height at harvest and number of primary branches, the range was wide for almost all the segregating populations (Fig. 3 and 4) and for number of clusters per plant and number of fruits per plant it was wider in case of CR (F_2) than for the other populations (Fig.5 and 6).

For number of flowers per inflorescence and average fruit weight, the range was comparatively narrow for all the crosses. In case of number of locules, the graph for CR (F_2) was a straight line because except a negligible proportion of plants with 3 locules, all were with 2 locules in this population (Fig. 14). This showed that the character is dominant gene controlled and few genes are involved in the inheritance. Another advantage of frequency distribution studies in segregating generations is that transgressive segregants occurring in the population can be detected.

5.4. Transgressive segregants

Transgressive segregation presents one of the rapid methods of enhancing the yield level or any other desirable character. Transgressive segregant exceeding the better parent of a cross can be fixed through inbreeding and selection (Smith, 1952).

For plant height at harvest, all the crosses showed transgressive segregants. For number of primary branches, all the crosses except AV X CR (F_1) showed transgressive segregants.

The cross AV X BS (F_1) had as high as 40.15 per cent of transgressive segregants for number of primary branches. For the character number of fruits per plant, there were no transgressive segregants in any of the populations. The absence of transgressive segregation for this character may be due to the same alleles contributed by both the parents and or absence of multiple factors for this trait. Recessive polygenes with minor effects towards this trait could also be a cause (Vega and Frey, 1980). The populations PR X CR (F_1) and CR (F_2) showed transgressive segregants for number of clusters per plant and AV X BS (F_1) and CR (F_2) for number of flowers per plant, yield per plant and total soluble solids. For average fruit weight and equatorial diameter, only AV X BS (F_1) showed transgressive segregants. The cross AV X BS (F_1) showed transgressive segregants for almost all the characters. This may be because of the comparatively poorer performance of BS (F_1) under the indigenous environmental conditions. But, the superior alleles however are expressed in the crosses involving BS (F_1) as a parent.

As a part of the present investigation, some of the outstanding segregants were selected for further multiplication from the different segregating populations included in the study.

Most of the selections were recovered from Pusa Ruby X Cherry Red (F_1 hybrid) (Table 9) since the segregants in this population possessed the desirable characters such as compact bunch, moderate fruit size and attractive skin colour of the fruit; the selections had all these characters in addition to their heavy bearing nature (Plates 5a and 5b). However, there were promising selections from other populations also (Plates 6a and 6b).

5.5 Correlations

Improvement of yield envisages changes in plant architecture. This involves clear understanding of components contributing to yield and consequently the inter-relationships of characters. In three out of six populations studied (AV X CR (F_1), CR (F_1) X PR and CR (F_2)) days to flower was negatively associated with yield, indicating that earliness resulted in increased yield. Kumar and Muthukrishnan (1983) have reported negative correlation between earliness and yield. Singh and Singh (1980) reported negative correlation between days to maturity and number of fruits per plant. The characters plant height at harvest and number of primary branches had positive correlation with each other (Nadar et al., 1986) in all except one cross indicating that plants with greater vigour had more number of branches. Except in AV X BS (F_1) and PR X CR (F_1) there was a consistent positive association between plant height at harvest and number of fruits per plant indicating that plant height contributes to yield through number of fruits per plant, as number of fruits and yield per plant



5a. A heavy bearing selection with desirable fruit size derived from the three-way cross Pusa Ruby X Cherry Red (F_1 hybrid).



5b. A promising selection with slightly bigger fruits and heavy bearing derived from the three-way cross Pusa Ruby X Cherry Red (F_1 hybrid).



6a. An outstanding selection with moderate fruit size from the cross Arka Vikas X Cherry Red (F_1 hybrid).



6b. Another promising selection with slightly smaller fruits with deep red colour derived from the F_2 of Cherry Red hybrid.

are clearly positively correlated. Even number of clusters per plant was consistently positively correlated with plant height at harvest. Number of fruits per plant and number of clusters per plant are highly correlated characters (positive).

Yield per plant was also positively correlated with plant height at harvest in all but two crosses. Similarly, positive correlation has been observed between these two characters by many workers (Govinda Rasu et al., 1980; Alvarez and Torres, 1983; Kumar and Muthukrishnan, 1983 and Ahmed et al., 1988). This consistent association shows that plant height can be selected for yield improvement.

