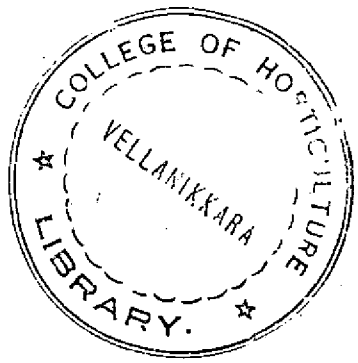
EVALUATION OF THE PRODUCTIVITY OF CHILLI HYBRIDS



By

ELIZABETH PHILIPOSE

THESIS
SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENT FOR THE DEGREE
MASTER OF SCIENCE IN AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF PLANT BREEDING
COLLEGE OF AGRICULTURE
VELLAYANI, TRIVANDRUM

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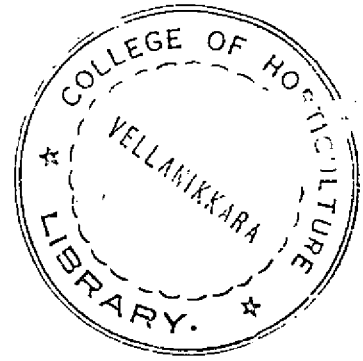

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DECLARATION

I hereby declare that this thesis entitled " Evaluation of the productivity of chilli hybrids" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Elizabeth Philipose

ELIZABETH PHILIPOSE

Vellayani,

10 - 11 - 1986.

C E R T I F I C A T E

Certified that this thesis entitled "Evaluation of the productivity of chilli hybrids" is a record of research work done independently by Smt. ELIZABETH PHILIPOSE under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Vellayani,
10 - 11 - 1986

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A C K N O W L E D G E M E N T

I wish to place on record my deep sense of gratitude and indebtedness to

Dr.P.Manikantan Nair, Professor of Plant Breeding, Chairman, Advisory Committee for suggesting the project work, his expert guidance during the course of investigation and generous help in the preparation of this thesis,

Dr.V.Gopinathan Nair, Professor and Head of the Department of Plant Breeding for his timely suggestions and the facilities provided in carrying out the research work,

Dr.Alice Abraham, Professor of Soil Science and Agricultural Chemistry for going through the manuscript and making valuable suggestions,

Sri.R.Balakrishnan Asan, Assistant Professor of Agricultural Statistics for his help in designing the field experiment, statistical analysis of data and preparation of the thesis,

Sri.L.Radhakrishnan Potti, Senior Office Superintendent for neatly typing the manuscript,

the ICAR for awarding a fellowship during the period of study,

the members of the staff and students of the Department of Plant Breeding and my friends for their whole hearted co-operation,

(contd..)

Sri.Abdul Hameed, Professor of Soil Science and Agricultural Chemistry and Sri.Kuriakose for their help in taking the photographs,

my parents for their constant encouragement and help during the entire course of my study and

last but not the least, God Almighty for enabling me to complete my course successfully.

ELIZABETH PHILIPOSE

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INTRODUCTION

1. INTRODUCTION

Vegetables form the cheapest source of natural protective foods which are rich in nutrients besides vitamins and minerals required by the human body. Along with cereals and other foods they constitute the essentials of a balanced diet. Besides their use in the fresh form, vegetables form raw materials in several industries and help to earn foreign exchange. Most of the vegetables, if properly grown can give yields which are five to ten times higher than any cereal crop (Choudhury, 1983). Despite all these facts, the area under vegetables is low, occupying only about 1.2 per cent of the total cultivated area of the country (Choudhury, 1983). The possibility for boosting up vegetable production through expansion of area under vegetable cultivation remains remote. Hence, increasing the production potential of vegetable crops seems to be the best alternative. Growing high yielding varieties of vegetables will go a long way to achieve this end.

Chilli, a member of the family Solanaceae, and genus Capsicum forms an indispensable vegetable in the diet of the people of India. The fruits are used in culinary and allied preparations in a variety of forms.

Capsicum annuum L. is the most common cultivated species and all green chillies in the market and most dry chillies belong to this group. The small highly pungent chillies belong to Capsicum frutescens L. The plant is diploid with a chromosome number of 2n = 24.

This crop originated from Tropical South America and was introduced to India by the Portuguese in the 15th century. Chillies are grown practically all over India and in almost all seasons. India is the largest producer and consumer of chillies in the world producing about 5,18,000 tonnes of dry chillies from an area of 7,91,000 hectares (Sontakke, 1984). Economically, chilli is an export oriented crop. This paramount vegetable crop has significant nutritional value and is rich in vitamins, especially Vitamins A and C. According to Choudhury (1983), green chillies contain 292 I.U. of Vitamin A and 111 mg of Vitamin C in 100 g of edible portion. Chilli is also considered as an important spice and condiment. The pungency in chillies is due to an alkaloid Capsaicin, which has good export possibilities. The medicinal value of chilli has been much realised. The fruits of chillies are also used for the extraction of colouring matter. In order to meet the increasing demand of this vegetable cum spice for export as well as domestic consumption, the production is to be augmented. Enhancement of the production potential of the crop by genetic improvement forms the

only alternative as the expansion of area has little possibilities.

Though chilli is generally considered as a self pollinated crop, natural cross pollination is as high as 68 per cent (Murthy and Murthy, 1962). As a result, natural populations tend to be heterozygous. Besides, wide variation exists among the various cultivars with regards to the important economic attributes. These facts point towards the immense scope for effecting genetic improvement through various breeding methods. Mostly, conventional methods are being adopted to bring about genetic improvement in this crop. Heterosis breeding is gaining importance in cross pollinated crops and in self pollinated crops with a fair degree of outcrossing. The possibility for exploitation of heterosis in chilli has been reported by Deshpande as early as 1933. Since then, several workers have pointed out many instances in which the hybrids have exhibited significant heterosis for a large number of economic attributes. Besides high degree of cross pollination, high reproductive potential acts as another plus point in the exploitation of hybrid vigour in chilli. The discovery of male sterility is expected to pave way for the production of hybrid seeds at a lower cost since it will help to dispense with the processes of hand emasculation and artificial pollination.

The present investigation entitled, 'evaluation of the productivity of chilli hybrids', was aimed at assessing the productivity of six chilli hybrids obtained by crossing four inbreds in all possible combinations without reciprocals. Since the germination percentage of the seeds of one of the combinations was very poor, it could not be included in the evaluation. The other five hybrids along with their four parents were evaluated in a 9 x 3 RBD during 1984-'85 and 1985- '86.

Data on twenty different quantitative and five qualitative attributes were collected. The former data were subjected to statistical analysis for estimating the genetic parameters, correlations and the three types of heterosis namely, relative heterosis, heterobeltiosis and standard heterosis.

The study enabled to unravel the extent of heritability, genetic advance, genetic gain, associations among characters, and heterosis of important economic traits in chilli. Further, the investigation could identify two promising chilli hybrids with high production potential coupled with other desirable attributes. Above all, the present investigation undoubtedly underlined the prospects of heterosis breeding in promoting the production potential of Capsicum annuum L.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Though chilli possesses a perfect flower and is generally considered as a self pollinated crop, there appears to be no complete agreement on this view since a good percentage of natural cross pollination takes place. The extent of natural cross pollination in chilli is dependent upon the proximity among lines and bee population. Attempts made by many workers revealed that the extent of natural cross pollination in chillies varied from 4.24 (Singh et al., 1973) to 68 (Murthy and Murthy, 1962) per cent. There is also a wide variation among the cultivars with regards to the economic attributes. High estimates of heritability and genetic advance for the important economic attributes were reported by many workers. There are also various reports on the exhibition of significant heterosis by the hybrids in different economic attributes namely yield, number of fruits, length and girth of fruits, number of branches, number of leaves, leaf area, earliness in blooming, duration etc. The discovery of male sterile lines in chillies opened new vistas in the commercial exploitationof hybrid vigour in this crop. Efforts are also being made to find out the conditions which are most congenial for obtaining more number of hybrid seeds. The fact that a single pollination will yield more number of

seeds is another added advantage in the exploitation of hybrid vigour in chillies.

2.1 Anthesis and pollination

Deshpande (1933) reported that the flowers open in the morning some time after sunrise, the majority opening between 8 and 10 A.M. The anthers commence dehiscing an hour or so after the opening of the flower. Both the flower opening and anther dehiscence are to a large extent, dependent upon weather conditions.

At Guntur, flowers commenced opening as early as 2 A.M. and continued upto 4 A.M. as reported by Gopalaratnam (1933). According to him majority of the flowers open by 6 A.M. Dehiscence of anthers was found to follow, rather than be simultaneous with the opening of flowers. In general, dehiscence starts only after sunrise and this indicates that the atmospheric temperature is the determining factor for anther dehiscence. The author observed that the flowers commence closing from about 5 P.M. on the day of opening and remain closed during the night. Once again, they commence to open from 4 A.M. on the next day and close by the evening. The corolla along with its stamens are shed in the course of another 12 hours.

According to Jagdish (1964) flowers of Capsicum annuum L. started opening as early as 5.30 A.M. under Coimbatore conditions. The opening continued upto 10 A.M. on bright and clear days and was however, delayed upto 12 noon on cold and cloudy days. The anther dehiscence started only after 9 A.M. and continued upto 3 P.M. This was also found to be delayed by more than an hour during cloudy days.

The flowers started opening by 7 A.M. and continued upto 9.30 A.M. under Vellayani conditions, as observed by Nair (1970).

An attempt was made to find out the percentage of natural crossing in chilli under Guntur conditions, by Gopalaratnam (1933). Flower buds expected to open on the next day were bagged with tissue paper covers at about 6 P.M. The protected flower buds were emasculated early next morning at 5.30 A.M. before the anthers could possibly dehisce. These were allowed to be cross pollinated and the setting of the same was examined on the 7th day. Observations were carried out at the end of every month in two seasons. The average percentage of natural crossing was found to be 7.2.

Murthy and Murthy (1962) reported that two separate trials were being conducted at Agricultural Research Station, Lam, to assess the extent of natural cross pollination in

chilli. The extent of natural cross pollination was found to be 58-68 per cent. Wind, late dehiscence of anthers (1-10 hours after flower opening), failure of bursting of anthers due to some unfavourable physiological conditions and prolonged phase of flowering (about three months) were suggested as possible reasons for the high degree of natural cross pollination.

Natural cross pollination in chilli as affected by the direction and the distance of planting between varieties was assessed by Singh et al. (1973). Four replications were laid in the open and two in cages. Among the five isolation distances adopted under open field conditions, the least degree of natural cross pollination between the Capsicum varieties Rajpura Long Red and Red Puri was observed with 2250 cm between rows, while under covered set, the figure was less at 225 cm among the two isolation distances tried. Natural crossing was highest on the Southern side in both open (21.91 per cent) and protected (43.80 per cent) conditions The South East direction of wind was suggested to be responsible for the high rate of natural crossing on the Southern side. The degree of natural cross pollination ranged from 4.24 to 22.15 per cent under open field conditions while the figures ranged from 15.75 to 26.02 per cent in protected conditions.

As reported by Lorenzetti and Cirica (1974) in a study of crosses between C. annuum L. var. grossum and C. annuum L. var. cerasiforme and between red and yellow fruited cultivars of C. annuum L. var. grossum, it was shown that in Umbria, as elsewhere, the degree of natural crossing was high, ranging from 5 to 25 per cent.

According to Free (1975) in Jamaica, fruit set in C. frutescens L., C. annuum L. and Solanum melongena L. occurred by automatic self pollination and external agents did not appear to increase it greatly. The bee Exomolopsis pulchella visited flowers of all the species and was responsible for any cross pollination that took place.

According to Purseglove (1977) both self and cross pollination occur in chilli, the latter being about 16 per cent. Bees and ants visit the flowers. Anthesis takes place some time after the flowers have opened. Flowers remain open for 2 to 3 days.

Studies were initiated at U.P. Institute of Agricultural Sciences (Vegetable Section), Kalyanpur, Kanpur, to obtain precise information on the amount of natural crossing occurring in various strains of chilli under Kanpur conditions. As reported by Singh and Singh (1977b) amongst the eight strains examined, natural cross pollination ranged from 35 to 58.85 per cent.

Tanksley (1984) reported that experiments were conducted over a two year period in a total of five commercial fields in Southern Mexico to determine the rate of natural cross pollination in C. annuum L. using isoenzyme variation in tester lines. The average natural cross pollination for both years was 42 per cent with the rate of individual plants as high as 91 per cent. Such high rates of natural cross pollination indicate the need for strict precautions in the production of commercial seed and in the design and execution of breeding procedures. Honey bees, bumble bees and leaf cutter bees were reported to be found visiting the flowers.

2.2. Genetic parameters and correlation studies

Arya and Saini (1976) reported a study of genetic variability and correlation in bell peppers. High phenotypic and genotypic variances and estimates of genetic advance were obtained for fruit number per plant and fruit size. Heritability estimates were high for all characters. Correlation studies indicated that fruit size contributed positively to fruit yield while plant height, leaf length, fruit number and capsaicin content were negatively correlated with yield.

A wide range of phenotypic variability was observed for seven agronomic characters in thirty eight varieties of chilli by Awasthi et al. (1976). Heritability was high for

six of the characters studied. Estimated genetic advance was high for height, fruit length and fruit yield. High heritability, but lower expected genetic advance, indicating non-additive gene effects were recorded for number of branches per plant, fruit diameter and average fruit weight. Fruit number per plant was intermediate with respect to both heritability and expected genetic advance.

Rocchetta et al. (1976) conducted correlation analysis between morphological traits and productivity in cultivated capsicum for an understanding of the heterosis phenomenon. Correlation and multiple regression analysis showed that the yield mainly depended on the number and weight of fruits and that the other characters measured contributed to yield through number of fruits.

Arya and Saini (1977a) reported that in seven exotic and indigenous varieties of salad type peppers studied, phenotypic and genotypic coefficients of variation and estimates of genetic gain and genetic advance were high for green fruit yield per plant, fruit size and fruit number per plant. Heritability estimates for all characters were high, except for number of branches. Heritability was highest for weight of seed per fruit (99.92 per cent) closely followed by fruit size (99.83 per cent), fruit number per plant (99.63 per cent), green fruit yield per plant (99.58 per cent),

rind thickness (99.39 per cent) etc. and least in number of branches per plant (60.22 per cent).

Variability studies conducted by Arya and Saini (1977b) in eleven characters with thirty varieties revealed that rind thickness per fruit and fruit size per plant recorded highest genetic variability. The highest heritability estimates were for seed number per fruit, fruit size per plant, branch number per plant and rind thickness per fruit. The highest estimates of genetic advance were for fruit yield per plant and seed number per fruit while Chang (1977) observed high heritabilities in height, days to flower and first mature fruit, total number of flowers, fruit length and stalk length. Yield was positively correlated with vegetative characters, fruit number, total number of flowers and fruit and stalk length. Principal component and varimax analysis showed that total number of flowers, fruit length and mean length of secondary branches were positively correlated with yield.

In another study, Singh and Singh (1977a) observed high broad sense heritability in plant height, number of branches, days to flower, days to maturity, fruit length, fruit thickness, number of fruits per plant and yield per plant. Estimates of narrow sense heritability were high for number of branches, plant height, days to maturity, number

of fruits per plant and yield per plant. Expected genetic advance was high for number of fruits per plant and yield per plant.

Singh and Singh (1977c) studied heritability and genetic advance in a diallel cross involving eight genetically diverse lines of chilli in eight quantitative characters. High estimates of heritability in narrow sense were observed for fruit thickness (83 to 91 per cent), fruit length (76 to 94 per cent), days to maturity (45 to 86 per cent), plant height (45 to 70 per cent) and days to flower (35 to 55 per cent) in both F_1 and F_2. Moderate estimates of heritability were found for number of branches (22 to 28 per cent) in both F_1 sets. Very low estimates of heritability were found for number of fruits per plant and yield per plant. High estimates of heritability in broad sense were obtained for yield and its components. Maximum genetic advance in percentage mean was observed for fruit length followed by fruit thickness.

Genotypic and phenotypic coefficients of variation, heritability and genetic advance for eight characters were studied by Singh and Brar (1979) in thirty one varieties of sweet pepper. High genotypic and phenotypic coefficients of variation were recorded for fruit number and fruit yield, while the values were medium for fruit weight and low for

all the other characters. Plant height, fruit number, fruit diameter and number of days taken to first picking showed high heritability. Heritability was moderate for fruit weight and yield and low for number of branches. Genetic advance was high for yield and number of fruits per plant, medium for fruit weight, plant height and number of days to first picking and low for number of branches and length and diameter of fruit.

Gill et al. (1980) investigated five characters in the cross NP 46 x Hungarian Wax and found that heritability estimates ranged from 26 per cent for flowering time to 87 per cent for fruit shape index.

In a study with seventeen pure lines at two plant densities (50 x 40 cm and 50 x 30 cm) Raju (1980) recorded significant positive correlations among yield components. Days to first flowering had negative correlation with fruit yield and fruit number. Fruit breadth was positively correlated with early and total fruit yield. Generally association between traits tended to be of higher magnitude under normal spacing. Heritability estimates were moderate to high for ash percentage in the fruits, fruit length, fruit breadth and plant height under both spacings and at closer spacing, for early fruit number and number of seeds. The study indicated that the ideotype of Capsicum should be early flowering with more height, spread and number of fruits per plant.

Shifriss and Sacks (1980) while studying the effect of distance between parents on the yield of sweet pepper x hot pepper hybrids found that the correlation between distance and total yield per plant was small, negative and statistically non-significant.

Elangovan et al. (1981) evaluated thirty types of Capsicum annuum L. of diverse origin for eight traits related to yield. Heritability estimates were high for fruit girth (96.7 per cent), fruit length (95.8 per cent), seeds per fruit (94 per cent), plant spread (89.4 per cent) and fruit weight (85.7 per cent). Plant spread, number of fruits per plant and fruit weight had high estimates of genetic advance in addition to high heritability, showing the influence of additive gene effects.

In a study consisting of twelve varieties for yield and five yield components, Ramkumar et al. (1981) observed high heritability and high genetic advance for height, number of fruits per plant and girth of fruit, indicating additive gene action for these traits. Fruit yield was highly correlated with number of fruits per plant, height and plant spread. Similarly Rao and Chhonkar (1981) reported significant positive correlation of fruit number and branch number per plant with ripe fruit yield per plant.

From a study including parents, F_1, F_2, BC_1 and BC_2 for eight characters, Singh and Rai (1981) concluded that plant height had the highest heritability estimate followed by days to flowering, fruit length, number of branches, number of fruits per plant and fruit breadth. High estimated genetic advance was found for number of branches, fruit length and fruit breadth.

Singh et al. (1981) conducted genetic studies in thirty five strains of chilli of diverse origin. Mean weight per fruit, number of fruits per plant and fresh fruit weight per plant gave high heritability and genetic advance estimates. The highest and lowest estimates of heritability were recorded by fresh fruit weight per plant and days to maturity respectively. Correlation studies revealed that genotypic correlations were on par with phenotypic correlations. Fruit thickness and number of fruits per plant had significant positive correlations at phenotypic level with dry yield per fruit, fresh weight of fruit per plant and average weight of fruit.

Observation of six characters in twenty five varieties of chilli, by Bavaji and Murthy (1982), showed that yield was positively correlated with number of fruits per plant and number of branches per plant. Heritability and expected genetic advance were high for number of branches

per plant, fruit length, 50 fruit weight and number of fruits per plant.

Nair et al.(1984) based on a study of fifteen characters in thirty cultivars of Capsicum annuum L. recorded high heritability for all the characters studied. Heritability in the broad sense varied from 70.915 per cent for number of primary branches to 99.924 per cent for girth of fruit. Total yield, number of fruits and girth of fruit exhibited high genetic advance. Number of fruits, with the highest genotypic coefficient of variation, had the highest estimate of genetic advance while life span, with the least genetic variability, had the least estimate of genetic advance. This phenomenon suggested that the more the genetic variability in the population for a particular character, the higher would be the genetic advance.

2.3 Studies on yield and its components

Singh and Singh (1976b) reported that days to flowering, fruit length and number of fruits per plant are the major yield components while Gill et al.(1977), based on correlation, path coefficient and multiple regression analyses in sweet pepper, suggested that selection for high yield should be based on number of fruits per plant.

Korla and Rastogi (1977) did path coefficient analysis in twenty varieties of chilli and found that number of fruits per plant had the highest direct effect on fruit yield followed by weight per fruit and plant height. Direct effect of number of fruits per plant on fruit yield was even more than its correlation coefficient. Fruit length had negative correlation with fruit yield, but substantial positive direct effect. Fruit thickness had negative direct effect on fruit yield and the indirect effects through plant height, number of fruits per plant and fruit length might have resulted its negative correlation with yield. Thus, number of fruits per plant, weight per fruit and fruit length, besides possessing high direct effects on fruit yield, were found to have negative indirect effects among each other.

Based on path coefficient analysis in Capsicum frutescens L., Mehrotra et al. (1977) reported that seeds per fruit, fresh fruit weight, number of fruits per plant, number of primary branches and days to flowering had positive direct effects on dry fruit yield. Fresh fruit weight, days to flowering and number of fruits per plant also had positive indirect effects.

Path coefficient and multiple regression analyses of fruit yield as a function of fourteen component characters and of fresh fruit weight as a function of seven component characters were conducted by Mehra and Peter (1980) on data on eighteen quantitative traits from twenty seven Capsicum annuum L. forms. Genetic advance through selection for yield per se was higher than that from selection based on the components such as number of primary branches per plant, number of fruits per plant, fresh fruit weight and seed weight per fruit. Fresh weight of fruits was highly correlated with fruit girth, locules per fruit and seed weight of fruits. Fruit length was negatively correlated with fresh weight of fruits, but had a positive direct effect on fruit size.

In a study involving seventeen pure lines, conducted by Raju (1980), path analysis revealed that early fruit yield had the highest direct effect on total fruit yield. Fruit number (early and total) had positive direct and indirect effects on total fruit yield. The direct effect of days to flowering was low but indirect effects through early fruit yield and total fruit number were moderate and negative. Indirect effects of plant height and plant spread through early fruit yield and total fruit number were also moderate and positive.

Ripe fruit yield, dry yield and nine yield components were investigated in ten parental forms of Capsicum frutescens L. and their forty five F_1s and F_2s from a diallel cross without reciprocals by Rao and Chhonkar (1981). Fruit number per plant and branch number per plant were positively and significantly correlated with ripe fruit yield per plant. Path coefficient analysis revealed that fruit number per plant, individual fruit weight and dry yield per plant had direct positive effects on ripe fruit yield per plant.

In another study conducted by Rao and Chhonkar (1983a) on twelve yield related characters from a ten parent diallel cross, fruit circumference, ripe fruit yield per plant, dry matter percentage and ascorbic acid content were found to have major direct effects on dry chilli yield.

With a view to elucidate the cause and effect relationship of various plant characters and yield, a path coefficient analysis was undertaken using thirty cultivars, which were selected based on their adaptation, performance and disease tolerance, as reported by Nair et al. (1984). The number of fruits was found to be the principal yield attribute. Yield in chilli can be considered as the effect of five first order components namely number of fruits, number of secondary branches,

girth and weight of individual fruit and duration, which accounted for 68 per cent of the variability in yield.

2.4 Combining ability and heterosis

Deshpande (1933) was the first to report heterosis in Chilli. He crossed two types (viz. Type 3 and Type 29) with sharply contrasting characters. He found that the F_1 seedlings showed more rapid growth than the parental seedlings and at the time of transplanting were nearly one and a half times taller than the latter. They were also much more vigorous. Heterosis was expressed in general vigour, maturity, plant height, productivity (both in the total number of fruits produced and in the total weight of dry produce) and thickness of fruit.

A marked degree of heterosis in many economically important attributes like earliness in blooming, number of leaves, number of branches, leaf area and chemical constituents like ascorbic acid and sucrose, was observed by Nair (1970) in all the four F_1s studied. An intermediate condition was observed with regards to height, spread, number of fruits, fruit size and number of F_2 seeds. The fruit size in F_1s was more, approximately, towards the arithmetic mean than towards the geometric mean except in one cross. Pollen grains of all hybrids displayed an

increase in size, probably due to heterosis.

In a study of combining ability in sweet pepper (Capsicum annuum L. var. grossum) with six varieties in a diallel Gill et al. (1973) observed that general and specific combining ability variances were significant for all the five characters evaluated namely, number of days taken to flowering, number of fruits per plant, fruit size and early and total yield per plant. Parents giving high yields were usually high general combiners. The g.c.a and s.c.a estimates revealed the importance of non-additive type of gene action which can be best exploited where hybrid seed production is commercially feasible. Further, they observed that genetic diversity of parents was positively related to heterosis in the F_1.

Nair and George (1973) observed 100 per cent increase in number of branches in 50 per cent of the crosses studied. They further noticed positive heterotic effect in number of leaves in 50 per cent of the crosses. Earliness in blooming was also an important economic attribute.

According to Lippert (1975) in a 9 x 9 diallel cross, significant heterosis occurred for dry fruit weight per plant, fruit length and percentage of mature fruit at harvest. Total dry fruit weight per plant was superior in all hybrids with a significant heterosis value of 27.4

per cent. This increased fruit weight per plant appeared to be due to an increase in average fruit length, a greater percentage of mature fruit at harvest and to a lesser degree, increased fruit width and dry weight per fruit.

Mishra et al. (1976) compared eight yield components between the F_1 plants and the eight parental lines. Dominance was observed for fruit length and number of primary branches per plant. Crosses involving lines 5403-1 and 6208-2 exhibited heterosis for most of the characters except when they were crossed with each other.

While studying the inheritance of some quantitative characters on heterotic combinations of Capsicum annuum L. Popova and Mihailov (1976) observed that the seeds, resulting from the crosses studied, had larger embryos and a greater 1000 seed weight than that of the parents. It was suggested that this may contribute to the greater vigour of the hybrids. This confirms the concept that heterosis is manifested immediately after the fecundation of the egg cell and exerts influence on the formation of seeds. The heterotic combinations had larger number of leaves and greater assimilation area in comparison to the parental varieties.

Ten characters associated with yield and maturity were assessed in the parents, F_1 and F_2 of a half diallel cross involving six Capsicum annuum L. varieties which were high yielding, intermediate or low yielding, by Rochetta et al. (1976). In the F_1 heterosis for yield was observed in crosses between the yield types high x intermediate, intermediate x intermediate and low x low.

Singh and Singh (1976a) studied the F_1, F_2, BC_1 and BC_2 generations derived from a half diallel cross involving, eight lines of Capsicum annuum L. from different agro-climatological regions. Number of branches, number of days to flowering, number of days to maturity, fruit length, fruit thickness, fruit number and yield exhibited heterosis.

Combining ability in chilli was studied by Singh and Singh (1976c) by growing the parents, F_1 and F_2 of a diallel cross involving eight Capsicum annuum L. lines. Three characters were measured and for all those characters, both g.c.a and s.c.a effects were significant, the g.c.a effects being the larger.

While collecting data on plant height, number of branches, number of days to flowering, number of days to maturity, fruit length and thickness and fruit number and weight per plant from the crosses involving four diverse

Capsicum annuum L. inbreds, Singh and Singh (1976d) revealed that the predominant gene effects conditioning all characters were additive, dominant and epistatic. Significant heterosis was observed for all characters in all the crosses except for number of fruits per plant in crosses 5416-4 x 6718 and 6718 x 5417-1 and for fruit length in the cross 6718 x 5417-1. When dominance of particular parents was considered, the better parent was found exhibiting dominance in F_1 for majority of characters.

Heterosis in interspecific hybrids of five species of Capsicum has been reported by Pillai et al. (1977). Hybrids from Capsicum microcarpum x Capsicum frutescens showed positive heterosis for height. Capsicum microcarpum x Capsicum pendulum and Capsicum frutescens x Capsicum baccatum showed positive heterosis for percentage fruit set. The largest number of fruits per plant was obtained from Capsicum frutescens x Capsicum baccatum while the heaviest fruits were obtained from Capsicum pendulum x Capsicum microcarpum.

In a diallel set including ten parental lines and 45 F_4s excluding reciprocals, Sharma and Saini (1977), while studying fruit yield per plant, plant height, number of branches per plant and leaf area per plant, observed heterosis over the better parent in fruit yield and plant

height as well as high estimates of s.c.a. The F_1 crosses Waxy Globe x Hot Portugal, Hungarian Wax x Solan Yellow and Solan Yellow x Hot Portugal, which showed high s.c.a. effects, were also heterotic for yield.

