COMBINING ABILITY AND HETEROSIS IN BITTERGOURD (*Momordica charantia* L.)

By

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2000

dedicated
to

My
Beloved Parents

DECLARATION

I hereby declare that this thesis entitled "**Combining ability and heterosis in bittergourd (*Momordica charantia* L.)** " 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 of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellayani,

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CERTIFICATE

Certified that this thesis entitled **"Combining ability and heterosis in bittergourd** *(Momordica charantia* L.)" is a record of research work done independently by **Mr. Iswara Prasad C.M.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

1. INTRODUCTION

Bittergourd (*Momordica charantia* L., 2n = 22) also known as bitter cucumber belongs to the family cucurbitaceae consisting of 117 genera and 825 species. *Momordica* is a large genus comprising of more than 23 species. Eventhough bittergourd has its origin in the Indo-Burma region (Garrison, 1977), its cultivation is widespread throughout the tropics and subtropics. It is the most accepted crop among the cucurbitaceous vegetables and is being extensively cultivated in many parts of India throughout the year.

Considering the nutritive and medicinal properties, bittergourd ranks first among the cucurbits, the most important constituents being proteins (1.6 - 2.1 g/100 g fruit) minerals (0.8 - 1.4 g/100 g fruit) and vitamin C (88-96 mg/100 g fruit) (Gopalan *et al.*, 1982). The antidiabetic properties of bittergourd extracts is well established. The seeds yield an oil which is an antihelmintic. Due to these unique properties, there is always a consumer preference for bittergourd compared to the other cucurbitaceous crops. However, the crop has not been fully exploited by the plant breeders for its improvement in yield and as well as quality which necessitates a need based crop improvement programme.

Bittergourd is a highly cross pollinated crop with monoecious nature and hence the most important method to develop superior varieties is heterosis breeding. Knowledge on the combining ability of the parents, nature of the gene action and the relative magnitude of additive, dominance and epistatic variances in the population are highly essential for increasing the productivity of bittergourd.

The present investigation was aimed to assess the combining ability of the parents and crosses, to study the nature of gene action with respect to the different yield characters and to identify the heterotic cross combinations by evaluating the hybrids.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Bittergourd (*Momordica charantia* L.) is the most accepted crop among the cucurbitaceous vegetables. Being cross pollinated in nature due to its monoecious condition, exploitation of hybrid vigour is the most suitable approach for increasing yield in bittergourd. Commercial exploitation of hybrid vigour has not been practised fully in this crop eventhough considerable extent of heterosis for yield has been reported by several authors. Informations on the combining ability and the nature of gene action of the divergent parents involved in hybridisation, play an important role in the production of heterotic hybrids. A review of the reports on research already made in the above context on bittergourd and other cucurbitaceous crops is being attempted here.

2.1 Variability

The selection of parents may be effective only when major part of the variability of the trait is genetic. Variability available in a population can be partitioned into heritable and non heritable components with the aid of genetic parameters such as genotypic and phenotypic coefficients of variation (GCV and PCV) heritability (h^2) and genetic advance (GA) which serve as a basis for selection.

2.1.1 Coefficients of variation

In **bittergourd**, Srivastava and Srivastava (1976) conducted studies with 10 lines and observed significant differences for all the characters except for male flowers per plant. The highest GCV was for fruits per plant (37.45 per cent) followed by yield per plant (32.13 per cent) and fruit weight (30.02 per cent) while the lowest (11.47 per cent) was for male flowers per plant. Singh *et al.* (1977) reported significant differences among the varieties for yield per plant, fruits per plant, fruit width, days to flowering and age of edible fruit, in a study with 25 lines. The yield and its main components, fruits per plant and fruit length showed high GCV (35 per cent, 39 per cent and 34 per cent respectively) while days to flower showed the lowest GCV (4 per cent). Ramachandran and Gopalakrishnan (1979) evaluated 25 types and observed significant variability for primary branches per plant, main vine length, node to first female flower, days to first female flower opening, number of female flowers, days to picking maturity, yield per plant, number, weight, length and girth of fruits, seeds per fruit and 100 seed weight. They observed highest PCV (39.88 per cent) and GCV (37.82 per cent) for yield per plant. The lowest GCV was for seeds per fruit. Ramachandran and Gopalakrishnan (1980) observed significant variability with respect to certain biochemical traits in bittergourd.

Mangal *et al.* (1981) conducted studies on 21 varieties of bittergourd and significant variation was observed for all the characters. The highest GCV was shown by yield per plant and the lowest by days to first female flower opening. Indiresh (1982) studied 24 lines and observed high GCV for fruit fresh weight, yield per plant and fruit length. Suribabu *et al.* (1986) analysed six lines of bittergourd and GCV was moderate to high for all the characters except number of fruits per plant and percentage fruit set. Chaudhary (1987) reported significant variability in respect of various vegetative and yield characters. The highest PCV and GCV were noticed for yield per plant, fruits per plant, vine length and fruit weight. However, PCV and GCV were low for early female flower formation and early harvest. Vahab (1989) while studying genetic variability in 50 genotypes, observed significant differences for 18 characters. The highest PCV was observed for fruit weight, yield and fruits per plant while earliness exhibited low PCV. The GCV was of high magnitude for majority of the characters.

In **snakegourd,** Joseph (1978) reported highest GCV for fruit weight (28.29 per cent) and fruit length (29.81 per cent). Varghese (1991) observed highest PCV for fruiting nodes on main vine followed by male flowers per plant, sex ratio and fruits per plant. The PCV was lowest for crop duration. The GCV was high for majority of the characters. Varghese and Rajan (1993a) also observed highest PCV and GCV for fruiting nodes on main vine and lowest for total crop duration. Mathew (1996) reported the highest PCV and GCV for mean weight of fruit and the lowest PCV and GCV for flesh thickness. Radhika (1999) found that the PCV values ranged from 5.63 to 21.83 per cent. PCV for flesh thickness was the highest followed by fruit yield per plant and number of fruits per plant. The GCV values ranged from 4.22 per cent (days to first fruit harvest) to 21.54 per cent (flesh thickness). Fruit yield per plant and number of fruits per plant also had high values of GCV.

In **bottlegourd,** Tyagi (1972) conducted variability studies with 25 inbreds and significant differences were noticed among the strains in respect of all the characters. Fruits per plant had the highest GCV (48.26 per cent) followed by seed breadth (31.96 per cent), fruit length (26.64 per cent) and fruit girth (23.28 per cent). Kumar *et al.* (1999) noticed maximum GCV for number of fruits per plant followed by fruit yield per plant.

Singh *et al.* (1986) reported high GCV for yield per plant, fruit length and fruits per plant in **pointedgourd**. Sarkar *et al.* (1990) observed high genotypic and phenotypic variances for fruits per plant and fruit volume.

Reddy and Rao (1984) found that in **ridgegourd**, PCV ranged from 14.38 to 162.62 per cent and GCV from 13.56 to 112.03 per cent for days to first marketable fruit formation and yield per plant respectively. While studying genetic variability in ridgegourd, Varalakshmi *et al.* (1995) reported high PCV and GCV for fruits per plant, fruit weight, seeds per fruit and yield per plant.

In **spongegourd**, Arora *et al.* (1983) reported maximum range of variation and high GCV and PCV for yield per plant and was closely followed by fruits per plant and sex ratio.

In **pumpkin**, Doijode and Sulladmath (1986) reported highest PCV and GCV for fruit weight and β carotene as compared to other characters. Rana *et al.* (1986), while studying genetic variability on yield per plant and 11 yield related quality and development traits, found highly significant differences for all traits except dry matter and carotenoid content. The PCV and GCV were high for vine length, fruit set per cent, branches per plant and fruit weight. Sureshbabu (1989) observed highest GCV for seeds per fruit (37.37 per cent) and the lowest for node at which the first female flower is formed (12.77 per cent). The highest and lowest PCV were observed for yield per plant (58 per cent) and days to first male flower anthesis (13.08 per cent) respectively. Borthakur and Shadeque (1990) reported high genotypic and phenotypic variances for main creeper length, leaves per plant and fruit size index.

In **cucumber**, Solanki and Seth (1980) reported highest PCV and GCV for plant height and lowest for fruits per plant. Prasunna and Rao (1988) conducted variability studies and noticed that the GCV ranged from 5.14 to 73.35 per cent and PCV from 8.52 to 80.13 per cent. Abusaleha and Dutta (1990) observed high phenotypic and genotypic variances for all the characters studied. Mariappan and Pappiah (1990) reported highest PCV for seeds per fruit. Rastogi and Deep (1990a) observed the maximum PCV and GCV estimates for days to fruit maturity and minimum for fruit yield per plant. Gayathri (1997) reported highest PCV (95.8 per cent) and GCV (92.9 per cent) for yield per plant and lowest PCV (13.6 per cent) for days to first fruit harvest and lowest GCV (11.2 per cent) for days to first male flower opening.

In **watermelon**, Thakur and Nandpuri (1974) observed variability for vine length, branches/plant, sex ratio, days to fruit picking, fruits per vine, average fruit weight, yield per vine, seeds per kilogram of fruit, 100 seed weight and total soluble solids. The PCV was maximum for seeds per kilogram of fruit (41.31 per cent) and minimum for days to fruit picking (6.46 per cent). The GCV value also showed the same trend. Prasad *et al.* (1988) reported high PCV and GCV for fruits per plant, average fruit weight, seeds per fruit, 100 seed weight and fruit yield per plant. Rajendran and Thamburaj (1994) reported highest PCV and GCV for yield per vine.

In **muskmelon**, Kalyanasundaram (1976) reported significant differences among the three varieties for economic characters. Swamy *et al.* (1985) observed maximum PCV and GCV for marketable yield per plant. Chacko (1992) noticed moderate to high GCV for yield per plant.

2.1.2 Heritability and genetic advance

In **bittergourd**, Srivastava and Srivastava (1976) observed highest heritability (99.31 per cent) and genetic advance (71.75 per cent) for fruits per plant and lowest heritability (49.93 per cent) and genetic advance (16.73 per cent) for male flowers per plant. Singh *et al.* (1977) reported high heritability for yield (92 per cent), fruits per plant (93 per cent) and fruit length (95 per cent) and high expected genetic advance of 69, 76 and 68 per cent respectively, while the lowest heritability (22 per cent) and genetic advance (3.52 per cent) were observed for days to flower. Ramachandran (1978) reported high estimates of heritability and genetic advance for yield per plant. Ramachandran and Gopalakrishnan (1979) reported highest heritability of 99.80 per cent for fruits per plant and highest genetic advance of 81. 90 per cent for yield per plant. Ramachandran and Gopalakrishnan (1980) noticed high or moderate estimates of heritability and high genetic gain for vitamin C, phosphorus, total soluble solids and iron contents. Mangal *et al.* (1981) observed high heritability values for leaf length, plant height, average fruit weight, branches, fruits, yield per plant and seeds per fruit. Indiresh (1982) reported high heritability values for all the characters except yield per plant and days for fruit development in bittergourd. Suribabu *et al.* (1986) noticed moderate to high genetic advance for seeds per fruit, days to first female flower and yield per plant whereas, fruits per plant showed moderate heritability and low genetic advance. Chaudhary (1987) observed very high genetic advance for yield per plant and vine length. Vahab (1989) observed high heritability coupled with high genetic gain for fruit weight, yield and fruits per plant in bittergourd. Chaudhary *et al.* (1991) also reported high estimates of heritability and genetic advance for yield per plant.

In **snakegourd**, Varghese (1991) noticed high heritability coupled with high genetic gain for male flowers per plant, sex ratio and fruiting nodes on the main vine. Varghese and Rajan (1993 a) observed high magnitude of both heritability and genetic advance for fruits per plant, while yield per plant, fruit length, crop duration, days to first harvest and first male flower showed high heritability coupled with low genetic gain (Varghese, 1991 and Varghese and Rajan, 1993a). Mathew (1996) noticed high heritability and high genetic advance for all the characters except flesh thickness. Radhika (1999) reported the highest and lowest values of heritability for days to first female flower and vine length, respectively. High heritability along with high genetic advance was noticed for days to first male flower, days to first female flower, fruit length, fruit yield per plant, flesh thickness, number of fruits per plant and 100 seed weight.

In **bottlegourd**, Prasad and Prasad (1979) reported high heritability coupled with high genetic advance for fruit length and fruit diameter. Sirohi *et al.* (1986) recorded high narrow sense heritability for days to first male and female flower, fruit length, girth and weight and fruits per plant, while Sirohi *et al.* (1988) observed low estimates of narrow sense heritability for all the characters except fruit length and weight. Sharma and Dhankar (1990) reported high heritability coupled with high genetic advance for fruits per plant. Kumar *et al.* (1999) observed high heritability for all the characters studied and high genetic advance for fruit yield per plant followed by number of fruits per plant and number of branches per plant.

Singh *et al.* (1986) observed high heritability with high expected genetic advance for fruits per plant and yield per plant in **pointedgourd**.

In **ridgegourd**, Reddy and Rao (1984) recorded highest heritability for average fruit weight and the lowest for days to first harvest. High heritability coupled with high magnitude of genetic gain were recorded for yield, individual fruit weight, number of fruits and fruit length. Kadam and Kale (1987) reported high heritability and genetic advance for days to flowering. While studying heritability and genetic advance in ridge gourd, Prasad and Singh (1989) noticed high heritability and low genetic advance for number of nodes, node on which the first female flower appeared, fruit length and fruit diameter. These were attributable to the non-additive effects. High heritability coupled with high genetic advance was noticed for yield in quintals per hectare, yield per plant and number of fruits. Low heritability was recorded for vine length, followed by fruit diameter, number of nodes and node on which the first female flower appeared. Varalakshmi *et al.* (1995) observed high heritability values for seeds per fruit, fruit weight, days to first female and male flower, fruit length, 100 seed weight and fruits per plant and low heritability for fruit diameter. Seeds per fruit and 100 seed weight showed high estimates of heritability and genetic advance.

In **spongegourd**, Arora *et al.* (1983) reported high estimates of heritability and genetic advance for yield per plant and fruits per plant. Prasad *et al.* (1984) found that yield per plant and four other traits gave heritability estimates of 100 per cent. High values for both heritability and genetic advance were obtained for five traits including fruit length and diameter.

In **pumpkin**, Rana *et al.* (1986) reported high heritability associated with high genetic gain for fruit number. Singh *et al.* (1988) and Borthakur and Shadeque (1990) reported the same for fruit weight. Sureshbabu (1989) reported high genetic gain for seeds per fruit (73.05 per cent).

In **cucumber**, Solanki and Seth (1980) noticed high heritability and low expected genetic advance for average fruit weight and number of fruits per plant. Prasunna and Rao (1988) observed high heritability for fruits per vine and average fruit weight, whereas, Mariappan and Pappiah (1990) reported high heritability values for fruit length and girth, days to first staminate flower, number of seeds per fruit and fruit weight. Rastogi and Deep (1990a) observed high heritability for yield per plant and days to fruit maturity. In cucumber, high heritability estimates coupled with high genetic advance were noticed for fruit yield (Solanki and Seth, 1980 and Rastogi and Deep, 1990a), fruit weight (Mariappan and Pappiah, 1990 and Rastogi and Deep, 1990a) and fruits per vine (Abusaleha and Dutta, 1990 and Rastogi and Deep, 1990a). Gayathri (1997) reported high heritability along with high genetic advance for yield per plant, fruits per plant, average fruit weight and node to first female flower.

Prasad *et al.* (1988) reported high heritability estimates for all the characters studied except for days to first picking and branches per plant in **watermelon**. Rajendran and Thamburaj (1994) observed high heritability estimates for 100 seed weight, average fruit weight, yield per vine and number of seeds per fruit. Prasad *et al.* (1988) and Rajendran and Thamburaj (1994) recorded high heritability and genetic advance for number of fruits per plant, number of seeds per fruit and 100 seed weight.

In **muskmelon**, while studying genetic variability, Chonkar *et al.* (1979) reported that the values of heritability and genetic advance showed effectiveness in selection for pulp thickness, fruit weight and percentage of total soluble solids. Kalloo *et al.* (1981) observed high heritability estimates for fruit length, fruit weight, yield and number of fruits. High heritability coupled with high genetic gain was noticed for yield per vine, fruits per plant and fruit weight. Swamy *et al.* (1985) reported moderate to high heritability estimates for all the characters studied. High heritability along with high genetic gain was observed for yield per vine and fruit weight, while high heritability with low genetic gain was noticed for days to first fruit harvest. Vijay (1987) noticed high heritability and high genetic advance for fruits per vine, total soluble solids, flesh thickness, yield per vine, fruit weight and days to flower in muskmelon. Singh *et al.* (1989) reported moderate estimates of narrow sense heritability for all the traits except number of primary branches.

2.2 Combining ability

Combining ability is aimed at getting informations about the general combining ability (GCA) of parents and specific combining ability (SCA) of hybrids. Combining ability analysis helps in evaluation of inbreds in terms of their genetic value, in the selection of suitable parents for hybridisation and in the identification of superior cross combinations.

In **bittergourd**, Sirohi and Choudhury (1977) conducted an 8 x 8 diallel cross without reciprocals and the parents Pusa Do Mausmi, S 63 and S 144 showed the best combining ability for the eight characters studied. When one or both of the parental lines S 63 and S113 which displayed high GCA for yield components, were involved in a cross, the resulting F_1 hybrids were the best. GCA variance was greater than that due to SCA for all characters. Singh and Joshi (1979) in a 5 x 5 diallel of bittergourd, observed high GCA values for BWL 1 for fruit length and number and weight of fruits per plant. Hybrids of BWL 1 with BB 1 and BWM 1 with BS 1 had high SCA values for weight of fruits per plant. Pal *et al.* (1983) reported that the combining ability analysis involving 5 x 2 line x tester cross in bittergourd, showed high GCA for days to female flower initiation and fruits per plant. Monsoon miracle was the best general combiner for yield, fruit weight, fruit size and fruit cavity size. Srivastava and Nath (1983) studied combining ability in bittergourd and reported the GCA and SCA effects for days to flowering, fruits per plant, fruit weight per plant and total yield per plant in the parental and F_1 generations of a 10 x 10 diallel. For each of the four traits, several parental breeding lines showed significant GCA and SCA effects. Chaudhary (1987) conducted a 11 parental diallel analysis in bittergourd and observed that the GCA and SCA variances were significant for all the 13 characters observed. The variance due to GCA was greater than the SCA variance for all the characters. The parents Coimbatore Long, Hissar Selection and Khandesh Mali were found to be the best combiners for most of the yield contributing characters. Vahab (1989) reported significant GCA variances for all the character studied and the SCA variances were also significant for majority of the characters. Parents of high GCA gave F_1's with best performance. Mishra *et al.* (1994) reported high SCA effect for fruit yield per plant in the hybrids, Coimbatore Long x Gadabeta and Tiansi x Gadabeta. At least one parent with high GCA was involved in most of the hybrids showing high SCA effects. Devadas *et al.* (1995) conducted combining ability studies and found that the cultivar MC 13 was a good general combiner for 100 seed weight and MC 84 for field emergence and seedling length.

In **snakegourd**, Varghese (1991) carried out combining ability analysis and observed significant GCA variance for all the characters. The SCA variance was also significant for all characters except for total crop duration, sex ratio and fruits per plant. Varghese and Rajan (1994) conducted line x tester analysis using eight lines and three testers in snakegourd and studied their combining ability on seven yield components. The results revealed that the yield per plant and fruits per plant had high and significant GCA and SCA variances. Radhika (1999) while studying combining ability, observed significant GCV and SCA variances in almost all the characters studied. SCA variance was found to be more than the GCA variance in all the characters except mean weight of fruit, fruit length, number of seeds per fruit, and duration of the crop.

Sivakami *et al.* (1987) studied combining ability for yield per plant and eight related characters in a diallel cross of 10 varieties of **bottlegourd**. GCA and SCA effects were significant for all the nine characters. GCA effects predominated over SCA effects for these characters, suggesting that recurrent selection would be effective in improving them. Janakiram and Sirohi (1988) conducted an incomplete diallel cross of 10 round fruited bottlegourd and noticed that the variance of GCA was larger than those for SCA for all the characters studied except days to opening of first male and female flowers and fruit polar diameter.

In a combining ability study in **pumpkin**, Sirohi *et al.* (1986) observed that SCA variance exceeded GCA variance for all the characters except vine length.

In a half diallel cross of several varieties of **cucumber**, Om *et al.* (1978) reported significant GCA and SCA variances for early yield per plant. Smith *et al.* (1978) reported high GCA variances for node to first female flower per vine, branches per vine, fruits per vine, average fruit weight, fruit length to diameter ratio and total yield per vine in cucumber. Solanki and Seth (1980) noted high SCA variance over GCA variance for characters like average fruit weight, duration of flowering, primary branches per plant, fruits per plant and secondary branches per plant. Wang and Wang (1980) conducted combining ability studies in autumn cucumber with 36 combinations involving 16 parents and found that both GCA and SCA effects were significant for a number of yield and maturity characters. Shawaf and Baker (1981) reported that the GCA effect for time to harvest, gynoecious expression and yield of female parents was more than male parents.

Tasdighi and Baker (1981) studied combining ability in cucumber and found that GCA effects were important for total yield and marketable yield. In a study for combining ability with 60 F_1 hybrids, Dolgikh and Siderova (1983) observed GCA to be important for early and total yield and fruit number per plant. While studying combining ability in the production of cucumber hybrids, Guseva and Mospan (1984) reported high GCA effects for parthenocarpy and disease resistance. Prudek (1984) conducted diallel analysis of combining ability for yield components in cucumber and observed that both GCA and SCA were significant in determining both the number and weight of fruits per plant but GCA was more important. SCA was of no importance with regard to earliness and mean single fruit weight. Owens *et al.* (1985) carried out genetic analysis and observed significant GCA and SCA estimates for fruit length and weight.

On the basis of a diallel analysis of data on four yield components in crosses involving 5 monoecious cucumber lines, Prudek and Wolf (1985) reported lines and crosses with high GCA and SCA estimates. The lines PS 66 and PS 13 had high GCA effects for all characters and are recommended for breeding. The SCA variances and interactions of SCA with years were significant only for mean fruit weight. Musmade and Kale (1986) crossed seven cultivars of cucumber in all possible combinations and observed that both GCA and SCA variances were significant for all the characters studied. Frederick and Staub (1989) carried out combining ability analysis of fruit yield and quality and observed significant GCA estimates for all the traits. While studying combining ability in cucumber on nine yield components in four female and eight male genotypes and their F_1 hybrids Hormuzdi and More (1989) reported SR 551 F (female) and Balam (male) as the best combiners for majority of the characters. The highest yield was obtained from the cross SR 551F x Japanese Long Green. Solanki and Shah (1990) conducted L x T analysis of combining ability for yield and its components in cucumber and observed significant contribution of GCA and SCA variances at varied proportions and magnitude for yield contributing characters. The SCA effects were significant for vine length, internodal length, female flowers per plant, fruits per plant and fruit yield per plant in most of the crosses. Satyanarayana (1991) carried out genetical studies in cucumber and reported significant GCA for all the characters except branches per vine, specific leaf weight, specific leaf area and cavity size. The SCA was significant for all the 27 characters studied except for branches per vine. Gayathri (1997) observed significant GCA and SCA variances for all the 15 traits considered.

Brar and Sukhija (1977) studied combining ability in **watermelon**, involving 4 characters, viz., yield per plant, fruit number, fruit weight and total soluble solids. The variance due to GCA was higher than that due to SCA for all characters. The crosses exhibiting high SCA for yield also had high or average combining ability for yield components. Dyustin and Prosvirnin (1979) carried out diallel analysis of economically useful characters in watermelon and observed that for almost all the characters GCA variance exceeded SCA variance. In an analysis of data on brix value, fruit weight, fruit number per plant, pericarp thickness and hardiness in 15 hybrids of watermelon from a diallel cross, Li and Shu (1985) found that GCA effect was significant for all the five characters, while SCA effect was significant only for brix value and fruit weight. Gill and Kumar (1988) studied combining ability in watermelon and reported 'Shipper' as the good combiner for yield and fruit weight and Sugar Baby for days to maturity and fruit number per plant. Kale and Seshadri (1988) while studying combining ability in watermelon on seven yield and quality characters in six genotypes and their 15 F_1 hybrids, identified Asahi Yamato, Sugar Baby, Pusa Rasaal and Russian as the best combiners. The best specific combination for all the traits studied was Pusa Rasaal x Asahi Yamato.

Chadha and Nandpuri (1980) conducted combining ability analysis of a diallel set of 10 **muskmelon** cultivars and reported that both GCA and SCA variances were highly significant for all the characters. However, GCA variance contributed major part of genetic variation for most of the traits. Kalb and Davis (1984) carried out combining ability analysis for yield, maturity and various plant traits in a 6 parental diallel cross in bush muskmelon and observed that the variance of GCA was greater than that of SCA for all traits. Swamy and Dutta (1985) in a diallel cross involving 10 varieties of muskmelon observed significant GCA and SCA effects for fruit ascorbic acid content. In muskmelon, Kuti and Ng (1989) observed significance of GCA variance for tolerance to disease and toxin and significance of SCA for inoculations involving pathogens. Randhawa and Singh (1990) found that the best general combiners were Durgapur Madhu for fruit yield and Punjab Sunehri for traits associated with earliness and WMR 29 for vine length.

In **orientalmelon,** Om *et al.* (1987) observed that GCA was important for fruit weight, soluble solid content, flesh firmness, days to maturity and yield per plant.

Korzeniewska and Nierricrowicz (1994) carried out combining ability analysis in **wintersquash** and noted high GCA values for all the yield components, while significant SCA was noted for fruit yield.

Bhagchandani *et al.* (1980) carried out combining ability analysis in **summersquash** for vine length, branches, fruits and yield per plant. Vegetable Marrow x Early Yellow Prolific was the best combiner.

2.3 Gene action

Knowledge about the gene action is important in any crop improvement programme. Higher magnitude of GCA variance indicates the predominant role of additive gene action which is fixable and higher SCA variance indicates dominance deviation and epistatic effect.

Sirohi and Choudhury (1977) conducted combining ability analysis in **bittergourd** and found that GCA variance was greater than SCA variance for all the characters indicating the predominance of additive gene action for all the characters studied. Sirohi and Choudhury (1979) studied gene effect in bittergourd for vine length, days to first harvest, fruits per plant and total yield and observed duplicate epistasis for vine length in many of the crosses. The dominance and dominance x dominance components chiefly contributed to vine length. Additive and additive x additive components were more pronounced for days to first harvest. For total yield per plant, most of the crosses exhibited the presence of complementary epistasis and the contribution of the dominance and dominance x dominance components of genetic variance were higher. Singh and Joshi (1979) reported additive gene action for all the characters studied. Pal *et al.* (1983) noticed the operation of more additive genes for days to first female flower and fruits per plant and non-additive genes for node of first female flower formation, days to maturity, fruit yield, fruit size, fruit weight and fruit cavity size. Sirohi and Choudhury (1983) conducted studies on variability in bittergourd and observed additive gene action with partial dominance for vine length, days to first fruit harvest, fruit length and diameter, fruit flesh thickness, fruits per plant and fruit weight. Vahab (1989) studied inheritance of fruit colour and surface and reported that both are monogenic; green and spiny fruits being dominant over white and smooth fruits. Inheritance of bitterness suggested involvement of additive, dominance and additive x dominance types of gene action. Mishra *et al.* (1994) noticed both additive and non-additive gene action for fruits per plant, fruit length, breadth, weight and yield.

In **snakegourd**, Varghese (1991) reported additive as well as non-additive gene actions in the control of most of the characters, except for sex ratio, fruits per plant and total crop duration. Varghese and Rajan (1994) also observed both additive and non-additive gene actions for yield per plant and fruits per plant. Radhika (1999) observed significant variance due to general and specific combining abilities in almost all the characters studied indicating the significance of both additive and non-additive gene action in the characters. However, the SCA variance was found to be more than the GCA variance in majority of the characters studied indicating the predominance of non-additive gene action.

In **bottlegourd**, Janakiram and Sirohi (1988) reported importance of additive gene action for all the characters studied except days to opening of first male and female flowers and fruit polar diameter.

In **pumpkin**, Sirohi *et al.* (1986) conducted combining ability analysis and concluded that the superior performance of hybrid with high SCA was due to epistatic effect. Sirohi (1993) reported overdominance for vine length, fruits per plant, fruit size index and fruit flesh thickness and dominant gene action for fruit weight and yield per plant.