The three important yield components, number of clusters, number of fruits per plant and number of flowers per plant had high positive correlation with yield per plant in all the crosses except in AV X BS (F_1). However, the positive correlation between fruit number and yield has been reported by many workers earlier (Srivasthava and Sachan, 1973 ; Singh and Singh, 1980 ; Dudi and Kalloo, 1982 ; Alvarez and Torres, 1983 ; Patil, 1985 ; Munoz et al., 1986 ; Das and Chakraborty, 1987; Gomez, 1987; Sonone et al., 1987 and Ahmed et al., 1988). These results prove the worthiness of selecting for fruit number for increased yield indirectly.

In all the crosses except two, number of primary branches was positively correlated with yield. Similar correlations were

reported by Govindarasu et al. (1980), Singh and Singh (1980), Kumar and Muthukrishnan (1983) and Nadar et al. (1980).

In the present study the association between average fruit weight and yield per plant was non-significant for most of the crosses. But, significantly negative in AV X BS (F_1) and in the cross PR X CR (F_1), was significantly positive. Many of the studies on the correlation between these two characters has revealed high positive correlation (Dudi and Kalloo, 1982 ; Kumar and Muthukrishnan, 1983 ; Patil, 1985 ; Munoz et al., 1986 ; Ahmed, 1987 ; Sonone et al., 1987 and Ahmed et al., 1988).

The correlation between number of fruits per plant and average fruit weight was negative in some of the populations though not significant. However, many workers have arrived at a significant negative association between the two characters (Srivastava and Sachan, 1973 ; Kumar and Muthukrishnan, 1983 ; Alvarez and Torres, 1983 ; Patil, 1985 ; Das and Chakraborty, 1987 and Gomez, 1987).

Since both number of fruits per plant and average fruit weight are positively correlated with yield, inspite of their negative correlation with each other, a compromise should be reached while selecting for yield indirectly via number of fruits per plant and average fruit weight.

5.6 Path analysis

The estimation of correlation coefficients reveal only the relationship between yield and yield components but do not show the direct and indirect effects of different yield components on yield per se. This is because the attributes which are in association do not exist by themselves but are associated with other components.

Path analysis suggested by Dewey and Lu (1959) provides an effective measure of direct and indirect causes of association and analyses the relative importance of each factor contributing to final yield.

In all the crosses except PR X CR (F_1) and AV X BS (F_1), the characters plant height at harvest, number of primary branches, number of clusters per plant and number of flowers per plant contributed to yield indirectly via number of fruits per plant. However, their direct effects except in few cases are either negative or very low. Number of fruits per plant had the highest direct effect on yield in all the crosses except in PR X CR (F_1) and AV X BS (F_1). In PR X CR (F_1) plant height at harvest and number of flowers per plant showed a high direct effect on yield. In all the crosses except PR X CR (F_1) and CR (F_2), the direct effect of number of clusters per plant was negative, though it contributed via number of fruits per plant to yield to a great extent. Plant height had negative direct effect in case of AV X

BS (F_1) and CR (F_2). In CR (F_2) number of flowers per plant and in AV X CR (F_1) number of primary branches had negative direct effects on yield.

The important outcome of the path analysis in the present study seems to be the importance of number of fruits per plant as an yield component both directly and indirectly via other components. Earlier studies have also revealed the high direct influence of number of fruits per plant on yield (Srivasthava and Sachan, 1973 ; Dudi and Kalloo, 1982 ; Gonzalez, 1985 b and Patil, 1985). During the present study, it was possible to arrive at intermediate types for fruit size which is more desirable, by crossing the small fruited cherry red hybrid with big fruit types (Pusa Ruby and Arka vikas) (Table 7). There were considerable number of transgressive segregants for some of the important characters in three-way crosses, as well, (Table-8) which can be used for further selection programmes.

It is established that the fruit number and the fruit size are negatively correlated with each other (Though not evident in the results of the present study). Hence, selection of transgressive segregants for fruit number, with intermediate fruit size is recommended. This strategy is further strengthened by the high heritability and genetic advance estimates obtained for the character, fruit number. There were good number of transgressive segregants for total soluble solids and hence selection could be applied for high TSS types.

The present study has indicated that involvement of diverse genotypes like exotic hybrids in tomato leads to wide spectrum of variability. By applying appropriate selection criteria considering the type of correlations exhibited in the population, new genotypes having high yield potential can be isolated. In the present study the character of fruits-in-clustres which was transferred from the exotic hybrid - Cherry Red to Arka Vikas and Pusa Ruby has led to new recombinants which are highly promising. In addition to clustered fruits, the individual fruits in the recombinants have attractive colour, thick rind and high TSS content. Isolation of many recombinants with extremely high yielding traits is an indication of the success of the approach of using exotic hybrids in improving the locally adapted varieties.