In an evaluation of the parents and F_1s of a diallel cross involving eight strains of Capsicum annuum L., Singh and Singh (1978a) reported significant variances in both g.c.a. and s.c.a. for the eight traits studied. The cross 5430 x 5438 exhibited the highest s.c.a. effects for yield and three of its components, and these strains were among the four best general combiners.

When sixteen widely variable lines were crossed with four pollen parents showing a range of adaptation and agronomic characters and, days to maturity, height, fruit thickness and fruit number and fresh fruit yield per plant were assessed, Singh and Singh (1978b) observed that s.c.a variance was greater than that for g.c.a. for all characters except for fruit yield per plant in both F_1 and F_2 studies.

Singh and Singh (1978c) studied heterosis and its components for yield in chilli in 28 crosses between eight varieties of Capsicum annuum L. All hybrids showed heterosis over the better parent for yield. Dominance components were mainly responsible for heterosis, being at least twice as

great as additive components.

Out of the seven F_1s from crosses among five varieties, Joshi and Singh (1980) observed that three were heterotic over the better parent for height. Yolo Wonder x Golden Queen had more number of primary branches than the better parent Golden Queen. Yolo Wonder x MC 201 had longer fruits as well as more number of fruits per plant than the better parent Yolo Wonder. Four hybrids showed heterosis over the better parent for number of fruits per kg. Yolo Wonder x MC 201 gave the highest fruit yield per plant and showed the maximum heterosis over the best variety Golden Queen.

The F_1s of crosses of a cytoplasmically male sterile sweet form of chilli with fourteen phenotypically diverse inbreds of the hot type were all fertile and hot, as reported by Shifriss and Sacks (1980). Observations on characters such as number of fruits per plant, total yield, fruit weight, fruit length, fruit width, days to flowering and days to harvest were recorded. The mean yield of the crosses exceeded that of the hot lines by about 30 per cent. The best crosses equalled the best parent in total yield per plant. The hybrids had fewer and larger fruits than their respective hot inbred parents.

Nair (1981) in a 9 x 9 diallel observed that hybrid vigour was manifested in respect of thirteen out of the

eighteen quantitative traits studied. The phenomenon of positive heterosis was negligible in five characters namely, weight, length, girth and size of fruit and number of seeds per fruit. Wide variation in the range of heterosis was observed. As much as 1488.04 per cent and 1366.51 per cent heterosis were manifested for the production of number of leaves and total yield respectively. Purple Round was the best general combiner for height, number of primary branches, spread and life span. Further, it was the second best general combiner for number of leaves, number of fruits and total yield. Vellanotchi topped in g.c.a. for total yield in addition to its being the second best general combiner for weight, girth and size of fruit and Vitamin C content. Pant C-1, which is known for its resistance to leaf curl disease, was the best general combiner for number of fruits and the second best general combiner for spread of the plant. Purple Round and Vellanotchi, both good general combiners for yield, had produced the hybrid with highest yield of 1443.8 g of fruits per plant (hybrid vigour over better parent was 1246.83 per cent). Besides, this hybrid was bestowed with desirable economic attributes like enhanced number of fruits (334), less number of seeds (26.7), long life span (230.2 days) and higher Vitamin C (307.6 mg per cent) and Capsaicin (0.80 per cent) contents. The second best hybrid combination was Pant C-1 x Purple

Cluster, which produced a total number of 142.8 fruits, yield of 162.3 g and with a life span of 194.3 days. Erect fruiting habit enables uniform maturity and ripening. Both these hybrids were found to be tolerant to leaf curl.

Superiority over the beatter parent with respect to two characters namely fruit number and yield per plant was observed by Pandey et al.(1981) in a line x tester analysis.

Uzo (1984), while studying the parents, F_1, F_2 and BC_1 of crosses among three cultivars of Capsicum annuum L. found that the hybrids exceeded the taller parent in height by 21 per cent. Leaf areas of the two F_1s did not significantly exceed that of the common parent with the larger leaf area, indicating no significant hybrid vigour for leaf size. But the leaf areas of the F_1s were very significantly higher than that of the other generations. The highest number of fruits were those of the F_1s. The sum of the parental numbers of fruits was less than that of the resultant F_1s. F_1s gave the highest fruit weights per plant. But there was no detectable increase in average weight of fruit above that of the better parent.

2.5 Techniques of hybrid seed production

According to Betlach and Novák (1972) the most favourable times of the day for emasculation were 08.00 to 10.00 and 16.00 to 18.00 h. Pollination was best effected

at temperatures of 18 to 24°C. Seed set was also strongly affected by the maternal parent and pollen fertility.

Alpatév and Marfutina (1974) observed that after the pollination of unemasculated newly opened flowers, the yield of hybrid seeds was higher and the F_1 inter-varietal hybrids had a greater viability and yield than in the same cross combinations obtained by pollination of emasculated flowers.

Without preliminary emasculation, the best time for pollination proved to be the budding stage, in sweet pepper, when own pollen had not ripened but the stigma was ready to receive pollen, as reported by Marfutina (1974). The fruits ripened earlier in the hybrids produced without emasculation, but no difference in fruit yield was observed.

In the annual report of the year 1976, of the Institute of Horticultural Plant Breeding, Wageningen, Netherlands, it is stated that seed set was favoured by high relative humidity (95 per cent) and fruit set by a low one (55 per cent). A study of crossing procedures showed that better results were obtained on young plants without fruits than on older fruiting plants. In the annual report of the year 1977, it is further stated that in reciprocal crosses of Capsicum annuum and Capsicum chinense with representatives of other species, those in

which primitive forms were used generally gave better seed set than those using cultivated material.

Radhakrishnan et al. (1977) described a technique in which the upper part of the style along with the stigma was excised and a drop of 5 per cent sucrose solution applied to the cut surface prior to pollination. This resulted in fruit set and seed set in crosses between Capsicum annuum, Capsicum frutescens and Capsicum pendulum in all possible combinations including reciprocals. In crosses in which Capsicum annuum was female, the percentage fruit set was lower than that in the reciprocals. Maximum fruit set was observed in the cross Capsicum pendulum X Capsicum annuum (13.1 per cent) followed by Capsicum frutescens x Capsicum pendulum (12.8 per cent). It was observed that there was increase in the percentage of fruit set when pollination was done immediately after emasculation.

The use of gelatin capsules in controlled pollination was described by Mc Ardle and Bouwkamp (1980). The system involved cutting a V-shaped notch in one section of the capsule and closing the two sections together around a single flower. After emasculation, the capsule kept the stigma from being contaminated prior to controlled pollination. This system had been used successfully in Capsicum, Lycopersicon, Phaseolus and Cucumis.

As chilli flowers are bisexual, they have to be emasculated before controlled pollination. Male sterile lines will solve the problem of hand emasculation. Clayberg et al. (1966) reported that extensive screening for isolating male sterile mutants was not made in chilli, though in tomatoes such screening discovered many male sterile mutants. According to Daskaloff (1976) though heterosis for yield in pepper has been documented in both hot and sweet cultivars, commercial exploitation on a large scale is limited due to the inefficient systems of male sterility and male fertility restoration.

The natural cross pollination in chilli can be used to a certain extent to exploit male sterility. Experiments on hybrid seed production indicated that when male sterile plants and male fertile plants were grown in alternate rows, natural pollination resulted in 50 per cent of the normal seed set (Daskaloff, 1971).

Two types of male sterility in Capsicum have been reported by Gikalo and Latysheva (1972). (a) the Peterson type with abortive pollen and poorly developed anthers and (b) the Bulgerian type with no stamens or with anther filaments only, without pollen sacs. Cytoplasmic male sterility was manifested only if there was a combination of 'S' cytoplasm and the homozygous recessive state of the 'ms' gene.

Shifriss (1973) reported that a stable male sterile recessive mutant had been found in Gambo pepper and it appeared useful for the production of hybrid chilli varieties. This plant and its male progenies appeared similar to male fertile plants under field and greenhouse conditions except for the different morphology of male sterile flowers in which post-meiotic breakdown of microspores occurs. It had small and shrunken anthers which did not produce pollen grains during a year in the greenhouse. The production of four hybrids viz. hybrid No.12, 15, 16 and 17 using two genes for male sterility viz. ms_1 and ms_2 was reported by Shifriss and Rylski (1973).

Dikii (1974) reported that by distant hyoridization, new lines with cytoplasmic male sterility were obtained. Male sterile analogues of good sweet Capsicum varieties were produced and promising heterotic hybrids of hot Capsicum were bred using male sterile forms.

At the Maikop Experimental station in the USSR, a small collection had been made, of forms which could be used in breeding for heterosis. These included the stamenless forms 12,15, 23 and MS bred in Bulgaria by interspecific hybridization. Although they were considerably improved, they have some defects like lateness and low seed set (Dikii and Studentsova, 1974).

As reported by Dikii and Anikeenko (1975), multiple back crosses involving forms with cytoplasmic male sterility yielded several heterotic hybrids, the best of which exceeded the standard by 23 to 52 per cent in early yield and by 11 to 20 per cent in total yield.

Chauhan (1977) reported that a study of fertile plants and corresponding lines with genic, cytoplasmic, genic- cytoplasmic or chemically induced male sterility provided evidence that the presence of the tapetum inhibits androecium development. In partially or completely male sterile material, tapetum degeneration was delayed, thickening of the endothecium was inhibited or the tapetum was abnormal.

A method for the production of hybrid seeds of Capsicum annuum L. using a male sterile line of the variety Fresno Chile as maternal parent and male fertile Fresno Chile, Astrakhan 628 and Hatvan as pollen parents was described by Dikii and Anikeenko (1980). The best ratio of parental rows (seed parent: pollen parent) was 2:1 or 3:1 especially the former.

Meshram and Narkhede (1982) reported that a natural male sterile mutant with excessive vegetative growth and bushy habit was observed in a population of CA 452-1. The male sterility was governed by a single recessive gene 'ms'.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The experiments were conducted in the Department of Plant Breeding, College of Agriculture, Vellayani, during 1984-'85 and 1985- '86. The different steps involved were:-

1. Production of inbreds of four varieties namely, Vellanotchi, Pant C-1, Purple Round and Purple Cluster.
2. Crossing the four inbreds in all possible combinations without reciprocals to produce six hybrids.
3. Evaluation of the six hybrids along with their four parents in a Randomized Block Design (RBD) with three replications in two different seasons.

3.1 Production of inbreds

The four varieties were selfed for one generation to produce the inbreds.

Technique of selfing: Since the chilli flowers are bisexual and have the natural adaptation for self pollination, selfing is easy. The mature flower buds which would open the following day were covered by butter paper covers in the previous evening. The covers were retained for three days. The fruits were labelled, harvested at maturity and seeds extracted.

3.2 Production of hybrid seeds:

The seeds obtained after selfing were sown to raise the inbred seedlings which were transplanted after one month.

Technique of crossing: Crossing involved three steps namely, emasculation of the flowers, protection and artificial pollination.

For emasculation, the flower buds which would open the following day were selected in the previous evening. The petals were forced open and anthers removed using fine forceps. The emasculated flower buds were then covered with butter paper covers to prevent contamination by foreign pollen. The mature flower buds of the pollen parents were also covered with butter paper covers in the previous evening of their blooming.

Artificial pollination was done between 7 a.m. and 9 a.m. For this, protected flowers were collected from the pollen parents and the anthers separated from the petals. The pollen grains were then scooped out from the anthers using a needle, through the longitudinal slits of the anthers. The pollen mass was then applied on the receptive stigma of the emasculated flowers. The pollinated

flowers were again protected and the covers retained for three days. The fruits were harvested when ripe and the seeds extracted.

3.3 Evaluation of the parents and hybrids:

The parents and hybrids comprised of

A. Parents:-

i. Vellanotchi

ii. Pant C-1

iii. Purple Round

iv. Purple Cluster.

B. Hybrids:-

1. Vellanotchi x Pant C-1 (V x PC-1)
2. Vellanotchi x Purple Round (V x PR)
3. Vellanotchi x Purple Cluster (V x PCl)
4. Pant C-1 x Purple Round (PC-1 x PR)
5. Pant C-1 x Purple Cluster (PC-1 x PCl)
6. Purple Round x Purple Cluster (PR x PCl)

C. Standard:- Vellanotchi

Since the germination of the seeds of the combination Purple Round x Purple Cluster was very poor, this hybrid could not be included in the two evaluation trials.

The first evaluation trial involving four parents and five hybrids was conducted during the period July 1984 to January 1985. Each treatment consisted of thirty plants each in three replications. A spacing of 45 x 45 cm was

given between and within rows. The management practices were followed as per the Package of Practices of Kerala Agricultural University (1982). The second evaluation trial was conducted in the same manner from October 1985 to April 1986.

3.3.1 Observations recorded

The following observations were recorded

1. Percentage of fruit set: The total number of flowers pollinated and the number of fruits developed were used for the computation of percentage of fruit set.

2. Percentage of germination: The number of seeds germinated was expressed in percentage.

From each treatment in each replication ten plants were randomly selected for recording observations.

3. Days to 50 per cent flowering: The number of days taken by fifty per cent of the plants to bloom was recorded.

4. Height at 25 days after transplanting: Height of the plant from ground level to the tip was measured 25 days after transplanting, averaged and expressed in centimetres.

5. Number of branches at 25 days after transplanting:

The total number of branches was counted and averaged 25 days after transplanting.

6. Number of leaves at 25 days after transplanting:

The total number of leaves produced was counted and averaged, 25 days after transplanting.

7. Number of fruits per plant: The total number of fruits obtained from each observational plant was counted and averaged.

8. Weight of fruits per plant: The total weight of fruits obtained from each observational plant was recorded, averaged and expressed in grams.

9. Number of fruits per plot: The total number of fruits obtained from all the thirty plants of each treatment in each replication was recorded and averaged.

10. Weight of fruits per plot:- The total weight of fruits from all the thirty plants of each treatment in each replication was recorded, averaged and expressed in Kilograms.

11. Weight of individual fruit: A total of ten fruits from the first four pickings were chosen at random from each observational plant, weighed, averaged and expressed in grams.

12. Length of individual fruit: The fruits chosen for recording weight were taken, measurements taken from the base to the tip, averaged and expressed in centimetres.

13. Girth of individual fruit: The fruits chosen for recording weight and length were taken for measuring girth.

Maximum girth of each fruit was measured, averaged and expressed in centimetres.

14. Leaf area: Five mature leaves from each observational plant were chosen at random seventy five days after transplanting, leaf area measured using leaf area meter, averaged and expressed in square centimetres.

15. Height: The height of each observational plant was measured from ground level to the tip after the last picking, averaged and expressed in centimetres.

16. Number of branches: The total number of branches produced by each observational plant was counted after the last picking and averaged.

17. Spread: Maximum spread of each observational plant was measured after the last picking, averaged and expressed in centimetres.

18. Fruit shape index: The fruit shape index was calculated as the ratio of length to maximum diameter of the fruit.

19. Life span: Number of days from sowing till the last picking of each treatment was taken into account.

20. Number of pickings: The total number of pickings from each treatment was recorded.

21. Qualitative traits:

(a) Pigmentation of the stem

(b) Pigmentation of the leaf

(c) Pigmentation of the flower

(d) Pigmentation of the fruit

(e) Orientation of the fruit

3.3.2 Statistical analysis: The data collected from the two experiments in respect of the biometrical observations were tabulated and subjected to statistical analysis.

3.3.2.1 Analysis of variance: The analysis of variance in respect of the different traits was done (Panse and Sukhatme, 1957). The critical difference for the comparison of means was calculated as follows:-

$$C.D. = t_e\ (0.05)\ \sqrt{\frac{2\ MSe}{r}}$$

Where C.D. = Critical difference

$t_e(0.05)$ = Critical value of 't' corresponding to the error degrees of freedom at 0.05 level of significance.

MSe = Mean square of error

and r = Number of replications.

3.3.2.2 Phenotypic variance, Genotypic variance and genetic parameters:

(a) Phenotypic variance,

$$\sigma^2_p = \sigma^2_g + \sigma^2_e$$ (Singh and Choudhary, 1977)

Where σ^2_g = Genotypic variance

and σ^2_e = Error variance

(b) Genotypic variance,

$$\sigma^2_g = \frac{MS_v - MS_e}{r}$$ (Singh and Choudhary, 1977)

Where MS_v = Treatment mean square

MS_e = Error mean square

and r = Number of replications.

The genetic parameters were worked out as per Allard (1960), Singh and Choudhary (1977).

(c) Phenotypic coefficient of variation (P.C.V)

$$= \frac{\sqrt{V_{(p)}}}{\bar{X}} \times 100$$

Where $V_{(p)}$ = Phenotypic variance

and $\bar{X}$ = Mean of the character

(d) Genotypic coefficient of variation (G.C.V.)

$$= \frac{\sqrt{V_{(g)}}}{\bar{X}} \times 100$$

Where $V_{(g)}$ = Genotypic variance

and $\bar{X}$ = Mean of the character

(e) Heritability in broad sense in percentage,

$$h^2 = \frac{V_{(g)}}{V_{(p)}} \times 100$$

Where h^2 = Heritability in broad sense

$V_{(g)}$ = Genotypic variance

and $V_{(p)}$ = Phenotypic variance

(f) Genetic advance,

$$GA = k.\ h^2 \sqrt{V_{(p)}}$$

Where k = Selection differential, expressed in phenotypic standard deviation, whose value is 2.06 in the case of 5 per cent of selection in large samples.

h^2 = Heritability in broad sense

and $V_{(p)}$ = Phenotypic variance

(g) Genetic gain,

$$GG = \frac{GA}{\bar{X}} \times 100$$

Where GA = Genetic advance

and $\bar{X}$ = Mean of the character.

3.3.2.3 Correlation coefficients:

The phenotypic and genotypic correlation coefficients were estimated following Singh and Choudhary (1977).

a) Phenotypic Correlation Coefficient,

$$r_{P_1P_2} = \frac{Cov\ (p_1, p_2)}{\sqrt{V_{(p_1)} \cdot V_{(p_2)}}}$$

Where Cov (p_1, p_2) = Phenotypic coveriance between the two characters

$V_{(p_1)}$ = Phenotypic variance of the first character

and $V_{(p_2)}$ = Phenotypic variance of the second character.

(b) Genotypic Correlation Coefficient,

$$r_{g_1 g_2} = \frac{\text{Cov } (g_1 . g_2)}{\sqrt{V_{(g_1)} \cdot V_{(g_2)}}}$$

Where Cov $(g_1 . g_2)$ = Genotypic covariance between the two characters

$V_{(g_1)}$ = Genotypic variance of the first character

and $V_{(g_2)}$ = Genotypic variance of the second character

3.3.2.4 Heterosis :

Three types of heterosis namely, relative heterosis, heterobeltiosis and standard heterosis were estimated.

a) Relative heterosis

$$= \frac{F_1 \text{ mean} - \text{Mean value of the mid-parent}}{\text{Mean value of the mid-parent}} \times 100$$

b) Heterobeltiosis

$$= \frac{F_1 \text{ mean} - \text{Mean value of the better parent}}{\text{Mean value of the better parent}} \times 100$$

c) Standard heterosis

$$= \frac{F_1 \text{ mean} - \text{Mean value of the Standard variety}}{\text{Mean value of the standard variety}} \times 100$$

The critical difference values were calculated as follows :-

a) C.D. I (for testing the significance over the mid-parental value)

$$\text{C.D. I } (0.01) = t_e \ (0.01) \sqrt{\frac{3 \ MS_e}{2r}}$$

$$\text{and C.D.I } (0.05) = t_e \ (0.05) \sqrt{\frac{3 \ MS_e}{2r}}$$

b) C.D II (for testing the significance over the better parent and the standard variety)

$$C.D.\ II\ (0.01) = t_e(0.01)\sqrt{\frac{2\ MS_e}{r}}$$

$$\text{and } C.D.\ II\ (0.05) = t_e\ (0.05)\sqrt{\frac{2\ MS_e}{r}}$$

Where C.D.(0.01) = Critical difference value at 0.01 level of significance

C.D.(0.05) = Critical difference value at 0.05 level of significance

$t_e(0.01)$ = Critical value of 't' corresponding to the error degrees of freedom at 0.01 level of significance

$t_e(0.05)$ = Critical value of 't' corresponding to the error degree of freedom at 0.05 level of significance

MS_e = Mean square for error

and r = Number of replications

3.3.2.5 Pooled analysis

The pooled analysis of the two evaluation trials was done as proposed by Panse and Sukhatme (1957).

The homogeneity of error variances obtained from the two trials was tested by Bartlett's test which is as follows:-

$$\chi^2_{(n-1)} = \frac{x_i^2}{c}$$

Where $\chi^2 = k \left(n \log \bar{S}^2 - \sum_1^n \log Sr^2 \right)$

$$C = 1 + \frac{n+1}{3nk}$$

$$\bar{S}^2 = \frac{1}{n} \sum_1^n Sr^2$$

Here k = Treatment x Season degrees of freedom

n = Number of trials

Sr^2 = Error mean square

If the computed value of $\chi^2_{(n-1)}$ was not greater than the table value, the error variances were homogeneous. Then, the error variances from the two evaluation trials were pooled to obtain a joint estimate of the error variances. The mean square for seasons, treatments and interaction were computed. In order to test the significance of genotype x environment interaction, the interaction mean square was tested against the mean square for pooled error. When the interaction was non-significant, the mean squares for interaction and pooled error were pooled by the following formula to obtain a more precise estimate of σ^2_e :-

$$\sigma^2_e = (\text{Interaction df} \times \text{Interaction mean square}) + \frac{(\text{Pooled error df} \times \text{Pooled error mean square})}{\text{Interaction df} + \text{Pooled error df}}$$

Then, treatment mean square was tested against this pooled estimate of experimental error. Where interaction was significant, treatment mean square was tested against interaction mean square.

If the computed value of $\chi^2_{(n-1)}$ was found to be greater than the table value, the error variances were heterogeneous. Then a weighted analysis of variance was done. The weights were computed as follows:-

$$Wi = \frac{r}{Si^2}$$ Where r = Number of replications

Si^2 = Error mean square

Then, for each season, Wi Pi was computed where 'Pi' is the season total. For each treatment, Σ Witi was calculated, where 'ti' is the mean for each treatment at each place. Then total sum of squares and sum of squares for seasons, treatments and interaction were computed. For testing the significance of interaction, the sum of squares for interaction (I) was transformed into χ^2 using the formula,

$$\chi^2 = \frac{(n-4)(n-2)}{n(n+t-3)} I$$ Where 'n' = df for error mean square

t = Number of treatments.

This χ^2 had a degrees of freedom,

$$\frac{(p-1)\ (t-1)\ (n-4)}{(n\ +\ t-3)}$$

Where p = Number of trials

n = df for error mean square

t = Number of treatments

Since interaction was found to be significant by this test, the significance of treatment differences was tested by comparing the treatment and interaction mean square obtained from an unweighted analysis.

RESULTS

4. RESULTS

Observations on sixteen quantitative characters were recorded and subjected to statistical analysis. Since the germination percentage of one of the combinations, namely PR x PCl was very poor, this hybrid could not be included in both the trials (Plates 1 and 2). The data obtained from the two trials with four parents (Plates 3 to 6) and five hybrids were subjected to analysis of variance. Further, pooled analysis of the data collected from the two trials, was also done. The various genetic parameters such as phenotypic and genotypic variances, phenotypic and genotypic coefficients of variation, heritability, genetic advance and genetic gain were computed for sixteen quantitative traits. The phenotypic and genotypic correlations among sixteen quantitative characters were also computed. Three types of heterosis namely, relative heterosis, heterobeltiosis and standard heterosis pertaining to these quantitative characters were calculated. The results on the various aspects are presented below.

4.1 Percentage of fruit set after hybridization

The number of flowers pollinated, number of fruits set and the percentage of fruit set after hybridization are presented in Table 1.

The percentage of fruit set after hybridization ranged from 12.00 to 28.89 and from 23.24 to 80.49 in the

Table 1 Percentage of fruit set after hybridization

Combinations	Frist trial			Second trial		
	Number of flowers pollinated	Number of fruits set	Percentage of fruit set	Number of flowers pollinated	Number of fruits set	Percentage of fruit set
V x PC-1	257.00	62.00	24.12	51.00	24.00	47.06
V x PR	56.00	7.00	12.50	142.00	33.00	23.24
V x PC1	110.00	19.00	17.27	76.00	24.00	31.58
PC-1 x PR	45.00	13.00	28.89	42.00	33.00	78.57
PC-1 x PC1	50.00	6.00	12.00	41.00	33.00	80.49
PR x PC1	145.00	35.00	24.14	60.00	45.00	75.00

Table 2 Percentage of germination

Parents and hybrids	First trial			Second trial		
	Number of seeds sown	Number of seeds germinated	Percentage of germination.	Number of seeds sown	Number of seeds germinated	Percentage of germination
Vellanotchi	445.00	114.00	25.62	240.00	121.00	50.42
Pant C-1	437.00	181.00	41.42	240.00	193.00	80.42
Purple Round	573.00	94.00	16.40	240.00	148.00	61.67
Purple Cluster	392.00	158.00	40.31	200.00	134.00	67.00
V x PC-1	376.00	180.00	47.87	240.00	200.00	83.33
V x PR	421.00	125.00	29.69	1029.00	110.00	10.69
V x PCl	412.00	127.00	30.83	240.00	186.00	77.50
PC-1 x PR	364.00	97.00	26.65	240.00	116.00	48.83
PC-1 x PCl	144.00	94.00	65.28	240.00	202.00	84.17
PR x PCl	378.00	5.00	1.32	1000.00	0.00	0.00

first and second trials respectively. The highest percentage of fruit set was recorded by PC-1 x PR (28.89) and PC-1 x PCl (80.49) in the first and second trials respectively. While PC-1 x PCl (12.00) registered the minimum value in the first trial, the hybrid V x PR (23.24) recorded minimum in the second trial.

4.2 Percentage of germination

The number of seeds sown, number of seeds germinated and the percentage of germination of the parents and hybrids are presented in Table 2.

Among the four parents, Pant C-1 exhibited the maximum germination percentage of 41.42 and 80.42 in the first and second trials respectively. The lowest germination percentage was recorded by Purple Round (16.40) in the first trial and Vellanotchi (50.42) in the second. When the hybrids were considered, PC-1 x PCl recorded the maximum germination percentage (65.28 and 84.17) while PR x PCl registered the minimum (1.32 and 0.00) in both the trials.

4.3 Analysis of variance of the sixteen quantitative characters

The analysis of variance computed separately for the sixteen characters in the two evaluation trials revealed

Table 3 Analysis of variance table for sixteen quantitative characters in the two trials

Character	Replication		Treatment		Error		Total	
	df	Mean square	df	Mean square	df	Mean square	df	Mean square
Days to 50 per cent flowering	2	4.93 2.48	8	196.15** 304.43**	16	3.51 4.56	26	62.89 96.67
Height at 25 days after transplanting	2	2.46 35.42	8	25.72* 18.64*	16	9.74 5.92	26	14.09 12.11
Number of branches at 25 days after transplanting	2	9.17 1.73	8	5.49 0.91	16	2.32 0.59	26	3.82 0.78
Number of leaves at 25 days after transplanting	2	97.64 88.91	8	338.94 35.25	16	149.29 21.04	26	203.67 30.63
Number of fruits per plant	2	1061.00 2819.49	8	10864.42** 22193.56**	16	1450.92 1231.91	26	4317.39 7803.77
Weight of fruits per plant	2	6505.02 11106.47	8	25055.73* 40248.63**	16	6703.16 3309.29	26	12334.86 15275.03
Number of fruits per plot	2	2163290.76 1415552.00	8	7633320.01** 8013192.00**	16	752766.96 276182.00	26	2978362.04 2744444.20
Weight of fruits per plot	2	4.02 6.55	8	15.85** 29.61**	16	1.81 0.96	26	6.30 10.20
Weight of individual fruit	2	0.07 0.66	8	4.73** 4.61**	16	0.07 0.08	26	1.50 1.52

(contd..)

Table 3 (contd.)