In **cucumber**, Om *et al.* (1978) noticed that both additive and non-additive components of genetic variation were important and additive component was more important for early yield per plant. Smith *et al.* (1978) observed that additive gene action was important for expression of node to first female flower per vine, branches per vine, fruits per vine, average fruit weight, fruit length to diameter ratio and total yield per vine. Solanki and Seth (1980) observed non-additive gene effect for characters like average fruit weight, duration of flowering, primary branches per plant, fruits per plant and secondary branches per plant. Wang and Wang (1980) reported that additive variance was of importance for phenotypic variation in cucumber. Ghaderi and Lower (1981) observed significant additive and or dominance variance in some crosses for fruit weight per plant, fruits per plant and average fruit weight. Shawaf and Baker (1981) observed importance of additive gene effects for yield and its components except for gynoecious expression where non-additive variance was more important. Tasdighi and Baker (1981) noticed predominance of additive gene effects for yield and femaleness. Dolgikh and

Siderova (1983) reported that early yield was controlled by non-additive genes and total yield, fruits per plant and fruit weight were controlled mainly by additive genes in cucumber. Prudek (1984) noticed that both number and weight of fruits per plant depended on overdominance. Owens *et al.* (1985) observed importance of both additive and non-additive effects for fruit length and weight. Musmade and Kale (1986) observed importance of additive and non-additive effects for all the characters studied except yield per vine. Rastogi and Deep (1990a) observed the importance of non-additive genes for the expression of vine length, primary branches per plant, male flowers per plant and days to fruit maturity in cucumber. Satyanarayana (1991) reported that SCA variance was more than GCA variance for all the 27 characters indicating the role of non-additive gene effects. Prasad and Singh (1994) observed additive gene action, for the expression of yield components in cucumber.

In **watermelon**, Dyustin and Prosvirnin (1979) found that GCA variance exceeded SCA variance for yield characters, indicating the role of additive genes while for length of growth period, seed number and seed weight dominance and epistatic effects were important.

In **muskmelon**, Chadha and Nandpuri (1980) reported the role of additive genetic variance in the expression of all the 10 characters studied. Kalb and Davis (1984) observed the importance of additive variance for all the fruit quality traits. Swamy and Dutta (1985) noticed the importance of both additive and non-additive gene effects for fruit ascorbic acid content. Swamy and Dutta (1993) reported the importance of both additive and dominance effect, dominance being predominant, in the control of total soluble solids content.

In **orientalmelon**, Om *et al.* (1987) showed the importance of non-allelic interaction in the control of total soluble solids.

In **summersquash**, Bhagchandani *et al.* (1980) observed additive gene effect for vine length, while it was non-additive for yield. However, additive and non-additive effects were prevalent for branches as well as fruits per plant.

2.4 Heterosis

In **bittergourd**, Pal and Singh (1946) observed heterosis in crosses involving five diverse lines. Heterobeltiosis was observed for male and female flowers, main vine length, fruit size and total yield per plant. Aiyadurai (1951) carried out preliminary studies in bittergourd and noted heterosis for earliness, fruits per plant, fruit size, fruit flesh thickness and total yield. Agrawal *et al.* (1957) crossed wild types of bittergourd with cultivated varieties and observed intermediate performance for earliness, vine length, female flowers, fruits and yield per plant. While studying heterosis, Srivastava (1970) found that as much as 45 out of 90 F_1 hybrids produced female flowers significantly earlier than the better parent and reported that days to female flower formation could be reduced to 16.7 per cent from that of the parents. For yield, 64 per cent heterobeltiosis was observed and for fruit length, fruit girth, fruit weight and fruits per plant also significant increase was noticed in hybrids. Kohle (1972) analysed hybrid vigour for yield in six hybrids selected from various cross combinations of six parents and reported that none of the hybrids possessed standard heterosis. Most of the crosses showed negative heterosis.

Lal *et al.* (1976) conducted studies on heterosis in bittergourd and observed heterosis for internode length, leaf petiole length, leaf length, leaf width, branches per plant, shoot length, node at which the first female flower formed, fruits per plant, length, girth and weight of fruits and total yield. They isolated two hybrids - Green Local x White Local and Green Local x Bundel Khand Local which were heterotic for vegetative growth, floral character and fruit yield. Green Local x White Local had 139.1 per cent increase in total yield over the better parent. In the hybrid Green Local x Bundel Khand Local, 7.02 per cent negative heterosis was observed for days to flower. Sirohi and Choudhuri (1977) observed that the bittergourd hybrids Pusa Do Mausmi x S 144, Pusa Do Mausmi x S 63 and Coimbatore Long x S 63 were found to be the best for total yield per plant and its component characters. Singh and Joshi (1979) studied a five parental diallel cross of bittergourd with five inbred lines and their 10 hybrids. Fruit length exhibited significant heterobeltiosis (29.9 per cent) in BWM I x Coimbatore Long. Crosses BW1 x BWL1 and BWL1 x BS 1 had significantly more fruits per plant with 13.7 per cent and 34.4 per cent heterobeltiosis respectively. These two crosses yielded significantly higher than their respective better parents. Plant height and primary branches per plant showed 22.3 and 37.0 per cent heterobeltiosis respectively. Heterosis for yield was too low for commercial exploitation of the F_1s. Pal *et al.* (1983) carried out a line x tester analysis (with 5 lines and 2 testers) in bittergourd and examined the presence of hybrid vigour. In all the 10 hybrids, manifestation of heterosis was found to be very limited as a whole. While studying parental and F_1 generations of a 10 x 10 diallel, Srivastava and Nath (1983) observed significant reduction in days to opening of first female flower (0.3 to 16.7 per cent) in the hybrids. Heterobeltiosis was observed in 35 hybrids for vine length (0.4 to 27.1 per cent) and 40 hybrids for fruits per plant (0.2 to 47.2 per cent). They also reported as much as 64 per cent increased yield in the hybrids. Ranpise (1985) reported significant relative heterosis, heterobeltiosis and standard heterosis for vine length, fruits per plant and yield per plant. Chaudhary (1987) conducted a 11 x 11 diallel cross in bittergourd and observed relative heterosis, heterobeltiosis and standard heterosis for various characters. Similarly, Vahab (1989) reported that several bittergourd hybrids showed significant relative heterosis, standard heterosis and heterobeltiosis for majority of the characters studied.

Lawande and Patil (1990) studied heterosis in bittergourd using 11 diverse breeding lines and their 55 F_1 hybrids and reported that heterosis for yield per vine was 86.1 per cent. Ranpise *et al.* (1992) reported appreciable heterosis over superior parent for yield per plant (93.69 per cent) in a diallel analysis with eight parents excluding reciprocals. Good amount of heterosis was observed for flesh thickness (43.18 per cent), fruit weight (36.09 per cent), number of fruits per plant (32.70 per cent), fruit length (26.02 per cent), number of internode at which first female flower appeared (-24.72 per cent) and vine length (24.63 per cent). Heterosis was also observed for fruit diameter (13.95 per cent), days to first female flower (-5.40 per cent) and days to first harvest (-4.32 per cent). Increase in the yield over respective superior parent in heterotic hybrids ranged from 19.21 to 93.69 per cent. Mishra *et al.*

(1994) studied a 9 x 9 diallel in bittergourd and reported heterosis for fruits per plant, fruit length, breadth, weight and yield. The hybrids Coimbatore Long x Gadabeta and Tiansi x Gadabeta showed high heterosis. Devadas *et al.* (1995) studied six yield components in 12 parental genotypes and their F_1 hybrids, in which six hybrids showed high degree of heterosis for total yield and number of fruits.

Kennedy *et al.* (1995) observed that the range of heterosis percentage in F_1 crosses varied from 9.37 (crop duration) to 77.95 (number of fruits per vine) over better parental values in bittergourd. Out of 60 F_1 hybrids, the heterotic effects over better parents were observed in 24 crosses for vine length, 30 for number of primary branches per vine, 46 for node number of first harvest, five for fruit length, three for fruit diameter, 13 for fruit flesh thickness, 20 for edible portion of fruits, 39 for number of fruits per vine, 10 for mean fruit weight, 19 for fruit yield per vine and 10 for crop duration. The first top three hybrids showed 65.74, 61.92 and 48.04 per cent heterosis over the standard variety (MC 84). Celine and Sirohi (1996) observed remarkable heterosis for yield and yield attributes over better parent, top parent and commercial check. Ram *et al.* (1997) conducted studies in bittergourd with 11 parents and 24 F_1s and observed negative heterosis which is desirable for days to male flower anthesis, days to female flower anthesis and plant height in most of the crosses. The results indicated that fruits per plant and yield per plant were the most heterotic characters. Positive heterosis was absent for the characters fruit length, fruit diameter and fruit weight. High positive heterosis over better parent was observed in the cross IC-50516 x VRBT-77 for fruits per plant and in crosses Narendra x VRBT-46 and IC 50516 x VRBT-77 for yield per plant.

Varghese (1991) studied heterosis in **snakegourd** and reported that eight hybrids had high heterobeltiosis for yield. Varghese and Rajan (1993b), while studying heterosis of growth characters and earliness in snakegourd, noticed significant heterobeltiosis and standard heterosis for main vine length, primary branches per plant, days to fruit maturity and days to first fruit picking maturity. Radhika (1999) conducted heterosis studies in snakegourd and manifestation of heterosis was reported for all the characters studied. Among the hybrids, Thrikkannapuram Local x Kaumudi had the maximum standard heterosis for yield and yield related characters.

Pal *et al.* (1984) reported heterosis in **bottlegourd** for rapid germination, earlier fruit maturity, flesh thickness, higher early yields and longer harvesting periods. Janakiram and Sirohi (1992) conducted studies on heterosis for quantitative characters and reported significant values over the better parent for yield and yield attributes. Sharma *et al.* (1995) studied heterosis in bottlegourd and found that the cross Summer Long Green Sel 2 x Faizabadi Long had the highest heterosis over the control cultivar PSPL for number of fruits and total yield per plant. Kumar *et al.* (1999) observed significant heterosis over better parent and standard parent, particularly for fruit yield and its component characters, namely fruit weight, number of fruits per plant, fruit length and diameter and for the traits deciding earliness.

While studying heterosis for certain seed characters in **pumpkin**, Doijode *et al.* (1983) noticed heterosis for seed number, seed weight per fruit, 100 seed weight and seed size index. Doijode and Sulladmath (1984) reported that the cross IHR 6 x CM 12 showed heterosis for several characters.

In **cucumber**, Imam *et al.* (1977) reported that the heterosis ranged from 15.34 for fruit diameter to 59.22 per cent for fruit shape index and heterobeltiosis was observed for fruit weight per plant and main stem length. Solanki *et al.* (1982) while studying heterosis in cucumber observed that heterosis for fruit yield was highest (120.23 per cent) in Furkin Riesenschel x Furkin Delikoless. Nikulenkova (1984) reported heterosis over standard parent for earliness and fruit yield. Rubino and Wehner (1986) reported significant relative heterosis and heterobeltiosis for total yield and marketable yield, earliness and fruit quality traits in cucumber. Delancy and Lower (1987) reported significant heterosis for the F_1 over the mean parental values for fruit yield and four plant traits and heterosis over better parent was observed for average internode length. Aleksandrova (1988) observed 2 hybrids Vikhra and Lora, showing significant heterosis for fruit yield, fruit size and other quality traits in cucumber. Hormuzdi and More (1989) observed heterosis for various economic characters, except for total yield, in crosses involving gynoecious, monoecious, and gynomonoecious lines. Satyanarayana (1991) while conducting genetic analysis in cucumber with nine x nine diallel, observed a mean heterosis of 61.1 per cent over mid parent and 52.2 per cent over better parent for total fruit yield per vine. Vijayakumari *et al.* (1993) while investigating heterosis in tropical and temperate gynoecious hybrids in cucumber, obtained maximum heterosis over better parent with 77.6 per cent superiority over the top parent for earliness and yield and its components in tropical gynoecious hybrid 304 x RKS 296. From a cross between line 90271 and line 90211, Fang *et al.* (1994) developed a hybrid "Zhongnong 8" and observed heterosis over the standard variety for early and total yield, vine length, average fruit weight, fruit quality and disease resistance. Musmade *et al.* (1995) studied heterosis in cucumber and noticed significant and positive heterosis for yield and its contributing characters. Ram *et al.* (1995) reported three promising heterotic hybrids having higher yield, earliness, uniformity and quality. Gayathri (1997) observed heterosis for most of the characters studied. Significant relative heterosis, heterobeltiosis and standard heterosis were expressed for days to first female flower opening.

More and Sheshadri (1980) carried out heterosis studies in **muskmelon** and reported significant heterosis over better parent for earliness, yield and quality. While studying heterosis in muskmelon, with seven varieties and their 28 F_1 hybrids, Dixit and Kalloo (1983) noticed that heterosis over the better parent was highest for fruit number per plant and stem length. Kalb and Davis (1984) observed favourable heterosis over mid parental value for total solvents, net density and to a lesser extent for amount of flesh, rind thickness, amount of cavity and cavity dryness. Munshi and Verma (1997) studied six parental lines and 15 F_1 hybrids of muskmelon obtained from half diallel, to investigate the extent of heterosis for yield and its contributing characters. Appreciable heterosis was recorded over better parent and top parent for all the characters studied except total soluble solids. In the order of merit, F_1 hybrids Pusa Madhuras x Ravi, Pusa Sharbati x Pusa Madhuras and Pusa Madhuras x Hara Madhu were observed to be three best performing F_1 hybrids for yield per plant.

Kasrawi (1994) studied yield per plant and five yield components in F_1 hybrids of **summersquash**. Heterosis over the mid parental value was found for the yield traits but was negative for flowering traits. Estimated heterosis over the superior parent was also negative for flowering and positive for yield, fruit number and fruit set. Ghai *et al*. (1998) studied the mean performance of parents and hybrids and it indicated the superiority of F_1 hybrids for earliness and yield.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study was conducted to estimate the combining ability and heterosis and thereby to identify suitable parental lines for production of commercial hybrids in bittergourd. The investigation was carried out in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani, during the period from 1998-2000.

3.1 Materials

The experimental material included seven diverse genotypes selected based on the D^2 analysis from the project "Development of hybrid varieties of bittergourd" previously conducted in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani and a check variety. The seven genotypes selected as parents are,

P_1 - MC 17

P_2 - MC 18

P_3 - MC 21

P_4 - MC 23

P_5 - MC 34

P_6 - MC 40

P_7 - MC 53

Check variety - Preethi

Selfed seeds of these seven types were utilized for producing single cross hybrids by crossing in diallel pattern excluding reciprocals.

3.1.1 Production of hybrid seeds

For the production of hybrid seeds, the male and female flower buds of the seven inbred parents which were expected to open the next day morning were covered with butter paper cover on the previous day evening. On the following day between 6.30 and 9.00 am, pollen grains were collected from the protected male flowers of one inbred and dusted on to the stigma of the protected female flower of the other inbred. After pollination, the butter paper cover was replaced over the female flower and labelled. The cover was later removed on the third day after pollination. Thus, hybrid seeds were produced in all possible combinations excluding reciprocals.

The seeds of the 21 crosses, the seven parents and the check variety were used for evaluating the combining ability and gene action and for estimation of heterosis.

3.2 Experimental methods

3.2.1 Design and layout

The seven parents and the twenty one hybrids, along with check variety were evaluated in a randomised block design with three replications. In each replication five pits per treatment spaced 2 m apart were taken and a single plant was grown in each pit.

3.2.2 Cultural practices

The cultural and management practices were followed according to the Package of Practices Recommendations (KAU, 1996) of the Kerala Agricultural University.

3.2.3 Biometric observations

The following observations were made on each plant per treatment adopting the standard procedures and the average was worked out for each replication.

3.2.3.1 Days to first male flower

The number of days were counted from the date of sowing to the bloom of the first male flower in each plant.

3.2.3.2 Days to first female flower

The number of days from sowing to the bloom of the first female flower in each plant was recorded.

3.2.3.3 Days to first fruit harvest

The number of days from sowing to the harvest of the first fruit in each plant was recorded.

3.2.3.4 Number of female flowers per plant

The total number of female flowers produced in each plant was recorded.

3.2.3.5 Number of fruits per plant

The total number of fruits produced in each plant was recorded.

3.2.3.6 Mean weight of fruit

The sum of weight of four fruits selected at random from each plant was taken and their average was expressed in grams.

3.2.3.7 Fruit yield per plant

Total fruit yield from each plant was recorded and expressed in kilograms.

3.2.3.8 Fruit length

The length of four fruits taken at random from each plant was recorded and the average was worked out and expressed in centimetres.

3.2.3.9 Fruit girth

The girth of four fruits (used for fruit length measurement) were recorded and worked out the average and expressed in centimetres.

3.2.3.10 Flesh thickness

Each fruit taken for the above two observations was cut at the middle, the thickness of the flesh measured, average was worked out and expressed in centimetres.

3.2.3.11 Number of seeds per fruit

The seeds were taken from the four fruits selected for flesh thickness measurement and total number was counted and worked out the average and recorded.

3.2.3.12 100 seed weight

One hundred seeds at random from each plant were collected, dried, weighed and expressed in grams.

3.2.3.13 Duration of the crop

The number of days taken by each plant from sowing to the harvest of the last fruit was recorded, averaged and expressed in days.

3.2.3.14 Colour of the fruit

The colour of the fruit was graded on a scale from one to four.

Score 1	-	Dark green
2	-	Green
3	-	Light green
4	-	Whitish green

3.2.3.15 Incidence of pests and diseases

No significant incidence of pests or diseases were noticed in the crop in any of the growth stages and hence no scoring for pests and disease incidence was done.

3.3 Statistical analysis

The data collected from the parents, hybrids and the check variety were subjected to statistical analysis.

Preliminary analysis was carried out as in the case of RBD experiment with 29 treatments comprising of parents p = 7, number of crosses (F_1s)

$$= \frac{p\,(p-1)}{2} = \frac{7\,(7-1)}{2} = \frac{7 \times 6}{2} = 21\ F_1\text{s and one check variety.}$$

The data collected were subjected to analysis of variance. If the genotypic differences were significant, combining ability analysis was performed with mean values. Heterosis was also worked out based on the mean values. (For combining ability analysis 28 treatments were utilized excluding the check variety).

Table 1 Analysis of variance for each character

Sources of variation	Degrees of freedom	Mean square	F
Replication	(r-1)	MSR	MSR/MSE
Treatment	(v-1)	MST	MST/MSE
Error	(r-1) (v-1)	MSE	
Total	(vr-1)		

where,

r = number of replications

v = number of treatments

MSR = Replication mean square

MST = Treatment mean square

MSE = Error variance

$$\text{Critical difference (CD)} = t_\alpha \sqrt{\frac{2\ \text{MSE}}{r}}$$

Where, t_α is the students t table value at the error degrees of freedom and 'α' level of significance (α is taken at five per cent level).

3.3.1 Estimation of variance components

The variance components were estimated according of the method proposed by Johnson *et al.* (1955).

a. Genotypic variance ($\sigma^2 g$) = $\dfrac{MST - MSE}{r}$

b. Environmental variance ($\sigma^2 e$) = MSE

c. Phenotypic variance ($\sigma^2 p$) = $\sigma^2 g + \sigma^2 e$

3.3.2 Coefficient of variation

To study the variability in the population, phenotypic and genotypic coefficients of variation (PCV and GCV) were worked out, by the method suggested by Burton (1952).

$$PCV = \frac{\sigma p}{\bar{x}} \times 100$$

$$GCV = \frac{\sigma g}{\bar{x}} \times 100$$

σp = Phenotypic standard deviation

σg = Genotypic standard deviation

$\bar{x}$ = Population mean

Phenotypic standard deviation and genotypic standard deviation were obtained as square root of the respective variances.

3.3.3 Heritability (Broad sense)

Heritability in the broad sense ($h^2_{(b)}$) was calculated to estimate the proportion of heritable component of variation. Heritability in broad sense was estimated using the formula by Burton (1952).

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

It can be expressed in percentage as follows

$$h^2_{(b)} = \frac{\text{Genotypic varaince}}{\text{Phenotypic variance}} \times 100$$

3.3.4 Genetic advance (GA)

Genetic advance measures the change in the mean genotypic level of population brought about by selection and GA as percentage of mean is calculated as,

$$GA = \frac{k\, h^2 \sigma p}{\bar{x}} \times 100$$

where, k = selection differential with values 2.06 per cent at five per cent and 1.76 at 10 per cent selection intensity.

3.3.5 Combining ability analysis

The combining ability analysis was performed on the mean values of treatments according to Griffing, model I, method II (1956).

Table 2 Analysis of variance of combining ability

Source	Degrees of freedom	Mean square	Expected mean squares E (MS)
Genotypes	$p + \frac{p(p-1)}{2} - 1$	M	$\sigma^2_e + \sigma^2_g$
GCA	$p - 1$	Mg	$\sigma^2_e + \sigma^2_{sca} + (p+2)\,\sigma^2_{gca}$
SCA	$\frac{p(p-1)}{2}$	Ms	$\sigma^2_e + \sigma^2_{sca}$
Error	$\left[p + \frac{p(p-1)}{2} - 1\right](r-1)$	Me	σ^2_e

where,

$$Me = \frac{MSE}{r}$$

MSE = error mean square

r = number of replications

p = number of parents

If significant differences among gca and sca were obtained, their effects were estimated as follows.

General combining ability effect (gi)

$$= \frac{1}{p+2}\left[\Sigma\,(Y_{i.} + Y_{ii}) - \frac{2\,Y_{..}}{p}\right]$$

Specific combining effect of i x jth cross,

$$(s_{ij}) = Y_{ij} - \frac{(Y_{i.} + Y_{ii} + Y_{j.} + Y_{jj})}{p+2} + \frac{2\,Y_{..}}{(p+1)(p+2)}$$

where, Y_{ij} = Mean of character with respect to i x jth cross over the three replications

$Y_{i.}$ = Total of mean values (over replications) corresponding to jth parent over the other crosses involving ith parent.

$Y_{j.}$ = Total of the mean values corresponding to jth parent over the other crosses involving jth parent

$Y_{..}$ = Total of all the mean values

The significance of gi and sij effects are tested using t test.

$$\text{Standard error (SE) of } (g_i) = \left[\frac{(p - 1)\ Me}{p\ (p + 2)}\right]^{1/2}$$

$$SE\ (s_{ij}) = \left[\frac{p\ (p - 1)\ Me}{(p + 1)\ (p + 2)}\right]^{1/2}$$

SE for difference of GCA and SCA effects are,

$$SE\ (g_i - g_j) = \left[\frac{2\ Me}{(p + 2)}\right]^{1/2}$$

$$SE\ (s_{ii} - s_{jj}) = \left[\frac{2\ (p - 2)\ Me}{(p + 2)}\right]^{1/2}$$

$$SE\ (s_{ij} - s_{ik}) = \left[\frac{2\ (p + 1)\ Me}{(p + 2)}\right]^{1/2}$$

$$SE\ (s_{ij} - s_{kl}) = \left[\frac{2\ p\ Me}{(p + 2)}\right]^{1/2}$$

Critical difference (CD) for making comparisons among different effects mentioned above were worked out as,

CD = t x SE,

where, t = table value at error degrees of freedom

The significance of GCA effect reveals the importance of additive heritable variance for the inheritance of the character, whereas significance of

SCA effect indicates the importance of non-additive variance for the inheritance of that character.

Components of variances for the GCA and SCA effects were estimated as,

$$\sigma^2 GCA = \frac{Mg - Ms}{(p + 2)}$$

$$\sigma^2 SCA = (Ms - Me)$$

The additive variance, $\sigma^2 a$ = 2 σ^2GCA
The dominance variance, $\sigma^2 d$ = σ^2SCA

Additive to dominance ratio was estimated and if it is more than unity then there is predominance of additive gene action, otherwise there is predominance of non-additive gene action.

3.3.6 Heterosis

Mean values over three replications for each character were used for estimation of heterosis. Magnitude of heterosis was calculated in terms of three parameters. Heterosis over mid parent (relative heterosis), better parent (heterobeltiosis) and standard variety (standard heterosis) were carried out as suggested by Rai (1979).

1. Relative heterosis (RH)

It is the percentage deviation of the hybrid mean from the mid parental value.

$$= \frac{\bar{F}_1 - \bar{MP}}{\bar{MP}} \times 100$$

$\bar{F}_1$ = average performance of F_1

$\bar{MP}$ = mid parental value

2) Heterobeltiosis (HB)

It is the percentage deviation of the hybrid mean from the better parental value.

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

$\bar{BP}$ = average performance of better parent.

3) Standard heterosis (SH)

It is the percentage deviation of the hybrid mean from the standard variety mean.

$$= \frac{\bar{F}_1 - \bar{SP}}{\bar{SP}} \times 100$$

$\bar{SP}$ = average performance of standard variety.

To test the significance of difference of F_1 mean over mid parent, better parent and check variety, C.D. was calculated as detailed below.

CD (0.05) for comparing the difference of $\bar{F}_1$ with $\bar{MP}$.

$$= t_\alpha \sqrt{\frac{3\ MSE}{2\ r}}$$

CD (0.05) for comparing difference of $\bar{F}_1$ with $\bar{BP}$.

$$= t_\alpha \sqrt{\frac{2\ MSE}{r}}$$

CD (0.05) for comparing difference of $\bar{F}_1$ with $\bar{SP}$

$$= t_\alpha \sqrt{\frac{2\ MSE}{r}}$$

where, t_α = Table value for error degrees of freedom
MSE = Error mean square
r = number of replications

RESULTS

4. RESULTS

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

4.1 Mean performance

The analysis of variance of 13 characters was carried out and the 29 genotypes of bittergourd showed significant differences with respect to all the characters studied (Appendix I). The mean performance of the seven parents, twenty one hybrids and the check variety for the various characters are presented in Table 3.

4.1.1 Days to first male flower

Among the parents, the mean values for days to first male flower ranged from 32.67 (P_6) to 39.27 (P_5) and the parent P_7 (33.07) was on par with P_6. The hybrid P_2 x P_6 took the minimum number of days to first male flower (25.67) and P_6 x P_7 had the maximum (30.60). The hybrids P_5 x P_6 (26.13), P_1 x P_7 (26.47), P_4 x P_5 (27.00), P_5 x P_7 (27.13), P_4 x P_6 (27.20) and P_2 x P_5 (27.27) were on par with P_2 x P_6. The mean of the check variety was 33.87.

4.1.2 Days to first female flower

The mean ranged from 44.53 (P_6) to 55.47 (P_5) among parents and P_6 was significantly superior to others. Among the hybrids, the mean values ranged from 35.27 (P_2 x P_6) to 43.13 (P_3 x P_4). The hybrids P_4 x P_6 (36.60), P_5 x P_7 (36.73) and P_5 x P_6 (36.80) were on par with P_2 x P_6. The check variety had a mean of 43.20.