SUMMARY

VI SUMMARY

The present investigation was carried out to estimate variability generated following hybrid X variety crosses, with the aid of several genetic parameters such as genotypic and phenotypic coefficients of variability, heritability and genetic advance and to identify the transgressive segregants for important characters, besides studying the inter-relationships between yield and its components and among the components themselves with an idea to know the relative contributions of various yield components to yield, through path analysis.

The study was conducted at the Hebbal Farm, U.A.S., Bangalore during Kharif 1990. It included parents, five three-way crosses and the F_2 population of the cherry red hybrid ($CR(F_2)$). A total of 15 characters were studied comprising vegetative, reproductive and fruit characters. The summary of results of various aspects of the investigation are given below.

For the characters plant height at harvest, number of primary branches, number of clusters, number of fruits and number of flowers per plant, parents differed significantly indicating the presence of wider range of variability for these characters among parents ; for all these characters $CR(F_1)$ had the highest mean values.

The mean values of all the crosses involving CR(F_1) as a parent for some characters (polar diameter, equatorial diameter, number of locules and rind thickness) were lower than the average of the parents for that character. These characters might be controlled by the recessive genes. But for total soluble solids, the means of the crosses were higher than the average of the parents indicating the predominance of both dominant and additive gene action for this character.

Variance recorded for different characters differed with the crosses. For number of days to flowering, the genotypic variance was low, this was reflected by a lower value of estimated genetic advance for this character. AV X BS (F_1) for number of primary branches and PR X CR (F_1) for plant height at flowering had higher GCV, PCV, heritability and genetic advance estimates in addition to higher mean values, indicating that selection from such crosses is desirable. Higher heritability and GA estimates for plant height at harvest in almost all the crosses show that both proportion of genotypic variance (out of total phenotypic variance) and the amount of genotypic variance are high. For the characters, namely, number of flowers, number of clusters and number of fruits per plant, the crosses, PR X CR(F_1), AV X CR(F_1) and CR (F_1) X PR had higher variances as well as higher mean values, indicating the worthiness of selection in these populations. The result of innumerable studies have revealed that number of fruits per plant is an important yield attribute

and a character with high heritability and GA. On the contrary, moderate values of heritability and GA were recorded for yield per plant, suggesting that environmental influence is high for this character.

All the characters except days to flowering, number of flowers per plant and number of locules showed nearly normal distribution. Transgressive segregation was observed for all the characters except number of fruits per plant which may be due to the same alleles contributed by both the parents and/or absence of multiple factors. The populations PR X CR(F_1) and CR (F_2) showed transgressive segregants for number of clusters per plant. AV X BS(F_1) and CR (F_2) for number of flowers per plant, yield per plant and for total soluble solids. AV X BS (F_1) showed transgressive segregants for almost all the characters.

In three out of six populations studied (AV X CR (F_1), CR (F_1) X PR and CR (F_2)) days to flower was negatively associated with yield indicating that earliness resulted in increased yield. In all the crosses except two, there was a consistent positive association between plant height at harvest and number of fruits per plant suggesting that plant height contributes to yield through number of fruits per plant, as number of fruits per plant and yield are positively correlated. The three important yield components number of clusters, number of fruits per plant and number of flowers per plant had high positive correlation with yield in almost all the crosses. In

most of the crosses number of primary branches was positively correlated with yield.

In all the crosses except PR X CR (F_1) and AV X BS (F_1), the characters, plant height at harvest, number of primary branches, number of clusters per plant and number of flowers per plant contributed to yield via number of fruits per plant indirectly. However their direct effects were either low or negative. Number of fruits per plant had the highest direct effect on yield in all crosses except in PR X CR (F_1) and AV X BS (F_1).

Several transgressive segregants for important characters were recovered from three-way crosses, which can be used for further breeding programme. Selection for increased fruit number with moderate fruit size is advocated.

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* Original not referred.

