COMBINING ABILITY IN BHINDI

(*Abelmoschus esculentus* (L.) Moench)

By

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THESIS
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for
my parents

DECLARATION

I hereby declare that this thesis entitled "Combining ability in bhindi (*Abelmoschus esculentus* (L.) Moench)" 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.

B. RAJANI

Vellayani,
4-10-1995

CERTIFICATE

Certified that this thesis entitled "Combining ability in bhindi (*Abelmoschus esculentus* (L.) Moench)" is a record of research work done independently by Kum.B.Rajani under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Introduction

1. INTRODUCTION

Bhindi (Abelmoschus esculentus (L.) Moench) has captured a prominent position among the vegetables due to its year round cultivation, export potential and high nutritive value, containing vitamins A, B and C, protein, minerals and iodine. It is also believed to be very useful against genito-urinary disorders, spermatorrhoea and chronic dysentry.

The chromosome number (2n) of bhindi has variously been reported to be 66, 92, 108, 118, 120, 122, 124, 126, 130, 132, 134 and 144 (Siemonsma, 1982). However, majority of the investigators agree that the species has 2n=30 chromosomes. Allopolyploid nature of Abelmoschus esculentus has been reported by Joshi and Hardas (1956).

Experimentally it has been found that there is no significant difference in fruit set under open pollinated and self pollinated conditions indicating that it is potentially a self pollinated crop. The inbreeding depression, well pronounced in cross pollinated crops, has not been reported in this crop. Though essentially self pollinated, because of its showy corolla, the possibility of cross pollination by insects cannot be ruled out. Consequently cross pollination to the extent of 4.0 - 19.0%

(Purewal and Randhawa, 1947; Choudhary and Choomsai, 1970) with maximum of 42.2% (Mitidieri and Vencovsky, 1974) has been reported.

The quick rate of growth, short duration and photo-insensitive nature of bhindi enables the geneticists and breeders to raise the crop round the year and thus achieve the results in a shorter period. Besides these qualities, its large flowers and monadelphous nature of the stamens make emasculation and pollination processes easier. Success in crossing is also fairly high besides the large number of the seeds borne on a single fruit. Exploitation of heterosis has been attempted in this crop and hybrid vigour has been reported with as much as 86% increased yield (Elmaksoud *et al*., 1986).

Precise information on the genetic architecture of a population under improvement is necessary for formulating an effective breeding programme. The genetic improvement of the population depends largely upon the nature and relative magnitude of components of variance and gene effects. Combining ability of parents is becoming increasingly important in plant breeding especially in hybrid production. It is useful in connection with the testing procedures in which it is desired to study and compare the performance of the lines in hybrid combinations.

Information on the relative size of general and specific combining abilities will be helpful in the analysis and interpretation of the genetic basis of important traits. Therefore the present study was undertaken with a view to assess the combining ability, nature of gene action and extent of heterosis manifested with respect to yield and its components using six genetically divergent lines of bhindi in a diallel analysis and to select superior cross combinations by evaluating the hybrids.

Review of Literature

2. REVIEW OF LITERATURE

Bhindi is an important vegetable crop cultivated extensively throughout India due to its high adaptability over a wide range of environmental conditions. The recent trend in breeding of bhindi is the development of hybrid varieties and this is achieved through the exploitation of heterosis for major characters like earliness and high yield. Commercial exploitation of hybrid vigour has not been practised fully in this crop even though considerable extent of heterosis for yield has been reported by various authors. Information on the combining ability of the divergent parents involved in hybridisation and also on the nature of gene action play an important role in the production of superior hybrids. A review of the reports on research already made in the above context is being attempted here.

2.1 Mean performance

Information on the mean performance of the parents and hybrids is essential for the comparison of the parents and hybrids and for determining the extent of variation existing for the different traits. Hence the estimation of the mean performance of the genotypes for the various characters is a pre-requisite for any breeding programme.

Raman (1965) studied the bhindi hybrids from crosses with Pusa Sawani and Pusa Makhmali as pollen parents and five other varieties as female parents and observed that some hybrids showed early flowering, early maturity, high individual fruit weight, increased number of nodes and also increased shoot length and weight.

Akram and Shafi (1971) crossed five varieties of bhindi in a diallel fashion to obtain 20 F_1 hybrids. Compared with the mean of the parents, the F_1S had better looking fruits which were more tender and softer.

Fifteen hybrids from a diallel cross of six varieties of bhindi were studied by Rao and Giriraj (1974). They found ten hybrids giving higher fruit yield than the control (Pusa Sawani) mainly due to many pods per plant and seeds per fruit.

Rao (1977) crossed seven tester varieties of bhindi each with two female lines and on the basis of mean performance, found varieties White Velvet and Emarald and hybrids White Velvet x Rajas Septilatus and White Velvet x IC 9223 to show increased plant height among males, females and hybrids respectively. Significant differences were observed within females and hybrids for number of pods per plant indicating high degree of genetic variation for number of pods compared to other characters.

Singh et al. (1980) studied 43 genetic stocks of okra comprising 13 parents and 30 hybrids. They observed a wide range of variability for most of the characters studied.

Pratap et al. (1981) observed that in an evaluation of a seven parent half diallel cross in bhindi, some hybrids had a lower incidence of yellow vein mosaic virus than their respective parents.

In a diallel cross among six varieties of bhindi, Rao and Ramu (1981) found AE.107, Sevendhari and Pusa Sawani to be the best parents. The best crosses were Pusa Sawani x Dwarf Green, Pusa Sawani x AE. 107 and Sevendhari x Dwarf Green.

In a line x tester analysis of bhindi Palaniveluchamy et al. (1983) reported significant variability in six yield related characters. Variability within the crosses was found to be moderate to low.

Reddy et al. (1985) evaluated eight varieties of bhindi and their 28 F_1 hybrids for yield, plant height and six other related characters and found wide variability for fruit yield per plant and plant height.

Agarrado and Rasco (1986) crossed ten inbred lines of bhindi in a diallel fashion and evaluated the parents and hybrids for yield and its components. They found the hybrid 124977 x 370028 to be the best one as compared to the standard cultivar Smooth Green.

Singh (1986) observed significant differences between parents and hybrids for all traits studied in a line × tester analysis in bhindi involving 25 lines and 5 testers.

Balakrishnan and Balakrishnan (1988) studied variability in bhindi for 11 quantitative characters in 15 intervarietal crosses involving seven parents and found high variability for yield per plant and plant height and low variability for number of ridges per fruit and fruit girth.

An evaluation of 12 different genotypes of bhindi by Vijayaraghavakumar and Sheela (1988) revealed the hybrids Sevendhari x Kilichundan and Selection 2-2 x Kilichundan to show superiority than the rest.

In a 7 x 7 full diallel analysis in bhindi, Veeraraghavathatham and Irulappan (1991b) adjudged three crosses AE.974 x AE. 180, AE. 974 x Pusa Sawani and AE. 974 x Punjab Padmini to be the best among the 42 combinations based on mean performance for yield and certain component traits like number of fruits, individual fruit weight, fruit length and fruit girth.

Significant variation for all traits studied was observed by Patel and Dalal (1992) among seven genotypes of bhindi and their F_1 hybrids.

Singh and Mandal (1993) studied 15 F_1 hybrids derived from six varieties of bhindi and observed the highest total yield for the hybrid Selection 7 x KS 312 followed by Parbhani Kranti x KS 312.

Suresh et al. (1994) evaluated nine F_1 hybrids and a check variety for five characters and reported significant differences between treatments with respect to fruit yield per plant and fruits per plant, whereas days to 50 per cent flowering, fruit length and fruit girth did not exhibit much differences.

2.2 Combining ability

Information on the nature of general and specific combining ability with respect to parents and hybrids will facilitate the breeder to plan the breeding programmes effectively.

Akram and Shafi (1967) while studying the combining ability of five varieties of bhindi and their hybrids found high general combining ability effects for leaf number and fruit weight and high specific combining ability effects for time required for seed germination, leaf number, earliness, plant height and total yield.

Rao and Ramu (1975) raised 15 hybrids of bhindi obtained by diallel crossing of six parents along with their parents and found AE. 107 and Sevendhari to be good combiners for pod length and number of edges on the pod. White Velvet was a good combiner for pod girth.

Kulkarni (1976) conducted biometrical investigations in bhindi and found Sevendhari and AE. 107 as good combiners for days to flowering, plant height and number of pods per plant. Crosses of Sevendhari with Pusa Sawani and Dwarf Green showed good specific combining ability for all the three characters. Ramu (1976) also found AE. 107, Sevendhari and Pusa Sawani to be good combiners for many characters. The crosses Pusa Sawani x Dwarf Green, Pusa Sawani x White Velvet and Sevendhari x Dwarf Green showed good performance.

Rao (1977) crossed seven tester varieties of bhindi with two female lines and after an analysis for combining ability concluded that parents with good general combining ability effects need not produce superior crosses with good specific combining ability effects. But the parental _per se_ performance is a good indication of general combining ability effect of parents.

Rao and Satiyavathi (1977) examined number of days to flowering, pod number per plant and height in a diallel cross involving six parents in bhindi and found significant general combining ability variance for pod number per plant.

Six parents and 15 hybrids from a diallel cross of bhindi were examined for combining ability by Rao and Ramu (1978). They found three of the parents showing good combining ability for most of the characters studied and three of the crosses to be the best on the basis of both performance *per se* and combining ability values.

A study of combining ability in bhindi by Singh and Singh (1978) using 25 lines and five testers indicated the parents Pusa Sawani, 7104, 7106, 6907 and 5614 to be good combiners.

Elangovan *et al*. (1981a) estimated combining ability from a 14 line x 4 tester analysis in bhindi and found the line AE. 1068 and tester AE. 180 to be the best general combiners for yield and its components. High specific combining ability was expressed in hybrids involving high x high, high x medium or low x low general combiners.

A seven parent half diallel cross in bhindi conducted by Pratap *et al*. (1981) revealed that general and specific combining ability variances were significant for all traits except yield per plant and virus disease incidence.

Thaker *et al*. (1981) analysed a 7 x 7 half diallel in bhindi and found high general combining ability for some components of yield viz., fruit length and fruit weight. They found the combination IC 18960 x IC 18974 to be promising as initial material for breeding.

Following analysis of data from a partial diallel involving 20 strains of bhindi, Singh and Singh (1984) reported that Pusa Sawani was the best general combiner for seven traits and 7121 for eight traits. Pusa Sawani also proved to be resistant to yellow vein mosaic virus and they opined that it can be used as a donor of resistance in breeding programmes.

Poshiya and Shukla (1986b) reported that in a half diallel cross of seven varieties of bhindi, the specific combining ability effects were significant for fruit yield per plant. General and specific combining ability effects were significant for days to 50 per cent flowering, fruit length, number of fruits per plant and nodes on the main stem. New Selection x AE. 91 was the most promising cross for the improvement of fruit yield.

Vijay and Manohar (1986a) found that in a 10 x 10 diallel analysis excluding reciprocals in bhindi, the general combining ability effects were highly significant for days to 50 per cent flowering, pod number, weight, length, thickness and yield, branch number and seed number. Specific combining ability effects were highly significant for all the 11 characters. The crosses Pusa Sawani x Climson Spineless and Pusa Sawani x IC 8911 were noted for pod yield and most of the yield components except pod length.

Radhika (1988) carried out a 6 x 6 diallel analysis in bhindi and reported that the varieties Seven Leaves, PB No. 57 and Pusa Sawani were the best general combiners for yield and related characters. The highest specific combining ability effects were recorded for internodal number, fruit number, fruit weight, fruit length and yield per plant in different crosses.

Shukla _et al_. (1989) conducted a line x tester analysis in bhindi using 16 elite lines and 3 testers - Pusa Sawani, Parbhani Kranti and Punjab-7 and estimated the general combining ability and specific combining ability effects of the lines, testers and their F_1 hybrids for important yield components. They reported that the tester Parbhani Kranti had high general combining ability.

Veeraraghavathatham (1989) observed that among seven genotypes studied in bhindi, AE. 974 was the best general combiner for yield and number of fruits per plant. The _per se_ performance of some of the hybrids had significant correlation with specific combining ability effect of the hybrids for some of the characters.

Jawili and Rasco (1990) studied 19 characters in six parents of bhindi and their 15 F_1 hybrids and reported Smooth Green to be the best combiner for almost all the traits.

Chaudhary _et al_. (1991) reported that in a line x tester analysis involving five lines and three testers in bhindi, the line Pusa Makhmali and the tester Punjab Padmini proved to be the best general combiners for yield and its components.

Veeraraghavathatham and Irulappan (1991a) while estimating the combining ability of seven parents of bhindi and their 42 hybrids including reciprocals noticed that the general combining ability variance was significant for most of the traits when compared to the specific combining ability variance. The correlations between specific combining ability of hybrids and _per se_ performance of the respective hybrid was not as strong as that of the parental array mean (vs) parental general combining ability or even that of parental _per se_ (vs) general combining ability. Hence choice of hybrid combination based on _per se_ and heterosis may be considered as appropriate.

Lakshmi (1992) carried out a diallel analysis involving eight diverse genotypes of bhindi and observed that among the parents, PB No. 58, Parbhani Kranti and Pusa Sawani were the superior general combiners for most of the yield attributing characters and yield per plant. Three of the crosses showed high specific combining ability effects also.

From an 8 x 8 half diallel cross in bhindi, Mandal and Das (1992) found highly significant general combining ability and specific combining ability variances. They found Pusa Sawani to be a good combiner for yield and most other characters while the cross Punjab Padmini x Selection 10 to be the best specific combination for yield per plant.

Shivagamasundari *et al*. (1992a) involved six inbreds of bhindi in a full diallel cross and observed that the parent Arka Abhay was the best general combiner for yield and number of fruits per plant. For yield and number of fruits per plant, *per se* performance of the parents and their general combining ability had good relationship whereas the hybrid *per se* and specific combining ability did not agree with each other. The hybrid Arka Abhay x Arka Anamika which had high specific combining ability resulted because of high x high combination.

2.3 Gene Action

Hayman's (1954) graphical and numerical approach to diallel analysis provides information on several valuable aspects of the genetic make up of a quantitative character such as the adequacy of additive - dominance model, average degree of dominance involved in the action of genes, preponderance of dominant and recessive genes among the parental lines, symmetrical or asymmetrical distribution of genes with positive and negative effects on the attribute, etc.

Kulkarni (1976) carried out biometrical investigations in bhindi and observed that days to flowering and number of pods per plant were controlled by one to three groups of dominant genes where as plant height was controlled by four to five groups of dominant genes.

Kulkarni et al. (1976) while studying gene action in bhindi observed both additive and non-additive types of gene action operating for days to flowering, plant height and number of fruits per plant. Dominance was found to be acting in the direction of earliness, tallness and greater number of fruits per plant. There was an asymmetrical distribution of positive and negative alleles for all the characters. Days to flowering and number of fruits per plant were found to be controlled by one to three groups of dominant genes while it was four to five for plant height. Overdominance was observed for all the three characters.

Ramu (1976) carried out breeding investigations in bhindi and reported the presence of both additive and nonadditive components of genetic variation for plant height, fruit number per plant and yield per plant.

In a diallel cross involving six parents of bhindi, Rao and Satiyavathi (1977) obtained greater general combining ability variances than specific combining ability variances for height and pod number per plant indicating considerable additive genetic effects for these characters. It was the reverse in case of number of days to flowering indicating non-additive effect for this character.

While studying the quantitative inheritance in bhindi, Kulkarni _et_ _al_. (1978) found additive x additive interaction with epistatic action in the inheritance of days to flower, plant height and fruits per plant.

Sharma and Mahajan (1978) analysed a line x tester experiment in bhindi and found that all the nine traits studied were influenced by non-additive gene action. Overdominance was observed for days to first flowering, plant height, fruit weight and yield.

Singh and Singh (1978) studied combining ability in an analysis with 25 lines and 5 testers and reported importance of non - additive gene action for all the characters as indicated by the general combining ability and specific combining ability variances.

The data obtained from a half diallel cross of six parents of bhindi by Rao and Ramu (1978) revealed the presence of additive gene action for number of days to flowering, number of pods per plant and yield per plant and non-additive gene action for height and seed number per pod.

Singh and Singh (1979b) crossed ten lines of bhindi with two testers and the analysis revealed that gene action was predominantly non - additive for height, number of branches per plant and number of fruits per plant and additive for number of days to flowering and fruit yield per plant.

Pratap and Dhankar (1980a) reported from a seven parent diallel analysis in bhindi that both additive and non - additive gene effects were important for all characters except seed number per fruit.

Pratap and Dhankar (1980b) carried out a 7 x 7 diallel analysis in bhindi and found that general combining ability variances were higher than those due to specific combining ability for all traits indicating the predominance of additive gene action. However, significant specific combining ability variances for several traits suggested the involvement of non additive gene action.

Pratap *et al*. (1980) reported that the additive variance was higher than the non-additive variance for all the characters except number of fruits and yield per plant. Estimates of degree of dominance showed partial dominance for days to flowering, plant height and fruit length, complete dominance for fruit diameter and number of fruits per plant and overdominance for yield per plant. Variance - covariance regression graphs confirmed similar results except complete dominance for days to flowering and partial dominance for fruit diameter.

The ratios of general combining ability and specific combining ability obtained from a 14 line x 4 tester analysis in bhindi by Elangovan et al. (1981a) indicated preponderance of non additive gene expression.

Prâtap et al. (1981) evaluated a seven parent half diallel cross in bhindi and observed both additive and non additive gene actions for yield per plant. Only the former was important for number of days to appearance of the first fruiting node and to 50 per cent flowering.

Analysis of a 7 x 7 half diallel of bhindi by Thaker et al. (1981) indicated that additive component was the chief determinant of genetic variance in fruit yield per plant, single fruit weight and fruit length. However, the number of fruits per plant was seen to be governed by non-additive components.

While studying the genetics of yield components in bhindi, Korla et al. (1985) observed dominance and dominance x dominance gene effects for plant height and number of fruits per plant where as additive and additive x additive gene effects for inheritance of node of first fruit set and days to first flower.

Additive gene effects for plant height, fruit yield per plant, branch number and other related characters was reported by Reddy et al. (1985).

Singh (1986) studied a line x tester analysis involving 25 lines and 5 testers and observed the major role of dominance variance in controlling first fruiting node, number of branches, number of fruits per plant, days to flower and fruit yield per plant in bhindi. The character days to flower had high heritability.

Korla and Sharma (1987) reported presence of epistasis in the expression of yield. However, three of the crosses exhibited partial to complete dominance for yield with additive gene effects being significant. Overdominance for yield was observed in three crosses.

Radhika (1988) carried out a genetic analysis of yield and its components in a 6 x 6 diallel set of bhindi and reported additive type of gene action for plant height and yield per plant as indicated by high heritability and high genetic advance. On the other hand, high heritability coupled with low genetic advance was an indication of non-additive type of gene action for fruit girth, stem diameter and leaf area index.

Randhawa (1989) reported partial to complete dominance for most of the economic characters except for yield per plant which displayed overdominance. Hence he suggested that selection for high yielding varieties should be made in early generations.

Gene action elicited through genetic and graphic analysis by Veeraraghavathatham (1989) employing diallel mating of seven genotypes of bhindi showed that there was preponderance of additive gene action for yellow vein mosaic incidence and dominant gene action for plant height. Non-additive gene action was evident for yield of fruits per plant.

Vashist (1990) found that the additive gene effects were more important than the dominance gene effects for number of fruits per plant, total yield per plant and marketable yield per plant which could be exploited for the improvement of important characters in bhindi.

A genetic analysis in bhindi by Veeraraghavathatham and Irulappan (1990) from a 7 x7 diallel set indicated operation of additive and non-additive gene action for plant height, number of fruits per plant, fruit length and fruit girth, while additive genes played a significant role in yellow vein mosaic incidence. The importance of dominant genes was stressed for individual fruit weight and yield.

Choudhary _et al_. (1991) reported that in the line x tester analysis involving five lines and three testers of bhindi, the dominant component of variance was higher than the additive indicating the role of non-additive gene action.

Veeraraghavathatham and Irulappan (1991a) while estimating the combining ability in certain okra hybrids and parents noticed that the general combining ability variance was significant for most of the traits when compared to the specific combining ability variance indicating the preponderance of additive gene action.

Lakshmi (1992) observed that general combining ability variance was higher than specific combining ability variance for all the characters except for plant height and fruit weight indicating additive gene action for all the characters studied in a diallel analysis involving eight genotypes of bhindi.

Shivagamasundari et al. (1992a) used six inbreds of okra in a full diallel cross to estimate the combining ability effects. Results revealed that the general combining ability/specific combining ability ratios were less than unity indicating the role of non-additive gene action.

2.4 Heterosis

Joshi et al. (1958) studied six varieties of bhindi along with their hybrids with respect to plant height, fruit size, number of branches per plant and number and weight of fruits per plant. Out of the 29 combinations, 13 crosses gave greater weight of fruits per plant than their respective higher yielding parents, whereas 10 hybrids yielded less than their parents with lower yields. They attributed the increased yield to increase in fruit number. Cases of reciprocal differences were noted in all the characters studied.

Significant heterosis for number of flowers per plant, number of fruits per plant and girth of fruit compared to the better parent was found by Issack (1965) in bhindi. He noticed that there was no significant heterosis with regard to height of plant, days to flower and length of fruit compared to the respective better parents.

In a study on heterosis in bhindi, Raman (1965) noticed heterosis for earliness and individual fruit weight.

Akram *et al.* (1973) found that among 20 crosses from five varieties of bhindi, the greatest heterosis for yield was observed in T_1 x Indian.

Jalani and Graham (1973) made crosses among local and American varieties of bhindi and observed four F_1 hybrids exhibiting heterosis for percentage germination, precocity of flowering, plant height and yield performance as indicated by fresh weight of fruits per plant.

Among 11 crosses of bhindi, Lal and Srivastava (1973) found that one cross each for plant height, fruit thickness and number of fruits per plant and two crosses each for fruit length and fruit yield per plant showed positive hybrid vigour.

Lal et al. (1975) reported positive heterosis in bhindi for plant height, days to flower, internodal length, fruit thickness, number of fruits per plant and yield per plant.

Singh et al. (1977) found maximum heterosis in bhindi for fruit yield per plant, number of fruits per plant and plant height.

Kulkarni and Virupakshappa (1977) while studying a six parent diallel cross in bhindi found that Dwarf Green x AE. 107 showed significant heterosis over the best parent for earliness and Sevendhari x AE. 107 for plant height and fruit number per plant. Similar observations were made by Rao and Kulkarni (1977).

Rao (1978) evaluated a 6 x 6 diallel cross in bhindi and found four hybrids exhibiting positive heterosis and five hybrids exhibiting negative heterosis for fruit number. None of the hybrids showed positive heterosis for plant height and negative heterosis for days to flowering.

Singh and Singh (1978), from a 25 line x 5 tester analysis in bhindi, reported substantial heterosis for days to flowering, plant height, first fruiting node, number of branches, internodal distance, fruit length, number of fruits per plant and yield per plant. The highest heterosis over better parent for fruit number per plant (71.5%) followed by yield per plant (70.3%) was observed by Singh and Singh (1979a). They reported that the crosses 7114 x PS, 6301 x 6313 and 7114 x 6313 showed heterosis for yield and most yield components.

Pratap and Dhankar (1980a) studied heterosis in seven varieties of bhindi and their hybrids derived from a diallel cross without reciprocals and observed that the cross IC 6653 x IC 6316 displayed heterosis for fruit yield per plant, fruit number per plant and fruit length while IC 6653 x IC 12930 showed heterosis for fruit yield per plant, fruit number per plant and fruit number per branch.

Elangovan et al. (1981b) carried out a genetic analysis in bhindi using 14 lines and four testers and found heterosis over mid parental value and better parent for plant height, number of branches, first fruiting node, earliness, fruit length, width and number, fruit yield and 100 seed weight. They found highest heterosis for yield and its components in AE.1068 x AE. 180 followed by AE. 800 x AE. 142 and AE. 825 x AE. 142 while AE. 711 x AE. 106 had the highest heterosis for earliness.

Heterosis for fruit yield per plant was observed by Pratap et al. (1981) in a study of seven parent half diallel cross in bhindi.

In 21 crosses of seven varieties of bhindi, Thaker et al. (1982) found that percentage increase over the better parent was highest for fruit yield per plant, followed by number of fruits per plant and fruit length. Seven crosses showed significant increase over the better parent for fruit yield and four showed increase over the best parent.

Balachandran (1984) observed desirable heterosis in bhindi in respect of all the 17 characters studied in the three types of heterosis comparisons. The major yield contributing characters viz., number of fruits per plant and length and weight of fruits displayed relatively higher percentage of increase over the mid parental, better parental and standard cultivar values in higher proportion of hybrids.

Changani and Shukla (1985) observed marked heterosis in several of the 30 cross combinations of bhindi studied for yield contributing characters. Of these, 18 crosses exhibited heterosis over mid parent and 14 exhibited heterosis over better parent.

Agarrado and Rasco (1986) crossed 10 inbred lines of bhindi in a diallel pattern to get 45 F_1 hybrids which were evaluated with parents for yield and its components. Heterosis over the mean parental value was strongly expressed by most of the hybrids for yield, plant height, pod length, pod weight, number of pods per plant, days to flowering and distance between internodes. Heterosis over the better parent was observed for yield and pod weight, length and diameter.

In a 10 line x 10 tester analysis of bhindi, Elmaksoud et al. (1986) observed heterosis over the mid parental value for plant height (143.9%), days to first flowering (85.8%), fruit number per plant (149.2%) and fruit weight (124.9%).

Poshiya and Shukla (1986a) noticed highest heterosis for number of pods per plant and yield per plant in a 7 x 7 diallel cross of bhindi. The cross New Selection x AE. 91 showed the highest heterosis for yield with 29.9% over the mid parental value and 27.8% over the better parent. They attributed this heterosis mainly to increase in the number of pods per plant.

Vijay and Manohar (1986b) calculated heterosis over the better parent in 45 hybrids of bhindi derived from 10 lines. Pusa Sawani x Climson Spineless and Pusa Sawani x IC 8911 exhibited the highest values for pod yield (64.93% and 66.81%). These two crosses along with Pusa Sawani x Selection-6-1 and Selection-6-1 x Summer Beauty showed the highest heterobeltiosis for days to 50% flowering.

Korla and Sharma (1988) while studying inheritance of seed characters in bhindi found no heterosis over the better parent in any of the crosses for seeds per fruit. However, one cross showed heterosis for seed weight per fruit and two crosses for 100 seed weight.

Sheela et al. (1988) evaluated six parents of bhindi and their six hybrids on the basis of percentage of heterosis manifested by them for yield and its components and found that all the hybrids displayed desirable heterosis for the major economic characters such as weight of fruits per plant, number of fruits per plant,etc. They identified two hybrids Selection-2-2 x Kilichundan and Sevendhari x Kilichundan outyielding the standard cultivar Pusa Sawani by 65.1% and 50.3% respectively.

Radhika (1988), in a 6 x 6 diallel analysis in bhindi noticed maximum heterosis in Seven Leaves x Pusa Sawani for fruit yield and fruits per plant, Pusa Sawani x Janardhan for fruit weight, Janardhan x Parbhani Kranti for fruit length and Seven Leaves x Punjab Padmini for harvest index.

Shukla et al. (1989) analysed 19 lines of bhindi and their F_1 hybrids for six yield components and reported that Punjab Padmini x Parbhani Kranti showed the highest heterosis over the better parent.

Heterosis over mid, better and best parents were estimated for yield and seven related components in a 6 x 6 full diallel cross of bhindi by Shivagamasundari et al. (1992b). Eight hybrids recorded positive and better than average heterosis over the best parent for fruits per plant, fruit weight, fruit length and/or yield.

Kumbhani et al. (1993) crossed eight diverse genotypes of bhindi in all possible combinations to find out the combination of parents giving the highest degree of useful heterosis and observed that high heterosis for yield per plant resulted from the combined effect of heterosis for yield component characters viz., number of pods per plant, pod length, pod girth, plant height and internodal length.

Mandal and Dana (1993) while studying a 6 x 6 diallel cross in bhindi excluding reciprocals found only EMS 8 x Punjab Padmini to show significant heterosis over the best parent for both plant height and fruits per plant.

Fifteen F_1 hybrids derived from six varieties of bhindi were evaluated by Singh and Mandal (1993). They observed the highest heterosis over mid and better parental values for early yield, number of fruits per plant, number of branches per plant and total yield.

Materials and Methods

3. MATERIALS AND METHODS

The present study was undertaken in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 1994-95 with a view to estimate the gene action through combining ability analysis for yield and yield attributes in bhindi and to determine the extent of heterosis manifested by the hybrids for each character.

3.1 Materials

The parents utilized were selected from six genetically divergent clusters obtained from a previous investigation undertaken in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani (Bindu et al., 1994). From each cluster, one type having the highest fruit yield was selected as parents for the present study. These six selected parents were crossed in all possible combinations in a diallel fashion such that the experimental material consisted of parents, F_1s and reciprocal F_1s. The six parents and the 30 hybrids are listed in Table 1.

3.2 Methods

3.2.1 Intervarietal Hybridization

The six selected parents were raised in pots during 1994 with three replications, where each replication consisted of five plants per parent. At the time of flowering the parents

Table 1. Parents, hybrids and check variety used in the 6x6 diallel in bhindi

Sl.No.	Treatment No.	Name of variety/cross
1.	T_1	NBPGR/TCR 893 (P_1)
2.	T_2	NBPGR/TCR 861 (P_2)
3.	T_3	NBPGR/TCR 854 (P_3)
4.	T_4	NBPGR/TCR 864 (P_4)
5.	T_5	NBPGR/TCR 865 (P_5)
6.	T_6	NBPGR/TCR 438 (P_6)
7.	T_7	P_1 x P_2
8.	T_8	P_1 x P_3
9.	T_9	P_1 x P_4
10.	T_{10}	P_1 x P_5
11.	T_{11}	P_1 x P_6
12.	T_{12}	P_2 x P_3
13.	T_{13}	P_2 x P_4
14.	T_{14}	P_2 x P_5
15.	T_{15}	P_2 x P_6
16.	T_{16}	P_3 x P_4
17.	T_{17}	P_3 x P_5
18.	T_{18}	P_3 x P_6
19.	T_{19}	P_4 x P_5
20.	T_{20}	P_4 x P_6
21.	T_{21}	P_5 x P_6
22.	T_{22}	P_2 x P_1
23.	T_{23}	P_3 x P_1
24.	T_{24}	P_3 x P_2
25.	T_{25}	P_4 x P_1
26.	T_{26}	P_4 x P_2
27.	T_{27}	P_4 x P_3
28.	T_{28}	P_5 x P_1
29.	T_{29}	P_5 x P_2
30.	T_{30}	P_5 x P_3
31.	T_{31}	P_5 x P_4
32.	T_{32}	P_6 x P_1
33.	T_{33}	P_6 x P_2
34.	T_{34}	P_6 x P_3
35.	T_{35}	P_6 x P_4
36.	T_{36}	P_6 x P_5
37.	T_{37}	Kiran

were crossed in all possible combinations to obtain 30 hybrids (T_7 to T_{36}). For crossing, the flowers on the female parents due to open on the next day were selected and emasculated on the previous evening by the method suggested by Giriraj and Rao (1973). For emasculation, a shallow circular cut was made around the fused calyx at about 1 cm. from its base. Calyx cups along with the corolla were removed as a hood exposing the stigma and the staminal tube. The stamens were then scraped off after which the flowers were covered with butter paper covers. The flowers on the male parents were also covered to avoid contamination with foreign pollen. The next morning these emasculated flowers were pollinated between 8 and 9 AM using pollen from the covered flowers of the desired male parent. The crossed as well as selfed flowers were labelled and again protected with butter paper covers. The covers were removed a day after pollination. This was continued till the end of the flowering phase. The labelled fruits were harvested separately on maturity and hybrid seeds collected.

3.2.2 Estimation of combining ability

The six parents along with the 30 hybrids and a standard check (variety Kiran) were laid out in Randomised Block Design with three replications during November, 1994, with a spacing of 60 x 40 cm where each treatment consisted of 10 plants per replication. Cultural and manurial practices were done as per the Package of Practices Recommendations (1993) of Kerala Agricultural University. Observations on the following characters were recorded from five plants at random in each treatment per replication for the estimation of combining ability.

3.2.2.1 Biometric observations

i) Days to first flowering - Number of days taken for the first flower to bloom was recorded in each of five observational plants.

ii) Leaf axil bearing the first flower - The number of the leaf axil from which the first flower was produced was recorded.

iii) Leaf number - The total number of leaves produced by each plant was counted.

iv) Leaf area - Three leaves from the third, sixth and ninth node were collected from each plant and leaf area in square centimetres was determined using a planimeter and their mean recorded..

v) Number of branches - Total number of primary branches in each plant was counted at final harvest.

vi) Number of flowers per plant - The total number of flowers produced per plant was counted.

vii) Number of fruits per plant - The total number of fruits harvested from each plant was counted.

viii) Length of fruit - Length of the fruit from the base to the tip was measured from the third, sixth and ninth node in each plant and their mean in centimetres was recorded.

ix) Girth of fruit - The girth of those fruits used for recording the length were measured at the middle portion of the fruit and their mean expressed in centimetres.

x) Weight of single fruit - Weight of each fruit was taken at the time of harvest and their mean in grams was recorded.

xi) Weight of fruits per plant - The weight of single fruit was multiplied by the number of fruits per plant to obtain the weight of fruits per plant and was expressed in grams.

xii) Number of seeds per fruit - The seeds were extracted from each of the fruits used for measuring the length and girth and their mean was recorded.

xiii) Fruiting phase - The duration between first harvest and final harvest was recorded in days in each treatment.

xiv) Height of plant - Height of the plant was measured from the ground level to the tip of the main shoot after the last harvest and expressed in centimetres.

xv) Percentage fruit set - The ratio of the number of fruits to the total number of flowers was calculated in each plant and expressed in percentage.

3.2.2.2 Observations on the incidence of disease and pest:

i) Yellow vein mosaic disease incidence

The rating scale by Arumugam *et al*. (1975) was used for scoring yellow vein mosaic disease intensity (Table 2).

The scoring was done according to the characteristic symptoms appearing on the leaves or the fruits of each observational plant. The ratio of the sum of disease scores in the observational plants to the number of plants in each replication was taken as the disease rating mean of each treatment in a replication.

ii) Shoot and fruit borer incidence

The number of fruits infested by shoot and fruit borer (*Earias vitella* F.) in the observational plants was recorded, averaged and expressed in percentage

Table 2. Yellow vein mosaic disease scoring

	Symptom	Grade	Rating scale
1.	No visible symptoms characteristic of the disease	Highly resistant	1
2.	Very mild symptoms - Basal half of the primary veins green and mild yellowing of anterior half of primary veins and veinlets	Resistant	2
3.	Vein and veinlets turn completely yellow	Moderately resistant	3
4.	Pronounced yellowing of vein and veinlets - 50 percentage of leaf lamina turned yellow, fruits exhibit slight yellowing	Susceptible	4
5.	Petiole, veins, veinlets and interveinal space turned yellow in colour, leaves start drying from margin, fruits turn yellow in colour	Highly susceptible	5

3.2.3 Statistical Analysis

Data recorded from the parents, hybrids and standard check were initially subjected to analysis of variance for each character so as to detect the genotypic differences.

The characters for which genotypic differences were detected were further subjected to diallel analysis to estimate the additive components of heritable variation. The following parameters were estimated.

i) Combining ability through Griffing's Approach.

- General combining ability
- Specific combining ability

ii) D, H, E components through Hayman's Approach

iii) V_r - W_r graph

- Graphical analysis of diallel crosses as suggested by Hayman (1954).

3.2.3.1 Combining ability analysis

The different genotypes were subjected to combining ability analysis only if they showed significant difference for the character under study. The analysis was carried out according to the Method I, Model I of Griffing's approach (1956).

The linear mathematical model for combining ability analysis of this model is:

$$Y_{ij} = \mu + g_i + g_j + r_{ij} + S_{ij} + \frac{1}{bc} \sum_k \sum_l e_{ijkl}$$

where μ = Population mean

g_i and g_j = General combining ability effects of i^{th} and j^{th} inbred lines respectively.

S_{ij} = Specific combining ability effect of ij^{th} cross such that $S_{ij} = S_{ji}$.

r_{ij} = Reciprocal effect such that $r_{ij} = - r_{ji}$

b = Number of replications

c = Number of observational plants

Restrictions are imposed on combining ability effects such that $\sum_i g_i = 0$ and $\sum_i S_{ij} = 0$ (for each j).

Table 3. Combining ability analysis with 'p' parents

Sources of variation	d.f.	M.S.	F
General combining ability (g.c.a.)	$(P-1) = 5$	Mg	Mg/Me
Specific combining ability (s.c.a.)	$\frac{P\ (P-1)}{2} = 15$	Ms	Ms/Me
Reciprocal effects	$\frac{P\ (P-1)}{2} = 15$	Mr	Mr/Me
Error	M = 72	Me	

The combining ability effects were estimated as follows:

General combining ability effect of i^{th} parent

$$g_i = \frac{1}{2p} (Y_{i.} + Y_{.j}) - \frac{1}{p^2} Y_{..}$$

Specific combining ability effect of i x j cross

$$S_{ij} = \frac{1}{2} (Y_{ij} + Y_{ji}) - \frac{1}{2P} (Y_{i.} + Y_{.i} + Y_{j.} + Y_{.j})$$

Reciprocal effect for the i x j cross

$$r_{ij} = \frac{1}{2} (Y_{ij} - Y_{ji})$$

where Y_{ij} is the mean value with respect to ixj cross.

$$Y_{i.} = \sum_j Y_{ij}, \quad Y_{.j} = \sum_i Y_{ij} \text{ and } Y_{..} = \sum_{ij} Y_{ij}$$

The following standard errors are used to test the significance of the estimates.

$$\text{g.c.a} : \text{SE } \hat{g}_i = (\frac{P-1}{2p^2} \text{Me})^{1/2}$$

$$\text{SE } (\hat{g}_i - \hat{g}_j) = (\frac{1}{P} \text{Me})^{1/2}$$

$$\text{s.c.a.} : \text{SE } (\hat{s}_{ij}) = (\frac{1}{2p^2} (P^2 - 2p - 2) \text{ Me})^{1/2}$$

$$\text{SE } (\hat{s}_{ij} - \hat{s}_{ik}) = (\frac{(P-1)}{P} \text{Me})^{1/2}$$

$$\text{SE } (\hat{s}_{ij} - \hat{s}_{kl}) = (\frac{(P-2)}{P} \text{Me})^{1/2}$$

The significance of g.c.a, s.c.a and reciprocal effects are tested using Students 't' test with the following test criteria.

t = $|g_i|/SE(g_i)$ for the significance of g_i.

t = $|g_i - g_j|/SE(g_i - g_j)$ for the significant difference between g_i and g_j.

t = $|s_{ij}|/SE(s_{ij})$ for the significance of s_{ij}.

t = $|s_{ij} - s_{ik}|/SE(s_{ij} - s_{ik})$ for the significant difference between s_{ij} and s_{ik} (one parent common)

t = $|s_{ij} - s_{kl}|/SE(s_{ij} - s_{kl})$ for the significant difference between s_{ij} and s_{kl} (no common parent)

t = $|r_{ij}|/SE(r_{ij})$ for significance of r_{ij}., the degrees of freedom for 't' being equal to the error degrees of freedom at a chosen level of significance, generally 5% or 1%.

3.2.3.2 Estimate of additive and dominance components (Hayman's numerical approach)

The estimation of additive and dominance components ie., D, H components was done through Hayman's Approach which provides information on the genetic make up of a character based on an additive-dominance model.

Hayman's approach was used to estimate the following components

Variance components and their estimates	Standard Error Estimates
$D = V_p - \hat{E}$	$\left(\frac{n^5 + n^4}{n^5} \times Me\right)^{1/2}$
$H_1 = 4\bar{V_r} + V_p - 4\bar{W_r} - \left(\frac{3n-2}{n}\right)\hat{E}$	$\left(\frac{n^5 + 41n^4 - 12n^3 + 4n^2}{n^5}\right) \times Me)^{1/2}$
$H_2 = 4\bar{V_r} - 4V_r\ 2\hat{E}$	$\left(\frac{36n^4}{n^5} \times Me\right)^{1/2}$
$F = 2V_p - 4W_r - \frac{2(n-2)}{n}\hat{E}$	$\left(\frac{4n^5 + 20n^4 - 16n^3 + 16n^2}{n^5}\right) \times Me)^{1/2}$
$h^2 = 4(M_{L1} - M_{Lo})^2 - \frac{n(4-1)}{n^2}\hat{E}$	$\left(\frac{16n^4 + 16n^2 - 32n + 16}{n^5} \times Me\right)^{1/2}$
$E = \frac{SSB - SSE}{n^2(r-1)}$	$\left(\frac{n^4}{n^5} \times Me\right)^{1/2}$

where D = Variance due to additive effect

H_1 & H_2 = Variance due to dominance effect of positive and negative genes respectively.

F = Average covariance between additive and dominance effect over all the parental arrays.

h^2 = Dominance effect

E = Environmental effect

V_p = Variance of parents

$\bar{V}_r$ = Mean variance over arrays

$\overline{W}_r$ = Mean covariance between parents and offsprings over the arrays.

n = Number of parents

r = Number of replications

M_{L1} = Mean of n^2 progeny families

M_{L0} = Parental mean

Me = Environmental variance

The following ratios were also derived.