Table 3 Mean performance of genotypes

Characters / Treatments	1 Days to first male flower	2 Days to first female flower	3 Days to first fruit harvest	4 Number of female flowers per plant	5 Number of fruits per plant	6 Mean weight of fruit (g)	7 Fruit yield per plant (kg)	8 Fruit length (cm)	9 Fruit girth (cm)	10 Flesh thickness (cm)	11 Number of seeds per fruit	12 100 seed weight (g)	13 Duration of the crop (days)
P_1	34.40	50.33	78.80	63.73	27.20	246.26	6.70	23.25	18.10	0.45	30.20	17.21	139.87
P_2	36.53	49.47	75.33	65.07	28.20	198.27	5.58	18.42	16.12	0.40	28.40	18.53	132.80
P_3	35.40	50.83	76.07	82.00	32.33	175.91	5.69	13.17	12.47	0.37	22.20	17.62	137.93
P_4	36.60	54.47	72.73	78.93	31.60	150.97	4.78	14.38	13.83	0.43	20.53	16.44	129.60
P_5	39.27	55.47	75.07	82.67	32.27	121.59	3.90	10.23	14.50	0.31	15.87	23.33	130.07
P_6	32.67	44.53	72.00	52.27	23.47	248.98	5.84	24.08	17.39	0.40	22.73	16.47	136.07
P_7	33.07	47.40	71.07	51.13	20.53	224.83	4.62	20.64	17.12	0.42	31.53	24.96	135.27
$P_1 \times P_2$	27.67	39.40	66.73	67.67	27.87	225.97	6.28	23.25	18.77	0.52	33.47	21.79	130.80
$P_1 \times P_3$	28.33	41.47	67.60	64.57	26.27	191.49	5.03	19.17	17.39	0.46	23.67	20.24	140.20
$P_1 \times P_4$	28.47	39.27	68.80	67.93	27.13	124.60	3.34	14.33	13.39	0.45	23.27	20.58	143.27
$P_1 \times P_5$	27.60	37.27	62.67	69.33	28.00	206.05	5.77	21.78	18.55	0.49	28.33	26.54	120.33
$P_1 \times P_6$	28.53	38.47	63.53	86.07	32.87	276.29	9.08	24.48	18.53	0.53	39.00	23.47	118.13
$P_1 \times P_7$	26.47	37.47	64.33	72.20	29.60	249.73	7.39	22.11	19.15	0.50	36.93	24.64	115.27
$P_2 \times P_3$	29.40	42.40	62.80	79.60	32.47	153.03	4.97	15.50	14.10	0.46	24.93	18.73	108.53
$P_2 \times P_4$	28.53	40.67	62.00	66.80	26.87	177.87	4.77	15.74	18.96	0.56	27.47	21.45	112.47
$P_2 \times P_5$	27.27	37.47	62.53	73.67	28.93	206.26	5.96	18.31	17.24	0.53	30.20	22.51	121.47
$P_2 \times P_6$	25.67	35.27	62.13	87.47	32.07	324.77	10.41	28.00	22.69	0.59	44.40	26.08	140.47
$P_2 \times P_7$	30.20	40.60	64.17	78.13	27.80	253.93	7.06	21.65	19.70	0.57	36.13	27.47	139.13

Table 3 Contd...

P_3 x P_4	29.60	43.13	63.93	78.27	27.40	108.73	2.98	12.55	10.37	0.44	16.27	12.27	122.47
P_3 x P_5	27.47	38.47	62.80	89.93	41.73	125.10	5.21	13.04	11.56	0.50	22.07	27.45	116.60
P_3 x P_6	27.53	38.27	62.60	75.13	29.93	229.33	6.87	18.86	17.32	0.53	31.60	24.53	126.47
P_3 x P_7	30.47	39.07	63.73	75.73	30.67	225.81	6.92	21.14	18.38	0.46	33.00	23.68	122.40
P_4 x P_5	27.00	42.33	63.80	75.53	22.27	126.23	2.81	10.09	13.91	0.45	19.53	19.60	114.73
P_4 x P_6	27.20	36.60	62.87	76.07	28.93	209.97	6.08	22.07	16.33	0.52	32.07	18.62	138.13
P_4 x P_7	29.53	41.47	64.67	82.40	30.13	126.07	3.79	13.83	15.30	0.52	24.00	21.39	130.27
P_5 x P_6	26.13	36.80	62.60	85.87	29.87	207.09	6.18	15.85	16.91	0.53	29.20	14.70	110.33
P_5 x P_7	27.13	36.73	62.67	84.40	28.13	175.07	4.93	16.19	18.85	0.49	22.13	27.34	105.93
P_6 x P_7	30.60	42.60	68.80	86.67	32.00	228.87	7.29	20.05	16.30	0.61	34.07	26.68	120.33
Check variety	33.87	43.20	73.00	58.67	23.27	223.60	5.18	20.99	18.07	0.48	28.53	26.55	127.87
MSE	0.978	1.156	1.754	5.456	3.584	16.854	0.125	0.460	0.324	0.0003	3.328	0.780	4.083
CD (5 %)	1.618	1.760	2.167	3.822	3.098	6.718	0.578	1.110	0.931	0.028	2.985	1.446	3.307
CD (1 %)	2.155	2.343	2.886	5.090	4.125	8.946	0.769	1.478	1.240	0.038	3.975	1.925	4.403

4.1.3 Days to first fruit harvest

The mean values for days to first fruit harvest ranged from 71.07 (P_7) to 78.80 (P_1) among the parents and P_6 (72.00) and P_4 (72.73) were on par with P_7. The hybrids exhibited a range from 62.00 (P_2 x P_4) to 68.80 (P_1 x P_4 and P_6 x P_7). Fourteen hybrids were on par with P_2 x P_4. The mean of the check variety was 73.00.

4.1.4 Number of female flowers per plant

Among the parents, minimum number of female flowers per plant was produced by P_7 (51.13) and the maximum by P_5 (82.67). The parents P_3 (82.00) and P_4 (78.93) were on par with P_5. Among the hybrids, the minimum number of female flowers was observed on P_1 x P_3 (64.57) and the maximum on P_3 x P_5 (89.93). The hybrids P_2 x P_6 (87.47) and P_6 x P_7 (86.67) were on par with P_3 x P_5. The check variety had a mean value of 58.67.

4.1.5 Number of fruits per plant

The minimum number of fruits per plant was observed on the parent P_7 (20.53) and the maximum on P_3 (32.33), whereas P_5 (32.27) and P_4 (31.60) were on par with P_3. Among the hybrids, P_4 x P_5 (22.27) showed the minimum number of fruits per plant while P_3 x P_5 (41.73) recorded the maximum number. None of the hybrids were on par with P_3 x P_5. The hybrids P_1 x P_6 (32.87), P_2 x P_3 (32.47), P_2 x P_6 (32.07) and P_6 x P_7 (32.00) also showed high mean values for the character. The check variety recorded a mean value of 23.27.

4.1.6 Mean weight of fruit

Among the parents, the lowest fruit weight was recorded in P_5 (121.59 g) and the highest in P_6 (248.98 g) while P_1 (246.26g) was on par with P_6. The hybrid P_3 x P_4 (108.73 g) showed the lowest mean fruit weight and the hybrid P_2 x P_6 (324.77 g) recorded the highest value. None of the hybrids were on par with P_2 x P_6. The hybrids P_1 x P_6 (276.29 g) and P_2 x P_7 (253.93 g) also exhibited high mean values. The mean fruit weight of the check variety was 223.60 g.

4.1.7 Fruit yield per plant

The fruit yield per plant was lowest in the parent P_5 (3.90 kg) and the highest in P_1 (6.70 kg) which was significantly superior to other parents. Among the hybrids, P_4 x P_5 (2.81 kg) was the lowest fruit yielder whereas P_2 x P_6 (10.41 kg) was the highest yielder. None of the hybrids were on par with P_2 x P_6. The hybrids P_1 x P_6 (9.08 kg), P_1 x P_7 (7.39 kg), P_6 x P_7 (7.29 kg) and P_2 x P_7 (7.06 kg) also produced high yields while the check variety yielded only 5.18 kg.

4.1.8 Fruit length

The parent P_5 (10.23 cm) recorded the minimum fruit length while the parent P_6 (24.08 cm) had fruits with maximum length and P_1 (23.25 cm) was on par with P_6. Among the hybrids, the fruits of P_4 x P_5 (10.09 cm) were the shortest and the fruits of P_2 x P_6 (28.00 cm) were the longest. None of the hybrids were on par with P_2 x P_6. The hybrids P_1 x P_6 (24.48 cm) and P_1 x P_2 (23.25 cm) were the other crosses with long fruits. The check variety had a fruit length of 20.99 cm.

4.1.9 Fruit girth

Among the parents, the fruit girth was minimum in the parent P_3 (12.47 cm) and maximum in P_1 (18.10 cm) while P_6 (17.39 cm) was on par with P_1. Among the hybrids, P_3 x P_4 (10.37 cm) had the minimum fruit girth whereas the fruits of the hybrid P_2 x P_6 (22.69 cm) showed the maximum girth. None of the other hybrids were on par with P_2 x P_6. The hybrids P_2 x P_7 (19.70 cm) and P_1 x P_7 (19.15 cm) also recorded high mean values whereas the fruits of the check variety recorded a girth of 18.07 cm.

4.1.10 Flesh thickness

The parent P_5 (0.31 cm) had fruits with minimum flesh thickness whereas the fruits of the parent P_1 (0.45 cm) had the maximum. The parents P_4 (0.43 cm) and P_7 (0.42 cm) were on par with P_1. Among the hybrids, P_3 x P_4 (0.44 cm) recorded the minimum flesh thickness of the fruit and the hybrid P_6 x P_7 (0.61 cm) showed the maximum flesh thickness. The hybrid P_2 x P_6 (0.59 cm) was on par with P_6 x P_7. The flesh thickness of the check variety was 0.48 cm.

4.1.11 Number of seeds per fruit

The parent P_5 (15.87) recorded minimum number of seeds per fruit and P_7 (31.53) had the maximum number. The parent P_1 (30.20) was on par with P_7. Among the hybrids, P_3 x P_4 (16.27) had the lowest number of seeds per fruit while P_2 x P_6 (44.40) recorded the maximum number of seeds per fruit. None of the hybrids were on par with P_2 x P_6. The number of seeds per fruit of the check variety was 28.53. The hybrids P_1 x P_6 (39.00), P_1 x P_7 (36.93) and P_2 x P_7 (36.13) also recorded a high value for number of seeds per fruit.

4.1.12 100 seed weight

100 seed weight was minimum in the parent P_4 (16.44 g) and maximum in parent P_7 (24.96 g). None of the parents were on par with P_7. In the hybrids, P_3 x P_4 (12.27 g) had the minimum 100 seed weight and P_2 x P_7 (27.47 g) had the maximum value. The hybrids P_3 x P_5, (27.45 g), P_5 x P_7 (27.34 g), P_6 x P_7 (26.68 g), P_1 x P_5 (26.54 g), P_2 x P_6 (26.08 g) and were on par with P_2 x P_7. 100 seed weight of check variety was 26.55 g.

4.1.13 Duration of the crop

Among the parents, P_4 (129.60 days) took the minimum number of days from sowing to harvest of the last fruit, whereas P_1 (139.87 days) recorded the maximum. The parents P_5 (130.07 days) and P_2 (132.80 days) were on par with P_4. In the hybrids, the shortest duration was recorded in P_5 x P_7 (105.93 days) and the longest duration in P_1 x P_4 (143.27 days). The hybrid P_2 x P_3 (108.53 days) was on par with P_5 x P_7. The duration of check variety was 127.87 days.

4.1.14 Colour of the fruit

The different genotypes were graded for fruit colour with respect to a score ranging from 1 to 4 (Plate 1).

The parents P_1, P_5, P_6 and P_7 were grouped under score 3 (light green), P_3 and P_4 under score 4 (whitish green) and P_2 under score 1 (dark green). Seventeen hybrids showed a score of 3, three showed a score of 4 and one hybrid had score 2. The check variety had a score of 3. The score for parents, hybrids and check variety are given in Table 4.

Plate 1 Variation in fruit colour

Score 1 - Dark green

2 - Green

3 - Light green

4 - Whitish green

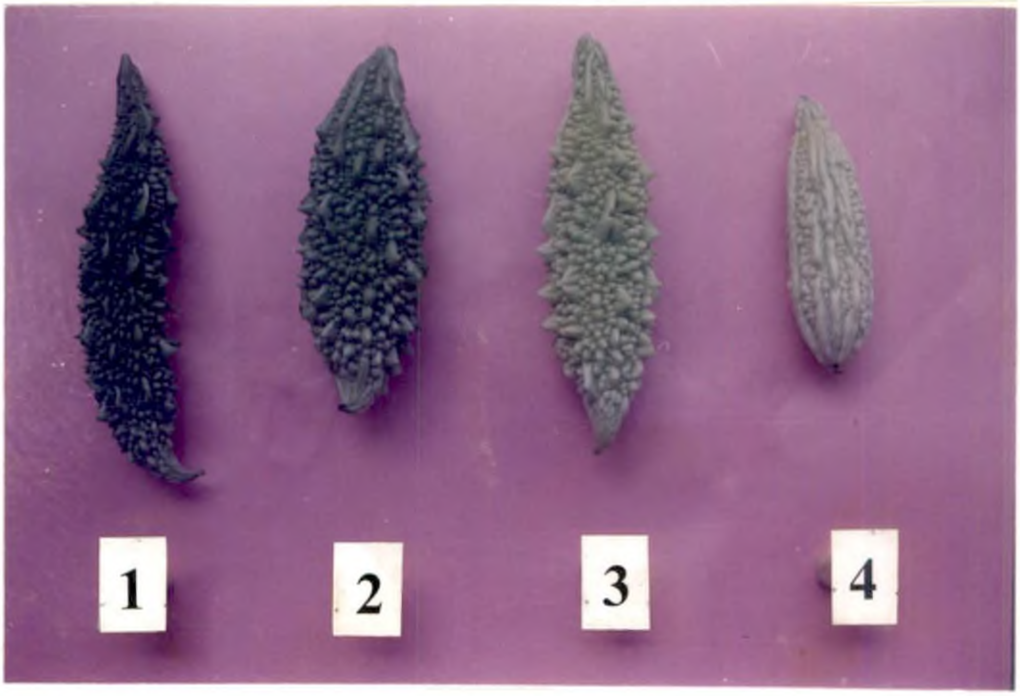


Plate 1

Table 4 Colour of the fruit

Sl. No.	Treatments	Score
1	P_1	3
2	P_2	1
3	P_3	4
4	P_4	4
5	P_5	3
6	P_6	3
7	P_7	3
8	$P_1 \times P_2$	4
9	$P_1 \times P_3$	3
10	$P_1 \times P_4$	2
11	$P_1 \times P_5$	3
12	$P_1 \times P_6$	3
13	$P_1 \times P_7$	3
14	$P_2 \times P_3$	3
15	$P_2 \times P_4$	3
16	$P_2 \times P_5$	3
17	$P_2 \times P_6$	3
18	$P_2 \times P_7$	3
19	$P_3 \times P_4$	4
20	$P_3 \times P_5$	3
21	$P_3 \times P_6$	3
22	$P_3 \times P_7$	3
23	$P_4 \times P_5$	3
24	$P_4 \times P_6$	3
25	$P_4 \times P_7$	4
26	$P_5 \times P_6$	3
27	$P_5 \times P_7$	3
28	$P_6 \times P_7$	3
29	Check variety	3

4.1.15 Incidence of pests and diseases

No significant incidence of pests or diseases were noticed in the crop in any of the growth stages. Hence no scoring for pests and disease incidence was carried out.

4.2 Phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h^2) and genetic advance (GA)

PCV, GCV, heritability and genetic advance were calculated and presented in Table 5.

The highest value for PCV was noticed for fruit yield per plant (29.83) and the lowest value for days to first fruit harvest (7.82). The characters weight of fruit (26.82), fruit length (25.08) and number of seeds per fruit (24.84) also showed high values for PCV. GCV ranged from 7.56 for days to first fruit harvest to 29.18 for fruit yield per plant. High values for GCV were also noticed for mean weight of fruit (26.74), fruit length (24.81) and number of seeds per fruit (23.97).

Heritability values ranged from 80.5 for number of fruits per plant to 99.4 for mean weight of fruit. All the characters showed high heritability values.

Fruit yield per plant (58.73 per cent) had the highest genetic advance and days to first fruit harvest (15.07 per cent) had the least genetic advance. All the characters have recorded high values for genetic advance, except days to first fruit harvest (15.07 per cent) and duration of the crop (17.29 per cent).

Table 5 PCV, GCV, heritability (in percentage) and genetic advance (in percentage) of different characters

Sl. No.	Characters	PCV	GCV	$h^2_{(b)}$ (%)	GA (%)
1.	Days to first male flower	12.30	11.85	92.9	23.53
2.	Days to first female flower	13.18	12.93	96.2	26.12
3.	Days to first fruit harvest	7.82	7.56	93.6	15.07
4.	Number of female flowers per plant	14.04	13.69	95.0	27.48
5.	Number of fruits per plant	14.82	13.30	80.5	24.59
6.	Mean weight of fruit	26.82	26.74	99.4	54.93
7.	Fruit yield per plant	29.83	29.18	95.7	58.73
8.	Fruit length	25.08	24.81	97.8	50.52
9.	Fruit girth	16.56	16.20	95.7	32.66
10.	Flesh thickness	13.97	13.50	93.4	26.97
11.	Number of seeds per fruit	24.84	23.97	93.1	47.66
12.	100 seed weight	19.57	19.14	95.7	38.57
13.	Duration of the crop	8.69	8.54	96.6	17.29

4.3 Combining ability analysis

The analysis of variance for 28 treatments excluding the check variety showed significant differences among the treatments, for all the characters studied (Appendix II). Hence, the data were subjected to combining ability analysis.

The analysis of variance for combining ability was carried out for 13 characters studied (Appendix III). GCA and SCA variances were found to be significant for all the characters. The general combining ability effects of parents and specific combining ability effects of the hybrids for 13 characters are given in Tables 6 and 7 respectively.

4.3.1 Days to first male flower

Among the parents, significant negative GCA effects were shown by P_6 (-0.96) and P_1 (-0.42) and they were on par. Significant positive GCA effects were shown by P_3 (0.44) and P_4 (0.43). The hybrid P_6 x P_7 (1.51) showed significant positive SCA effect, whereas all the other hybrids except P_1 x P_6, P_2 x P_7 and P_3 x P_7 showed significant negative SCA effects. The hybrid P_2 x P_6 (-3.57) showed the highest significant negative SCA effect. Eight hybrids were on par with P_2 x P_6 (Fig.1).

4.3.2 Days to first female flower

Significant negative GCA effects were shown by the parents P_6 (-2.16) and P_7 (-0.42), while P_4 (1.76) and P_3 (0.88) recorded significant positive GCA

Table 6 The general combining ability effects of parents for various characters

Characters / Treatments	1 Days to first male flower	2 Days to first female flower	3 Days to first fruit harvest	4 Number of female flowers per plant	5 Number of fruits per plant	6 Mean weight of fruit	7 Fruit yield per plant	8 Fruit length	9 Fruit girth	10 Flesh thickness	11 Number of seeds per fruit	12 100 seed weight	13 Duration of the crop
P_1	-0.42*	-0.24 ^{NS}	1.99**	-4.95**	-0.80*	21.09**	0.50**	2.81**	1.07**	0.00 ^{NS}	2.37**	-0.11 ^{NS}	4.06**
P_2	0.24 ^{NS}	-0.20 ^{NS}	-0.26 ^{NS}	-1.81**	-0.10 ^{NS}	17.94**	0.54**	1.44**	1.26**	0.02**	3.29**	0.27 ^{NS}	0.80*
P_3	0.44*	0.88**	0.25 ^{NS}	3.05**	2.20**	-21.29**	-0.27**	-2.19**	-2.03**	-0.03**	-3.09**	-1.17**	0.14 ^{NS}
P_4	0.43*	1.76**	-0.21 ^{NS}	0.57 ^{NS}	-0.82*	-44.61**	-1.38**	-3.22**	-1.83**	-0.01**	-4.46**	-2.87**	1.03**
P_5	0.17 ^{NS}	0.38 ^{NS}	-0.69**	4.92**	1.13**	-31.99**	-0.79**	-3.40**	-0.70**	-0.03**	-4.51**	1.35**	-6.86**
P_6	-0.96**	-2.16**	-0.76**	0.22 ^{NS}	-0.08 ^{NS}	44.16**	1.31**	3.46**	1.17**	0.03**	3.56**	-0.63**	1.64**
P_7	0.10 ^{NS}	-0.42*	-0.32 ^{NS}	-2.00**	-1.54**	14.70**	0.09 ^{NS}	1.10**	1.06**	0.02**	2.84**	3.16**	-0.82*
SE (g_i)	0.1785	0.1911	0.2370	0.4111	0.3415	0.7431	0.0635	0.1219	0.1032	0.0031	0.3266	0.1596	0.3581
CD (5 %)	0.3581	0.3834	0.4755	0.8248	0.6852	1.4910	0.1274	0.2446	0.2071	0.0062	0.6553	0.3202	0.7185
CD (1 %)	0.4772	0.5109	0.6336	1.0990	0.9129	1.9870	0.1698	0.3259	0.2759	0.0083	0.8731	0.4266	0.9573
SE (g_i - g_j)	0.2726	0.2919	0.3621	0.6279	0.5215	1.1351	0.0971	0.1862	0.1576	0.0047	0.4989	0.2437	0.5469
CD (5 %)	0.5469	0.5856	0.7265	1.2598	1.0460	2.2770	0.1948	0.3736	0.3162	0.0094	1.0009	0.4889	1.0970
CD (1 %)	0.7287	0.7803	0.9680	1.6790	1.3941	3.0340	0.2596	0.4977	0.4213	0.0126	1.3340	0.6515	1.4620

** Significant at 1 per cent level   * Significant at 5 per cent level   NS - Non significant

Table 7 The specific combining ability effects of hybrids

Characters / Treatments	1 Days to first male flower	2 Days to first female flower	3 Days to first fruit harvest	4 Number of female flowers per plant	5 Number of fruits per plant	6 Mean weight of fruit	7 Fruit yield per plant	8 Fruit length	9 Fruit girth	10 Flesh thickness	11 Number of seeds per fruit	12 100 seed weight	13 Duration of the crop
P_1 x P_2	-2.11**	-2.23**	-1.67**	-0.54 NS	-0.40 NS	-10.17**	-0.48**	0.71*	-0.10 NS	0.02*	-0.16 NS	0.05 NS	-0.46 NS
P_1 x P_3	-1.64**	-1.24*	-1.31*	-8.51**	-4.30**	-5.42**	-0.93**	0.26 NS	1.81**	0.01 NS	-3.58**	-0.06 NS	9.60**
P_1 x P_4	-1.50**	-4.33**	0.35 NS	-2.65*	-0.41 NS	-48.99**	-1.50**	-3.55**	-2.40**	-0.03**	-2.61**	1.99**	11.77**
P_1 x P_5	-2.10**	-4.95**	-5.31**	-5.61**	-1.50 NS	19.85**	0.34*	4.08**	1.64**	0.04**	2.50**	3.72**	-3.27**
P_1 x P_6	-0.04NS	-1.20*	-4.37**	15.82**	4.58**	13.94**	1.54**	-0.08 NS	-0.25 NS	0.02*	5.10**	2.62**	-13.97**
P_1 x P_7	-3.17**	-3.94**	-4.01**	4.18**	2.78**	16.84**	1.08**	-0.09 NS	0.47 NS	0.00 NS	3.76**	0.00 NS	-14.37**
P_2 x P_3	-1.24**	-0.35 NS	-3.86**	3.39**	1.20 NS	-40.73**	-1.02**	-2.04**	-1.67**	-0.01 NS	-3.24**	-1.95**	-18.82**
P_2 x P_4	-2.09**	-2.96**	-4.21**	-6.93**	-1.38 NS	7.43**	-0.11 NS	-0.77*	2.98**	0.06**	0.66 NS	2.47**	-15.77**
P_2 x P_5	-3.09**	-4.78**	-3.19**	-4.41**	-1.26 NS	23.19**	0.49**	1.98**	0.14 NS	0.06**	3.44**	-0.69 NS	1.11 NS
P_2 x P_6	-3.57**	-4.44**	-3.52**	14.08**	3.08**	65.56**	2.84**	4.81**	3.72**	0.06**	9.58**	4.85**	11.62**
P_2 x P_7	-0.09 NS	-0.84 NS	-1.93**	6.97**	0.28 NS	24.18**	0.71**	0.82**	0.83**	0.05**	2.03*	2.46**	12.74**
P_3 x P_4	-1.23**	-1.58**	-2.78**	-0.32 NS	-3.15**	-22.49**	-1.09**	-0.33 NS	-2.31**	-0.01 NS	-4.16**	-5.27**	-5.11**
P_3 x P_5	-3.09**	-4.87**	-3.43**	6.99**	9.24**	-18.74**	0.55**	0.34 NS	-2.25**	0.07**	1.70*	5.69**	-3.09**
P_3 x P_6	-1.09*	-2.52**	-3.56**	-3.11**	-1.36 NS	9.35**	0.10 NS	-0.70*	1.64**	0.05**	3.16**	4.75**	-1.72 NS
P_3 x P_7	-0.03 NS	-3.46**	-2.87**	-0.29 NS	0.84 NS	35.29**	1.38**	3.94**	2.81**	-0.01 NS	5.28**	0.10 NS	-3.33**
P_4 x P_5	-3.55**	-1.88**	-1.98**	-4.92**	-7.21**	5.71**	-0.74**	-1.58**	-0.11 NS	0.00 NS	0.53 NS	-0.46 NS	-5.85**
P_4 x P_6	-2.23**	-5.07**	-2.84**	0.30 NS	0.67 NS	13.31**	0.43**	3.53**	0.44 NS	0.01 NS	4.99**	0.54 NS	9.06**
P_4 x P_7	-0.95*	-1.94**	-1.48*	8.86**	3.33**	-41.13**	-0.64**	-2.35**	-0.48 NS	0.03**	-2.36**	-0.48 NS	3.65**

Table 7 Contd...

P_5 x P_6	-3.03**	-3.49**	-2.63**	5.75**	-0.35^{NS}	-2.19^{NS}	-0.06^{NS}	-2.50**	-0.10^{NS}	0.05**	2.18**	-7.60**	-10.86**
P_5 x P_7	-3.09**	-5.30**	-3.00**	6.50**	-0.61^{NS}	-4.75*	-0.10^{NS}	0.20^{NS}	1.95**	0.02*	-4.17**	1.25**	-12.80**
P_6 x P_7	1.51**	3.12**	3.21**	13.47**	4.46**	-27.10**	0.16^{NS}	-2.80**	-2.47**	0.09**	-0.30^{NS}	2.56**	-6.89**
SE (S_{ij})	0.4417	0.4729	0.5866	1.0173	0.8449	1.8391	0.1572	0.3016	0.2553	0.0075	0.8083	0.3949	0.8861
CD (5 %)	0.8862	0.9488	1.1769	2.0410	1.6950	3.6898	0.3154	0.6051	0.5122	0.0151	1.6217	0.7923	1.7780
CD (1 %)	1.1810	1.2640	1.5680	2.7195	2.2590	4.9160	0.4202	0.8062	0.6825	0.0201	2.1610	1.0560	2.3690
SE (S_{ij} - S_{ik})	0.7710	0.8254	1.0240	1.7759	1.4750	3.2105	0.2744	0.5265	0.4457	0.0132	1.4111	0.6894	1.5468
CD (5 %)	1.5469	1.6560	2.0550	3.5630	2.9590	6.4410	0.5505	1.0560	0.8940	0.0270	2.8310	1.3830	3.1030
CD (1 %)	2.0610	2.2060	2.7370	4.7470	3.9430	8.5820	0.7335	1.4070	1.1920	0.0353	3.7720	1.8430	4.1350
SE (S_{ij} - S_{kl})	0.7213	0.7721	0.9579	1.6612	1.3798	3.0031	0.2568	0.4924	0.4169	0.0123	1.3200	0.6449	1.4469
CD (5 %)	1.4470	1.5490	1.9220	3.3330	2.7680	6.0250	0.5152	0.9879	0.8364	0.0248	2.6480	1.2940	2.9030
CD (1 %)	1.9280	2.0640	2.5610	4.4410	3.6890	8.0280	0.6865	1.3163	1.1150	0.0329	3.5290	1.7240	3.8680

** Significant at 1 per cent level * Significant at 5 per cent level NS - Non significant effects. The parent P_6 was significantly superior to other parents. The hybrid P_6 x P_7 (3.12) had a significant positive SCA effect. All the other hybrids except P_2 x P_7 and P_2 x P_3 had significant negative SCA effects. The highest significant negative SCA effect was shown by P_5 x P_7 (-5.30) and seven hybrids were found to be on par with it (Fig. 2).

4.3.3 Days to first fruit harvest

In the parents, P_6 (-0.76) and P_5 (-0.69) were on par and had significant negative GCA effects, while P_1 (1.99) had significant positive GCA effect. Among the hybrids, P_6 x P_7 (3.21) had a significant positive SCA effect, while all the other hybrids, except P_1 x P_4 recorded significant negative SCA effects. The highest significant negative SCA effect was recorded by P_1 x P_5 (-5.31) and seven hybrids were on par with P_1 x P_5 (Fig. 3).

4.3.4 Number of female flowers per plant

Significant positive GCA effects were observed in the parents P_5 (4.92) and P_3 (3.05) and were on par. The parents P_1 (-4.95), P_7 (-2.00) and P_2 (-1.81) had significant negative GCA effects. In the hybrids, P_1 x P_6 (15.82), P_2 x P_6 (14.08), P_6 x P_7 (13.47), P_4 x P_7 (8.86), P_3 x P_5 (6.99), P_2 x P_7 (6.97), P_5 x P_7 (6.50); P_5 x P_6 (5.75), P_1 x P_7 (4.18) and P_2 x P_3 (3.39) had significant positive SCA effects whereas all other hybrids except P_1 x P_2, P_3 x P_4, P_3 x P_7 and P_4 x P_6 had significant negative SCA effects. The hybrids P_2 x P_6 (14.08) and P_6 x P_7 (13.47) were on par with P_1 x P_6 (Fig. 4).