APPENDICES

Appendix 1. Phenotypic correlation coefficients among fifteen characters in AVX BS (F1)

Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
X1	1.000	0.366**	0.047	-0.013	0.009	-0.019	-0.388**	-0.031	0.071	0.009	-0.129	0.231*	-0.080	-0.093	0.099
X2		1.000	0.006	-0.410**	0.170	0.092	0.136	-0.428**	0.182	-0.415**	0.198	0.005	-0.066	-0.126	-0.092
X3			1.000	-0.282**	0.210	0.016	-0.010	-0.329**	0.369**	-0.321**	0.369**	-0.001	-0.091	-0.038	0.272**
X4				1.000	-0.081	-0.039	-0.038	0.978**	-0.635**	-0.653**	-0.653**	0.241*	-0.061	0.183	0.082
X5					1.000	0.803**	0.509**	-0.176	0.115	-0.135	0.054	0.107	-0.175	-0.075	0.145
X6						1.000	0.515**	-0.102	0.025	-0.069	-0.010	0.121	-0.175	-0.065	0.119
X7							1.000	-0.087	-0.045	-0.102	0.024	-0.119	-0.114	-0.045	-0.103
X8								1.000	-0.677**	0.992**	-0.651**	0.195	-0.045	0.159	0.054
X9									1.000	-0.653**	0.469**	0.143	0.159	0.018	0.293**
X10										1.000	-0.668**	0.229**	-0.443**	0.145	0.093
X11											1.000	-0.237**	-0.068	0.092	-0.049
X12												1.000	-0.028	-0.059	0.485**
X13													1.000	-0.052	0.997**
X14														1.000	-0.151
X15															1.000

X1 : Days to flowering. X2 : Plant height at flowering (cm). X3 : Plant height at harvest (cm).
 X4 : Number of Binary branches. X5 : Number of clusters per plant. X6 : Number of fruits per plant.
 X7 : Number of flowers per plant. X8 : Number of flowers per inflorescence. X9 : Average fruit weight (g).
 X10 : Yield per plant (kg). X11 : Total soluble solids (%). X12 : Polar diameter (cm).
 X13 : Equatorial Diameter (cm) X14 : Number of locules. X15 : Rind thickness (mm).

Note : ** indicates significance at 1% level.
 * indicates significance at 5% level.

Appendix 2. Phenotypic correlation coefficients among fifteen characters in PRXBs (F1).

Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
X 1	1.000	0.426**	-0.196	-0.191	-0.128	-0.059	-0.465**	-0.500	0.169	-0.212	0.134	0.065	0.196	0.176	-0.089
X 2		1.000	0.154	0.063	0.049	0.127	0.083	-0.074	0.052	0.127	-0.172	0.061	0.108	0.145	-0.041
X 3			1.000	0.366**	0.657**	0.494**	0.675**	0.292	0.023	0.591**	-0.404**	-0.067	0.078	0.136	0.289
X 4				1.000	0.293*	0.224	0.341**	-0.026	-0.133	0.336*	0.101	-0.037	0.084	0.046	0.091
X 5					1.000	0.036**	0.540**	0.178	0.124	0.659**	-0.346**	0.062	-0.028	0.083	0.140
X 6						1.000	0.476**	0.228	0.114	0.741**	-0.239	0.149	0.004	0.234	0.221
X 7							1.000	0.289	0.060	0.586**	-0.211	-0.011	0.034	0.156	0.307**
X 8								1.000	-0.113	0.221	-0.122	-0.381**	-0.112	0.152	-0.055
X 9									1.000	0.105	-0.093	0.380**	0.539**	0.191	0.065
X10										1.000	-0.124	-0.036	0.186	0.286	0.096
X11											1.000	0.062	-0.269	-0.209	-0.071
X12												1.000	0.180	0.170	0.303**
X13													1.000	0.329	0.031
X14														1.000	-0.023
X15															1.000

X 1 : Days to flowering. X 2 : Plant height at flowering (cm). X 3 : Plant height at harvest (cm).
 X 4 : Number of Binary branches. X 5 : Number of clusters per plant. X 6 : Number of fruits per plant.
 X 7 : Number of flowers per plant. X 8 : Number of flowers per inflorescence. X 9 : Average fruit weight (g).
 X10 : Yield per plant (kg). X11 : Total soluble solids (%). X12 : Polar diameter (cm).
 X13 : Equatorial Diameter (cm) X14 : Number of locules. X15 : Rind thickness (mm).

Note : ** indicates significance at 1% level.

* indicates significance at 5% level.

Appendix 3. Phenotypic correlation coefficients among fifteen characters in AVXCR (F1).