Average degree of dominance = $\left(\frac{H_1}{D}\right)^{1/2}$

If this ratio equals unity, complete dominance is indicated. A value of less than unity and more than unity suggests partial dominance and overdominance respectively.

Distribution of increasing (positive) and decreasing (negative) genes among the common parents of arrays = $\frac{H_2}{4H_1}$

A symmetrical distribution of these genes is indicated if the ratio attains a value of 0.25 and deviation from this value implies an asymmetrical distribution.

Proportion of dominant and recessive genes among parents

$$= \frac{(4\ D\ H_1)^{1/2} + F}{(4\ D\ H_1)^{1/2} - F}$$

This ratio will attain unit value if the dominant and recessive genes are symmetrically distributed among parents. Deviation from unity indicates an asymmetrical distribution of these genes.

Standardised deviations graphs were plotted for each character with standardised values of W_r+V_r on Y-axis and those of $\bar{Y}_r$ (mean of common parent of the array) in order to determine the type of genes possessed by the parents.

$W_r + V_r$

Quadrant 2 Recessive genes with negative effects	Quadrant 1 Recessive genes with positive effects
Quadrant 3 Dominant genes with negative effects	Quadrant 4 Dominant genes with positive effects

$\bar{Y}_r$

3.2.3.3 Hayman's Graphical approach:

The W_r - V_r graph was drawn using a regression relationship between W_r and V_r where W_r is the covariance between the parents and offsprings in the r^{th} array and Vr is the variance of the r^{th} array.

The linear regression of $W_r = a + b\ V_r$, where 'b' is the regression coefficient of W_r on V_r and 'a' the constant term which is taken as an indication of the type of gene action governing the character because 'a' is the intercept made by the regression line on W_r-axis.

If the regression line passes through the origin (ie., a = 0), it can be taken as an indication of complete dominance. But if it passes above the origin (ie., $a > 0$), it can be taken as an indication of absence of dominance ie., partial dominance while the line passing below the origin (ie., $a < 0$) indicates the presence of over-dominance.

3.2.3.4 Heterosis

Heterosis was calculated as the per cent deviation of the mean performance of F_1s ($\overline{F_1}$) from their mid parent ($\overline{MP}$), better parent ($\overline{BP}$) and the standard parent ($\overline{CP}$) for each cross combination as suggested by Hayes _et al_. (1955) and Briggle (1963).

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

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

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

The significance of heterosis over MP, BP and CP are compared using the following critical difference (CD) values.

$$CD_{(0.05)} = te_{(0.005)} \times (\frac{3\ Me}{2r})^{1/2}$$

$$CD_{(0.05)} = te_{(0.005)} \times (\frac{2\ Me}{r})^{1/2}$$

where Me is the estimated error variance with respect to each character.

Results

4. RESULTS

Statistical analysis of the data relating to the experiment was done and the results are presented.

4.1 Mean Performance

The mean performance of the six parents and the 30 hybrids for the 17 characters studied are presented in Table 4.

Significant differences were detected among the genotypes with respect to all the characters.

With respect to days to first flowering the mean performance of the parents ranged from 40.27 days (P_3) to 44.47 days (P_1) and that of the crosses ranged from 39.87 days (P_3xP_5) to 46 days (P_4 x P_6).

Considering the leaf axil bearing the first flower, the mean values recorded by the parents ranged from 3.33 for P_3 and P_5 to 5.53 for P_4, and in the hybrids it ranged from 3.13 for P_5xP_6 to 5.0 for P_4xP_1.

The maximum number of leaves was found in the parent P_4 (19.73) and hybrid P_4 x P_2 (21.93) and the minimum in parent P_5 (14.47) and hybrid P_5 x P_4 (14.93). Almost all the hybrids had leaf numbers intermediate to those of parents except for the hybrids P_1 x P_4 (20.47), P_2 x P_4 (20.27) and P_4 x P_2 (21.93).

Table 4. Mean performance of the genotypes

Parents/ Crosses	Days to first flowering	Leaf axil bearing the first flower	Leaf number	Leaf area (cm^2)	Number of branches	Number of flowers/plant
P_1	44.47	3.87	16.27	227.95	0.47	11.33
P_2	43.60	4.07	16.00	287.23	1.20	12.40
P_3	40.27	3.33	17.87	240.11	1.20	13.20
P_4	43.87	5.53	19.73	261.99	3.70	12.40
P_5	42.47	3.33	14.47	244.66	0.67	11.60
P_6	42.20	3.80	18.73	271.23	0.87	13.93
P_1 x P_2	42.33	4.20	18.07	264.45	1.07	12.93
P_1 x P_3	41.80	3.27	15.60	210.08	0.07	10.67
P_1 x P_4	41.07	4.40	20.47	274.37	1.80	16.00
P_1 x P_5	40.87	3.53	15.80	247.74	0.40	11.00
P_1 x P_6	43.87	3.40	15.13	199.31	0.13	11.00
P_2 x P_3	40.47	3.87	17.00	271.47	1.53	11.87
P_2 x P_4	43.07	4.87	20.27	302.25	1.80	14.53
P_2 x P_5	40.47	3.53	17.20	250.20	0.67	11.53
P_2 x P_6	40.60	3.87	15.80	257.01	0.07	11.67
P_3 x P_4	43.53	4.53	15.27	250.53	1.20	11.80
P_3 x P_5	39.87	3.67	16.53	256.78	1.07	12.13
P_3 x P_6	40.00	4.00	17.13	256.17	1.00	12.33
P_4 x P_5	43.33	4.00	17.13	237.95	1.20	11.87
P_4 x P_6	46.00	4.87	21.53	284.67	2.40	14.27
P_5 x P_6	40.67	3.13	16.27	254.37	0.67	11.67
P_2 x P_1	41.33	4.00	17.47	267.10	0.47	10.87
P_3 x P_1	40.40	3.80	18.67	291.87	0.60	12.87
P_3 x P_2	41.53	4.73	19.20	286.19	1.27	13.00
P_4 x P_1	44.87	5.00	19.73	264.50	1.87	12.07
P_4 x P_2	43.27	4.20	21.93	261.94	0.93	14.40
P_4 x P_3	45.00	4.20	19.23	225.07	1.27	14.00
P_5 x P_1	40.87	3.27	15.47	233.49	0.13	10.60
P_5 x P_2	42.93	3.60	16.53	223.40	0.47	12.47
P_5 x P_3	40.07	3.40	17.27	314.94	1.13	13.40
P_5 x P_4	41.27	3.40	14.93	289.41	0.93	11.33
P_6 x P_1	42.40	3.87	18.60	244.73	0.87	13.33
P_6 x P_2	43.67	4.20	19.53	239.81	1.40	15.60
P_6 x P_3	42.13	3.87	17.87	282.92	0.80	12.40
F_6 x P_4	42.13	4.07	16.07	273.97	0.27	12.53
P_6 x P_5	42.07	3.80	19.67	275.23	1.40	14.27
Check	40.13	3.47	15.07	182.07	0.33	10.8
F	2.38^{**}	4.33^{**}	2.07^{*}	1.99^{*}	9.02^{**}	2.10^{*}
SE (m)	1.04	0.26	1.34	21.38	0.24	1.08

Table 4 continued

Parents/ Crosses	Number of fruits/plant	Length of fruit (cm)	Girth of fruit (cm)	Weight of single fruit (g)	Weight of fruits/plant (g)
P_1	9.00	14.17	5.68	15.26	132.93
P_2	11.33	13.97	6.20	17.82	163.90
P_3	11.80	13.68	6.98	16.73	168.90
P_4	9.87	13.03	6.11	15.28	151.03
P_5	9.80	15.55	6.19	18.56	187.77
P_6	10.93	13.08	6.02	14.71	160.20
P_1 x P_2	10.40	16.65	6.85	19.04	232.17
P_1 x P_3	8.93	13.86	6.08	15.63	138.37
P_1 x P_4	13.33	15.23	6.35	16.08	186.87
P_1 x P_5	9.87	14.17	6.00	17.03	161.47
P_1 x P_6	8.67	14.08	5.90	16.57	143.50
P_2 x P_3	10.40	16.12	6.46	19.63	197.97
P_2 x P_4	10.87	14.10	6.77	18.11	188.90
P_2 x P_5	10.13	16.24	6.55	20.37	200.23
P_2 x P_6	10.00	15.06	6.33	18.52	185.17
P_3 x P_4	10.60	14.02	6.34	15.93	166.97
P_3 x P_5	9.87	15.66	6.68	19.81	196.30
P_3 x P_6	11.00	14.52	6.11	17.85	194.10
P_4 x P_5	9.33	15.28	6.48	18.55	171.87
P_4 x P_6	11.07	12.50	5.87	14.43	159.33
P_5 x P_6	9.93	14.21	5.89	17.06	162.90
P_2 x P_1	9.67	16.20	6.88	22.06	248.17
P_3 x P_1	10.73	15.05	6.42	18.12	190.00
P_3 x P_2	10.73	14.31	6.31	18.30	195.90
P_4 x P_1	10.73	14.57	6.55	18.51	194.73
P_4 x P_2	11.93	13.63	6.11	15.88	194.33
P_4 x P_3	12.27	12.09	5.75	13.01	133.33
P_5 x P_1	9.20	15.97	6.05	19.83	182.90
P_5 x P_2	9.73	14.04	5.83	16.35	161.17
P_5 x P_3	11.33	14.37	6.53	17.31	194.17
P_5 x P_4	9.20	15.05	6.63	18.13	169.97
P_6 x P_1	11.47	15.03	6.28	18.27	208.97
P_6 x P_2	11.87	12.69	5.92	13.12	152.73
P_6 x P_3	10.40	13.53	6.21	16.53	169.20
F_6 x P_4	10.40	13.53	5.93	14.86	156.80
P_6 x P_5	10.67	13.36	6.27	18.45	220.70
Check	9.40	14.89	6.27	16.51	154.87
F	2.21*	2.31*	2.11*	2.49*	3.13**
SE (m)	0.96	0.73	0.23	1.27	1.02

Table 4 continued

Parents/ Crosses	Number of seeds/fruit	Fruiting phase	Height of plant (cm)	Percentage fruit set	Incidence of yellow vein mosaic	Incidence of shoot and fruit borer
P_1	57.47	47.03	75.86	81.56	1.20	13.69
P_2	63.73	46.53	68.57	75.80	1.73	14.18
P_3	73.98	48.87	68.97	79.64	2.27	15.20
P_4	55.70	47.40	50.37	82.37	1.73	16.66
P_5	68.33	46.90	59.42	85.47	1.67	14.00
P_6	63.91	46.17	89.77	81.32	2.07	17.01
P_1 x P_2	73.07	49.23	93.57	82.88	2.13	13.83
P_1 x P_3	62.07	48.07	81.02	84.56	1.93	12.63
P_1 x P_4	68.75	47.77	85.69	84.37	1.20	16.06
P_1 x P_5	63.00	50.93	68.38	90.13	1.73	11.81
P_1 x P_6	60.22	48.77	70.65	80.65	1.47	16.15
P_2 x P_3	77.11	47.60	75.07	86.64	1.47	18.10
P_2 x P_4	68.47	45.70	87.23	75.79	1.80	17.35
P_2 x P_5	73.33	45.00	73.93	87.45	1.60	15.74
P_2 x P_6	67.85	47.30	92.32	85.66	2.20	14.95
P_3 x P_4	64.73	43.27	73.23	90.88	1.20	17.32
P_3 x P_5	67.07	48.83	68.39	82.51	2.33	18.05
P_3 x P_6	60.78	46.40	72.43	88.97	1.67	18.44
P_4 x P_5	65.96	44.50	67.92	80.52	2.07	14.73
P_4 x P_6	67.47	46.40	71.83	78.81	1.67	15.47
P_5 x P_6	65.67	51.37	70.20	85.36	1.80	15.89
P_2 x P_1	83.34	48.17	78.30	89.24	1.60	8.00
P_3 x P_1	72.60	48.50	75.67	83.11	1.27	15.50
P_3 x P_2	65.73	46.73	86.09	83.56	1.60	19.37
P_4 x P_1	62.98	45.50	72.71	89.30	1.40	18.14
P_4 x P_2	67.06	45.87	89.41	82.41	1.27	17.97
P_4 x P_3	54.11	44.43	79.45	75.90	1.80	13.65
P_5 x P_1	65.68	47.40	79.45	89.47	1.67	12.05
P_5 x P_2	66.78	47.53	75.17	80.91	1.53	12.34
P_5 x P_3	76.15	48.20	76.07	84.00	2.33	13.88
P_5 x P_4	78.91	50.83	81.67	82.51	1.87	17.16
P_6 x P_1	73.87	45.80	89.25	86.11	2.07	17.71
P_6 x P_2	64.42	49.80	84.73	78.79	1.47	16.86
P_6 x P_3	76.42	47.07	74.89	84.95	2.60	14.31
F_6 x P_4	69.64	44.70	82.13	85.89	1.73	14.42
P_6 x P_5	78.58	43.47	84.36	84.57	1.53	17.58
Check	62.51	49.87	74.65	88.17	1.53	16.37
F	2.11*	2.91*	2.95*	2.09*	3.59*	2.33*
SE (m)	0.84	0.98	0.99	0.60	1.09	0.67

* Significant (P < 0.05)   Significant (< 0.01)

The leaf area values recorded by the parents ranged from 227.95 sq.cm. in P_1 to 287.23 sq.cm. in P_2, whereas it ranged from 199.31 sq. cm. to 314.94 sq.cm. in the hybrids $P_1 x P_6$ and P_5 x P_3 respectively.

The parents showed a wide range of variability for number of branches ranging from 0.47 in P_1 to 3.70 in P_4. In the hybrids, the number of branches ranged from 0.07 for P_1 x P_3 and P_2 x P_6 to 2.40 for P_4 x P_6.

The maximum number of flowers per plant among the parents was exhibited by P_6 (13.93) and the minimum by P_1 (11.33). The hybrids showed a wider variability for this character, ranging from 10.6 (P_5 x P_1) to 16.0 (P_1 x P_4).

The lowest number of 9.0 fruits per plant was seen in the parent P_1 and the highest number in the parent P_3 (11.8). The variability among the hybrids for this character was wider, ranging from 8.67 for P_1 x P_6 to 13.33 for P_1 x P_4.

The length of fruit recorded by the parents ranged from 13.03 cm. in P_4 to 15.55 cm. in P_5. Among the hybrids, it ranged from 12.09 cm. in P_4 x P_3 to 16.65 cm. in P_1 x P_2.

Among the parents, P_1 produced fruits having a mean girth of 5.68 cm., being the minimum value while P_3 had fruits with maximum girth (6.98 cm). The poorest performance among the hybrids for this character was exhibited by P_4 x P_3 (5.75 cm.) and the best performance by P_2 x P_1 (6.88 cm.) which was however lesser than the best performing parent P_3.

The weight of single fruit recorded by the parents ranged from 14.71 g in P_6 to 18.56 g in P_5. A wider variability for this character was seen among the hybrids with a range of 13.01 g (P_4 x P_3) to 22.06 g (P_2 x P_1).

The weight of fruits per plant was the lowest in the parent P_1 (132.93 g) while it was highest (187.77 g) in the parent P_5. Among the hybrids, the maximum weight of fruits was exhibited by P_2 x P_1 (248.17 g) and the minimum by P_4 x P_3 (133.33 g). 13 hybrids were seen to have higher fruit yield than the highest yielding parent.

The number of seeds per pod ranged from 55.70 in P_4 to 73.98 in P_3 in the parents while the range for this character was from 54.11 (P_4 x P_3) to 83.34 (P_2 x P_1) in the hybrids.

The fruiting phase recorded by the parents ranged from 46.17 days in P_6 to 48.87 days in P_3. Among the hybrids, P_3 x P_4 had the shortest fruiting phase of 43.27 days while P_5 x P_6 had the longest fruiting phase of 51.37 days.

With regard to plant height, the shortest plants were observed in P_4 (50.37 cm.) and the tallest ones in P_6 (89.77 cm.)

among the six parents. The shortest hybrid was P_4 x P_5 (67.92 cm.) and the tallest one was P_1 x P_2 (93.57 cm.).

The percentage fruit set among the parents was maximum in P_5 (85.47%) and minimum in P_2 (75.80%). Among the hybrids, the percentage fruit set ranged from 75.79% in P_2 x P_4 to 90.88% in P_3 x P_4.

The incidence of yellow vein mosaic disease was low in parent P_1 (1.2) and high in parent P_3 (2.27). Among the hybrids the mean scores recorded ranged from 1.2 in two hybrids P_1 x P_4 and P_3 x P_4 to 2.6 in P_6 x P_3. The incidence of the disease was found to be intermediate among the hybrids when compared to the parents except for three hybrids viz., P_3 x P_5 and P_5 x P_3 (2.33) and P_6 x P_3 (2.60).

The highest incidence of shoot and fruit borer among the parents was recorded by P_6 (17.01%) and the lowest by P_1 (13.69%). The hybrids showed a wider variability in the incidence with a range of 8.00% in P_2 x P_1 to 19.37% in P_3 xP_2.

In general, it was seen that the parent P_5 showed the highest values for length of fruit, weight of single fruit, weight of fruits per plant and percentage fruit set. Among the hybrids, P_1 x P_2 had maximum plant height and fruit length while its reciprocal cross P_2 x P_1 showed best performance with respect to girth of fruit, weight of single fruit, weight of fruits per plant and number of seeds per pod and it was also least affected by shoot and fruit borer incidence.

4.2 Combining ability

Combining ability analysis was carried out by the Method 1 under Model I as suggested by Griffing (1956). The analysis of variance for combining ability is presented in Table 5.

The general combining ability (g.c.a.) effect was significant for eight characters viz., leaf axil bearing the first flower, leaf number, leaf area, number of branches, length of fruit, weight of single fruit, height of plant and incidence of yellow vein mosaic.

The specific combining ability (s.c.a.) effect was significant for days to first flowering, leaf axil bearing the first flower, number of branches, length of fruit, girth of fruit, weight of single fruit, weight of fruits per plant, number of seeds per fruit, height of plant and incidence of yellow vein mosaic.

The mean squares due to reciprocal effects were significant for days to first flowering, leaf axil bearing the first flower, leaf number, number of branches, number of flowers

Table 5. Analysis of variance for combining ability for the 17 characters

Sl. No.	Character	Mean squares			
		g.c.a.	s.c.a.	Reciprocal effects	Error
1.	Days to first flowering	0.93	3.14^{**}	2.53^{**}	1.08
2.	Leaf axil bearing the first flower	0.52^{**}	0.28^{**}	0.26^{**}	0.07
3.	Leaf number	4.56^{*}	1.88	5.33^{**}	1.80
4.	Leaf area	1065.81^{**}	527.25	639.09	457.15
5.	Number of branches	0.68^{**}	0.63^{**}	0.33^{**}	0.06
6.	Number flowers per plant	1.02	1.09	2.84^{**}	1.16
7.	Number of fruits per plant	0.43	0.97	1.49	0.92
8.	Length of fruit	1.56^{*}	1.79^{**}	0.59	0.54
9.	Girth of fruit	0.12	0.15^{*}	0.07	0.05
10.	Weight of single fruit	4.39^{*}	4.79^{**}	3.13^{*}	1.61
11.	Weight of fruits per plant	425.50	874.41^{**}	610.14^{**}	222.73
12.	Number of seeds per fruit	7.85	72.76^{*}	29.36	21.24
13.	Fruiting phase	2.22	1.73	6.60^{*}	1.34
14.	Height of plant	110.73^{**}	97.62^{**}	66.02^{*}	29.14
15.	Percentage fruit set	9.09	11.28	22.87	14.49
16.	Incidence of yellow vein mosaic	0.17^{**}	0.11^{**}	0.12^{**}	0.03
17.	Incidence of shoot and fruit borer	7.89	3.92	6.44	4.18

* Significant ($P < 0.05$) ** Significant ($P < 0.01$)

per plant, weight of single fruit, weight of fruits per plant, fruiting phase, height of plant and incidence of yellow vein mosaic.

The estimates of the g.c.a. effects of the six parents and the s.c.a effects of the F_1 hybrids and the reciprocal crosses are presented in Tables 6 and 7 respectively (Figures 1.1 to 1.21).

4.2.1 Days to first flowering

The combining ability analysis for days to first flowering showed that the g.c.a. effect was not significant. However, the s.c.a. and reciprocal effects were significant. This shows the importance of s.c.a. for this character.

Significant s.c.a. effects were shown by four crosses viz. P_2 x P_4, P_2 x P_5, P_2 x P_6 and P_3 x P_5. Of these, only P_2 x P_4 and P_2 x P_5 showed negative effects of -1.45 and -1.42 respectively, both of which were on par. Significant reciprocal effects were seen in four crosses viz., P_3 x P_2, P_5 x P_1, P_5 x P_3 and P_5 x P_4 of which significant negative effects were shown by P_5 x P_4 (-2.40) and P_3 x P_2 and P_5 x P_3 (-1.53), indicating earliness in flowering in these crosses.

Table 6. Estimates of g.c.a effects of the six parents.

Character	P_1	P_2	P_3	P_4	P_5	P_6	SE$_{(gi)}$	SE$_{(gi-gj)}$
Days to first flowering@	-	-		-	-	-	-	-
Leaf axil bearing the first flower	-0.11	0.06	-0.07	0.39**	-0.16**	-0.12	0.069	0.108
Leaf number	-0.11	0.06	-0.19	1.09**	-0.55	0.10	0.354	0.548
Leaf area	-15.95**	6.95	-2.78	11.55*	-0.30	0.53	5.634	8.728
Number of branches	-0.23**	-0.04	-0.07	0.44**	-0.08	-0.17**	0.063	0.097
Number of flowers/plant@	-	-	-	-	-	-	-	-
Number of fruits/plant@	-	-	-	-	-	-	-	-
Length of fruit	0.31	0.41*	-0.36	0.05	0.08	-0.50*	0.194	0.300
Girth of fruit@	-	-	-	-	-	-	-	-
Weight of single fruit	0.03	0.74*	-0.10	0.28	0.12	-1.08**	0.335	0.519
Weight of fruits /plant@	-	-	-	-	-	-	-	-
Number of seeds/fruit@	-	-	-	-	-	-	-	-
Fruiting phase@	-	-	-	-	-	-	-	-
Height of plant	1.40	1.67	-2.63	-3.00*	-2.04	4.61**	1.423	2.204
Percentage fruit set@	-	-	-	-	-	-	-	-
Incidence of YVM	-0.06	-0.08	0.22**	-0.11*	0.01	0.02	0.049	0.075
Incidence of shoot and fruit borer@	-	-	-	-	-	-	-	-

* Significant ($P < 0.05$), ** Significant ($P < 0.01$)

@ g.c.a. effects are not estimated as their g.c.a. variance was not significant

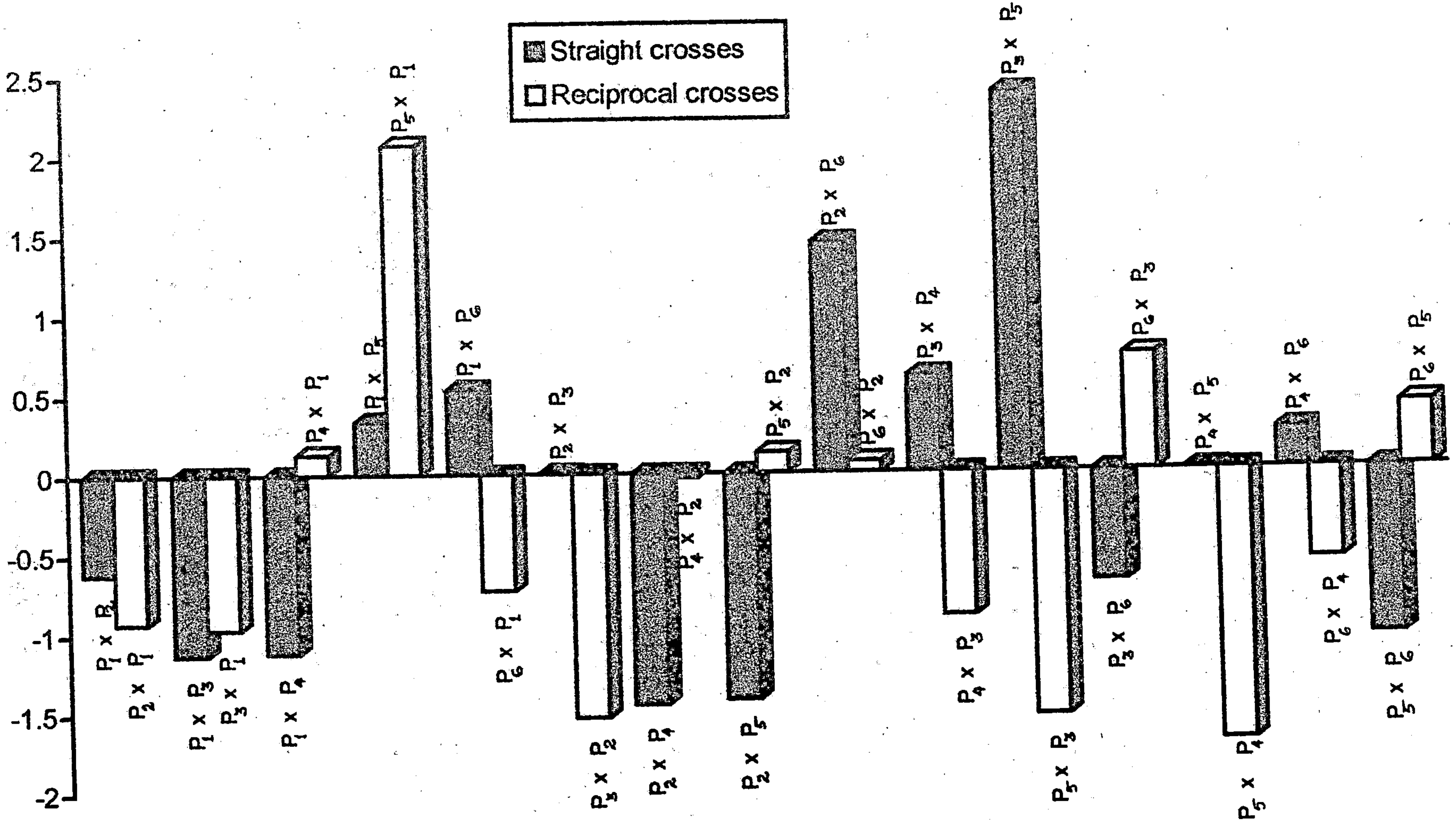


Fig.1.1 Days to first flowering - s.c.a effects

Table 7. Estimates of s.c.a. effects of the 30 hybrids.

Crosses	Days to first flowering	Leaf axil bearing the first flower	Leaf number	Number of branches	Number of flowers per plant	Length of fruit	Girth of fruit
$P_1 \times P_2$	-0.62	0.12	-	0.54**	-	1.19**	0.35**
$P_1 \times P_3$	-1.13	-0.31	-	-0.30*	-	0.38	0.08
$P_1 \times P_4$	-1.12	-0.04	-	-0.11	-	0.88**	0.30*
$P_1 \times P_5$	0.34	0.18	-	0.11	-	-1.74**	-0.26
$P_1 \times P_6$	0.54	-0.09	-	-0.13	-	0.26	0.02
$P_2 \times P_3$	0.01	0.48**	-	0.34*	-	-0.21	0.00
$P_2 \times P_4$	-1.45*	-0.75**	-	-0.80**	-	0.71	0.04
$P_2 \times P_5$	-1.42*	-0.30	-	-0.81**	-	0.55	-0.08
$P_2 \times P_6$	1.45*	0.46**	-	0.48**	-	-0.93*	-0.08
$P_3 \times P_4$	0.61	0.09	-	-0.30*	-	0.63	-0.05
$P_3 \times P_5$	2.38**	0.50**	-	0.42**	-	-0.92*	-0.42**
$P_3 \times P_6$	-0.69	-0.27	-	-0.20	-	0.25	-0.16
$P_4 \times P_5$	0.01	0.01	-	0.11	-	-0.14	0.26
$P_4 \times P_6$	0.25	-0.10	-	-0.70**	-	-0.53	-0.21
$P_5 \times P_6$	-1.05	-0.08	-	0.38**	-	1.34**	0.41**
$P_2 \times P_1$	-0.93	-0.17	-0.53	0.23	-0.53	-	-
$P_3 \times P_1$	-0.97	0.20	0.47	0.50**	0.73	-	-
$P_3 \times P_2$	-1.53*	-0.43**	-1.57	0.40*	-1.10	-	-
$P_4 \times P_1$	0.13	-0.20	-1.50	-0.67**	-2.57**	-	-
$P_4 \times P_2$	-0.03	0.13	0.73	-0.03	0.67	-	-
$P_4 \times P_3$	-0.90	0.37**	1.03	0.03	0.57	-	-
$P_5 \times P_1$	2.07**	0.33	1.72	0.43*	1.50*	-	-
$P_5 \times P_2$	0.13	-0.30	-0.17	0.03	-0.53	-	-
$P_5 \times P_3$	-1.53*	-0.63**	-2.50**	-0.97**	-0.90	-	-
$P_5 \times P_4$	-2.40**	-0.80*	-1.23	-0.37**	0.67	-	-
$P_6 \times P_1$	-0.73	0.23	1.73	0.37**	1.17	-	-
$P_6 \times P_2$	0.07	-0.17	2.13*	0.10	1.90*	-	-
$P_6 \times P_3$	0.73	0.37*	0.80	0.07	0.37	-	-
$P_6 \times P_4$	-0.57	-0.07	-2.93**	-0.33*	-0.93	-	-
$P_6 \times P_5$	0.40	0.20	2.37*	0.23	1.47	-	-
$SE_{(Sij)}$	0.62	0.16	0.81	0.14	0.65	0.44	0.14
$SE_{(Sij-Skl)}$	0.95	0.24	1.23	0.22	0.98	0.67	0.21
$SE_{(Sij-Sik)}$	0.85	0.22	1.09	0.19	0.88	0.60	0.19

Table 7 continued

Crosses	Weight of single fruit	Weight of fruits/plant	Number of seeds/plant	Fruiting phase	Height of plant	Incidence of yellow vein mosaic
$P_1 \times P_2$	1.29	32.52**	8.59**	-	4.20	0.20
$P_1 \times P_3$	0.51	-3.29	-1.85	-	-1.12	0.24*
$P_1 \times P_4$	1.49*	33.62**	9.42**	-	6.55*	-0.16
$P_1 \times P_5$	-2.41*	-28.44**	-8.17**	-	-2.52	0.07
$P_1 \times P_6$	1.20	6.39	-0.45	-	-3.12	0.07
$P_2 \times P_3$	0.06	12.04	-3.28	-	3.73	-0.15
$P_2 \times P_4$	0.95	2.39	4.85	-	-0.92	-0.11
$P_2 \times P_5$	1.04	-0.64	-1.50	-	9.20**	0.26*
$P_2 \times P_6$	-2.40**	-18.82	-4.41	-	-4.36	-0.35
$P_3 \times P_4$	0.97	3.08	-2.19	-	5.58	-0.01
$P_3 \times P_5$	-1.91*	-12.50	-1.00	-	1.12	-0.38**
$P_3 \times P_6$	-0.71	-0.70	2.15	-	-6.49*	0.22*
$P_4 \times P_5$	0.24	8.42	1.23	-	2.38	0.22*
$P_4 \times P_6$	-1.10	-4.46	-0.76	-	7.10*	-0.15
$P_5 \times P_6$	1.98**	23.36**	9.54**	-	3.38	-0.08
$P_2 \times P_1$	0.29	-17.10	-	-0.82	-9.25*	-0.33*
$P_3 \times P_1$	2.09*	28.97**	-	0.38	-6.32	0.20
$P_3 \times P_2$	-0.13	2.60	-	0.35	-7.40*	-0.07
$P_4 \times P_1$	2.99**	30.65**	-	0.20	-3.70	0.20
$P_4 \times P_2$	-1.12	-5.12	-	1.75*	0.87	-0.17
$P_4 \times P_3$	-0.12	12.02	-	1.12	9.08*	-0.23
$P_5 \times P_1$	-2.01*	-14.07	-	-3.25**	5.56	0.03
$P_5 \times P_2$	0.65	-1.13	-	0.05	-6.43	-0.27*
$P_5 \times P_3$	0.96	0.92	-	0.57	1.67	-0.07
$P_5 \times P_4$	-0.60	-0.28	-	1.40	1.68	0.47**
$P_6 \times P_1$	0.85	32.73*	-	-1.48	9.30*	0.30*
$P_6 \times P_2$	-1.40	-7.12	-	3.27**	5.75	0.13
$P_6 \times P_3$	-0.26	3.15	-	-2.15**	2.34	0.40**
$P_6 \times P_4$	-0.51	18.77	-	-0.58	-3.64	0.23
$P_6 \times P_5$	0.16	25.37*	-	-3.68**	1.35	-0.17
$SE_{(Sij)}$	0.76	8.97	2.77	0.69	3.24	0.11
$SE_{(Sij-Skl)}$	1.16	13.62	4.21	1.06	4.93	0.17
$SE_{(Sij-Skl)}$	1.04	12.19	3.76	0.94	4.41	0.15

* Significant ($P < 0.05$) ** Significant ($P < 0.01$)

The s.c.a. effects are not estimated for those characters for which the s.c.a variances lacked significance.

4.2.2 Leaf axil bearing the first flower

The combining ability analysis showed significant g.c.a., s.c.a. and reciprocal variances for this character. The g.c.a. variance was higher than the s.c.a. variance indicating the importance of g.c.a. for this character.

The parent P_5 showed significant negative g.c.a. effect of -0.16 and parent P_4 showed significant positive g.c.a. effect of 0.39. Three hybrids P_2 x P_3, P_2 x P_6 and P_3 x P_5 showed significant positive s.c.a. effects whereas only one hybrid P_2 x P_4 showed significant negative effect (-0.75). Significant s.c.a. effects were also seen in five reciprocal crosses P_3 x P_2, P_4 x P_3, P_5 x P_3, P_5 x P_4 and P_6 x P_3. Of these only P_5 x P_4, P_5 x P_3 and P_3 x P_2 showed negative effects of -0.80, -0.63 and -0.43 respectively. Thus the parent P_5 can be considered as the best general combiner and the crosses P_2 x P_4 and P_5x P_4 as the best specific combinations for this character.

4.2.3 Leaf number

Significant g.c.a. and reciprocal effects were observed indicating the importance of g.c.a. for this character.

Significant positive g.c.a. effect was shown by one parent P_4 (1.09). Two reciprocal crosses P_6 x P_5 and P_6 x P_2

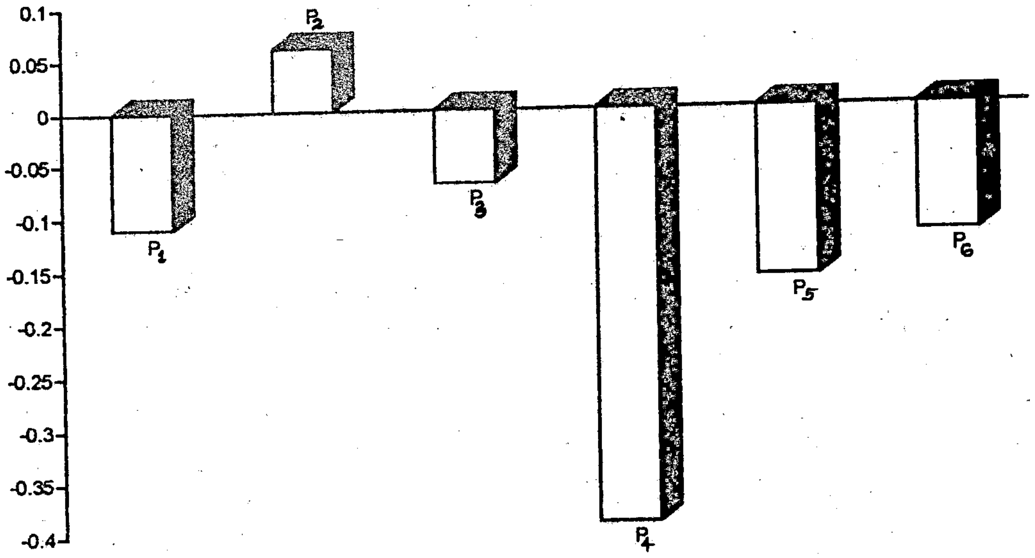


Fig.1.2 Leaf axil bearing the first flower - g.c.a effects

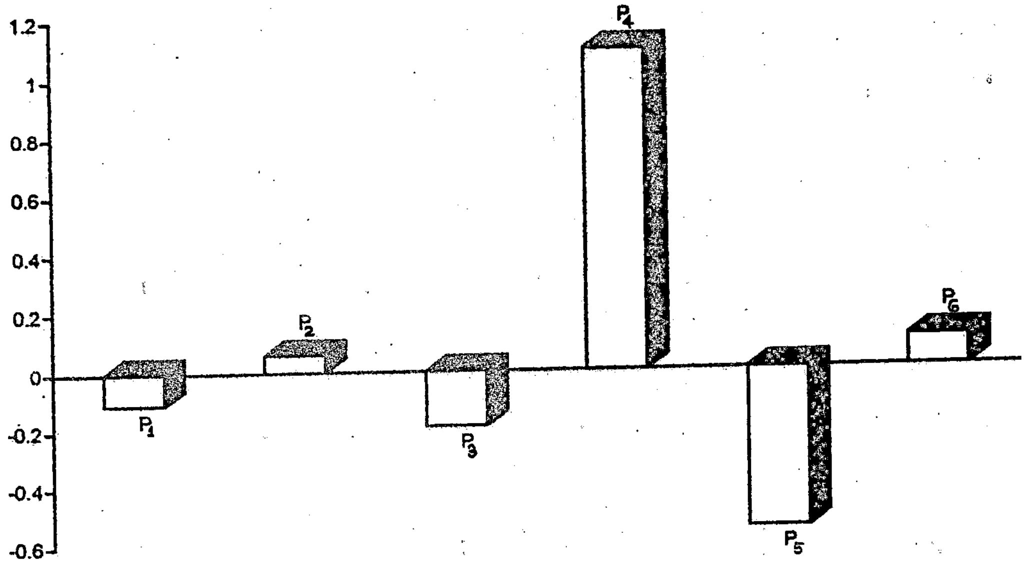


Fig.1.3 Leaf Number - g.c.a effects

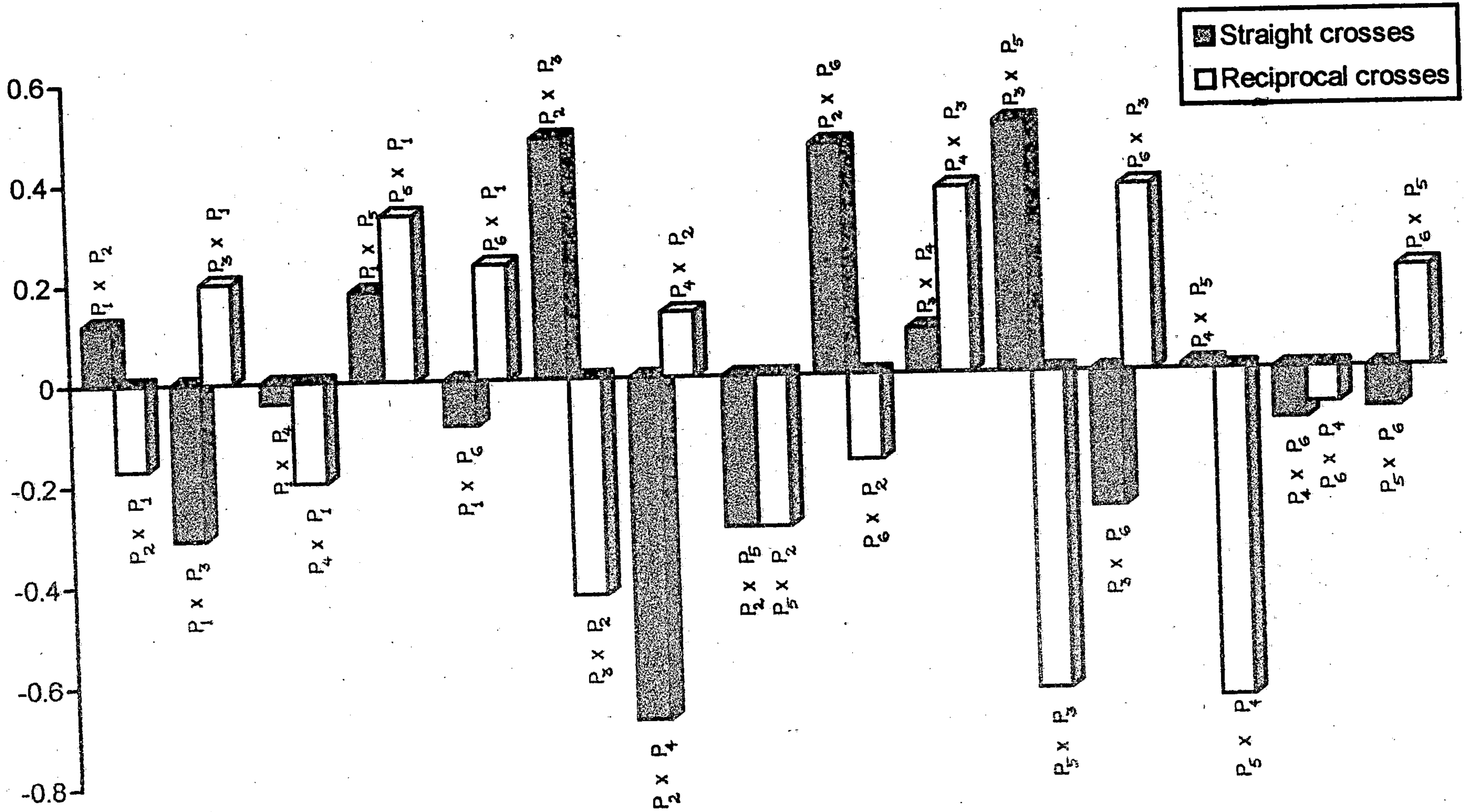


Fig.1.4 Leaf axil bearing the first flower - s.c.a effects

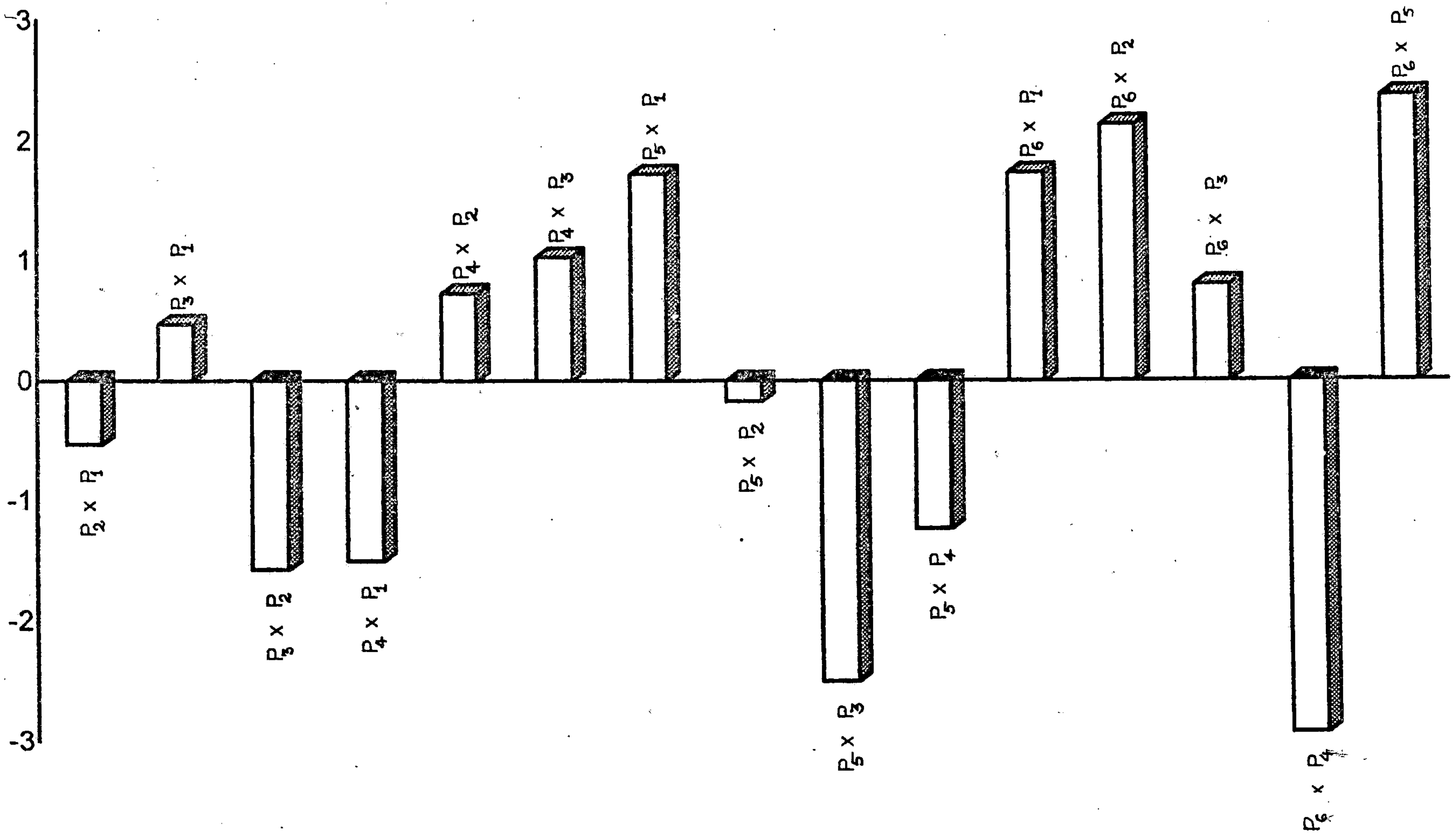


Fig.1.5 Leaf number - s.c.a effects

showed significant positive s.c.a effects of 2.37 and 2.13 respectively. Two other reciprocal crosses P_5 x P_3 and P_6 x P_4 showed significant negative s.c.a effect for leaf number. Thus the parent P_4 was the best general combiner and the cross P_6 x P_5 was the best specific combination followed by P_6 x P_2 for leaf number.