Character	Replication		Treatment		Error		Total	
	df	Mean square	df	Mean square	df	Mean square	df	Mean square
Length of individual fruit	2	0.01 0.20	8	5.96** 6.17**	16	0.04 0.04	26	1.86 1.94
Girth of individual fruit	2	0.02 0.18	8	7.17** 11.55**	16	0.06 0.12	26	2.24 3.65
Fruit shape index	2	0.0004 0.004	8	5.34** 8.82**	16	0.03 0.02	26	1.66 2.73
Leaf area	2	26.56 30.90	8	567.25** 437.83**	16	15.79 12.38	26	186.30 144.71
Height	2	40.89 106.45	8	823.06** 5233.69**	16	51.85 49.44	26	288.30 1648.98
Number of branches	2	223.11 2210.94	8	15106.50** 255931.20**	16	1018.45 4906.74	26	5292.05 81937.65
Spread	2	12.61 80.97	8	380.74** 3211.90**	16	41.19 40.69	26	143.47 1019.55

The figures in the upper column denote mean square values of the first trial
The figures in the Lower column denote mean square values of the second trial

* Significant at 5 per cent level
** Significant at 1 per cent level

Table 4 Analysis of variance (pooled) table for fourteen quantitative characters

Characters	χ^2	Season		Treatment		Interaction		Error	
		df	Mean square	df	Mean square	df	Mean square	df	Mean square
Days to 50 per cent flowering	0.26	1	1695.17	8	156.63**	8	10.23*	32	4.04
Height at 25 days after transplanting	0.95	1	36.75	8	11.98	8	2.80	32	7.83
Number of fruits per plant	0.10	1	8833.35	8	9075.14**	8	1944.47	32	1341.42
Weight of fruits per plant	1.89	1	46930.00	8	17921.44**	8	3846.65	32	5006.23
Number of fruits per plot	3.75	1	11928116.00	8	4599180.00**	8	616326.66	32	514474.48
Weight of fruits per plot	1.53	1	16.76	8	13.00**	8	2.16	32	1.39
Weight of individual fruit	0.24	1	0.10	8	3.03**	8	0.08	32	0.08
Length of individual fruit	0.00	1	0.17	8	3.38**	8	0.16**	32	0.04

(contd..)

Table 4 (Contd.)

Characters	χ^2	Season		Treatment		Interaction		Error	
		df	Mean square	df	Mean square	df	Mean square	df	Mean square
Girth of individual fruit	1.83	1	0.15	8	6.08**	8	0.16	32	0.09
Fruit shape index	0.63	1	0.23	8	4.55**	8	0.17*	32	0.03
Leaf area	0.23	1	304.06	8	325.36**	8	9.71	32	14.09
Height	0.01	1	2664.24	8	1660.55**	8	358.48**	32	50.65
Number of branches	8.74	1	42914.69	8	64868.67	8	25476.81	32	2962.60
Spread	0.001	1	1247.16	8	940.89**	8	256.69**	32	40.94

* Significant at 5 per cent level

** Significant at 1 per cent level

that the four parents and their five hybrids differed significantly for these characters, except for number of branches and number of leaves at 25 days after transplanting. The analysis of variance for the sixteen characters in the two trials is presented in Table 3. In order to test the influence of environment on these characters, pooled analysis was also done, except for number of branches and number of leaves at 25 days after transplanting which did not differ significantly among the nine treatments in both the trials. The pooled analysis of variance is presented in Table 4. The mean values of the parents and hybrids for the sixteen quantitative characters in the two evaluations and the pooled means are presented in Table 5.

4.3.1 Days to 50 per cent flowering

The analysis of variance revealed that the parents and hybrids differed significantly with respect to the number of days to attain 50 per cent flowering in both the trials. Since the error variances were homogeneous, an unweighted analysis was done to ascertain the genotype x environment interaction. Since this interaction was significant, the treatment mean square was tested against interaction mean square which revealed that the treatment differences were significant.

Purple Round availed maximum number of days for 50 per cent flowering (56.67 and 76.33) in both the evaluations. Purple Cluster, which required the minimum number of days to 50 per cent flowering was statistically on par with V x PCl and PC-1 x PCl in the first trial and Vellanotchi in the second trial. When the pooled means were taken into consideration, Purple Round and Purple Cluster had the maximum and minimum values respectively.

4.3.2 Height at 25 days after transplanting

The analysis of variance revealed that the treatments differed significantly for this character in the two trials. An unweighted analysis was done since the error variances were homogeneous and interaction was found to be absent. Hence, a more precise estimate of error variance was obtained by pooling the interaction mean square and mean square for pooled error. The treatment mean square was then tested against this error variance and the treatment differences were found to be non-significant.

Though V x PCl (17.27 cm) had the maximum height in the first trial, the same was on par with PC-1 x PCl, Pant C-1, V x PC-1, Vellanotchi, V x PR and PC-1 x PR while Purple Round which possessed the minimum height (9.40 cm) was on par with Purple Cluster and PC-1 x PR.

In the second trial, V x PC-1 with the maximum height (16.00 cm) was on par with V x PR, PC-1 x PCl, PC-1 x PR, V x PCl and Vellanotchi. Purple Cluster with the minimum height (8.57 cm) was on par with Purple Round, Pant C-1, Vellanotchi, V x PCl, PC-1 x PR and PC-1xPCl. When the pooled means were considered, V x PC-1 (16.09 cm) and Purple Round (9.21 cm) had the maximum and minimum values respectively.

4.3.3 Number of fruits per plant

Significant differences existed among the treatments, as revealed by the analysis of variance, in both the evaluations as regards the number of fruits per plant. The error variances being homogeneous, an unweighted analysis was done, which showed that interaction was not significant. Therefore, the treatment mean square was tested against a more precise estimate of error variance and the treatments were found to differ significantly.

In the first evaluation trial, PC-1 x PR produced the maximum number of fruits per plant (207.37) and was on par with Pant C-1, PC-1 x PCl and V x PR while Purple Round which produced the minimum number of fruits (52.97) was on par with Vellanotchi, Purple Cluster, V x PCl and V x PC-1. PC-1 x PR had the maximum value (287.27) in

the second trial also, followed by V x PR (173.73) (Plates 7 to 9). Vellanotchi, with the minimum value (30.23) was on par with the remaining six treatments with respect to this character. The pooled means revealed similar trend of first trial.

4.3.4 Weight of fruits per plant

The analysis of variance indicated that the treatments differed significantly with respect to weight of fruits per plant in the two evaluations. Since the error variances were homogeneous, an unweighted analysis was conducted. Since the interaction was not significant, the treatment mean square was tested against a more precise estimate of error variance. The treatments exhibited significant differences.

V x PR had the highest value (423.02 g and 401.62 g) in both the evaluations and the same was on par with Vellanotchi, PC-1 x PR, V x PC-1, V x PCl and PC-1 x PCl in the first trial, and only with PC-1 x PR in the second trial. The minimum value was recorded by Purple Round (120.34 g) in the first trial and was on par with Purple Cluster, while in the second trial, Purple Cluster had the minimum value and was on par with Pant C-1, Purple Round, V x PC-1, Vellanotchi and PC-1 x PCl. The pooled means revealed a trend similar to the second trial.

4.3.5 Number of fruits per plot

The treatments were found to differ significantly in the two trials with respect to number of fruits per plot, as revealed by the analysis of variance. The interaction was found to be non-significant from the unweighted analysis. The treatment mean square was then tested against a more precise estimate of error variance, which revealed significant treatment differences.

The highest number of fruits per plot was recorded by PC-1 x PR (5659.00) which was on par with Pant C-1, V x PR and PC-1 x PCl, in the first evaluation trial. Purple Round registered the minimum value (1078.00) and was on par with Vellanotchi and Purple Cluster. In the second trial, V x PR produced the highest number of fruits per plot (4828.33) and was on par with only one hybrid namely, PC-1 x PR while Purple Cluster which recorded the minimum value (523.67) was on par with Vellanotchi, Purple Round, V x PCl and V x PC-1. The pooled means exhibited a trend similar to the first evaluation trial.

4.3.6 Weight of fruits per plot

Significant treatment differences were displayed in both the evaluations, as revealed by the analysis of

variance. The error variances being homogenous, an unweighted analysis was conducted which indicated non-significant interaction. Consequently, the treatment mean square was tested against a more precise estimate of error variance and the treatments were found to differ significantly when the pooled means were taken into account.

V x PR registered the maximum weight of fruits (10.27 kg and 11.74 kg) in both the trials. The minimum value was recorded by Purple Round (1.80 kg) which was on par with Purple Cluster in the first trial while Purple Cluster exhibited the minimum value (1.01 kg) in the second trial and was on par with Pant C-1. PC-1 x PR (5.43 kg) stood second in the second evaluation. When the pooled means were taken into consideration, they exhibited a trend which was almost similar to the second trial.

4.3.7 Weight of individual fruit

The analysis of variance indicated significant differences among treatments in the two experiments. Since the error variances were homogeneous, an unweighted analysis of variance was done which revealed the absence of interaction. Hence, the treatment mean square was tested against a more precise estimate of error variance

and significant treatment differences were found to exist.

Weight of individual fruit was maximum for Vellanotchi (5.83 g and 5.16 g) followed by V x PCl in both the trials. Pant C-1, which exhibited the minimum weight of fruit in the two trials (1.76 g and 1.24 g) was found to be on par with PC-1 x PCl in the first trial. The trend was similar among the pooled means.

4.3.8 Length of individual fruit

The nine treatments differed significantly with respect to length of individual fruit, as revealed by the analysis of variance. The unweighted analysis done as the error variance were homogeneous, indicated significant genotype x environment interaction. As such, the treatment mean square was tested against interaction mean square and significant treatment differences were found to exist.

Maximum and minimum lengths of individual fruit were displayed by V x PC-1 (6.06 cm and 6.12 cm) and Purple Round (1.64 cm and 2.00 cm) respectively in the two evaluations. The same trend was exhibited by the pooled means too.

4.3.9 Girth of individual fruit

Significant treatment differences existed among the nine treatments as regards girth of individual fruit, as inferred from the analysis of variance conducted for the two experiments. The error variances being homogeneous, an unweighted analysis was done which revealed the absence of interaction. The treatment mean square was hence tested against the more precise estimate of error variance and significant differences were found to exist among the treatments.

Purple Round (7.68 cm and 8.58 cm) and Pant C-1 (3.29 cm and 2.86 cm) exhibited the maximum and minimum girth respectively in both the trials. In the first trial, Pant C-1 was statistically on par with PC-1 x PC1. A similar trend was displayed by the pooled means.

The fruits of the four parents and five hybrids are shown in Plates 10 to 14.

4.3.10 Fruit shape index

Significant treatment differences were revealed by analysis of variance for the two evaluation trials. Owing to the homogeneity of error variances an unweighted analysis was done which showed significant genotype x environment interaction. Hence, treatment mean square was tested against interaction mean square and the treatments were found to differ significantly.

Pant C-1 (4.55 and 5.88) and Purple Round (0.67 and 0.73) displayed the maximum and minimum values respectively in both the evaluations. In the first trial, Pant C-1 was on par with PC-1 x PCl. In the second trial, only two treatments namely, Purple Cluster and V x PCl were statistically on par. The trend exhibited by the pooled means was almost similar to that in the first evaluation.

4.3.11 Leaf area

Leaf area was found to differ significantly among the nine treatments, as revealed by the analysis of variance in the two trials. Due to homogeneity of error variances, an unweighted analysis was done to test the genotype x environment interaction which was found to be absent. Hence, the treatment mean square was tested against a more precise estimate of error variance and the treatments were found to differ significantly with respect to this character.

Though the maximum leaf area was dispalyed by Purple Round (58.16 cm^2 and 40.31 cm^2) in the two evaluation trials, the value was on par with PC-1 x PR in the second trial. PC-1 x PR and V x PR occupied the second and third positions while V x PCl (17.17 cm^2) which was on par with the remaining five treatments exhibited minimum leaf area in the first trial. The hybrid V x PR occupied the third place while Vellanotchi (10.14 cm^2) displayed the minimum value

and was on par with the other five treatments in the second trial. The pooled means also displayed a similar trend.

4.3.12 Height

The analysis of variance revealed significant treatment differences with respect to height in both the evaluation trials. Since the error variances were homogeneous, an unweighted analysis was done and interaction was found to be significant. The treatment mean square was then tested against interaction mean square which showed the significant difference among treatments.

In both the trials, PC-1 x PR (75.50 cm and 157.02 cm) and Purple Cluster (20.85 cm and 22.68 cm) displayed the maximum and minimum heights respectively. PC-1 x PR was statistically on par with V x PR in the first trial. When the pooled means were taken into account, a similar trend was observed.

4.3.13 Number of branches

The nine treatments exhibited significant differences with respect to this character, as inferred from the analysis of variance done separately for the two trials. Since the error variances were heterogeneous, a weighted

Table 6 Weighted analysis of variance for number of branches

Source	df	Mean square
Total	53	579.39
Season	1	43.46
Treatment	8	329.54
Interaction	8	206.39*

* Significant at 5 per cent level

analysis was done in which a χ^2 value of 98.50 revealed significant genotype x environment interaction. Hence the treatment mean square was tested against the interaction mean square, both obtained from an unweighted analysis. No significant difference was observed among the treatments. The weighted analysis is presented in Table 6.

PC-1 x PR (278.10 and 917.23) and Purple Cluster (20.00 and 35.73) produced the maximum and minimum number of branches respectively in both the trials. V x PR came second in the two trials and was on par with Purple Round, Pant C-1, V x PC-1, Vellanotchi and PC-1 x PCl in the first trial. Purple Cluster was on par with V x PCl in the first trial while in the second trial, the same was on par with the remaining six treatments. An almost similar trend was displayed by the pooled means.

4.3.14 Spread

Spread of the plant differed significantly among the treatments in both the evaluation trials, as revealed by the analysis of variance. An unweighted analysis of variance was done due to homogeneity of error variances and interaction was found to be significant. The treatment mean square was hence tested against the interaction mean square, which revealed significant treatment differences.

The maximum and minimum spread were exhibited by PC-1 x PR (61.00 cm and 125.37 cm) and Purple Cluster (24.70 cm and 20.92 cm) respectively in the two evaluation trials. PC-1 x PR and Purple Cluster were on par with V x PR and V x PC1 respectively in the first trial. The pooled means displayed a trend which was similar to the second evaluation trial.

4.4 Genetic parameters

The phenotypic and genotypic variances, phenotypic and genotypic coefficients of variation, heritability, genetic advance and genetic gain pertaining to the sixteen quantitative characters studied in the two evaluation trials are presented in Table 7.

Number of fruits per plot exhibited the maximum phenotypic variance in the two evaluation trials (3040262.11 and 2855185.99) while the minimum value was registered by weight of individual fruit in the first evaluation trial (1.62) and for number of branches at 25 days after transplanting in the second (0.70). Next to number of fruits per plot, the highest values were exhibited by weight of fruits per plant (12820.68) and number of branches (88604.21) in the first and second evaluation trials respectively.

In both the evaluation trials, the maximum genotypic variance was exhibited by number of fruits per plot (2293536.43 and 2579003.33). In the first evaluation, this character was followed by weight of fruits per plant (6117.52) while in the second trial, number of branches occupied the second place (83690.16). The minimum value was registered by number of branches at 25 days after transplanting (1.06 and 0.10).

The highest phenotypic coefficient of variation was recorded by number of branches after the last picking (70.22 and 144.98) followed by number of branches at 25 days after transplanting (60.28 and 114.61) in both the experiments. Days to 50 per cent flowering exhibited the minimum value (22.40 and 18.21).

The maximum genotypic coefficient of variation was registered by number of branches in both the trials (63.65 and 140.90) followed by fruit shape index (47.69) in the first evaluation and number of fruits per plant (92.00) in the second. The minimum values were registered by height at 25 days after transplanting (15.64) and number of leaves at 25 days after transplanting (15.40) in the first and second trials respectively.

The maximum heritability was registered by fruit shape index (98.33 per cent and 98.99 per cent) closely followed by length of individual fruit (98.01 per cent and 98.08 per cent) in both the trials. Number of leaves at 25 days after transplanting exhibited the minimum value (29.75 per cent) in the first evaluation while heritability was minimum for number of branches at 25 days after transplanting (14.29 per cent) in the second trial.

Number of fruits per plot recorded the highest value for genetic advance (2707.00 and 3144.25) followed by number of branches (127.97 and 579.16) in the two trials. The minimum value was exhibited by number of branches at 25 days after transplanting (1.19 and 0.25).

The highest and lowest values for genetic gain were registered by number of branches (118.86) and height at 25 days after transplanting (19.19) respectively in the first trial while number of branches (282.08) and number of leaves at 25 days after transplanting (13.58) recorded the highest and lowest values respectively in the second evaluation. Next to number of branches, fruit shape index (97.49) and number of fruits per plant (174.73) exhibited the highest values in the first and second evaluation trials respectively.

4.5 Phenotypic and genotypic correlations among the different quantitative attributes

Tables 8 and 9 represent the phenotypic and genotypic correlation coefficients among the sixteen quantitative characters in the two evaluation trials.

4.5.1 Genotypic correlations in the first evaluation trial

Days to 50 per cent flowering exhibited positive and significant correlations with girth of individual fruit, leaf area and spread while this character displayed significant negative associations with height at 25 days after transplanting, number of branches at 25 days after transplanting, number of leaves at 25 days after transplanting, length of individual fruit and fruit shape index.

Height at 25 days after transplanting showed positive and significant associations with number of branches at 25 days after transplanting, number of leaves at 25 days after transplanting, number of fruits per plant, weight of fruits per plant, number of fruits per plot, weight of fruits per plot, length of individual fruit and fruit shape index. The association of this character with girth of individual fruit and leaf area were negative and significant.

Number of leaves at 25 days after transplanting, number of fruits per plant, weight of fruits per plant, number of fruits per plot, weight of fruits per plot, length of individual fruit and fruit shape index displayed positive and significant correlations with number of branches at 25 days after transplanting while girth of individual fruit and leaf area were negatively and significantly associated with this trait.

Correlations of number of leaves at 25 days after transplanting were positive and significant with weight of fruits per plot, length of individual fruit and fruit shape index while associations with girth of individual fruit, leaf area and spread were negative and significant.

Number of fruits per plant was found to display positive and significant correlations with number of fruits per plot, weight of fruits per plot, height, number of branches and spread. Weight and girth of individual fruit exhibited negative and significant associations with number of fruits per plant.

Positive and significant associations were manifested by number of fruits per plot, weight of fruits per plot and length of individual fruit with weight of

fruits per plant. Negative correlation with this trait was exhibited by leaf area, but the association was non-significant.

Weight of fruits per plot, height, number of branches and spread displayed positive and significant correlations with number of fruits per plot while weight of individual fruit exhibited negative and significant correlation.

Weight of fruits per plot showed positive and non-significant correlations with weight of individual fruit, length of individual fruit, height, number of branches, spread and fruit shape index, while the character had negative and non-significant associations with girth of individual fruit and leaf area.

The associations of length of individual fruit and girth of individual fruit with weight of individual fruit were positive, the association of girth of individual fruit being significant. Leaf area, height, number of branches, spread and fruit shape index displayed negative and non-significant correlations with weight of individual fruit.

Length of individual fruit exhibited positive and significant correlation with fruit shape index while it displayed negative and significant correlation with leaf area. The associations of this character with girth of individual fruit, height, number of branches and spread were negative and non-significant.

Significant positive correlation was shown by girth of individual fruit with leaf area, while the association with fruit shape index was negative and significant. Girth of individual fruit exhibited positive and non-significant correlations with height, number of branches and spread. Fruit shape index was negatively and significantly associated with leaf area while its correlations with height, number of branches and spread were negative but non-significant. Leaf area was found to be positivelyand significantly correlated with height and spread while its association with number of branches was positive and non-significant.

Height displayed positive and significant correlations with number of branches and spread. The association of number of branches with spread was positive and significant.

1 - Days to 50 per cent flowering

2 - Height at 25 days after transplanting

3 - Number of branches at 25 days after transplanting

4 - Number of leaves at 25 days after transplanting

5 - Number of fruits per plant

6 - Weight of fruits per plant

7 - Number of fruits per plot

8 - Weight of fruits per plot

9 - Weight of individual fruit

10 - Length of individual fruit

11 - Girth of individual fruit

12 - Fruit shape index

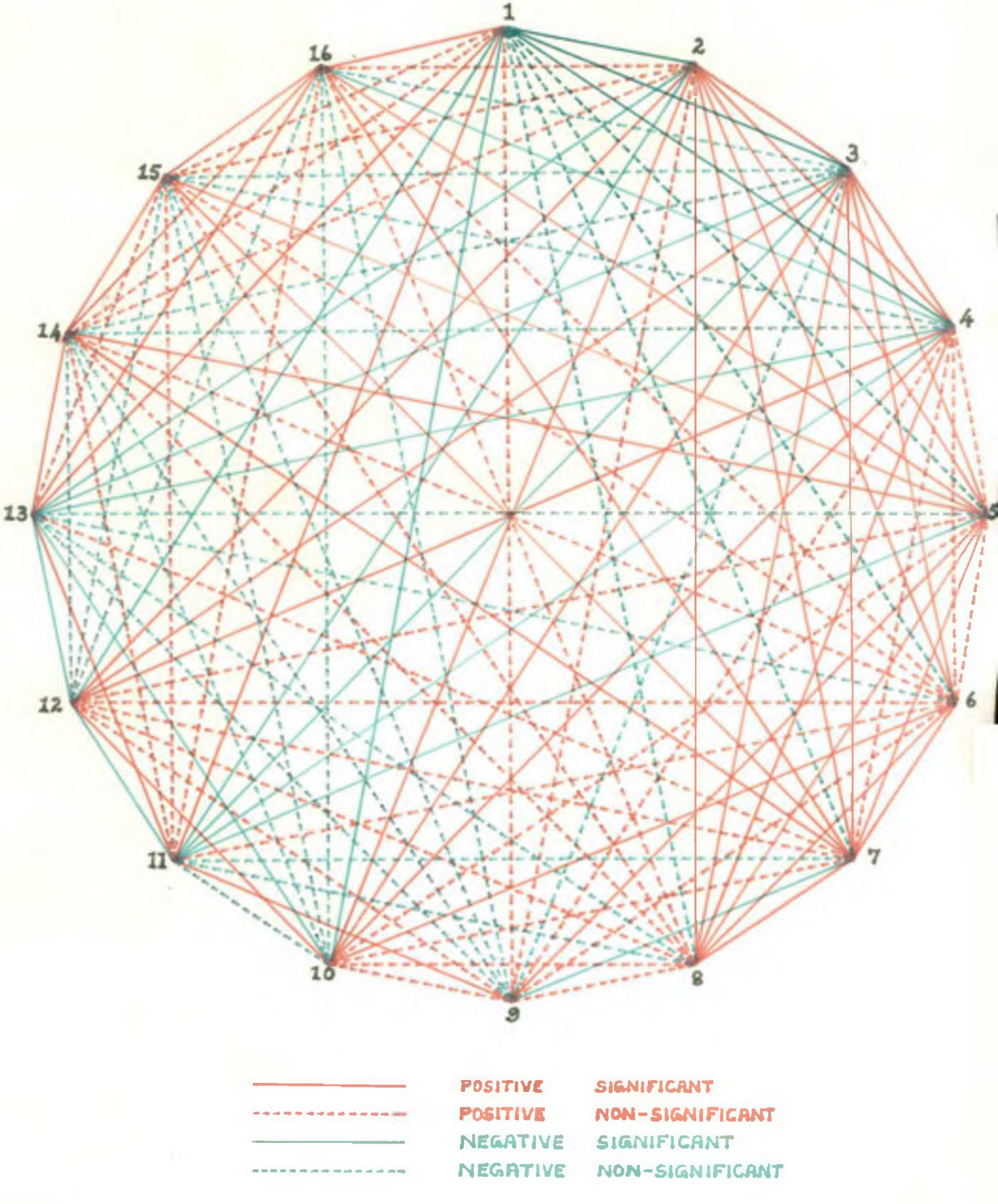
13 - Leaf area

14 - Height after the last picking

15 - Number of branches after the last picking

16 - Spread after the last picking.

FIG.1. DIAGRAM SHOWING GENOTYPIC CORRELATIONS AMONG SIXTEEN QUANTITATIVE TRAITS IN THE FIRST TRIAL



A diagrammatic representation of the genotypic correlations among the sixteen quantitative traits in the first evaluation trial is presented in Fig.1.

4.5.2 Genotypic correlations in the second evaluation trial

Days to 50 per cent flowering exhibited positive and significant genotypic correlations with girth of individual fruit, leaf area, height and spread. Number of branches at 25 days after transplanting, number of leaves at 25 days after transplanting, length of individual fruit and fruit shape index displayed negative and significant associations with days to 50 per cent flowering.

Height at 25 days after transplanting was found to exhibit positive and significant correlations with number of leaves at 25 days after transplanting, weight of fruits per plant, number of fruits per plot, weight of fruits per plot, height and spread. The character displayed negative and non-significant associations with weight and girth of individual fruit and leaf area.

Positive and significant correlations were registered by number of branches at 25 days after transplanting with number of leaves at 25 days after transplanting,

length of individualfruit and fruit shape index while the associations of this character with number of fruits per plant, weight of fruits per plant, number and weight of fruits per plot, girth of individual fruit, leaf area, height, number of branches and spread were negative and significant.

Number of leaves at 25 days after transplanting was positively and significantly associated with length of individual fruit and fruit shape index while the correlations of this character with girth of individual fruit and leaf area were negative and significant. Negative and non-significant correlations were exhibited by this character with the remaining eight characters.

Number of fruits per plant manifested positive and significant correlations with weight of fruits per plant, number and weight of fruits per plot, leaf area, height, number of branches and spread. Weight, length and girth of individual fruit were found to display negative and non-significant associations with number of fruits per plant.

Positive and significant associations were registered by weight of fruits per plant with number and weight of fruits per plot, leaf area, height, number of branches

and spread. The correlations of this character with length of individual fruit and fruit shape index were negative but non-significant.

Number of fruits per plot exhibited positive and significant correlations with weight of fruits per plot, leaf area, height, number of branches and spread while this character displayed negative and non-significant associations with weight of individual fruit, length of individual fruit and fruit shape index.

The associations of weight of fruits per plot with height, number of branches and spread were positive and significant and the correlations with length of individual fruit and fruit shape index were negative, but non-significant. Weight and girth of individual fruit and leaf area manifested positive and non-significant associations with weight of fruits per plot.

Weight of individual fruit was positively and significantly associated with girth of individual fruit while its correlation with fruit shape index was negative and significant. Length of individual fruit, height, number of branches and spread manifested negative and non-significant correlations and leaf area displayed non-significant but positive correlation with the character.

Length of individual fruit was positively and significantly associated with fruit shape index while it was negatively and significantly correlated with girth of individual fruit and leaf area. Height, number of branches and spread were found to display negative and non-significant associations with length of individual fruit.

Positive and significant correlation was shown by girth of individual fruit with leaf area and this character exhibited negative and significant association with fruit shape index. Correlations of girth of individual fruit with height, number of branches and spread were positive and non-significant. Fruit shape index displayed negative and significant association with leaf area while the character was negatively and non-significantly associated with height, number of branches and spread. Leaf area exhibited positive and significant association with height, number of branches and spread.

Height displayed significant positive correlations with number of branches and spread. Number of branches was significantly and positively correlated with spread.

A diagrammatic representation of the genotypic correlations among the sixteen characters studied in the second evaluation trial is shown in Fig. 2.