Chara- cters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
X 1	1.000	0.566**	-0.347*	-0.027	-0.276	-0.343*	-0.602**	-0.255	0.151	-0.338*	-0.050	-0.192	-0.169	-0.168	-0.062
X 2		1.000	-0.023	0.242	0.131	0.076	-0.151	-0.215	-0.039	0.061	0.282	-0.114	-0.077	0.044	-0.033
X 3			1.000	0.487**	0.536**	0.615**	0.436**	0.216	-0.057	0.621**	-0.107	0.149	0.396**	0.420**	0.043
X 4				1.000	0.483**	0.475**	0.301*	0.042	-0.131	0.458**	-0.026	0.053	0.229	0.449**	-0.033
X 5					1.000	0.919**	0.572**	0.257	-0.279	0.883**	0.093	0.239	0.265	0.465**	0.067
X 6						1.000	0.615**	0.249	-0.249	0.978**	0.127	0.265	0.314*	0.565**	-0.015
X 7							1.000	0.453**	0.032	0.638**	-0.101	0.257	0.223	0.326*	-0.048
X 8								1.000	0.002	0.248	-0.229	0.321*	0.291*	0.047	0.318*
X 9									1.000	-0.068	-0.128	0.104	0.264	-0.013	-0.071
X 10										1.000	0.104	0.304*	0.375**	0.578**	-0.026
X 11											1.000	0.028	0.024	0.101	-0.009
X 12												1.000	0.691	-0.030	0.552**
X 13													1.000	0.082	0.450**
X 14														1.000	0.075
X 15															1.000

X 1 : Days to flowering. X 2 : Plant height at flowering (cm). X 3 : Plant height at harvest (cm).
 X 4 : Number of Binary branches. X 5 : Number of clusters per plant. X 6 : Number of fruits per plant.
 X 7 : Number of flowers per plant. X 8 : Number of flowers per inflorescence. X 9 : Average fruit weight (g).
 X 10 : Yield per plant (kg). X 11 : Total soluble solids (%). X 12 : Polar diameter (cm).
 X 13 : Equatorial Diameter (cm) X 14 : Number of locules. X 15 : Rind thickness (mm).

Note : ** indicates significance at 1% level.
 * indicates significance at 5% level.

Appendix 4. Phenotypic correlation coefficients among fifteen characters in PRXCR (F1).

Chara- cters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
X 1	1.000	0.126	0.144	-0.108	-0.233*	-0.204*	-0.369**	-0.170	0.132	-0.063	0.052	-0.084	0.099	0.012	-0.051
X 2		1.000	0.038	-0.068	0.027	0.031	0.129	-0.133	0.060	0.078	-0.026	0.057	0.068	-0.087	0.107
X 3			1.000	0.054	0.398**	0.213*	0.314**	-0.016	0.308**	0.552**	0.049	0.281**	0.281**	0.104	0.247*
X 4				1.000	0.012	-0.034	0.104	0.047	-0.132	0.034	-0.058	0.051	-0.047	0.076	-0.139
X 5					1.000	0.443**	0.571**	0.173	0.035	0.647**	-0.017	0.124	0.102	0.073	0.162
X 6						1.000	0.474**	0.159	0.077	0.549**	-0.020	0.109	0.054	-0.127	0.020
X 7							1.000	0.365**	0.102	0.713**	-0.033	0.126	0.085	-0.054	0.109
X 8								1.000	-0.001	0.281**	-0.044	-0.015	0.001	-0.062	0.024
X 9									1.000	0.351**	-0.129	0.504**	0.683**	-0.006	0.354**
X10										1.000	-0.087	0.290**	0.327**	-0.026	0.291*
X11											1.000	-0.123	-0.096	0.029	-0.069
X12												1.000	0.649**	-0.041	0.558**
X13													1.000	0.033	0.534**
X14														1.000	-0.144
X15															1.000

X 1 : Days to flowering. X 2 : Plant height at flowering (cm). X 3 : Plant height at harvest (cm).
X 4 : Number of Binary branches. X 5 : Number of clusters per plant. X 6 : Number of fruits per plant.
X 7 : Number of flowers per plant. X 8 : Number of flowers per inflorescence. X 9 : Average fruit weight (g).
X10 : Yield per plant (kg). X11 : Total soluble solids (%). X12 : Polar diameter (cm).
X13 : Equatorial Diameter (cm) X14 : Number of locules. X15 : Rind thickness (mm).

Note : ** indicates significance at 1% level.

* indicates significance at 5% level.

Appendix 5. Phenotypic correlation coefficients among fifteen characters in CR (F1) XPR.