4.2.4 Leaf area

The combining ability analysis showed significance only for g.c.a. variance indicating the importance of g.c.a. for this character.

The parents P_1 and P_4 showed significant g.c.a. effects of which only P_4 showed positive effect of 11.55. Thus it can be seen that the parent P_4 was the best general combiner for leaf area and none of the crosses proved to be good combinations for this character.

4.2.5 Number of branches

The combining ability analysis for this character showed significant variances for g.c.a., s.c.a. and reciprocal effects. The g.c.a. variance was greater than the s.c.a. variance indicating the importance of g.c.a. for this character.

The parents P_1, P_4 and P_6 showed significant g.c.a. effects of which only P_4 showed positive effect of 0.44,

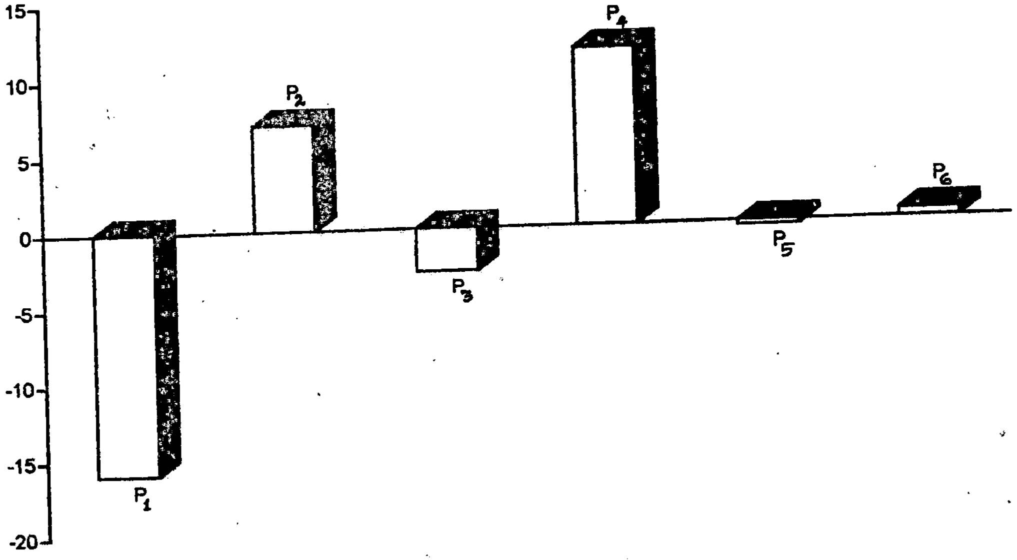


Fig. 1.6 Leaf area - g.c.a effects

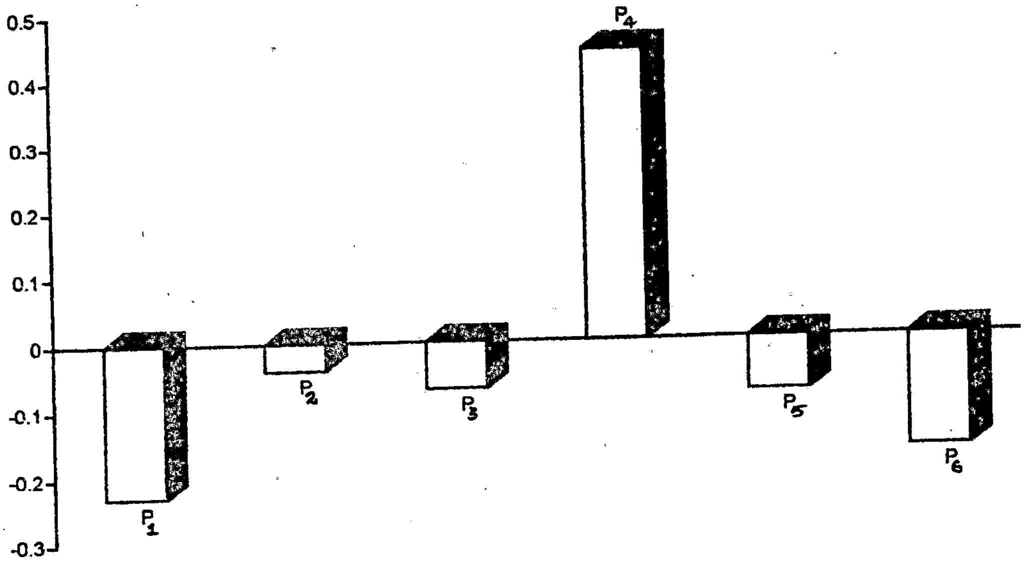


Fig. 1.7 Number of branches - g.c.a effects

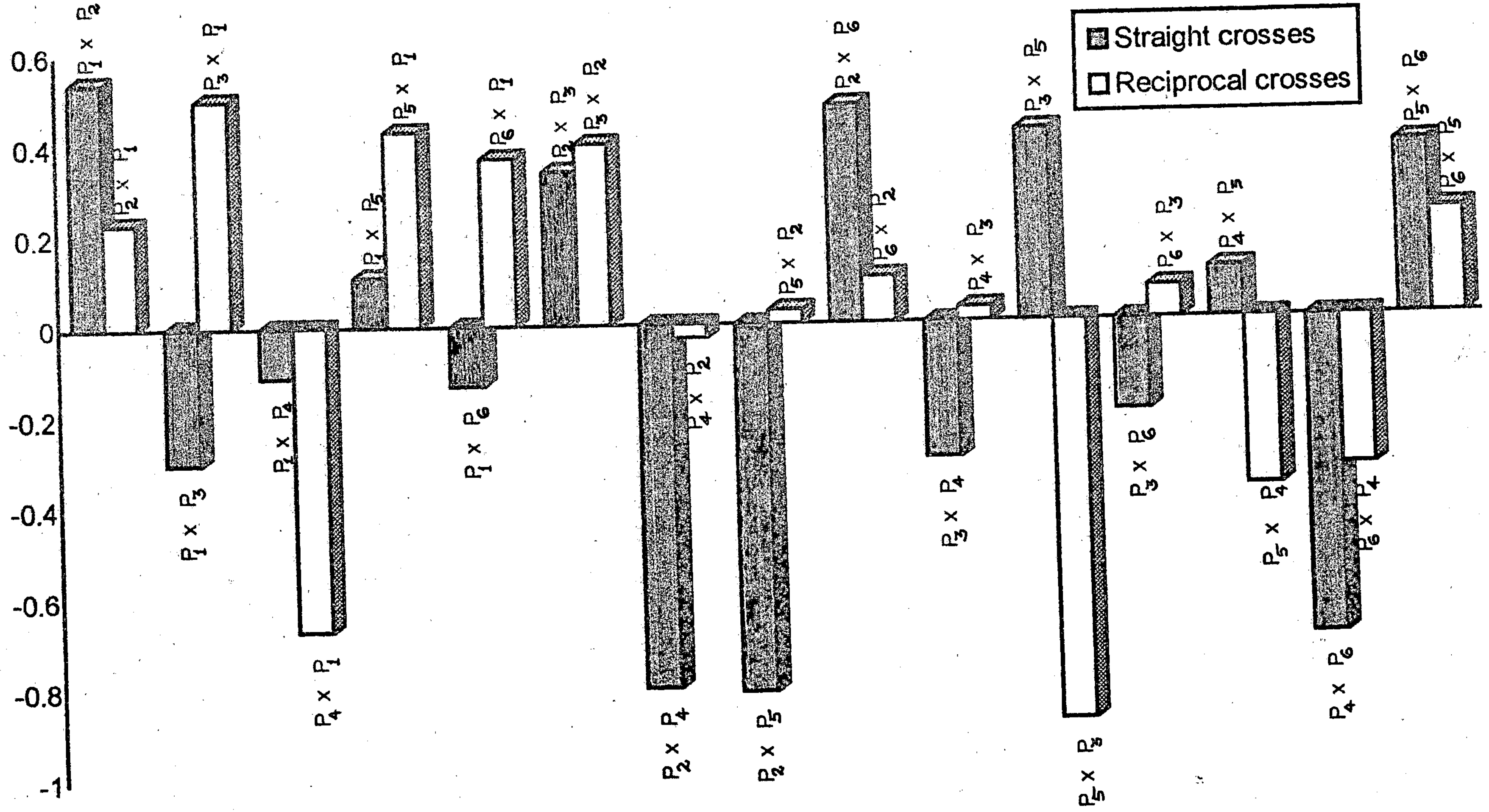


Fig.1.8 Number of branches - s.c.a effects

indicating this parent as the best general combiner for number of branches. Significant s.c.a. effects were exhibited by ten hybrids viz., P_1 x P_2, P_1 x P_3, P_2 x P_3, P_2 x P_4, P_2 x P_5, P_2 x P_6, P_3 x P_4, P_3 x P_5, P_4 x P_6 and P_5 x P_6. Of these, significant positive s.c.a. effects were seen only in P_1 x P_2 (0.54), P_2 x P_6 (0.48), P_3 x P_5 (0.42), P_5 x P_6 (0.38) and P_2 x P_3 (0.34). Significant reciprocal effects were seen in eight crosses of which only three crosses P_3 x P_1 (0.50), P_5 x P_1 (0.43) and P_6 x P_1 (0.37) showed positive effects. Thus many crosses proved to be good specific combinations for this character.

4.2.6 Number of flowers per plant

The analysis of variance for combining ability showed significance for reciprocal effects only.

Significant s.c.a. effects for this character were seen only for the reciprocal crosses. Two reciprocal crosses P_6 x P_2 and P_5 x P_1 showed significant s.c.a. effects of 1.90 and 1.50 respectively while the reciprocal cross P_4 x P_1 showed significant negative s.c.a. effect. Hence the hybrid P_6 x P_2 can be considered as the best specific combination closely followed by P_5 x P_1.

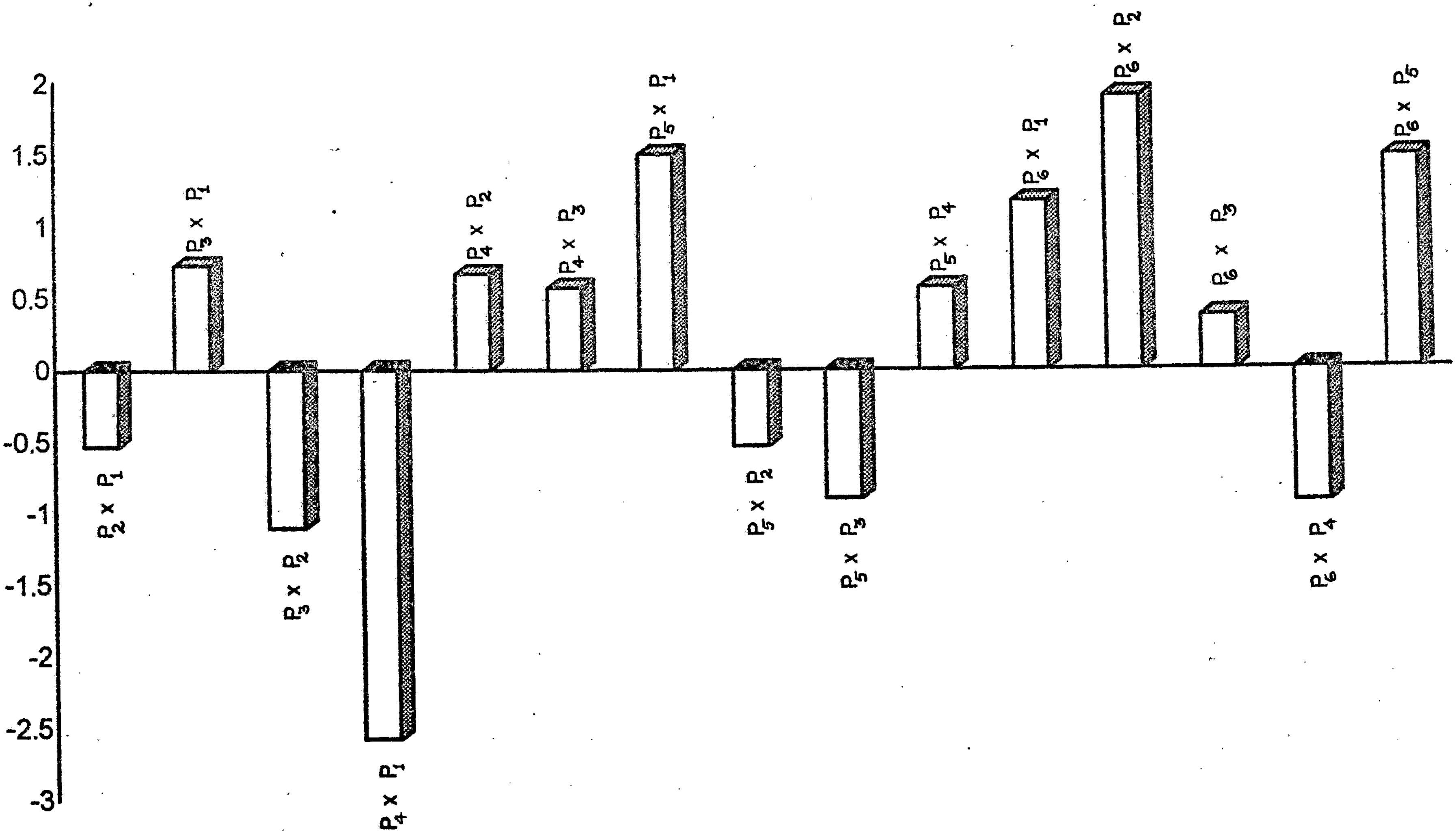


Fig.1.9 Number of flowers per plant - s.c.a effects

4.2.7 Number of fruits per plant

The combining ability analysis for this character showed lack of significance of the variances due to g.c.a., s.c.a. as well as reciprocal effects.

4.2.8 Length of fruit

Significant variance for g.c.a. and s.c.a. were noticed for fruit length. The s.c.a. variance was greater than the g.c.a. variance indicating the importance of s.c.a. for this character.

Significant g.c.a. effect was exhibited by two parents P_2 and P_6 where P_2 showed positive effect (0.41) and P_6 showed negative effect (-0.50). Six crosses showed significant s.c.a. effects. However, only three of them showed positive s.c.a. effects viz., P_5 x P_6 (1.34), P_1 x P_2 (1.19) and P_1 x P_4 (0.88). None of the crosses showed significant reciprocal effects. Thus the parent P_2 can be considered as the best general combiner for fruit length and the crosses P_5 x P_6, P_1 x P_2 and P_1 x P_4 as the best specific combinations for this character.

4.2.9 Girth of fruit

Combining ability analysis for girth of fruit indicated significance for variance due to s.c.a. only. The variance due to g.c.a. and reciprocal effects were not significant.

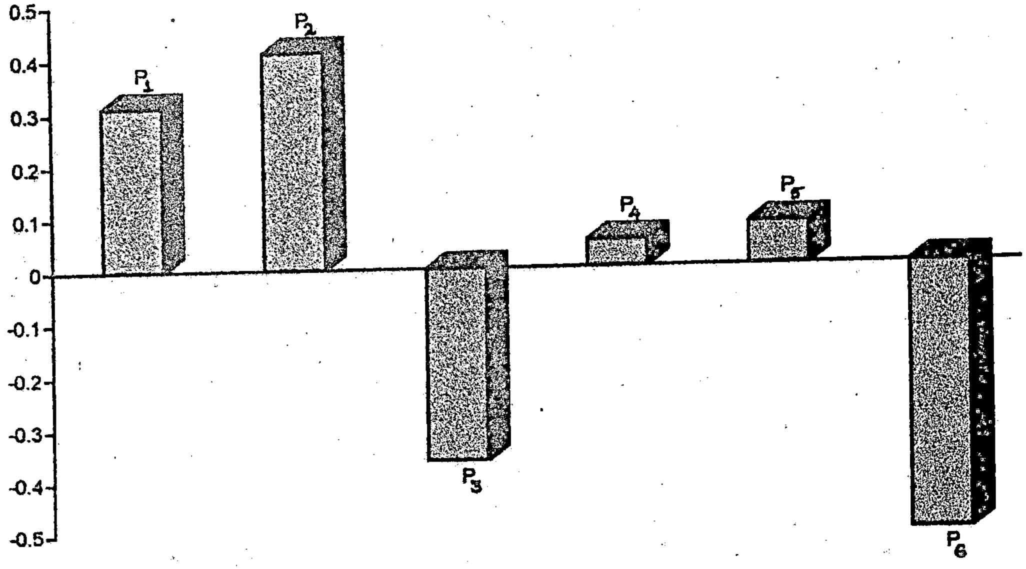


Fig.1.10 Length of fruit - g.c.a effects

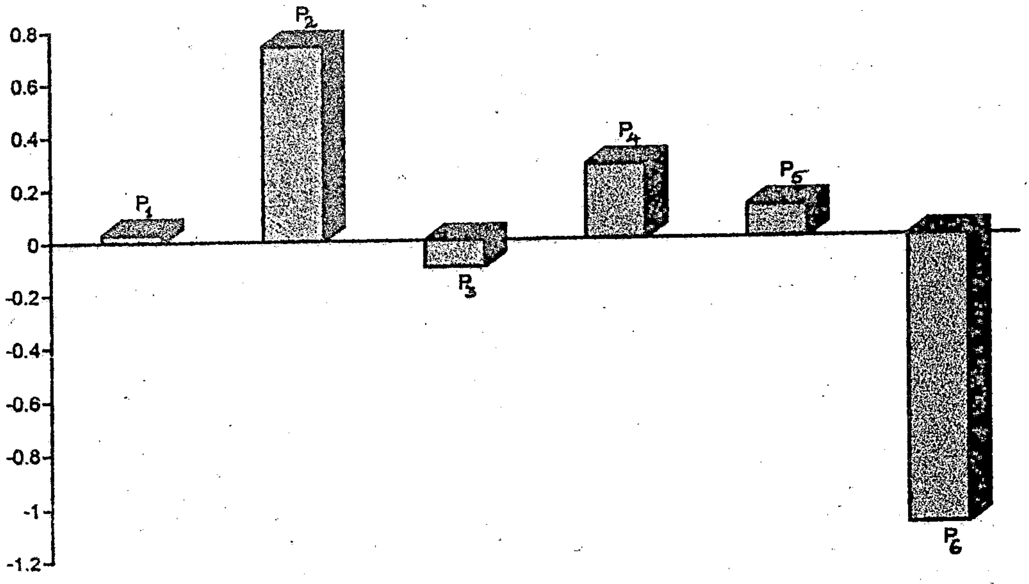


Fig.1.11 Weight of single fruit - g.c.a effects

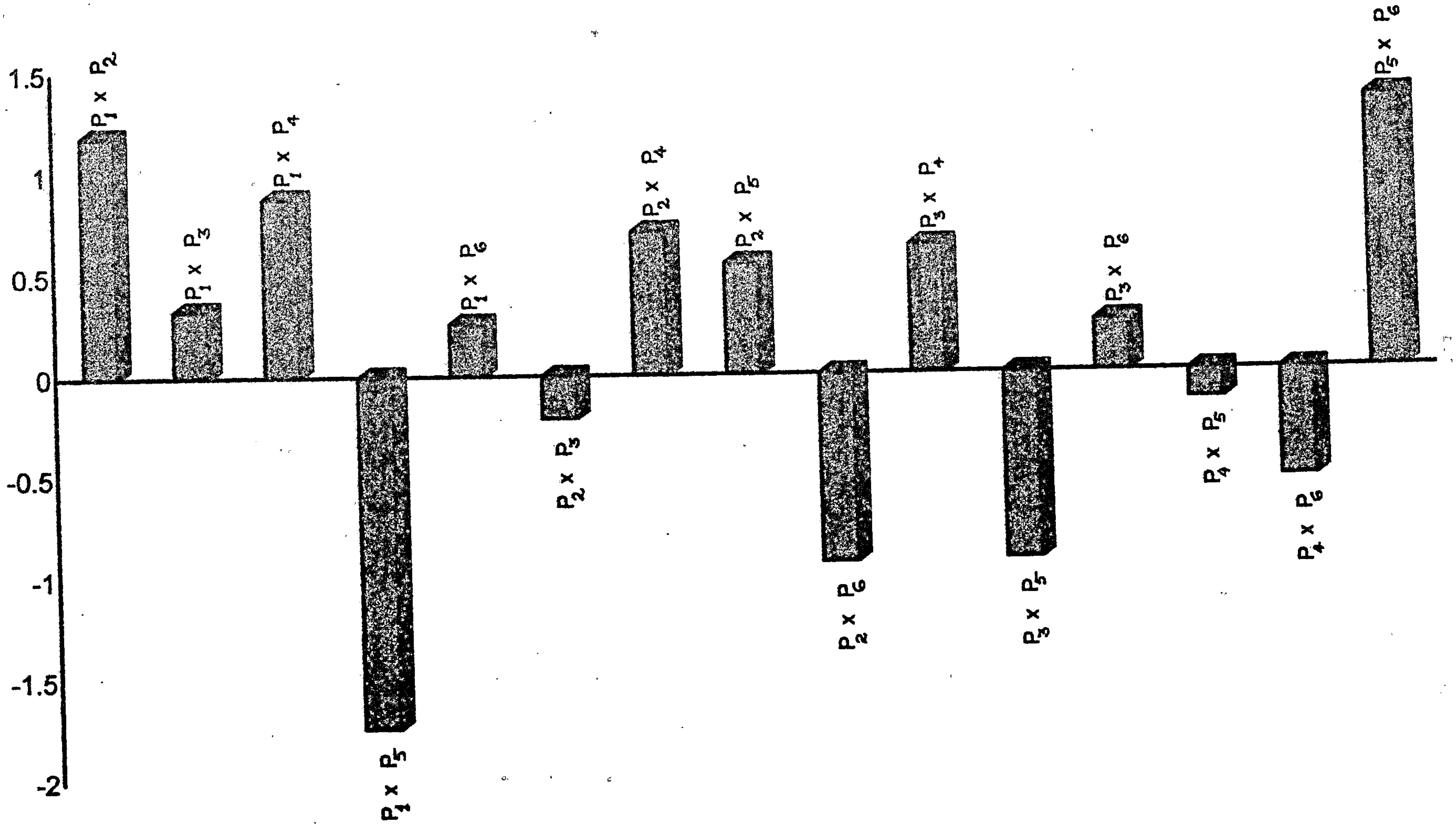


Fig.1.12 Length of fruit - s.c.a effects

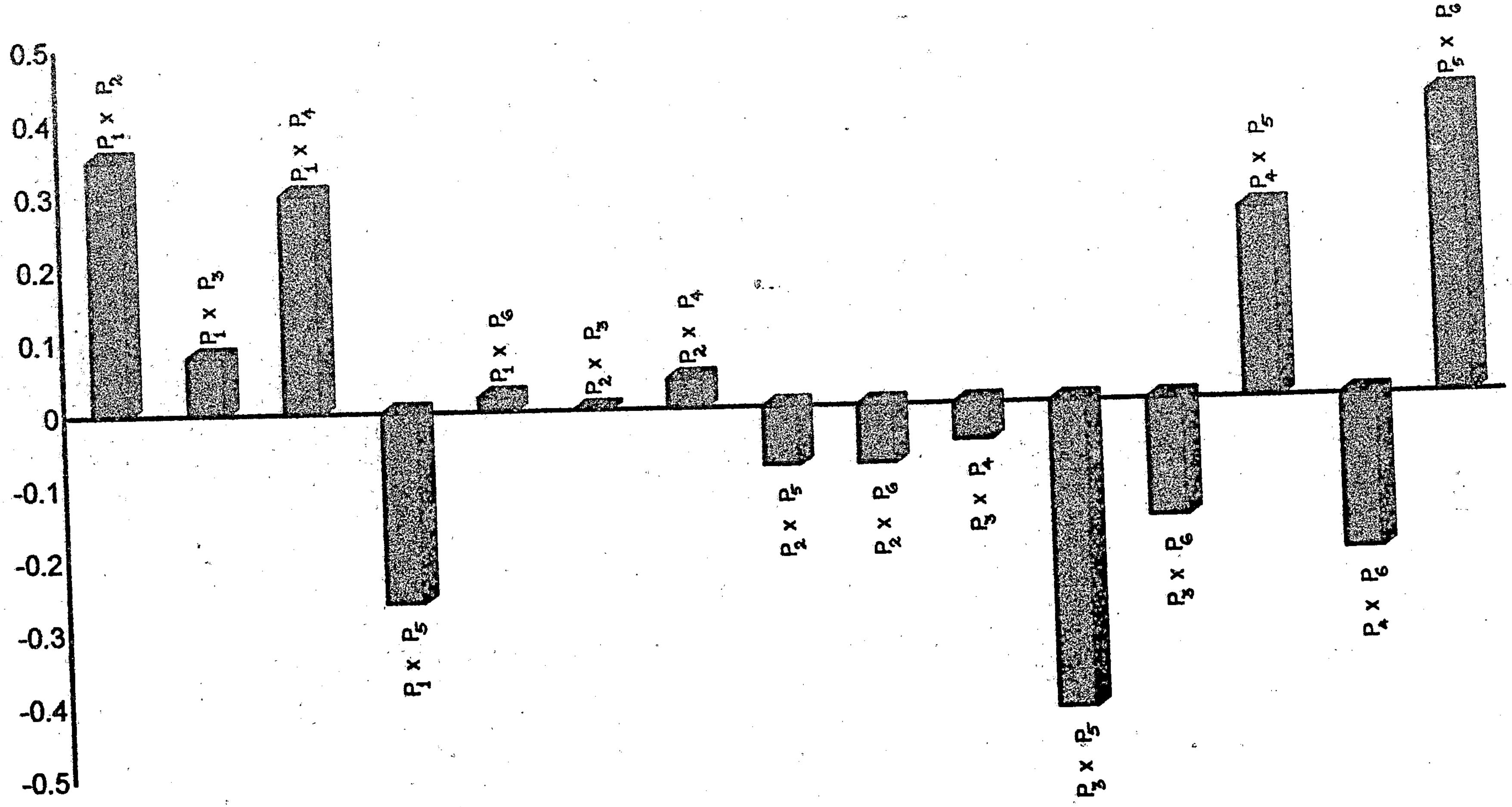


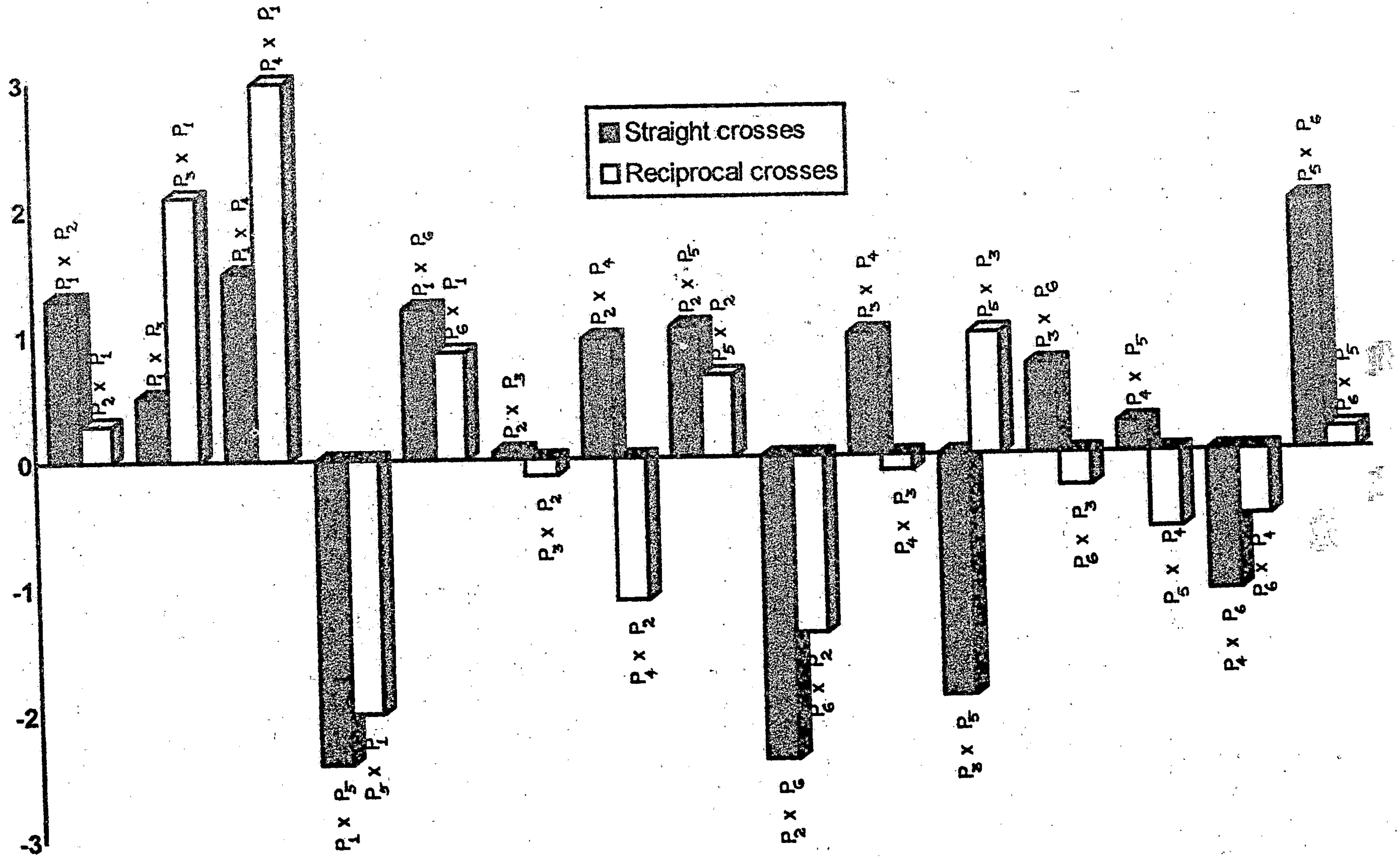
Fig 1.13 Girth of fruit - s.c.a effects

None of the parents showed significant g.c.a. effects for girth of fruit. Significant positive s.c.a. effects were exhibited by three crosses P_5 x P_6 (0.41), P_1 x P_2 (0.35) and P_1 x P_4 (0.30). The cross P_3 x P_5 showed significant negative s.c.a. effect (-0.42). None of the crosses showed significant reciprocal effects. Thus the cross P_5 x P_6 can be considered as the best specific combination closely followed by P_1 x P_2 and P_1 x P_4.

4.2.10 Weight of single fruit

The analysis of variance for combining ability revealed significant variance for g.c.a., s.c.a and reciprocal effects. The s.c.a. variance was greater than the g.c.a. variance indicating the importance of s.c.a. for this character.

Significant positive g.c.a. effect was exhibited by only one parent P_2 (0.74) while the parent P_6 showed significant negative g.c.a. effect (-1.08). Five of the crosses namely P_1 x P_4, P_1 x P_5, P_2 x P_6, P_3 x P_5 and P_5 x P_6 showed significant s.c.a. effects. However, three of them showed negative effects and only two crosses P_5 x P_6 and P_1 x P_4 showed positive s.c.a. effects of 1.98 and 1.49 respectively. Significant positive


3
2
1
0
-1
-2
-3
Straight crosses
Reciprocal crosses
P_1 x P_2
P_2 x P_1
P_1 x P_3
P_3 x P_1
P_1 x P_4
P_4 x P_1
P_1 x P_5
P_5 x P_1
P_1 x P_6
P_6 x P_1
P_2 x P_3
P_3 x P_2
P_2 x P_4
P_4 x P_2
P_2 x P_5
P_5 x P_2
P_2 x P_6
P_6 x P_2
P_3 x P_4
P_4 x P_3
P_3 x P_5
P_5 x P_3
P_3 x P_6
P_6 x P_3
P_4 x P_5
P_5 x P_4
P_4 x P_6
P_6 x P_4
P_5 x P_6
P_6 x P_5

reciprocal effects were shown by two crosses, P_4 x P_1 (2.99) and P_3 x P_1 (2.09). The cross P_5 x P_1 showed significant negative reciprocal effect (-2.01). Thus the parent P_2 was found to be the best general combiner for weight of single fruit, and the hybrid P_4 x P_1 to be the best specific combination closely followed by P_3 x P_1 and P_5 x P_6.

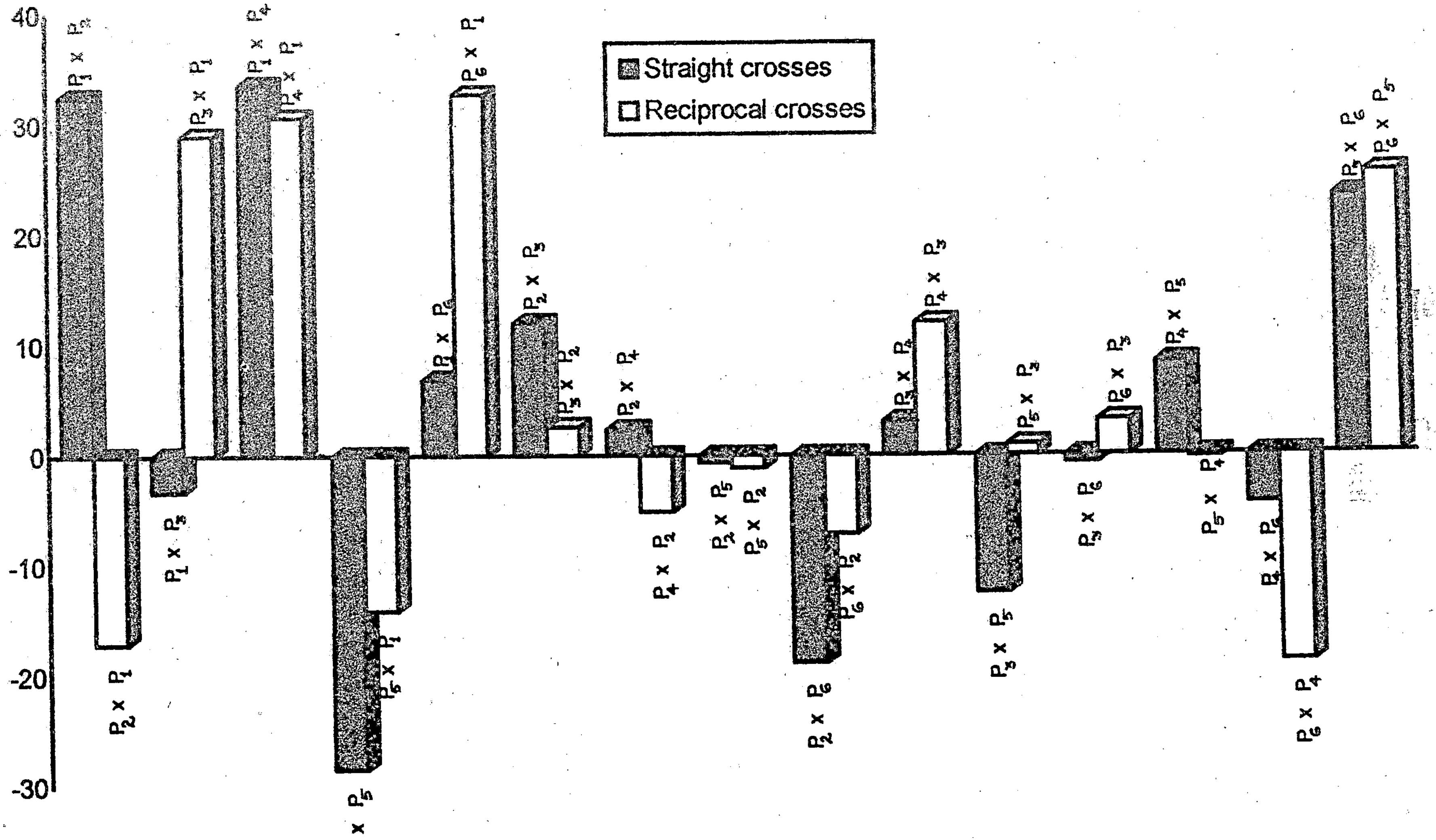
4.2.11 Weight of fruits per plant

The combining ability analysis showed significant variances for s.c.a and reciprocal effects. The g.c.a. variance was found to be non significant. This shows the importance of s.c.a. for yield per plant.