4.3.5 Number of fruits per plant

Among the parents, P_3 (2.20) and P_5 (1.13) showed significant positive GCA effects, while P_7 (-1.54), P_4 (-0.82) and P_1 (-0.80) showed significant negative GCA effects. The parent P_3 was significantly superior to others. Among the hybrids, P_4 x P_5 (-7.21), P_1 x P_3 (-4.30) and P_3 x P_4 (-3.15) have recorded significant negative SCA effects. The hybrids P_3 x P_5 (9.24), P_1 x P_6 (4.58), P_6 x P_7 (4.46), P_4 x P_7 (3.33), P_2 x P_6 (3.08) and P_1 x P_7 (2.78) showed significant positive SCA effect. None of the hybrids were on par with P_3 x P_5 (Fig. 5).

4.3.6 Mean weight of fruit

All the parents showed significant GCA effects, of which P_6 (44.16), P_1 (21.09), P_2 (17.94) and P_7 (14.70) had significant positive GCA effects, whereas the parents P_4 (-44.61), P_5 (-31.99) and P_3 (-21.29) had significant negative GCA effects. The parent P_6 was significantly superior to all other parents. All the hybrids except P_5 x P_6 showed significant SCA effects. The hybrids P_2 x P_6 (65.56), P_3 x P_7 (35.29), P_2 x P_7 (24.18), P_2 x P_5 (23.19), P_1 x P_5 (19.85), P_1 x P_7 (16.84), P_1 x P_6 (13.94), P_4 x P_6 (13.31), P_3 x P_6 (9.35), P_2 x P_4 (7.43) and P_4 x P_5 (5.71) showed significant positive SCA effects. The other crosses exhibited significant negative SCA effects. The hybrid P_2 x P_6 (65.56) exhibited the highest significant positive SCA effect and none of the hybrids were on par with it (Fig. 6).