Chara- cters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
X 1	1.000	0.335**	-0.242*	0.077	-0.327**	-0.315**	-0.478**	-0.232*	-0.037	-0.345**	-0.171	-0.043	0.009	0.123	-0.129
X 2		1.000	0.186	0.198*	0.111	0.215*	0.148	-0.045	0.164	0.162	-0.115	0.584**	0.137	0.247*	0.035
X 3			1.000	0.144	0.489**	0.531**	0.557**	0.438**	0.338**	0.543**	0.193	0.319**	0.228*	0.014	0.276**
X 4				1.000	0.272**	0.235*	0.256**	-0.041	0.164	0.254**	0.040	0.128	0.126	0.159	0.127
X 5					1.000	0.943**	0.823**	0.194*	-0.068	0.919**	-0.066	-0.150	-0.169	-0.201*	0.115
X 6						1.000	0.896**	0.244*	-0.013	0.974**	-0.073	-0.143	-0.089	-0.197*	0.074
X 7							1.000	0.297**	0.094	0.879**	0.182	-0.012	0.085	-0.184	0.205*
X 8								1.000	0.143	0.234*	0.198*	0.061	0.157	0.046	0.134
X 9									1.000	0.154	0.109	0.478**	0.619**	-0.008	0.417**
X10										1.000	-0.067	-0.070	-0.019	-0.238*	0.149
X11											1.000	0.048	0.122	-0.069	0.130
X12												1.000	0.761**	0.253*	0.513**
X13													1.000	0.329**	0.437**
X14														1.000	0.218*
X15															1.000

X 1 : Days to flowering. X 2 : Plant height at flowering (cm). X 3 : Plant height at harvest (cm).
X 4 : Number of Binary branches. X 5 : Number of clusters per plant. X 6 : Number of fruits per plant.
X 7 : Number of flowers per plant. X 8 : Number of flowers per inflorescence. X 9 : Average fruit weight (g).
X10 : Yield per plant (kg). X11 : Total soluble solids (%). X12 : Polar diameter (cm).
X13 : Equatorial Diameter (cm) X14 : Number of locules. X15 : Rind thickness (mm).

Note : ** indicates significance at 1% level. * indicates significant at 5% level.

Appendix 6. Phenotypic correlation coefficients among fifteen characters in CR (F2).

Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
X 1	1.000	-0.071	-0.251*	-0.219*	-0.362**	-0.274**	-0.479**	0.063	-0.016	-0.264**	0.076	-0.143	-0.063	-0.267	0.095
X 2		1.000	-0.156	0.048	-0.025	-0.098	-0.096	0.034	-0.089	-0.047	0.101	-0.134	-0.213*	-0.063	-0.009
X 3			1.000	0.277**	0.310**	0.215*	0.273**	-0.158	0.179	0.157	-0.143	0.241*	0.322**	0.411**	-0.219*
X 4				1.000	0.523**	0.531**	0.462**	0.159	0.123	0.520**	0.009	0.082	0.355**	0.149	0.171
X 5					1.000	0.886**	0.736**	0.124	0.085	0.839**	0.057	0.138	0.239*	0.222*	-0.175
X 6						1.000	0.762**	0.196*	0.103	0.938**	0.060	0.181	0.305**	0.155	0.020
X 7							1.000	0.460**	0.041	0.711**	-0.049	0.029	0.169	0.211*	-0.162
X 8								1.000	0.042	0.256**	0.214*	0.013	0.078	-0.148	0.118
X 9									1.000	0.159	-0.066	0.139	0.122	-0.007	0.094
X10										1.000	0.077	0.168	0.290*	0.146	0.005
X11											1.000	-0.132	-0.013	0.024	-0.004
X12												1.000	0.463**	0.309**	0.016
X13													1.000	0.183	0.162
X14														1.000	-0.539**
X15															1.000

X 1 : Days to flowering. X 2 : Plant height at flowering (cm). X 3 : Plant height at harvest (cm).
X 4 : Number of Binary branches. X 5 : Number of clusters per plant. X 6 : Number of fruits per plant.
X 7 : Number of flowers per plant. X 8 : Number of flowers per inflorescence. X 9 : Average fruit weight (g).
X10 : Yeild per plant (kg). X11 : Total soluble solids (%). X12 : Polar diameter (cm).
X13 : Equatorial Diameter (cm) X14 : Number of locules. X15 : Rind thickness (mm).

Note : ** indicates significance at 1% level.
* indicates significance at 5% level.

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ಗಂ. ಕ್ಯ. ವಿ. ಕೆ., ಬೆಂಗಳೂರು-65.
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