Among the hybrids, P_1 x P_4, P_1 x P_2 and P_5 x P_6 showed significant positive s.c.a. effects of 33.62, 32.52 and 23.36 respectively while P_1 x P_5 showed significant negative s.c.a. effect. Among the reciprocal crosses, four of them showed significant reciprocal effects viz., P_6 x P_1 (32.73), P_4 x P_1 (30.65), P_3 x P_1 (28.97) and P_6 x P_5 (25.37). Thus the hybrids P_1 x P_4, P_6 x P_1, P_1 x P_2 and P_4 x P_1 were good specific combinations for yield.

4.2.12 Number of seeds per fruit

The analysis of combining ability revealed significance only for s.c.a. variance indicating the importance of s.c.a. for



▨ Straight crosses
☐ Reciprocal crosses
40
30
20
10
0
-10
-20
-30
P_1 x P_2
P_2 x P_1
P_1 x P_3
P_3 x P_1
P_1 x P_4
P_4 x P_1
x P_5
P_5 x P_1
P_1 x P_6
P_6 x P_1
P_2 x P_3
P_3 x P_2
P_2 x P_4
P_4 x P_2
P_2 x P_5
P_5 x P_2
P_2 x P_6
P_6 x P_2
P_3 x P_4
P_4 x P_3
P_3 x P_5
P_5 x P_3
P_3 x P_6
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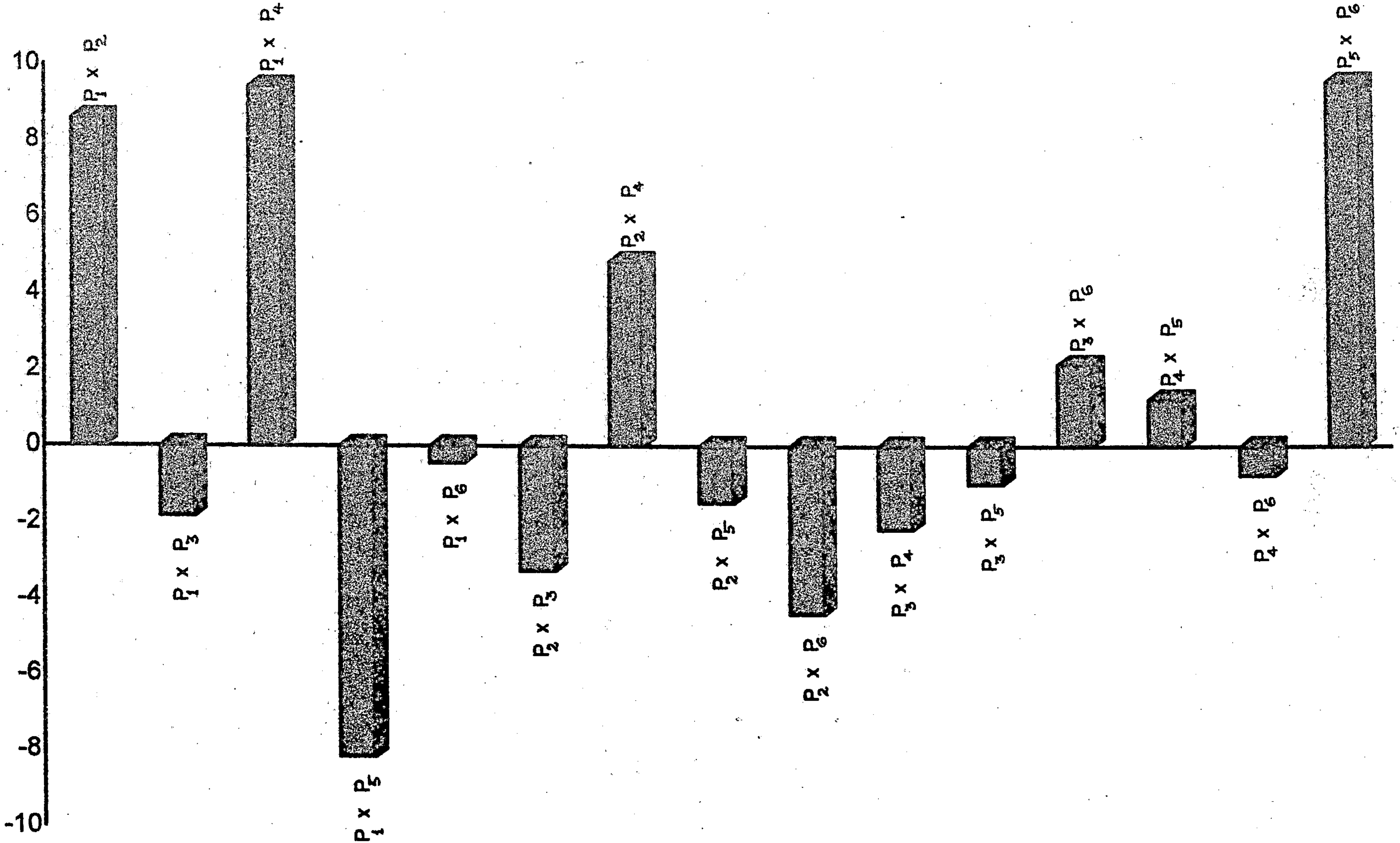
P_5 x P_6
P_6 x P_5


10
8
6
4
2
0
-2
-4
-6
-8
-10
P_1 x P_2
P_1 x P_3
P_1 x P_4
P_1 x P_5
P_1 x P_6
P_2 x P_3
P_2 x P_4
P_2 x P_5
P_2 x P_6
P_3 x P_4
P_3 x P_5
P_3 x P_6
P_4 x P_5
P_4 x P_6
P_5 x P_6

this character. The g.c.a. variance and reciprocal effects lacked significance.

None of the parents showed significant g.c.a. effects. However, three crosses P_5 x P_6, P_1 x P_4 and P_1 x P_2 showed significant positive s.c.a. effects (9.54, 9.42 and 8.59 respectively). The hybrid P_1 x P_5 showed significant negative s.c.a. effect (-8.17) indicating the cross to be a poor specific combination. Thus, for the number of seeds per fruit, there were no good general combiners. However, the cross P_5 x P_6 proved to be the best specific combination followed by P_1 x P_4.

4.2.13 Fruiting phase

The analysis for combining ability showed significance only for variance due to reciprocal effects. The g.c.a. and s.c.a. variances were non significant.

Among the reciprocal crosses, P_6 x P_2 and P_4 x P_2 showed significant positive s.c.a. effects of 3.27 and 1.75 respectively whereas P_5 x P_1 (-3.25) and P_6 x P_3 (-2.15) exhibited significant negative s.c.a effects. Thus the hybrid P_6 x P_2 can be considered as the best specific combination for fruiting phase.

4.2.14 Height of plant

The combining ability analysis showed significant variances due to g.c.a., s.c.a. and reciprocal effects. The

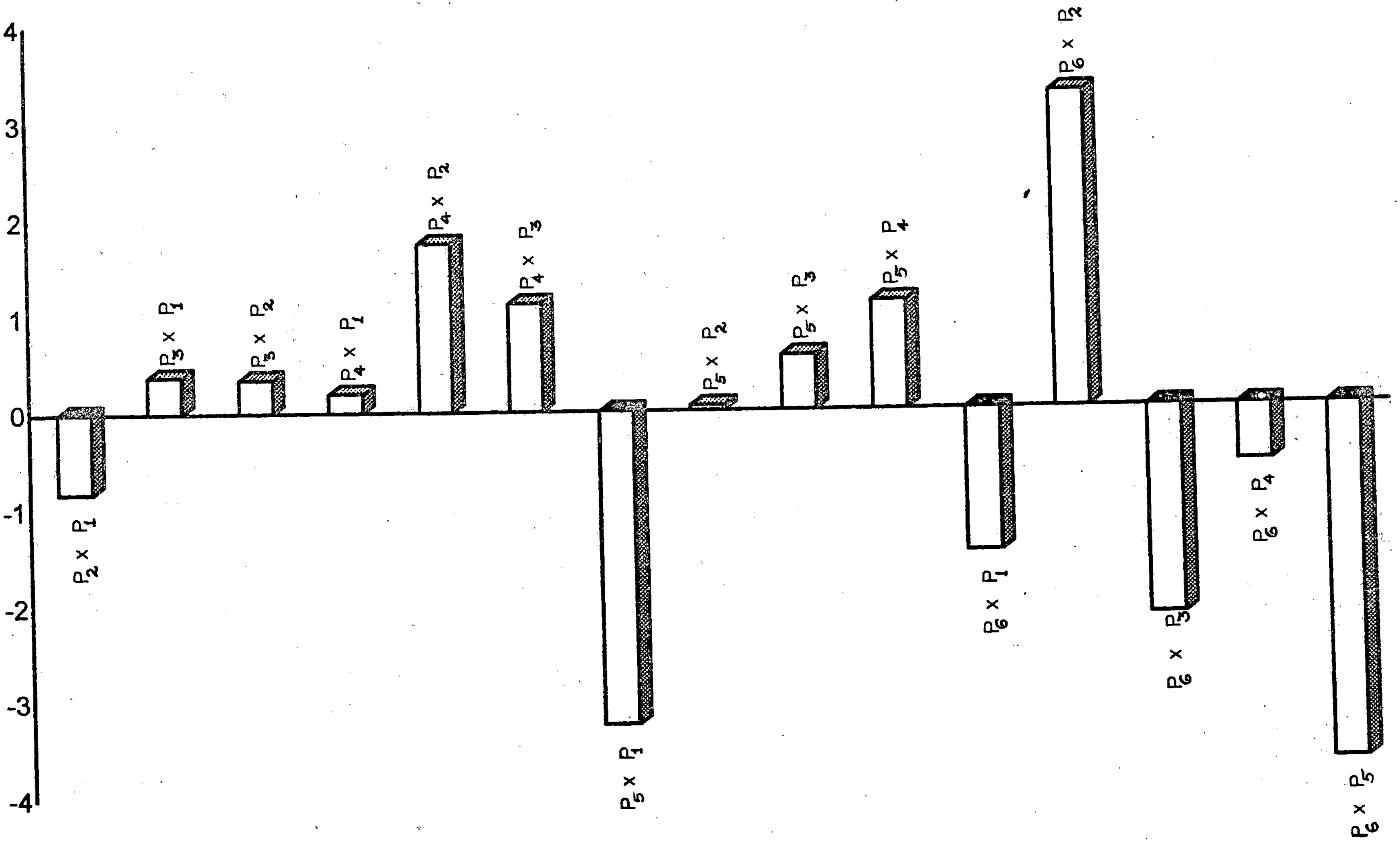


Fig.1.17 Fruiting phase - s.c.a effects

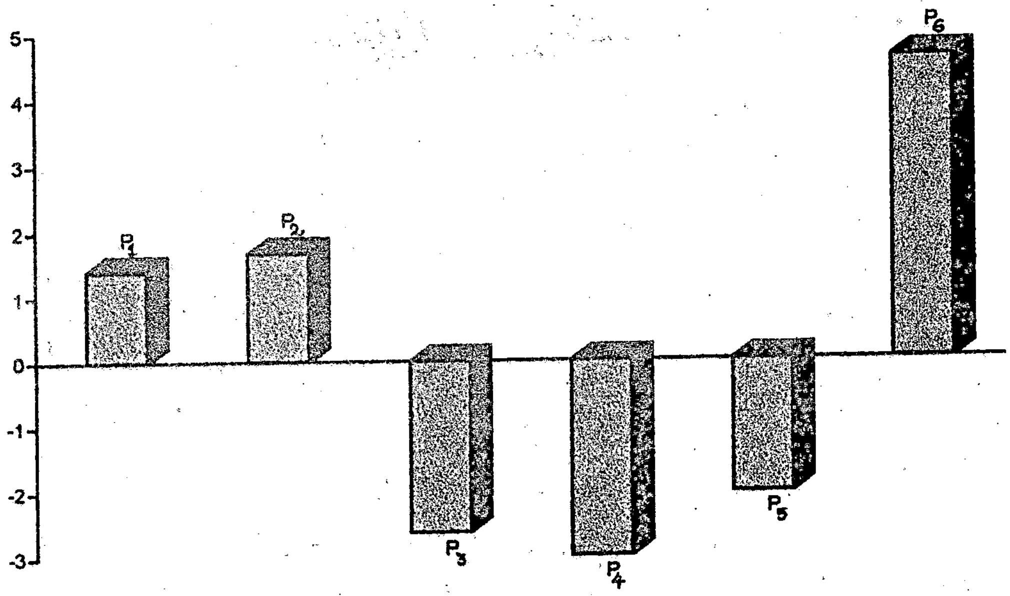


Fig.1.18 Height of plant - g.c.a effects

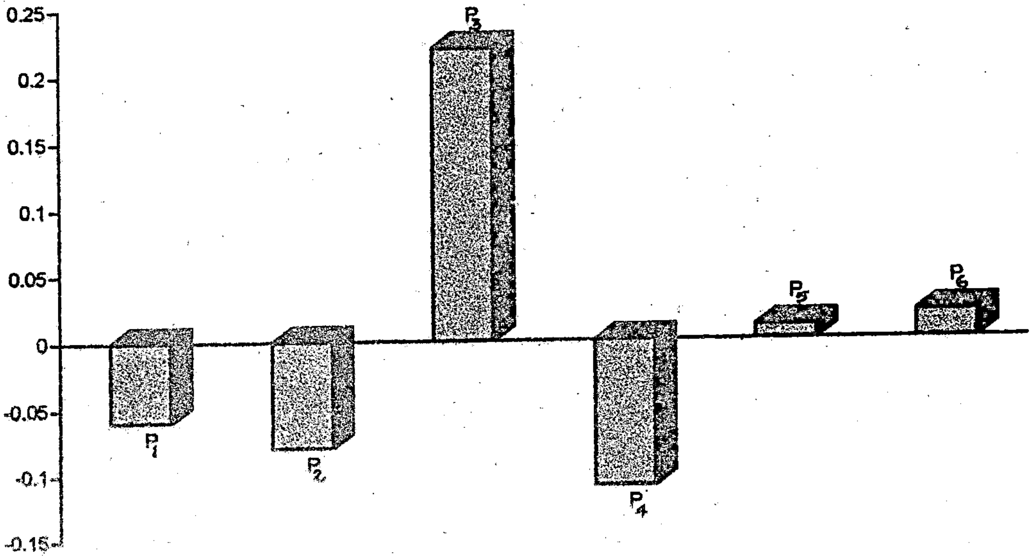
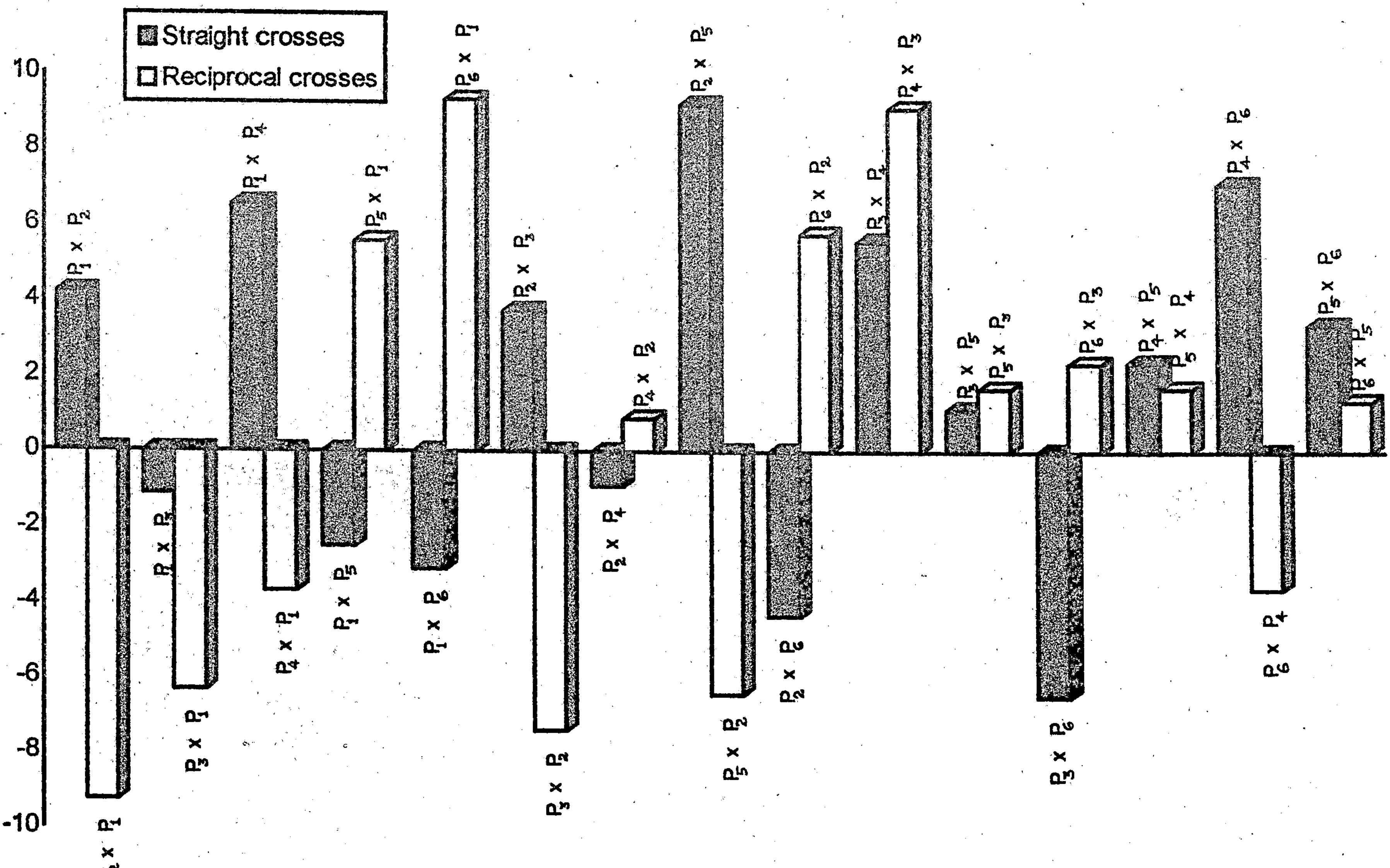


Fig.1.19 Incidence of YVM - g.c.a effects


▨ Straight crosses
☐ Reciprocal crosses
10
8
6
4
2
0
-2
-4
-6
-8
-10
P_1 x P_2
P_2 x P_1
P_1 x P_3
P_3 x P_1
P_1 x P_4
P_4 x P_1
P_1 x P_5
P_5 x P_1
P_1 x P_6
P_6 x P_1
P_2 x P_3
P_3 x P_2
P_2 x P_4
P_4 x P_2
P_2 x P_5
P_5 x P_2
P_2 x P_6
P_6 x P_2
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P_4 x P_3
P_3 x P_5
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P_3 x P_6
P_6 x P_3
P_4 x P_5
P_5 x P_4
P_4 x P_6
P_6 x P_4
P_5 x P_6
P_6 x P_5

g.c.a. variance was greater than s.c.a. variance indicating the importance of g.c.a. for plant height.

Among the six parents, only P_6 showed significant positive g.c.a. effect (4.61). Parent P_4 showed significant negative g.c.a. effect. The three hybrids that showed significant positive effects are P_2 x P_5 (9.20), P_4 x P_6 (7.10) and P_1 x P_4 (6.55). Significant positive reciprocal effects were exhibited by two crosses P_6 x p_1 (9.30) and P_4 x P_3 (9.08). Two crosses P_2 x P_1 and P_3 x P_2 showed significant negative s.c.a. effects. Thus the parent P_6 proved to be the best general combiner for plant height and the hybrid P_6 x P_1 was the best specific combination closely followed by P_2 x P_5 and P_4 x P_3.

4.2.15 Percentage fruit set

The analysis of variance for combining ability for percentage fruit set revealed lack of significance for variances due to g.c.a., s.c.a as well as reciprocal effects.

The nonsignificance of g.c.a. variance indicated the absence of good general combiners for this trait. Among the crosses as well as its reciprocals also none of them showed significant s.c.a. effects.

4.2.16 Incidence of yellow vein mosaic

The combining ability analysis showed highly significant variances due to g.c.a., s.c.a. and reciprocal effects. The g.c.a. variance was greater than the s.c.a. variance indicating the importance of g.c.a. for this character.

The parent P_3 showed significant positive g.c.a. effect (0.22) while the parent P_4 showed significant negative g.c.a. effect (-0.11). Significant s.c.a. effects were exhibited by five hybrids of which only one cross P_3 x P_5 showed significant negative effect (-0.38). The other four hybrids P_2 x P_5, P_1 x P_3, P_4 x P_5 and P_3 x P_6 showed significant positive effects indicating increased incidence of the disease in these four crosses. Five reciprocal crosses exhibited significant s.c.a. effects of which only two showed negative effects. viz., P_2 x P_1 (-0.33) and P_5 x P_2 (-0.27) indicating some tolerance to the incidence of yellow vein mosaic disease. Hence the parent P_4 proved to be the best general combiner and the crosses P_3 x P_5, P_2 x P_1 and P_5 x P_2 as good specific combinations.

4.2.17 Incidence of shoot and fruit borer

Analysis of variance for combining ability for this character, showed that neither g.c.a. nor s.c.a. variance exhibited significance. The variance due to reciprocals was also non significant.

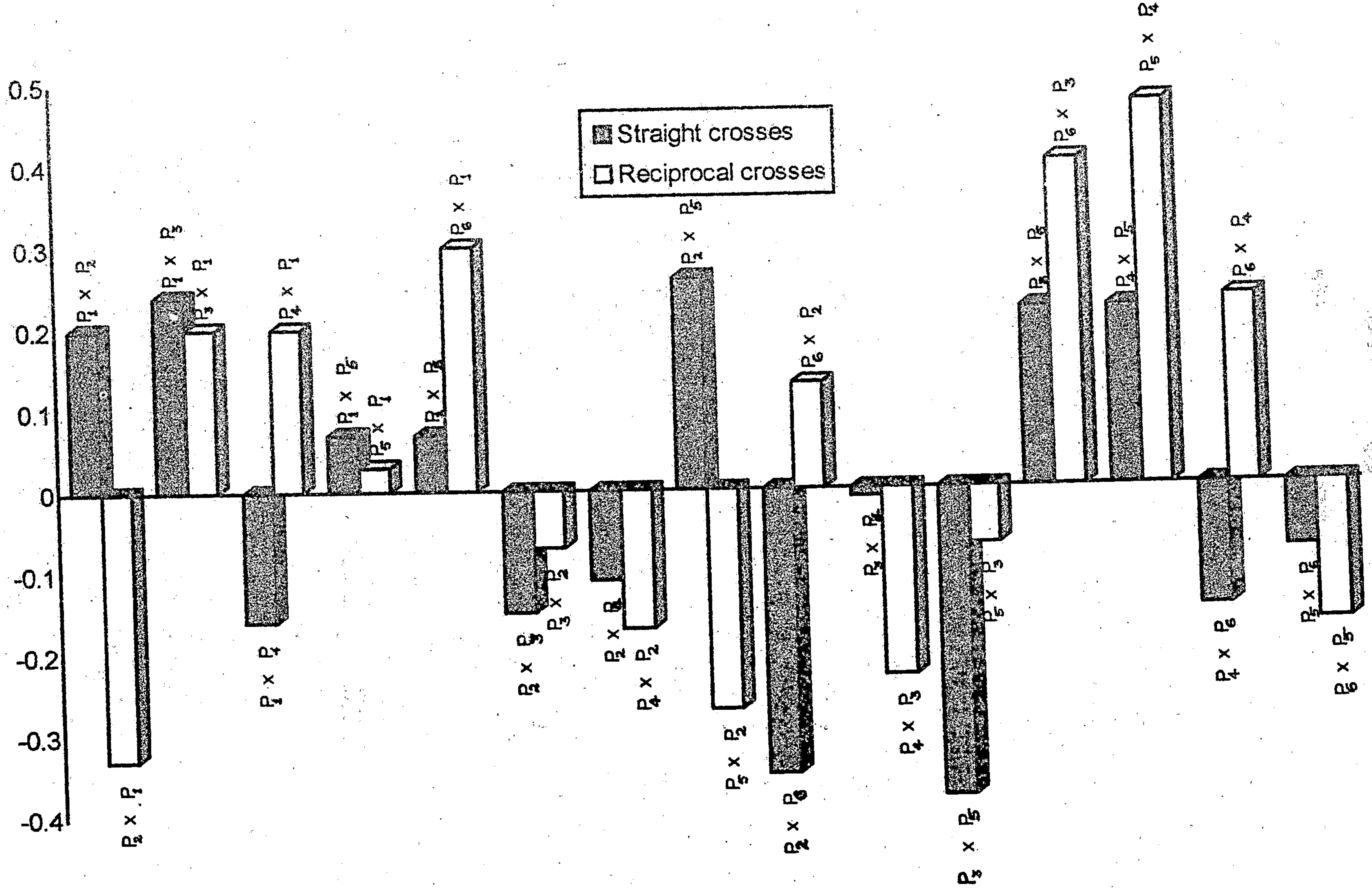

Fig.1.21 Incidence of YVM - s.c.a effects

None of the parents was a good general combiner, indicated by the non significant g.c.a. effects. Good specific combinations were also absent for tolerance to the pest.

In general, it was seen that parent P_4 was a good general combiner for the economic character, yield per plant and also for a few related characters. Among the crosses, the most outstanding specific combining ability effect for yield per plant was exhibited by P_1 x P_4. The other specific combinations for yield and its attributes were P_4 x P_1 and P_5 x P_6. It can be concluded that the crosses involving parent P_4 were in general good specific combinations.

4.3 Gene action

The data relating to the 17 characters under study were subjected to analysis by Hayman's Approach (1954), both numerically and graphically to determine the type of gene action governing the different characters. The results are presented below.

4.3.1 Numerical analysis

The data relating to those characters which did not satisfy the assumption of absence of reciprocal differences among crosses were subjected to numerical analysis independently with parents and a set of F_{1s} and with parents and a set of reciprocal

F_1s to estimate the D, H, E components of variance. The estimates of the variance components and their proportions for the 17 characters are presented in Tables 8 and 9.

4.3.1.1 Days to first flowering

The assumption of no reciprocal differences between crosses was not satisfied for this character. Considering parents and F_1s, the estimates of H_1, H_2 and E were significant while those of D, F and h^2 were nonsignificant. Though nonsignificant, the positive value of $\hat{F}$ indicated that increasing alleles were dominant in the parents. The value of $\hat{H}_1$ was significantly greater than $\hat{D}$ indicating overdominance for this character. The average degree of dominance (2.13) and the proportion of dominant and recessive genes in the parents (3.05) deviated from unit value. The value of $H_2/4H_1$ (0.19) seemed to approach the maximum attainable value of 0.25. The standardised deviations graph revealed that the parental line P_4 possessed dominant genes with positive effects for this character (Fig. 2.1). On the other hand P_3 and P_6 possessed recessive genes with negative effects, P_1 and P_2 had recessive genes with positive effects and P_5 had the dominant genes with negative effect.

In the case of parents and reciprocal F_1s also, the estimates of H_1, H_2 and E were significant and $\hat{D}$, $\hat{F}$ and $\hat{h}^2$ were nonsignificant. Decreasing alleles were dominant in the parents

Table 8. Estimates of genetic parameters and their proportions for parents and F_1s

Sl. No.	Character	$\hat{D} \pm SE$	$\hat{H}_1 \pm SE$	$\hat{H}_2 \pm SE$	$\hat{F} \pm SE$	$\hat{h}^2 \pm SE$	$\hat{E} \pm SE$	$\sqrt{\frac{H_1}{D}}$ (1)	$\frac{H_2}{4H_1}$ (2)	$\frac{\sqrt{4DH_1}+F}{\sqrt{4DH_1}-F}$ (3)
1.	Days to first flowering	1.21 ± 0.80	5.48^{**} ± 2.03	4.13^{*} ± 1.81	2.61 ± 1.95	0.96 ± 1.22	1.08^{**} ± 0.30	2.13	0.19	3.05
2.	Leaf axil bearing the first flower	0.59^{**} ± 0.09	0.56^{*} ± 0.23	0.42^{*} ± 0.21	0.59^{**} ± 0.22	-0.04 ± 0.14	0.07^{*} ± 0.03	0.98	0.18	3.09
3.	Leaf number	1.99^{**} ± 0.67	-0.09 ± 1.69	0.16 ± 1.51	0.83 ± 1.63	-0.21 ± 1.02	1.80^{**} ± 0.25	N.E	-0.45	N.E
4.	Leaf area	24.79 ± 121.48	41.46 ± 308.38	140.18 ± 275.48	-276.84 ± 296.77	-204.97 ± -185.42	457.15^{**} ± 45.91	1.29	0.85	-0.62
5.	Number of branches	1.35^{**} ± 0.15	1.65^{**} ± 0.37	1.14^{**} ± 0.33	1.65^{**} ± 0.36	0.39 ± 0.22	0.06 ± 0.06	1.10	0.17	3.48
6.	Number of flowers/plant	-0.21 ± 0.16	-0.65 ± 0.40	-0.13 ± 0.36	-0.69 ± 0.39	-0.59^{*} ± 0.24	1.16^{**} ± 0.06	1.76	0.05	0.04
7.	Number of fruits/plant	0.22 ± 0.37	0.38 ± 0.93	0.10 ± 0.83	0.65 ± 0.90	-0.49 ± 0.56	0.92^{**} ± 0.14	1.31	0.07	-15.59
8.	Length of fruit	0.31 ± 0.50	2.98^{*} ± 1.26	2.52^{*} ± 1.12	0.43 ± 1.21	0.95 ± 0.76	0.54^{**} ± 0.19	3.09	0.21	1.58
9.	Girth of fruit	0.13^{**} ± 0.02	0.30^{**} ± 0.06	0.20^{**} ± 0.05	0.21^{**} ± 0.06	-0.01 ± 0.04	0.05^{**} ± 0.01	1.52	0.16	3.24
10.	Weight of single fruit	0.82 ± 0.61	6.97^{**} ± 1.55	6.35^{**} ± 1.38	0.52 ± 1.49	2.16^{*} ± 0.93	1.61^{**} ± 0.23	2.91	0.23	1.24
11.	Weight of fruits/plant	112.21 ± 307.39	1661.50^{*} ± 780.33	1303.35 ± 697.09	402.78 ± 750.95	1122.74^{*} ± 469.19	222.73^{*} ± 116.18	3.85	0.20	2.75
12.	Number of seeds/fruit	24.72 ± 21.97	130.57^{*} ± 55.78	103.05^{*} ± 49.83	56.70 ± 53.68	54.07 ± 33.54	21.24^{**} ± 8.31	2.30	0.20	2.99
13.	Fruiting phase	-0.45 ± 0.56	0.89 ± 1.43	0.78 ± 1.27	-0.64 ± 1.37	-0.74 ± 0.86	1.34^{**} ± 0.21	N.E	0.22	N.E
14.	Height of plant	154.32^{**} ± 6.39	193.71^{**} ± 16.23	136.96^{**} ± 14.50	183.87^{**} ± 15.62	255.05^{**} ± 9.76	29.14^{**} ± 2.42	1.12	0.18	3.27
15.	Percentage fruitset	-4.27^{*} ± 1.58	-9.00^{**} ± 4.01	-6.42 ± 3.58	-5.04 ± 3.86	19.84^{**} ± 2.41	14.49^{**} ± 0.60	1.45	0.18	0.42
16.	Incidence of YVM	0.10^{**} ± 0.02	0.19^{**} ± 0.06	0.14^{**} ± 0.05	0.10^{*} ± 0.05	-0.01 ± 0.03	0.03^{**} ± 0.01	1.37	0.19	2.11
17.	Incidence of shoot and fruit borer	-2.15^{**} ± 0.66	-2.34 ± 1.68	-0.53 ± 1.50	-5.20^{**} ± 1.61	-1.90 ± 1.01	4.18^{**} ± 0.25	1.04	0.06	-0.07

* Significant (P<0.05) ** Significant (P<0.01)

(1) Dominance action of genes

(2) Asymmetry in the distribution of genes.

(3) Ratio of total number of dominant genes to total number of recessive genes.

Table 9. Estimates of genetic parameters and their proportions for parents and reciprocal F_1s

Sl. No.	Character	$\hat{D} \pm SE$	$\hat{H}_1 \pm SE$	$\hat{H}_2 \pm SE$	$\hat{F} \pm SE$	$\hat{h}^2 \pm SE$	$\hat{E} \pm SE$	$\sqrt{\frac{H_1}{D}}$ (1)	$\frac{H_2}{4H_1}$ (2)	$\frac{\sqrt{4DH_1}+F}{\sqrt{4DH_1}-F}$ (3)
1.	Days to first flower	1.21 ± 1.02	24.98^{*} ± 10.33	21.01^{*} ± 9.23	-1.26 ± 4.97	1.90 ± 1.55	1.08^{**} ± 0.38	4.54	0.21	0.79
2.	Leaf axil bearing the first flower	0.59^{**} ± 0.02	0.38 ± 0.25	0.40 ± 0.22	-0.10 ± 0.12	-0.03 ± 0.04	0.07^{**} ± 0.01	0.80	0.27	0.81
3.	Leaf number	1.99 ± 1.23	25.60 ± 12.46	22.88^{*} ± 11.13	-1.42 ± 5.99	-0.97 ± 1.87	1.80^{**} ± 0.46	3.58	0.22	0.82
4.	Leaf area	-	-	-	-	-	-	-	-	-
5.	Number of branches	1.35^{**} ± 0.07	3.11^{**} ± 0.74	3.07^{**} ± 0.66	0.84^{*} ± 0.35	0.30^{**} ± 0.11	0.06^{*} ± 0.03	1.51	0.25	1.52
6.	Number of flowers/plant	-0.21 ± 1.37	18.54 ± 13.93	13.71 ± 12.44	-0.40 ± 6.70	-0.60 ± 2.09	1.16^{*} ± 0.52	N.E	0.18	N.E
7.	Number of fruits/plant	-	-	-	-	-	-	-	-	-
8.	Length of fruit	-	-	-	-	-	-	-	-	-
9.	Girth of fruit	-	-	-	-	-	-	-	-	-
10.	Weight of single fruit	0.82^{**} ± 0.25	1.59 ± 2.53	3.02 ± 2.26	-7.73^{**} ± 1.22	3.41^{**} ± 0.38	1.61^{**} ± 0.09	1.39	0.47	-0.54
11.	Weight of fruits/plant	112.21 ± 360.86	6264.35 ±3664.26	5344.11 ±3273.37	-77.74 ±1763.14	804.93 ± 550.80	222.73 ±136.39	7.47	0.21	0.91
12.	Number of seeds/fruit	-	-	-	-	-	-	-	-	-
13.	Fruiting phase	-0.45 ± 1.86	57.48^{**} ± 18.88	39.22^{*} ± 16.87	1.69 ± 9.08	-0.56 ± 2.84	1.34^{*} ± 0.70	N.E	0.17	N.E
14.	Height of plant	153.77^{**} ± 38.90	1224.05^{**} ± 395.04	781.90^{*} ± 352.90	346.65 ± 190.08	162.35^{**} ± 59.38	29.69^{*} ± 14.70	2.82	0.16	2.33
15.	Percentage fruitset	-	-	-	-	-	-	-	-	-
16.	Incidence of YVM	0.10^{*} ± 0.05	1.69^{**} ± 0.48	1.41^{**} ± 0.43	0.26 ± 0.23	-0.02 ± 0.07	0.03 ± 0.07	4.10	0.21	1.91
17.	Incidence of shoot and fruit borer	-	-	-	-	-	-	-	-	-

* Significant ($P<0.05$) ** Significant ($P<0.01$)

(1) Dominance action of genes.

(2) Asymmetry in the distribution of genes.

(3) Ratio of total number of dominant genes to total number of recessive genes.

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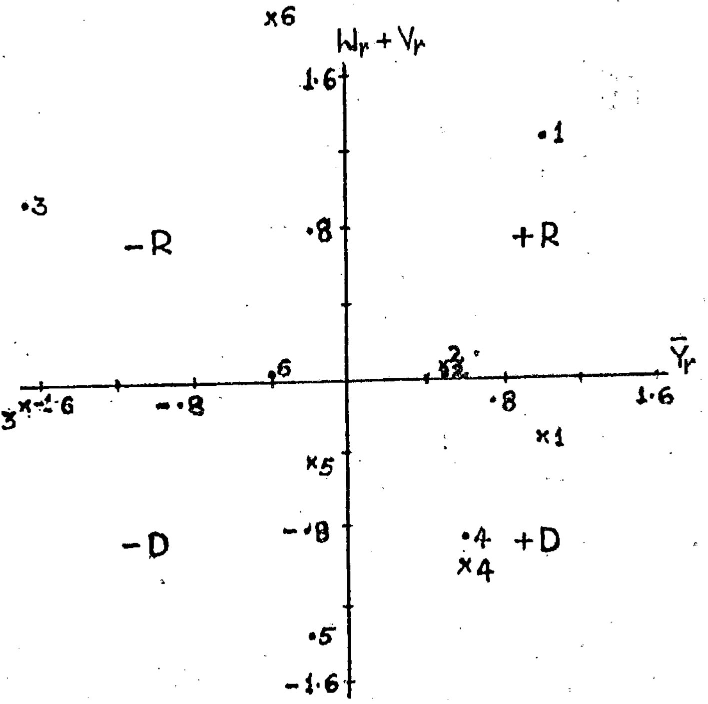

Fig. 2.1 Days to first flowering

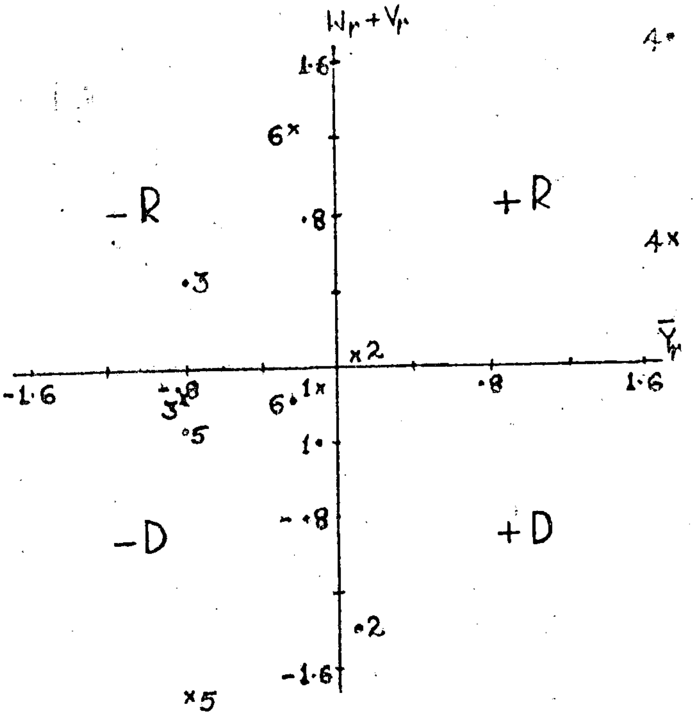

Fig. 2.2 Leaf axil bearing the first flower

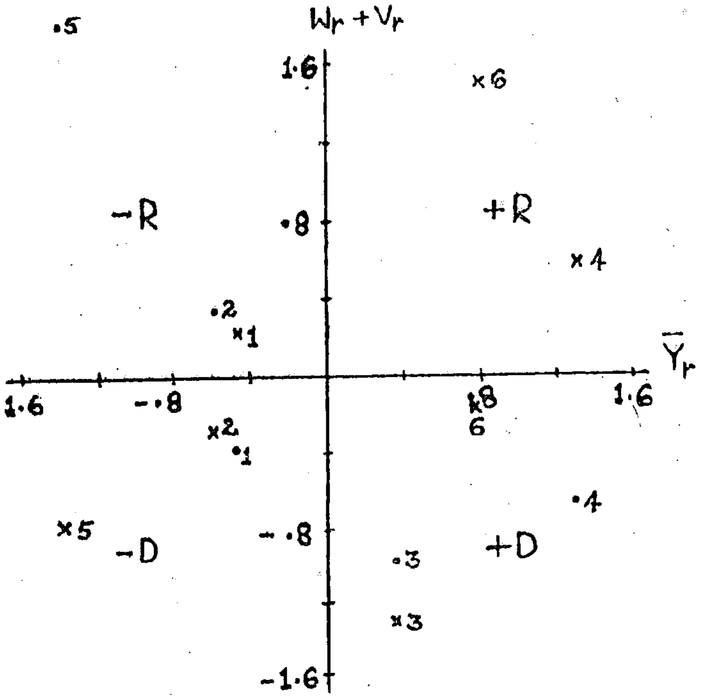

Fig. 2.3 Leaf number

- • Array points for parents of straight crosses
- × Array points for parents of reciprocal crosses

as indicated by the negative value of $\hat{F}$. The average degree of dominance (4.54) and proportion of dominant and recessive genes among parents (0.79) did not possess unit value and the ratio of H_2 to $4H_1$ valued upto 0.21. It was seen from the standardised deviations graph that the parents P_1 and P_4 possessed dominant genes with positive effects while P_6 possessed recessive genes with negative effect on this character (Fig. 2.1).