1 - Days to 50 per cent flowering

2 - Height at 25 days after transplanting

3 - Number of branches at 25 days after transplanting

4 - Number of leaves at 25 days after transplanting

5 - Number of fruits per plant

6 - Weight of fruits per plant

7 - Number of fruits per plot

8 - Weight of fruits per plot

9 - Weight of individual fruit

10 - Length of individual fruit

11 - Girth of individual fruit

12 - Fruit shape index

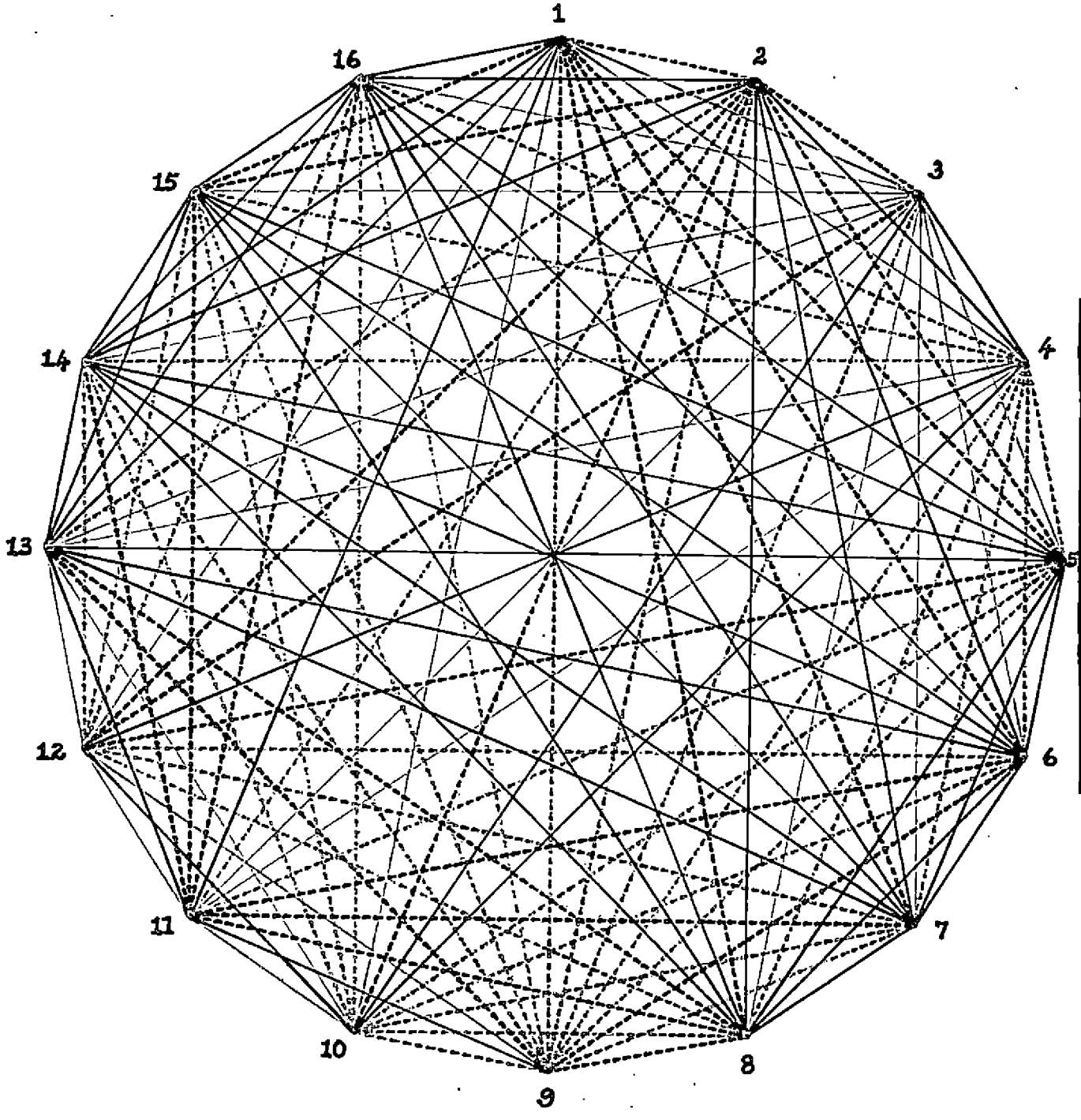
13 - Leaf area

14 - Height after the last picking

15 - Number of branches after the last picking

16 - Spread after the last picking

FIG. 2. DIAGRAM SHOWING GENOTYPIC CORRELATIONS AMONG SIXTEEN QUANTITATIVE TRAITS IN THE SECOND TRIAL



4.6 Heterosis

The mean values of the four parents and five hybrids in the two evaluations, the pooled means and the three types of heterosis namely, relative heterosis, heterobeltiosis and standard heterosis relating to sixteen quantiative traits studied are presented in Tables 10 to 25.

4.6.1 Days to 50 per cent flowering

The mean number of days taken for 50 per cent flowering by the parents and hybrids in the two trials, the pooled means and the three type of heterosis pertaining to this character are given in Table 10.

Among the parents, Purple Round and Purple Cluster availed the maximum and minimum number of days respectively for 50 per cent flowering in all the three computations. The number of days required by the hybrids to attain 50 per cent flowering ranged from 30.33 (V x PC1) to 39.33 (PC-1 x PR) in the first trial while the figures ranged from 50.67 (PC-1 x PC1) to 66.00 (PC-1 x PR) in the second evaluation. When the pooled means were taken into consideration, the figures ranged from 40.83 (V x PC1) to 52.67 (PC-1 x PR).

Table 10 The mean values of parents and hybrids and heterosis in percentage - Days to 50 per cent flowering

Parents and hybrids	Mean			Relative heterosis			Heterobeltiosis			Standard heterosis		
	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled
Vellanotchi	35.00	46.00	40.50									
Pant C-1	34.00	54.00	44.00									
Purple Round	56.67	76.33	66.50									
Purple Cluster	30.00	45.67	37.84									
V x PC-1	35.33	53.67	44.50	2.41	7.34	5.33	3.91	16.67**	9.88	0.94	16.67**	9.88
V x PR	37.67	61.67	49.67	-17.81**	0.83	-7.16	7.63	34.07**	22.64	7.63	34.07**	22.64
V x PCl	30.33	51.33	40.83	-6.68**	11.99**	-4.24	1.10	12.39**	7.90	-13.34**	11.59**	0.81
PC-1 x PR	39.33	66.00	52.67	-13.25**	1.28	-4.67	15.68**	22.22**	19.70	12.37*	43.48**	30.05
PC-1 x PCl	32.33	50.67	41.50	1.03	1.68	1.42	7.77	10.95*	9.67	-7.63	10.15*	2.47

First trial -

C.D. I (0.01) = 3.87
C.D. I (0.05) = 2.81
C.D.II (0.01) = 4.47
C.D.II (0.05) = 3.24

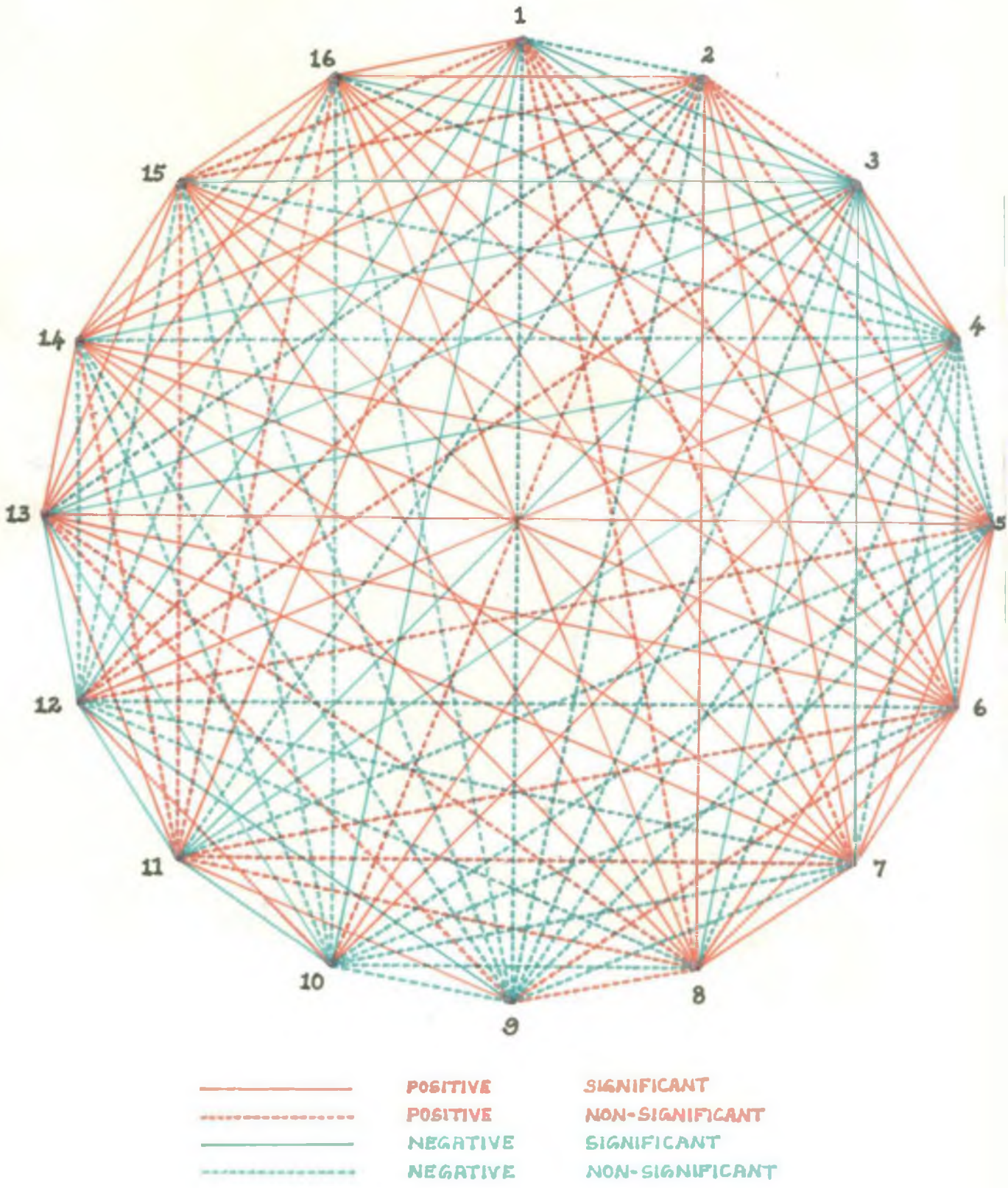
Second trial -

C.D. I (0.01) = 4.41
C.D. I (0.05) = 3.20
C.D.II (0.01) = 5.09
C.D.II (0.05) = 3.70

* Significant at 5 per cent level

** Significant at 1 per cent level

FIG. 2. DIAGRAM SHOWING GENOTYPIC CORRELATIONS AMONG SIXTEEN QUANTITATIVE TRAITS IN THE SECOND TRIAL



In the first experiment, V x PR and PC-1 x PR exhibited negative and significant relative heterosis while V x PC1 displayed negative relative heterosis which was non-significant. Positive, but non-significant relative heterosis was displayed by V x PC-1 and PC-1 x PC1. All the five hybrids exhibited positive relative heterosis in the second trial, the value of V x PC1 being significant. When relative heterosis was computed with respect to pooled means, three hybrids namely, V x PR, V x PC1 and PC-1 X PR registered negative heterosis.

All the hybrids recorded positive heterobeltiosis in the first evaluation, the value for PC-1 x PR being significant. In the second trial, all the five hybrids registered positive and significant heterobeltiosis. As regards the pooled means, all the hybrids availed more number of days for 50 per cent flowering when compared with their corresponding better parents. The increase in number of days for 50 per cent flowering ranged from 7.90 per cent (V x PC1) to 22.64 per cent (V x PR).

V x PC1 and PC-1 x PC1 exhibited negative standard heterosis, the value for the former being significant, in the first evaluation. Though the values were positive

for the other three hybrids, only PC-1 x PR exhibited significant value. In the second experiment, all the hybrids displayed positive and significant standard heterosis. When the pooled means were taken into account, the five hybrids availed more number of days for 50 per cent flowering, than the standard variety Vellanotchi. The increase over the standard variety ranged from 0.81 (V x PC1) to 30.05 (PC-1 x PR).

4.6.2 Height at 25 days after transplanting

The mean values for the parents and hybrids in the two evaluation trials, the pooled means and the three types of heterosis are presented in Table 11.

When the first trial and the pooled means were considered, Pant C-1 recorded the maximum height at 25 days after transplanting among the parents, while the minimum value was registered by Purple Round. In the second experiment, the maximum and minimum heights were exhibited by Vellanotchi and Purple Cluster respectively. In the first trial, the heights of the hybrids ranged from 14.92 cm (PC-1 x PR) to 17.27 cm (V x PC1) while the figures ranged from 11.47 cm (V x PC1) to 16.00 cm (V x PC-1) in the second evaluation. When the pooled means were taken into account, V x PC-1 (16.09 cm) and

Table 11 The mean values of parents and hybrids and heterosis in percentage - height at 25 days after transplanting

Parents and hybrids	Mean (cm)			Relative heterosis			Heterobeltiosis			Standard heterosis		
	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled
Vellanotchi	15.33	10.73	13.03									
Pant C-1	16.88	10.33	13.61									
Purple Round	9.40	9.02	9.21									
Purple Cluster	10.25	8.57	9.41									
V x PC-1	16.18	16.00	16.09	0.47	51.95**	20.80	-4.15	49.11*	18.22	5.54	49.11*	23.48
V x PR	15.30	14.10	14.70	23.74	42.78*	32.19	-0.20	31.41	12.82	-0.20	31.41	12.82
V x PCl	17.27	11.47	14.37	35.03	18.86	28.07	12.65	6.90	10.28	12.65	6.90	10.28
PC-1 x PR	14.92	13.23	14.08	13.55	36.74	23.40	-11.61	28.07	3.45	-2.67	23.30	8.06
PC-1 x PCl	17.22	13.58	15.40	26.94	43.70*	33.80	2.01	31.46	13.15	12.33	26.56	18.19

First trial -

C.D I (0.01) = 6.45
C.D.I (0.05) = 4.68
C.D.II (0.01) = 7.44
C.D.II (0.05) = 5.40

Second trial -

C.D. I (0.01) = 5.03
C.D.I (0.05) = 3.65
C.D.II (0.01) = 5.80
C.D.II (0.05) = 4.21

* Significant at 5 per cent level

** Significant at 1 per cent level

PC-1 x PR (14.08 cm) registered the maximum and minimum heights respectively.

Positive but non-significant relative heterosis was manifested by all the hybrids in the first evaluation. In the second trial also, the values were positive for the five hybrids, the values for V x PC-1, V x PR and PC-1 x PC1 being significant. When the pooled means were considered, all the hybrids displayed an increase in height over their corresponding mid-parental values. The increase in height at 25 days after transplanting ranged from 20.80 per cent (V x PC-1) to 33.80 per cent (PC-1 x PC1).

V x PC-1, V x PR and PC-1 x PR registered negative and non-significant heterobeltiosis while V x PC1 and PC-1 x PC1 recorded positive, but non-significant heterobeltiosis in the first trial. All the five hybrids exhibited positive values in the second evaluation, the value for V x PC-1 alone being significant. When the pooled means were taken into account the increase in height over the respective better parents ranged from 3.45 per cent (PC-1 x PR) to 18.22 per cent (V x PC-1).

As regards standard heterosis in the first evaluation trial, V x PC-1, V x PC1 and PC-1 x PC1 displayed positive non-significant heterosis while the remaining two hybrids exhibited negative, but non-significant heterosis.

Standard heterosis was positive for all the hybrids in the second experiment, the value for V x PC-1 alone being significant. All the hybrids exhibited an increase in height at 25 days after transplanting over the standard variety, when the means were pooled, the range of increase in height being 8.06 per cent (PC-1 x PR) to 23.48 per cent (V x PC-1).

4.6.3 Number of branches at 25 days after transplanting

The mean values of the parents and hybrids in the two trials, the pooled means and the three types of heterosis pertaining to this character are represented in Table 12.

Out of the four parents, the maximum number of branches at 25 days after transplanting was produced by Vellanotchi in the first evaluation and by Purple Cluster in the second. Purple Cluster registered the same trend when the pooled means were computed. In all the three computations, Purple Round exhibited the minimum value. In respect of the hybrids, the value ranged from 2.77 (V x PC-1) to 5.07 (PC-1 x PCl), from 0.20 (V x PR) to 1.60 (PC-1 x PCl) and from 1.68 (PC-1 x PR) to 3.34 (PC-1 x PCl) respectively in the three computations.

Table 12 The mean values of parents and hybrids and heterosis in percentage - Number of branches at 25 days after transplanting

Parents and hybrids	Mean			Relative heterosis			Heterobeltiosis			Standard heterosis		
	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled
llanotchi	3.03	0.47	1.75									
nt C-1	2.97	0.53	1.75									
rple Round	0.13	0.07	0.10									
rple Cluster	2.73	0.80	1.77									
x PC-1	2.77	1.40	2.09	-7.67	180.00	19.43	-8.58	164.15	19.43	-8.56	197.87	19.43
x PR	3.30	0.20	1.75	108.86	-25.93	89.19	8.91	-57.45	0.00	8.91	-57.45	0.00
x PCl	4.40	1.20	2.80	52.78	88.98	59.09	45.21	50.00	56.19	45.21	155.32	60.00
-1 x PR	3.03	0.33	1.68	95.48	10.00	81.62	2.02	-37.74	-4.00	0.00	-29.79	-4.00
-1 x PCl	5.07	1.60	3.34	77.89	140.60	89.77	70.71	100.00	88.70	67.33	240.43	90.86

First trial -

C.D. I (0.01) = 3.15
C.D. I (0.05) = 2.28
C.D.II (0.01) = 3.63
C.D.II (0.05) = 2.64

Second trial -

C.D. I (0.01) = 1.59
C.D. I (0.05) = 1.15
C.D.II (0.01) = 1.83
C.D.II (0.05) = 1.33

In the first experiment, all the hybrids except V x PC-1 displayed positive non-significant relative heterosis, the value for V x PC-1 being negative and non-significant. V x PR registered negative but non-significant relative heterosis while the values for the remaining four hybrids were positive and non-significant in the second evaluation. All the hybrids produced more number of branches at 25 days after transplanting than their corresponding mid-parental values when the pooled means were considered. The increase in number of branches ranged from 19.43 per cent (V x PC-1) to 89.77 per cent (PC-1 x PC1).

V x PC-1 alone exhibited negative non-significant heterobeltiosis while the remaining hybrids displayed positive non-significant heterobeltiosis in the first trial. In the second evaluation, positive and non-significant heterobeltiosis was registered by V x PC-1, V x PC1 and PC-1 x PC1 while the other two hybrids exhibited negative and non-significant heterobeltiosis. When the means were pooled, V x PR displayed no increase at all while PC-1 x PR recorded a slight decrease in number of branches when compared to their respective better parents. V x PC-1, V x PC1 and PC-1 x PC1 registered an increase of 19.43 per cent, 58.19 per cent and 88.70 per cent respectively.

When standard heterosis was computed, V x PC-1 exhibited negative but non-significant heterosis and PC-1 x PR exhibited no heterosis at all, in the first experiment. The remaining three hybrids manifested positive non-significant heterosis. In the second evaluation, V x PC-1, V x PC1 and PC-1 x PC1 showed positive and non-significant heterosis while the values for V x PR and PC-1 x PR were negative, but non-significant. When the pooled means were taken into account, V x PR showed no increase at all and PC-1 x PR displayed a slight decrease in number of branches in relation to the standard variety Vellanotchi. The increase exhibited by the other three hybrids ranged from 19.43 per cent (V x PC-1) to 90.86 per cent (PC-1 x PC1).

4.6.4 Number of leaves at 25 days after transplanting

The mean number of leaves at 25 days after transplanting produced by the parents and hybrids, the pooled means of the two evaluation trials and the three types of heterosis computed are given in Table 13.

Among parents, the maximum number of leaves at 25 days after transplanting were produced by Pant C-1 and Purple Cluster in the first and second trials respectively. When the means were pooled, Pant C-1 accounted the maximum value. The minimum number of leaves were produced by Purple Round in all the three computations. When the hybrids were

Table 13 The mean values of parents and hybrids and heterosis in percentage - Number of leaves at 25 days after transplanting

arents and hybrids	Mean			Relative heterosis			Heterobeltiosis			Standard heterosis		
	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled
ellanotchi	30.37	11.80	21.09									
ent C-1	36.50	13.00	24.75									
urple Round	9.33	9.10	9.22									
urple Cluster	27.23	13.23	20.23									
x PC-1	30.47	18.23	24.35	-8.88	47.02	6.24	-16.52	40.23	-1.62	0.33	84.49	15.46
x PR	27.93	12.57	20.25	40.71	20.29	33.62	-8.03	6.53	-3.98	-8.03	6.53	-3.98
x PC1	47.83	17.10	32.47	66.08*	36.64	57.16	57.49	29.25	53.96	57.49	44.92	53.96
C-1 x PR	27.06	12.57	19.82	18.09	13.76	16.69	-25.66	-3.31	-19.92	-10.90	6.53	-6.02
C-1 x PC1	40.03	19.67	29.85	25.62	49.98	32.73	9.67	48.68	20.61	31.81	66.69	41.54

First trial -

C.D. I (0.01) = 25.24
C.D. I (0.05) = 18.32
C.D.II (0.01) = 29.14
C.D.II (0.05) = 21.15

Second trial -

C.D. I (0.01) = 9.47
C.D. I (0.05) = 6.88
C.D.II (0.01) =10.94
C.D.II (0.05) = 7.94

* Significant at 5 per cent level

taken into consideration, the maximum value was displayed by V x PC1 in the first trial and among pooled means, while in the second evaluation, the maximum number of leaves were produced by PC-1 x PC1. The minimum number was produced by PC-1 x PR in all the three computations. In the second experiment, along with PC-1 x PR, V x PR also had the minimum number.

Relative heterosis was negative and non-significant for V x PC-1 while it was positive for the other four hybrids, the value for V x PC1 being significant in the first trial. In the second evaluation, all the hybrids displayed positive non-significant relative heterosis. When the means were pooled, all the hybrids were found to produce more number of leaves than their corresponding mid-parental values. The increase in number of leaves at 25 days after transplanting over the mid-parental values ranged from 6.24 per cent (Vx PC-1) to 57.16 per cent (V x PC1.)

When the hybrids were compared with the better parent in the first evaluation trial, three hybrids namely V x PC-1, V x PR and PC-1 x PR registered negative non-significant values while the remaining two hybrids accounted positive non-significant heterobeltiosis. In the second

trial, all hybrids except PC-1 x PR displayed positive non-significant heterobeltiosis, the value for PC-1 x PR being negative, but non-significant. Pooled means showed an increase in the number of leaves at 25 days after transplanting over the better parent only for two hybrids namely, V x PCl and PC-1 x PCl.

When standard heterosis was considered, V x PC-1, V x PCl and PC-1 x PCl manifested positive but non-significant heterosis and the other two hybrids had negative non-significant values in the first experiment. All the hybrids exhibited positive non-significant standard heterosis in the second evaluation. When the pooled means were taken into account three hybrids namely V x PC-1, V x PCl and PC-1 x PCl recorded an increase in number of leaves over the standard variety, which ranged from 15.46 per cent to 53.96 per cent.

4.6.5 Number of fruits per plant

The mean values of the parents and hybrids in the two experiments, the pooled means and the three types of heterosis are presented in Table 14.

In all the three computations, the maximum number of fruits per plant was produced by Pant C-1 among the parents. Purple Round exhibited the minimum value in the

Table 14 The mean values of parents and hybrids and heterosis in percentage - Number of fruits per plant

Parents and hybrids	Mean			Relative heterosis			Heterobeltiosis			Standard heterosis		
	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled
Vellanotchi	78.20	30.23	54.22									
Pant C-1	203.07	68.87	135.97									
Purple Round	52.97	39.43	46.20									
Purple Cluster	85.60	31.00	58.30									
V x PC-1	116.60	46.53	81.57	-17.09**	-6.09**	-14.22	-42.55**	-32.44**	-40.01	49.10**	53.92**	50.44
V x PR	175.83	173.73	174.78	168.09**	398.79**	248.10	124.35**	340.60**	222.35	124.85**	474.69**	222.35
V x PCl	101.83	53.83	77.83	24.33**	75.83**	38.34	18.96	73.65**	33.50	30.22**	78.07**	43.54
PC-1 x PR	207.37	287.27	247.32	61.98**	490.51**	171.53	2.12	317.12**	81.89	165.18**	850.28**	356.14
PC-1 x PCl	195.00	86.83	140.92	35.10	73.89	45.08	-3.97	26.08	3.64	149.36**	187.23**	159.90

First trial -

C.D. I (0.01) = 78.68
C.D. I (0.05) = 57.10
C.D. II (0.01) = 90.85
C.D.II (0.05) = 65.93

Second trial -

C.D. I (0.01) = 72.49
C.D. I (0.05) = 52.62
C.D. II (0.01) = 83.71
C.D. II (0.05) = 60.75

* Significant at 5 per cent level
** Significant at 1 per cent level

first trial and also when the means were pooled, while in the second evaluation, Vellanotchi produced the minimum number of fruits per plant. Among the five hybrids, the maximum number of fruits per plant was produced by PC-1 x PR in all the three computations. The minimum value was registered by V x PCl in the first trial and among pooled means, while in the second evaluation the minimum number of fruits was produced by V x PC-1.

Negative, but non-significant relative heterosis was exhibited by V x PC-1 in the first evaluation trial. The remaining four hybrids displayed positive heterosis, the values for V x PR and PC-1 x PR being significant. The hybrids behaved in the same manner with respect to the second trial also. V x PC-1 alone registered a decline in number of fruits when the pooled means were taken into account. The remaining four hybrids recorded an increase in number of fruits, the range of increase being 38.34 per cent (V x PCl) to 248.10 per cent (V x PR).

Heterobeltiosis was negative for V x PC-1 and PC-1 x PCl, the value for the former being significant, in the first trial. The remaining three hybrids showed positive heterobeltiosis, the value for V x PR being significant. In the second evaluation, V x PC-1 alone recorded negative but non-significant heterobeltiosis while the

1 - Vellanotchi

2 - Pant C-1

3 - Purple Round

4 - Purple Cluster

1 x 2 - Vellanotchi x Pant C-1

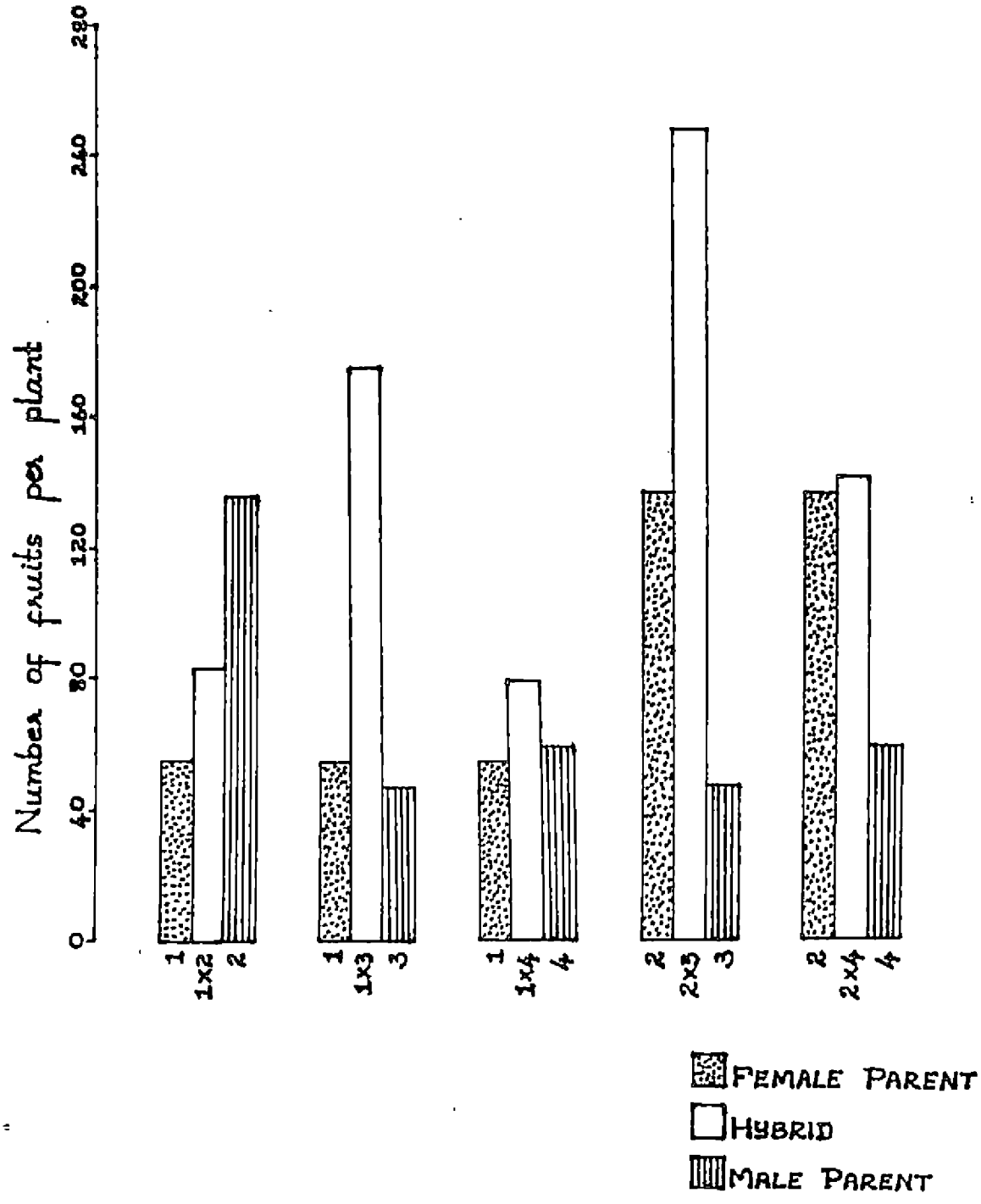
1 x 3 - Vellanotchi x Purple Round

1 x 4 - Vellanotchi x Purple Cluster

2 x 3 - Pant C-1 x Purple Round

2 x 4 - Pant C-1 x Purple Cluster

FIG.3. NUMBER OF FRUITS PER PLANT IN PARENTS AND HYBRIDS



remaining four hybrids displayed positive heterobeltiosis, the values for V x PR and PC-1 x PR being significant. When the pooled means were considered, V x PC-1 alone produced lesser number of fruits while all the other four hybrids produced more than their respective better parents. V x PR had registered an increase of 222.35 per cent over its better parent.