Fig. 1 GCA and SCA - days to first male flower

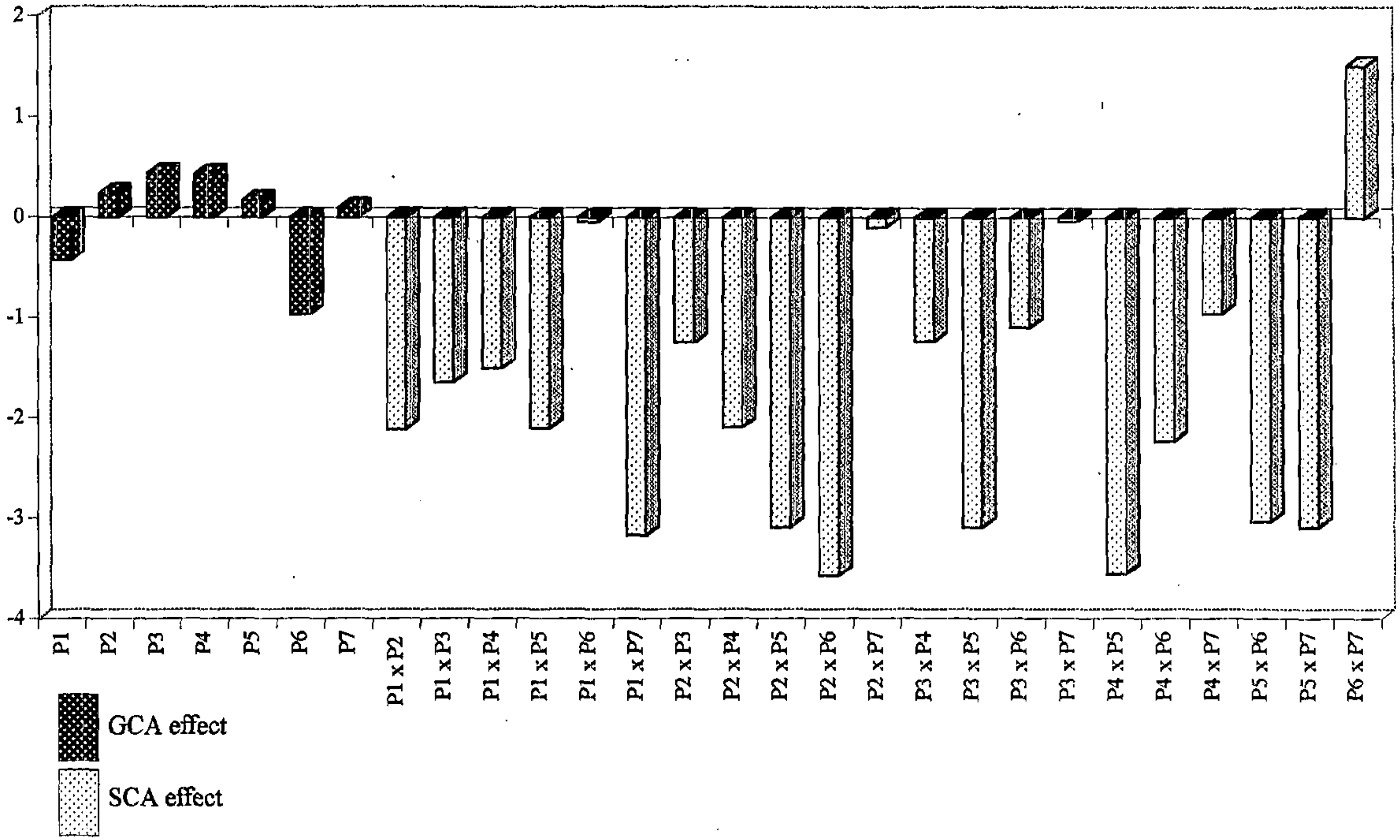


Fig. 2 GCA and SCA - days to first female flower

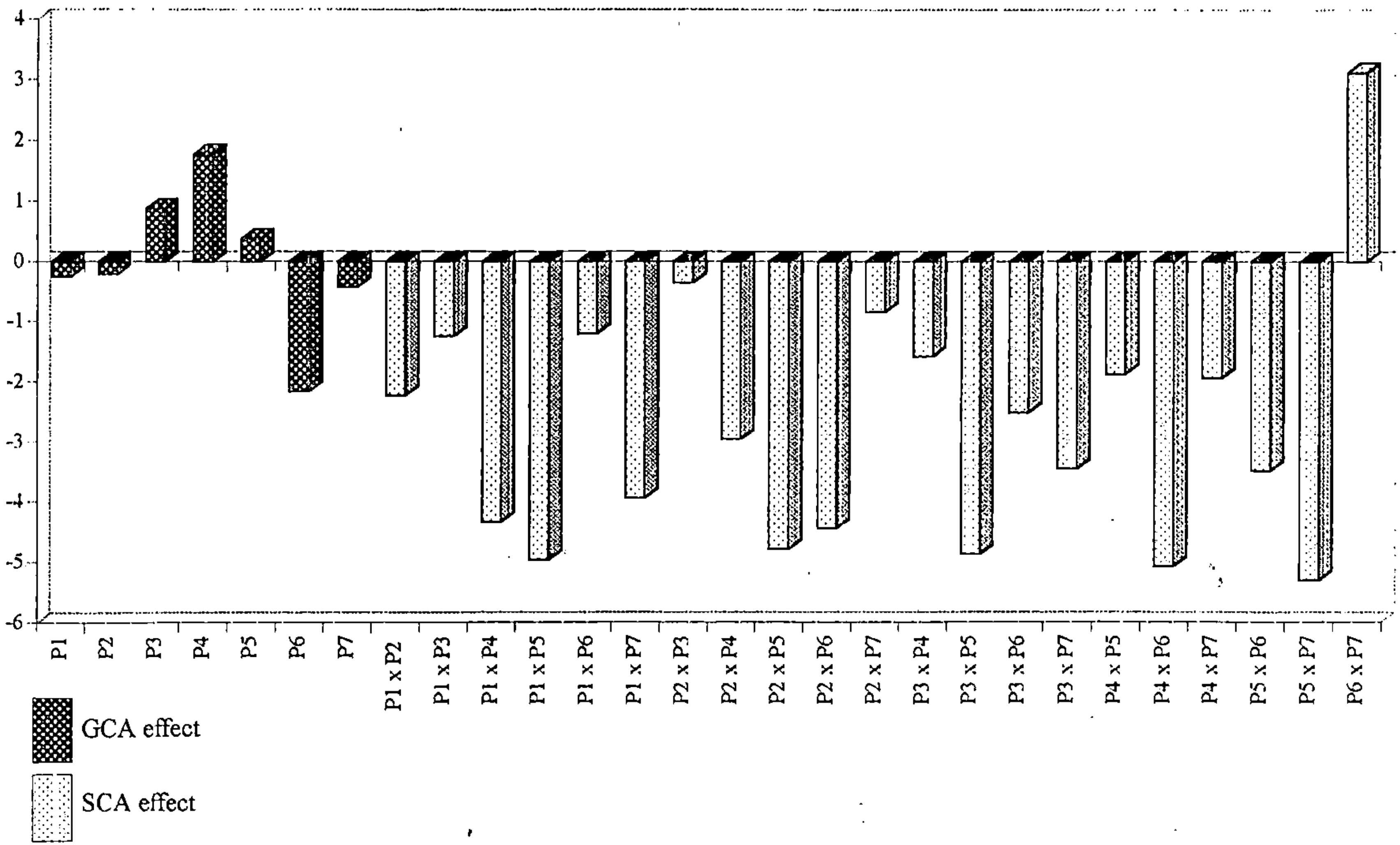


Fig. 3 GCA and SCA - days to first fruit harvest

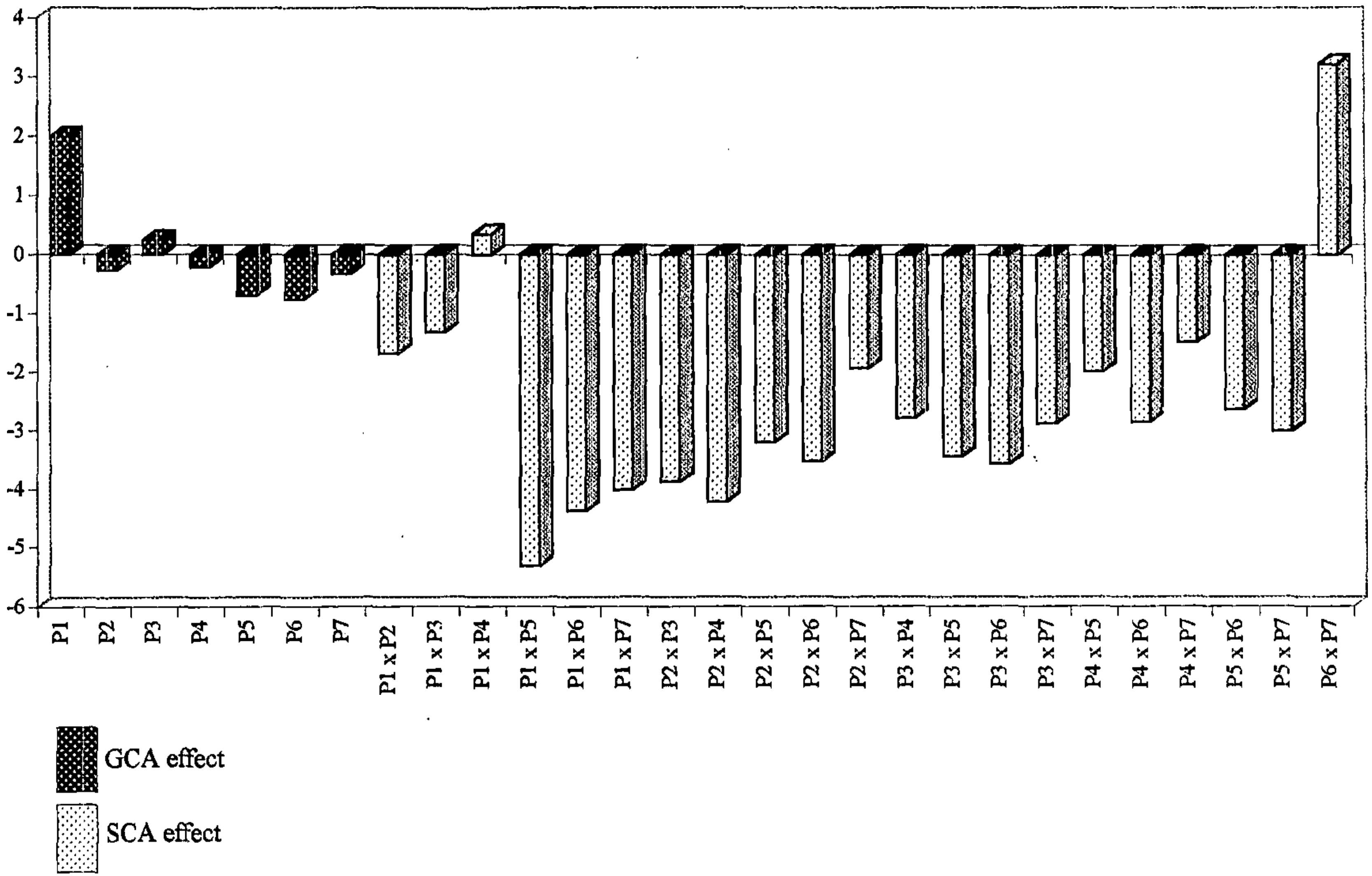


Fig. 4 GCA and SCA - number of female flowers per plant

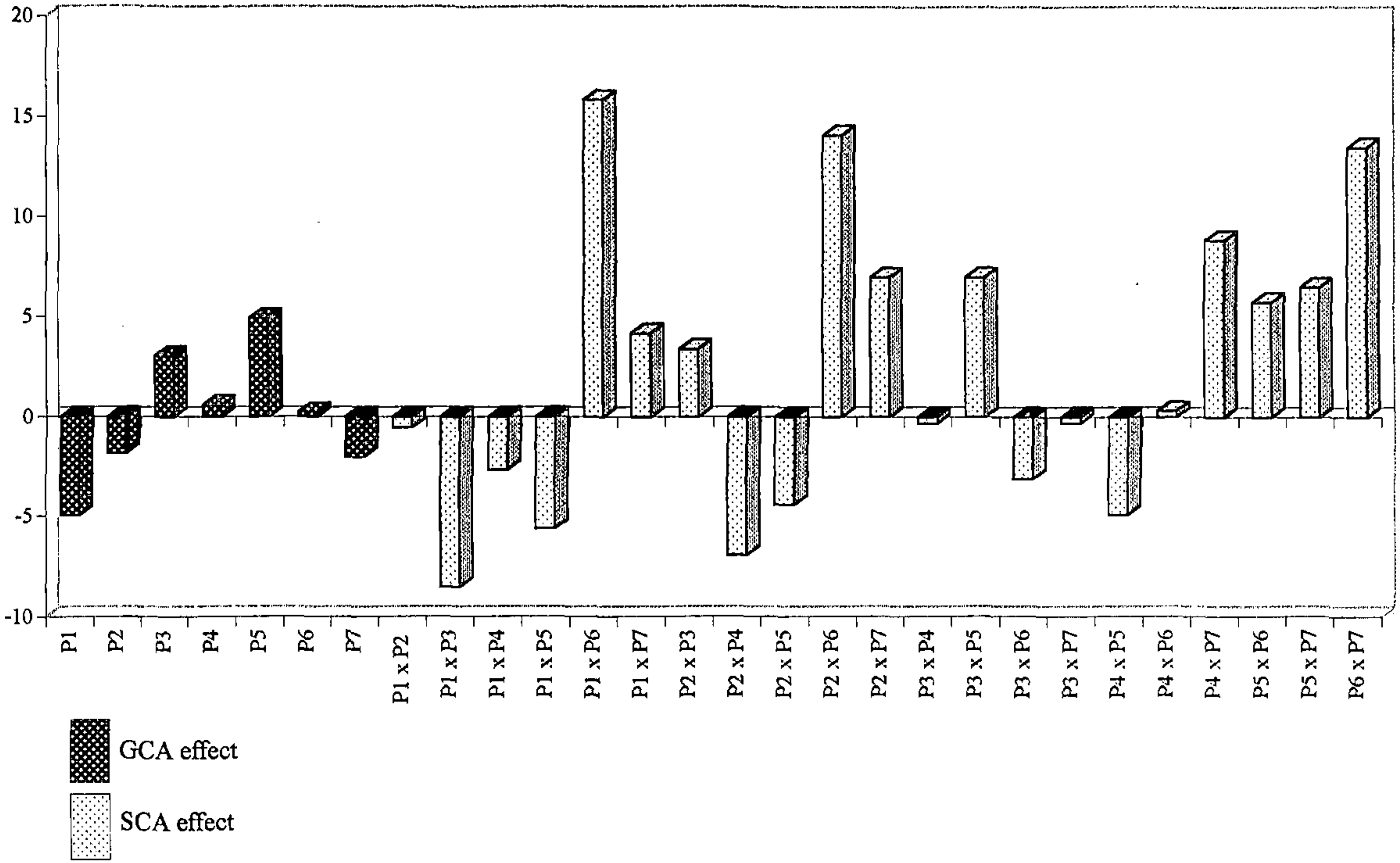


Fig. 5 GCA and SCA - number of fruits per plant

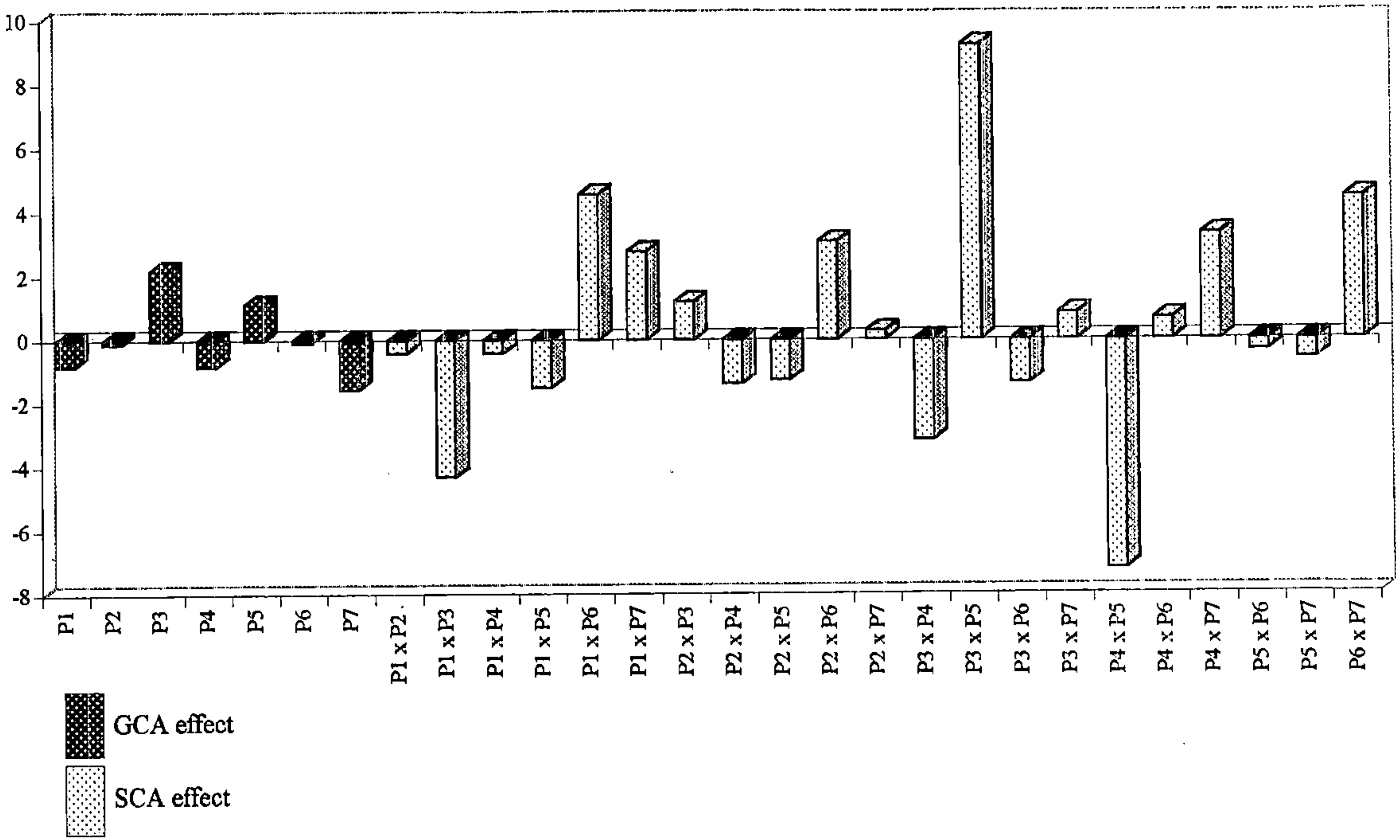


Fig. 6 GCA and SCA - mean weight of fruit

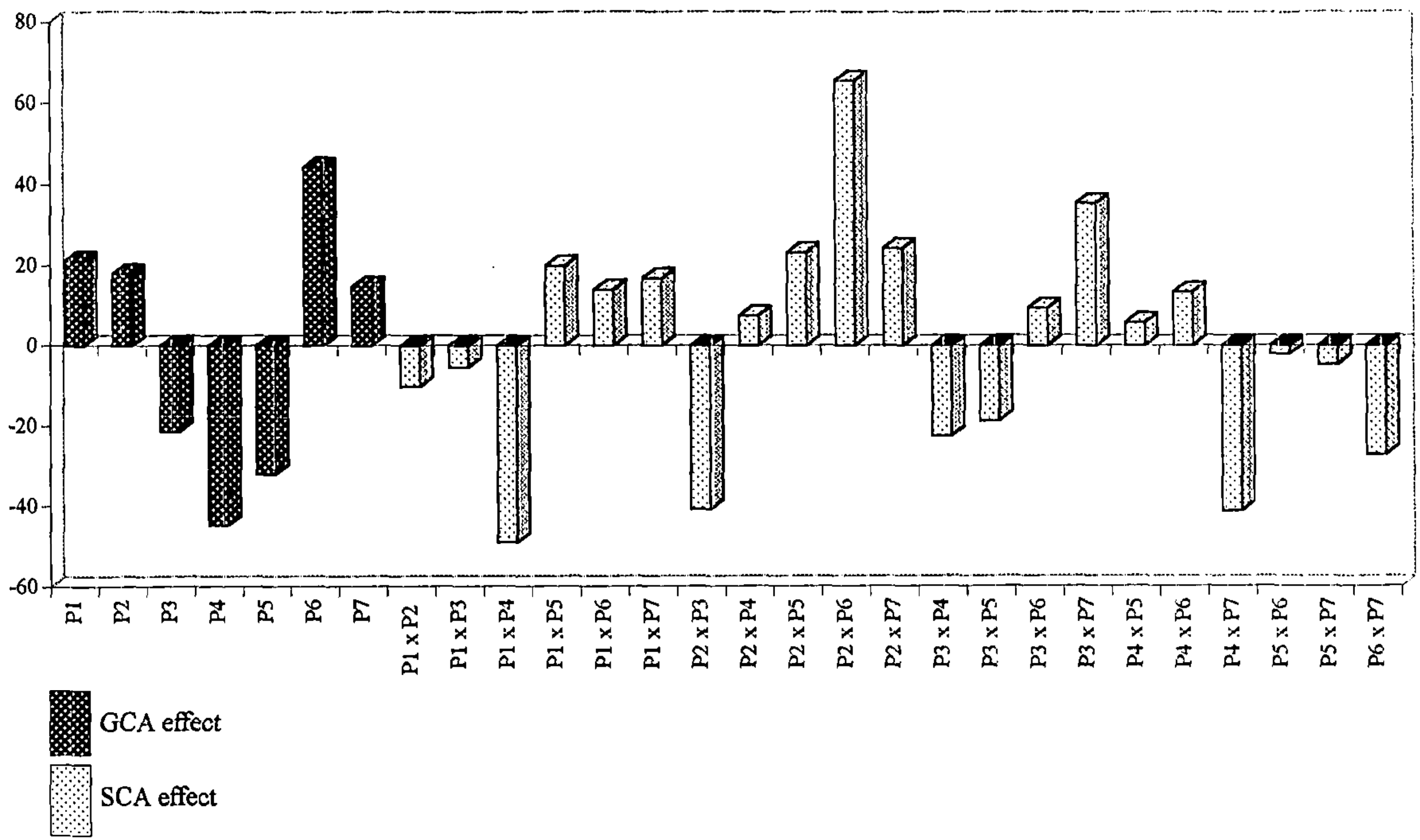


Fig. 7 GCA and SCA - fruit yield per plant

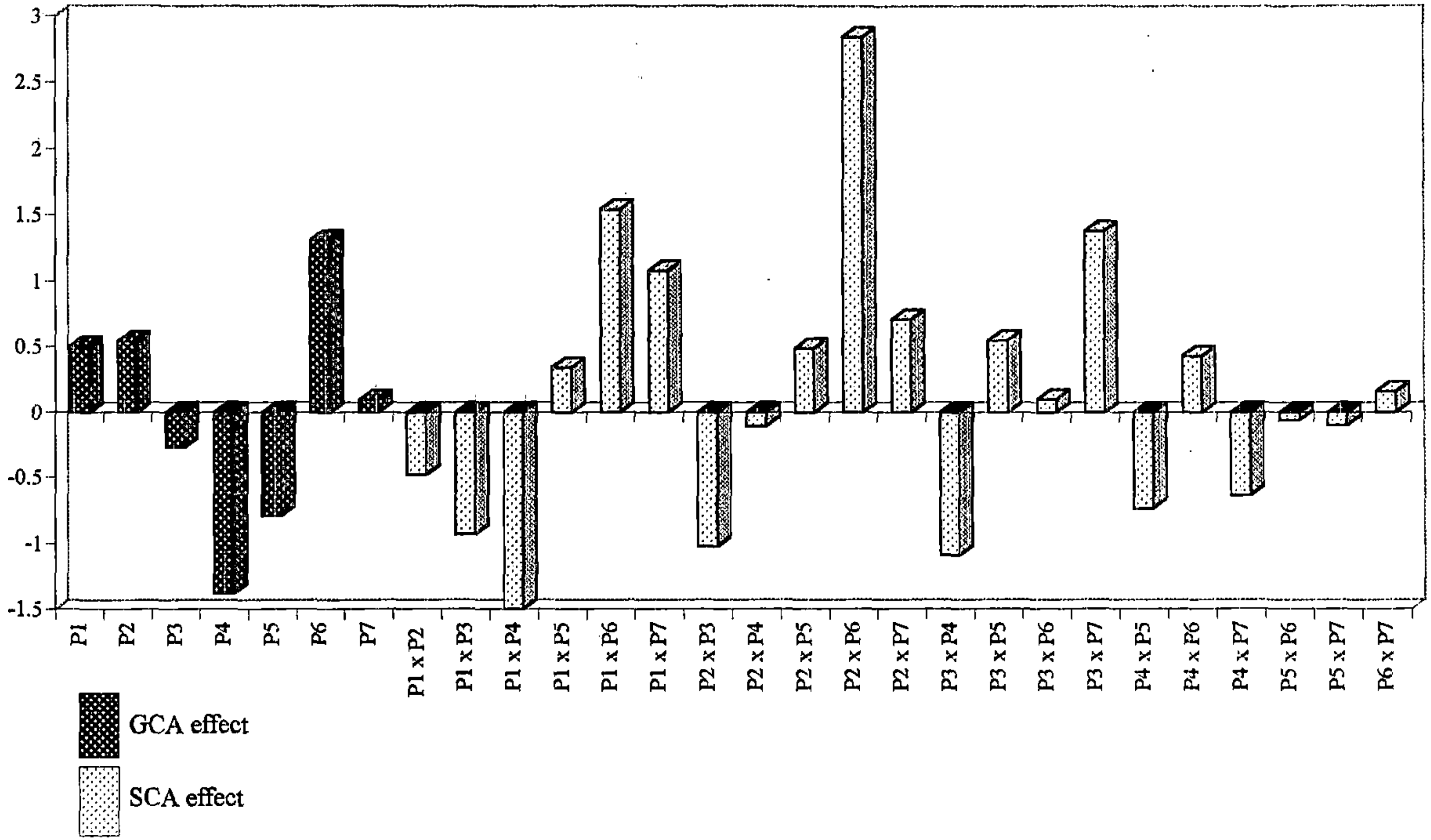


Fig. 8 GCA and SCA - fruit length

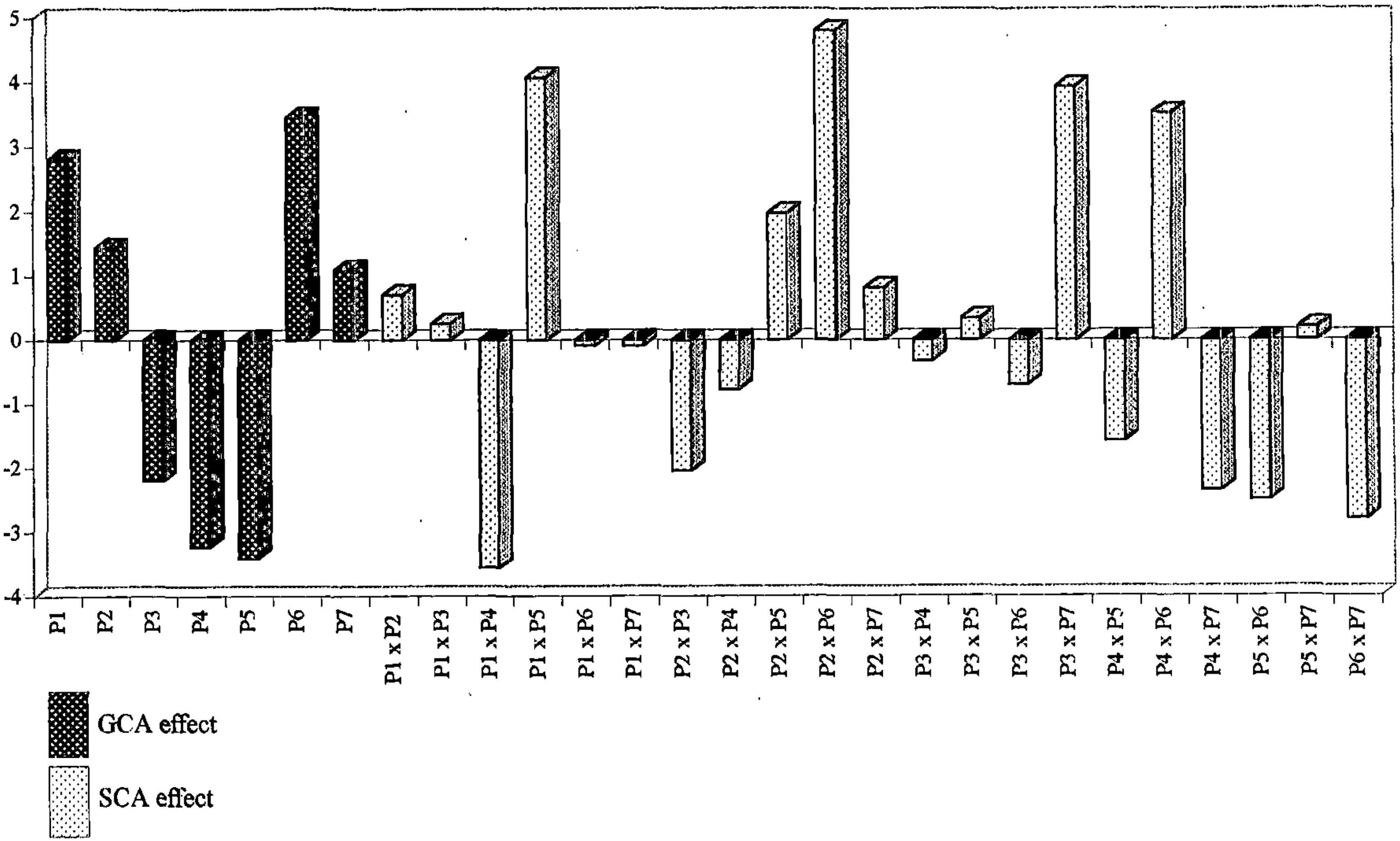


Fig. 9 GCA and SCA - fruit girth

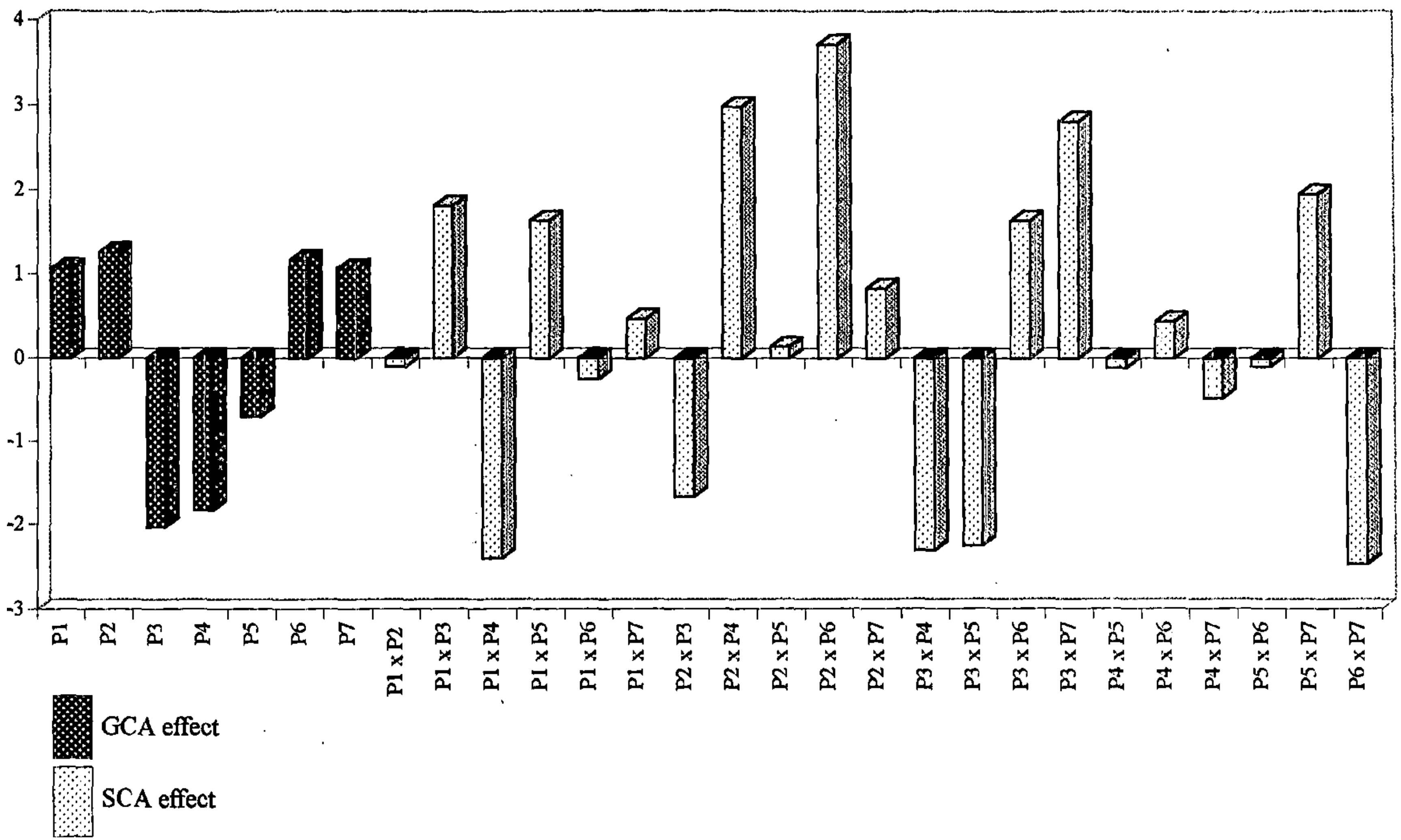


Fig. 10 GCA and SCA - flesh thickness

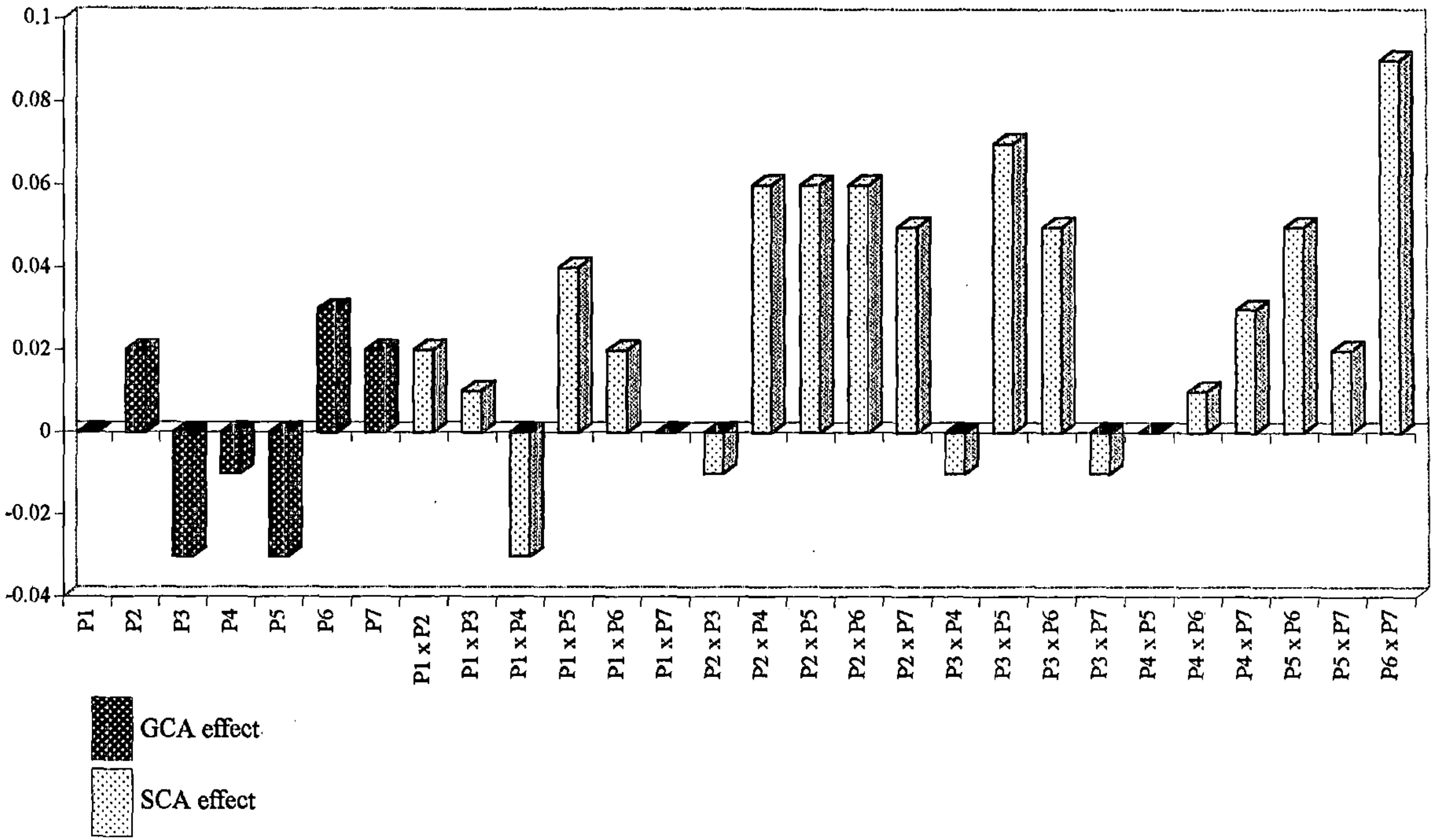


Fig. 11 GCA and SCA - number of seeds per fruit

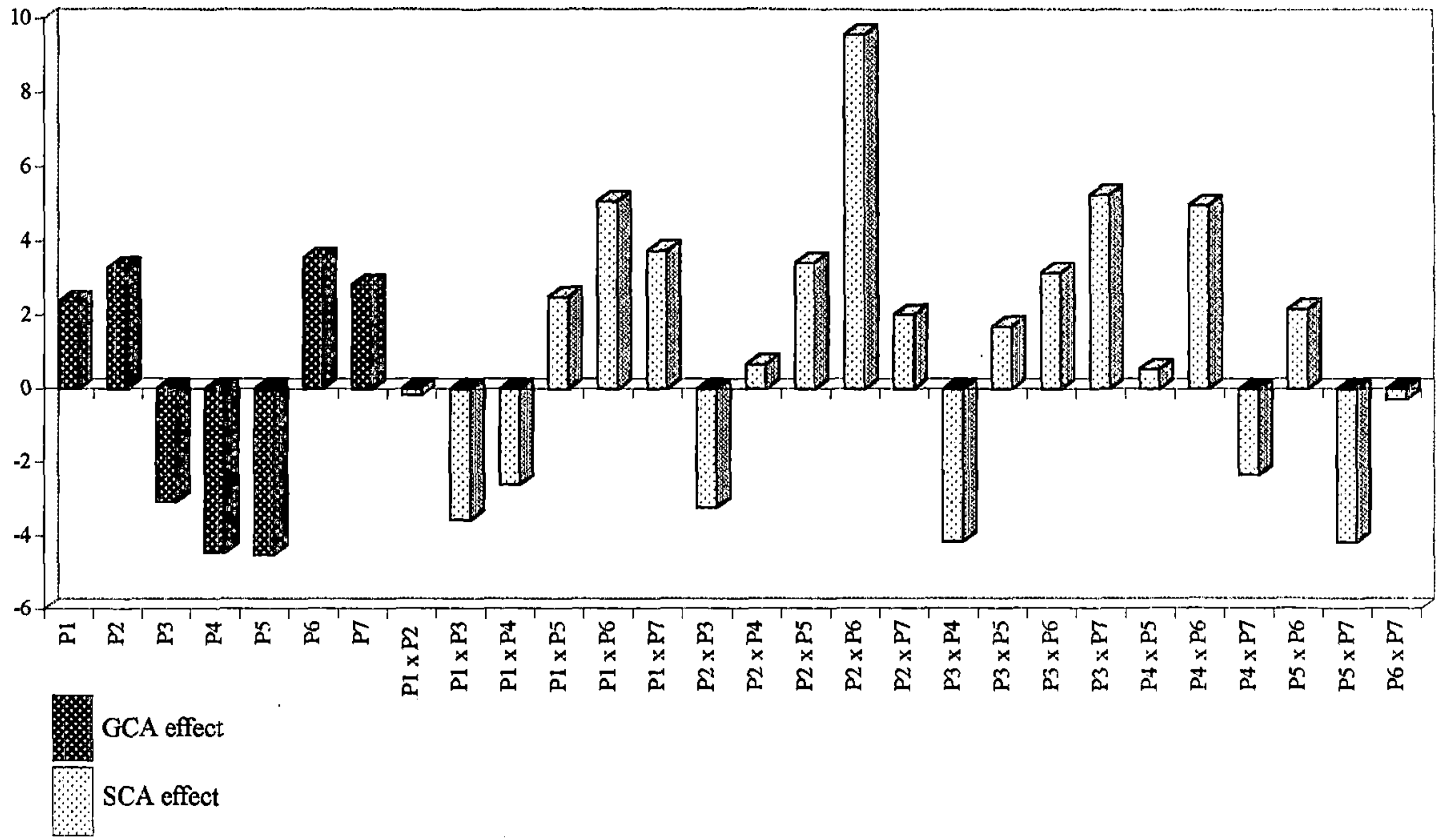


Fig. 12 GCA and SCA - 100 seed weight

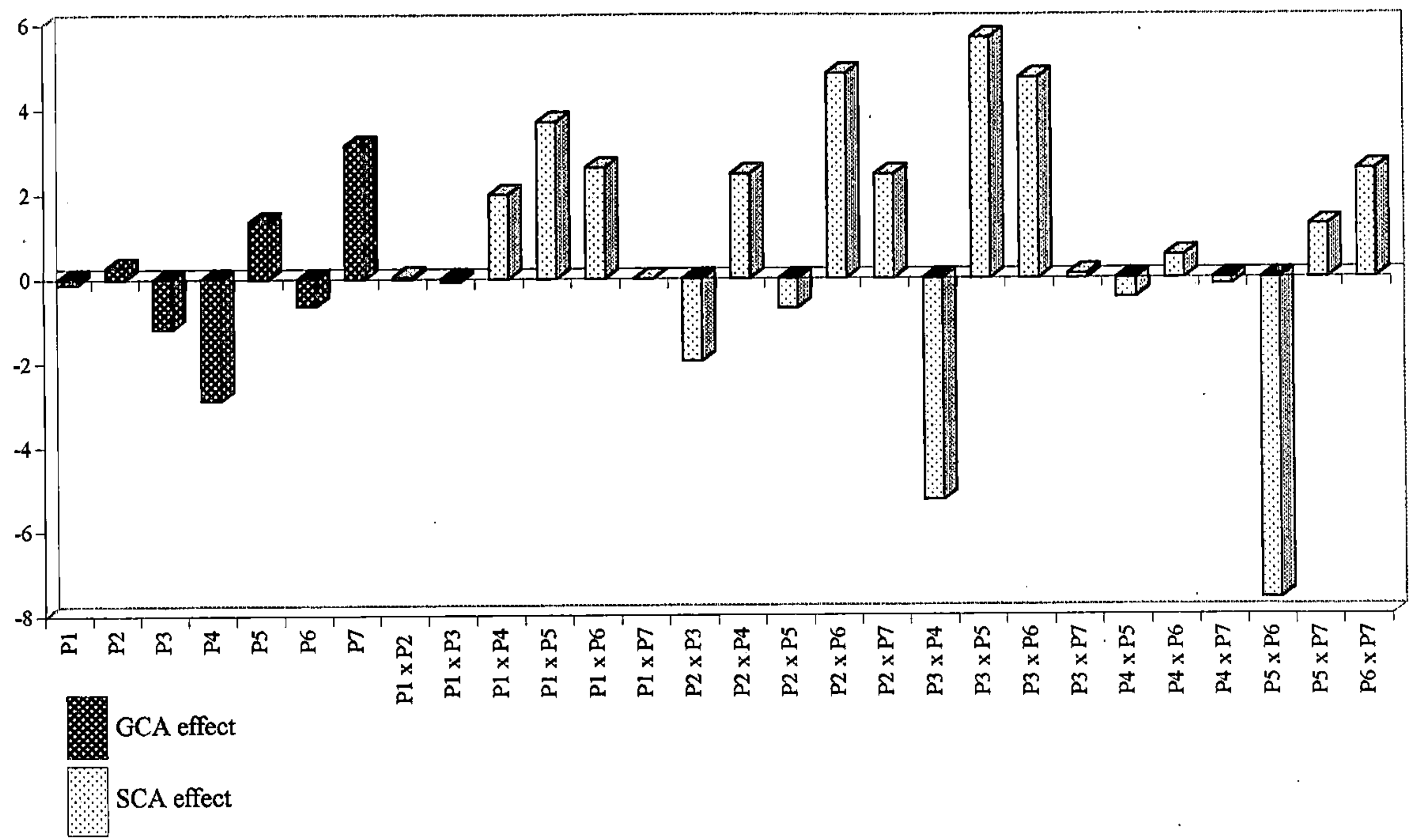
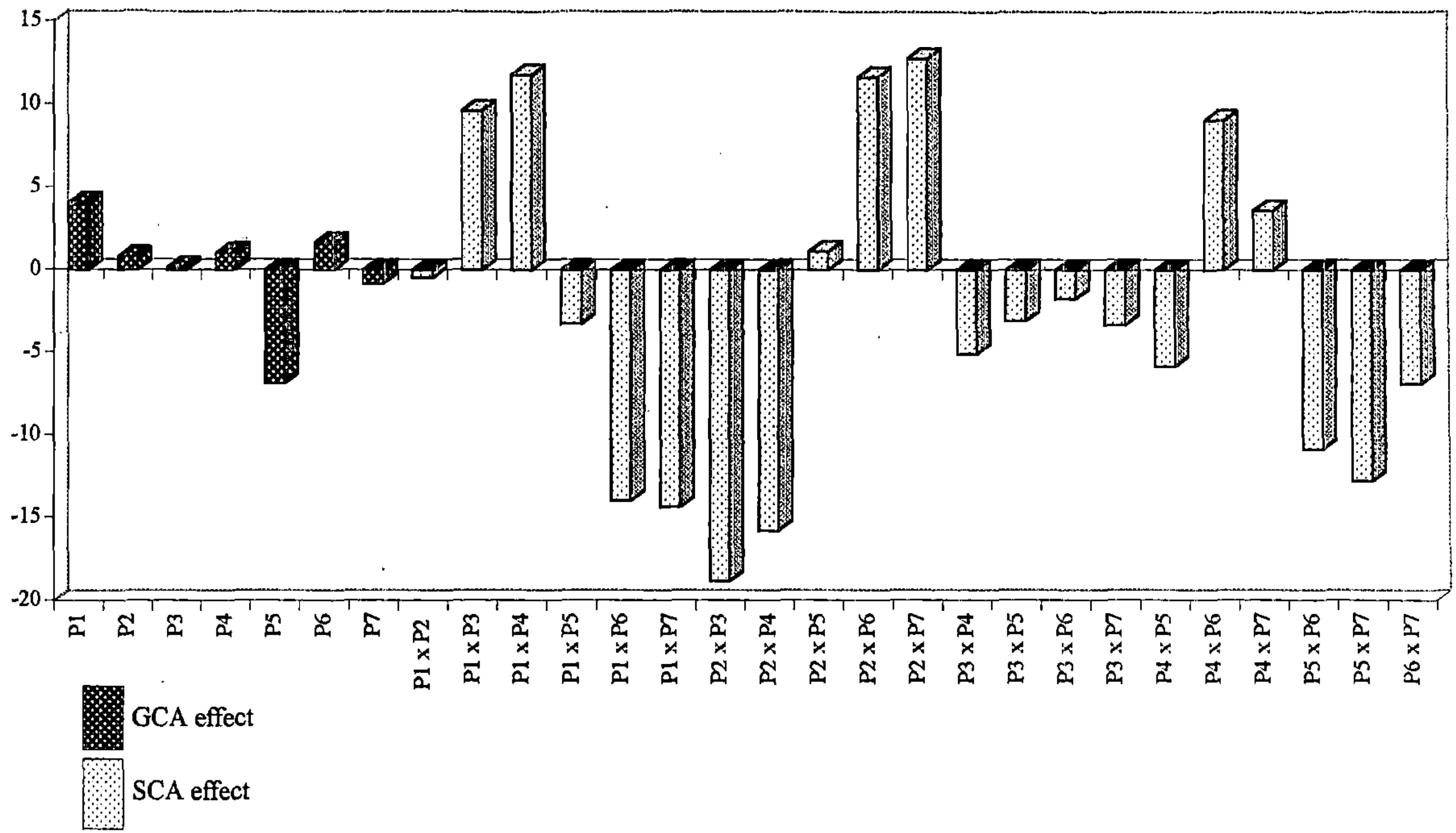


Fig. 13 GCA and SCA - duration of the crop



4.3.7 Fruit yield per plant

The parents P_6 (1.31), P_2 (0.54) and P_1 (0.50) had significant positive GCA effects while P_4 (-1.38), P_5 (-0.79) and P_3 (-0.27) had significant negative GCA effects. None of the parents were on par with P_6. All the hybrids except P_2 x P_4, P_3 x P_6, P_5 x P_6, P_5 x P_7 and P_6 x P_7 showed significant SCA effects. The hybrids P_2 x P_6 (2.84), P_1 x P_6 (1.54), P_3 x P_7 (1.38), P_1 x P_7 (1.08), P_2 x P_7 (0.71), P_3 x P_5 (0.55), P_2 x P_5 (0.49), P_4 x P_6 (0.43) and P_1 x P_5 (0.34) exhibited significant positive SCA effects whereas the others exhibited significant negative SCA effects. The highest significant positive SCA effect was shown by the hybrid P_2 x P_6 and none of the other hybrids were on par with this. Other hybrids with high significant positive SCA effects were P_1 x P_6, P_3 x P_7 and P_1 x P_7 (Fig. 7).

4.3.8 Fruit length

All the parents showed significant GCA effects. The parents P_6 (3.46), P_1 (2.81), P_2 (1.44) and P_7 (1.10) had significant positive GCA effects whereas P_5 (-3.40), P_4 (-3.22) and P_3 (-2.19) had significant negative GCA effects. None of the parents were on par with P_6. Among the hybrids, P_2 x P_6 (4.81), P_1 x P_5 (4.08), P_3 x P_7 (3.94), P_4 x P_6 (3.53), P_2 x P_5 (1.98), P_2 x P_7 (0.82) and P_1 x P_2 (0.71) had significant positive SCA effects. The other hybrids, except P_1 x P_3, P_1 x P_6, P_1 x P_7, P_3 x P_4, P_3 x P_5 and P_5 x P_7 showed significant negative SCA effects. The hybrid P_2 x P_6 exhibited the highest significant positive SCA effect. The hybrids P_1 x P_5 and P_3 x P_7 were on par with P_2 x P_6 (Fig. 8).

4.3.9 Fruit girth

All the parents showed significant GCA effects. In the parents, P_2 (1.26), P_6 (1.17), P_1 (1.07) and P_7 (1.06) had significant positive GCA effects and were on par, while P_3 (-2.03), P_4 (-1.83) and P_5 (-0.70) had significant negative GCA effects. All except eight hybrids showed significant SCA effects, in which P_6 x P_7 (-2.47), P_1 x P_4 (-2.40), P_3 x P_4 (-2.31), P_3 x P_5 (-2.25) and P_2 x P_3 (-1.67) showed significant negative SCA effects while the others had significant positive SCA effects. The highest significant positive SCA effect was recorded by P_2 x P_6 (3.72) which was on par with P_2 x P_4 (2.98) (Fig. 9).

4.3.10 Flesh thickness

Among the parents, P_6 (0.03), P_2 (0.02) and P_7 (0.02) showed significant positive GCA effects and were on par, whereas P_3 (-0.03), P_5 (-0.03) and P_4 (-0.01) showed significant negative GCA effects. Fourteen hybrids exhibited significant SCA effects, in which P_1 x P_4 (-0.03) showed significant negative SCA effect while all the other hybrids showed significant positive SCA effects. The highest significant positive SCA effect was recorded by P_6 x P_7 (0.09) which was on par with the hybrid P_3 x P_5 (0.07) (Fig. 10).

4.3.11 Number of seeds per fruit

All the parents showed significant GCA effects. The parents P_6 (3.56), P_2 (3.29), P_7 (2.84) and P_1 (2.37) had significant positive GCA effects while P_5

(-4.51), P_4 (-4.46) and P_3 (-3.09) had significant negative GCA effects. The parents P_6, P_2 and P_7 were on par. Seventeen hybrids showed significant SCA effects and among them P_5 x P_7 (-4.17), P_3 x P_4 (-4.16), P_1 x P_3 (-3.58), P_2 x P_3 (-3.24), P_1 x P_4 (-2.61) and P_4 x P_7 (-2.36) had significant negative effects while all the others had significant positive effects. The hybrid P_2 x P_6 (9.58) recorded highest positive significant SCA effect and no other hybrid was on par with this (Fig. 11).

4.3.12 100 seed weight

The parents P_7 (3.16) and P_5 (1.35) showed significant positive GCA effects, whereas P_4 (-2.87), P_3 (-1.17) and P_6 (-0.63) showed significant negative GCA effects. The parent P_7 was significantly superior to others. Thirteen hybrids recorded significant SCA effects, in which P_5 x P_6 (-7.60), P_3 x P_4 (-5.27) and P_2 x P_3 (-1.95) had significant negative SCA effects and all the others had significant positive SCA effects. The hybrid P_3 x P_5 (5.69) had the maximum significant positive SCA effect. The hybrids P_2 x P_6 (4.85) and P_3 x P_6 (4.75) were on par with P_3 x P_5 (Fig. 12).