4.3.1.2 Leaf axil bearing the first flower

The assumption of the absence of reciprocal differences among crosses was not satisfied. With regard to parents and F_1s, significant estimates were obtained for D, H_1, H_2, F and E whereas the dominance effect ($\hat{h}^2$) was nonsignificant. The value of $\hat{F}$ being greater than zero indicated dominance of increasing alleles in the parents. The value of $\hat{D}$ was almost equal to $\hat{H}_1$ indicating complete dominance for this character. The average degree of dominance equalled unity while the proportion of dominant and recessive genes among parents deviated from unit value. The value of $H_2/4H_1$ came upto 0.18. According to the standardised deviations graph, parent P_2 alone had dominant genes with positive effect while P_3 had recessive genes with negative effect on this character (Fig. 2.2). P_4 possessed recessive genes with positive effect while dominant genes with negative effect were mostly concentrated in P_1. Parents P_5 and P_6 seemed to possess genes with negative effect that were both dominant and recessive in nature.

While considering parents and reciprocal F_1s only $\hat{D}$ and $\hat{E}$ were significant. The negative value of F indicated dominance of decreasing alleles. The value of $\hat{H}_1$ was lesser than that of $\hat{D}$ suggesting the presence of partial dominance for this character. The average degree of dominance (0.80) and the proportion of dominant and recessive genes among parents (0.81) were lesser than unity. The ratio of H_2 to $4H_1$ had a value of 0.27. Figure 2.2 revealed that none of the parents possessed dominant genes with positive effect while parents P_1, P_3 and P_5 possessed dominant genes with negative effect. However, the genes with negative effect in P_3 and P_1 seemed to be both dominant and recessive in nature. Parent P_2 was a border line case having genes possessing both dominant and recessive nature with positive effect. P_4 had recessive genes with positive effect. Genes with dominant and recessive nature were noticed in P_6 with negative effect.

4.3.1.3 Leaf number

The assumption that there are no differences between reciprocal crosses was not satisfied for this character. The estimates of D and E were significant when parents and F_1s were considered. The other variance components were nonsignificant. Though the estimate of F was nonsignificant, its positive value indicated dominance of increasing alleles in the parents.

Partial dominance was indicated by the significantly higher value of $\hat{D}$ than $\hat{H}_1$. The average degree of dominance and proportion of dominant and recessive genes among parents were not estimable. The ratio of H_2 to 4 H_1 (-0.45) deviated significantly from 0.25. Parents P_3 and P_4 were seen to possess dominant genes with positive effect from the standardised deviations graph (Fig. 2.3). P_6 was a border line case with positive genes that had both dominant and recessive nature. The genes with negative effect in P_1 were dominant and in P_2 and P_5 were recessive.

Analysis with parents and reciprocal F_1s revealed significant values for $\hat{H}_2$ and $\hat{E}$ only. The value of $\hat{F}$ being lesser than zero indicated dominance of decreasing alleles. The value of $\hat{H}_1$ was higher than $\hat{D}$ indicating overdominance for this character. The average degree of dominance (3.58) was greater than unity while the proportion of dominant and recessive genes among parents (0.82) was lesser than unity. The ratio of H_2 to $4H_1$ (0.22) was very close to the maximum attainable value of 0.25. Preponderance of dominant genes with positive effect was seen in parent P_3 and with negative effect in P_2 and P_5 (Fig. 2.3). Parents P_4 and P_6 had recessive genes with positive effect on leaf number. The genes with negative effect seen in P_1 and P_2 had both dominant and recessive nature.

4.3.1.4 Leaf area

There were no differences between reciprocal crosses for leaf area, thus satisfying the assumption of no reciprocal differences. None of the estimates of variance components were significant except environmental component (E) which alone was highly significant. Though the estimate of F was nonsignificant, its negative value indicated dominance of decreasing alleles. The higher value of H_1 than D indicated overdominance for this trait. The average degree of dominance was greater than unity (1.29) while the proportion of dominant and recessive genes among parents was lesser than unity (-0.62). The ratio of H_2 and $4H_1$ valued upto 0.85. The standardised deviations graph showed that parents P_2 and P_4 possessed most of the dominant genes with positive effect for leaf area (Fig. 2.4), while P_1, P_3 and P_5 possessed recessive genes with negative effect. The genes with positive effect seen in P_6 had both dominant and recessive nature.

4.3.1.5 Number of branches

The assumption of no reciprocal differences was not satisfied for number of branches. Analysis with parents and F_1s indicated significance for the estimates of D_1, H_1, H_2 and F while those of h^2 and E were not significant. The significant positive value of F indicated preponderance of dominant alleles with increasing effect. The estimate of H_1 was slightly greater than that of D indicating overdominance for this trait. The average degree of dominance (1.10) and the proportion of dominant and recessive genes among parents (3.48) were greater than unity. The value of $H_2/4H_1$ (0.17) was lesser than 0.25. It

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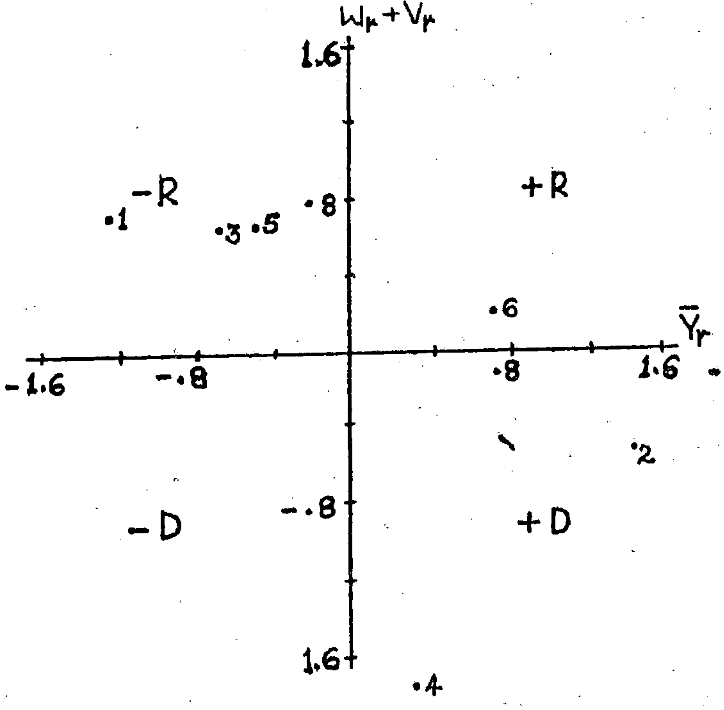

Fig. 2.4 Leaf area

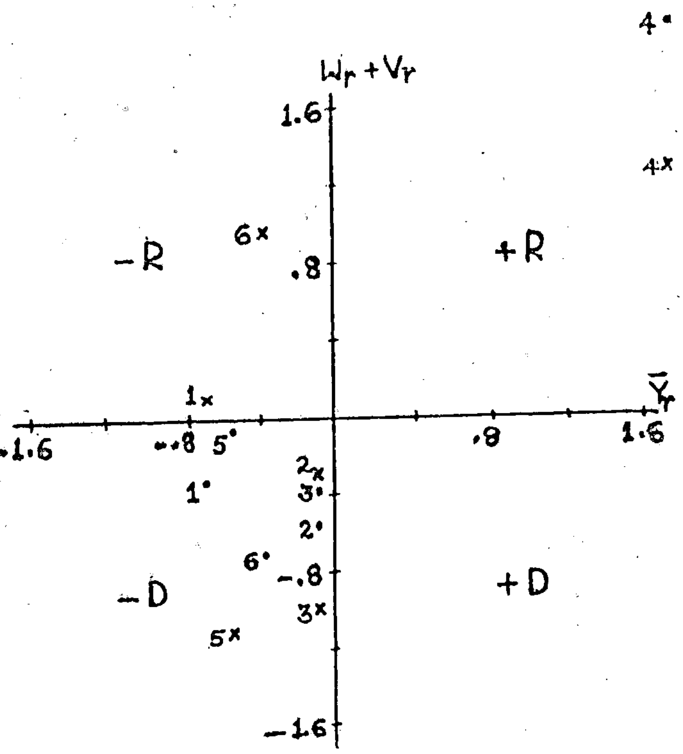

Fig. 2.5 Number of branches

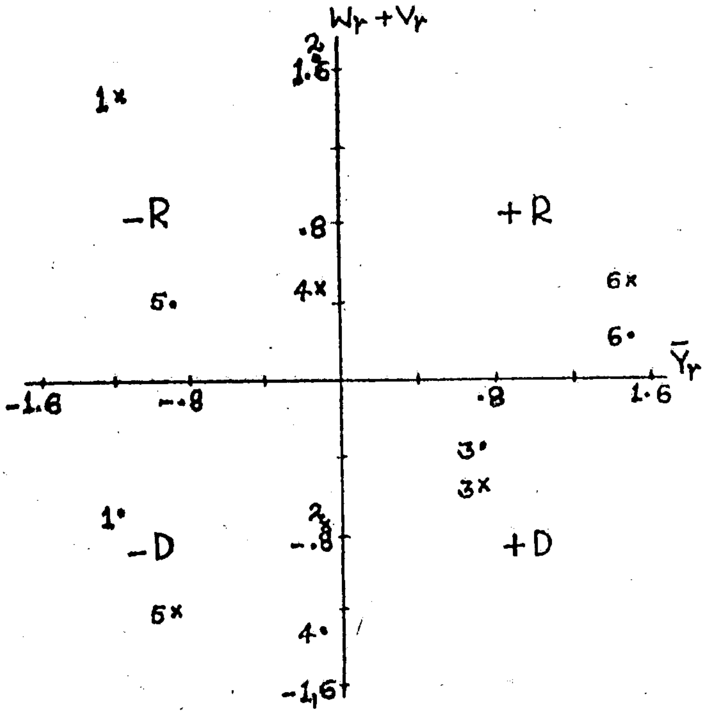

Fig. 2.6 Number of flowers per plant

- ● Array points for parents of straight crosses
- × Array points for parents of reciprocal crosses

was seen from Figure 2.5 that parent P_4 possessed recessive genes with positive effect. The dominant genes with negative effect were seen in P_1, P_2, P_3 and P_6. The genes with negative effect found in P_5 seemed to show both dominant and recessive nature.

Considering parents and reciprocal F_1s, all the six variance components were significant. The positive value of $\hat{F}$ indicated preponderance of dominant genes with increasing effect. The significantly higher value of $\hat{F}_1$ than $\hat{D}$ indicated overdominance for this character. The average degree of dominance (1.51) and the proportion of dominant and recessive genes in the parents (1.52) were greater than unity. The ratio of H_2 to $4H_1$ valued exactly upto 0.25. The graph indicated that parents P_2, P_3 and P_5 had dominant genes with negative effect while P_4 had recessive genes with positive effect (Fig. 2.5). P_1 had genes with negative effect possessing both dominant and recessive nature.

4.3.1.6 Number of flowers per plant

The analysis of variance for combining ability revealed that this character did not satisfy the assumption of no reciprocal differences among crosses. Among the variance components obtained using parents and F_1s, only $\hat{h}^2$ and $\hat{E}$ were significant. The negative value of $\hat{F}$ though nonsignificant indicated that the parents had more of decreasing alleles with dominant effect. The higher value of $\hat{H}_1$ than $\hat{D}$ indicated overdominance governing this trait. The average degree of dominance (1.76) was greater than unity while the proportion of dominant and recessive genes among parents (0.04) was lesser than unity. The value of $H_2/4H_1$ was only 0.05. It was seen from Figure 2.6 that the dominant genes with positive effect was possessed by parent P_3 and with negative effect by P_4 and P_1. The genes with positive effect possessed by P_6 seemed to have both dominant and recessive nature. P_2 and P_5 had recessive genes with negative influence on this trait.

Analysis using parents and reciprocal F_1s indicated significant estimate for environmental component (E) alone. Preponderance of decreasing alleles was indicated by the negative value of $\hat{F}$. The very high value of $\hat{H}_1$ than $\hat{D}$ indicated overdominance for this character. The average degree of dominance and proportion of dominant and recessive genes were not estimable. The value of $H_2/4H_1$ came upto 0.18. The standardised deviations graph indicated that P_3 had dominant genes with positive influence while P_2 and P_5 had dominant genes with negative influence on the character (Fig. 2.6). P_4 and P_1 possessed mostly recessive genes with negative effect and P_6 had recesive genes with positive effect.

4.3.1.7 Number of fruits per plant

This character was seen to satisfy the assumption of no reciprocal differences among crosses. Estimation of variance components using parents and F_1s revealed that only the environmental component (E) was significant. The positive value of F indicated the presence of increasing alleles with dominance effect among parents. The value of H_1 was greater than D indicating overdominance for fruit number. The average degree of dominance (1.31) was greater than unity but the proportion of dominant and recessive genes valued only upto -15.59. The ratio of H_2 to $4H_1$ (0.07) was also very low. The graph revealed that the dominant genes with positive influence were preponderant in parent P_6 and with negative influence in P_4 and P_5 (Fig. 2.7). The recessive genes with positive effect were mostly concentrated in P_2 and P_3 and with negative effect in P_1.

4.3.1.8 Length of fruit

The assumption of no differences among reciprocal crosses was satisfied for fruit length as indicated by the analysis of variance for combining ability. The analysis using parents and F_1s indicated significance for the estimates of H_1, H_2 and E while those of D, F and h^2 were nonsignificant. The positive value of F indicated preponderance of increasing alleles

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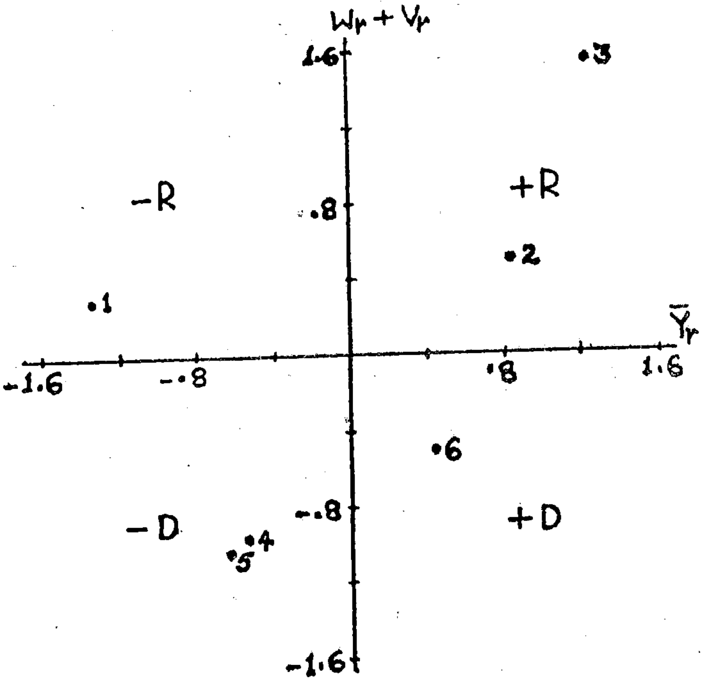

Fig. 2.7 Number of fruits per plant

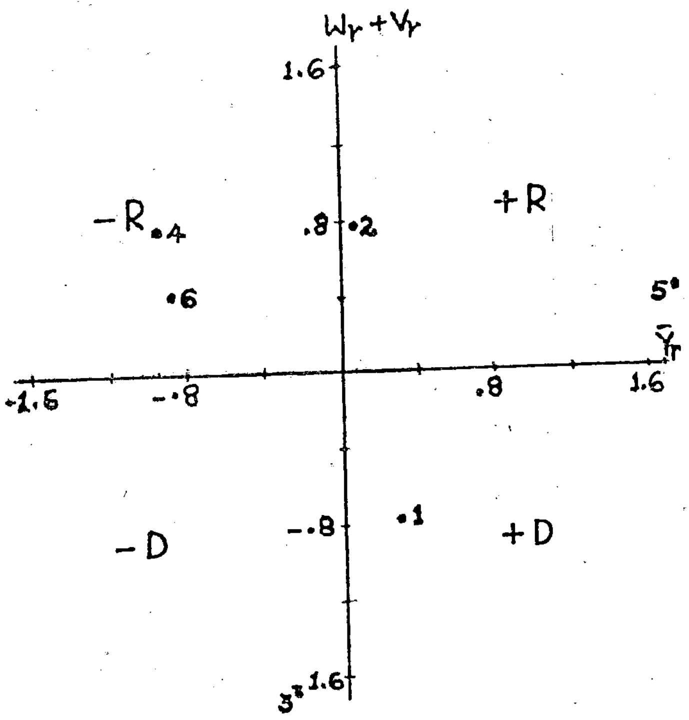

Fig. 2.8 Length of fruit

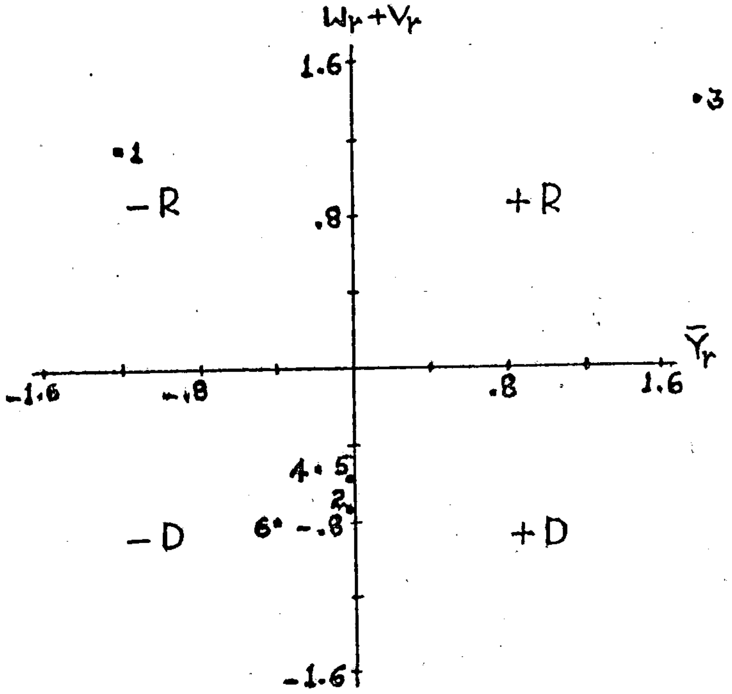

Fig. 2.9 Girth of fruit

• Array points for parents of straight crosses

× Array points for parents of reciprocal crosses with dominant effect among parents. The higher value of $\hat{H}_1$ than $\hat{D}$ indicated overdominance for this character. The ratio of H_2 to $4H_1$ (0.21) neared the maximum attainable value of 0.25. The average degree of dominance (3.09) as well as the proportion of dominant and recessive genes among parents (1.58) were greater than unity. The standardised deviations graph revealed that parent P_1 possessed dominant genes with positive influence and parents P_2 and P_5 possessed recessive genes with positive effect (Fig. 2.8). Parents P_4 and P_6 had recessive genes with negative influence while P_3 had dominant genes with negative influence on fruit length.

4.3.1.9 Girth of fruit

The assumption of the absence of differences between reciprocal crosses was satisfied for this character. The analysis using parents and F_1s showed that the components $\hat{D}$, $\hat{F}$, $\hat{H}_1$, $\hat{H}_2$ and $\hat{E}$ were significant while $\hat{h}^2$ alone was nonsignificant. The positive value of $\hat{F}$ indicated that the parents had more of increasing alleles with dominant effect. The value of $\hat{H}_1$ was greater than $\hat{D}$ suggesting the presence of overdominance for this trait. The average degree of dominance (1.52) and the proportion of dominant and recessive genes among parents (3.24) were higher than unit value. The ratio of H_2 to $4H_1$ valued upto 0.16 only. It was seen from Figure 2.9 that none of the parents had dominant genes with positive effect while the parents P_2, P_4, P_5 and P_6

had dominant genes with negative influence on fruit girth. P_3 was seen to possess recessive genes with positive effect whereas those with negative effect were present in P_1.

4.3.1.10 Weight of single fruit

This character did not satisfy the assumption of no reciprocal differences among crosses. The analysis using parents and F_1s revealed significant estimates for H_1, H_2, h^2 and E, while those of D and F were not significant. The positive value of $\hat{F}$ indicated preponderance of increasing alleles with dominant effect among parents. The significantly higher value of $\hat{H}_1$ than $\hat{D}$ indicated that this character was governed by overdominance. The value of $H_2/4H_1$ (0.23) was very close to the maximum attainable value of 0.25. The average degree of dominance (2.91) and the proportion of dominant and recessive genes among parents (1.24) were greater than unity. The graph indicated that parent P_3 possessed dominant genes with positive influence (Fig. 2.10). The genes with negative effect possessed by P_1 and P_6 seemed to possess both dominant and recessive nature. Parents P_2 and P_5 possessed recessive genes with positive effect whereas P_4 had recessive genes with negative effect on weight of single fruit.

Considering the parents and reciprocal F_1s, significant estimates were obtained for D, F, h^2 and E, while $\hat{H}_1$ and $\hat{H}_2$ were nonsignificant. Preponderance of decreasing alleles in the parents was indicated by the negative value of $\hat{F}$. The

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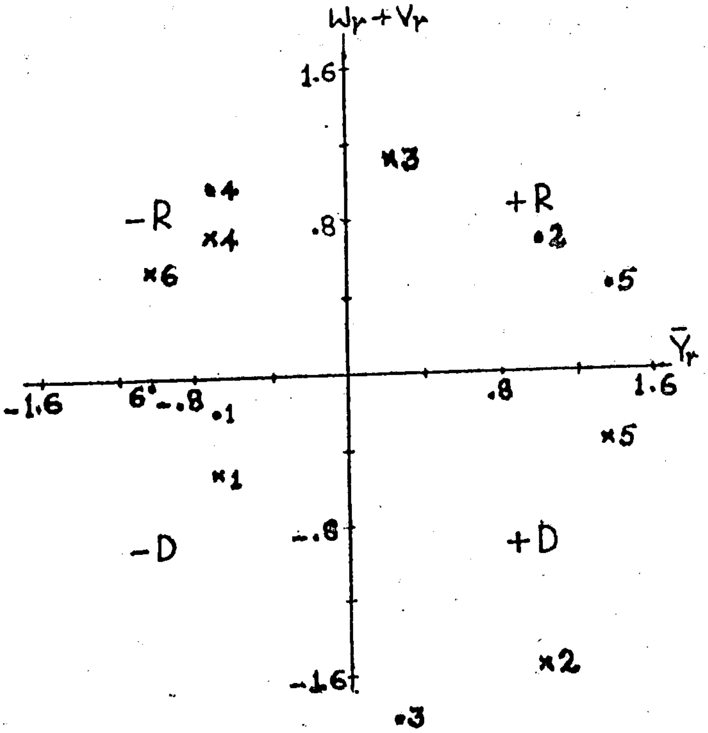

Fig. 2.10 Weight of single fruit

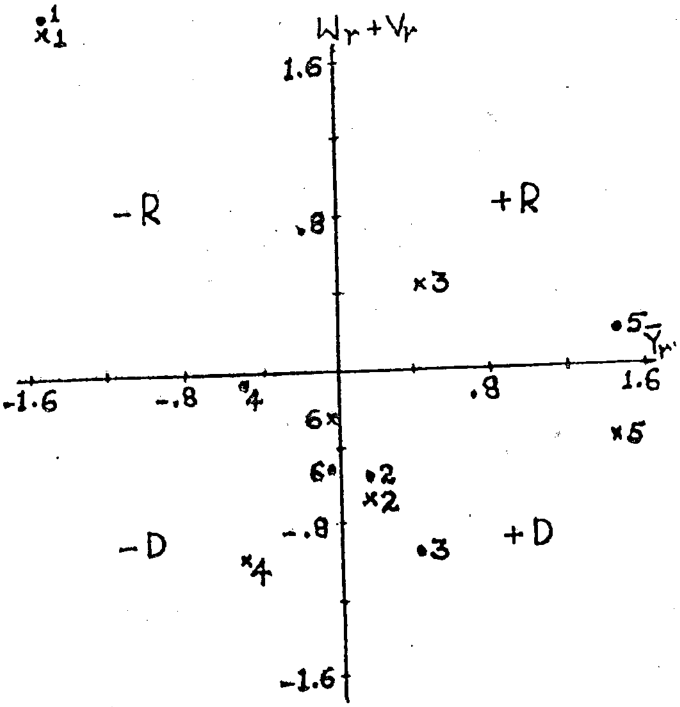

Fig. 2.11 Weight of fruits per plant

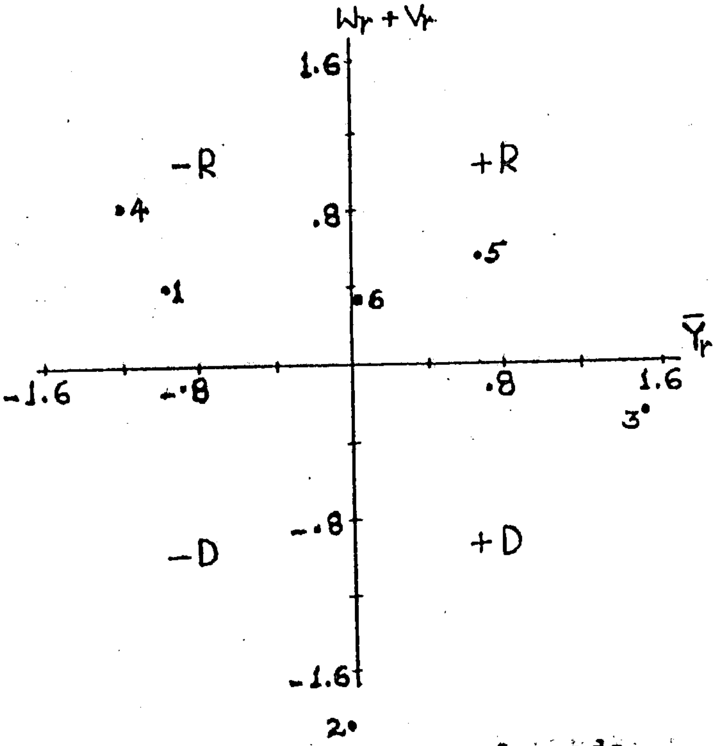

Fig. 2.12 Number of seeds per fruit

- Array points for parents of straight crosses

ints for parents of reciprocal crosses

value of $\hat{H}_1$ was greater than $\hat{D}$ implying the presence of overdominance for this trait. The value of $H_2/4H_1$ (0.47) was very much higher than 0.25. The average degree of dominance (1.39) was greater than unity whereas the value of the proportion of dominant and recessive genes (-0.54) was very low. Figure 2.10 revealed the parents P_2 and P_5 to possess most of the dominant genes with positive effect and P_1 to possess dominant genes with negative effect. Preponderance of recessive genes with positive effect was seen in P_3 and with negative effect in P_4 and P_6.

4.3.1.11 Weight of fruits per plant

The analysis of variance for combining ability revealed significant differences between reciprocal crosses. The analysis using parents and F_1s revealed significant estimates for H_1, h^2 and E while $\hat{D}$, $\hat{H}_2$ and $\hat{F}$ were not significant. The positive value of $\hat{F}$ though nonsignificant indicated excess of increasing alleles with dominance in the parents. The value of $\hat{H}_1$ was greater than $\hat{D}$ indicating overdominance for yield. The average degree of dominance (3.85) as well as the value of the proportion of dominant and recessive genes among parents were greater than unity. The ratio of H_2 to 4 H_1 (0.20) seemed to approach 0.25. The graph revealed that the parents P_2 and P_3 possessed dominant genes with positive effect while P_6 had dominant genes with negative effect (Fig. 2.11). The genes with positive effect seen in P_5 and those with negative effect in P_4 seemed to show both dominant and recessive nature.

The analysis using parents and reciprocal F_1s indicated that none of the variance components were significant. However, the negative value of $\hat{F}$ indicated excess of decreasing alleles in the parents. The higher values of $\hat{H}_1$ than $\hat{D}$ indicated over dominance for yield. The ratio of H_2 to $4H_1$ (0.21) was close to the maximum attainable value of 0.25. The average degree of dominance (7.47) was greater than unity while the proportion of dominant and recessive genes among parents (0.91) was close to unit value. Figure 2.11 showed that the dominant genes seen in parents P_2 and P_5 had positive effect while in P_4 and P_6 they showed negative influence on fruit yield. Preponderance of recessive genes with positive effect was seen in P_3 and with negative effect in P_1.

4.3.1.12 Number of seeds per fruit

The assumption of the absence of differences between reciprocal crosses was satisfied for this trait. The analysis using the parents and F_1s revealed that the variance components $\hat{H}_1$, $\hat{H}_2$ and $\hat{E}$ were significant while $\hat{D}$, $\hat{F}$ and $\hat{h}^2$ were nonsignificant. The positive value of $\hat{F}$ indicated preponderance of increasing alleles in the parents. The value of $\hat{H}_1$ was greater than $\hat{D}$ suggesting the presence of overdominance. The average degree of dominance (2.30) and the proportion of dominant and recessive genes among parents (2.99) were greater than unity. The value of $H_2/4H_1$ came upto 0.20. The standardised deviations graph indicated that the genes with positive effect seen in the parent P_3 were dominant as well as recessive in nature (Fig. 2.12). Preponderance of dominant genes with negative effect were observed in P_2. Recessive genes with positive effect were observed in P_5 and P_6 and with negative effect in P_1 and P_4.

4.3.1.13 Fruiting phase

The analysis of variance for combining ability indicated that this character showed significant reciprocal differences. Considering the parents and F_1s, only the environmental component of variance was significant while all the other estimates were nonsignificant. The negative value of $\hat{F}$ indicated dominance of decreasing alleles in the parents. The higher value of $\hat{H}_1$ than $\hat{D}$ indicated overdominance governing fruiting phase. The value of H_2/4H, (0.22) was close to 0.25. The average degree of dominance and proportion of dominant and recessive genes among parents were not estimable. The graph showed that the genes with positive effect in the parent P_4 showed dominance as well as recessiveness (Fig. 2.13). The parents P_1 and P_2 had dominant genes with negative effect. Preponderance of recessive genes with positive effect were seen in P_3 and with negative effect in P_5 and P_6.

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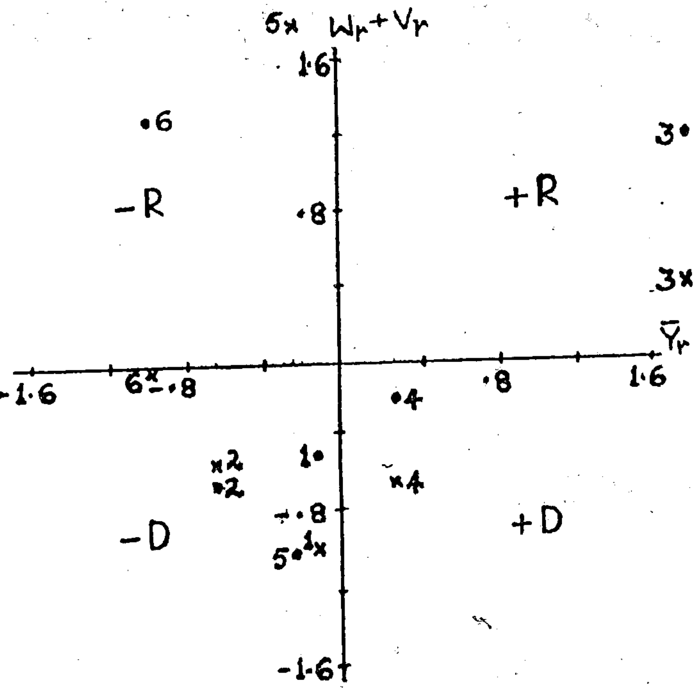

Fig. 2.13 Fruiting phase

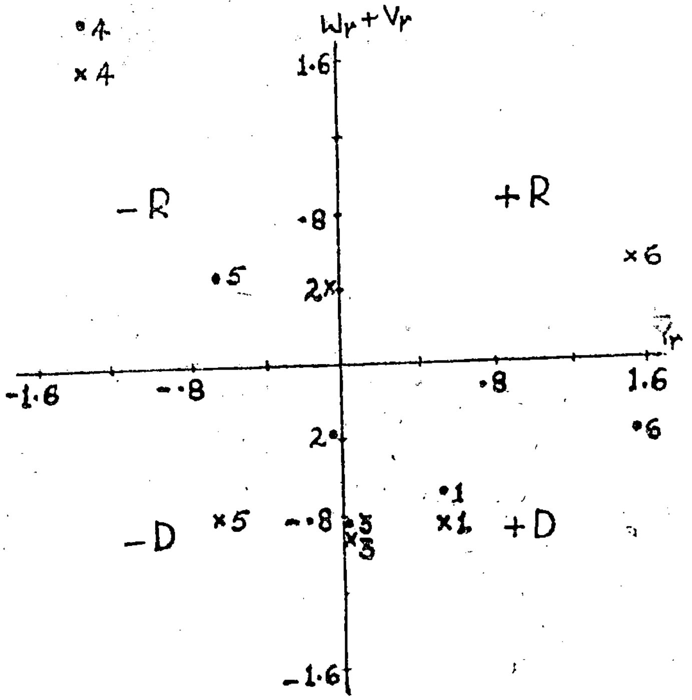

Fig. 2.14 Height of plant

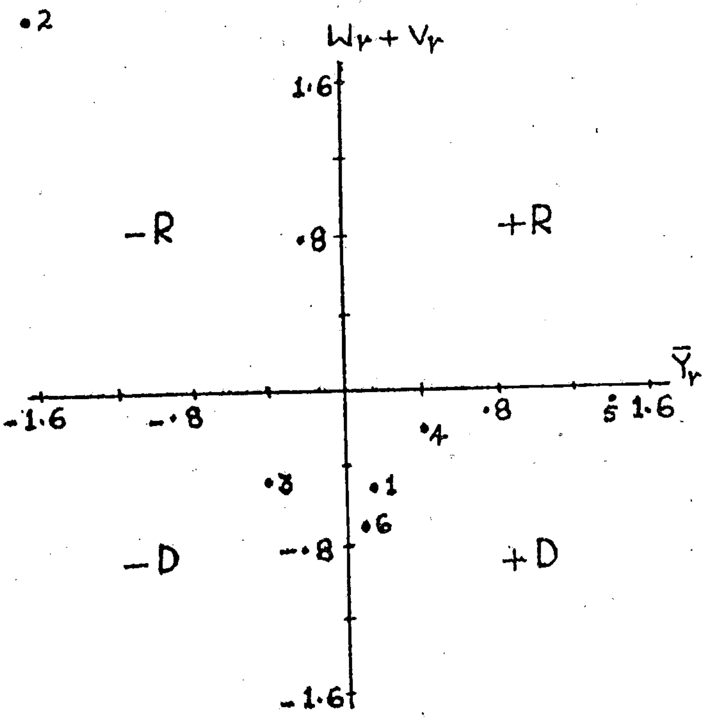

Fig.2.15. Percentage Fruit Set

- Array points for parents of straight crosses

Array points for parents of reciprocal crosses

The analysis using parents and reciprocal F_1s revealed significant estimates for H_1, H_2 and E only. Preponderance of increasing alleles among parents was indicated by the positive value of $\hat{F}$. The value of $\hat{H}_1$ was greater than $\hat{D}$ indicating overdominance for this trait. The value of $H_2/4H_1$ (0.17) was low compared to the maximum attainable value of 0.25. The average degree of dominance and proportion of dominant and recessive genes among parents were not estimable. Figure 2.13 revealed that the dominant genes with positive effect were seen in parent P_4 and with negative effect in P_1 and P_2. The genes with negative effect seen in P_6 seemed to show dominance as well as recessiveness. Preponderance of recessive genes with positive effect was seen in P_3 and with negative effect in P_5.

4.3.1.14 Height of plant

This character did not satisfy the assumption of no reciprocal differences among crosses. The analysis using parents and F_1s revealed significant estimates for all the variance components. The highly significant positive value of $\hat{F}$ indicated dominance of increasing alleles among the parents. The greater value of $\hat{H}_1$ than $\hat{D}$ indicated overdominance for plant height. The average degree of dominance (1.12) as well as the proportion of dominant and recessive genes among parents (3.27) were greater than unity. The ratio of H_2 to 4 H_1 valued upto 0.18. The standardised deviations graph revealed preponderance of dominant genes with positive effect in the parents P_1, P_3 and P_6 and with negative effect in P_2 (Fig. 2.14). Parents P_4 and P_5 possessed recessive genes with negative influence on plant height.

Considering the parents and the reciprocal F_1s, the estimates of D, H_1, H_2, h^2 and E were significant. The positive value of $\hat{F}$ though nonsignificant indicated dominance of increasing alleles in the parents. The higher value of $\hat{H}_1$ than $\hat{D}$ indicated presence of overdominance for plant height. The average degree of dominance (2.82) as well as the proportion of dominant and recessive genes among parents (2.33) were greater than unity. The ratio of H_2 to $4H_1$ valued upto 0.16. The graph showed preponderance of dominant genes with positive effect in the parent P_1 and with negative effect in P_4 and P_5 (Fig. 2.14). The recessive genes possessed by the parent P_6 had positive effect while those in P_2 had negative influence on plant height.

4.3.1.15 Percentage fruit set

This character satisfied the assumption of no differences between reciprocal crosses. The estimation of variance components using parents and F_1s revealed significance for $\hat{D}$, $\hat{H}_1$, $\hat{h}^2$ and $\hat{E}$ while $\hat{H}_2$ and $\hat{F}$ were nonsignificant. The negative value of $\hat{F}$ indicated the presence of decreasing alleles among the parents. The value of $\hat{H}_1$ was higher than $\hat{D}$ indicating overdominance for this trait. The average degree of dominance

(1.45) was greater than unity while the value of the proportion of dominant and recessive genes among parents (0.42) was low. The ratio of H_2 to $4H_1$ valued upto 0.18. The graph showed preponderance of dominant genes with positive effect in the parents P_1 and P_6 and with negative effect in P_3 (Fig. 2.15). The genes with positive effect seen in P_4 and P_5 seemed to show both dominant and recessive nature. Parent P_2 possessed mostly recessive genes with negative effect.

4.3.1.16 Incidence of yellow vein mosaic

This character showed significant differences between reciprocal crosses. The analysis using parents and F_1s revealed that the estimates of D, H_1, H_2, F and E were significant. The positive value of F indicated preponderance of increasing alleles among the parents. The greater value of H_1 than D implied the presence of overdominance. The average degree of dominance (1.37) as well as the proportion of dominant and recessive genes among parents (2.11) were greater than unity. The ratio of H_2 to $4H_1$ valued upto 0.19. Figure 2.16 indicated that the genes with positive effect seen in the parent P_3 showed both dominance and recessiveness. Parents P_2, P_4 and P_5 possessed dominant genes with negative effect. There was preponderance of recessive genes with positive effect in P_6 and with negative effect in P_1

Considering parents and reciprocal F_1s, the estimates of D, H_1 and H_2 were significant while those of F, h^2 and E were

STANDARDISED DEVIATIONS GRAPH

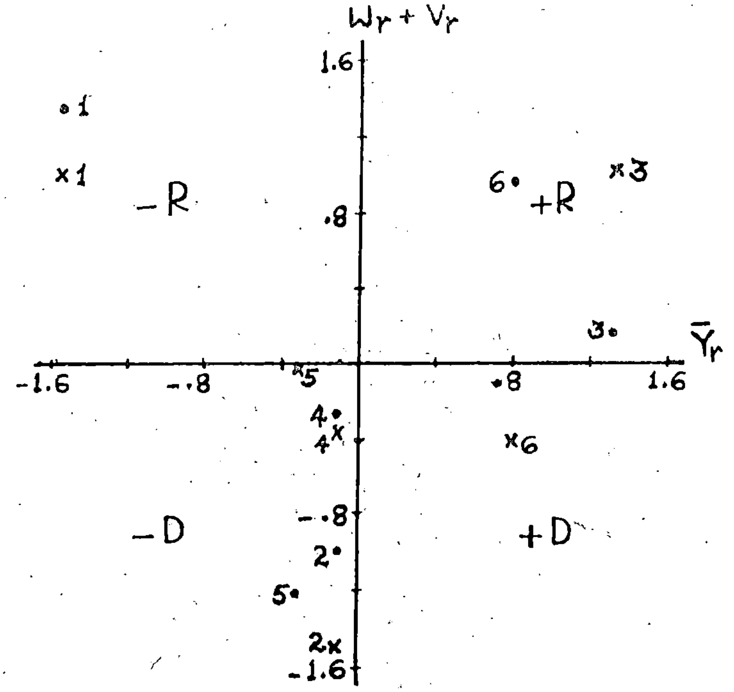

Fig. 2.16 Incidence of YVM

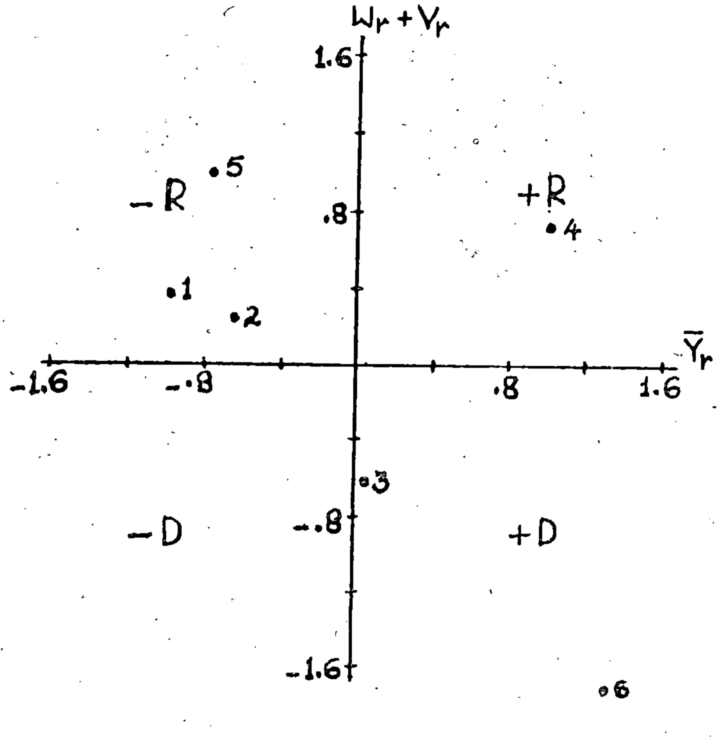

Fig. 2.17 Incidence of shoot and fruit borer

- Array points for parents of straight crosses nonsignificant. The positive sign of $\hat{F}$ indicated more of increasing alleles with dominant effect in the parents. The higher value of $\hat{H}_1$ than $\hat{D}$ indicated overdominance for resistance to the virus. The average degree of dominance (4.10) and the proportion of dominant and recessive genes among the parents (1.91) were greater than unity. The ratio of H_2 to $4H_1$ (0.21) was close to the maximum attainable value of 0.25. The graph revealed that parent P_6 possessed dominant genes with positive influence while parents P_2 and P_4 had dominant genes with negative influence (Fig. 2.16). The genes with negative effect seen in P_5 seemed to show dominance as well as recessiveness. There was a preponderance of recessive genes with positive effect in P_3 and with negative effect in P_1.