All the five hybrids registered positive standard heterosis in both the evaluations. V x PR and PC-1 x PR recorded positive and significant heterosis in both the trials. All the hybrids outyielded the standard variety when the pooled means were taken into account. The hybrid PC-1 x PR surpassed the standard variety by 356.14 per cent.

The mean number of fruits per plant produced by the parents and hybrids is diagrammatically presented in Fig.3.

4.6.6 Weight of fruits per plant

The mean values relative to the parents and hybrids for this character in the two evaluation trials, the pooled means and the three types of heterosis are presented in Table 15.

Among the four parents, Vellanotchi had the maximum weight of fruits in the two trials, besides in pooled means. Purple Round recorded the minimum weight of fruits

Table 15 The mean values of parents and hybrids and heterosis in percentage - Weight of fruits per plant

Parents and hybrids	Mean (g)			Relative heterosis			Heterobeltiosis			Standardheterosis		
	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled
Vellanotchi	336.01	127.76	231.89									
Pant C-1	279.50	86.73	183.12									
Purple Round	120.34	124.27	122.31									
Purple Cluster	156.52	61.44	108.98									
V x PC-1	306.98	125.81	216.40	-0.25	17.31**	4.29	-8.64	-1.53**	-6.68	-8.64	-1.53**	-6.68
V x PR	423.02	401.62	412.32	85.39	218.71**	132.82	25.90	214.36**	77.81	25.90	214.36**	77.81
V x PCl	304.62	179.37	242.00	23.69	89.61**	41.99	-9.34	40.40**	4.36	-9.34	40.40**	4.36
PC-1 x PR	313.86	341.58	327.72	56.99	223.77**	114.60	12.29	174.87**	78.96	-6.59	167.36**	41.33
PC-1 x PCl	282.19	155.36	218.78	29.44	109.71**	49.80	0.96	79.13**	19.47	-16.02	21.60**	-5.65

First trial -

C.D. I (0.01) = 169.10
C.D. I (0.05) = 122.73
C.D. II (0.01) = 195.27
C.D.II (0.05) = 141.72

Second trial -

C.D. I (0.01) = 118.82
C.D. I (0.05) = 86.24
C.D.II (0.01) = 137.20
C.D. II (0.05) = 99.58

** Significant at 1 per cent level

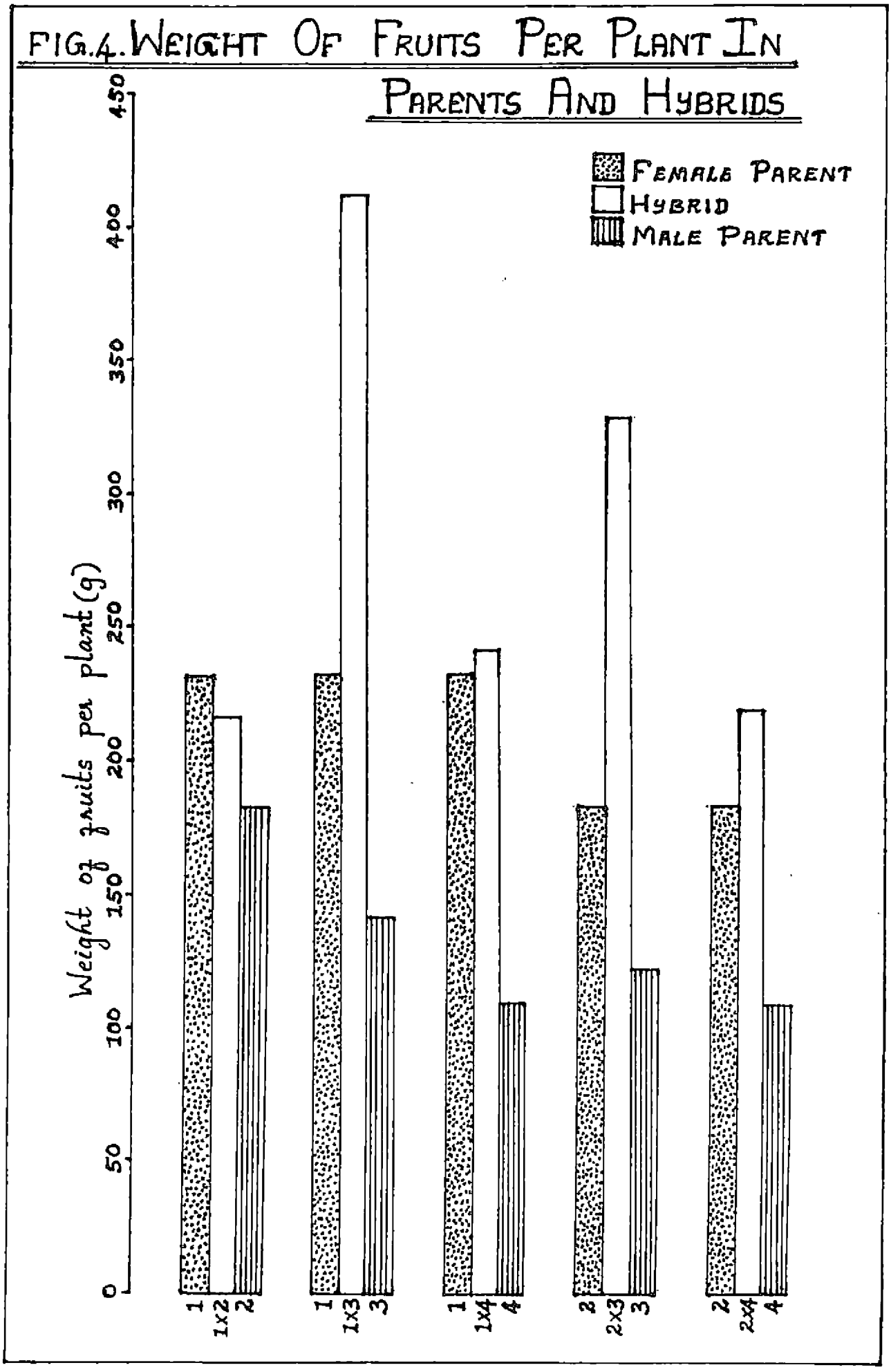
in the first trial while in the second evaluation and among the pooled means, Purple Cluster had the minimum weight of fruits. When the hybrids were considered, V x PR had maximum weight of fruits per plant in all the three computations while the minimum value was displayed by PC-1 x PCl in the first evaluation trial and V x PC-1 in the second trial and when the means were pooled.

Negative, but non-significant relative heterosis was exhibited by V x PC-1 while the remaining four hybrids manifested positive heterosis, the values for V x PR being significant in the first evaluation trial. All the hybrids displayed positive heterosis in the second trial, the values for V x PR and PC-1 x PR being significant. When the means were pooled, all the hybrids showed an increase in weight of fruits per plant over the mid-parental value and the increase ranged from 4.29 per cent (V x PC-1) to 132.32 per cent (V x PR).

With regards to heterobeltiosis, V x PC-1 and V x PCl recorded negative non-significant values and V x PR, PC-1 x PR and PC-1 x PCl showed positive non-significant values in the first evaluation. In the second trial, V x PC-1 was found to exhibit negative but non-significant value while heterobeltiosis relating to the other four hybrids was positive, the values for V x PR and PC-1 x PR being significant. V x PC-1 showed a lesser value for this character while the other four hybrids showed an increase in weight

1	- Vellanotchi
2	- Pant C-1
3	- Purple Round
4	- Purple Cluster
1 x 2	- Vellanotchi x Pant C-1
1 x 3	- Vellanotchi x Purple Round
1 x 4	- Vellanotchi x Purple Cluster
2 x 3	- Pant C-1 x Purple Round
2 x 4	- Pant C-1 x Purple Cluster

FIG.4. WEIGHT OF FRUITS PER PLANT IN PARENTS AND HYBRIDS



of fruits per plant compared to their corresponding better parents, the range of increase being 4.36 per cent (V x PCl) to 78.96 per cent (PC-1 x PR) when the pooled means were taken into account.

Standard heterosis was positive, but non-significant for V x PR while the same was negative and non-significant for the other four hybrids in the first experiment. Only one hybrid namely, V x PC-1 had negative non-significant standard heterosis in the second evaluation. The other four hybrids registered positive heterosis, the values for V x PR and PC-1 x PR being significant. When the means were pooled, V x PC-1 and PC-1 x PCl exhibited a decrease in weight of fruits per plant while the remaining three hybrids showed an increase compared to the standard variety Vellanotchi. The increase ranged from 4.36 per cent (V x PCl) to 77.81 per cent (V x PR).

The mean weight of fruits per plant of the parents and hybrids is diagrammatically represented in Fig.4.

4.6.7 Number of fruits per plot

The mean values of this character for the four parents and five hybrids in the two evaluations, the pooled means and the three types of heterosis are given in Table 16.

Table 16 The mean values of parents and hybrids and heterosis in percentage - Number of fruits per plot

Parents and hybrids	Mean			Relative heterosis			Heterobeltiosis			Standard heterosis		
	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled
Vellanotchi	1980.33	749.67	1365.00									
Pant C-1	5169.67	1469.67	3319.67									
Purple Round	1078.00	917.00	997.50									
Purple Cluster	2541.67	523.67	1532.67									
V x PC-1	3304.33	1220.00	2262.17	-7.57	9.94	-3.42	-36.08*	-16.99	-31.86	66.86	62.74	65.73
V x PR	5093.67	4828.33	4961.00	233.10**	479.40**	319.98	157.21**	426.54**	263.44	157.21**	544.06	263.44
V x PCl	2791.53	1112.33	1951.93	23.46	74.71	34.72	9.83	48.38	27.35	40.96**	48.38**	43.00
PC-1 x PR	5659.00	4610.67	5134.84	81.16**	286.37**	137.88	9.47	213.72**	54.68	185.76**	515.03**	276.18
PC-1 x PCl	4371.33	1905.33	3138.33	13.37	91.17*	29.35	-15.44	29.64	-5.46	120.74**	154.16*	129.91

First trial -

C.D. I (0.01) = 1792.04
C.D. I (0.05) = 1300.62
C.D. II (0.01) = 2069.27
C.D. II (0.05) = 1501.83

Second trial -

C.D. I (0.01) = 1085.46
C.D. I (0.05) = 787.80
C.D.II (0.01) = 1253.38
C.D.II (0.05) = 909.68

* Significant at 5 per cent level

** Significant at 1 per cent level

When the parents were considered, Pant C-1 produced the maximum number of fruits per plot in all the three computations. Purple Round displayed the minimum value in the first evaluation and among pooled means while Purple Cluster exhibited the minimum in the second trial, when the four parents were taken into account. Among the five hybrids, PC-1 x PR had the maximum value for this character in the first experiment and when the means were pooled. In the second evaluation trial, the maximum value was for V x PR. The hybrid V x PC1 recorded the minimum number of fruits per plot in all the three computations.

In the first trial, only V x PC-1 registered negative and non-significant relative heterosis. The remaining four hybrids manifested positive heterosis, the values for V x PR and PC-1 x PR being significant. In the second evaluation, all the five hybrids exhibited positive heterosis, the values for three hybrids namely, V x PR, PC-1 x PR and PC-1 x PC1 being significant. When the pooled means were considered, all the hybrids except V x PC-1 showed an increase in number of fruits per plot over the mid-parental value. The percentage of increase ranged from 29.35 (PC-1 x PC1) to 319.98 (V x PR).

Negative heterobeltiosis was manifested by V x PC-1 and PC-1 x PC1, the value for the former being

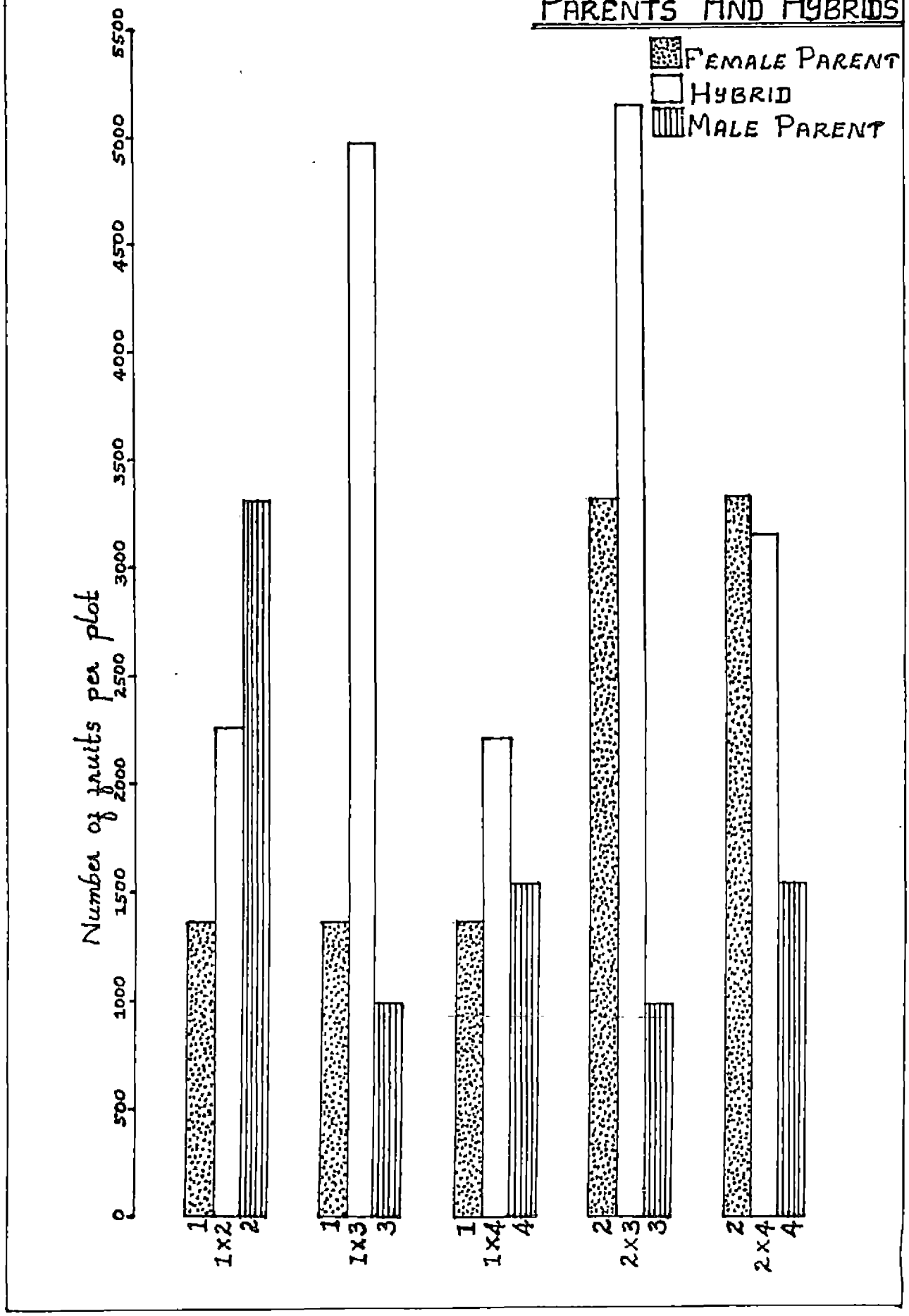
significant in the first evaluation trial. The other three hybrids displayed positive heterobeltiosis and V x PR alone had significant value. In the second trial, V x PC-1 exhibited negative but non-significant heterobeltiosis. Although the other four hybrids recorded positive heterobeltiosis, the values for only two hybrids namely V x PR and PC-1 x PR were significant. When the means were pooled, V x PC-1 and PC-1 x PCl exhibited a decrease, while the remaining three hybrids displayed an increase in number of fruits per plot over their respective better parents, the range of increase being 27.35 per cent (V x PCl) to 263.44 per cent (V x PR).

All the five hybrids exhibited positive standard heterosis, the values for three hybrids namely, V x PR, PC-1 x PR and PC-1 x PCl being significant in both the experiments. All the hybrids showed an increase in number of fruits per plot over the standard variety and the percentage of increase ranged from 43.00 (V x PCl) to 276.18 (PC-1 x PR), when the pooled means were taken into account.

The mean number of fruits per plot produced by the parents and hybrids is diagrammatically presented in Fig.5.

1	- Vellanotchi
2	- Pant C-1
3	- Purple Round
4	- Purple Cluster
1 x 2	- Vellanotchi x Pant C-1
1 x 3	- Vellanotchi x Purple Round
1 x 4	- Vellanotchix Purple Cluster
2 x 3	- Pant C-1 x Purple Round
2 x 4	- Pant C-1 x Purple Cluster

FIG. 5. NUMBER OF FRUITS PER PLOT IN PARENTS AND HYBRIDS



4.6.8 Weight of fruits per plot

The mean values perteining to the parents and hybrids for this character in the two trials, the pooled means and the three types of heterosis computed are given in Table 17.

Pant C-1 and Purple Round had the maximum weight of fruits per plot in the first and second trials respectively while Vellanotchi recorded maximum weight when the pooled means were taken into account. The minimum value was registered by Purple Round in the first trial while Purple Cluster showed the minimum value in the other two computations, when the parents were considered. As regards the hybrids, V x PR displayed maximum weight of fruits per plot in the three comparisons while the minimum weight of fruits was recorded by PC-1 x PCl in the first evalution and in the comparison of pooled means. In the second trial, the hybrid V x PC-1 exhibited maximum weight of fruits per plot.

All the five hybrids manifested positive relative heterosis, the values for V x PR, V x PCl and PC-1 x PR being significant in both the trials. In the second evaluation, the hybrid PC-1 x PCl also displayed positive and significant heterosis. When the pooled means were taken into

Table 17 The mean values of parents and hybrids and heterosis in percentage - Weight of fruits per plot

Parents and hybrids	Mean (kg)			Relative heterosis			Heterobeltiosis			Standard heterosis		
	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled
Vellanotchi	5.41	2.74	4.08									
Pant C-1	6.15	1.95	4.05									
Purple Round	1.80	3.13	2.47									
Purple Cluster	3.87	1.01	2.44									
V x PC-1	6.28	3.10	4.69	8.65	32.20	15.38	2.11	13.14	14.95	16.08	13.14	14.95
V x PR	10.27	11.74	11.01	184.88**	300.00**	236.18	89.83**	275.08**	169.85	89.83**	328.47**	169.85
V x PCl	7.15	3.52	5.34	54.09*	87.73*	63.80	32.16	28.47	30.88	32.16	28.47	30.88
PC-1 x PR	6.42	5.43	5.93	61.51*	113.78**	81.90	4.39	73.48*	46.42	18.67	98.18**	45.34
PC-1 x PCl	5.94	3.30	4.62	18.56	122.97*	42.37	-3.41	69.23	14.07	9.80	20.44	13.24

First trial -

C.D. I (0.01) = 2.78
C.D. I (0.05) = 2.02
C.D. II (0.01) = 3.21
C.D. II (0.05) = 2.33

Second trial -

C.D. I (0.01) = 2.02
C.D. I (0.05) = 1.47
C.D. II (0.01) = 2.34
C.D. II (0.05) = 1.70

* Significant at 5 per cent level

** Significant at 1 per cent level

account, all the hybrids exhibited an increase in weight of fruits per plot over their respective mid-parental values. The percentage of increase ranged from 15.38 (V x PC-1) to 236.18 (V x PR).

Heterobeltiosis was positive for the first four hybrids, the value for V x PR being significant in the first trial. PC-1 x PC1 exhibited negative non-significant heterobeltiosis. In the second evaluation, all the hybrids manifested positive heterobeltiosis, the values for V x PR and PC-1 x PR being significant. When the means were pooled, all the five hybrids showed an increase in weight of fruits per plot over their respective better parents. The percentage of increase ranged from 14.07 (PC-1 x PC1) to 169.85 (V x PR).

Positive standard heterosis was recorded by all the five hybrids, the values for V x PR being significant in both the evaluations. In the second trial, PC-1 x PR also registered positive and significant standard heterosis. Increase in weight of fruits per plot was exhibited by all the hybrids over the standard variety Vellanotchi. The increase ranged from 13.24 per cent (PC-1 x PC1) to 169.85 per cent (V x PR).

The mean weight of fruits per plot of the parents and hybrids is diagrammatically presented in Fig.6.

1 - Vellanotchi

2 - Pant C-1

3 - Purple Round

4 - Purple Cluster

1 x 2 - Vellanotchi x Pant C-1

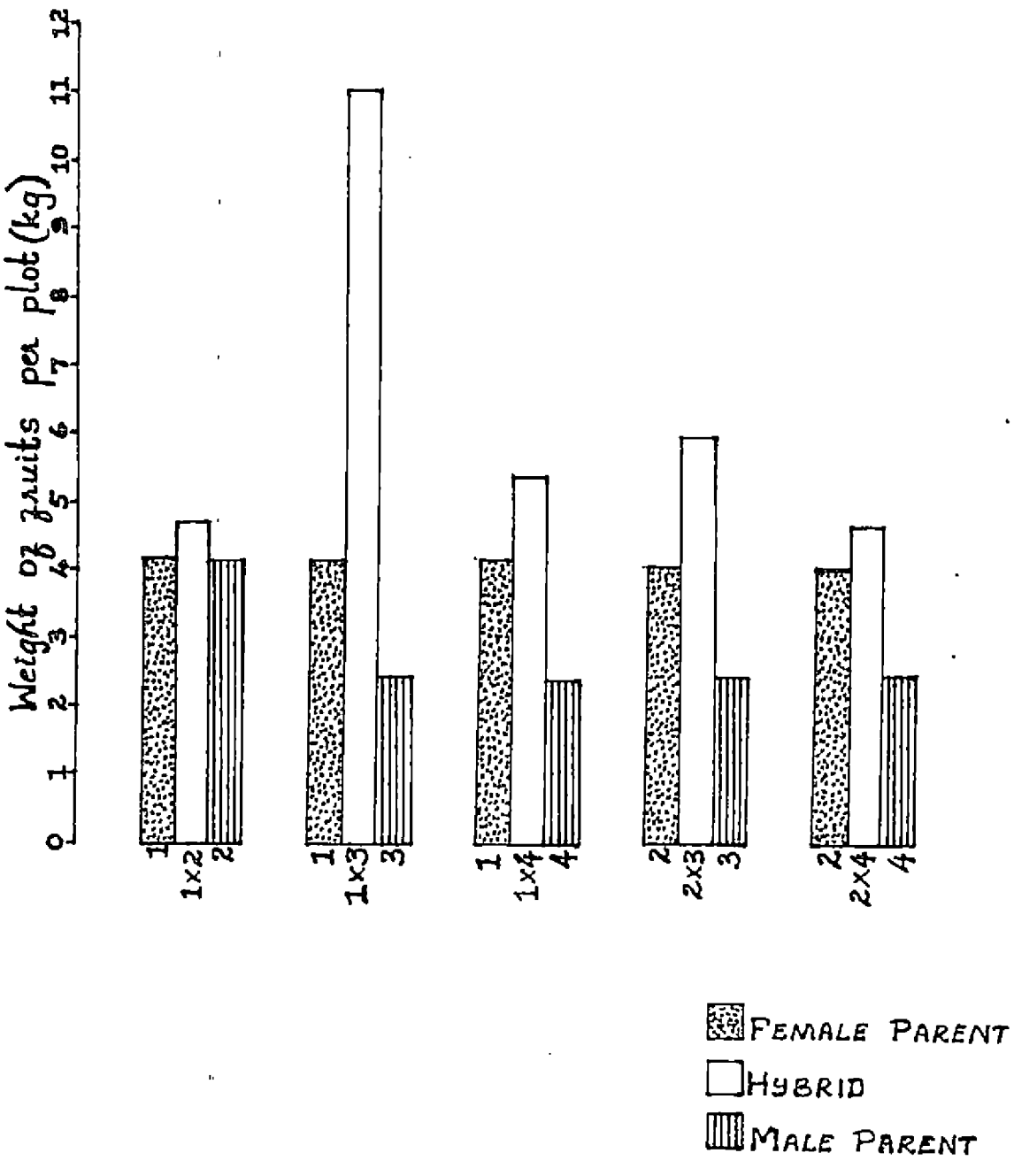
1 x 3 - Vellanotchi x Purple Round

1 x 4 - Vellanotchi x Purple Cluster

2 x 3 - Pant C-1 x Purple Round

2 x 4 - Pant C-1 x Purple Cluster

FIG. 6. WEIGHT OF FRUITS PER PLOT IN PARENTS AND HYBRIDS



4.6.9 Weight of individual fruit

The mean values for the parents and hybrids in the two trials, the pooled means and the three types of heterosis pertaining to this character are presented in Table 18.

Weight of individual fruit was maximum for Vellanotchi and minimum for Pant C-1 in all the three comparisons, when the parents were taken into account. The hybrids V x PCl and PC-1 x PCl produced fruits with maximum and minimum weights respectively in the three types of comparisons.

Relative heterosis was negative for all the hybrids except PC-1 x PR, the value for V x PR being significant. PC-1 x PR exhibited positive non-significant relative heterosis in the first experiment. In the second trial, positive relative heterosis was manifested by V x PCl and PC-1 x PCl, the value for the former being significant. The other three hybrids registered negative heterosis, the value for V x PR being significant. Pooled means displayed a decrease in weight of individual fruit for V x PC-1, V x PR and PC-1 x PR and an increase for V x PCl and PC-1 x PCl over the mid-parental values, the percentage of increase being 5.99 and 5.98 respectively for these two hybrids.