4.3.13 *Duration of the crop*

Among parents, P_1 (4.06), P_6 (1.64), P_4 (1.03) and P_2 (0.80) had significant positive GCA effects while P_5 (-6.86) and P_7 (-0.82) had significant negative GCA effects. No other parent was on par with P_5. The hybrids P_2 x P_7 (12.74), P_1 x P_4 (11.77), P_2 x P_6 (11.62), P_1 x P_3 (9.60), P_4 x P_6 (9.06) and P_4 x P_7 (3.65) showed significant positive SCA effects, whereas all other

Table 8 Components of genetic variance for various characters in bittergourd

Sl. No.	Characters	σ^2GCA	σ^2SCA	Additive variance $\sigma^2 a = 2\sigma^2$GCA	Dominance variance $\sigma^2 d = \sigma^2$SCA	$\sigma^2 a/\sigma^2 d$
1.	Days to first male flower	-1.517	15.680	-3.033	15.680	-
2.	Days to first female flower	-2.517	35.750	-5.033	35.750	-
3.	Days to first fruit harvest	-2.543	30.220	-5.087	30.220	-
4.	Number of female flowers per plant	-0.207	98.590	-0.414	98.590	-
5.	Number of fruits per plant	-0.810	14.350	-1.620	14.350	-
6.	Mean weight of fruit	958.380	966.730	1916.76	966.730	1.98
7.	Fruit yield per plant	0.632	1.598	1.264	1.598	0.79
8.	Fruit length	7.620	6.080	15.24	6.080	2.51
9.	Fruit girth	1.750	3.920	3.500	3.920	0.89
10.	Flesh thickness	0	0.0044	0	0.0044	-
11.	Number of seeds per fruit	11.790	23.120	23.580	23.120	1.02
12.	100 Seed weight	2.218	12.660	4.436	12.660	0.35
13.	Duration of the crop	-2.780	126.520	-5.560	126.520	-

hybrids except P_1 x P_2, P_2 x P_5 and P_3 x P_6 had significant negative SCA effects. The hybrid P_2 x P_3 (-18.82) had the highest significant negative SCA effect and the hybrid P_2 x P_4 (-15.77) was on par with it (Fig. 13).

4.4 Components of genetic variance

Additive and dominance components of genetic variance were calculated and presented in Table 8. Dominance variances were high compared to additive variances in all the characters studied except mean weight of fruit, fruit length and number of seeds per fruit. The additive variance to dominance variance ratio was more than unity for number of seeds per fruit (1.02), mean weight of fruit (1.98) and fruit length (2.51).

4.5 Heterosis

The superiority of the hybrids was estimated in comparison with the mean performance of the mid parent [Relative Heterosis (RH)], better parent [Heterobeltiosis, (HB)] and standard variety [Standard Heterosis (SH)] for the 13 characters studied.

The magnitude of relative heterosis, heterobeltiosis and standard heterosis for various characters are presented in Table 9.

4.5.1 Days to first male flower

All the hybrids exhibited significant negative values for relative heterosis, heterobeltiosis and standard heterosis. The hybrid P_4 x P_5 (-28.83) had the maximum negative value of relative heterosis and the hybrids P_2 x P_5

Table 9 Percentage heterosis over mid parent, better parent and standard variety

Parents / hybrids	1. Days to first male flower				2. Days to first female flower			
	Mean	R H	HB	SH	Mean	R H	HB	SH
P_1	34.40	-	-	-	50.53	-	-	-
P_2	36.53	-	-	-	49.47	-	-	-
P_3	35.40	-	-	-	50.83	-	-	-
P_4	36.60	-	-	-	54.47	-	-	-
P_5	39.27	-	-	-	55.47	-	-	-
P_6	32.67	-	-	-	44.53	-	-	-
P_7	33.07	-	-	-	47.40	-	-	
$P_1 \times P_2$	27.67	-21.98**	-19.56**	-18.31**	39.40	-21.20**	-20.36**	-8.79**
$P_1 \times P_3$	28.33	-18.83**	-17.65**	-16.36**	41.47	-18.17**	-17.93**	-4.01^{NS}
$P_1 \times P_4$	28.47	-19.80**	-17.24**	-15.94**	39.27	-25.20**	-22.28**	-9.09**
$P_1 \times P_5$	27.60	-25.08**	-19.77**	-18.51**	37.27	-29.68**	-26.24**	-13.73**
$P_1 \times P_6$	28.53	-14.93**	-12.67**	-15.77**	38.47	-19.06**	-13.61**	-10.95**
$P_1 \times P_7$	26.47	-21.54**	-19.96**	-21.85**	37.47	-23.48**	-20.95**	-13.26**
$P_2 \times P_3$	29.40	-18.25**	-16.95**	-13.19**	42.40	-15.45**	-14.29**	-1.85^{NS}
$P_2 \times P_4$	28.53	-21.98**	-21.90**	-15.77**	40.67	-21.74**	-17.79**	-5.86**
$P_2 \times P_5$	27.27	-28.33**	-25.35**	-19.49**	37.47	-28.59**	-24.26**	-13.26**
$P_2 \times P_6$	25.67	-25.81**	-21.43**	-24.21**	35.27	-24.96**	-20.79**	-18.36**
$P_2 \times P_7$	30.20	-13.22**	-8.68**	-10.84**	40.60	-16.18**	-14.35**	-6.02**
$P_3 \times P_4$	29.60	-17.78**	-16.38**	-12.61**	43.13	-18.08**	-15.15**	-0.16^{NS}
$P_3 \times P_5$	27.47	-26.42**	-22.40**	-18.89**	38.47	-27.62**	-24.32**	-10.95**
$P_3 \times P_6$	27.53	-19.11**	-15.73**	-18.72**	38.27	-19.74**	-14.06**	-11.41**
$P_3 \times P_7$	30.47	-10.99**	-7.86**	-10.04**	39.07	-20.45**	-17.57**	-9.56**
$P_4 \times P_5$	27.00	-28.83**	-26.23**	-20.28**	42.33	-22.99**	-22.29**	-2.01^{NS}
$P_4 \times P_6$	27.20	-21.47**	-16.74**	-19.69**	36.60	-26.06**	-17.81**	-15.28**
$P_4 \times P_7$	29.53	-15.23**	-10.71**	-12.81**	41.47	-18.58**	-12.51**	-4.01^{NS}
$P_5 \times P_6$	26.13	-27.36**	-20.02**	-22.85**	36.80	-26.40**	-17.36**	-14.82**
$P_5 \times P_7$	27.13	-24.99**	-17.96**	-19.89**	36.73	-28.59**	-22.51**	-14.98**
$P_6 \times P_7$	30.60	-6.91**	-6.34*	-9.66**	42.60	-7.32**	-4.33*	-1.39^{NS}
Check variety	33.87				43.20			
CD (5 %)		1.402	1.618	1.618		1.526	1.763	1.763
CD (1 %)		1.866	2.156	2.156		2.033	2.347	2.347

RH = Relative heterosis HB = Heterobeltiosis SH = Standard heterosis
** Significant at 1 per cent level * Significant at 5 per cent level

Table 9 Contd...

Parents / Hybrids	3. Days to first fruit harvest				4. Number of female flowers per plant			
	Mean	R H	HB	SH	Mean	R H	HB	SH
P_1	78.80	-	-	-	63.73	-	-	-
P_2	75.33	-	-	-	65.07	-	-	-
P_3	76.07	-	-	-	82.00	-	-	-
P_4	72.73	-	-	-	78.93	-	-	-
P_5	75.07	-	-	-	82.67	-	-	-
P_6	72.00	-	-	-	52.27	-	-	-
P_7	71.07	-	-	-	51.13	-	-	-
$P_1 \times P_2$	66.73	-13.41**	-11.42**	-8.59**	67.67	5.08^{NS}	3.99^{NS}	15.34**
$P_1 \times P_3$	67.60	-12.71**	-11.14**	-7.39**	64.57	-11.39**	-21.26**	10.06**
$P_1 \times P_4$	68.80	-9.19**	-5.40**	-5.75**	67.93	-4.77*	-13.94**	15.78**
$P_1 \times P_5$	62.67	-18.55**	-16.52**	-14.15**	69.33	-5.29*	-16.14**	18.17**
$P_1 \times P_6$	63.53	-15.74**	-11.76**	-12.97**	86.07	48.39**	35.05**	46.70**
$P_1 \times P_7$	64.33	-14.16**	-9.48**	-11.88**	72.20	25.72**	13.29**	23.06**
$P_2 \times P_3$	62.80	-17.04**	-16.63**	-13.97**	79.60	8.24**	-2.93^{NS}	35.67**
$P_2 \times P_4$	62.00	-16.25**	-14.75**	-15.07**	66.80	-7.22**	-15.37**	13.86**
$P_2 \times P_5$	62.53	-16.85**	-16.70**	-14.34**	73.67	-0.27^{NS}	-10.89**	25.57**
$P_2 \times P_6$	62.13	-15.67**	-13.71**	-14.89**	87.47	49.09**	34.42**	49.09**
$P_2 \times P_7$	64.17	-12.34**	-9.71**	-12.10**	78.13	34.48**	20.07**	33.17**
$P_3 \times P_4$	63.93	-14.07**	-12.09**	-12.43**	78.27	-2.73^{NS}	-4.55^{NS}	33.41**
$P_3 \times P_5$	62.80	-16.90**	-16.35**	-13.97**	89.93	9.22**	8.78**	53.28**
$P_3 \times P_6$	62.60	-15.45**	-13.06**	-14.25**	75.13	11.90**	-8.38**	28.06**
$P_3 \times P_7$	63.73	-13.38**	-10.33**	-12.70**	75.73	13.76**	-7.65**	29.08**
$P_4 \times P_5$	63.80	-13.67**	-12.28**	-12.60**	75.53	-6.52**	-8.64**	28.74**
$P_4 \times P_6$	62.87	-13.13**	-12.68**	-13.88**	76.07	15.96**	-3.62^{NS}	29.66**
$P_4 \times P_7$	64.67	-10.06**	-9.01**	-11.41**	82.40	26.71**	4.39^{NS}	40.45**
$P_5 \times P_6$	62.60	-14.88**	-13.06**	-14.25**	85.87	27.27**	3.87^{NS}	46.36**
$P_5 \times P_7$	62.67	-14.23**	-11.82**	-14.15**	84.40	26.16**	2.09^{NS}	43.86**
$P_6 \times P_7$	68.80	-3.83**	-3.19*	-5.75**	86.67	67.64**	65.81**	47.73**
Check variety	73.00				58.67			
CD (5 %)		1.875	2.165	2.165		3.312	3.824	3.824
CD (1 %)		2.496	2.882	2.882		4.409	5.092	5.092

Table 9 Contd...

Parents / Hybrids	5. Number of fruits per plant				6. Mean weight of fruit			
	Mean	R H	HB	SH	Mean	R H	HB	SH
P_1	27.20	-	-	-	246.26	-	-	-
P_2	28.20	-	-	-	198.27	-	-	-
P_3	32.33	-	-	-	175.91	-	-	-
P_4	31.60	-	-	-	150.97	-	-	-
P_5	32.27	-	-	-	121.59	-	-	-
P_6	23.47	-	-	-	248.98	-	-	-
P_7	20.53	-	-	-	224.83	-	-	-
$P_1 \times P_2$	27.87	0.61^{NS}	-1.17^{NS}	19.77**	225.97	1.67^{NS}	-8.24**	1.06^{NS}
$P_1 \times P_3$	26.27	-11.76*	-18.74**	12.89^{NS}	191.49	-9.29**	-22.24**	14.36**
$P_1 \times P_4$	27.13	-7.72^{NS}	-14.15**	16.59*	124.60	-37.27**	-49.40**	-44.28**
$P_1 \times P_5$	28.00	-5.85^{NS}	-13.23**	20.33**	206.05	12.03**	-16.33**	-7.85**
$P_1 \times P_6$	32.87	29.72**	20.85**	41.26**	276.29	11.58**	10.97**	23.56**
$P_1 \times P_7$	29.60	24.01**	8.82^{NS}	27.20**	249.73	6.02**	1.41^{NS}	11.69**
$P_2 \times P_3$	32.47	7.27^{NS}	0.43^{NS}	39.54**	153.03	-18.21**	-22.82**	-31.56**
$P_2 \times P_4$	26.87	-10.13*	-14.97**	15.47*	177.87	1.86^{NS}	-10.29**	-20.45**
$P_2 \times P_5$	28.93	-4.33^{NS}	-10.35*	24.32**	206.26	28.97**	4.03*	-7.76**
$P_2 \times P_6$	32.07	24.11**	13.72*	37.82**	324.77	45.23**	30.44**	45.25**
$P_2 \times P_7$	27.80	14.08*	-1.42^{NS}	19.47**	253.93	20.03**	12.94**	13.56**
$P_3 \times P_4$	27.40	-14.29**	-15.25**	17.75**	108.73	-33.47**	-38.19**	-51.37**
$P_3 \times P_5$	41.73	29.20**	29.08**	79.33**	125.10	-15.89**	-28.88**	-44.05**
$P_3 \times P_6$	29.93	7.28^{NS}	-7.42^{NS}	28.62**	229.33	7.95**	-7.89**	2.56^{NS}
$P_3 \times P_7$	30.67	16.04**	-5.14^{NS}	31.80**	225.81	12.69**	0.44^{NS}	0.99^{NS}
$P_4 \times P_5$	22.27	-30.28**	-30.99**	-4.29^{NS}	126.23	-7.38**	-16.39**	-43.55**
$P_4 \times P_6$	28.93	5.05^{NS}	-8.45^{NS}	24.32**	209.97	4.99**	-15.67**	-6.09**
$P_4 \times P_7$	30.13	15.57**	-4.65^{NS}	29.48**	126.07	-32.91**	-43.93**	-43.62**
$P_5 \times P_6$	29.87	7.18^{NS}	-7.44^{NS}	28.36**	207.09	11.77**	-16.83**	-7.38**
$P_5 \times P_7$	28.13	6.55^{NS}	-12.83**	20.89**	175.07	1.07^{NS}	-22.13**	-21.70**
$P_6 \times P_7$	32.00	45.46**	36.34**	37.52**	228.87	-3.39**	-8.08**	2.36^{NS}
Check variety	23.27				223.60			
CD (5 %)		2.681	3.096	3.096		5.817	6.717	6.717
CD (1 %)		3.571	4.123	4.123		7.747	8.945	8.945

Table 9 Contd...

Parents / Hybrids	7. Fruit yield per plant				8. Fruit length			
	Mean	R H	HB	SH	Mean	R H	HB	SH
P_1	6.70	-	-	-	23.25	-	-	-
P_2	5.58	-	-	-	18.42	-	-	-
P_3	5.69	-	-	-	13.17	-	-	-
P_4	4.78	-	-	-	14.38	-	-	-
P_5	3.90	-	-	-	10.23	-	-	-
P_6	5.84	-	-	-	24.08	-	-	-
P_7	4.62	-	-	-	20.64	-	-	-
$P_1 \times P_2$	6.28	2.28^{NS}	-6.27^{NS}	21.24**	23.25	11.56**	0^{NS}	10.77**
$P_1 \times P_3$	5.03	-18.81**	-24.93**	-2.89^{NS}	19.17	5.27^{NS}	-17.55**	-8.67**
$P_1 \times P_4$	3.34	-41.81**	-50.15**	-35.52**	14.33	-23.86**	-38.37**	-31.73**
$P_1 \times P_5$	5.77	8.87^{NS}	-13.88**	11.39*	21.78	30.11**	-6.32*	-3.76^{NS}
$P_1 \times P_6$	9.08	44.82**	35.52**	75.29**	24.48	3.42^{NS}	1.66^{NS}	16.63**
$P_1 \times P_7$	7.39	30.57**	10.29*	42.66**	22.11	0.73^{NS}	-4.90*	5.34*
$P_2 \times P_3$	4.97	-11.88*	-12.65*	-4.05^{NS}	15.50	-1.87^{NS}	-15.85**	-26.16**
$P_2 \times P_4$	4.77	-7.92^{NS}	-14.52**	-7.92^{NS}	15.74	-4.02^{NS}	-14.55**	-25.01**
$P_2 \times P_5$	5.96	25.74**	6.81^{NS}	15.06**	18.31	27.77**	-0.59^{NS}	-12.77**
$P_2 \times P_6$	10.41	82.31**	78.25**	100.97**	28.00	31.77**	16.28**	33.40**
$P_2 \times P_7$	7.06	38.43**	26.52**	36.29**	21.65	10.86**	4.67^{NS}	3.14^{NS}
$P_3 \times P_4$	2.98	-43.13**	-47.63**	-42.47**	12.55	-8.93*	-12.73**	-40.21**
$P_3 \times P_5$	5.21	8.66^{NS}	-8.44^{NS}	0.58^{NS}	13.04	11.45**	-0.99^{NS}	-37.88**
$P_3 \times P_6$	6.87	19.17**	17.64**	32.63**	18.86	1.24^{NS}	-21.68**	-10.15**
$P_3 \times P_7$	6.92	34.24**	21.62**	33.59**	21.14	25.02**	2.42^{NS}	0.72^{NS}
$P_4 \times P_5$	2.81	-35.25**	-41.21**	-45.75**	10.09	-18.03**	-29.83**	-51.93**
$P_4 \times P_6$	6.08	14.50**	4.11^{NS}	17.38**	22.07	14.77**	-8.35**	5.15^{NS}
$P_4 \times P_7$	3.79	-19.36**	-20.71**	-26.83**	13.83	-21.02**	-32.99**	-34.11**
$P_5 \times P_6$	6.18	26.89**	5.82^{NS}	19.31**	15.85	-7.63**	-34.18**	-24.49**
$P_5 \times P_7$	4.93	15.73**	6.71^{NS}	-4.83^{NS}	16.19	4.86^{NS}	-21.56**	-22.87**
$P_6 \times P_7$	7.29	39.39**	24.83**	40.73**	20.05	-10.33**	-16.74**	-4.48^{NS}
Check variety	5.18				20.99			
CD (5 %)		0.501	0.579	0.579		0.961	1.109	1.109
CD (1 %)		0.667	0.771	0.771		1.279	1.478	1.478

Table 9 Contd...

Parents / Hybrids	9. Fruit girth				10. Flesh thickness			
	Mean	R H	HB	SH	Mean	R H	HB	SH
P_1	18.10	-	-	-	0.45	-	-	-
P_2	16.12	-	-	-	0.40	-	-	-
P_3	12.47	-	-	-	0.37	-	-	-
P_4	13.83	-	-	-	0.43	-	-	-
P_5	14.50	-	-	-	0.31	-	-	-
P_6	17.39	-	-	-	0.40	-	-	-
P_7	17.12	-	-	-	0.42	-	-	-
$P_1 \times P_2$	18.77	9.70**	3.70 NS	3.87 NS	0.52	20.93**	15.56**	8.33*
$P_1 \times P_3$	17.39	13.74**	-3.92 NS	-3.76 NS	0.46	12.19**	2.22 NS	-4.17 NS
$P_1 \times P_4$	13.39	-16.16**	-26.02**	-25.89**	0.45	2.27 NS	0 NS	-6.25*
$P_1 \times P_5$	18.55	13.80**	2.49 NS	2.66 NS	0.49	28.95**	8.89*	2.08 NS
$P_1 \times P_6$	18.53	4.39NS	2.38 NS	2.55 NS	0.53	23.26**	17.78**	10.42**
$P_1 \times P_7$	19.15	8.75**	5.80*	5.98*	0.50	13.64**	11.11**	4.17 NS
$P_2 \times P_3$	14.10	-1.36 NS	-12.53**	-21.97**	0.46	17.95**	15.00**	-4.17 NS
$P_2 \times P_4$	18.96	26.57**	17.62**	4.93 NS	0.56	33.33**	30.23**	16.67**
$P_2 \times P_5$	17.24	12.61**	6.95*	-4.59 NS	0.53	47.22**	32.50**	10.42**
$P_2 \times P_6$	22.69	35.38**	30.48**	25.57**	0.59	47.50**	47.50**	22.92**
$P_2 \times P_7$	19.70	18.53**	15.07**	9.02**	0.57	39.02**	35.71**	18.75**
$P_3 \times P_4$	10.37	-21.14**	-25.02**	-42.61**	0.44	10.00**	2.33 NS	-8.33**
$P_3 \times P_5$	11.56	-14.31**	-20.28**	-36.03**	0.50	47.06**	35.14**	4.17 NS
$P_3 \times P_6$	17.32	16.01**	-0.40 NS	-4.15 NS	0.53	35.89**	32.50**	10.42**
$P_3 \times P_7$	18.38	24.23**	7.36**	1.72 NS	0.46	16.46**	9.52*	-4.17 NS
$P_4 \times P_5$	13.91	-1.84 NS	-4.07 NS	-23.02**	0.45	21.62**	4.65 NS	-6.25*
$P_4 \times P_6$	16.33	4.61 NS	-6.09*	-9.63**	0.52	23.81**	20.93**	8.33*
$P_4 \times P_7$	15.30	-1.16 NS	-10.63**	-15.33**	0.52	20.93**	20.93**	8.33*
$P_5 \times P_6$	16.91	6.02*	-2.76 NS	-6.42*	0.53	47.22**	32.50**	10.42**
$P_5 \times P_7$	18.85	19.23**	10.11**	4.32 NS	0.49	32.43**	16.67**	2.08 NS
$P_6 \times P_7$	16.30	-5.56*	-6.27*	-9.79**	0.61	48.78**	45.24**	27.08**
Check variety	18.07				0.48			
CD (5 %)		0.807	0.932	0.932		0.025	0.028	0.028
CD (1 %)		1.074	1.241	1.241		0.033	0.038	0.038

Table 9 Contd...

Parents / Hybrids	11. Number of seeds per fruit				12. 100 seed weight			
	Mean	R H	HB	SH	Mean	R H	HB	SH
P_1	30.20	-	-	-	17.21	-	-	-
P_2	28.40	-	-	-	18.53	-	-	-
P_3	22.20	-	-	-	17.62	-	-	-
P_4	20.53	-	-	-	16.44	-	-	-
P_5	15.87	-	-	-	23.33	-	-	-
P_6	22.73	-	-	-	16.47	-	-	-
P_7	31.53	-	-	-	24.96	-	-	-
$P_1 \times P_2$	33.47	14.23**	10.83*	17.32**	21.79	21.94**	17.59**	-17.93**
$P_1 \times P_3$	23.67	-9.66^{NS}	-21.62**	-17.04**	20.24	16.19**	14.87**	-23.77**
$P_1 \times P_4$	23.27	-8.28^{NS}	-22.95**	-18.44**	20.58	22.28**	19.58**	-22.49**
$P_1 \times P_5$	28.33	22.96**	-6.19^{NS}	-0.70^{NS}	26.54	30.93**	13.76**	-0.04^{NS}
$P_1 \times P_6$	39.00	47.34**	29.14**	36.69**	23.47	39.37**	36.37**	-11.60**
$P_1 \times P_7$	36.93	19.63**	17.13**	29.44**	24.64	16.83**	-1.28^{NS}	-7.19*
$P_2 \times P_3$	24.93	-1.46^{NS}	-12.22*	-12.62*	18.73	3.59^{NS}	1.08^{NS}	-29.45**
$P_2 \times P_4$	27.47	12.26*	-3.28^{NS}	-3.72^{NS}	21.45	22.64**	15.76**	-19.21**
$P_2 \times P_5$	30.20	36.41**	6.34^{NS}	5.85^{NS}	22.51	7.55*	-3.52^{NS}	-15.22**
$P_2 \times P_6$	44.40	73.64**	56.34**	55.63**	26.08	49.03**	40.75**	-1.77^{NS}
$P_2 \times P_7$	36.13	20.55**	14.59**	26.64**	27.47	26.29**	10.06**	3.47^{NS}
$P_3 \times P_4$	16.27	-23.87**	-26.71**	-42.97**	12.27	-27.95**	-30.36**	-53.79**
$P_3 \times P_5$	22.07	15.91*	-0.59^{NS}	-22.64**	27.45	34.03**	17.66**	3.39^{NS}
$P_3 \times P_6$	31.60	40.63**	39.02**	10.76*	24.53	43.87**	39.22**	-7.61**
$P_3 \times P_7$	33.00	22.81**	4.66^{NS}	15.67**	23.68	11.23**	-5.13^{NS}	-10.81**
$P_4 \times P_5$	19.53	7.31^{NS}	-4.87^{NS}	-31.55**	19.60	-1.46^{NS}	-15.99**	-26.18**
$P_4 \times P_6$	32.07	48.27**	41.09**	12.41*	18.62	13.12**	13.05**	-29.87**
$P_4 \times P_7$	24.00	-7.79^{NS}	-23.88**	-15.88**	21.39	3.33^{NS}	-14.30**	-19.44**
$P_5 \times P_6$	29.20	51.29**	28.47**	2.35^{NS}	14.70	-26.13**	-36.99**	-44.63**
$P_5 \times P_7$	22.13	-6.63^{NS}	-29.81**	-22.43**	27.34	13.21**	9.54**	2.98^{NS}
$P_6 \times P_7$	34.07	25.58**	8.06^{NS}	19.42**	26.68	28.77**	6.89*	0.49^{NS}
Check variety	28.53				26.55			
CD (5 %)		2.586	2.986	2.986		1.252	1.445	1.445
CD (1 %)		3.444	3.976	3.976		1.667	1.925	1.925

Table 9 Contd...

Parents / Hybrids	13. Duration of the crop			
	Mean	R H	HB	SH
P_1	139.87	-	-	-
P_2	132.80	-	-	-
P_3	137.93	-	-	-
P_4	129.60	-	-	-
P_5	130.07	-	-	-
P_6	136.07	-	-	-
P_7	135.27	-	-	-
$P_1 \times P_2$	130.80	-4.06**	-6.49**	2.29 NS
$P_1 \times P_3$	140.20	0.94NS	0.24 NS	9.64**
$P_1 \times P_4$	143.27	6.33**	2.43*	12.04**
$P_1 \times P_5$	120.33	-10.85**	-13.97**	-5.89**
$P_1 \times P_6$	118.13	-14.38**	-15.54**	-7.62**
$P_1 \times P_7$	115.27	-16.21**	-17.59**	-9.85**
$P_2 \times P_3$	108.53	-19.83**	-21.32**	-15.12**
$P_2 \times P_4$	112.47	-14.28**	-15.31**	-12.04**
$P_2 \times P_5$	121.47	-7.59**	-8.53**	-5.01**
$P_2 \times P_6$	140.47	4.49**	3.23*	9.85**
$P_2 \times P_7$	139.13	3.79**	2.85*	8.81**
$P_3 \times P_4$	122.47	-8.45**	-11.21**	-4.22**
$P_3 \times P_5$	116.60	-12.99**	-15.46**	-8.81**
$P_3 \times P_6$	126.47	-7.69**	-8.31**	-1.09 NS
$P_3 \times P_7$	122.40	-10.39**	-11.26**	-4.28**
$P_4 \times P_5$	114.73	-11.64**	-11.79**	-10.28**
$P_4 \times P_6$	138.13	3.98**	1.51 NS	8.02**
$P_4 \times P_7$	130.27	-1.64 NS	-3.69**	1.88 NS
$P_5 \times P_6$	110.33	-17.09**	-18.92**	-13.72**
$P_5 \times P_7$	105.93	-20.16**	-21.69**	-17.16**
$P_6 \times P_7$	120.33	-11.31**	-11.57**	-5.89**
Check variety	127.87			
CD (5 %)		2.863	3.305	3.305
CD (1 %)		3.812	4.402	4.402

(-28.33) and P_5 x P_6 (-27.36) were on par with P_4 x P_5. When compared with the mean values of better parent, the hybrid P_4 x P_5 (-26.23) showed the highest negative value and the hybrids P_2 x P_5 (-25.35) and P_2 x P_4 (-21.90) were on par with this. The hybrid P_2 x P_6 (-24.21) showed the maximum negative value for standard heterosis and six hybrids were on par with it (Fig. 14).

4.5.2 Days to first female flower

Significant negative relative heterosis was exhibited by all the hybrids. The hybrid P_1 x P_5 (-29.68) had the maximum negative value and P_2 x P_5 (-28.59) and P_3 x P_5 (-27.62) were on par with P_1 x P_5.

All the hybrids showed significant negative heterobeltiosis. The hybrid P_1 x P_5 (-26.24) recorded the maximum negative value which was on par with P_3 x P_5 (-24.32), P_2 x P_5 (-24.26) and P_4 x P_5 (-22.29).

All the hybrids exhibited negative standard heterosis of which six were not significant. The hybrid P_2 x P_6 (-18.36) had the maximum negative value and the hybrids P_4 x P_6 (-15.28), P_5 x P_7 (-14.98) and P_5 x P_6 (-14.82) were on par with P_2 x P_6 (Fig. 15).