4.3.1.17 Incidence of shoot and fruit borer

Analysis of variance for combining ability revealed that this character satisfied the assumption of no reciprocal differences among crosses. Estimation of variance components using parents and F_1s revealed significance for $\hat{D}$, $\hat{F}$ and $\hat{E}$ only. The negative value of $\hat{F}$ was an indication of dominance of decreasing alleles in the parents. The value of $\hat{H}_1$ was almost equal to $\hat{D}$ indicating complete dominance for this trait. The average degree of dominance almost equalled unity while the proportion of dominant and recessive genes among parents (-0.07) was lesser than unity. The value of $H_2/4H_1$ (0.06) was also very low. The standardised deviations graph revealed that there was preponderance of dominant genes with positive effect in the parents P_6 and P_3 (Fig. 2.17). The parents P_1, P_2 and P_5 possessed recessive genes with negative influence on resistance to fruit borer, while P_4 had recessive genes with positive effect on the pest incidence.

4.3.2 Graphical analysis

The data with respect to each of the 17 characters were subjected to a graphical analysis only if each character showed adequacy of additive - dominance model. For adequacy of this model, the regression (b) of Wr on Vr should equal unity, ie., the linear regression line should have unit slope. The regression equations used to plot the Vr-Wr graphs for the 17 characters are presented in Tables 10 and 11. They also depict the average level of dominance for each character. The analysis was carried out independently for parents and a set of F_1s and for parents and a set of reciprocal F_1s for those characters for which significant reciprocal differences were observed.

4.3.2.1. Days to first flowering

The combining ability analysis revealed significant reciprocal differences among crosses. Considering parents and F_1s, the assumption regarding adequacy of the additive-dominance model was satisfied. In the Vr-Wr graph, the regression line cut

Table 10. Regression equations used to plot the V_r-W_r graph for parents and F_1 s

Sl. No.	Character	Regression Equation $W_r = a + bV_r$	Average level of dominance
1	Days to first flowering	$W_r = -0.23 + 0.22V_r$	Overdominance
2	Leaf axil bearing the first flower	$W_r = -0.004 + 0.91V_r$	Complete dominance
3	Leaf number	$W_r = 0.02 + 0.81V_r$	Partial dominance
4	Leaf area	$W_r = -3.51 + 0.46V_r$	Overdominance
5	Number of branches	$W_r = -0.09 + 0.98V_r$	Complete dominance
6	Number of flowers/plant	$W_r = -0.47 + 1.16V_r$	Overdominance
7	Number of fruits/plant	$W_r = -0.04 + 0.27V_r$	Overdominance
8	Length of fruit	$W_r = -0.09 + 0.22V_r$	Overdominance
9	Girth of fruit	$W_r = -0.06 + 0.86V_r$	Overdominance
10	Weight of single fruit	$W_r = -1.30 + 0.67V_r$	Overdominance
11	Weight of fruits/plant	b deviates from unity	Overdominance
12	Number of seeds/fruit	b deviates from unity	Overdominance
13	Fruiting phase	b deviates from unity	Overdominance
14	Height of plant	b deviates from unity	Overdominance
15	Percentage fruit set	$W_r = -4.54 + 0.95V_r$	Overdominance
16	Incidence of yellow vein mosaic	$W_r = -0.05 + 1.17V_r$	Overdominance
17	Incidence of shoot and fruit borer.	$W_r = 0.001 + 0.35V_r$	complete dominance

Table 11. Regression equations used to plot the V_r-W_r graph for parents and reciprocal F_1 s.

Sl. No.	Character	Regression Equation $W_r = a + bV_r$	Average level of dominance
1	Days to first flowering	$W_r = -0.09 + 0.03V_r$	Overdominance
2	Leaf axil bearing the first flower	$W_r = 0.13 + 0.87V_r$	Partial dominance
3	Leaf number	b deviates from unity	overdominance
4	Leaf area	-	-
5	Number of branches	$W_r = -0.03 + 1.33V_r$	Overdominance
6	Number of flowers/plant	b deviates from unity	Overdominance
7	Number of fruits/plant	-	-
8	Length of fruit	-	-
9	Girth of fruit	-	-
10	Weight of single fruit	b deviates from unity	Overdominance
11	Weight of fruits/plant	b deviates from unity	Overdominance
12	Number of seeds/fruit	-	-
13	Fruiting phase	b deviates from unity	Overdominance
14	Height of plant	$W_r = -7.74 + 0.52V_r$	Overdominance
15	Percentage fruit set	-	-
16	Incidence of yellow vein mosaic	b deviates from unity	Overdominance
17	Incidence of shoot and fruit borer.	-	-

the Wr-axis below the origin (Fig. 3.1). Wide scattering of array points was noticed. The array points 2 and 5 were nearer to the origin while points 1 and 6 seemed to be far away from the origin.

With respect to parents and reciprocal F_1s also, the adequacy of additive-dominance model was satisfied. The regression line cut the Wr-axis below the origin (Fig. 3.1). All the array points were scattered far away from the origin.

4.3.2.2. Leaf axil bearing the first flower

The reciprocal crosses showed significant differences for this character. Adequacy of the additive-dominance model was noticed for parents and F_1s. The regression line passed almost through the origin (Fig. 3.2). There was no much scattering of array points for this character. The array points 1, 2, 3, 5 and 6 were closer to the origin than point 4.

For parents and reciprocal F_1s also, the additive-dominance model was found to be adequate. The regression line cut the Wr-axis just above the origin (Fig. 3.2). The array points were seen close to each other. The point 5 was the closest to the origin.

V_r - W_r GRAPH

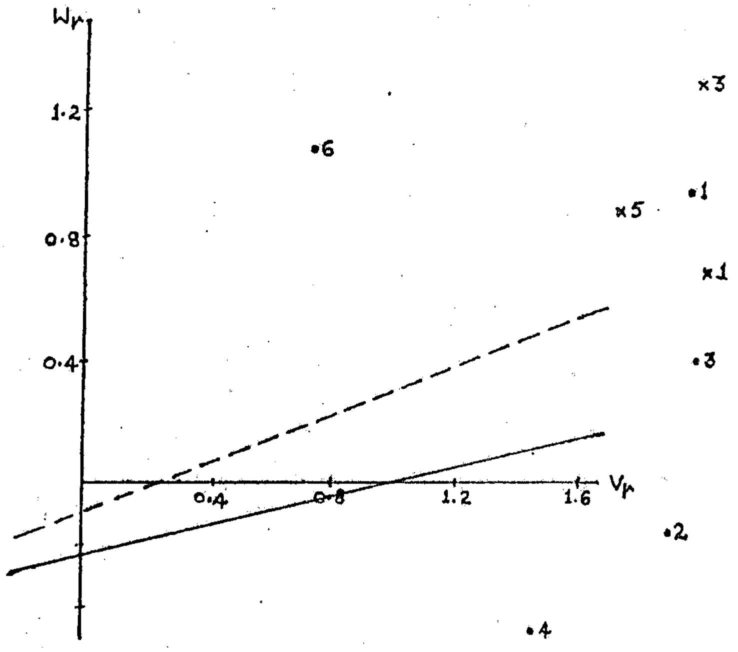

Fig. 3.1 Days to first flowering

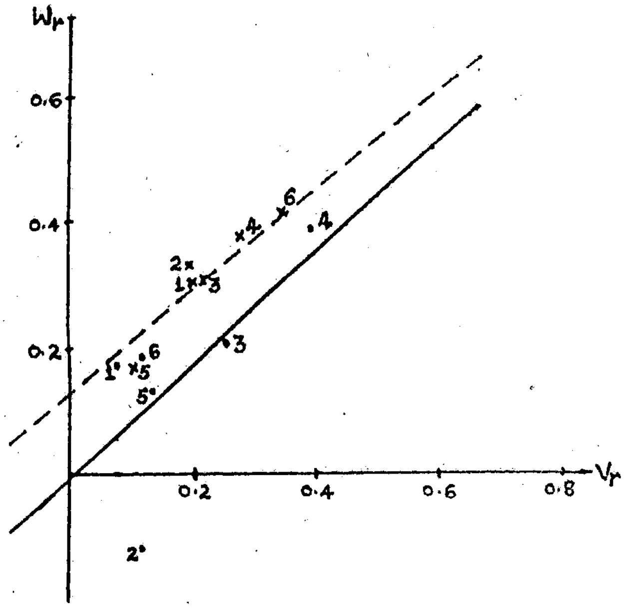

Fig. 3.2 Leaf axil bearing the first flower

—— Regression line for parents and straight crosses

- - - Regression line for parents and reciprocal crosses

• Array points for parents of straight crosses

⋆ Array points for parents of reciprocal crosses

4.3.2.3 Leaf number

The analysis of variance for combining ability indicated significant reciprocal differences among crosses. With respect to parents and F_1s, the regression of Wr on Vr indicated adequacy of additive-dominance model. It was seen from Figure 3.3 that the regression line cut the Wr-axis just above the origin. A wide scattering of array points was noticed for leaf number. All the array points were far away from the origin.

For parents and reciprocal F_1s, the regression of Wr on Vr showed significant deviation from unity indicating the presence of non-allelic interaction for leaf number.

4.3.2.4 Leaf area

The assumption of no reciprocal differences among crosses was satisfied for this trait as indicated by the combining ability analysis. The regression of Wr on Vr indicated adequacy of the additive-dominance model. The regression line in Figure 3.4 cut the Wr-axis below the origin. The graph also showed a wide scattering of array points except points 1 and 3 which were close to each other. Parent P_4 had its array point nearest to the origin.

4.3.2.5 Number of branches

The assumption of no reciprocal differences was not satisfied for this character as indicated by the analysis of

Vr - Wr GRAPH

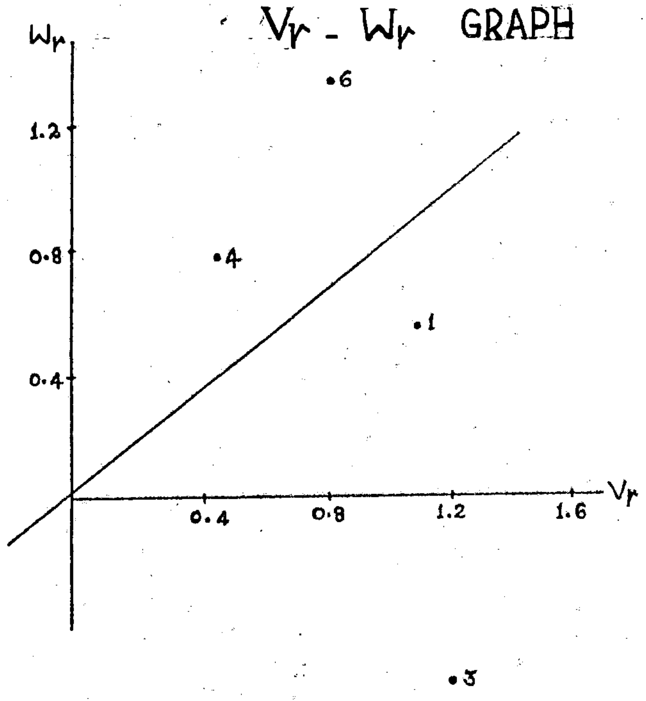

Fig. 3.3 Leaf number

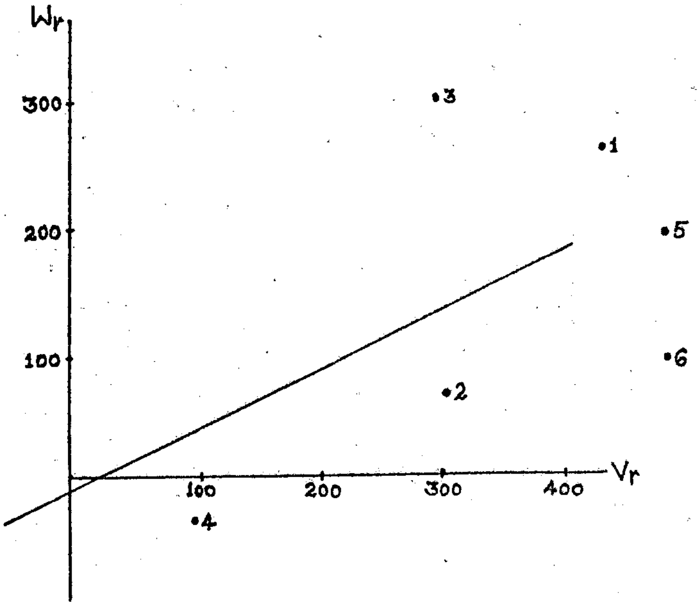

Fig. 3.4 Leaf area

—— Regression line for parents and straight crosses

• Array points for parents of straight crosses

variance for combining ability. For parents and F_1s, the assumption of the adequacy of additive-dominance model was satisfied. The Vr-Wr graph showed the linear regression line cutting the Wr-axis just below the origin (Fig. 3.5). The array points were quite close to each other with points 1, 2, 3, 5 and 6 being nearer to the origin than point 4.

Considering parents and reciprocal F_1s, the additive-dominance model was adequate. The linear regression line in the Figure 3.5 cut the Wr-axis just below the origin. The array point 5 was seen closest to the origin followed by point 3. Point 4 was the farthest from the origin.

4.3.2.6 Number of flowers per plant

The combining ability analysis indicated that the assumption of no reciprocal differences was not satisfied for flower number. The regression of Wr on Vr for parents and F_1s confirmed the adequacy of the additive - dominance model. In Figure 3.6, the regression line cut the Wr-axis well below the origin. The array points were seen lying quite close to each other. Array point 4 was the closest to the origin and point 2 farthest from the origin. The other points 1, 3, 5 and 6 were seen lying between points 2 and 4.

Considering parents and reciprocal F_1s, the regression of Wr on Vr showed significant deviation from unity thus giving evidence of the presence of nonallelic interaction.

V_r - W_r GRAPH

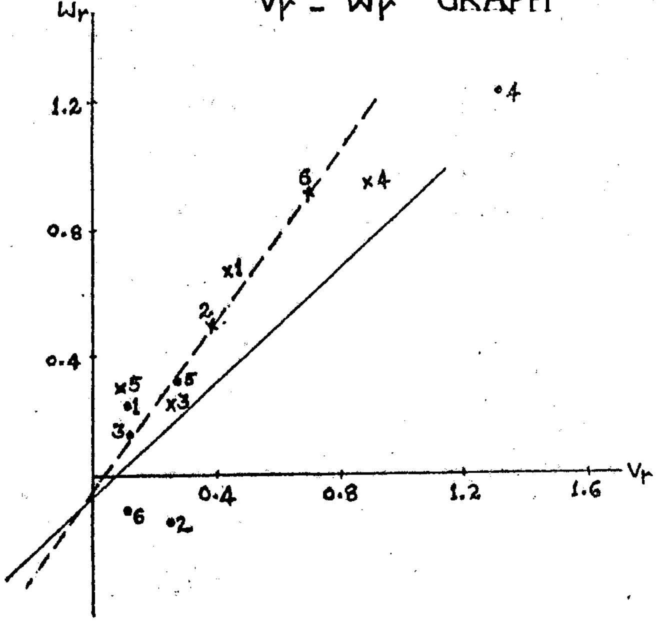

Fig. 3.5 Number of branches

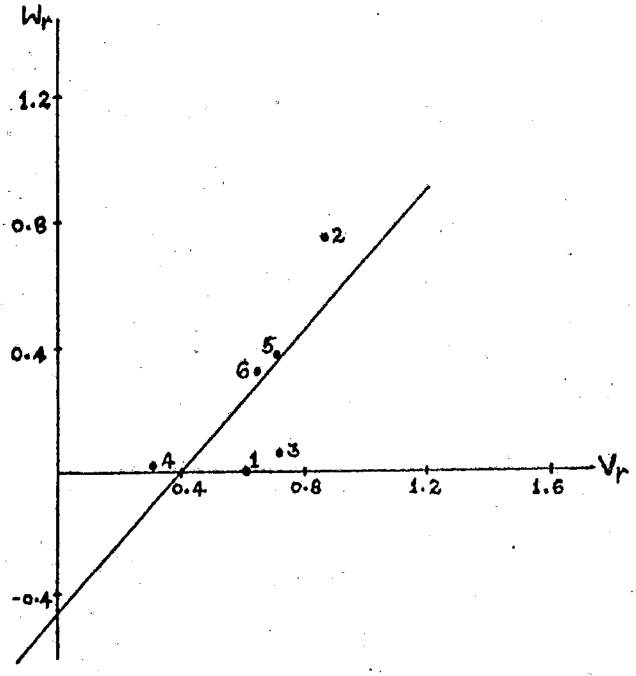

Fig. 3.6 Number of flowers per plant

Regression line for parents and straight crosses

Regression line for parents and reciprocal crosses

• Array points for parents of straight crosses

× Array points for parents of reciprocal crosses

4.3.2.7 Number of fruits per plant

The assumption of no reciprocal differences among crosses was satisfied for this character as revealed by the combining ability analysis. The regression of Wr or Vr revealed the adequacy of the additive - dominance model for this character. Figure 3.7 revealed the regression line cutting the Wr-axis just below the origin. There was a wide scattering of array-points with point 6 being nearest to the origin and points 1 and 3 far away from the origin. The array points 2, 4 and 5 were seen at varying distances from the origin.

4.3.2.8 Length of fruit

The analysis of variance for combining ability revealed that this character satisfied the assumption of no reciprocal differences. The regression of Wr on Vr for parents and F_1s revealed adequacy of the additive dominance model for this character. In the Vr-Wr graph, the regression line cut the Wr-axis below the origin (Fig. 3.8). The array point 3 was nearest to the origin and point 1 was farthest from the origin. The points 2, 4, 5 and 6 were seen lying between points 1 and 3.

4.3.2.9 Girth of fruit

The assumption of no reciprocal differences was satisfied for this character. The adequacy of additive-dominance model for this character was confirmed by the regression of Wr on Vr. The regression line in Figure 3.9 cut the Wr-axis well

V_r - W_r GRAPH

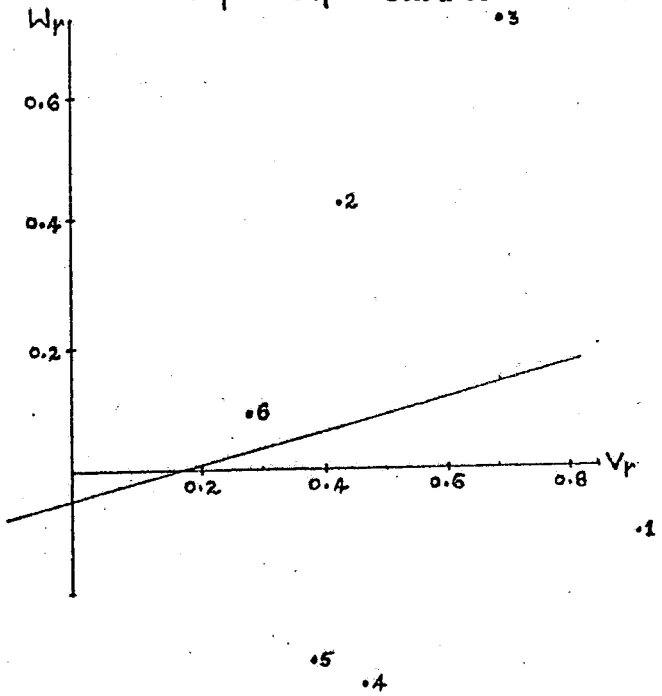

Fig. 3.7 Number of fruits per plant

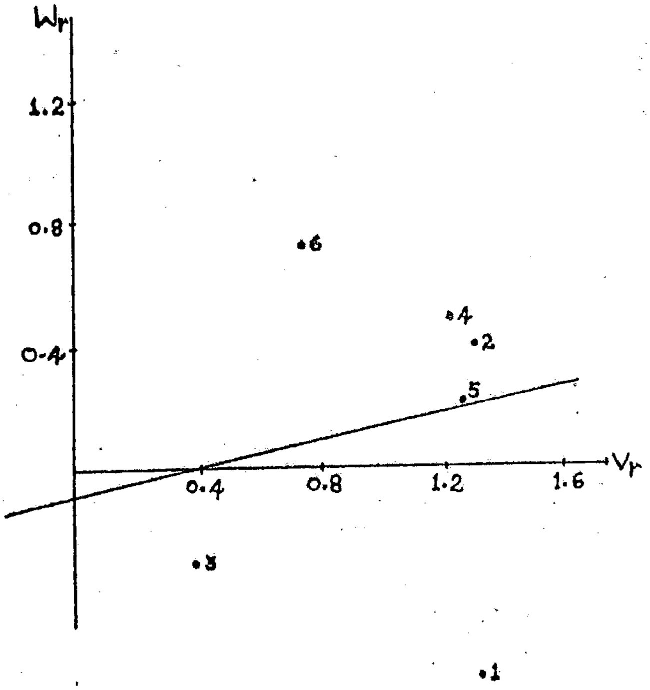

Fig. 3.8 Length of fruit

• Array points for parents of straight crosses

—— Regression line for parents and straight crosses

V_r - W_r GRAPH

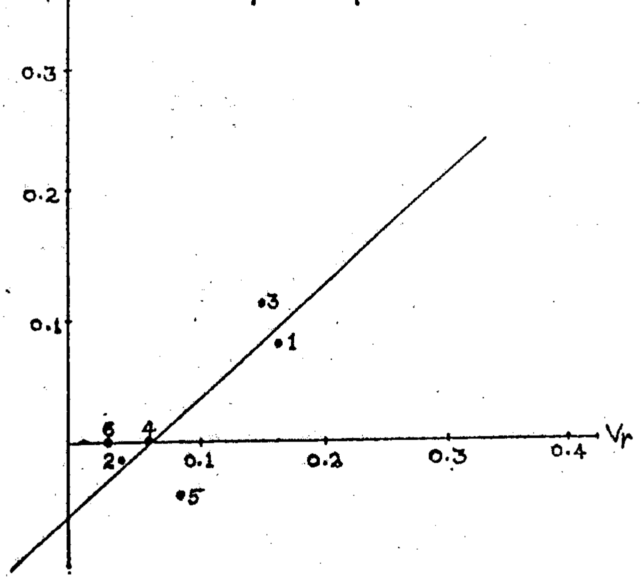

Fig. 3.9 Girth of fruit

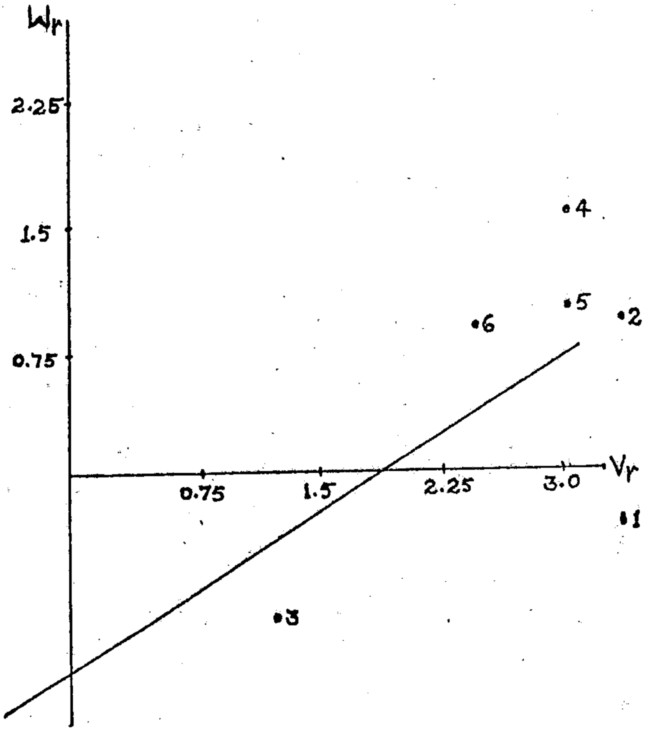

Fig. 3.10 Weight of single fruit

—— Regression line for parents and straight crosses

• Array points for parents of straight crosses

below the origin. Except for array points 1 and 3, all the others were seen crowding near the origin. Parents P_6, P_4, P_5 and P_2 had their array points near the origin. Points 1 and 3 were the farthest from the origin.

4.3.2.10 Weight of single fruit

The analysis of variance for combining ability revealed significant reciprocal differences among crosses. Considering parents and F_1s, the regression of Wr on Vr indicated the adequacy of the additive-dominance model. The linear regression line of the Vr-Wr graph cut the Wr-axis well below the origin (Fig. 3.10). There was a wide scattering of array points with points 3 and 4 lying farthest from the origin. The other array points 1, 2, 5 and 6 were seen at varying distances from the origin within points 3 and 4.

With respect to parents and reciprocal F_1s, the regression of Wr on Vr deviated significantly from unity thus indicating the presence of non-allelic interaction for weight of single fruit.

4.3.2.11 Weight of fruits per plant

The analysis of variance for combining ability revealed significant differences among reciprocal crosses. The regression of Wr on Vr for parents and F_1s as well as for parents and reciprocal F_1s deviated significantly from unity indicating the presence of nonallelic interaction in both the cases for yield per plant.

4.3.2.12 Number of seeds per fruit

The analysis of variance for combining ability revealed that the assumption of no reciprocal differences was satisfactory for this character. However, the regression of Wr on Vr for parents and F_1s deviated significantly from unit value indicating the presence of nonallelic interaction for seed number per fruit.

4.3.2.13 Fruiting phase

The assumption of no reciprocal differences among crosses was not satisfactory for this character as indicated by the analysis of variance for combining ability. In the analysis with parents and F_1s as well as with parents and reciprocal F_1s, the regression of Wr on Vr showed significant deviation from unity revealing the presence of nonallelic interaction in both the cases for fruiting phase.

4.3.2.14 Height of plant

The analysis of variance for combining ability revealed significant differences among reciprocal crosses. For parents and F_1s, the assumption of adequacy of additive-dominance model was not satisfied indicating the presence of nonallelic interaction for parents and F_1s.

However, for parents and reciprocal F_1s, the regression of Wr on Vr indicated adequacy of the additive - dominance model for this character. It was seen from Figure 3.11 that the linear regression line cut the Wr-axis below the origin. The array points were widely scattered with the point 3 lying closest to the origin closely followed by point 5.

4.3.2.15 Percentage fruit set

The assumption of no reciprocal differences was satisfied for this character as indicated by the combining ability analysis. The regression of Wr on Vr indicated that the additive-dominance model was satisfactory for this trait. Figure 3.12 showed the linear regression line cutting the Wr-axis below the origin. The array points were not much scattered for this character. Array points 6, 1, 3 and 4 were close to the origin and the point 2 was the farthest from the origin.

4.3.2.16 Incidence of yellow vein mosaic

The analysis of variance for combining ability revealed significant differences between reciprocal crosses. The adequacy of additive-dominance model was satisfactory in the case of

V_r - W_r GRAPH

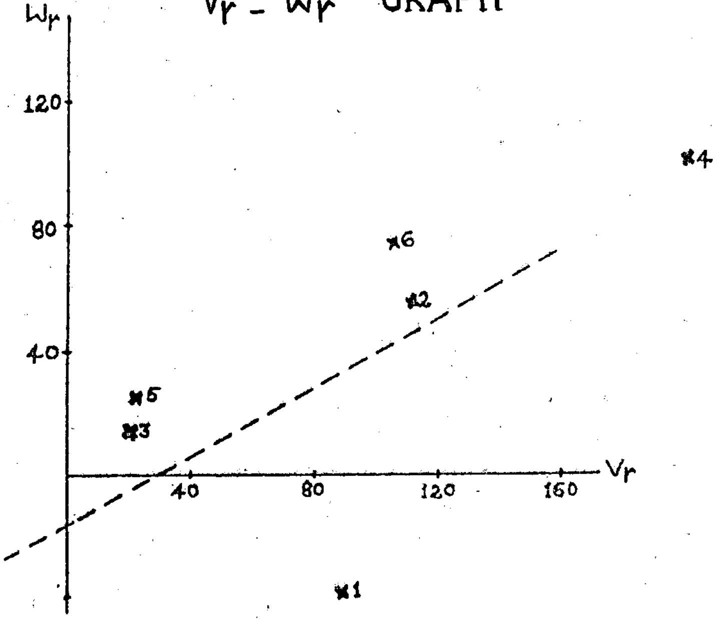

Fig. 3.11 Height of plant

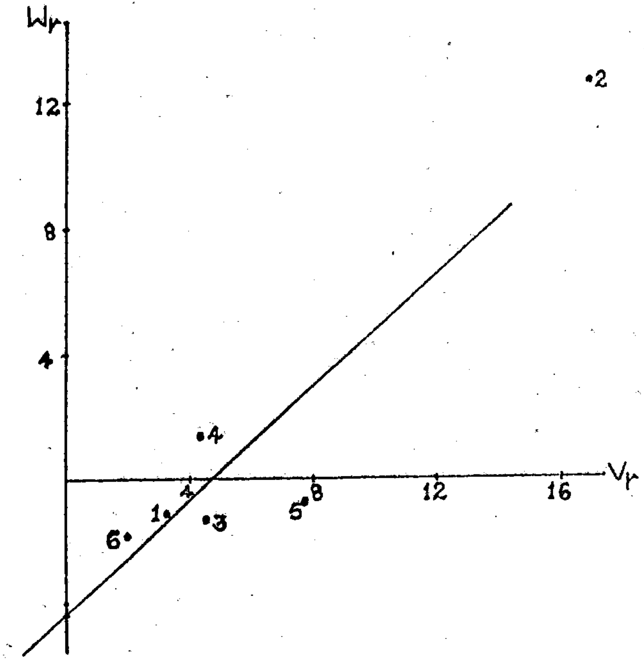

Fig. 3.12 Percentage fruit set

—— Regression line for parents and straight crosses

- - - - Regression line for parents and reciprocal crosses

● Array points for parents of straight crosses

x Array points for parents of reciprocal crosses parents and F_1s. The graph showed the linear regression line cutting the Wr-axis well below the origin (Fig. 3.13). There was a wide scattering of array points for this trait. Parent P_5 had its array point closer to the origin than parents P_2, P_4 and P_3. The point 6 was the farthest from the origin.

Analysis with parents and reciprocal F_1s revealed significant regression of Wr on Vr indicating the presence of nonallelic interaction for resistance to the virus.

4.3.2.17 Incidence of shoot and fruit borer

This character satisfied the assumption of the absence of reciprocal differences among crosses.

The regression of Wr on Vr for parents and F_1s showed adequacy of the additive-dominance model. In the Figure 3.14 the linear regression line was seen passing through the origin. There was some amount of scattering among the array points, with point 6 lying closest to the origin. All the other parents had their array points at varying distances from the origin.

4.4 Heterosis

The mean values of the parents and hybrids were used to determine the heterosis manifested by the hybrids for each character. The results are presented below.

Vr - Wr GRAPH

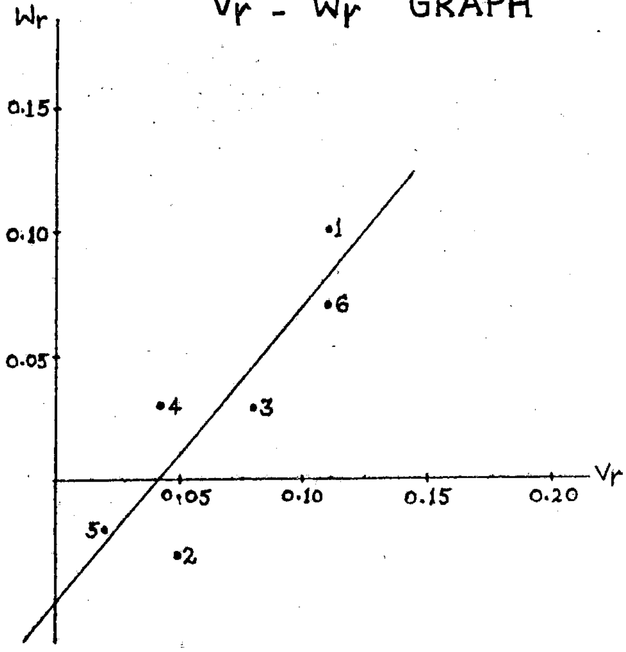

Fig. 3.13 Incidence of YVM

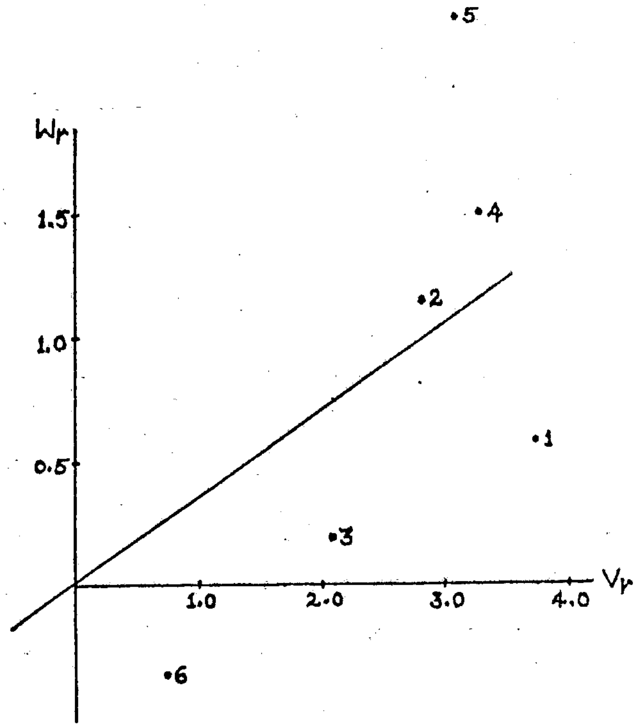

Fig. 3.14 Incidence of shoot and fruit borer

— Regression line for parents and straight crosses

• Array points for parents of straight crosses

Data on the percentage heterosis over mid parent (MP), better parent (BP) and check variety (CP) for the 17 characters are furnished in Table 12.

4.4.1 Days to first flowering

The percentage heterosis over mid parent for the 30 hybrids ranged from -7.02% to 6.96% for days to first flowering. Significant negative heterosis over mid parent was exhibited by five hybrids viz., P_1 x P_4 (-7.0%), P_2 x P_1 (-6.1%), P_1 x P_5 and P_5 x P_1 (-5.9%) and P_2 x P_5 (-5.9%), all being on par with each other. Compared to the better parent, the range of heterosis was from -6.4% to 11.8% but only one hybrid P_1 x P_4 showed significant negative heterosis of -6.4%. The standard heterosis ranged from -0.7% to 14.6% but none of the hybrids showed significant negative heterosis for this character.

4.4.2 Leaf axil bearing the first flower

The cross P_5 x P_4 exhibited the highest negative heterosis over mid parental value (-23.2%) for this character. The other hybrids had heterosis values lying between -23.2% and 27.8%. Considering heterobeltiosis, the least heterosis was shown by the cross P_1 x P_6 (-10.5 %) and the highest by P_3 x P_2 (42.0%). However, none of them exhibited significant heterosis in the negative direction. Similar situation was noticed in the case of standard heterosis also, which ranged from -0.02% to 44.1%.

Table 12. Percentage heterosis over mid parent (MP) better parent (BP) and check parent (CP)

Crosses	Days to first flowering Heterosis (%) over			Leaf axil bearing first flower Heterosis (%) over			Leaf number Heterosis (%) over		
	MP	BP	CP	MP	BP	CP	MP	BP	CP
$P_1 \times P_2$	-3.87	-2.9	5.5	5.8	8.5	21.0*	11.9	11.1	19.9
$P_1 \times P_3$	1.35	-3.8	4.2	-9.2	-1.8	-0.6	-8.6	-12.7	3.5
$P_1 \times P_4$	-7.02*	-6.4	2.3	-6.4	13.7	26.8	13.7*	3.7	35.8**
$P_1 \times P_5$	-5.98*	-3.8	1.8	-1.9	6.0	1.7	2.8	-2.9	4.8
$P_1 \times P_6$	1.23	3.9	9.3*	-11.3	-10.5	-1.5	-13.5	-19.2	0.4
$P_2 \times P_3$	-3.49	0.5	8.47	4.6	16.2	11.5	0.4	-4.9	12.8
$P_2 \times P_4$	-1.52	-1.2	7.3*	1.5	19.7*	40.3**	13.5	2.7	34.5**
$P_2 \times P_5$	-5.96*	-4.7	0.8	-4.6	6.0	1.73	12.9	7.5	14.1
$P_2 \times P_6$	-5.36	3.8	1.2	-1.6	1.8	11.5	-9.0	-15.6	4.8
$P_3 \times P_4$	3.47	8.1	8.5*	2.3	36.0**	30.5**	-18.8*	-22.6*	1.3
$P_3 \times P_5$	-3.63	-0.9	-0.6	10.2	10.2	5.8	2.2	-7.5	9.7
$P_3 \times P_6$	-2.99	-0.7	-0.3	12.2	20.1	15.3	-6.4	-8.5	13.7
$P^4 \times P_5$	0.37	2.0	7.9*	-9.7	20.1	15.3	0.2	-13.2	13.7
$P_4 \times P_6$	6.89	9.0	14.6*	4.4	28.2**	40.3**	11.9	9.1	42.9**
$P_5 \times P_6$	-3.93	-3.6	1.3	-12.2	-6.0	9.8	-1.9	-13.1	7.9
$P_2 \times P_1$	-6.14*	5.2	2.9	0.8	3.4	15.3	8.3	7.4	15.93
$P_3 \times P_1$	-4.65	0.3	6.7	5.5	14.1	9.5	9.4	4.5	23.9
$P_3 \times P_2$	-0.97	3.1	3.5	27.8**	42.0**	36.3**	13.4	7.4	27.4*
$P_4 \times P_1$	1.58	2.3	11.8**	6.4	-1.8	44.1**	9.6	0.0	30.9*
$P_4 \times P_2$	-1.06	-0.8	7.8*	-12.5	3.2	21.0*	22.7*	11.1	45.5**
$P_4 \times P_3$	6.96	11.7	12.1**	-5.2	26.1*	21.0*	2.3	-2.5	27.6*
$P_5 \times P_1$	-5.98*	-3.8	1.8	-9.2	-1.8	5.8	0.6	-4.9	2.6
$P_5 \times P_2$	-0.24	1.1	6.9*	-2.7	8.1	3.7	8.5	3.3	9.7
$P_5 \times P_3$	-3.14	-0.5	-0.1	2.1	2.1	-2.0	6.8	-3.4	14.6
$P_5 \times P_4$	-4.4	-2.8	2.8	-23.2**	2.1	-2.0	-12.7	-24.3**	-0.9
$P_6 \times P_1$	-2.2	0.5	5.7	0.9	1.8	11.5	6.3	-0.7	23.4
$P_6 \times P_2$	1.4	3.5	8.8*	6.7	10.5	21.0	12.5	4.3	29.6*
$P_6 \times P_3$	2.2	4.6	4.9	8.5	16.2	11.5	-2.3	-4.6	18.6
$P_6 \times P_4$	-2.1	-0.2	4.9	-12.7	7.1	17.3	-16.4*	-18.5*	6.6
$P_6 \times P_5$	-0.6	-0.3	4.8	6.6	14.1	9.5	18.5	5.0	30.5*

Table 12. continued..