Table 18 Mean values of parents and hybrids and heterosis in percentage - Weight of individual fruit

Parents and hybrids	Mean (g)			Relative heterosis			Heterobeltiosis			Standardheterosis		
	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled
Vellanotchi	5.83	5.16	5.50									
Pant C-1	1.76	1.24	1.50									
Purple Round	3.09	3.62	3.36									
Purple Cluster	2.23	2.13	2.18									
V x PC-1	3.50	2.94	3.22	-7.77	-8.13	-8.00	-39.97**	-43.02**	-41.45	-39.97**	-43.02**	-41.45
V x PR	3.35	3.48	3.42	-24.89**	-20.73**	-22.80	-42.54**	-32.56**	-37.82	-42.54**	-32.56**	-37.82
V x PCl	3.96	4.17	4.07	-1.74	14.40	5.99	-32.08**	-19.19**	-26.00	-32.08**	-19.19**	-26.00
PC-1 x PR	2.51	2.20	2.36	3.51	-9.47	-2.88	-18.77*	-39.23**	-29.76	-56.95**	-57.36**	-57.09
PC-1 x PCl	1.96	1.93	1.95	-1.75	14.54	5.98	-12.11	-9.39	-10.55	-66.38**	-62.60**	-64.55

First trial -

C.D. I (0.01) = 0.55
C.D. I (0.05) = 0.40
C.D. II (0.01) = 0.63
C.D. II (0.05) = 0.46

Second trial -

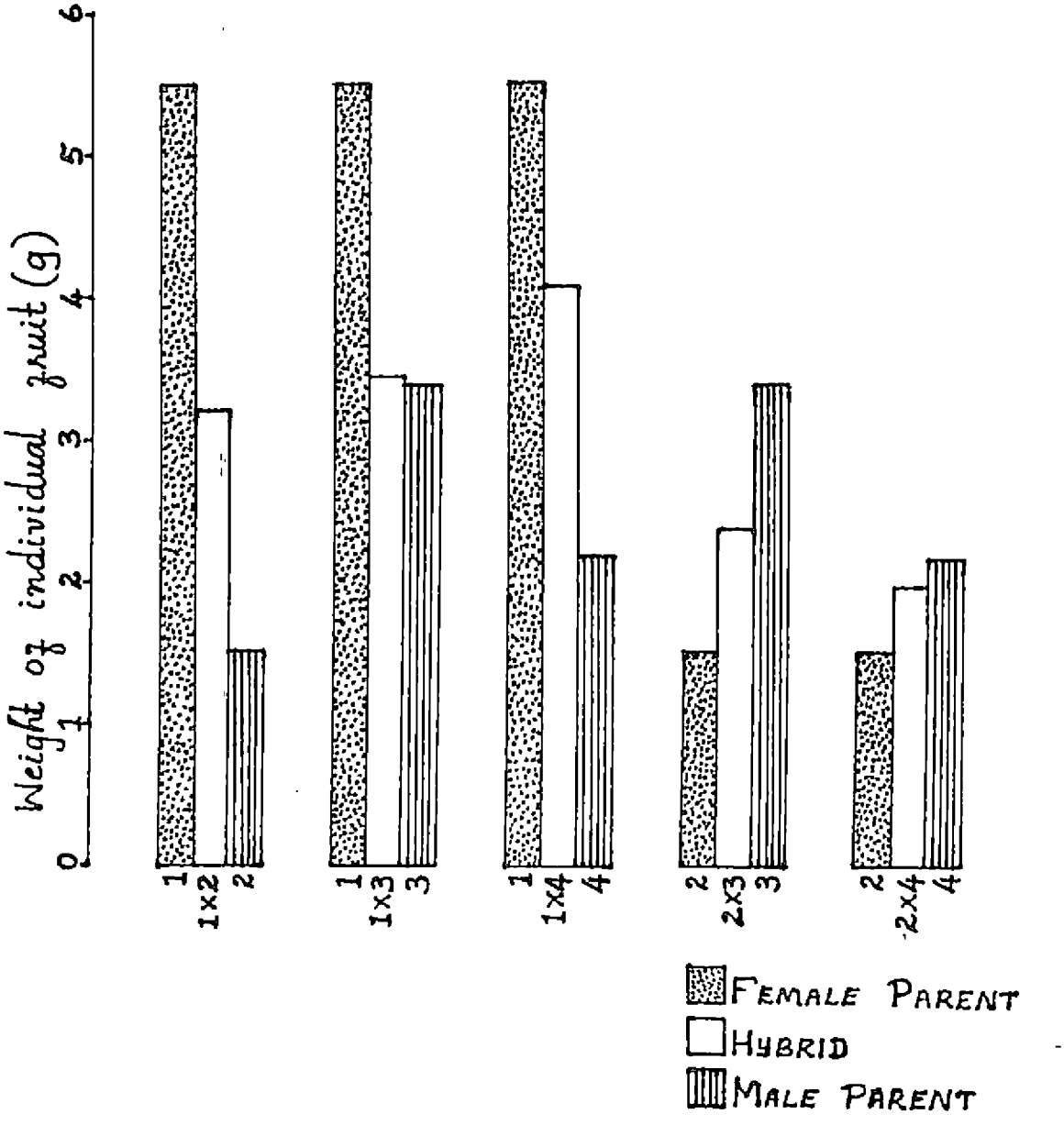
C.D. I (0.01) = 0.62
C.D. I (0.05) = 0.45
C.D.II (0.01) = 0.72
C.D.II (0.05) = 0.52

* Significant at 5 per cent level

** Significant at 1 per cent level

1	- Vellanotchi
2	- Pant C-1
3	- Purple Round
4	- Purple Cluster
1 x 2	- Vellanotchi x Pant C-1
1 x 3	- Vellanotchi x Purple Round
1 x 4	- Vellanotchi x Purple Cluster
2 x 3	- Pant C-1 x Purple Round
2 x 4	- Pant C-1 x Purple Cluster

FIG.7. WEIGHT OF INDIVIDUAL FRUIT IN PARENTS AND HYBRIDS



Negative heterobeltiosis was displayed by all the hybrids, the values for the first four hybrids being significant in both the evaluations. When the pooled means were taken into consideration, all the hybrids showed a decrease in weight of individual fruit compared to their corresponding better parents and the percentage of decrease ranged from 10.55 (PC-1 x PC1) to 41.45 (Vx PC-1).

All the five hybrids manifested negative significant standard heterosis in both the trials. Decrease in weight of individual fruit was exhibited by all the hybrids compared to the standard variety. The percentage of decrease had a range of 26.00 (V x PC1) to 64.55 (PC-1 x PC1) when the pooled means were considered.

The mean weight of individual fruit of the parents and hybrids is diagrammatically represented in Fig.7.

4.6.10 Length of individual fruit

The mean values for the parents and hybrids in the two trials, the pooled means and the three types of heterosis relating to length of individual fruit are given in Table 19.

The maximum length of fruit was exhibited by Vellanotchi in the first evaluation and when the means

Table 19 The mean values of parents and hybrids and heterosis in percentage - Length of individual fruit

Parents and hybrids	Mean (cm)			Relative heterosis			Heterobeltiosis			Standard heterosis		
	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled
Vellanotchi	5.72	5.10	5.41									
Pant C-1	4.75	5.36	5.06									
Purple Round	1.64	2.00	1.82									
Purple Cluster	3.41	3.83	3.62									
V x PC-1	6.06	6.12	6.09	15.76**	17.02**	16.33	5.94**	14.18**	12.57	5.94**	20.00**	12.57
V x PR	3.12	2.49	2.81	-15.22**	-29.86**	-22.27	-45.45**	-51.18**	-48.06	-45.45**	-51.18**	-48.06
V x PCl	5.00	5.30	5.15	9.53**	18.70**	14.06	-12.59**	3.92**	-4.81	-12.59**	3.92**	-4.81
PC-1 x PR	3.20	3.81	3.51	0.16**	3.53**	2.03	-32.63**	-28.92**	-30.63	-44.06**	-25.29**	-35.12
PC-1 x PCl	4.67	5.50	5.09	14.46**	19.70**	17.28	-1.68	2.61	0.59	-18.36**	7.84	-5.91

First trial -

C.D. I (0.01) = 0.41
C.D. I (0.05) = 0.30
C.D. II (0.01) = 0.48
C.D. II (0.05) = 0.35

Second trial -

C.D. I (0.01) = 0.41
C.D. I (0.05) = 0.30
C.D.II (0.01) = 0.48
C.D.II (0.05) = 0.35

** Significant at 1 per cent level

were pooled, while in the second trial, the longest fruits were produced by Pant C-1 among the parents. Purple Round produced the shortest fruits in all the three comparisons. When the hybrids were considered, the longest and shortest fruits were produced by V x PC-1 and V x PR respectively in all the three computations.

All the hybrids except V x PR displayed positive relative heterosis for length of individual fruit, the values for V x PC-1, V x PCl and PC-1 x PCl being significant in both the experiments and V x PR exhibited negative and significant values. When the mean values were pooled, all the hybrids except V x PR manifested an increase in length of individual fruit over the respective mid-parental values, the range of increase being 2.03 per cent (PC-1 x PR) to 17.28 per cent (PC-1 x PCl).

V x PC-1 exhibited positive non-significant heterobeltiosis while the remaining four hybrids showed negative heterosis, the values for V x PR, V x PCl and PC-1 x PR being significant in the first trial. In the second evaluation, V x PC-1, V x PCl and PC-1 x PCl registered positive heterobeltiosis, the value for V x PC-1 being significant. The other two hybrids displayed negative and significant heterobeltiosis. Pooled means

showed an increase in length of fruit over the better parent only for two hybrids namely V x PC-1 and PC-1 x PC1, the percentage of increase being 12.57 and 0.59 respectively. The other three hybrids exhibited a decrease in length of fruit compared to the better parent. The decrease in percentage ranged from 4.81 (V x PC1) to 48.06 (V x PR).

Positive and non-significant standard heterosis was registered by V x PC-1 while the remaining four hybrids displayed negative and significant standard heterosis in the first experiment. V x PC-1, V x PC1 and PC-1 x PC1 exhibited positive heterosis, the value for V x PC-1 being significant in the second trial. V x PR and PC-1 x PR recorded negative significant standard heterosis. Only V x PC-1 registered an increase in length of individual fruit over the standard variety, the increase in percentage being 12.57. The other four hybrids displayed a decrease in length of fruit compared to Vellanotchi and the decrease in percentage ranged from 4.81 (V x PC1) to 48.06 (V x PR).

4.6.11 Girth of individual fruit

The mean values of the parents and hybrids pertaining to this character in the two trials, pooled

Table 20 The mean values of parents and hybrids and heterosis in percentage Girth of individual fruit

Parents and hybrids	Mean (cm)			Relative heterosis			Heterobeltiosis			Standard heterosis		
	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled
Vellanotchi	6.78	7.32	7.05									
Pant C-1	3.29	2.86	3.08									
Purple Round	7.68	8.58	8.13									
Purple Cluster	4.13	4.16	4.15									
V x PC-1	4.64	4.59	4.62	-7.85*	-9.82	-8.79	-31.56**	-37.30**	-34.47	-31.56**	-37.30**	-34.47
V x PR	6.54	7.47	7.01	-9.54**	-6.04	-7.64	-14.84**	-12.94**	-13.78	-3.54	2.05	-5.67
V x PCl	5.52	5.88	5.70	1.19	2.44	1.79	-18.58**	-19.67**	-19.15	-18.58**	-19.67**	-19.15
PC-1 x PR	5.67	4.92	5.30	3.37	-13.99**	-5.44	-26.17**	-42.66**	-34.81	-16.37**	-32.79**	-24.82
PC-1 x PCl	3.38	3.48	3.43	-8.89	-0.85	-5.12	-18.16**	-16.35*	-17.35	-50.15**	-52.46**	-51.35

First trial —

C.D. I (0.01) = 0.51
C.D. I (0.05) = 0.37
C.D.II (0.01) = 0.58
C.D.II (0.05) = 0.42

Second trial —

C.D. I (0.01) = 0.72
C.D. I (0.05) = 0.52
C.D. II (0.01) = 0.83
C.D. II (0.05) = 0.60

* Significant at 5 per cent level

** Significant at 1 per cent level

means and the three types of heterosis computed are presented in Table 20.

Among the four parents, fruits with maximum girth were produced by Purple Round and those with minimum girth by Pant C-1 in the three comparisons. Out of the five hybrids V x PR exhibited maximum girth of fruit while PC-1 x PCl displayed minimum.

V x PC-1, V x PR and PC-1 x PCl exhibited negative relative heterosis, the values for the first two hybrids being significant in the first evaluation. Positive non-significant heterosis was displayed by V x PCl and PC-1 x PR. In the second trial, positive non-significant relative heterosis was registered by V x PCl while the other four hybrids recorded negative heterosis, the value for PC-1 x PR being significant. When the pooled means were considered, only V x PC-1 displayed an increase in girth of fruit over the mid-parental value, the increase in percentage being 1.79. The other four hybrids exhibited a reduction in girth of fruit and the decrease ranged from 5.12 per cent (PC-1 x PCl) to 8.79 per cent (V x PC-1).

All the five hybrids displayed negative and significant heterobeltiosis in both the evaluations.

Pooled means exhibited a decrease in girth of individual fruit compared to the better parent. The decrease in percentage showed a range of 13.78 (V x PR) to 34.81 (PC-1 x PR).

V x PR exhibited negative but non-significant and positive non-significant standard heterosis in the first and second evaluations respectively. The remaining four hybrids displayed negative significant heterosis in both the trials. All the five hybrids displayed a decrease in girth of fruit than the standard variety Vellanotchi and the percentage of decrease ranged from 5.67 (V x PR) to 51.35 (PC-1 x PCl).

4.6.12 Fruit shape index

The mean values for the parents and hybrids in the two trials, the pooled means and the three types of heterosis computed relating to fruit shape index are presented in Table 21.

Among parents, fruit shape index was maximum for Pant C-1 and minimum for Purple Round in all the three comparisons. As regards the hybrids, the maximum and minimum values were recorded by PC-1 x PCl and V x PR respectively.

The hybrids V x PC-1, V x PCl and PC-1 x PCl exhibited positive relative heterosis for this character,

Table 21 The mean values of parents and hybrids and heterosis in percentage - Fruit shape index

Parents and hybrids	Mean			Relative heterosis			Heterobeltiosis			Standard heterosis		
	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled
Vellanotchi	2.65	2.19	2.42									
Pant C-1	4.55	5.88	5.22									
Purple Round	0.67	0.73	0.70									
Purple Cluster	2.59	2.90	2.75									
V x PC-1	4.10	4.19	4.15	13.89**	3.84	8.64	-9.89**	-28.74**	-20.50	54.72**	91.32**	71.49
V x PR	1.60	1.05	1.33	-3.61	-28.08**	-14.74	-39.62**	-52.05**	-45.04	-39.62**	-52.05**	-45.04
V x PCl	2.84	2.84	2.84	8.40	11.59**	9.86	7.17	-2.07	3.27	7.17	29.68**	17.36
PC-1 x PR	1.78	2.44	2.11	-31.80**	-26.17**	-28.72	-60.88**	-58.50**	-59.58	-32.83**	11.42*	-12.81
PC-1 x PCl	4.35	4.97	4.66	21.85**	13.21**	16.94	-4.40	-15.48**	-10.73	64.15**	126.84**	92.56

First trial -

C.D. I (0.01) = 0.36
C.D. I (0.05) = 0.26
C.D. II (0.01) = 0.41
C.D. II (0.05) = 0.30

Second trial -

C.D. I (0.01) = 0.29
C.D.I (0.05) = 0.21
C.D.II (0.01) = 0.34
C.D.II (0.05) = 0.24

* Significant at 5 per cent level

** Significant at 1 per cent level

the values for V x PC-1 and PC-1 x PC1 being significant while V x PR and PC-1 x PR displayed negative heterosis, the value for the latter being significant, in the first evaluation. Relative heterosis was positive in the second trial too, for V x PC-1, V x PC1 and PC-1 x PC1, the values for V x PC1 and PC-1 x PC1 being significant. V x PR and PC-1 x PR manifested negative and significant heterosis. When the pooled means were compared, V x PC-1, V x PC1 and PC-1 x PC1 displayed an increase in fruit shape index over the mid-parental values and the percentage of increase ranged from 8.64 (V x PC-1) to 16.94 (PC-1 x PC1).

All the hybrids except V x PC1 displayed negative heterobeltiosis, the values for V x PC-1, V x PR and PC-1 x PR being significant in the first experiment. The value for V x PC1 was positive, but non-significant. In the second trial, all the hybrids displayed negative heterobeltiosis, the values for all hybrids except V x PC1 being significant. V x PC1 exhibited an increase of 3.27 per cent over the better parent when the pooled means were taken into consideration. The other four hybrids accounted a decrease which ranged from 10.73 per cent (PC-1 x PC1) to 59.58 per cent (PC-1 x PR).

Standard heterosis was positive for V x PC-1, Vx PC1 and PC-1 x PC1, the values of V x PC-1 and PC-1 x PC1

being significant in the first trial. The other two hybrids exhibited negative and significant heterosis. In the second evaluation, V x PR displayed negative significant heterosis while the remaining four hybrids registered positive significant heterosis. When the pooled means were taken into account, V x PC-1, V x PCl and PC-1 x PCl exhibited an increase which ranged from 17.36 per cent (V x PCl) to 92.56 per cent (PC-1 x PCl) over the standard variety. V x PR and PC-1 x PR recorded a decrease of 45.04 per cent and 12.81 per cent respectively compared to the standard variety Vellanotchi.

4.6.13 Leaf area

The mean values relating to parents and hybrids in the two trials, the pooled means and the three types of heterosis computed on account of the character are given in Table 22.

Purple Round produced leaves with maximum area and Vellanotchi with minimum area in all the three comparisons, when the four parents were compared. The hybrid V x PCl had minimum leaf area in the first trial and also when the means were pooled, while in the second experiment, leaf area was minimum for V x PC-1. In all the three computations, PC-1 x PR recorded maximum leaf area.

Table 22 The mean values of parents and hybrids and heterosis in percentage - Leaf area

Parents and hybrids	Mean (cm^2)			Relative heterosis			Heterobeltiosis			Standard heterosis		
	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled
Vellanotchi	20.06	10.14	15.10									
Pant C-1	21.18	12.28	16.73									
Purple Round	58.16	40.31	49.24									
Purple Cluster	20.24	14.21	17.23									
V x PC-1	22.32	11.89	17.11	8.24	6.07	7.51	5.38	-3.18	2.27	11.27	17.26	13.31
V x PR	34.73	30.55	32.64	-11.20	21.11*	1.46	-40.29**	-24.21**	-33.71	73.13**	201.28**	116.16
V x PCl	17.17	13.51	15.34	-14.79	10.97	-5.13	-15.17	-4.93	-10.97	-14.41	33.23	1.59
PC-1 x PR	41.64	36.94	39.29	4.97	40.48**	19.11	-28.40**	-8.36	-20.21	107.58**	264.30**	160.20
PC-1 x PCl	20.62	12.31	16.47	-0.43	-7.06	-3.00	-2.64	-13.37	-4.41	2.79	21.40	9.07

First trial -

C.D. I (0.01) = 8.21
C.D. I (0.05) = 5.96
C.D. II (0.01) = 9.48
C.D.II (0.05) = 6.89

Second trial -

C.D. I (0.01) = 7.27
C.D. I (0.05) = 5.27
C.D. II (0.01) = 8.39
C.D. II (0.05) = 6.09

* Significant at 5 per cent level

** Significant at 1 per cent level

Relative heterosis was positive and non-significant for V x PC-1 and PC-1 x PR while the same was negative, but non-significant for the other three hybrids in the first trial. PC-1 x PC1 registered negative but non-significant relative heterosis in the second evaluation, while all the other four hybrids exhibited positive heterosis, the values for V x PR and PC-1 x PR being significant. When the pooled means were taken into consideration, V x PC-1, V x PR and PC-1 x PR recorded an increase in leaf area over their respective mid-parental values, the range of increase being 1.46 per cent (V x PR) to 19.11 per cent (PC-1 x PR). V x PC1 and PC-1 x PC1 registered a decrease in percentage of 5.13 and 3.00 respectively.

Heterobeltiosis was positive, but non-significant for V x PC-1 while it was negative for the remaining four hybrids, the values for V x PR and PC-1 x PR being significant in the first trial. All the hybrids displayed negative heterobeltiosis in the second evaluation, the value for V x PR being significant. V x PC-1 displayed an increase of 2.27 per cent over the better parent while for the other four hybrids, the decrease in leaf area ranged from 4.41 per cent (PC-1 x PC1) to 33.71 per cent (V x PR) when the pooled means were considered.

V x PR exhibited negative non-significant standard heterosis while the remaining four hybrids recorded positive heterosis, the values for V x PR and PC-1 x PR being significant in the first evaluation. In the second trial, though all the hybrids displayed positive standard heterosis, the values of only V x PR and PC-1 x PR were significant. All the five hybrids exhibited an increase in leaf area over the standard variety, the range of increase in percentage being 1.59 (V x PC1) to 160.20 (PC-1 x PR), when the pooled means were taken into account.

4.6.14 Height

The mean heights of the parents and hybrids in the two evaluations, the pooled means and the three types of heterosis computed are presented in Table 23.

Among the parents, maximum height was exhibited by Pant C-1 in the first trial and Purple Round in the second experiment and when the means were pooled. Minimum height was displayed by Purple Cluster in all the three comparisons. The hybrids PC-1 x PR and V x PC1 recorded the maximum and minimum heights respectively in all the three computations.

Negative, but non-significant relative heterosis was exhibited by V x PC-1 while the remaining four hybrids displayed positive heterosis, the values for V x PR and

Table 23 The mean values of parents and hybrids and heterosis in percentage - Height

Parents and hybrids	Mean (cm)			Relative heterosis			Heterobeltiosis			Standard heterosis		
	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled
Vellanotchi	42.62	44.60	43.61									
Pant C-1	55.33	61.55	58.44									
Purple Round	54.80	87.30	71.05									
Purple Cluster	20.85	22.68	21.77									
V x PC-1	45.22	62.80	54.01	-7.67	18.32	5.85	-18.27	2.03	-7.58	5.10	40.81**	23.85
V x PR	69.83	121.07	95.45	43.36**	83.58**	66.49	27.43*	38.66**	34.34	63.84**	171.46**	118.87
V x PC1	36.25	46.80	42.53	20.53	39.12*	30.10	-10.25	4.93	-2.48	-10.25	4.93	-2.48
PC-1 x PR	75.50	157.02	116.26	37.11**	110.98**	79.55	36.45**	79.86**	63.63	77.15**	252.06**	166.59
PC-1 x PC1	44.00	61.57	52.79	15.52	46.19**	31.61	-20.42	3.25	-9.67	3.24	38.05**	21.05

First trial -

C.D. I (0.01) = 14.87
C.D. I (0.05) = 10.79
C.D.II (0.01) = 17.17
C.D.II (0.05) = 12.46

Second trial -

C.D. I (0.01) = 14.52
C.D. I (0.05) = 10.54
C.D. II (0.01) = 16.77
C.D. II (0.05) = 12.17

* Significant at 5 per cent level
** Significant at 1 per cent level

PC-1 x PR being significant, in the first experiment. All the hybrids showed positive heterosis in the second trial, the values for four hybrids namely, V x PR, V x PC1, PC-1 x PR and PC-1 x PC1 being significant. When the means were pooled, all the hybrids exhibited increased height over the mid-parental value and the percentage of increase ranged from 5.85 (V x PC-1) to 79.55 (PC-1 x PR).

The hybrids V x PC-1, V x PC1 and PC-1 x PC1 exhibited negative and non-significant heterobeltiosis while V x PR and PC-1 x PR displayed positive significant heterosis in the first trial. In the second evaluation, all the hybrids showed positive heterobeltiosis, the values for V x PR and PC-1 x PR being significant. When the means were pooled, V x PC-1, V x PC1 and PC-1 x PC1 exhibited a decrease in height compared to their corresponding better parents, which ranged from 2.48 per cent (V x PC1) to 9.67 per cent (PC-1 x PC1). V x PR and PC-1 x PR showed an increase of 34.34 per cent and 63.63 per cent over their respective better parents.

Positive but non-significant standard heterosis was recorded by V x PC1 in the first trial while the other four hybrids had positive values, the values for V x PR and PC-1 x PR being significant. In the second evaluation, all the hybrids exhibited positive heterosis, the values for four

hybrids namely V x PC-1, V x PR, PC-1 x PR and PC-1 x PCl being significant. Pooled means revealed a decrease of 2.48 per cent in height by V x PCl, compared to the standard variety Vellanotchi. The other four hybrids exhibited an increase in height over the standard variety, which ranged from 21.05 per cent (PC-1 x PCl) to 166.59 per cent (PC-1 x PR).

4.6.15 Number of branches

The mean number of branches of the parents and hybrids in the two trials, the pooled means and the three types of heterosis are given in Table 24.

In the first evaluation, Purple Round produced the maximum number of branches among the parents while Pant C-1 had the maximum in the other two comparisons. Purple Cluster recorded the minimum number of branches in all the three computations. Out of the five hybrids, PC-1 x PR displayed maximum number of branches and V x PCl had the minimum number in all the three comparisons.

In both the evaluations, V x PC-1 exhibited negative and non-significant relative heterosis while the other four hybrids displayed positive heterosis, the values for PC-1 x PR being significant. V x PR also showed positive and significant heterosis in the second trial. When the means were

Table 24 The mean values of parents and hybrids and heterosis in percentage - Number of branches

Parents and hybrids	Mean			Relative heterosis			Heterobelticosis			Standard heterosis		
	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled
Vellanotchi	91.70	57.27	74.49									
Pant C-1	95.67	104.97	100.32									
Purple Round	96.63	81.90	89.27									
Purple Cluster	20.00	35.73	27.87									
V x PC-1	93.50	77.67	85.59	-1.97	-4.25	-2.08	-2.27	-26.01	-14.68	1.96	35.62	14.90
V x PR	137.43	425.37	281.40	45.95	511.36**	243.67	42.22	419.56**	215.22	49.67	642.74**	277.77
V x PCl	68.57	59.93	64.25	22.78	28.88	25.54	-25.22	4.64	-13.75	-25.22	4.64	-13.75
PC-1 x PR	278.10	917.23	597.67	189.24**	881.68**	530.49	187.80**	773.80**	495.76	203.27**	1501.59**	702.35
PC-1 x PCl	87.30	87.73	87.52	50.95	24.71	36.55	-8.75	-16.42	-12.76	-4.80	53.19	17.49

Frist trial -

C.D. I (0.01) = 65.92
C.D. I (0.05) = 47.84
C.D. II (0.01) = 76.11
C.D. II (0.05) = 55.24

Second trial -

C.D. I (0.01) = 144.68
C.D. I (0.05) = 105.01
C.D.II (0.01) = 167.06
C.D.II (0.05) = 121.25

** Significant at 1 per cent level

pooled, V x PC-1 exhibited a decrease of 2.08 per cent in number of branches compared to its mid-parental value . All the other four hybrids produced more number of branches than their corresponding mid-parental values and the enhancement ranged from 25.54 per cent (V x PC1) to 530.49 per cent (PC-1 x PR).

Out of the five hybrids, three hybrids namely V x PC-1, V x PC1 and PC-1 x PC1 exhibited negative and non-significant heterobeltiosis in the first evaluation while V x PR and PC-1 x PR displayed positive heterosis, the value for the latter being significant. In the second trial, V x PC-1 and PC-1 x PC1 displayed negative non-significant heterobeltiosis while the remaining three hybrids showed positive heterosis, the values for V x PR and PC-1 x PR being significant. V x PC-1, V x PC1 and PC-1 x PC1 produced lesser number of branches than their corresponding better parents and the decrease in number of branches ranged from 12.76 per cent (PC-1 x PC1) to 14.68 per cent (V x PC-1), when the pooled means were taken into account. V x PR and PC-1 x PR showed an increase of 215.22 per cent and 495.76 per cent respectively.

Though standard heterosis was positive for V x PC-1, V x PR and PC-1 x PR, the value for only PC-1 x PR was

significant in the first evaluation. V x PCl and PC-1 x PCl displayed negative and non-significant standard heterosis. All the five hybrids exhibited positive standard heterosis in the first trial and the values for V x PR and PC-1 x PR were significant. Pooled means showed that V x PCl produced only lesser number of branches than the standard variety Vellanotchi, the percentage of decrease being 13.75. The remaining four hybrids exhibited an increase in number of branches and the percentage of enhancement ranged from 14.90 (V x PC-1) to 702.35 (PC-1 x PR).

4.6.16 Spread

The mean values of the parents and hybrids in the two evaluations pertaining to this character, the pooled means and the values of the three types of heterosis are presented in Table 25.

Purple Round and Purple Cluster displayed maximum and minimum spread respectively in all the three comparisons when the parents were considered. Among the hybrids, the maximum and minimum values were exhibited by PC-1 x PR and V x PCl respectively.