4.5.3 Days to first fruit harvest

All the hybrids exhibited significant negative relative heterosis, heterobeltiosis and standard heterosis. The hybrid P_1 x P_5 (-18.55) recorded the maximum negative value for relative heterosis and the hybrids P_3 x P_5 (-16.90), P_2 x P_5 (-16.85) and P_2 x P_3 (-17.04) were on par with P_1 x P_5. The hybrid P_2 x P_5 (-16.70) had the maximum value for negative heterobeltiosis which was on par with the hybrids P_2 x P_3 (-16.63), P_1 x P_5 (-16.52) and

P_3 x P_5 (-16.35). The hybrid P_2 x P_4 (-15.07) had the maximum value for negative standard heterosis and fifteen hybrids were on par with this. P_2 x P_4 was closely followed by P_2 x P_6 (-14.89) (Fig. 16).

4.5.4 Number of female flowers per plant

Thirteen and six hybrids showed significant positive relative heterosis and heterobeltiosis respectively, in which the hybrid P_6 x P_7 had a high value for both the types of heterosis (67.64 and 65.81 respectively) and was significantly superior to all others.

All the hybrids exhibited significant positive standard heterosis. The hybrid P_3 x P_5 (53.28) had the maximum value and the hybrids P_2 x P_6 (49.09) and P_6 x P_7 (47.73) were on par with P_3 x P_5 (Fig. 17).

4.5.5 Number of fruits per plant

Eight hybrids recorded significant positive relative heterosis. Maximum value of relative heterosis was shown by the hybrid P_6 x P_7 (45.46) which was on par with the hybrids P_1 x P_6 (29.72) and P_3 x P_5 (29.20).

Significant positive heterobeltiosis was expressed by four hybrids and the hybrid P_6 x P_7 (36.34) had the maximum value. It was on par with the hybrids P_3 x P_5 (29.08) and P_1 x P_6 (20.85).

All the hybrids except two (P_1 x P_3 and P_4 x P_5) showed significant positive standard heterosis for number of fruits per plant. The maximum value was expressed by the hybrid P_3 x P_5 (79.33) and it was significantly superior to all other hybrids. The other hybrids with high values for standard heterosis were P_1 x P_6 (41.26) and P_2 x P_3 (39.54) (Fig. 18).

4.5.6 Mean weight of fruit

Significant positive relative heterosis was exhibited by ten hybrids of which the maximum value was shown by the hybrid P_2 x P_6 (45.23) and it was significantly superior to all the other hybrids.

All the hybrids except two (P_1 x P_7 and P_3 x P_7) exhibited significant heterobeltiosis, of which only four hybrids had significant positive values. The hybrid P_2 x P_6 (30.44) had the highest significant positive value and was significantly superior to all the other hybrids.

When compared with the mean value of standard variety, only five hybrids showed significant positive standard heterosis, of which the hybrid P_2 x P_6 (45.25) had the maximum value. This hybrid was significantly superior to all the other hybrids. The hybrid P_1 x P_6 (23.56) also showed a high value for standard heterosis (Fig. 19).

4.5.7 Fruit yield per plant

Significant positive relative heterosis for the character was exhibited by eleven hybrids of which the hybrid P_2 x P_6 (82.31) had the maximum value and was significantly superior to all the other hybrids.

When compared with the mean value of better parent, seven hybrids showed significant positive heterosis. The hybrid P_2 x P_6 (78.25) had the highest value and none of the other hybrids were on par with this.

Twelve hybrids showed significant positive standard heterosis. The hybrid P_2 x P_6 (100.97) had the highest value and it was significantly superior to all the other hybrids. Higher values of standard heterosis were also observed in the crosses P_1 x P_6 (75.29) and P_1 x P_7 (42.66) (Fig. 20).

4.5.8 Fruit length

All the 21 hybrids except seven showed significant relative heterosis, of which eight hybrids had significant positive values. The hybrid P_2 x P_6 (31.77) showed the maximum positive value and none of the other hybrids were on par with this.

All hybrids except six, showed significant values for heterobeltiosis of which only one hybrid, P_2 x P_6 (16.28) had positive significant value. This hybrid was significantly superior to the other hybrids.

Only four hybrids had significant positive standard heterosis. The hybrid P_2 x P_6 (33.40) had the highest positive significant value and was significantly superior to all the other hybrids (Fig. 21).

4.5.9 Fruit girth

Sixteen hybrids exhibited significant relative heterosis and twelve among them had positive values. The hybrid P_2 x P_6 (35.38) had the highest value and none of the other hybrids were on par with this.

When compared with the mean of better parent, seven hybrids showed significant positive heterobeltiosis. The hybrid P_2 x P_6 (30.48) had the maximum value and it was significantly superior to all the others.

Significant positive standard heterosis was shown by the three hybrids P_2 x P_6 (25.57), P_2 x P_7 (9.02) and P_1 x P_7 (5.98). P_2 x P_6 was found to be significantly superior to all the other hybrids (Fig. 22).