Crosses	Leaf area Heterosis (%) over			Number of branches Heterosis (%) over			Number of flowers/plant Heterosis (%) over		
	MP	BP	CP	MP	BP	CP	MP	BP	CP
$P_1 \times P_2$	2.7	-7.9	45.2^{**}	28.1	-10.8	224.2^{*}	8.9	4.3	19.7
$P_1 \times P_3$	-10.2	-12.5	15.4	-91.6	-94.2^{**}	-78.8	-13.0	-19.2	-1.2
$P_1 \times P_4$	12.0	4.7	50.7^{**}	-13.7	-51.4^{*}	445.4^{**}	34.8^{**}	29.0^{*}	48.2^{**}
$P_1 \times P_5$	4.8	1.3	36.1^{*}	-29.8	-40.3	21.2	-4.1	-5.2	1.8
$P_1 \times P_6$	-20.1^{*}	-26.5^{*}	9.5	-80.6	-80.6	-60.6	-12.9	-21.0^{*}	1.8
$P_2 \times P_3$	2.9	-5.5	49.1^{**}	27.5	27.5	363.6^{**}	-7.3	-10.1	9.9
$P_2 \times P_4$	10.1	5.2	66.0^{**}	-26.5^{*}	-51.3^{**}	445.4^{**}	17.2	17.2	34.5^{*}
$P_2 \times P_5$	-5.9	-12.9	37.4^{*}	-28.3	-44.2	103.3	-3.9	-12.6	6.8
$P_2 \times P_6$	-7.9	-10.5	41.2^{*}	-93.2	-94.2^{**}	-78.8	-11.4	-16.2	8.1
$P_3 \times P_4$	-0.2	-4.4	37.6^{*}	-51.0^{**}	-67.6^{**}	263.6^{**}	-7.8	-10.6	9.3
$P_3 \times P_5$	5.9	4.9	41.0^{*}	-14.4	-10.8	224.2^{*}	-2.2	-8.1	12.3
$P_3 \times P_6$	0.2	-5.5	40.7^{*}	-3.4	-16.7	203.0^{*}	-9.1	-11.5	14.2
$P_4 \times P_5$	6.1	-9.2	30.7	-45.1^{**}	-67.6^{**}	263.6^{**}	-1.1	-4.3	9.9
$P_4 \times P_6$	6.8	4.9	56.3^{**}	5.0	-35.1^{**}	627.3^{**}	8.4	2.4	32.1^{*}
$P_5 \times P_6$	-1.4	-6.2	39.7^{*}	-12.9	-22.9	103.0	-8.6	-16.2	8.1
$P_2 \times P_1$	3.7	-7.0	46.7^{**}	-43.7	-60.8^{*}	42.4	-8.4	-12.3	0.6
$P_3 \times P_1$	24.7^{*}	21.6	60.3^{**}	-21.8	-50.0	81.8	4.9	-2.5	19.2
$P_3 \times P_2$	8.5	-0.4	57.2^{**}	5.8	5.8	284.8^{**}	1.6	-1.5	20.4
$P_4 \times P_1$	7.9	0.9	45.3^{**}	-10.3	-49.5^{**}	466.7^{**}	1.7	-2.7	11.8
$P_4 \times P_2$	-4.6	-8.8	43.9^{**}	-62.0^{**}	-74.9^{**}	181.8	16.1	16.1	33.3^{*}
$P_4 \times P_3$	-10.3	-14.1	23.6	-48.2^{**}	-65.7^{**}	284.8^{**}	9.4	6.1	29.6^{*}
$P_5 \times P_1$	-1.2	-4.6	28.2	-77.2	-80.6	60.6	-7.5	-8.6	-1.8
$P_5 \times P_2$	-15.9	-22.2^{*}	22.7	-49.7	-60.8^{*}	42.4	3.9	-5.5	19.2
$P_5 \times P_3$	29.9^{**}	28.8^{*}	72.9^{**}	20.9	-5.8	242.4^{*}	8.1	1.5	24.1
$P_5 \times P_4$	13.2	10.5	58.9^{**}	-57.4^{*}	-74.9^{**}	181.8	-5.6	-8.6	4.9
$P_6 \times P_1$	-1.9	-9.8	34.4^{*}	29.8	0.0	163.6	5.5	-4.3	23.4
$P_6 \times P_2$	-14.1	-16.5	31.7	35.3	16.7	324.2^{**}	18.5	11.9	44.4^{**}
$P_6 \times P_3$	10.6	4.3	55.4^{**}	-22.7	-33.3	142.4	-8.6	-10.9	14.8
$P_6 \times P_4$	2.8	1.0	50.5^{**}	-88.2^{**}	-92.7^{**}	-18.1	-4.8	-10.1	16.0
$P_6 \times P_5$	6.7	1.5	51.2^{**}	81.8^{*}	60.9	324.2^{**}	11.8	2.4	32.1^{*}

Table 12. continued..

Crosses	Number of fruits/plant Heterosis (%) over			Length of fruit Heterosis (%) over			Girth of fruit Heterosis (%) over		
	MP	BP	CP	MP	BP	CP	MP	BP	CP
P_1 x P_2	2.3	-8.2	10.6	18.3*	17.5*	11.8	15.3*	10.5*	9.3
P_1 x P_3	-14.1	-24.3	-5.0	-0.5	-2.2	-6.9	-3.9	-12.9	-3.0
P_1 x P_4	3.2	35.1*	41.8*	11.9*	7.5	2.3	7.7	3.9	1.3
P_1 x P_5	5.0	0.7	5.0	-4.6	-8.9	-4.8	1.1	-3.1	-4.3
P_1 x P_6	12.9	-20.7	-7.8	3.3	-0.6	-5.4	0.8	-1.9	-5.9
P_2 x P_3	-10.1	-11.9	10.6	16.6*	15.4*	8.3	-1.9	-7.4	3.0
P_2 x P_4	2.5	-4.1	15.6	4.4	0.9	-5.3	9.9*	9.2	7.9
P_2 x P_5	-4.1	-10.6	7.8	10.0	4.4	9.1	-5.7	5.6	4.5
P_2 x P_6	-10.1	-11.7	6.4	11.3	7.8	1.1	3.6	2.1	0.9
P_3 x P_4	-2.2	-10.2	12.8	4.9	2.5	5.8	-3.1	-9.2*	1.1
P_3 x P_5	-8.6	16.4	5.0	7.1	0.7	5.2	1.4	4.3	6.5
P_3 x P_6	-3.2	6.8	17.0	8.5	6.1	-2.5	-0.1	12.5*	-2.6
P_4 x P_5	-5.1	-5.5	-0.7	6.9	-1.7	2.6	5.4	-4.7	3.3
P_4 x P_6	6.4	1.3	17.8	-12.5	-4.4	-16.1*	-3.2	3.9	-6.4
P_5 x P_6	-4.2	-9.1	5.6	-0.7	-8.6	-4.6	-3.5	-4.8	-6.1
P_2 x P_1	-4.9	-14.6	2.9	15.1*	14.3	8.8	15.8*	10.9*	9.7*
P_3 x P_1	3.2	-9.1	14.1	8.1	6.2	1.1	1.4	-8.0	2.4
P_3 x P_2	-7.2	-9.1	14.1	3.5	2.4	-3.9	-4.2	-9.6	0.6
P_4 x P_1	13.7	8.7	14.1	7.1	2.8	-2.1	11.1*	7.2	4.5
P_4 x P_2	12.5	5.3	26.9	13.5	-2.4	-8.5	-0.7	-1.4	-2.5
P_4 x P_3	13.2	3.9	30.5*	-9.5	-11.6	-18.8*	-12.1	-17.6	-8.3
P_5 x P_1	-2.1	-6.1	-2.1	7.5	37.0	7.2	1.9	-2.3	-3.5
P_5 x P_2	-7.9	-14.1	3.5	-4.9	-9.7	-5.7	-5.9	-5.9	-7.0
P_5 x P_3	4.9	-3.9	20.5	-1.7	-7.6	-3.5	-0.8	-6.4	4.1
P_5 x P_4	-6.5	-6.8	-2.1	5.3	-3.2	1.1	7.8	7.1	5.7
P_6 x P_1	15.1	4.9	22.0	10.3	6.1	0.9	7.3	4.3	0.1
P_6 x P_2	6.6	4.8	26.3	-4.7	-7.7	-13.4*	-3.1	-4.5	-5.6
P_6 x P_3	-8.5	-11.9	10.6	1.1	-1.1	-9.1	-4.5	-11.0	-0.9
P_6 x P_4	2.6	-2.4	13.5	-6.5	2.1	-10.3	2.2	-2.9	-5.4
P_6 x P_5	16.4	10.4	28.4*	9.9	1.2	5.7	2.7	1.3	0.0

Table 12. continued..

Crosses	Weight of single fruit Heterosis (%) over			Weight of fruits/plant Heterosis (%) over			Number of seeds/fruit Heterosis (%) over		
	MP	BP	CP	MP	BP	CP	MP	BP	CP
P_1 x P_2	15.1	6.9	15.3	56.4*	41.6*	49.9*	20.6*	14.7	16.9
P_1 x P_3	2.3	-6.6	-5.3	-8.3	-18.1	-10.6	-5.6	-16.1	-0.7
P_1 x P_4	5.3	5.2	-2.6	31.6*	23.7	20.7	21.5*	19.6	9.9
P_1 x P_5	0.7	-8.2	3.1	0.7	-14.0	4.3	0.2	-7.8	0.8
P_1 x P_6	10.6	8.6	0.4	-2.1	-10.4	-7.3	-0.8	-5.8	-3.7
P_2 x P_3	13.6	10.2	18.9	18.9	17.2	27.8*	11.9	4.2	23.4*
P_2 x P_4	9.4	1.6	9.7	19.9	15.2	21.9	14.7	7.4	9.5
P_2 x P_5	11.9	9.7	23.4	13.9	6.6	29.3*	11.1	7.3	17.3
P_2 x P_6	13.9	3.1	12.2	14.3	12.9	19.6	6.3	6.2	8.5
P_3 x P_4	-0.5	-4.8	-3.5	4.4	-1.1	7.8	-0.2	-12.5	3.5
P_3 x P_5	12.3	6.7	19.9	10.1	4.5	26.7*	-5.7	-9.3	7.3
P_3 x P_6	13.5	6.7	8.1	17.9	14.9	25.3	-11.8	-17.8*	-2.8
P^4 x P_5	9.6	-0.1	12.4	1.5	-8.5	10.9	6.4	-3.5	5.5
P_4 x P_6	-3.8	-5.6	-12.6	2.4	-0.5	2.9	12.8	5.6	7.9
P_5 x P_6	2.5	-8.1	3.3	-6.4	-13.2	5.2	-0.7	-3.9	5.1
P_2 x P_1	33.4*	23.8*	33.6*	67.2*	51.4*	60.2*	37.5**	30.8**	33.3**
P_3 x P_1	13.3	8.3	9.7	25.9*	12.5	22.7	10.5	-1.9	16.1
P_3 x P_2	5.9	2.7	10.8	17.7	15.9	26.5*	-4.5	-11.1	5.1
P_4 x P_1	21.2*	21.1	12.1	37.1*	28.9*	25.7	11.3	9.6	0.7
P_4 x P_2	-4.1	-10.9	-3.8	23.4*	18.6	25.5	12.3	5.2	7.3
P_4 x P_3	-18.7	-22.2	-21.2*	-16.6	-21.1	-13.9	-16.5	-26.9**	-13.4
P_5 x P_1	17.3*	6.8	20.1*	14.1	-2.6	18.1	4.3	-4.0	4.9
P_5 x P_2	-10.1	-11.9	-0.9	8.3	-14.2	4.1	1.1	-2.3	6.8
P_5 x P_3	-1.9	-6.7	4.8	8.9	3.4	25.4	7.0	2.9	21.8*
P_5 x P_4	7.1	-2.3	9.8	0.3	-9.5	9.7	27.2**	15.5	26.2**
P_6 x P_1	21.9*	19.7	10.7	42.6*	30.4*	34.9*	21.7*	15.6	18.2
P_6 x P_2	-19.3	-26.4	-20.5*	-5.7	-6.8	-1.4	0.9	0.8	3.1
P_6 x P_3	5.8	-1.2	0.1	2.8	0.2	9.2	10.8	3.3	22.2*
P_6 x P_4	-0.9	-2.7	-9.9	0.8	-2.1	1.2	16.4	8.9	11.4
P_6 x P_5	10.9	-0.6	11.7	26.8*	17.5	42.5*	18.8*	15.0	25.7*

Table 12. continued..

Crosses	Fruiting phase Heterosis (%) over			Height of plant Heterosis (%) over			Percentage fruit set Heterosis (%) over		
	MP	BP	CP	MP	BP	CP	MP	BP	CP
P_1 x P_2	5.2	4.7	-1.3	29.6*	23.3*	1.6	5.3	1.6	-5.9
P_1 x P_3	0.2	-1.6	-3.6	11.9	6.8	8.5	4.9	3.7	-4.1
P_1 x P_4	1.2	0.8	-4.2	35.8*	12.9	14.8	2.9	2.4	4.3
P_1 x P_5	8.4**	8.3*	2.1	1.0	-9.9	-32.5*	7.9	5.4	2.2
P_1 x P_6	4.7	3.7	-2.2	-14.7	-21.3	-20.4*	-0.9	-1.1	-8.5
P_2 x P_3	-0.2	-2.6	-4.5	9.2	8.8	0.6	11.5*	8.8	-1.7
P_2 x P_4	-2.7	-3.6	-8.4*	46.7*	27.2*	16.8	-4.2	-7.9	-14.0*
P_2 x P_5	-3.7	-4.1	-9.8**	15.5	7.8	-0.9	8.4	2.3	-0.8
P_2 x P_6	2.1	1.6	-5.1	16.6	2.8	23.7*	6.2	5.3	-2.8
P_3 x P_4	-10.1**	-11.5**	-13.2**	22.7	6.2	-1.9	12.2*	10.3	3.1
P_3 x P_5	1.9	-0.1	-2.1	6.5	-0.8	-8.4	-0.1	-3.5	-6.4
P_3 x P_6	-2.4	-5.1	-6.9*	-8.7	-19.3	-2.9	10.5	9.4	-0.9
P^4 x P_5	-5.6	-6.1	-10.8**	23.7	14.3	-9.0	-4.0	-5.8	-8.7
P_4 x P_6	-0.8	-2.1	-6.9*	2.5	-19.9	-3.8	-3.7	-7.8	-10.6
P_5 x P_6	10.4**	9.5**	3.0	-5.9	-21.8	-5.9	2.4	-0.1	-3.2
P_2 x P_1	2.9	2.4	-3.4	8.4	3.2	4.9	13.4*	9.4	1.2
P_3 x P_1	1.1	-0.8	-2.7	4.5	-0.2	1.4	3.1	1.9	-5.7
P_3 x P_2	-2.0	-4.4	-6.3*	25.2	24.8*	15.3	7.5	4.9	-5.2
P_4 x P_1	-3.8	-4.2	-8.9**	15.2	-4.1	-2.6	8.9	8.4	1.3
P_4 x P_2	-2.3	-3.2	-8.0*	50.3*	30.4*	19.8*	4.2	0.1	-6.5
P_4 x P_3	-7.7**	-9.1**	-10.9**	33.1	15.2	6.4	-6.3	-7.8	-13.9*
P_5 x P_1	0.9	0.8	-4.9	17.5	4.7	6.4	7.1	4.7	1.5
P_5 x P_2	1.7	1.3	-4.7	17.5	8.7	0.7	0.3	-5.3	-8.2
P_5 x P_3	0.7	-1.4	-3.3	18.5	10.3	1.9	1.7	-1.7	-4.7
P_5 x P_4	7.8**	7.2*	1.9	48.8*	37.4*	9.4	-1.7	-3.5	-6.4
P_6 x P_1	-1.7	-2.6	-8.2*	7.8	-0.6	19.6*	5.7	5.6	-2.3
P_6 x P_2	7.4*	7.0*	-0.1	7.0	5.6	13.5*	-2.3	-3.1	-10.6
P_6 x P_3	-0.9	-3.7	-5.6	-5.6	-16.6	0.3	5.5	4.5	-3.6
P_6 x P_4	-4.5	-5.7	-10.5**	17.2	-8.5	10.0	4.9	0.5	-2.6
P_6 x P_5	-6.6*	-7.3*	-12.8	13.1	-6.0	13.0	1.4	-1.1	-4.1

Table 12. continued..

Crosses	Incidence of YVM Heterosis (%) over			Incidence of shoot and fruit borer Heterosis (%) over		
	MP	BP	CP	MP	BP	CP
P_1 x P_2	45.4**	-2.5	39.2*	-0.7	1.0	-15.5
P_1 x P_3	11.2	-16.9*	26.9	-12.6	-7.7	-22.8
P_1 x P_4	-18.1	30.6*	-21.6	5.8	17.3	-1.9
P_1 x P_5	20.6	3.6	13.1	-14.7	-13.7	-27.9
P_1 x P_6	-10.0	-28.9*	-3.9	5.2	17.9	-1.3
P_2 x P_3	-26.5*	-35.2**	-3.9	23.2	27.6	-10.6
P_2 x P_4	4.0	-4.1	17.6	12.5	22.4	5.9
P_2 x P_5	-5.9	-7.5	4.6	11.7	12.4	-3.8
P_2 x P_6	15.8	6.3	43.8**	-4.1	5.4	-8.7
P_3 x P_4	-40.0**	-47.1**	-21.6	8.7	13.9	5.8
P_3 x P_5	18.3	2.6	52.3**	23.6	28.9	10.3
P_3 x P_6	1.4	-26.4*	9.1	14.5	21.3	12.6
P^4 x P_5	21.8	19.6	35.3*	-3.9	5.2	-10.0
P_4 x P_6	-12.1	-19.3	9.1	-8.1	-7.1	-5.5
P_5 x P_6	-3.8	-13.0	17.6	2.5	13.5	-2.9
P_2 x P_1	9.2	-43.6**	4.6	-42.6*	-41.6**	-51.1**
P_3 x P_1	-26.8*	1.9	-16.9	7.3	13.2	-5.3
P_3 x P_2	-20.0	-29.5**	4.6	31.9	36.6	18.3
P_4 x P_1	-4.4	-19.1	-8.5	19.5	32.5	10.8
P_4 x P_2	-11.6	26.6	-16.9	16.5	26.7	9.8
P_4 x P_3	-10.0	-20.7	17.6	-14.3	-10.2	-16.6
P_5 x P_1	16.4	0.0	1.7	-12.9	-11.9	-26.4
P_5 x P_2	-10.0	-11.6	0.0	-12.4	-11.9	-24.6
P_5 x P_3	18.3	2.6	52.3**	-4.9	-0.9	-15.2
P_5 x P_4	10.0	8.1	22.2	11.9	22.6	4.8
P_6 x P_1	26.6*	0.0	35.3*	15.4	29.4	8.2
P_6 x P_2	-22.6*	-28.9*	-3.9	8.1	18.9	2.9
P_6 x P_3	19.8*	14.5	69.9**	-11.1	-5.9	-12.6
P_6 x P_4	-8.9	-16.4	13.1	-14.3	-13.4	-11.9
P_6 x P_5	-18.2	-26.1*	0.0	13.4	25.6	7.4

* Significant ($P < 0.05$) ** Significant ($P < 0.01$)

4.4.3 Leaf number

The relative heterosis for leaf number ranged from -18.8% (P_3 x P_4) to 22.7% (P_4 x P_2). However, significant positive heterosis was exhibted by only one hybrid P_4 x P_2 (22.7%). None of the hybrids showed significant positive heterobeltiosis for this trait, while three hybrids showed significant negative heterobeltiosis. Compared to the standard check, the least heterosis of -0.9% was shown by P_5 x P_4 and the highest by P_4 x P_2 (45.5%). Among the 30 hybrids, significant heterosis was exhibited by nine hybrids viz., P_4 x P_2, P_4 x P_6, P_1 x P_4, P_2 x P_4, P_4 x P_1, P_6 x P_5, P_6 x P_2, P_4 x P_3 and P_3 x P_2. Of these, the crosses P_4 x P_2 and P_4 x P_6 were the outstanding ones with 45.5% and 42.9% heterosis respectively.

4.4.4 Leaf area

The percentage heterosis over midparent for the 30 hybrids ranged from -20.1% to 29.9%. Two hybrids P_5 x P_3 and P_3 x P_1 showed significant positive heterosis of 29.9% and 24.7% respectively while significant negative heterosis of -20.1% was also seen in P_1 x P_6. In comparison to the better parent, the heterosis ranged from -26.5% in P_1 x P_6 to 28.8% in P_5 x P_3 which alone showed significant positive value. The cross P_5 x P_2 also exhibited significant negative heterosis of -22.2%. Among the 30 hybrids 23 crosses exhibited significant positive heterosis over the check parent. All these hybrids were on par with each other. The superior ones among them were P_5 x P_3 (72.9%), P_2 x P_4 (66.0%), P_3 x P_1 (60.1%), P_5 x P_4 (58.9%), P_3 x P_2 (57.2%) and P_4 x P_6 (56.3%).

4.4.5 Number of branches

Only one hybrid P_6 x P_5 showed significant positive heterosis of 81.8% over the midparent. However, seven hybrids exhibited significant negative heterosis. The poorest performance compared to the midparental value was shown by the cross P_6 x P_4 (-88.2%). When compared to the better parent, none of the crosses were found to exhibit significant positive heterosis. However, 14 hybrids exhibited significant heterobeltiosis in the negative direction, the maximum by the crosses P_1 x P_3 and P_2 x P_6 (-94.2%). Meanwhile, significant positive heterosis over the standard check was seen in 15 hybrids. The best among them was P_4 x P_6 with 627.3% heterosis followed by P_4 x P_1 (466.7%), P_1 x P_4 and P_2 x P_4 (445.4%) and P_2 x P_3 (363.6%). The lowest heterosis of 203.0% was exhibited by the cross P_3 x P_6.

4.4.6 Number of flowers per plant

Significant positive heterosis over the midparent was exhibited by only one hybrid P_1 x P_4 (34.8%). The values ranged between -13.0% in P_1 x P_3 and 34.8% in P_1 x P_4. The hybrid P_1 x P_4 was also the only one to show significant positive heterobeltiosis of 29.0%. Significant negative value was seen in the cross P_1 x P_6 (-21.0%). Compared to the standard check, significant positive heterosis was exhibited by seven crosses, the highest value by P_1 x P_4 (48.1%) followed by P_6 x P_2 (44.4%).

4.4.7 Number of fruits per plant

None of the hybrids were outstanding when compared to the mid parental value with respect to this character. However, heterosis over the better parent was exhibited by one hybrid P_1 x P_4 (35.1%). Among the 30 hybrids, standard heterosis was exhibited by three hybrids. The highest value was seen in the cross P_1 x P_4 (41.8%) followed by P_4 x P_3 and P_6 x P_5 with 30.5% and 28.4% heterosis respectively.

4.4.8 Length of fruit

Significant heterosis over mid parent for fruit length was exhibited by four hybrids and over better parent by two hybrids. The maximum relative heterosis of 18.3% was expressed by P_1 x P_2 followed by P_2 x P_3 (16.6%), P_2 x P_1 (15.1%) and P_1 x P_4 (11.9%). Compared to the better parent, P_1 x P_2 was the best hybrid with 17.5% heterosis followed by P_2 x P_3 with 15.39% heterosis. None of the hybrids showed significant standard heterosis.

4.4.9 Girth of fruit

Significant positive relative heterosis was expressed by four hybrids. The highest values were seen in the crosses P_2 x P_1 and P_1 x P_2 (15.8% and 15.3% respectively) followed by P_4 x P_1 with 11.1% and P_2 x P_4 with 9.9% heterosis. In comparison with the better parent, three hybrids showed significant positive heterosis viz., P_3 x P_6 expressing the maximum heterobeltiosis of 12.5% followed by P_2 x P_1 (10.9%) and P_1 x P_2 (10.5%), the latter two being on par with each other. Significant negative heterobeltiosis was also noticed in P_3 x P_4 (-9.2%). Compared to the standard check, only one hybrid P_2 x P_1 showed significant positive heterosis of 9.7%.

4.4.10 Weight of single fruit

Among the 30 hybrids, significant positive relative heterosis was noticed in four hybrids of which the maximum of 33.4% was seen in P_2 x P_1 followed by P_6 x P_1 (21.9%), P_4 x P_1 (21.2%) and P_5 x P_1 (17.3%). Compared to the better parent, the hybrid P_2 X P_1 alone expressed significant positive heterosis of 23.8% for this character. The hybrid P_2 x P_1 was also one among the three hybrids that showed significant positive heterosis (33.6%) over the standard check, the other two being P_2 x P_5 and P_5 x P_1 with 23.4% and 20.1% standard heterosis respectively.

4.4.11 Weight of fruits per plant

Significant positive heterosis over mid parent was exhibited by eight hybrids, over the better parent by four hybrids and over the standard check by eight hybrids. Maximum relative heterosis for yield per plant was seen in P_2 x P_1 (67.2%) which was on par with the hybrids P_1 x P_2 (56.4%), P_6 x P_1 (42.6%) and P_4 x P_1 (37.1%). These four hybrids also expressed similar trend for heterobeltiosis with 51.4%, 41.6%, 30.4% and 28.9% respectively. Compared to the standard check, the best hybrid was again P_2 x P_1 with 60.2% heterosis. Two other hybrids P_1 x P_2 and P_6 x P_5 were also found to be superior with 49.9% and 42.5% heterosis respectively, followed by P_6 x P_1 (34.9%), P_2 x P_5 (29.3%) and the others, all being on par with each other.

4.4.12 Number of seeds per fruit

Compared to the mid parental value six hybrids expressed significant positive heterosis. The hybrid P_2 x P_1 showed the maximum heterosis of 37.5% which was on par with the cross P_5 x P_4 (27.2%) and superior to P_6 x P_1 (21.7%), P_1 x P_4 (21.5%) and P_1 x P_2 (20.6%). The cross P_6 x P_5 expressed the least heterosis of 18.8%. Hybrid P_2 x P_1 alone showed significant positive heterobeltiosis of 30.8%, while two hybrids

P_3 x P_6 and P_4 x P_3 expressed significant negative heterosis of -17.8% and -26.9%. Standard heterosis was found to be significant and positive in six hybrids of which P_2 x P_1 was the most outstanding with 33.3% heterosis. However, the hybrids P_5 x P_4 (26.2%), P_6 x P_5 (25.7 %), P_2 x P_3 (23.4%), P_6 x P_3 (22.3%) and P_5 x P_3 (21.8%) were on par with P_2 x P_1.

4.4.13 Fruiting phase

Significant positive heterosis over the mid parent as well as over the better parent was noticed in four crosses viz., P_5 x P_6 (10.4% and 9.5%), P_1 x P_5 (8.4% and 8.3%), P_5 x P_4 (7.8% and 7.2%) and P_6 x P_2 (7.4% and 7.0%). Three crosses P_6x P_5, P_4 x P_3 and P_3 x P_4 showed significant negative heterosis over mid parent as well as over the better parent. When compared to the standard check, none of the crosses exhibited significant positive heterosis while 12 of them showed significant negative heterosis for fruiting phase.

4.4.14 Height of plant

Five of the 30 hybrids expressed significant positive heterosis for plant height. The superior crosses were P_4 x P_2 (50.3%), P_5 x P_4 (48.8%) and P_2 x P_4 (46.7%) followed by P_1 x P_4 (35.8%) and P_1 x P_2 (29.6%). Significant positive heterosis over the better parent was also noticed in five crosses viz., P_5 x P_4, P_4 x P_2, P_2 x P_4, P_1 x P_2 and P_3 x P_2 with 37.4%, 30.4%, 27.2%, 23.3% and 24.8% respectively, all of which were on par with each other. Significant positive standard heterosis was noticed in three hybrids P_2 x P_6, P_4 x P_2 and P_6 x P_1 with 23.7%, 19.8% and 19.6% heterosis respectively. Two hybrids P_1 x P_5 and P_1 x P_6 were found to express significant negative heterosis over standard check for plant height.

4.4.15 Percentage fruit set

In comparison with the mid parental value, three hybrids P_2 x P_1, P_3 x P_4 and P_2 x P_3 were found to exhibit significant positive heterosis of 13.4%, 12.2% and 11.5% respectively, all of which were on par with each other. None of the hybrids expressed significant heterobeltiosis for percentage fruit set. Similarly, in comparison with the standard check also, none of the hybrids expressed significant positive heterosis. However, two hybrids P_4 x P_3 and P_2 x P_4 exhibited significant negative heterosis of -13.9% and -14.0% over the standard check for this trait.

4.4.16 Incidence of yellow vein mosaic

When compared to the midparental value, negative heterosis was exhibited by four hybrids and nine hybrids expressed negative heterosis when compared to the better parent.

The maximum relative heterosis of -40.0% was noticed in P_3 x P_4 followed by P_3 x P_1 with -26.8%, P_2 x P_3 with -26.5% and P_6 x P_2 with -22.6% heterosis. The percentage heterobeltiosis was the highest in P_3 x P_4 (-47.1%) followed by P_2 x P_1 (-43.6%) and P_2 x P_3 (-35.2%). Though six crosses exhibited significant positive heterosis over the check parent, none of them expressed useful heterosis in the negative direction.

4.4.17 Incidence of shoot and fruit borer

The percentage heterosis over the mid parent ranged from -42.6% to 31.9% and the hybrid P_2 x P_1 alone was found to express significant negative heterosis (-42.6%) over the mid parent. This cross (P_2 x P_1) also showed significant negative heterosis over the better parent (-41.6%). The same hybrid P_2 x P_1 exhibited significant negative heterosis of -51.1% over the check parent.

From the above results it is evident that the crosses P_2 x P_1 and P_1 x P_2 were the most outstanding for yield and related characters (Figures 4.1 and 4.2). It was seen that many of the hybrids involving either parent P_1 or P_2 were heterotic. Figures 4.3 and 4.4 illustrate the hybrid vigour exhibited by the crosses P_2 x P_5 and P_5 x P_1.

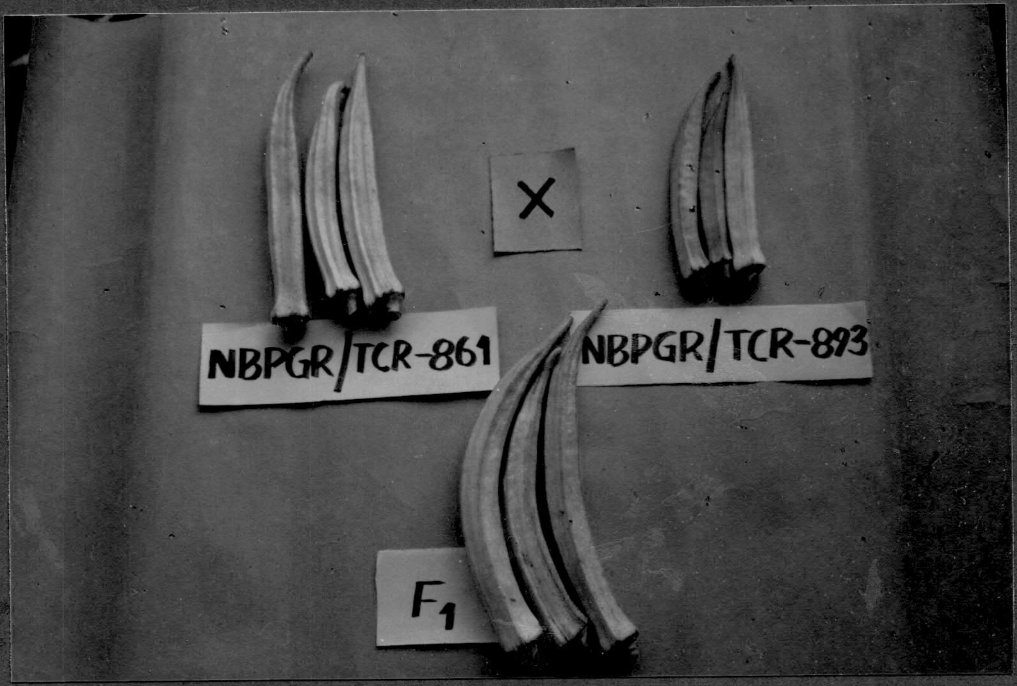

Fig. 4.1

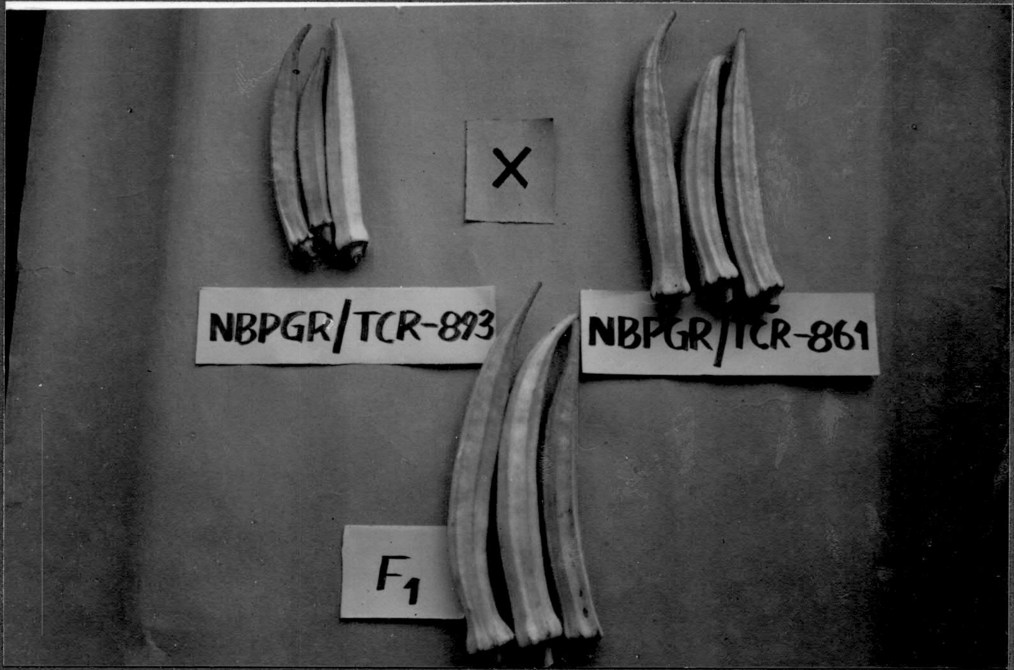

Fig. 4.2

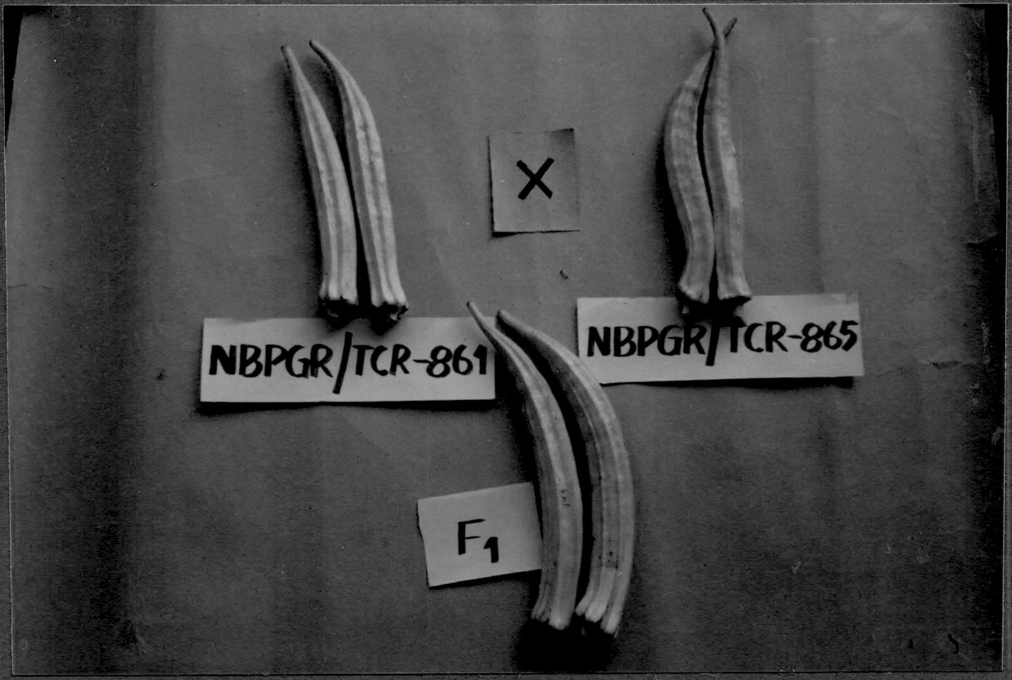

Fig. 4.3

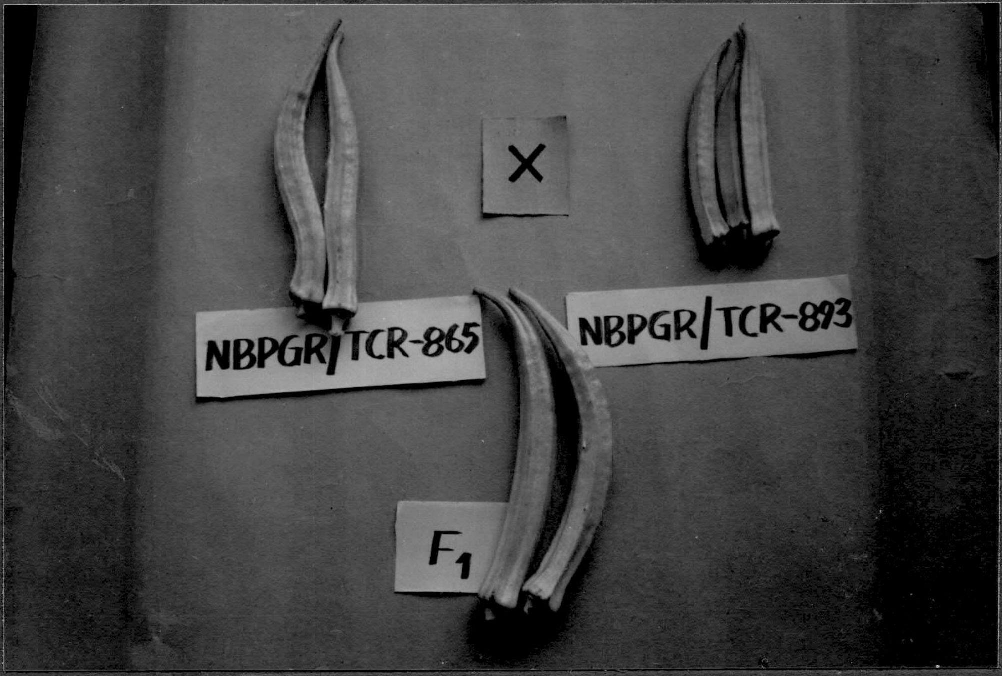

Fig. 4.4

Discussion

5. DISCUSSION

The diallel mating system involved in the present study is an effective method of determining the combining ability of the parents which enables a rational choice of the parental material to be used in a heterosis breeding programme. This method also helps to study the nature of gene action governing the different characters based on which an appropriate breeding methodology can be adopted. In the present study, six parental lines and their 30 F_1 hybrids obtained by crossing the parents in all possible combinations were subjected to diallel analysis employing Griffing's method 1 for studying combining ability and Hayman's numerical as well as graphical approach for studying the gene actions involved.

5.1 Combining ability

The study of the combining ability of the parents is an effective technique that permits identification of superior varieties to be used as parents for hybridization and also pinpoints cross combinations likely to be superior in their performance. Results of the combining ability analysis of the six parental lines and their 30 F_1 hybrids are discussed below.

The analysis of variance for combining ability revealed that the variances due to g.c.a. as well as s.c.a. were significant only for six characters viz., leaf axil bearing the first flower, number of branches, length of fruit, weight of single fruit, height of plant and incidence of yellow vein mosaic.

The character days to first flowering exhibited significant variance due to s.c.a. alone indicating the predominance of nonadditive gene action in the inheritance of this character. This is in conformity with the findings of Rao and Satiyavathi (1977), Sharma and Mahajan (1978), Singh and Singh (1978) and Singh (1986). Involvement of additive gene action for this character was also stressed by Rao and Ramu (1978), Singh and Singh (1979b), Pratap et al. (1981), Vijay and Manohar (1986a) and Randhawa (1989). This character exhibited significant reciprocal differences which may be due to cytoplasmic genes including mitochondrial genes. It was seen that the two straight crosses P_2 x P_4 and P_2 x P_5 and the three reciprocal crosses P_5 x P_4, P_5 x P_3 and P_3 x P_2 that showed high s.c.a. effects were a result of poor x poor combiners.

The significance of H_1 and H_2 indicated the operation of dominant genes for this character. This is in line with the finding of Kulkarni et al. (1976). Days to flowering was also found to be influenced by the environment. The dominance of increasing alleles observed was also reported by Kulkarni et al. (1976) and Pratap et al. (1980). The value of $H_2/4H_1$ suggested a somewhat asymmetrical distribution of genes with positive and negative effects (Kulkarni et al., 1976). The proportion of dominant and recessive genes also indicated an asymmetric distribution of these genes among parents. This is confirmed by the positive value of $\hat{F}$ which indicated preponderance of dominant alleles among the parents. The overdominance indicated in the numerical analysis was confirmed by the graphical analysis. This is in conformity with the report of Kulkarni et al. (1976). However, partial dominance was also stressed by Pratap et al. (1980) and Randhawa (1989). The Vr-Wr graph also indicated that the parents were genetically divergent for this trait and that the dominant genes were mostly concentrated in parents P_2 and P_5. Parents P_1 and P_6 seemed to possess recessive genes also. In the case of reciprocal crosses however, preponderance of recessive genes was seen in all the parents.