Relative heterosis was found to be negative, but non-significant for V x PC-1 while the same was positive for the other four hybrids, the values for V x PR and PC-1 x PR being significant in the first trial. In the second

Table 25 The mean values of parents and hybrids and heterosis in percentage-Spread

Parents and hybrids	Mean (cm)			Relative heterosis			Heterobeltiosis			Standard heterosis		
	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled	First trial	Second trial	Pooled
Vellanotchi	38.12	34.23	36.18									
Pant C-1	46.80	49.72	48.26									
Purple Round	47.10	60.23	53.67									
Purple Cluster	24.70	20.92	22.81									
V x PC-1	39.67	48.30	43.99	-6.57	15.07**	4.19	-15.24	-2.86**	-3.85	4.07**	41.10**	21.59
V x PR	57.40	99.00	78.20	34.71**	109.61**	74.07	21.87	64.37**	45.71	50.58**	189.22**	116.14
V x PCl	34.63	41.65	38.14	10.25	51.04**	29.31	-9.16**	21.68**	5.42	-9.16**	21.68**	5.42
PC-1 x PR	61.00	125.37	93.19	29.93	128.05**	82.85	29.51**	108.15**	73.64	60.02**	266.26**	157.57
PC-1 x PCl	39.37	59.20	49.29	10.13	67.61**	38.71	- 15.68	19.07	2.13	3.28	72.95**	36.24

First trial -

C.D. I (0.01) = 13.26
C.D. I (0.05) = 9.62
C.D.II (0.01) = 15.31
C.D.II (0.05) = 11.11

Second trial -

C.D. I (0.01) = 13.18
C.D. I (0.05) = 9.56
C.D. II (0.01) = 15.21
C.D.II (0.05) = 11.04

* Significant at 5 per cent level

** Significant at 1 per cent level

evaluation, all the hybrids exhibited positive heterosis, the values for all the hybrids except V x PC-1 being significant. Pooled means revealed that all the hybrids had increased spread compared to their corresponding mid-parental values. The percentage of increase ranged from 4.19 (V x PC-1) to 82.85 (PC-1 x PR).

Heterobeltiosis was negative, but non-significant for V x PC-1, V x PC1 and PC-1 x PC1 while the remaining two hybrids had positive values, the value of PC-1 x PR being significant in the first evaluation. One hybrid namely V x PC-1 displayed negative and non-significant heterobeltiosis in the second trial. As regards the remaining four hybrids, the values of only V x PR and PC-1 x PR were positive and significant. A decrease of 8.85 per cent was shown by V x PC-1 while an increase over better parent was recorded by the remaining four hybrids, when the pooled means are compared, which ranged from 2.13 per cent (PC-1 x PC1) to 73.64 per cent (PC-1 x PR).

The hybrid V x PC1 displayed negative but non-significant standard heterosis while the remaining four hybrids recorded positive heterosis, the values for V x PR and PC-1 x PR being significant, in the first evaluation. All the five hybrids exhibited positive standard heterosis, the values for all the hybrids except V x PC1 being significant

in the second experiment. Pooled means displayed increased spread for all the hybrids compared to the standard variety Vellanotchi and the enhancement ranged from 5.42 per cent (V x PC1) to 157.57 per cent (PC-1 x PR).

4.7 Life span

The life span of the parents and hybrids from seed to seed is presented in Table 26.

Among the parents, Purple Round had the maximum life span (195 days) in the first trial while in the second evaluation, Pant C-1 (1382 days) and Purple Round (182 days) recorded the maximum duration. The minimum life span was registered by Vellanotchi (160 days and 169 days) in both the trials. Among hybrids, PC-1 x PR exhibited the maximum life span (211 days and 190 days) while V x PC-1 (169 days and 175 days) and V x PC1 (169 days and 175 days) recorded the minimum in the two evaluations. The same trend was observed when the pooled means were taken into account.

The life span of the parents and hybrids is diagrammatically presented in Fig.8.

4.8 Number of pickings

The number of pickings relating to the four parents and five hybrids are presented in Table 27.

Table 26 Life span (from seed to seed)

Parents and hybrids	Life span (days)		
	First trial	Second trial	Pooled
Vellanotchi	160	169	164.50
Pant C-1	179	182	180.50
Purple Round	195	182	188.50
Purple Cluster	169	175	172.00
V x PC-1	169	175	172.00
V x PR	179	182	180.50
V x PCl	169	175	172.00
PC-1 x PR	211	190	200.50
PC-1 x PCl	179	182	180.50

1	- Vellanotchi
2	- Pant C-1
3	- Purple Round
4	- Purple Cluster
1 x 2	- Vellanotchi x Pant C-1
1 x 3	- Vellanotchi x Purple Round
1 x 4	- Vellanotchi x Purple Cluster
2 x 3	- Pant C-1 x Purple Round
2 x 4	- Pant C-1 x Purple Cluster

FIG. 8. LIFE SPAN OF PARENTS AND HYBRIDS

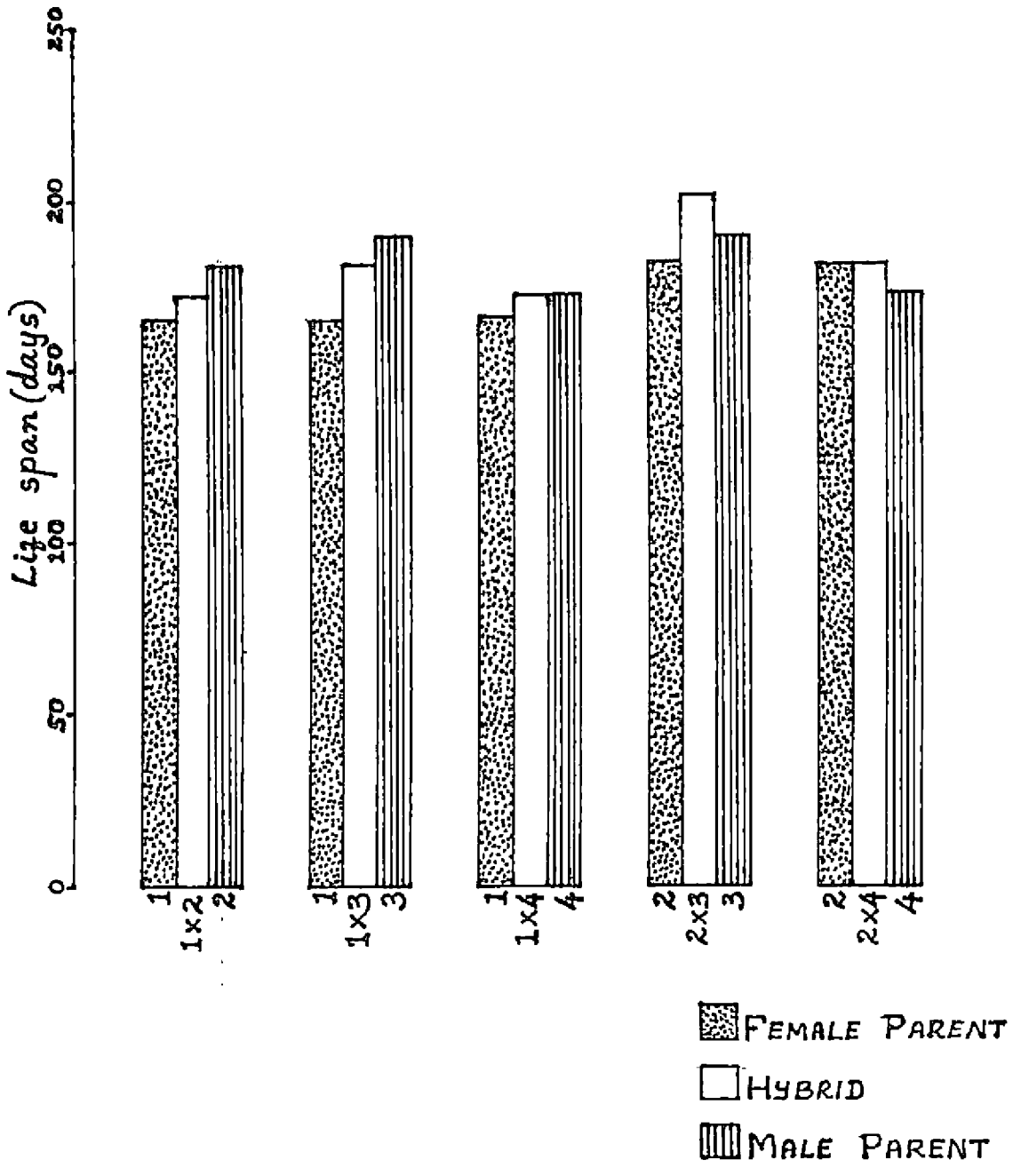


Table 27 Number of pickings

Parents and hybrids	Number of pickings		
	First trial	Second trial	Pooled
Vellanotchi	6	7	6.5
Pant C-1	8	9	8.5
Purple Round	8	6	7.0
Purple Cluster	7	8	7.5
V x PC-1	7	8	7.5
V x PR	8	9	8.5
V x PCl	7	8	7.5
PC-1 x PR	10	10	10.0
PC-1 x PCl	8	9	8.5

Among parents, the maximum number of pickings were recorded by Pant C-1 (8) and Purple Round (8) in the first trial and Pant C-1 (9) in the second evaluation. Vellanotchi (6) and Purple Round (6) registered the minimum number of pickings in the first and second trials respectively. Out of the five hybrids, PC-1 x PR (10) recorded the highest number of pickings while V x PC-1 (7 and 8) and V x PC1 (7 and 8) registered the lowest in both the evaluations.

4.9 Observations on qualitative characters

The observations on the various qualitative attributes namely, pigmentation of the stem, leaf, flower and fruit and orientation of fruit are presented in Table 28.

Out of the five hybrids, two hybrids namely V x PR and PC-1 x PR developed partial purple pigmentation of the stem, inherited from their male parent. The leaves were green in all the hybrids. The hybrids V x PC-1 produced white flowers while the flowers of the remaining four hybrids had purple pigmentation, either partial or complete. The hybrid V x PC-1 produced light green fruits while V x PR and PC-1 x PR produced purple fruits. Partial pigmentation was displayed by the fruits of two hybrids, namely V x PC1 and PC-1 x PC1. Fruit orientation differed in the hybrids. Drooping fruits were produced by the first three hybrids. When PC-1 x PR produced semi-erect fruits, PC-1 x PC1 had erect fruits.

Table 28 Observations on qualitative characters

Parents and hybrids	Characters				
	Pigmentation of stem	Pigmentation of leaf	Pigmentation of flowers	Pigmentation of fruit	Orientation of fruit
Vellanotchi	Green	Green	White	Light green	Drooping
Pant C-1	Green	Green	White	Green	Erect
Purple Round	Purple	Green with purplish tinge	Purple inside & light purple outside the petals	Purple	Semi-erect
Purple Cluster	Purple	Green with purplish tinge	Deep purple	Purple	Erect
V x PC-1	Green	Green	White	Light green	Drooping
V x PR	Partially Purple	Green	Purple inside & light purple outside the petals	Purple	Drooping
V x PC1	Green	Green	Purple at the tip of the petals	Green with partial purple colour	Drooping
PC-1 x PR	Partially purple	Green	Purple inside & light purple outside the petals	Purple	Semi-erect
PC-1 x PC1	Green	Green	Purple at the tip of the petals	Green with partial purple colour	Erect

DISCUSSION

5. DISCUSSION

Though chilli is generally considered as a self pollinated crop, considerable extent of natural cross pollination occurs, varying from 4.24 (Singh et al., 1973) to 68.00 per cent (Murthy and Murthy, 1962). Since a wide spectrum of variation exists in this crop with respect to the economic attributes, the scope for genetic improvement is immense. Fruit yield, which is the most important economic attribute, is found to depend on a number of contributing traits. An understanding of the interrelationships among these traits will be of invaluable help in bringing about enhancement in yield. Besides, in any breeding programme, ample informations on genetic parameters like coefficient of variation, heritability, genetic advance and genetic gain will be essential pre-requisites.

Though different methods of crop improvement are being adopted in chilli, heterosis breeding is now gaining importance owing to the fairly high degree of natural cross pollination and consequent heterozygous genetic constitution. The production of fairly good number of seeds from a single pollination is an added advantage in this crop. Several workers have emphasised the possibility of exploitation of heterosis in chilli (Deshpande, 1933; Lippert, 1975; Singh and Singh, 1976a; Sharma and Saini, 1977; Nair, 1981 and Uzo, 1984).

A study was conducted in the department of Plant Breeding, College of Agriculture, Vellayani to evaluate the productivity of six chilli hybrids. Four parents were selfed for one generation and the inbreds crossed in all possible combinations without reciprocals. Since the germination of one of the combinations was very poor, it could not be included in the study. The other five hybrids, along with the four parents, were laid out in an RBD with three replications during 1984-'85 and 1985-'86. Observations were recorded on twenty quantitative and five qualitative characters. The observations on sixteen quantitative traits were statistically analysed.

In order to estimate the extent of variability among the nine treatments for the sixteen characters, analysis of variance was done separately for each character for the two evaluation trials. Pooled analyses were also conducted to determine the influence of environment on each character except for number of branches and number of leaves at 25 days after transplanting which displayed no significant treatment differences in both the trials. Genetic parameters such as variances (phenotypic and genotypic), coefficients of variation (phenotypic and genotypic), heritability, genetic advance and genetic gain

were also estimated. Phenotypic and genotypic correlations were worked out for elucidating the association among different pairs of characters. The superiority of the hybrids over their corresponding mid-parental values, better parents and standard variety were assessed by estimating three types of heterosis namely, relative heterosis, heterobeltiosis and standard heterosis. The results are discussed hereunder.

The combination PC-1 x PR recorded high percentage of fruit set after hybridization while V x PR registered low values in both the evaluations. Though the combination PR x PC1 displayed fairly high percentage of fruit set, the majority of the seeds obtained from the crossed fruits were under-developed and papery. In those seeds with normal appearance, which were very less in number, the endosperm was scanty and the under-developed embryo was represented by a black spot in the centre of the seed. Consequently, the germination percentage was very poor and only five seedlings were obtained from 1378 seeds sown. Hence, this hybrid could not be included in both the trials. Sundaresan (1972) observed ill-developed papery seeds in the cross between Capsicum frutescens and Capsicum annuum leading to very poor seed fertility.

5.1 Analysis of variance

The anlysis of variance with respect to sixteen quantitative characters in the two evaluations revealed significant differences among the genotypes for these characters, except two traits namely, number of branches and number of leaves at 25 days after transplanting. Several earlier workers had observed significant variability among different genotypes for a large number of quantitative characters in chilli (Awasthi et al., 1976; Arya and Saini, 1977 b; Ramalingam and Murugarajendran, 1977; Rao and Chhonkar 1983 b and Gopalakrishnan et al., 1985.)

The pooled analysis of variance conducted for fourteen quantitative traits revealed significant genotype x environment interaction for five characters namely, days to 50 per cent flowering, length of individual fruit, fruit shape index and height and spread of the plant. This observation is in conformity with the findings of Sooch et al. (1981). Among the fourteen characters considered for pooled analysis, all except height at 25 days after transplanting and number of branches displayed significant differences.

5.2 Genetic parameters

Number of fruits per plot exhibited the maximum phenotypic and genotypic variances in both the trials. Weight of fruits per plant and number of branches also had high values for the two types of variances. These observations are in agreement with the findings of Arya and Saini (1976), Arya and Saini (1977 b) and Ramalingam and Murugarajendran (1977). Phenotypic variance was minimum for weight of individual fruit and number of branches at 25 days after transplanting in the first and second trials respectively while number of branches at 25 days after transplanting registered the minimum genotypic variance in both the evaluations.

The phenotypic and genotypic coefficients of variation were higher in the second evaluation trial compared to the first for most of the characters. Days to 50 per cent flowering, number of leaves at 25 days after transplanting and length of individual fruit registered values which were lower in the second trial. The difference in weather parameters in two seasons might have influenced the performance of these characters. Number of branches registered maximum phenotypic and genotypic coefficients of variation in both the evaluations. This observation agrees with the findings of Arya and Saini (1977 b) which

is contrary to the observations of Singh and Brar (1979). Phenotypic coefficient of variation was high for number of fruits per plant, moderate for weight of fruits per plant and moderately high for number and weight of fruits per plot in the second trial. Similar results were reported by Arya and Saini (1977 a) and Singh and Brar (1979). The values were low for weight of fruits per plant and number and weight of fruits per plot in the first trial.

The genotypic coefficient of variation gives a measure of the magnitude of genetic variability present in a population and provides an index for the nature of genetic improvement to be effected. Number and weight of fruits per plant and number and weight of fruits per plot exhibited moderate and high genotypic coefficients of variation in the second trial. This gives a clear indication of the higher performance of the hybrids especially V x PR and PC-1 x PR over the four parents. Similar observations were made by Arya and Saini (1977 a), Arya and Saini (1977 b), Singh and Brar (1979) and Nair et al. (1984). In the first evaluation, the values were low for number and weight of fruits per plant and number and weight of fruits per plot. In both the trials, weight of individual fruit recorded low values. This is contrary to

the observations of Singh and Brar (1979) and Gopalakrishnan *et al.* (1985). Length of individual fruit also displayed low values in both the trials and this finding agrees with that of Singh and Brar (1979). Genotypic coefficient of variation was low for girth of individual fruit in the two evaluations, which agrees with the observation of Singh and Brar (1979) while it is contrary to the observation made by Gopalakrishnan *et al.* (1985) who reported moderate value for the character. Contrary to both these observations, Gupta and Yadav (1984) reported high genotypic coefficient of variation for girth of fruit. Plant height displayed low and moderate values in the first and second trials respectively. Singh and Brar (1979), Gupta and Yadav (1984) and Gopalakrishnan *et al.* (1985) reported low values for this character. The difference in the observations is attributed to the different populations involved in the studies. Fruit shape index and leaf area registered low values in the first trial and moderate values in the second evaluation while plant spread recorded low and moderate values in the first and second trials respectively. The difference in behaviour of several characters in the two trials is attributed to the different weather parameters which prevailed during the two trials. Days to 50 per cent flowering and height, number of branches and number of leaves at 25 days after transplanting recorded low values in the two evaluations.

Heritability estimates were low in both the trials only for three characters namely, height, number of branches and number of leaves at 25 days after transplanting. In conformity with the findings of the present study, Arya and Saini (1976), Arya and Saini (1977 a), Chang (1977), Singh and Singh (1977 a) and Singh and Rai (1981) reported high heritability values for days to 50 per cent flowering while Gill et al. (1980) observed low value for this character. Number of fruits per plant registered moderate and moderately high heritability estimates in the first and second evaluations respectively. Arya and Saini (1977 a), Ramalingam and Murugarajendran (1977), Singh and Singh (1977 a), Singh and Brar (1979), Elangovan et al. (1981), Ramkumar et al. (1981), Singh and Rai (1981) and Bavaji and Murthy (1982) reported high values for this character while Awasthi et al. (1976) observed moderate value. Low and moderately high values were recorded by weight of fruits per plant in the first and second trials respectively. Arya and Saini (1977a), Singh and Singh (1977 a) and Singh et al. (1981) reported high values while Gopalakrishnan et al. (1985) reported moderate value for this character. Moderately high and high estimates of heritability were recorded by number and weight of fruits per plot in the first and second evaluations respectively. Awasthi et al. (1976) and Singh and Singh (1977 c) reported

high values while Singh and Brar (1979) observed moderate value for weight of fruits per plot.

High values for weight of individual fruit were observed in both the experiments. Similar observations were reported by Awasthi et al. (1976), Gill et al. (1980), Elangovan et al. (1981) Singh et al. (1981) and Gopalakrishnan et al. (1985) while Singh and Brar (1979) observed moderate value for this character. In total conformity with the observations on length of individual fruit, Awasthi et al. (1976), Chang (1977), Singh and Singh (1977 a), Raju (1980), Elangovan et al. (1981), Singh and Rai (1981) and Bavaji and Murthy (1982) observed high heritability estimates for the character. Gill et al. (1980) reported moderate value while Ramalingam and Murugarajendran (1977) recorded low value for length of fruit. The observation of high heritability for girth of individual fruit was in full agreement with the findings of Awasthi et al. (1976), Singh and Singh (1977 a), Singh and Brar (1979), Gill et al. (1980), Raju (1980), Elangovan et al. (1981), Ramkumar et al. (1981), Singh and Rai (1981), Nair et al. (1984) and Gopalakrishnan et al. (1985). Gill et al. (1980) reported high value for fruit shape index.

Height of the plant exhibited moderately high and high values in the first and second experiments respectively. This is in conformity with the observations made by Arya and Saini (1976), Awasthi et al. (1976), Chang (1977), Ramalingam and Murugarajendran (1977), Singh and Singh (1977 a), Singh and Brar (1979), Raju (1980), Ramkumar et al. (1981) and Singh and Rai (1981) while it is contrary to the observation made by Gupta and Yadav (1984). Number of branches behaved in the same manner as height of the plant. The reports of Arya and Saini (1976), Awasthi et al. (1976), Arya and Saini (1977 b), Ramalingam and Murugarajendran (1977), Singh and Singh (1977 a), Singh and Rai (1981) and Bavaji and Murthy (1982) conform to this observation. In contrary, moderate value was recorded by Arya and Saini (1977 a) while Singh and Brar (1979) and Gopalakrishnan et al. (1985) reported low values for this character. Moderately high and high values were registered by spread of the plant in the first and second trials respectively. Elangovan et al. (1981) reported high heritability for the character.

Genetic advance was high in both the evaluation trials only for number of fruits per plot. Number and weight of fruits per plant and number of branches recorded moderate values. Arya and Saini (1976), Arya and Saini (1977a), Ramalingam and Murugarajendran (1977), Singh and

Singh (1977 a), Singh and Singh (1977 c), Singh and Brar (1979), Elangoven et al. (1981), Ramkumar et al. (1981), Singh et al. (1981), Bavaji and Murthy (1982) and Nair et al. (1984) observed high values for number of fruits per plant. High values of genetic advance for weight of fruits per plant were recorded by Arya and Saini (1977 a), Arya and Saini (1977 b), Singh and Singh (1977 a), Singh and Brar (1979) and Singh et al. (1981). Number of branches exhibited high genetic advance according to Singh and Rai (1981) and Bavaji and Murthy (1982) while Awasthi et al. (1976) and Singh and Brar (1979) reported low values for this trait. For all the other characters, genetic advance was low. Though the observation on weight of individual fruit is in conformity with that of Awasthi et al. (1976), it disagrees with the report made by Singh and Brar (1979). Length of fruit displayed low genetic advance as per Singh and Brar (1979) while Singh and Rai (1981) observed high value for this trait. The observation on girth of fruit is in complete agreement with the reports of Awasthi et al. (1976) and Singh and Brar (1979) while it is contrary to the observation of Singh and Rai (1981). High values for height were recorded by Awasthi et al. (1976) and Ramkumar et al. (1981) while Singh and Brar (1979) reported low value.

High heritability coupled with high genetic advance was observed only for one character namely, number of fruits per plot, indicating that this trait is less influenced by environmental factors and possesses more number of fixable additive genes. This indicates that selection can be adopted to bring about improvement in this character. Both heritability and genetic advance were moderate for number and weight of fruits per plant while in respect of number of branches, high heritability was coupled with moderate genetic advance. But several workers including Arya and Saini (1976), Awasthi et al. (1976), Arya and Saini (1977 a), Singh and Singh (1977 a), Singh and Brar (1979), Elangovan et al. (1981), Ramkumar et al. (1981), Singh and Rai (1981), Singh et al. (1981) and Bavaji and Murthy (1982) observed high heritability and genetic advance for these characters. High heritability coupled with low genetic advance was observed for all other characters except height, number of branches and number of leaves at 25 days after transplanting, which displayed low heritability and genetic advance. Thus, for all the sixteen characters studied, except number of fruits per plot, observations on heritability and genetic advance suggested the role played by non-additive gene effects and high environmental influenco. Thus the present investigation points towards the possibility of

heterosis breeding in chilli. Similar observations were recorded by Arya and Saini (1976), Awasthi et al. (1976), Arya and Saini (1977 a), Singh and Brar (1979) and Elangovan et al. (1981). Singh and Singh (1970) reported low heritability coupled with low genetic advance for several characters.

Genetic gain was high in both the evaluations only for number of branches. The values were moderately high and high in the first and second trials respectively for fruit shape index and leaf area while for number of fruits per plant, number and weight of fruits per plot and height, the values were moderate and high in the first and second evaluations respectively. With regards to weight of fruits per plant, genetic gain was low in the first trial and high in the second. Moderate values were exhibited in both the trials by weight and length of individual fruit while girth of fruit displayed low and moderate values in the first and second experiments respectively. For the remaining four characters, the values were low in both the trials. In conformity with this observation, Arya and Saini (1977 a) reported low genetic gain for days to flowering. Arya and Saini (1977 a) reported high genetic gain for number and weight of fruits per plant. High values for number of fruits per plant

were also recorded by Arya and Saini (1976), Elangovan et al. (1981) and Ramkumar et al. (1981). Elangovan et al. (1981) reported high genetic gain for weight of individual fruit while Singh and Singh (1977 c) recorded high value for length of individual fruit. Singh and Singh (1977 c) also recorded high value for girth of fruit. Moderate values for plant height were reported by Arya and Saini (1976 and 1977 a) while low values were observed by Singh and Singh (1970) and Elangovan et al. (1981). In total conformity with the observation on number of branches, Arya and Saini (1976) reported high genetic gain for the character. Ramkumar et al. (1981) observed very low value while Elangovan et al. (1981) recorded moderate value for plant spread.

5.3 Correlations among the different quantitative attributes

Days to 50 per cent flowering exhibited negative and non-significant associations and positive and non-significant correlations with number and weight of fruits per plant and number and weight of fruits per plot in the first and second evaluations respectively. Raju (1980) recorded negative correlation of this character with fruit yield and fruit number while Singh and Singh (1976 b) and Mehrotra et al. (1977) included days to flowering

among the major yield components. The difference observed between the two trials may be due to the difference in weather parameters. Height, number of branches and number of leaves at 25 days after transplanting displayed positive associations with number and weight of fruits per plant and number and weight of fruits per plot, in the first trial. Though height at 25 days after transplanting exhibited positive correlations with these four characters, the associations of number of branches and number of leaves at 25 days after transplanting with them were negative, in the second trial.

Number and weight of fruits per plant and number and weight of fruits per plot were found to exhibit positive and significant associations among them in both the evaluations. The observation agrees with the reports of several workers such as Rocchetta et al. (1976), Singh and Singh (1976 b), Chang (1977), Korla and Rastogi (1977), Mehrotra et al. (1977), Raju (1980), Ramkumar et al. (1981), Rao and Chhonkar (1981), Bavaji and Murthy (1982), Joshi and Singh (1983), Rao and Chhonkar (1983a), Nair et al. (1984) and Gopalakrishnan et al. (1985). Contrary to these reports, Arya and Saini (1976) reported negative association of fruit number with yield. The correlation of number of fruits with yield was amply demonstrated by the hybrids V x PR and PC-1 x PR which occupied the first and second places respectively with regards to yield in both the trials.

Weight of individual fruit displayed negative associations with number of fruits per plant and number of fruits per plot while its correlations with weight of fruits per plant and weight of fruits per plot were positive. These were in conformity with the findings of Korla and Rastogi (1977), Rao and Chhonkar (1981), Nair et al. (1984), and Gopalakrishnan et al. (1985). In the present study, it was found that the hybrid V x PC1 which possessed the maximum weight of individual fruit produced only lesser number of fruits than the other four hybrids. But when the fruit yield was taken into consideration, this hybrid performed better than V x PC-1 and PC-1 x PC1.

Though the associations of length of individual fruit with number and weight of fruits per plant and number and weight of fruits per plot were positive in the first evaluation, the correlations with these characters in the second trial were negative. Korla and Rastogi (1977) and Sharma et al. (1981) recorded negative associations between fruit length and number of fruits. Positive correlations of fruit length with yield were observed by Singh and Singh (1976 b), Chang (1977), Sharma et al. (1981), Joshi and Singh (1983) and Gopalakrishnan et al. (1985) while Korla and Rastogi (1977) observed negative association between fruit length and yield. The hybrids V x PC-1, V x PC1 and

PC-1 x PC1 with more fruit length than the remaining two hybrids were inferior to them with respect to number of fruits, when the pooled means were taken into account. This resulted in reduced yield of these three hybrids compared to V x PR and PC-1 x PR.

Girth of individual fruit exhibited negative association with number of fruits per plant in both the trials and number of fruits per plot in the first trial. The positive correlation of fruit girth with number of fruits per plot in the second trial was non-significant. Korla and Rastogi (1977) reported negative association between girth and number of fruits per plant while Sharma et al. (1981) observed positive correlation between these two traits. The association of fruit girth with weight of fruits per plant was positive in both the trials while the correlation with weight of fruits per plot was negative and positive in the first and second trials respectively. Positive associations between girth of fruit and yield were reported by many workers (Mehra and Peter, 1980; Raju, 1980; Sharma et al. 1981; Rao and Chhonkar, 1983 and Nair et al. (1984)). According to Korla and Rastogi (1977) and Gopalakrishnan et al. (1985) the correlation between fruit girth and yield was negative. The positive association between fruit girth and yield was amply demonstrated by the hybrid V x PR.