Significant variances due to g.c.a. and s.c.a. were observed for leaf axil bearing the first flower, implying that both additive and non-additive components of genetic variance are operating for this character. Similar observation was noticed by Elangovan et al. (1981a). The g.c.a. variance was, however, greater than the s.c.a. variance indicating a major role of additive gene action as was reported by Pratap et al. (1981). But Singh and Singh (1978), Elangovan et al. (1981a) and Singh (1986) observed non additive gene action for this character.

Here, combining ability effects in the negative direction is desirable. Of the two crosses that possessed significantly negative s.c.a. effects viz., P_2 x P_4 and P_5 x P_4, the former was a combination of two poor general combiners and the latter was a result of good x poor combiners as the parent P_5 alone was the good general combiner for this trait.

Significance of $\hat{H}_1$ and $\hat{H}_2$ as well as $\hat{D}$ suggests the operation of additive and dominant genes in respect of leaf axil bearing the first flower. Environmental influence is also seen. The positive value of $\hat{F}$ indicated more of dominant alleles in the parents. This was also confirmed by the proportion of dominant and recessive alleles among the parents which indicated an asymmetrical distribution of these genes. The genes with positive and negative effects were also asymmetrically distributed in parents. The average degree of dominance indicated complete dominance which was confirmed by the Vr-Wr graph. Very little genetic divergence among the parents was noticed from this graph. The parents P_1, P_2, P_3, P_5 and P_6 seemed to possess more of dominant genes while P_4 had considerable amount of recessive genes also. The nature of dominance in the reciprocal crosses seemed to be in the range of partial dominance.

With respect to leaf number, significant g.c.a effects were noticed as reported by Akram and Shafi (1967) thus revealing the important role of additive genetic variance in the inheritance of leaf number. Parent P_4 was the best general combiner and though the s.c.a. variance was not significant, high s.c.a. effect was expressed in the hybrid P_3 x P_5 involving two poor general combiners. Reciprocal effects were also significant and two reciprocal crosses P_5 x P_3 and P_6 x P_4 involving poor general combiners as male and female parents exhibited high s.c.a. effect.

Additive genes were preponderant when the F_1s were considered while dominant genes were found in the case of reciprocal F_1s. Leaf number was also under environmental influence. Preponderance of dominant genes was indicated by the positive value of $\hat{F}$. But recessive genes were seen in the reciprocal crosses. The ratio of H_2 to $4H_1$ indicated an asymmetrical distribution of genes with positive and negative effect in the parents. The numerical as well as graphical analysis indicated the presence of partial dominance for leaf number. However, the greater value of $\hat{H}_1$ than $\hat{D}$ in the case of reciprocals indicated overdominance governing leaf number. The Vr-Wr graph showed a wide scattering of array points indicating genetic divergence among the parents for this trait. In the reciprocal crosses non allelic interactions were noticed.

Considering leaf area, only the variance due to g.c.a. was significant. This emphasises the importance of additive genetic variance for this character. Though parent P_4 showed high g.c.a. effect, none of the crosses involving this parent proved to be good specific combinations. This shows that good general combiners need not produce superior hybrids with good s.c.a. effects as opined by Rao (1977).

Leaf area was found to be highly influenced by the environment. The negative value of $\hat{F}$ indicated the presence of more of decreasing alleles in the parents. This was also confirmed by the value of the proportion of dominant and recessive genes among parents which indicated an asymmetrical distribution of these genes. An asymmetrical distribution of genes with positive and negative effects was also indicated by the ratio $H_2/4H_1$. Gene action was in the range of overdominance as revealed by the numerical analysis as well as the Vr-Wr graph. The array points in this graph indicated genetically divergent parents for leaf area except parents P_1 and P_3. P_4 was seen to consist mostly dominant genes while all the other parents seemed to possess recessive genes also.

The variances due to g.c.a., s.c.a. and reciprocal effects were significant for number of branches, indicating the importance of additive as well as non additive gene actions.

This is in conformity with the reports of Vijay and Manohar (1986a), Randhawa (1989) and Lakshmi (1992). However, preponderance of non additive gene effects was also reported by Singh and Singh (1978, 1979b), Elangovan _et al_. (1981a) and Singh (1986). Parent P_4 was the best general combiner for branch number and an examination of the hybrids possessing high s.c.a. effects showed that crosses involving poor x poor general combiners gave higher expression of this character.

Operation of additive as well as dominant genes was seen for number of branches. However, predominance of additive effects alone was stressed by the Randhawa (1989). The positive value of $\hat{F}$ indicated preponderance of dominant alleles. This unequal distribution of dominant and recessive genes was confirmed by the value of their proportion in the parents. The increasing and decreasing alleles were also asymmetrically distributed. The overdominance observed for this character through numerical analysis was confirmed by the graphical analysis. However, Randhawa (1989) observed partial to complete dominance operating for branch number. The Vr-Wr graph revealed very little genetic divergence among the parents. The parents P_1, P_2, P_3, P_5 and P_6 were seen to possess more of dominant genes while P_4 alone had an excess of recessive genes.

In the case of number of flowers per plant neither the s.c.a. nor the g.c.a variance was significant. However, significant reciprocal differences were detected. This may be attributed to cytoplasmic inheritance of the maternal effect. The two reciprocal crosses P_6 x P_2 and P_5 x $_1$ that showed high s.c.a. effects were a result of poor x poor general combiners.

Dominance effect was found to be operating for flower number per plant, which was highly influenced by environmental effects. The parents were seen to possess more of decreasing alleles since F had a negative value. The proportion of dominant and recessive alleles among the parents also showed an asymmetrical distribution of these genes thus supporting the negative value of F. The ratio of H_2 to $4H_1$ also showed a highly asymmetrical distribution of genes with positive and negative effects among the parents. The average degree of dominance indicated presence of overdominance for this character and this was supported by the Vr-Wr graph. Not much genetic divergence among the parents was seen in the graph. The parent P_2 seemed to possess more of recessive genes while P_4 had more of dominant genes. The other parents possessed varying proportions of these genes. The graphical analysis indicated the presence of epistasis in the reciprocal crosses.

For number of fruits per plant, neither g.c.a. nor s.c.a. variance was significant, indicating the role of environmental effect in the expression of the character.

However, importance of nonadditive genetic variance was reported by Rao and Satiyavathi (1977), Sharma and Mahajan (1978), Singh and Singh (1978, 1979b), Pratap et al. (1980), Elangovan et al. (1981a), Thaker et al. (1981), Singh (1986), Chaudhary et al. (1991) and Shivagamasundari et al. (1992a). Predominance of additive gene action was also stressed by Ramu (1976), Rao and Ramu (1978), Vijay and Manohar (1986a), Randhawa (1989), Vashist (1990), Veeraraghavathatham and Irulappan (1991a) and Lakshmi (1992). Involvement of both additive and non additive types of gene action was also reported by Kulkarni (1976), Kulkarni et al. (1976), Ramu (1976), Pratap and Dhankar (1980a), Poshiya and Shukla (1986b) and Veeraraghavathatham and Irulappan (1990) for this character. Though none of the parents were good general combiners, high s.c.a. was expressed in a cross P_1 x P_4 involving very poor x poor general combiners and also in two reciprocal crosses (P_6 x P_5 and P_6 x P_1) involving poor x very poor general combiners.

The fruit number was found to be under high environmental influence. Kulkarni et al. (1976) and Veeraraghavathatham and Irulappan (1990) also reported this character to be influenced by environment. It was evident from the positive value of $\hat{F}$ that the parents had preponderance of dominant alleles for this character. This was supported by the proportion of dominant and recessive genes which indicated an asymmetrical distribution of these genes among parents. Preponderance of dominant alleles for fruit number was also reported by Kulkarni et al. (1976), Pratap et al. (1981) and Veeraraghavathatham and Irulappan (1990). Unequal distribution of positive vs negative alleles was indicated by the ratio of H_2 to $4H_1$. This is in line with the reports of Kulkarni et al. (1981). The presence of overdominance was indicated by the numerical as well as graphical analysis. However partial dominance was reported by Kulkarni et al. (1976), Randhawa (1989) and Veeraraghavathatham and Irulappan (1990) and complete dominance by Pratap et al. (1981). It was seen from the Vr-Wr graph that the parents were genetically divergent for fruit number with parent P_6 having more of dominant genes and parents P_1 and P_3 having an excess of recessive genes for this trait. The other parents seemed to have varying proportions of these genes.

Significant variance due to g.c.a. and s.c.a. were detected for length of fruit indicating that both additive and nonadditive genetic variance are operating in the inheritance of fruit length in bhindi. Similar results were reported by Pratap and Dhankar (1980a), Pratap et al. (1980), Poshiya and Shukla (1986b), Vijay and Manohar (1986a), Shukla et al. (1989) and Veeraraghavathatham and Irulappan (1990). The ratio of g.c.a. to s.c.a. variance was less than unity implying that the non additive component was more important than the additive component of genetic variance. This is in line with the reports of Singh and Singh (1978), Elangovan _et al_. (1981a), Vijay and Manohar (1986a), Chaudhary _et al_. (1991) and Shivagamasundari _et al_. (1992a). Findings contradictory to this was also reported by Pratap _et al_. (1980) and Thaker _et al_. (1981). It was seen that among the three crosses that showed high s.c.a. effects, only one hybrid (P_1 x P_2) had a good general combiner (P_2) as one of its parents, while the other two crosses (P_5 x P_6 and P_1 x P_4) were combinations of poor x poor and poor x very poor general combiners.

It was evident from the significant values of $\hat{H}_1$ and $\hat{H}_2$ that dominant genes are operating for this character. However, the presence of dominant and additive genes was reported by Pratap _et al_. (1981) and Veeraraghavathatham and Irulappan (1990). Randhawa (1989) stressed the importance of additive gene effects alone. Influence of environment was also seen for fruit length. Preponderance of dominant alleles was indicated by the positive value of $\hat{F}$ and by the proportion of dominant and recessive genes. An almost unequal distribution of genes with positive and negative effects among parents was also indicated by the value of $H_2/4H_1$. This is in agreement with the findings of Pratap _et al_. (1981) and Veeraraghavathatham and Irulappan (1991). The average degree of dominance and the Vr-Wr graph revealed overdominance governing fruit length. However, Pratap et al. (1981) and Veeraraghavathatham and Irulappan (1991) reported partial dominance for this trait. The graph revealed not much genetic divergence between the parents P_2, P_4, P_5 and P_6. Dominant genes were preponderant in the parent P_3 and recessive genes in P_1. The other parents had varying proportions of these genes.

For girth of fruit, only the variance due to s.c.a. was significant indicating the importance of non additive genetic variance for this character. This is in agreement with the reports of Elangovan et al. (1981a), Radhika (1988), Chaudhary et al. (1991) and Shivagamasundari et al. (1992a), whereas the major role of additive genetic variance was stressed by Pratap et al. (1980), Vijay and Manohar (1986a), Veeraraghavathatham and Irulappan (1991a) and Lakshmi (1992). Though none of the parents exhibited significant g.c.a. effects, three crosses (P_5 x P_6, P_1 x P_2 and P_1 x P_4) resulting from poor x poor general combiners showed high s.c.a. effects.

Dominant as well as additive genes were seen operating for fruit girth. Similar results were observed by Pratap et al. (1981) and Veeraraghavathatham and Irulappan (1991). The influence of environment was also evident. The positive value of $\hat{F}$ indicated dominance of increasing alleles in the parents, and this was confirmed by the value of the proportion of dominant and recessive genes which indicated an unequal distribution of these genes among the parents. The genes with positive and negative effects were also unequally distributed. Similar findings were reported by Pratap <u>et</u> <u>al</u>. (1981) and Veeraraghavathatham and Irulappan (1991a). The numerical and graphical analyses indicated overdominance for fruit girth. This was also reported by Veeraraghavathatham and Irulappan (1991a) while partial dominance was reported by Pratap <u>et</u> <u>al</u>. (1981). Little genetic divergence among parents was revealed by the Vr-Wr graph. Except for parents P_1 and P_3, the others had preponderance of dominant genes for fruit girth.

With respect to the weight of single fruit significant g.c.a. and s.c.a. variances were obtained indicating that both additive and non additive genetic variance are operating for this character. This is in conformity with the findings of Vijay and Manohar (1986a) and Veeraraghavathatham and Irulappan (1990). But the s.c.a. variance was slightly greater than g.c.a. variance implying a major role of the non additive component of genetic variance. This was also reported by Sharma and Mahajan (1978), Radhika (1988), Chaudhary <u>et</u> <u>al</u>. (1991) and Shivagamasundari <u>et</u> <u>al</u>. (1992a), where as Thaker <u>et</u> <u>al</u>. (1981), Randhawa (1989), Vijay and Manohar (1986a) and Veeraraghavathatham and Irulappan (1991a) reported on the important role of additive gene action for weight of single fruit. This character exhibited significant reciprocal differences also which may be due to cytoplasmic inheritance of maternal effect. Veeraraghavathatham (1989), Veeraraghavathatham and Irulappan (1991a) and Shivagamasundari _et al_. (1992a) also observed reciprocal differences for this character. An examination of the crosses and their reciprocals revealed that the two straight crosses (P_5 x P_6 and P_1 x P_4) and two reciprocal crosses (P_4 x P_1 and P_3 x P_1) which showed high s.c.a. effects resulted from poor x poor general combiners.

Single fruit weight was mainly governed by dominant genes as indicated by the significance of $\hat{H}_1$ and $\hat{H}_2$. Environmental influence was also seen. Dominant genes operating for this trait was reported by Veeraraghavathatham and Irulappan (1991a) while additive effects were stressed by Randhawa (1989) as was seen in the case of reciprocals. The F_1s revealed preponderance of dominant alleles while the reciprocal F_1s revealed more of recessive alleles. The proportion of dominant and recessive genes confirmed the unequal distribution of these genes in the F_1s as well as in the reciprocals. This is in conformity with the report of Veeraraghavathatham and Irulappan (1991a). An almost symmetrical distribution of positive and negative alleles was observed. However, Veeraraghavathatham and Irulappan (1991a) observed an unequal distribution of these alleles among the parents. The numerical and graphical analyses revealed overdominance which is in accordance with the findings of Veeraraghavathatham and Irulappan (1991a) but contradictory to the report of Randhawa (1989). The Vr-Wr graph revealed considerable genetic divergence among the parents. Parents P_3 and P_4 possessed more of recessive genes while the others had varying proportions of dominant and recessive genes for this trait.

Results of the combining ability analysis for weight of fruits per plant revealed significance for s.c.a. variance only indicating the predominant role of nonadditive gene action. This is in conformity with the findings of Sharma and Mahajan (1978), Singh and Singh (1978), Elangovan et al. (1981a), Poshiya and Shukla (1986b), Singh (1986), Chaudhary et al. (1991) and Shivagamasundari et al. (1992a). However, additive type of gene action for yield per plant was reported by Rao and Ramu (1978), Singh and Singh (1979b), Pratap and Dhankar (1980b), Thaker et al. (1981), Vijay and Manohar (1986a), Radhika (1988), Randhawa (1989), Vashist (1990), Veeraraghavathatham and Irulappan (1991a) and Lakshmi (1992). The parent P_4 was the best general combiner and the hybrid $P_1 \times P_4$ involving the good combiner showed the highest s.c.a. effect closely followed by $P_6 \times P_1$ and $P_1 \times P_2$ resulting from poor x poor general combiners. The cross $P_4 \times P_1$ involving one good combiner was also a good combination. This character exhibited significant reciprocal differences as reported by Shivagamasundari et al. (1992a).

This character seemed to be under the control of dominance gene effects though there was environmental influence also. Similar finding was reported by Veeraraghavathatham and Irulappan (1991a). Dominance of increasing alleles was noticed when the F_1s were considered. But with the reciporcal F_1s, the decreasing alleles were found to be dominant. Pratap et al. (1981) and Veeraraghavathatham and Irulappan (1991a) noticed dominance of increasing alleles. The dominant and recessive genes were also asymmetrically distributed. The genes with positive and negative effects were almost symmetrically distributed among the parents. The average degree of dominance indicated overdominance for yield per plant. But the graphical analysis revealed the presence of epistasis for this trait. Over dominance was also reported by Pratap et al. (1981) Korla and Sharma (1987), Randhawa (1989) and Veeraraghavathatham and Irulappan (1991a).

Highly significant s.c.a. variance was observed for number of seeds per fruit indicating the predominant role of non additive gene action for this character. This is in agreement with the findings of Rao and Ramu (1978). However importance of additive genetic variance for seed number was stressed by Vijay and Manohar (1986a), Randhawa (1989) and Lakshmi (1992). Though none of the parents showed high g.c.a. effects, high s.c.a.

effects were observed in three straight crosses (P_5 x P_6, P_1 x P_4 and P_1 x P_2) and three reciprocal crosses (P_4 x P_1, P_6 x P_1 and P_5 x P_4) resulting from poor x poor general combiners.

Significance of $\hat{H}_1$ and $\hat{H}_2$ implied the presence of dominance effects for seed number. However, environmental influence cannot be ruled out. Randhawa (1989) reported predominance of additive gene effects for this trait. The parents seemed to have an excess of dominant alleles than the recessive alleles. This was confirmed by the asymmetrical distribution of these genes indicated by the value of their proportion in the parents. The value of $H_2/4H_1$ also indicated an almost asymmetrical distribution of genes with positive and negative effects. The overdominance observed for this trait in the numerical analysis was confirmed by the Vr-Wr graph. But the presence of partial to complete dominance was emphasized by Randhawa (1989). The graphical analysis however indicated the presence of epistasis for seed number.

The character fruiting phase showed no significant g.c.a. and s.c.a. variance but showed significant reciprocal differences owing to either cytoplasmic inheritance of maternal effect or parental effects of both the parents or paternal and maternal interaction as opined by Veeraraghavathatham and Irulappan (1991a). The non significant g.c.a. and s.c.a. effects imply that fruiting phase is much under the influence of environment. The parent P_1 exhibited high g.c.a. effect but the two reciprocal crosses (P_6 x P_2 and P_4 x P_2) and one straight cross (P_3 x P_6) that showed high s.c.a. effects were a combination of poor x poor general combiners indicating that good general combiners need not always produce superior crosses with high s.c.a. effects (Rao, 1977).

Fruiting phase was found to be highly influenced by environment. Dominance effect was observed in the case of reciprocals. The F_1s exhibited dominance of decreasing alleles while the reciprocal F_1S showed dominance of increasing alleles. An almost symmetrical distribution of genes with positive and negative effects was indicated by the F_1s but their distribution was more towards asymmetry when the reciprocals were considered. Though the numerical analysis revealed fruiting phase to be governed by overdominance the graphical analysis indicated the presence of epistasis also.

For plant height, significant g.c.a. as well as s.c.a. effects were obtained indicating the operation of both additive and non additive types of gene action in the inheritance of plant height. This is in conformity with the reports of Kulkarni et al. (1976), Ramu (1976), Pratap et al. (1980), Vijay and Manohar (1986a), Shukla et al. (1989) and Veeraraghavathatham and

Irulappan (1990). However, the g.c.a. variance was greater than s.c.a. variance implying preponderance of additive component than the non additive component for plant height as observed by Rao and Satiyavathi (1977), Reddy et al. (1985), Vijay and Manohar (1986a), Radhika (1988), Randhawa (1989) and Veeraraghavathatham and Irulappan (1991a). Plant height exhibited significant reciprocal differences also. Similar observation was made by Veeraraghavathatham (1989), Veeraraghavathatham and Irulappan (1991a) and Shivagamasundari et al. (1992a). Of these three crosses that showed high s.c.a. effects only one cross (P_4 x P_6) had a good general combiner (P_6) as one of its parents while the other two crosses (P_2 x P_5 and P_1 x P_4) were combinations of poor x poor general combiners. The two reciprocal crosses (P_6 x P_1 and P_4 x P_3) showing high s.c.a. effects were a result of good x poor and very poor x poor combinations.

Plant height was under the influence of additive, dominance as well as environmental effects. Similar results were obtained by Pratap et al. (1980) and Veeraraghavathatham and Irulappan (1991a). The distribution of dominant and recessive genes was asymmetrical with dominant alleles being preponderant as indicated by the positive value of $\hat{F}$ as well as by the value of their proportion in the parents. But a higher proportion of recessive alleles than dominant alleles was reported by Kulkarni et al. (1976), Pratap et al. (1980) and Veeraghavathatham and

Irulappan (1991a). An asymmetrical distribution of genes with positive and negative effects was also noticed as was reported by Pratap et al. (1980) and Veeraraghavathatham and Irulappan (1991a). The overdominance indicated by the average degree of dominance was confirmed by the Vr-Wr graph. Kulkarni et al. (1976) also reported overdominance but partial dominance for plant height was reported by Pratap et al. (1980), Randhawa (1989) and Veeraraghavathatham and Irulappan (1991a). The graph indicated considerable genetic divergence with parent P_3 having mostly dominant genes closely followed by P_5. Varying proportions of these genes were observed in the other parents.

The character percentage fruit set failed to exhibit significant g.c.a. and s.c.a. effects, indicating this character to be under environmental influence. However, Chandrashekhar (1988) reported non additive gene action for this character in tomato and the role of additive gene action for percentage fruit set was also stressed by Abdelmoneim (1977) in tomato.

Significant dominance and additive effects were observed for percentage fruit set. There was evidence of environmental influence also. More of decreasing alleles with dominance was noticed. Similarly, the proportion of dominant and recessive genes among the parents indicated an unequal distribution of these genes. The genes with positive and negative effects were also asymmetrically distributed. The overdominance indicated by the numerical analysis was confirmed by the Vr-Wr graph. The graph revealed not much genetic divergence among the parents. The parents P_1, P_3, P_4 and P_6 possessed predominantly dominant genes while P_2 alone had an excess of recessive genes.

Significant g.c.a. and s.c.a. effects were observed for the incidence of yellow vein mosaic disease. Combining ability effects in the negative direction was desirable for the disease incidence. The ratio of g.c.a. variance to s.c.a. variance was greater than unity indicating that though additive and non additive gene actions were prevalent, the additive component had a greater role. This is in conformity with the findings of Veeraraghavathatham and Irulappan (1990, 1991a). The disease incidence was influenced by reciprocal differences also. All the crosses viz., P_3 x P_5, P_2 x P_1 and P_5 x P_2 that showed high s.c.a. effects in the negative direction were a combination of poor x poor general combiners. The parent with high negative g.c.a. (P_4) could not produce superior crosses with high s.c.a. as observed by Rao (1977).

The disease incidence was governed by dominance and additive gene effects. There was considerable influence of environment also. Veeraraghavathatham (1989) and

Veeraraghavathatham and Irulappan (1991a) reported the same results. Preponderance of increasing alleles was denoted by the positive value of $\hat{F}$. This was confirmed by the value of the proportion of dominant and recessive genes among the parents. The value of $H_2/4H_1$ also revealed an asymmetrical distribution of positive and negative genes. The average degree of dominance and the Vr-Wr graph revealed dominance in the range of overdominance. However, Veeraraghavathatham and Irulappan (1991a) reported partial dominance for the disease resistance. The graph indicated genetic divergence among the parents. Parent P_5 had mostly dominant genes while P_6 had more of recessive genes. Varying proportion of these genes were observed in the parents P_2, P_3 and P_4. The graphical analysis also revealed the presence of epistasis in the case of reciprocal crosses.

The g.c.a. and s.c.a. effects were not significant for the incidence of shoot and fruit borer. Here also, the combining ability effects in the negative direction was favourable. The nonsignificant g.c.a. and s.c.a. effects were an indication of environmental effect on the incidence of shoot and fruit borer. None of the parents were good combiners and the two crosses (P_4 x P_1 and P_1 x P_4) that exhibited significnat negative s.c.a. effects resulted from poor general combiners.

Incidence of the pest was under the control of additive gene effects as well as environmental effects. The negative value of $\hat{F}$ indicated dominance of decreasing alleles. This was confirmed by the proportion of dominant and recessive genes among the parents. The ratio of H_2 to $4H_1$ also indicated an asymmetrical distribution of genes with positive and negative effects among the parents. The average degree of dominance indicated complete dominance and this was confirmed by the Vr-Wr graph. The graph also indicated considerable amount of genetic divergence among the parents for this trait, with the parent P_6 having more of dominant genes and all the others having both dominant and recessive genes in varying proportions.

The contradictory results on the nature of gene action controlling inheritance of the different characters obtained by the various authors may be due to the difference in the parental material used in the study.

An overall ranking of the lines for all the traits indicated that good general combiners gave either average or good per se performance for only seven of the ten characters for which g.c.a. effects were significant. This suggests that combining ability of parents cannot always be judged accurately by their per se performance and hence the g.c.a. estimates and per se performance of the breeding lines should be taken together for assessing their breeding potentiality. Sharma and Mahajan (1978) and Elangovan et al. (1981a) had similar opinion.

In some of the characters studied, parents with significantly high g.c.a. produced hybrids with low s.c.a. effects. This may be due to the role of complementary gene action. On the other hand,parents with poor g.c.a. produced hybrids with high s.c.a. effects which can be attributed to the complementation of favourable genes (Shivagamasundari et al., 1992a).

The overdominance observed for weight of fruits per plant, number of seeds per fruit, fruiting phase, height of plant and also for the reciprocal crosses in number of flowers per plant, weight of single fruit and incidence of yellow vein mosaic may be spurious because of the presence of nonallelic interactions for these traits as revealed by the graphical analysis. Commercial exploitation of heterosis is possible for all those characters exhibiting overdominance while those characters governed by partial to complete dominance can be improved by selection in early generations as opined by Randhawa (1989).

5.2 Heterosis

Exploitation of hybrid vigour to increase the yield of fruits has become one of the most important techniques in vegetable breeding. Manifestation of heterosis for various economic traits in bhindi has been reported by Elmaksoud et al. (1984) thus justifying the commercial utilization of hybrid vigour in bhindi. The present study was also aimed to identify superior hybrids and to find out the magnitude of heterosis on yield and its components. The results are discussed below.

For days to first flowering, five hybrids were found to exhibit significant negative heterosis when compared to the mid parental value and one cross expressed significant heterobeltiosis. Agarrado and Rasco (1986) and Elmaksoud et al. (1986) reported heterosis over mean parental value in most of the hybrids studied for days to flowering, while heterobeltiosis for this trait was reported by Kulkarni and Virupakshappa (1977), Vijay and Manohar (1986b), Shukla et al. (1989) and Singh and Mandal (1993). Expression of relative heterosis as well as heterobeltiosis for this trait was also reported by Rao (1977) and Elangovan et al. (1981b). None of the hybrids were found to express significant standard heterosis for this trait. Thus, the hybrid P_1 x P_4 which showed significant heterosis over the mid and better parental values can be considered as the earliest in flowering.

Considering the leaf axil bearing the first flower, only one hybrid P_5 x P_4 expressed significant heterosis over the mid parental value, while none of the hybrids were superior in comparison with the midparent and the check variety. This is in conformity with the findings of Singh et al. (1977). However, Elangovan et al. (1981b) found the presence of both mid parental and better parental heterosis for the first fruiting node.

With regard to leaf number, one hybrid P_4 x P_2 expressed significant relative heterosis while none of the hybrids expressed significant heterobeltiosis. However, in comparison with the check parent, heterosis was observed in nine hybrids, the outstanding ones being P_4 xP_2, P_4 x P_6, P_1 x P_4, P_2 x P_4 and P_4 x P_1. It is evident that most of the outstanding hybrids have the parent P_4 as one of its parents.

Two hybrids P_5 x P_3 and P_3 x P_1 exhibited significant relative heterosis for leaf area while significant heterobeltiosis was noticed in one hybrid P_5 x P_3 alone. However, in comparison with the standard check, heterosis was observed in 23 hybrids, the best being P_5 x P_3 followed by P_2 x P_4, P_3 x P_1 and many others. Thus, the hybrid P_5 x P_3 was found to have the highest leaf area in all the three comparisons of heterosis.

In the case of number of branches, the hybrid P_6 x P_5 alone exhibited significant heterosis over mid parental value while none of the hybrids performed better than the better parent. However, standard heterosis was observed in 15 hybrids including P_4 x P_6, P_4 x P_1, P_2 x P_4, P_1 x P_4, P_6 x P_5 etc.

Elangovan et al. (1981b) and Changani and Shukla (1985) observed heterosis over the midparent and better parent for branch number. Vijay and Manohar (1986b) observed heterobeltiosis alone while Singh and Mandal (1993) noticed only relative heterosis for this character. However, significant heterosis with respect to all the three types of comparisons was reported by Lakshmi (1992).

The hybrid P_1 x P_4 was found to exhibit heterosis in all the three types of comparisons for number of flowers per plant. This was the only hybrid expressing relative heterosis and heterobeltiosis while six more hybrids exhibited standard heterosis for this character. It was seen that most of the hybrids that exhibited heterosis had P_4 as one of its parents.

For number of fruits per plant, heterosis over the better parent was exhibited by only one hybrid P_1 x P_4 whereas none of the hybrids were outstanding when compared to the midparental value. High heterosis over the better parent for number of fruits per plant was also reported by Singh and Singh (1979a), Thaker et al. (1982) and Shukla et al. (1989), while significant heterosis over mid parental value was reported by Agarrado and Rasco (1986) and Elmaksoud et al. (1986). However, relative heterosis as well as heterobeltiosis was reported by Singh et al. (1977) and Poshiya and Shukla (1986a). Standard heterosis was exhibited by three hybrids P_1 x P_4, P_4 x P_3

and P_6 x P_5. Shukla et al. (1989) and Kumbhani et al. (1993) also obtained standard heterosis for fruit number per plant.

Significant heterosis over mid parent and better parent for length of fruit was exhibited by four and two hybrids respectively. Maximum relative heterosis was expressed by P_1 x P_2 followed by P_2 x P_3, P_2 x P_1 and P_1 x P_4. Agarrado and Rasco (1986) also obtained significant relative heterosis for fruit length in bhindi. Compared to the better parent, P_1 x P_2 was the best hybrid followed by P_2 x P_3. Significant heterobeltiosis for fruit length was also reported by Thaker et al. (1982), Vijay and Manohar (1986b) and Shukla et al. (1989). Both these types of heterosis were obtained by Elangovan et al. (1981b) and Changani and Shukla (1985). None of the hybrids showed significant standard heterosis. However, Kumbhani et al. (1993) reported useful heterosis for fruit length in bhindi.

Four hybrids showed significant relative heterosis for girth of fruit, the maximum being exhibited by P_2 x P_1 closely followed by P_1 x P_2. These two hybrids also showed significant heterobeltiosis for this character. However, the hybrid showing maximum heterobeltiosis was P_3 x P_6. Lakshmi (1992) observed the presence of relative heterosis for fruit girth while Agarrado and Rasco (1986) and Vijay and Manohar (1986b) found heterobeltiosis for this character. Hybrids expressing both mid and better parental heterosis were also reported by Elangovan et al. (1981b). Compared to the standard check, only one hybrid P_2 x P_1 showed significant heterosis. Lakshmi (1992) and Kumbhani et al. (1993) observed useful heterosis in some of the hybrids for fruit girth in bhindi. It is clear from the results that the hybrid P_2 x P_1 exhibited significant superiority for fruit girth in all the three comparisons of heterosis.

Among the 30 hybrids, only four hybrids showed significant relative heterosis for weight of single fruit. The maximum value was seen in P_2 x P_1 followed by P_4 x P_1 and P_6 x P_1. The hybrid P_2 x P_1 also exhibited significant heterosis in comparison with the better parent as well as the standard check, indicating this hybrid to be the best for single fruit weight.

Significant positive heterosis over mid parent, better parent and standard check for weight of fruits per plant (yield per plant) was exhibited by eight, four and eight hybrids respectively. Singh et al. (1977), Elangovan et al. (1981b), Agarrado and Rasco (1986), Poshiya and Shukla (1986a) and Singh and Mandal (1993) reported heterosis over mid and better parental values. Heterosis over the mid parental value was observed by Lakshmi (1992) and over better parent by Singh and Singh (1979a), Thaker et al. (1982), Vijay and Manohar (1986b) and Shukla et al. (1989). Maximum relative heterosis was noticed in the hybrid

P_2 x P_1 followed by P_1 x P_2 and P_6 x P_1. These three hybrids expressed similar trend for heterobeltiosis also. Compared to standard check, the best hybrid was again P_2 x P_1 indicating this hybrid to be the best for yield per plant. Shukla et al. (1989), Lakshmi (1992) and Kumbhani et al. (1993) also obtained significant standard heterosis for yield. The results revealed that the crosses involving the parents P_2 and P_1 exhibited significant superiority for yield per plant, the most economic character. Hence, these two parents offer immense scope for developing superior hybrids with high yield potential in bhindi.

Among the 30 hybrids, significant relative heterosis, heterobeltiosis and standard heterosis were exhibited in six, one and six hybrids respectively for number of seeds per fruit. The hybrid P_2 x P_1 was seen to express significant heterosis in all the three types of comparisons, implying this hybrid to have the maximum number of seeds per fruit. Lakshmi (1992) observed significant heterosis over the mid parental value as well as the standard check, while Vijay and Manohar (1986b) and Korla and Sharma (1988) observed heterobeltiosis for seed number in bhindi.

With regard to fruiting phase, three hybrids exhibited significant heterosis over mid parent, the maximum being in the cross P_5 x P_6 followed by P_1 x P_5 and P_5 x P_4. These three hybrids were found to exhibit significant heterobeltiosis also for fruiting phase, thereby indicating that these hybrids have longer fruiting phase than the others. None of the hybrids showed significant standard heterosis.

When compared to the mid parental value, significant heterosis for plant height was observed in five hybrids viz., P_4 x P_2, P_5 x P_4, P_2 x P_4, P_1 x P_4 and P_1 x P_2. Except the cross P_1 x P_4, the other four crosses expressed significant heterobeltiosis also for plant height. Relative heterosis for this character was reported earlier by Changani and Shukla (1985), Agarrado and Rasco (1986), Elmaksoud et al. (1986) and Lakshmi (1992), while Vijay and Manohar (1986b) and Shukla et al. (1989) observed heterobeltiosis. However, Elangovan et al. (1981b) reported both relative heterosis and heterobeltiosis for plant height in bhindi. Standard heterosis was observed in three hybrids P_2 x P_6, P_4 x P_2 and P_6 x P_1. Shukla et al. (1989), Lakshmi (1992) and Kumbhani (1993) also reported useful heterosis for plant height in bhindi. It was seen that the crosses involving either parent P_2 or parent P_4 were in general taller than the others.

For percentage fruit set only mid parental heterosis was observed in three hybrids P_2 x P_1, P_3 x P_4 and P_2 x P_3 while none of the hybrids exhibited significant heterosis over the better parent and the check variety.

The hybrid P_1 x P_4 was found to exhibit significant negative heterosis with respect to the three types of comparisons for the incidence of yellow vein mosaic. Five more hybrids expressed significant standard heterosis but only P_1 x P_4 can be considered to be tolerant to the disease compared to the others.

In the case of incidence of shoot and fruit borer also, only one hybrid P_2 x P_1 was found to exhibit significant negative heterosis over all the three types of comparisons suggesting that this hybrid alone was tolerant to the pest.

It was seen that among the 30 hybrids, P_2 x P_1 was the most outstanding one for majority of the yield related characters when compared to the mid parental value, the better parent and the standard check. The cross P_1 x P_2 was also found to be heterotic. In general, the hybrids involving the parents P_1, P_2 and P_4 were found to be superior in their performance with respect to most of the characters studied.

Summary

6. SUMMARY

The present study on the combining ability in bhindi was carried out in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 1994-95 in order to determine the combining ability of the parental strains, to study the nature of gene action governing the different characters and also to study the heterosis for the different characters. The experimental material consisted of six parental lines obtained from six genetically divergent clusters, their 30 F_1 hybrids obtained by crossing the parents in all possible combinations and a check variety Kiran. The experiment was laid out in Randomised Block Design with three replications. The observations were recorded on yield of fruits and important yield attributes and also on the incidence of yellow vein mosaic disease and incidence of shoot and fruit borer.

Significant differences were detected among the genotypes for all the 17 characters studied. It was seen that the parent P_5 showed the highest values for length of fruit, weight of single fruit, weight of fruits per plant and percentage fruit set. Among the hybrids, $P_1 \times P_2$ had the tallest plants and the longest fruits while its reciprocal cross $P_2 \times P_1$ exhibited the maximum girth of fruit, weight of single fruit, weight of fruits per plant and number of seeds per pod and it was also the least affected by shoot and fruit borer incidence.

The combining ability analysis carried out by the Method 1 under Model I as suggested by Griffing (1956) indicated significant variances due to g.c.a., s.c.a. and reciprocal effects for eight, ten and ten characters respectively. The combining ability analysis revealed that the parent P_4 was the best general combiner for the economic character, yield per plant and also for a few related characters. Among the crosses, $P_1 \times P_4$ exhibited outstanding s.c.a. effects for yield per plant followed by $P_4 \times P_1$ and $P_5 \times P_6$. In general, the crosses involving parent P_4 were good specific combinations.

The s.c.a. variance was found to be greater than the g.c.a. variance for days to first flowering, number of flowers per plant, length of fruit, girth of fruit, weight of single fruit, weight of fruits per plant and number of seeds per fruit indicating the operation of non additive gene action in the inheritance of these traits. For the remaining characters the presence of additive gene action was indicated by the greater magnitude of g.c.a. variance than s.c.a. variance.

The numerical analysis by Hayman's approach indicated that the parental strains had more of dominant genes for days to first flowering, length of fruit, weight of single fruit, weight of fruits per plant and number of seeds per fruit while predominance of additive genes was seen for leaf number and incidence of shoot and fruit borer. However, the presence of additive as well as dominant genes in the parents was found for six characters. Environmental influence was also seen for a few traits.

The dominance of increasing alleles in the parents was indicated by the positive value of $\hat{F}$ for almost all characters except leaf area, number of flowers per plant, fruiting phase, percentage fruit set and incidence of shoot and fruit borer for which decreasing alleles were predominant. Similarly the value of the proportion of dominant and recessive genes also indicated an asymmetrical distribution of these genes among the parents for all the characters. An unequal distribution of genes with positive and negative effects was also indicated by the ratio of H_2 to $4H_1$ for all the characters except fruiting phase.

The average degree of dominance indicated overdominance for almost all characters except leaf axil bearing the first flower and incidence of shoot and fruit borer for which complete dominance was seen and leaf number for which partial dominance was noticed. This was confirmed by the graphical analysis. In the graphical analysis the regression of Wr on Vr deviated significantly from unity for weight of fruits per plant, number of seeds per fruit, fruiting phase and height of plant indicating the presence of epistasis for these traits. Thus the overdominance indicated by the numerical analysis for these traits may be spurious.

The Vr-Wr graph also indicated that the parents were genetically divergent for seven characters viz., days to first flowering, leaf number, leaf area, number of fruits per plant, weight of single fruit, incidence of yellow vein mosaic and incidence of shoot and fruit borer while very little genetic divergence was seen among the parents for the remaining six characters.

Manifestation of heterosis was seen for all the characters studied. Among the 30 hybrids evaluated, the hybrid P_2 x P_1 was found to be the most outstanding for yield and yield related characters viz., weight of single fruit, girth of fruit, length of fruit, percentage fruit set and also for seed number per fruit when compared to the mid parent, better parent and the standard check and it also exhibited heterosis for tolerance to shoot and fruit borer. The hybrid P_1 x P_4 was found to show heterosis for earliness, number of flowers per plant and leaf number. In general, the hybrids involving either the parent P_1 (NBPGR/TCR 893) or the parent P_2 (NBPGR/TCR 861) were found to be heterotic.

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ABSTRACT

The study was carried out in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 1994-95 to estimate the combining ability of six genetically divergent parental strains of bhindi and their 30 F_1 hybrids obtained by crossing the six parents in a diallel pattern. The magnitude of heterosis and nature of gene action governing the yield of fruits and other important yield attributes was also elicited through Hayman's numerical and graphical approach.

The combining ability analysis by the Method 1 of Griffing's (1956) approach revealed that the parent P_4 (NBPGR/TCR 864) was the best general combiner for yield and a few yield related characters. Among the hybrids, P_1 x P_4 (NBPGR/TCR 893 x NBPGR/TCR 864) exhibited outstanding s.c.a. effects for yield. Non additive gene action was found to govern days to first flowering number of flowers per plant, length of fruit, girth of fruit, weight of single fruit, weight of fruits per plant and number of seeds per fruit while the remaining characters were governed by additive gene action.

The numerical and graphical analysis indicated overdominance for almost all characters except leaf axil bearing the first flower and incidence of shoot and fruit borer for which

complete dominance was seen and leaf number for which partial dominance was noticed. The Vr-Wr graph also indicated the presence of epistasis for weight of fruits per plant, number of seeds per fruit, fruiting phase and height of plant.

There was manifestation of heterosis for all the characters studied. The hybrid P_2 x P_1 (NBPGR/TCR 861 x NBPGR/TCR 893) was the most outstanding for yield and yield related characters when compared to the mid parent, better parent and the standard check and it also exhibited heterosis for tolerance to shoot and fruit borer. The cross P_1 x P_4 (NBPGR/TCR 893 x NBPGR/TCR 864) was also heterotic for earliness in flowering. In general, the parents NBPGR/TCR 893 and NBPGR/TCR 861 either alone or together produced heterotic combinations.