The longer the fruits, the lesser would be the girth as indicated by the present findings since the association between these two attributes were negative in both the evaluations. Weight of fruits enhances with increase in girth as inferred from the significant positive association between these two characters. Weight increased with increase in length of fruit in the first trial while the reverse happened in the second evaluation. This is attributed to the influence of the weather parameters which prevailed during the two trials.

Fruit shape index displayed positive correlations with number and weight of fruits per plant and number and weight of fruits per plot in the first trial. Though the association of this trait was positive with number of fruits per plant in the second trial, the correlations were negative with weight of fruits per plant and number and weight of fruits per plot.

Though in the first trial, leaf area exhibited negative correlations with number and weight of fruits per plant and number and weight of fruits per plot, the associations of leaf area with these four traits were positive in the second trial. Sharma et al. (1981) reported positive association between leaf area and fruit yield per plant. Here also, the difference observed

between the two trials is attributed to the different weather parameters. Though V x PR displayed lesser leaf area than PC-1 x PR, fruit yield was more for this hybrid.

In both the evaluations, plant height was positively associated with number and weight of fruits per plant and number and weight of fruits per plot. Korla and Rastogi (1977), Raju (1980) and Ramkumar et al. (1981) made similar observations while Arya and Saini (1976) and Gopalakrishnan et al. (1985) recorded contrary findings. In the present study, V x PR and PC-1 x PR with more height performed better than the remaining three hybrids, with respect to yield.

Number of branches behaved in the same manner as height with respect to its associations with the four characters namely, number and weight of fruits per plant and number and weight of fruits per plot. The observations of Mehrotra et al. (1977), Rao and Chhonkar (1981), Bavaji and Murthy (1982), Joshi and Singh (1983) and Nair et al. (1984) were in full agreement with these findings. The hybrids V x PR and PC-1 x PR had more number of branches than the remaining three hybrids. Plant spread also performed in the same manner as height and number of branches. Raju (1980) and Ramkumar et al.

(1981) recorded observations which were in conformity with this finding. The hybrids V x PR and PC-1 x PR exhibited more plant spread than the remaining three hybrids.

5.4 Heterosis

In general, most of the hybrids studied displayed comparatively higher magnitudes of the three types of heterosis computed namely, relative heterosis, heterobeltiosis and standard heterosis.

Out of the five hybrids, three hybrids namely V x PR, V x PC1 and PC-1 x PR were found to manifest negative ralative heterosis when days to 50 per cent flowering was taken into account. This indeed is a desirable attribute as far as a vegetable crop is concerned. The remaining two hybrids availed more number of days to 50 per cent flowering than their mid-parental values. When heterobeltiosis and standard heterosis were considered, all the hybrids displayed positive heterosis. Earliness in blooming in hybrids was reported by many earlier workers including Nair (1970), Nair and George (1973), Singh and Singh (1976a), Singh and Singh (1976d), Nair (1981) and Sekar and Arumugam (1985). All these workers have also observed positive heterosis for this character in some of the hybrids studied by them.

Though the increase in height was less, all the hybrids manifested positive heterosis with regards to height at 25 days after transplanting. The five hybrids behaved in the same manner with respect to number of branches at 25 days after transplanting, except PC-1 x PR which exhibited negative heterobeltiosis and standard heterosis. More number of leaves were produced at 25 days after transplanting by all hybrids compared to their mid-parental values. These findings indicate that heterosis is being manifested from the early growth phase of the crop. This is in conformity with the findings of Deshpande (1933), the pioneer worker in heterosis breeding in chilli. The hybrids V x PR and PC-1 x PR displayed a decrease in number of leaves at 25 days after transplanting than their corresponding better parents and the standard variety Vellanotchi.

Singh and Singh (1976d), Pillai et al. (1977), Joshi and Singh (1980), Nair (1981), Pandey et al. (1981), Uzo (1984) and Sekar and Arumugam (1985) reported the manifestation of heterosis with respect to number of fruits per plant. In total conformity with their findings, all the hybrids in the present study displayed positive heterosis with respect to number of fruits per plant, except one hybrid namely V x PC-1 which exhibited negative relative

heterosis and heterobeltiosis. The hybrid V x PR exhibited the maximum increase in percentage in number of fruits per plant over the mid-parental value (249.10) and better parent (222.35) followed by PC-1 x PR (171.53 and 81.89) while maximum standard heterosis was exhibited by PC-1 x PR (356.14 per cent) followed by V x PR (222.35 per cent).

All the five hybrids manifested positive relative heterosis and heterobeltiosis except one hybrid namely V x PC-1 and positive standard heterosis was exhibited by V x PR, V x PC1 and PC-1 x PR, when weight of fruits per plant was taken into account. V x PR displayed maximum relative heterosis (132.82 per cent) and standard heterosis (77.84 per cent) followed by PC-1 x PR (114.60 per cent and 41.33 per cent) while maximum increase in percentage in weight of fruits per plant over the better parent was displayed by PC-1 x PR (78.96) closely followed by V x PR (77.81). Reports in support of these findings include those of Lippert (1975), Singh and Singh (1976d), Sharma and Saini (1977), Joshi and Singh (1980), Nair (1981), Pandey et al. (1981) and Uzo (1984).

The present work elucidated that the hybrids with more number of fruits produced higher yields indicating the attribute as a major yield component.

As in the case of number of fruits per plant, all the hybrids exhibited positive relative heterosis and standard heterosis except V x PC-1 which manifested negative relative heterosis with respect to number of fruits per plot. Three hybrids namely V x PR, V x PC1 and PC-1 x PR produced more number of fruits per plot than their respective better parents. Here also, V x PR which topped the list in respect of relative heterosis (319.98 per cent) and heterobeltiosis (263.44 per cent) was followed by PC-1 x PR (137.88 per cent and 54.68 per cent). Standard heterosis was maximum for PC-1 x PR (276.18 per cent) which was followed by V x PR (263.44 per cent). Heterosis with respect to total number of fruits was reported by Deshpande (1933) and Singh and Singh (1976a).

When weight of fruits per plot was taken into consideration, all the hybrids exhibited positive heterosis. The maximum increase in percentage over the mid-parental value, better parent and standard variety was displayed by V x PR (236.18, 169.85 and 169.85) followed by PC-1 x PR (81.90, 46.42 and 45.34). Heterosis with respect to total yield was observed by Deshpande (1933), Rocchetta et al. (1976), Singh and Singh (1976 a), Singh and Singh (1978 c), Shifriss and Sacks (1980) and Nair (1981).

With respect to weight of individual fruit, only two hybrids namely, V x PCl and PC-1 x PCl manifested positive relative heterosis. Heterobeltiosis and standard heterosis was negative for all the hybrids. Lippert (1975), Pillai et al. (1977) and Shifriss and Sacks (1980) reported increased weight of fruits. According to Nair (1981), the value of positive heterosis was negligible for fruit weight while Uzo (1984) observed no detectable increase in average weight of fruit over the better parent. It is interesting to note that the hybrids V x PR and PC-1 x PR with more number and weight of fruits manifested negative heterosis with respect to weight of individual fruit. This reveals the fact that increase in weight of individual fruit leads to a reduction in number of fruits, consequently bringing about a decrease in yield.

All the hybrids except V x PR displayed positive relative heterosis with respect to length of individual fruit while two hybrids namely V x PC-1 and PC-1 x PCl exhibited positive heterobeltiosis. Standard heterosis was positive only for V x PC-1. Lippert (1975), Singh and Singh (1976 a), Singh and Singh (1976 d), Joshi and Singh (1980) and Sekar and Arumugam (1985) reported increased length of fruits in some of the hybrids studied by them while Nair (1981) observed only negligible

positive heterosis for fruit length. The highest yield obtained by V x PR is attributed to increased number of fruits resulting from lesser weight of individual fruit consequent on reduced length of fruit.

Only one hybrid namely V x PC1 manifested positive relative heterosis while heterobeltiosis and standard heterosis were negative for all the hybrids with respect to girth of individual fruit. Increase in fruit girth was reported by Lippert (1975), Singh and Singh (1976 a), Singh and Singh (1976 d) and Sekar and Arumugam (1985) while negligible positive heterosis was observed for this character by Nair (1981). From the results obtained, it is inferred that the decrease in fruit girth has an indirect bearing on increased yield through weight of individual fruit and number of fruits. With respect to fruit shape index, three hybrids namely V x PC-1, V x PC1 and PC-1 x PC1 exhibited positive relative heterosis and standard heterosis while heterobeltiosis was positive only for V x PC1. The hybrids V x PR and PC-1 x PR displayed negative values for the three types of heterosis.

Positive relative heterosis with respect to leaf area was displayed by three hybrids namely V x PC-1, V x PR and PC-1 x PR while only V x PC-1 exhibited positive heterobeltiosis. Standard heterosis was positive for all

the five hybrids. Earlier workers including Nair (1970) and Uzo (1984) recorded positive heterosis for leaf area. The hybrids V x PR and PC-1 x PR exhibited very high percentage increase in leaf area over the standard variety Vellanotchi.

All the five hybrids manifested positive relative heterosis while V x PR and PC-1 x PR exhibited positive heterobeltiosis with respect to plant height. Increased height over the standard variety Vellanotchi was displayed by all the hybrids except V x PC1. Positive heterosis for height was observed by Deshpande (1933), Nair (1970), Pillai et al. (1977), Sharma and Saini (1977), Joshi and Singh (1980), Nair (1981), Uzo (1984) and Sekar and Arumugam (1985). It can be inferred from these findings that the high yield of V x PR and PC-1 x PR were dependent on another yield component also, namely, height of the plant.

When number of branches was considered, all hybrids except V x PC1 exhibited positive relative heterosis. Though only two hybrids namely V x PR and PC-1 x PR exhibited positive heterobeltiosis, all the hybrids except V x PC1 displayed positive standard heterosis. Increase in number of branches in hybrids was observed by Nair (1970) Nair and George (1973), Singh and Singh (1976 a), Singh

and Singh (1976 d), Joshi and Singh (1980) and Nair (1981). The enhancement in yield consequent to increase in number of branches is fully demonstrated by the hybrids V x PR and PC-1 x PR.

When spread of the plant was taken into account, all the hybrids manifested positive heterosis except V x PC-1 which displayed negative heterobeltiosis. Nair (1970 and 1981) also recorded similar observations on plant spread. Here also, the increase in spread was more for the higher yielding hybrids namely V x PR and PC-1 x PR.

5.5 Life span and number of pickings

The hybrid PC-1 x PR had the longest life span (200.50 days) and the maximum number of pickings (10) were obtained from this hybrid. The hybrids V x PR and PC-1 x PCl followed PC-1 x PR in these two aspects. In spite of the shorter life span and lesser number of pickings than PC-1 x PR, the hybrid V x PR recorded the highest yield, probably owing to heavier fruits. Though PC-1 x PCl had the same duration and number of pickings as that of V x PR its yield was considerably lower due to a decrease in number of fruits, weight of individual fruit, height, number of branches and spread compared to V x PR.

The hybrids V x PC-1 and V x PC1 had the shortest life span and lowest number of pickings among the five hybrids. But V x PC1 yielded higher than V x PC-1. This is attributed to the fact that though V x PC1 produced only lesser number of fruits than V x PC-1, the weight of individual fruit was considerably higher for V x PC1, resulting an increase in total yield. The positive association between life span and yield was clearly demonstrated by Nair (1981) in a study of eighteen quantitative traits in a 9 x 9 diallel.

From the present study it may be inferred that the ideal plant type in chilli to tap high yield potential would be one with earliness in flowering coupled with more number of medium sized fruits, moderate number of branches and spread, reasonable height and fairly long life span, as indicated by the hybrids V x PR and PC-1 x PR. An almost similar suggestion was put forth by Raju (1980).

5.6 Observations on qualitative characters

From the various observations recorded on the qualitative characters studied, it could be seen that the purple pigmentation of the stem in the present namely Purple Round was not fully inherited in the hybrids V x PR and PC-1 x PR. This character can be considered as partially dominant. With respect to the pigmentation of the leaf, the purplish

tinge in Purple Round was not expressed in the hybrids V x PR and PC-1 x PR. It may be due to the recessive nature of this character or the presence of some inhibitory factors which prevent its expression, as suggested by Nair (1970). In the hybrids V x PCl and PC-1 x PCl the purple pigmentation of the stem and the purplish tinge of the leaves in Purple Cluster was totally absent. Here also, the recessive nature or the presence of inhibitory factors may be the cause. Purple pigmentation of the flowers in Purple Round was completely dominant in the hybrids V x PR and PC-1 x PR while the deep purple pigmentation in Purple Cluster was only partially expressed in V x PCl and PC-1 x PCl.

The light green colour of the fruit in Vellanotchi was fully expressed in the hybrid V x PC-1. Similarly, the purple colour in Purple Round was dominant in V x PR and PC-1 x PR. But in the hybrids V x PCl and PC-1 x PCl there was only partial pigmentation inherited from Purple Cluster. In the hybrids V x PC-1, V x PR and V x PCl, the drooping nature of the fruit in Vellanotchi was dominant while in PC-1 x PR, the semi-erect nature of Purple Round was dominant. Since both Pant C-1 and Purple Cluster have erect fruits, the hybrid PC-1 x PCl also produced fruits which were erect in orientation.

The results obtained from the present study provide ample evidence for the exploitation of desirable heterosis in many economic attributes in chilli. The investigation could identify two chilli hybrids (V x PR and PC-1 x PR) with desirable economic attributes. These two hybrids outyielded the standard variety Vellanotchi by 169.85 per cent and 45.34 per cent respectively in weight of fruits per plot. The hybrid V x PR, which outyielded the other four hybrids as well as the parents, was also bestowed with several other desirable economic attributes like enhanced number of fruits per plant (174.78), increased height (95.45 cm), number of branches (281.40) and spread (78.20 cm) and a comparatively longer life span (182 days). Though the hybrid PC-1 x PR possessed increased number of fruits per plant (247.32), height (116.26 cm), number of branches (597.67), spread (93.19 cm) and life span (190 days) compared to V x PR, the yield was lesser than that of V x PR. This is attributed to the fact that in V x PR, coupled with increased number of fruits, the fruits were heavier than the fruits produced by PC-1 x PR. The production of a reasonably high number of seeds per pollination makes the prospects of hybrid seed production more promising in chilli. The hybrids V x PR and PC-1 x PR provide ample evidence for augmenting the yield potential in chilli through heterosis breeding.

SUMMARY

6. SUMMARY

With the objective of evaluating the productivity of six intervarietal chilli (Capsicum annuum L.) hybrids, a study was conducted in the Department of Plant Breeding, College of Agriculture, Vellayani. Four parents namely, Vellanotchi, Pant C-1, Purple Round and Purple Cluster were selfed for one generation and the inbreds crossed in all possible combinations without reciprocals. Since the germination of one of the combinations namely PR x PC1 was very poor, it could not be included in the study. The other five hybrids and the four parents were laid out in a 9 x 3 RBD during 1984-'85 and 1985-'86 and evaluated for twenty quantitative and five qualitative attributes.

The observations on sixteen quantitative traits were statistically analysed which included the analysis of variance, pooled analysis and the estimation of genetic parameters, correlations among sixteen characters and the three types of heterosis namely, relative heterosis, heterobeltiosis and standard heterosis. The local variety Vellanotchi was taken as the standard. The salient results of the study are summarised below.

6.1 Analysis of variance

The analysis of variance revealed significant differences among the genotypes for the characters studied, except number of branches and number of leaves at 25 days after transplanting, in both the evaluations. The pooled analysis conducted for fourteen traits revealed genotype x environment interaction for five characters namely, days to 50 per cent flowering, length of individual fruit, fruit shape index, height and spread of the plant. Among the fourteen characters subjected to pooled analysis, all except height at 25 days after transplanting and number of branches exhibited significant differences.

6.2 Genetic parameters

The maximum phenotypic and genotypic variances were displayed by number of fruits per plot in both the evaluations. Weight of fruits per plant and number of branches also exhibited high values for the two types of variances. Number of branches registered the maximum phenotypic and genotypic coefficients of variation in both the trials. Though the values were low for number and weight of fruits per plant and number and weight of fruits per plot in the first evaluation, these characters exhibited moderate and high values in the second trial.

Heritability estimates were high in both the evaluations for six characters namely, days to 50 per cent flowering, weight, length and girth of individual fruit, fruit shape index and leaf area. Moderate and moderately high values were exhibited by number of fruits per plant in the first and second trials respectively while weight of fruits per plant recorded low and moderately high values in the first and second evaluations respectively. Number and weight of fruits per plot displayed moderately high values in the first trial and high values in the second. Height, number of branches and spread behaved in the same manner as number and weight of fruits per plot while height, number of branches and number of leaves at 25 days after transplanting registered low values in both the evaluations. Genetic advance was high in the two trials only for one character namely, number of fruits per plot. Number and weight of fruits per plant and number of branches recorded moderate values. Genetic advance was low for the remaining twelve characters.

High heritability coupled with high genetic advance was observed for number of fruits per plot, indicating the presence of more number of fixable additive genes for selection and low environmental influence. Heritability and genetic advance were moderate for number and weight

of fruits per plant while number of branches manifested high heritability coupled with moderate genetic advance. Low heritability and genetic advance were displayed by height, number of branches and number of leaves at 25 days after transplanting while for the remaining nine traits, high heritability coupled with low genetic advance was observed. Thus, all the sixteen characters studied, except number of fruits per plot, appeared to be under the control of non-additive genes, a condition conducive for genetic improvement through heterosis breeding.

Genetic gain was high in both the evaluations only for number of branches. Number of fruits per plant and number and weight of fruits per plot exhibited moderate and high values in the first and second trials respectively while weight of fruits per plant registered low genetic gain in the first experiment and high value in the second.

6.3 Correlations among the different quantitative attributes

The four most important quantitative attributes namely, number and weight of fruits per plant and number and weight of fruits per plot displayed significant positive associations among them in both the evaluations.

Days to 50 per cent flowering exhibited negative non-significant associations and positive non-significant correlations with these four characters in the first and second trials respectively. Height at 25 days after transplanting exhibited positive correlations with the four traits while associations of number of branches and number of leaves at 25 days after transplanting with them were negative in the second trial. Weight of individual fruit was negatively associated with number of fruits per plant and number of fruits per plot while its correlations with weight of fruits per plant and weight of fruits per plot were positive. The associations of length of individual fruit with the four characters were positive in the first trial and negative in the second. The correlations of girth of individual fruit were negative with number of fruits per plant in the two trials and number of fruits per plot in the first trial. The character was positively associated with weight of fruits per plant in both the trials and weight of fruits per plot in the second trial. Fruit shape index displayed positive correlations with number and weight of fruits per plant and number and weight of fruits per plot in the first trial and number of fruits per plant in the second trial. The character was negatively associated with weight of fruits per plant, and number

and weight of fruits per plot, in the second trial. Leaf area registered negative and positive correlations with number and weight of fruits per plant and number and weight of fruits per plot in the first and second experiments respectively. The difference in the performance of several characters observed in the two trials is attributed to the influence of the weather parameters which prevailed during the two evaluations. Height, number of branches and spread exhibited positive associations with number and weight of fruits per plant and number and weight of fruits per plot in both the trials.

6.4 Heterosis

Although the percentage of heterosis varied, most of the hybrids studied displayed desirable magnitudes of the three types of heterosis namely, relative heterosis, heterobeltiosis and standard heterosis.

When days to 50 per cent flowering was taken into account, three out of the five hybrids manifested negative relative heterosis, which is a desirable attribute as far as a vegetable crop is concerned. All the hybrids displayed an increase in height at 25 days after transplanting. Most of the hybrids also exhibited enhanced number of branches and number of leaves at 25 days after transplanting, which shows that manifestation of hybrid vigour starts from the

early growth phase of the crop. Positive heterosis with respect to number of fruits per plant was exhibited by all the hybrids except V x PC-1. When weight of fruits per plant was taken into account, positive relative heterosis and heterobeltiosis were recorded by all the hybrids except V x PC-1. Three hybrids exhibited positive standard heterosis for this character. As regards number of fruits per plot, all hybrids except V x PC-1 registered positive relative heterosis and standard heterosis while three hybrids produced more number of fruits per plot than their respective better parents. The five hybrids exhibited positive heterosis for weight of fruits per plot. Only two hybrids manifested positive relative heterosis with respect to weight of individual fruit. Heterobeltiosis and standard heterosis were negative for all the hybrids. Four hybrids displayed positive relative heterosis with respect to length of individual fruit. Positive relative heterosis for girth of individual fruit was registered by one hybrid only. Heterobeltiosis and standard heterosis were negative for the five hybrids with respect to fruit girth. Positive relative heterosis and standard heterosis were registered by three hybrids while positive heterobeltiosis was recorded by only one hybrid when fruit shape index was considered. Three hybrids displayed positive relative heterosis while only one hybrid recorded

positive heterobeltiosis with respect to leaf area. Standard heterosis was positive for the five hybrids. All the five hybrids manifested positive relative heterosis for plant height. With respect to number of branches, all except V x PC-1 displayed positive relative heterosis. Two hybrids recorded positive heterobeltiosis while four hybrids exhibited positive standard heterosis when height and number of branches were taken into consideration. All the hybrids except V x PC-1 registered positive heterosis with respect to plant spread.

5.5 Life span and number of pickings

The longest life span (200.50 days) and the maximum number of pickings (10) were recorded by PC-1 x PR followed by two hybrids namely V x PR and PC-1 x PCl. The increased yield produced by V x PR over PC-1 x PR is attributed to its heavier fruits. The hybrids V x PC-1 and V x PCl registered the shortest life span and the lowest number of pickings among the five hybrids.

Based on the results obtained from the present study, the ideal plant type in chilli for enhanced yield potential may be suggested to be one with earliness in flowering, more number of medium sized fruits, reasonable height, number of branches and spread and fairly long life span.

5.6 Observations on qualitative characters

The purple pigmentation of the stem in Purple Round was only partially dominant in the hybrids V x PR and PC-1 x PR while the purplish tinge of the leaves was totally concealed in the two hybrids. In the hybrids V x PCl and PC-1 x PCl, the purple pigmentation in Purple Cluster was totally absent. With respect to pigmentation of the flower, the character was dominant in the hybrids V x PR and PC-1 x PR and partially expressed in V x PCl and PC-1 x PCl. Pigmentation of the fruit also behaved in the same manner. Three hybrids produced drooping fruits while another hybrid produced semi-erect fruits. PC-1 x PCl produced erect fruits.

Two chilli hybrids with desirable economic attributes were identified from the present study. The hybrid V x PR outyielded the standard variety Vellanotchi by 77.81 per cent with respect to weight of fruits per plant while the increase in the hybrid PC-1 x PR was 41.33 per cent. The present study points towards the possibility of augmenting the yield potential of chilli by exploiting hybrid vigour. The reasonably high reproductive potential makes the prospect of hybrid seed production in this crop more promising.

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* Original not seen.

PLATES

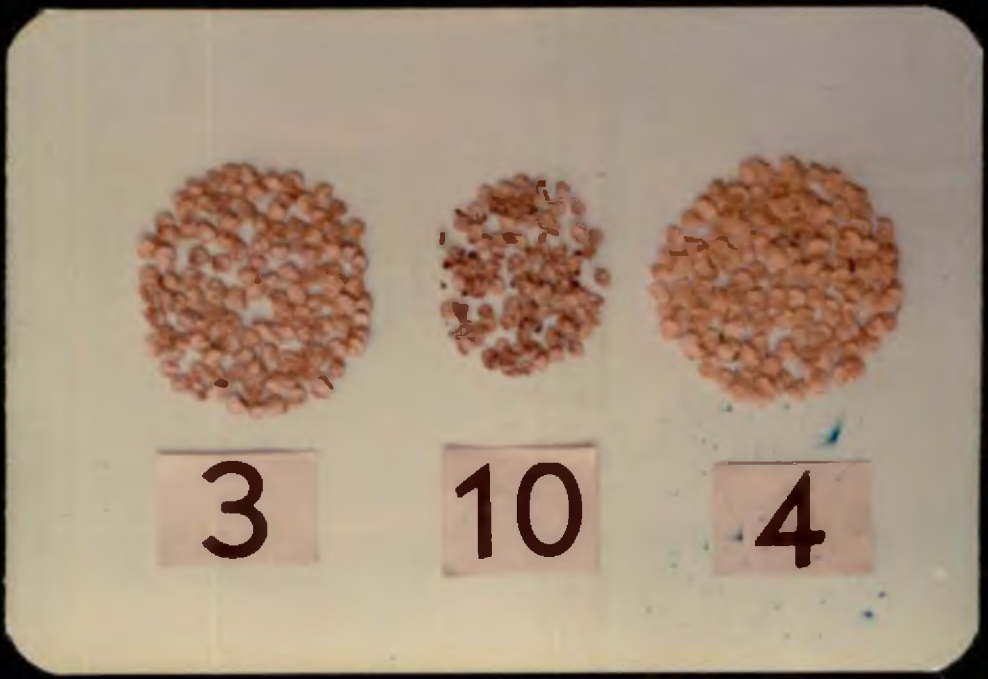
Plate 1

3 - Longitudinal section of the fruit of Purple Round

10 - Longitudinal section of the crossed fruit of Purple Round x Purple Cluster

4- Longitudinel section of the fruit of Purple Cluster

Plate 2



3 - Seeds obtained from the fruits of Purple Round

10 - Seeds obtained from the crossed fruits of Purple Round x Purple Cluster

4 - Seeds obtained from the fruits of Purple Cluster

EVALUATION OF THE PRODUCTIVITY OF CHILLI HYBRIDS

By

ELIZABETH PHILIPOSE

ABSTRACT OF A THESIS
SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENT FOR THE DEGREE
MASTER OF SCIENCE IN AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF PLANT BREEDING
COLLEGE OF AGRICULTURE
VELLAYANI, TRIVANDRUM.

1986

ABSTRACT

A study was conducted at College of Agriculture, Vellayani, for evaluating the productivity of six inter-varietal chilli (Capsicum annuum L.) hybrids obtained by crossing four inbreds in all possible combinations without reciprocals. Since the germination of the combination PR x PCl was poor, the other five hybrids along with the four parents were evaluated in a 9 x 3 RBD during 1984- '85 and 1985- '86. Observations on twenty quantitative and five qualitative attributes were recorded. The statistical analysis included analysis of variance, pooled analysis and the estimation of genetic parameters, correlations among sixteen quantitative traits and three types of heterosis namely relative heterosis, heterobeltiosis and standard heterosis.

Significant treatment differences were observed for the characters studied, except number of branches and number of leaves at 25 days after transplanting in both the trials, as revealed by the analysis of variance. The pooled analysis revealed genotype x environment interaction for days to 50 per cent flowering, length of individual fruit, fruit shape index, height and spread while significant treatment differences existed for all the traits except number of branches. Among the characters studied,

number of fruits per plot exhibited the maximum phenotypic and genotypic variances in both the evaluations. Maximum phenotypic and genotypic coefficients of variation were displayed by number of branches in both the trials. High heritability coupled with high genetic advance was observed for number of fruits per plot, indicating the presence of more number of fixable additive genes for selection and low environmental influence. Observations on heritability and genetic advance of the other fifteen characters studied indicated the presence of non-additive genes, a condition conducive for genetic improvement through heterosis breeding.

Correlation studies revealed significant positive associations among number and weight of fruits per plant and number and weight of fruits per plot. Weight and girth of individual fruit were found to contribute positively to total yield while the association of these traits with number of fruits was negative. Height, number of branches and spread exhibited positive correlations with number and weight of fruits per plant and number and weight of fruits per plot.

Desirable magnitudes of the three types of heterosis namely relative heterosis, heterobeltiosis and standard heterosis were displayed by most of the hybrids studied. Majority of the hybrids exhibited positive heterosis for the

four most important traits namely, number and weight of fruits per plant and number and weight of fruits per plot. Similar observations were recorded on the yield contributing characters namely height, number of branches and spread.

The hybrid PC-1 x PR registered the longest life span and the maximum number of pickings. Two hybrids produced totally purple fruits. The fruits were drooping in three hybrids, semi-erect in one hybrid and erect in PC-1 x PC1. The study could identify two promising hybrids namely, V x PR and PC-1 x PR with high yield potential.

The results obtained from the present study pointed out the possibility of augmenting the yield potential in chilli by employing heterosis breeding.