Fig. 14 Heterosis - days to first male flower

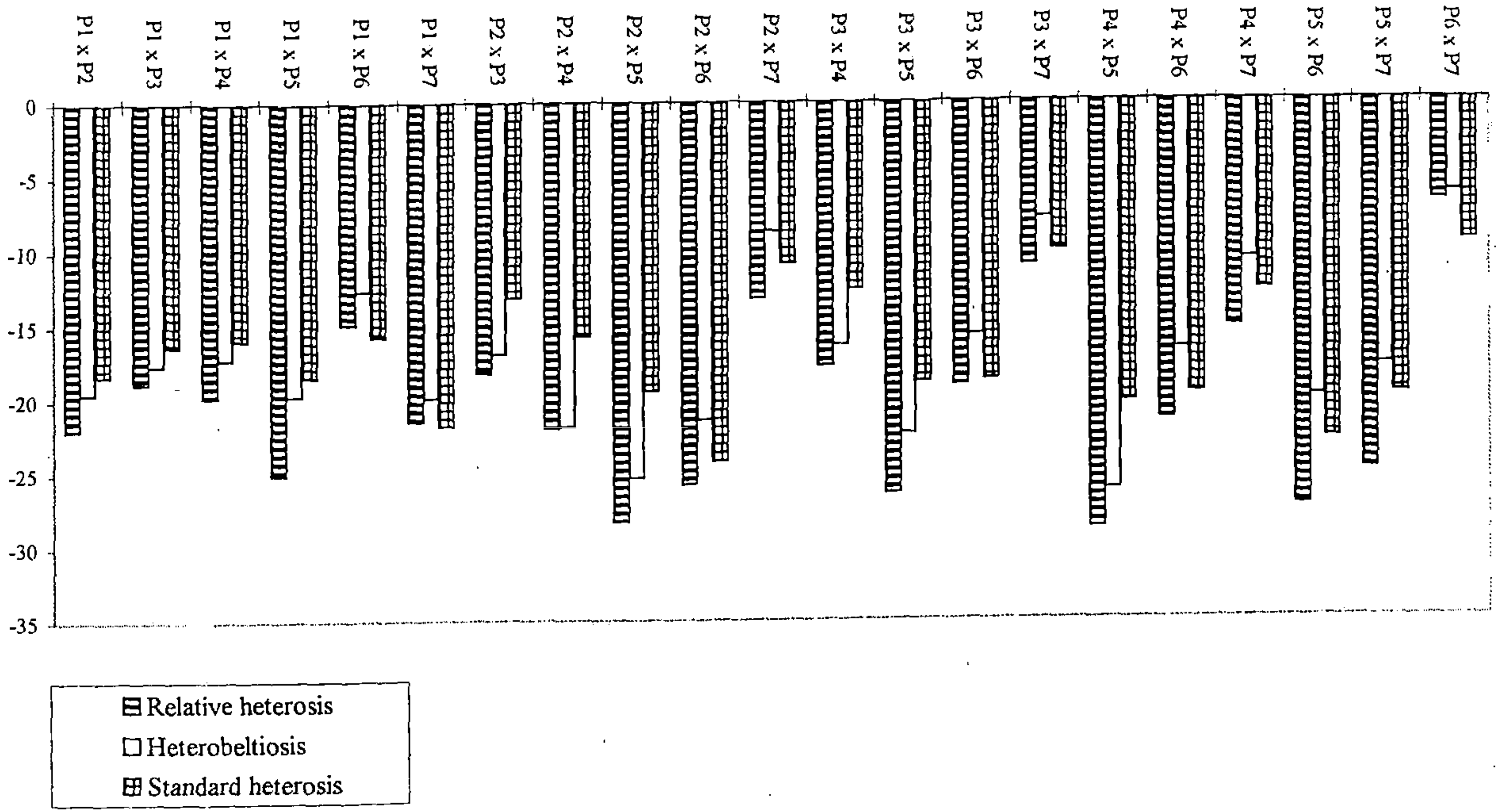


Fig. 15 Heterosis - days to first female flower

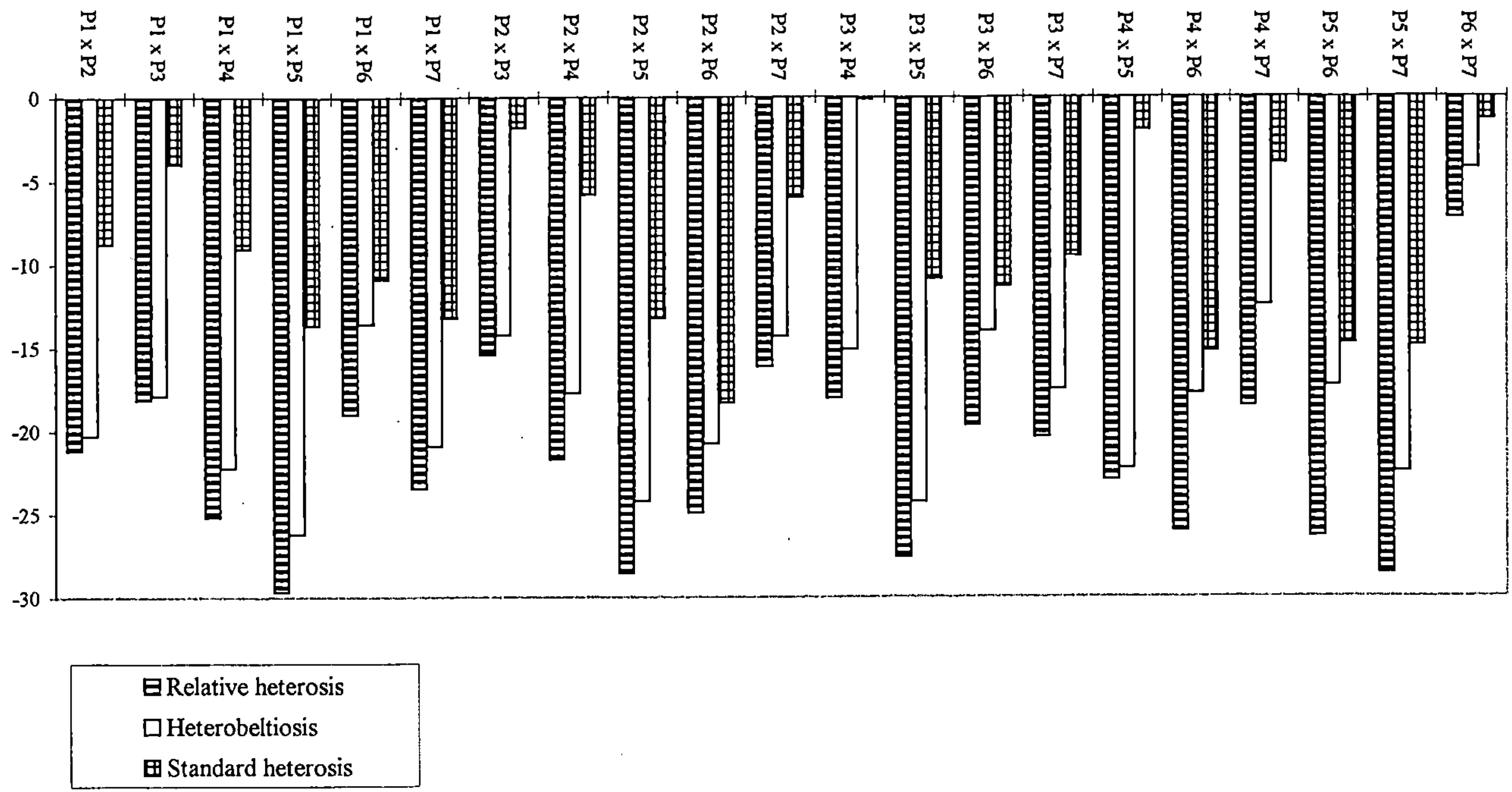


Fig. 16 Heterosis - days to first fruit harvest

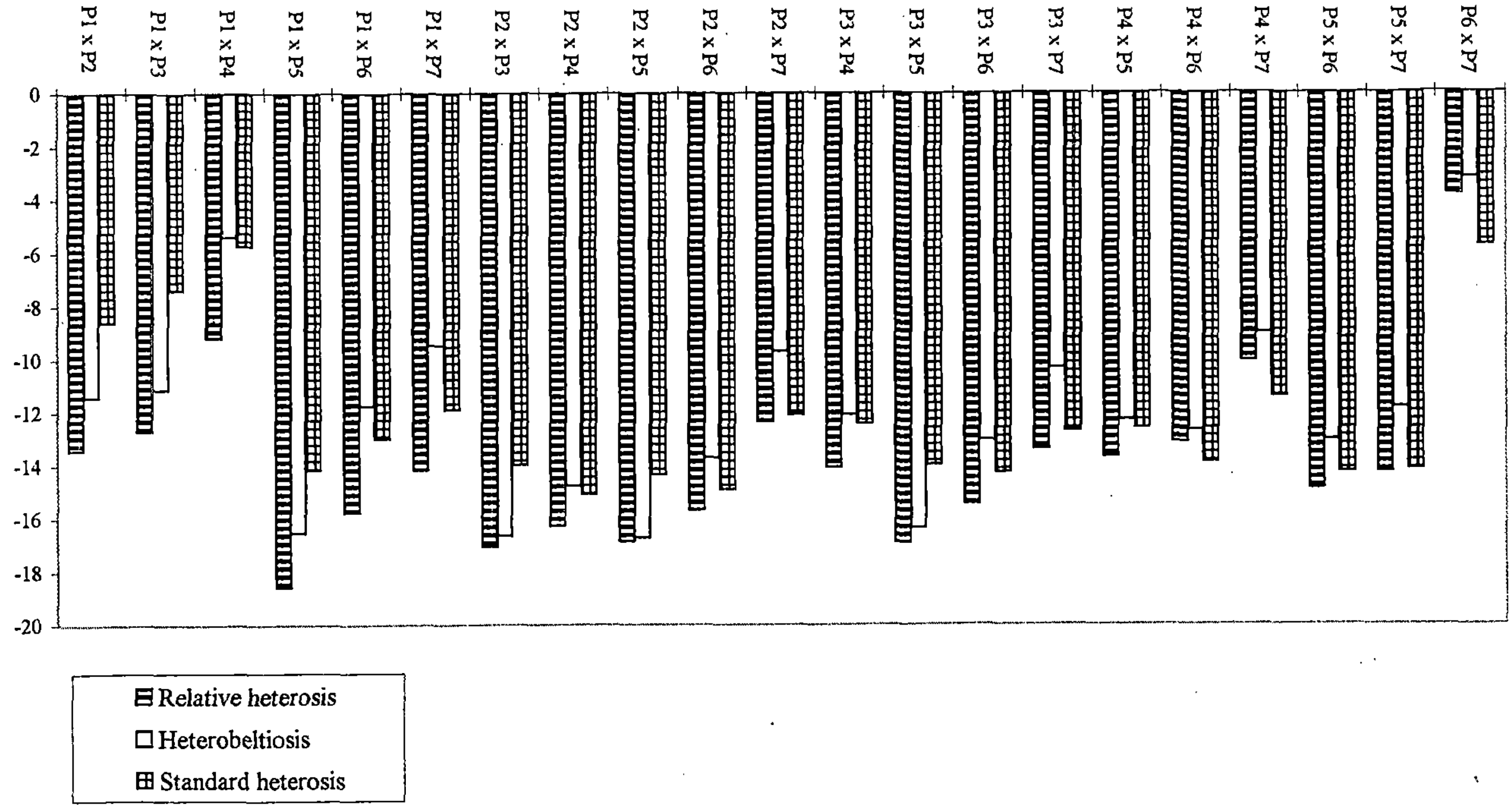


Fig. 17 Heterosis - number of female flowers per plant

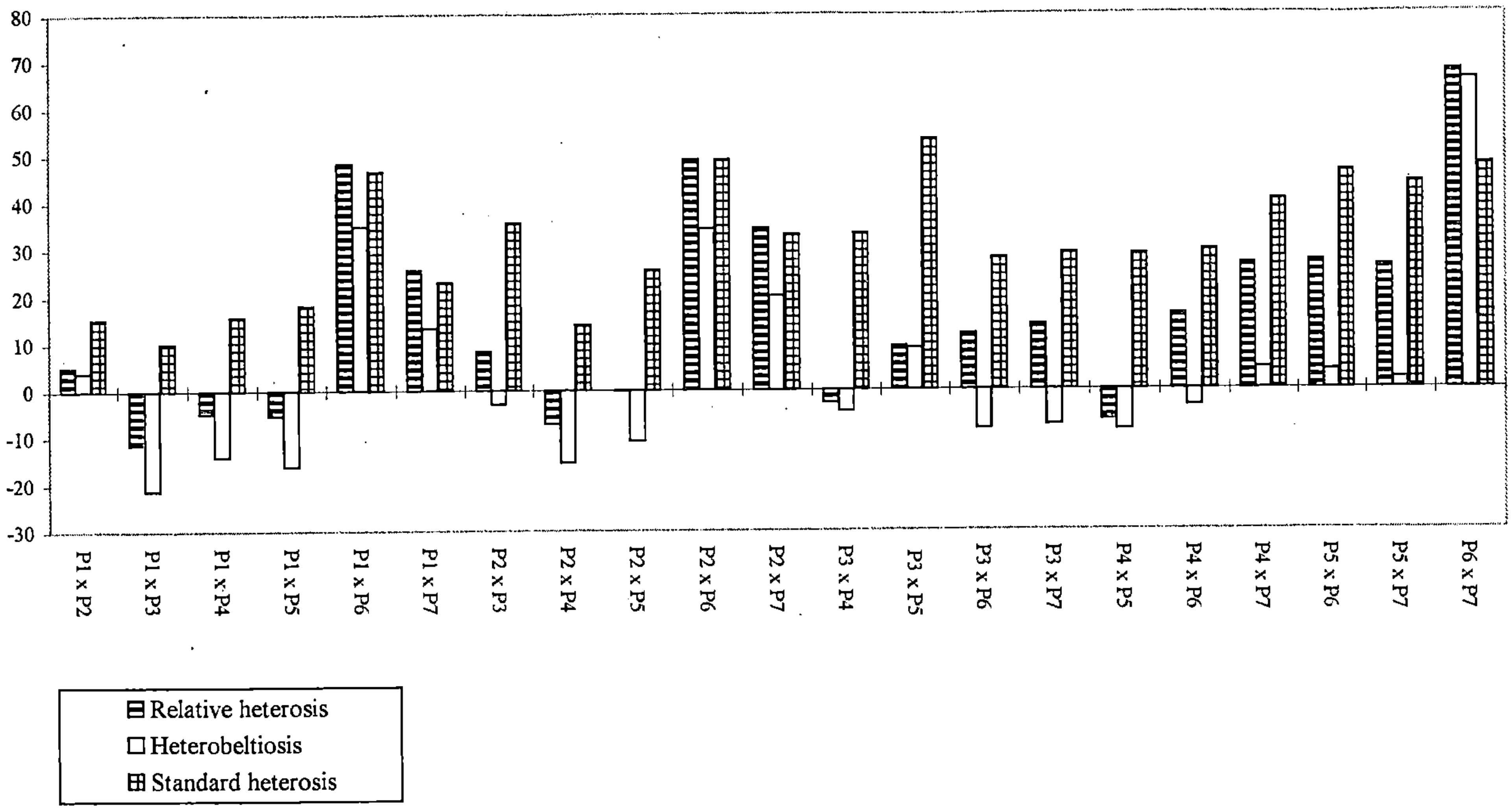


Fig. 18 Heterosis - number of fruits per plant

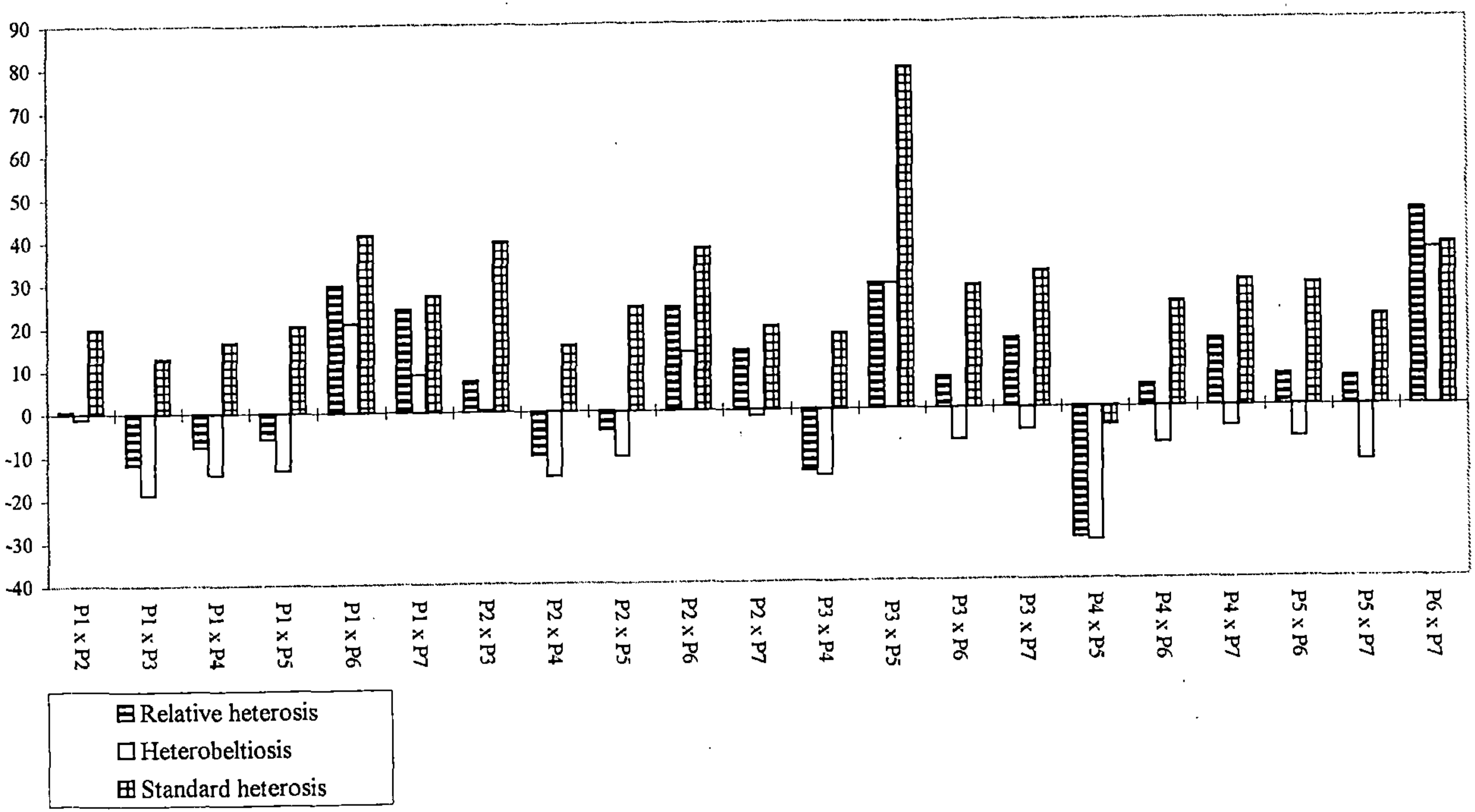


Fig. 19 Heterosis - mean weight of fruit

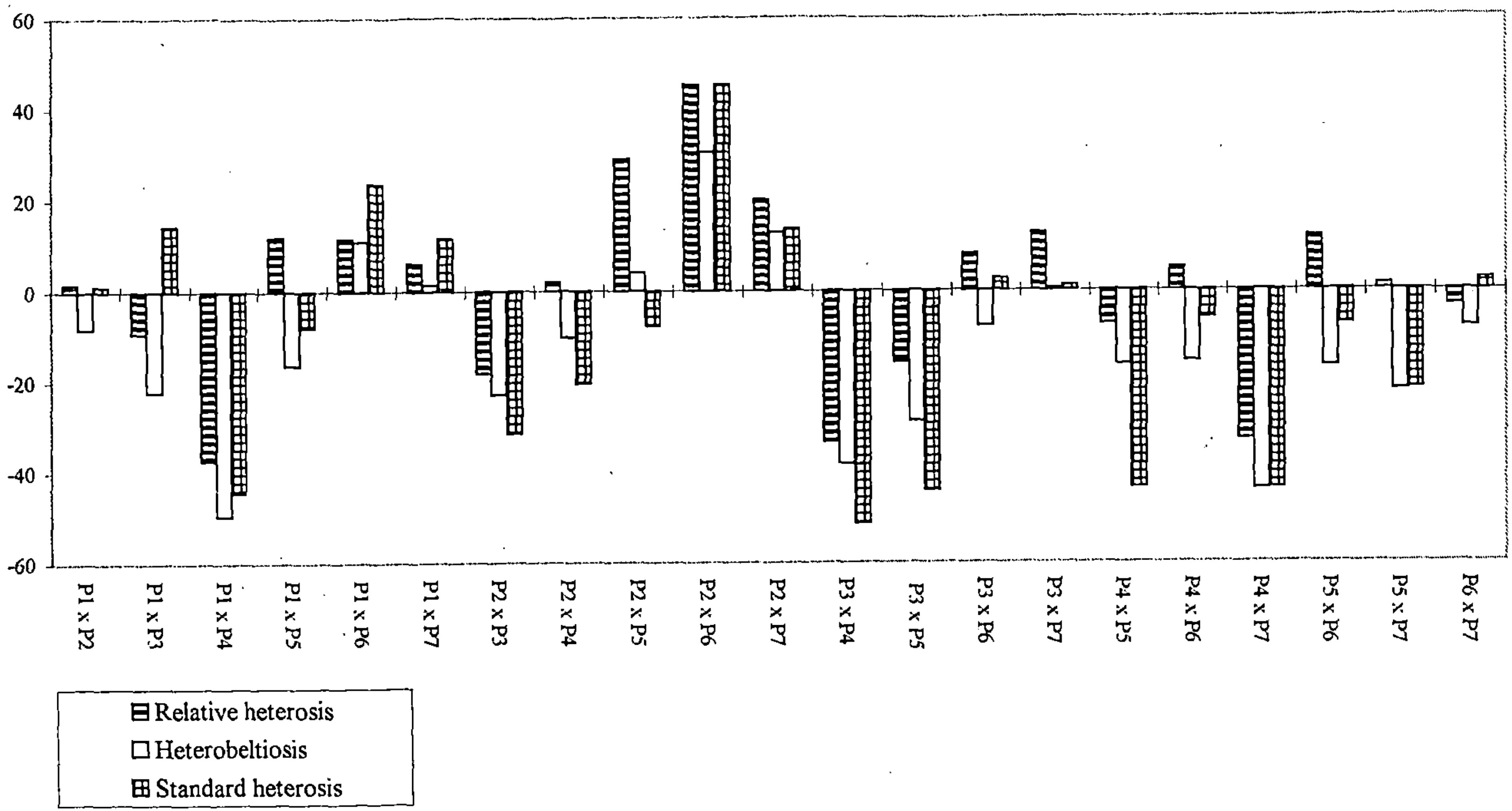


Fig. 20 Heterosis - fruit yield per plant

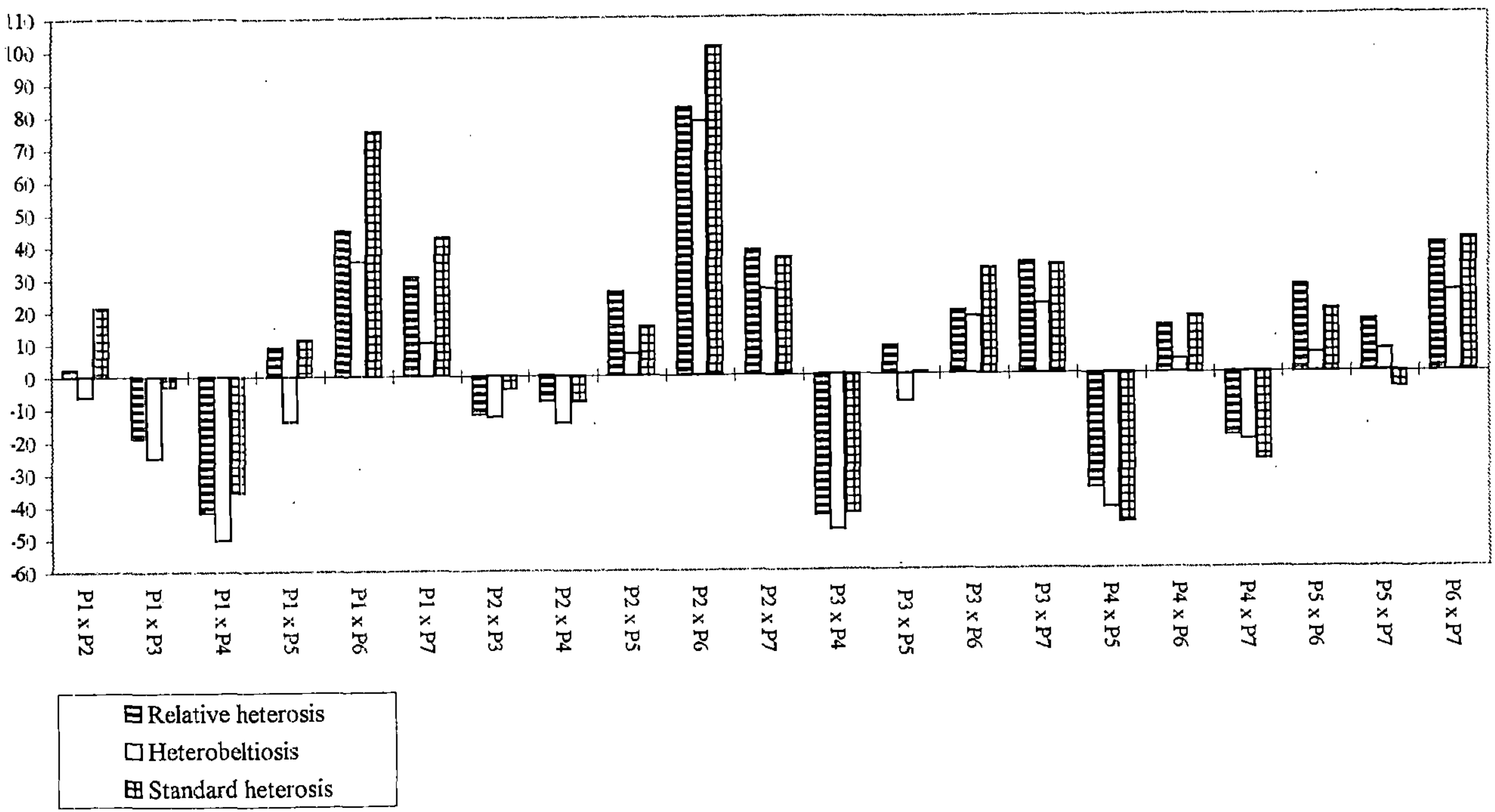


Fig. 21 Heterosis - fruit length

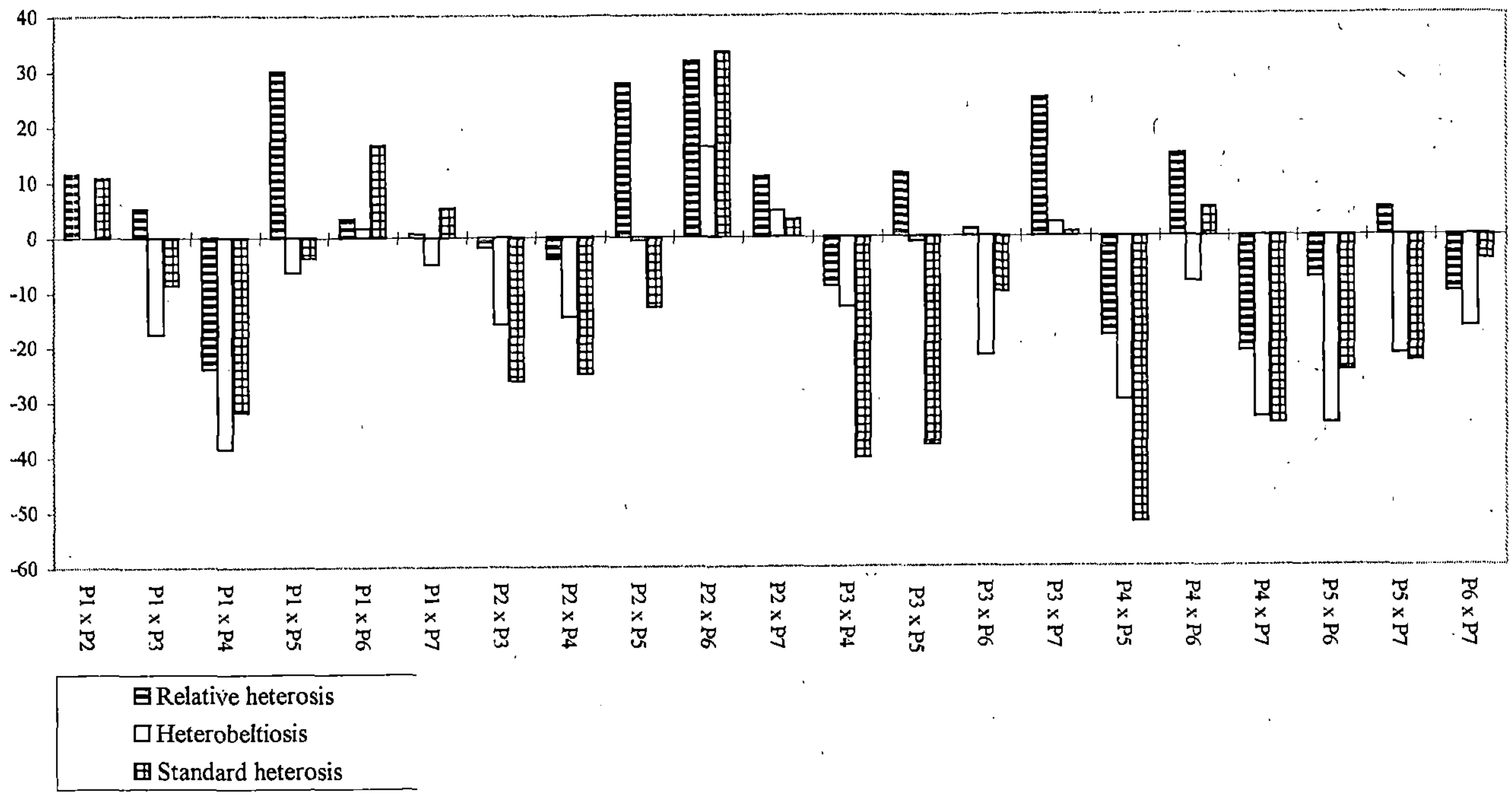


Fig. 22 Heterosis - fruit girth

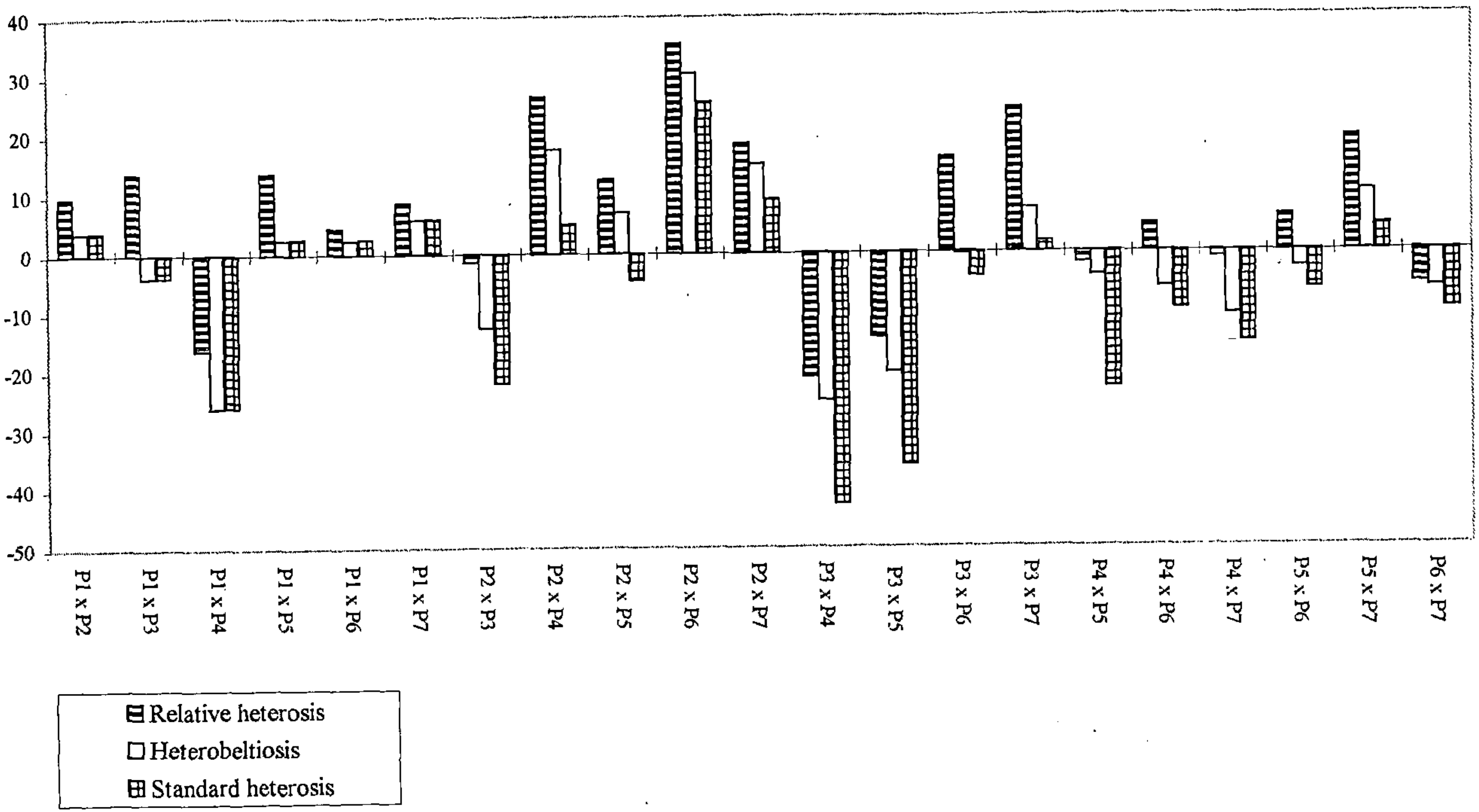


Fig. 23 Heterosis - flesh thickness

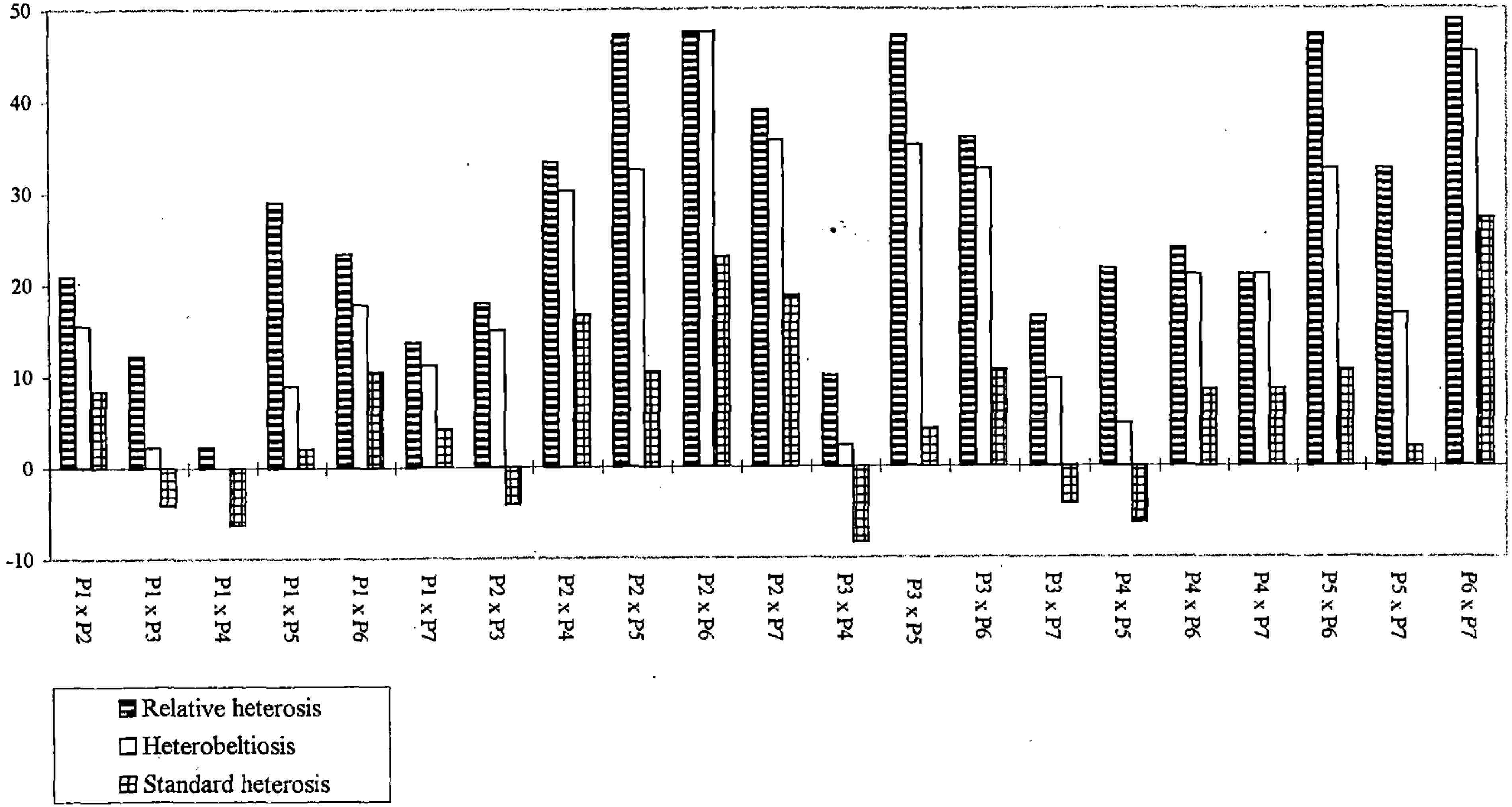


Fig. 24 Heterosis - number of seeds per fruit

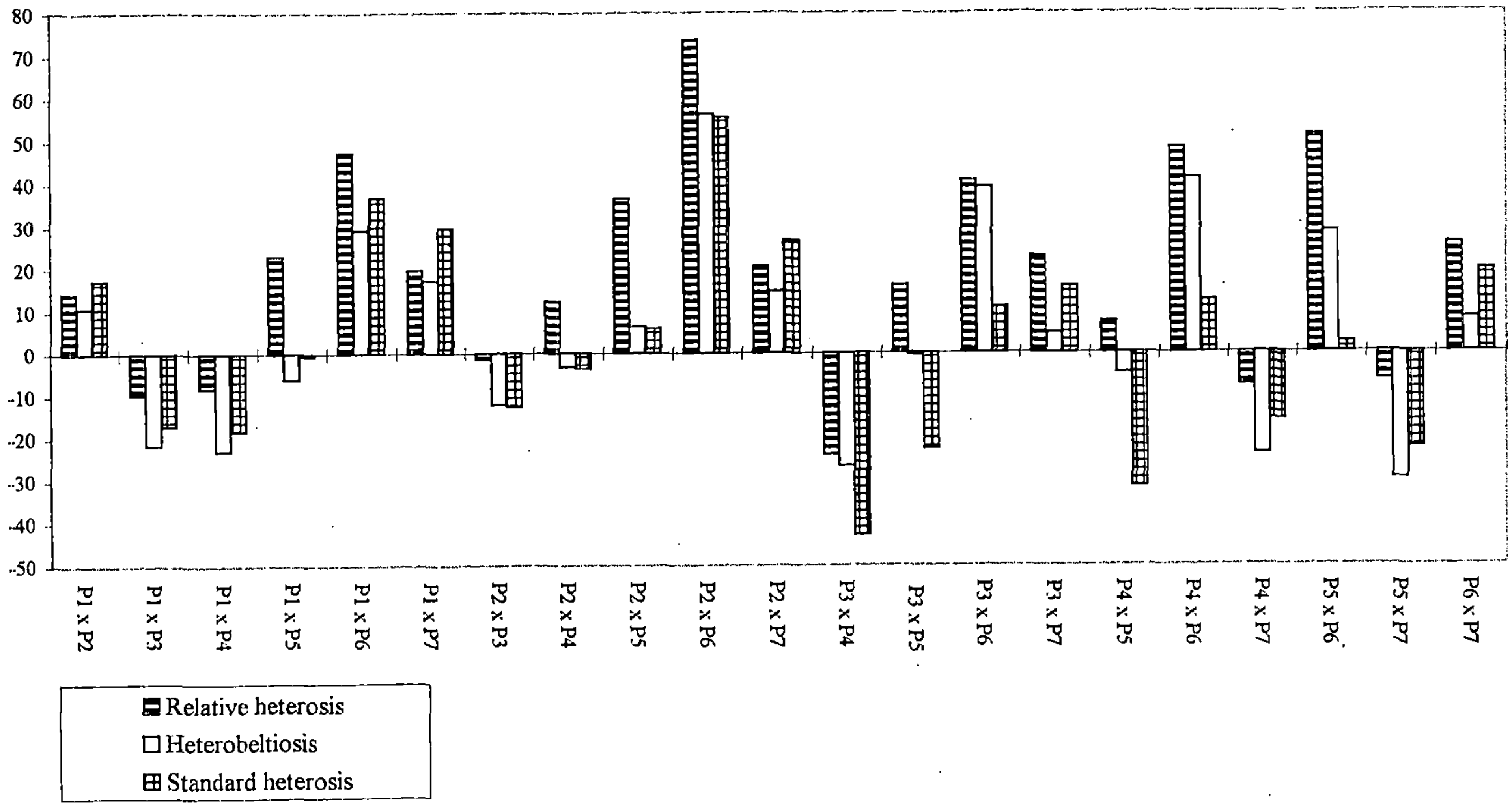


Fig. 25 Heterosis - 100 seed weight

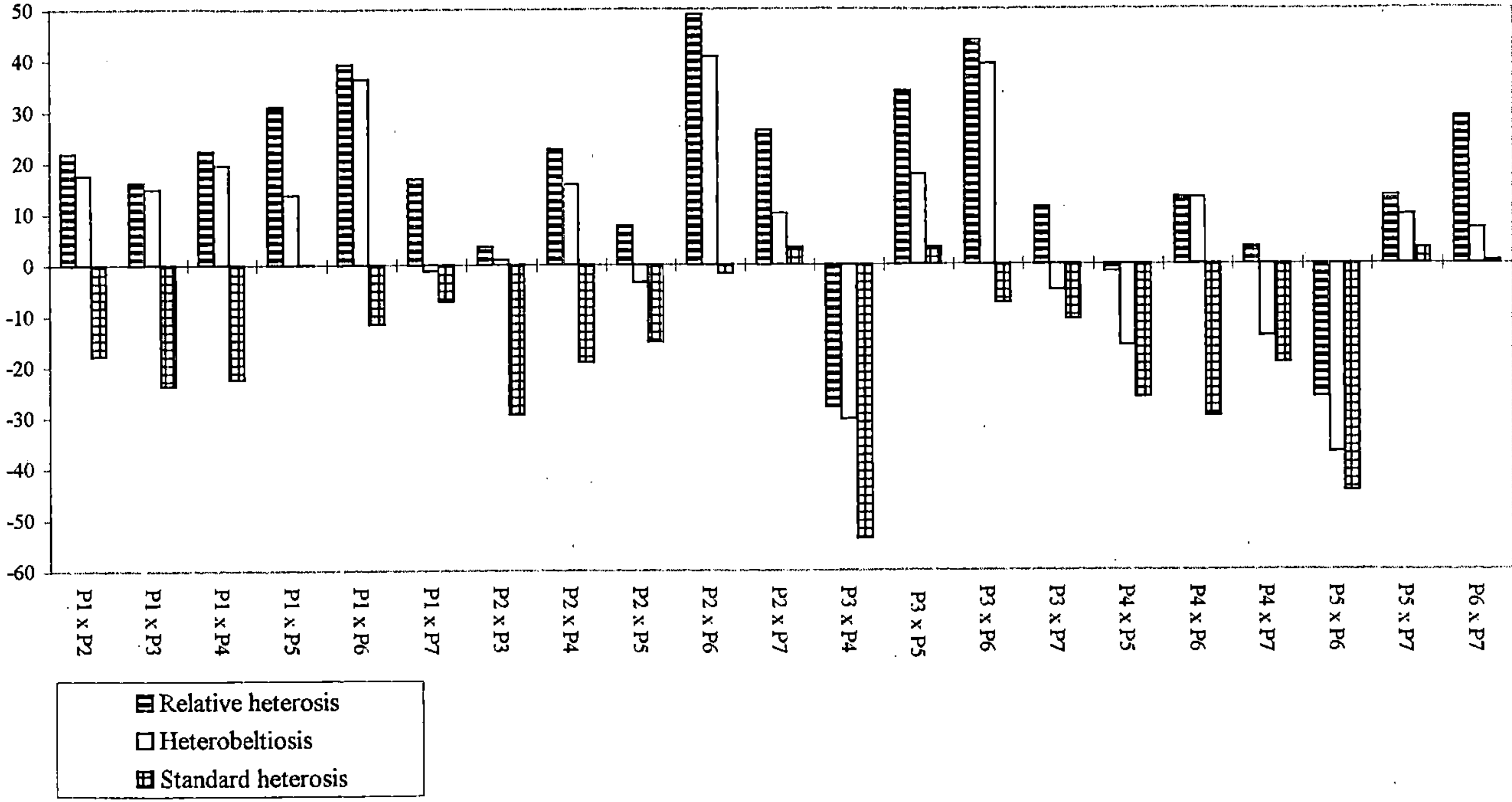
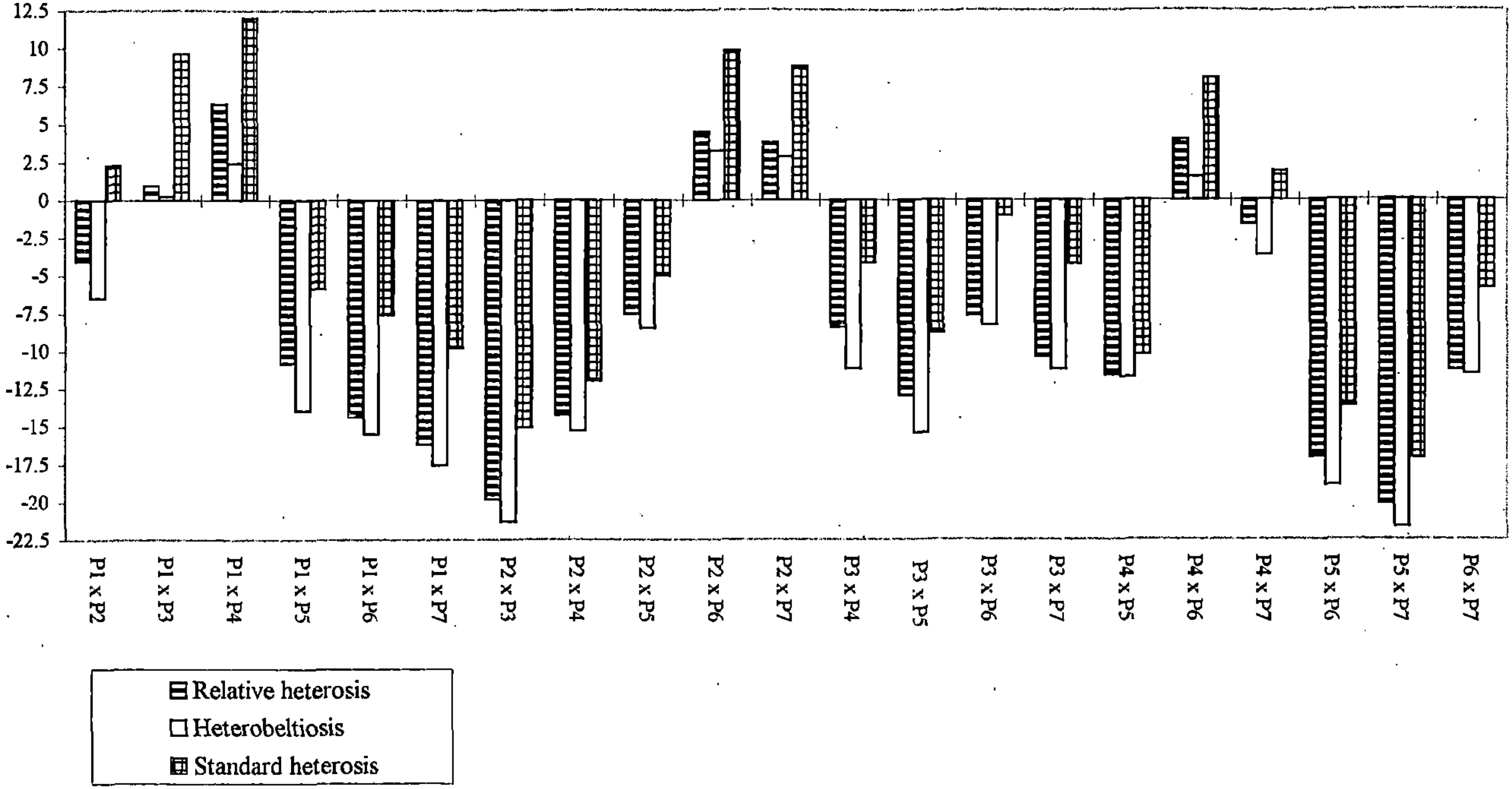


Fig. 26 Heterosis - duration of the crop



4.5.10 Flesh thickness

All the hybrids except one (P_1 x P_4) showed significant values for relative heterosis. The hybrids had significant positive values and the maximum value was recorded by the hybrid P_6 x P_7 (48.78) which was on par with P_2 x P_6 (47.50).

When compared with the better parent, seventeen hybrids showed significant positive values. The maximum value was exhibited by the hybrid P_2 x P_6 (47.50) and it was on par with P_6 x P_7 (45.24).

When compared with the mean value of standard parent, eleven hybrids showed significant positive standard heterosis. The hybrid P_6 x P_7 (27.08) had the highest value and P_2 x P_6 (22.92) was on par with it (Fig. 23).

4.5.11 Number of seeds per fruit

Fourteen hybrids exhibited significant positive relative heterosis on comparison with the mid parental value. The hybrid P_2 x P_6 (73.64) recorded the highest value and no other hybrid was on par with it.

Eight hybrids exhibited significant positive heterobeltiosis, of which the hybrid P_2 x P_6 (56.34) had the maximum value with no other hybrid on par with it.

Significant positive standard heterosis was exhibited by nine hybrids. The hybrid P_2 x P_6 (55.63) recorded the highest value and was significantly superior to all the others (Fig. 24).

4.5.12 100 seed weight

Sixteen hybrids showed significant positive relative heterosis and the hybrid P_2 x P_6 (49.03) exhibited the maximum value. It was on par with the hybrid P_3 x P_6 (43.87).

Thirteen hybrids recorded significant positive heterobeltiosis. The hybrid P_2 x P_6 (40.75) showed the highest value and the hybrids P_3 x P_6 (39.22) and P_1 x P_6 (36.37) were on par with P_2 x P_6.

Only four hybrids, P_2 x P_7 (3.47), P_3 x P_5 (3.39), P_5 x P_7 (2.98) and P_6 x P_7 (0.49) had positive standard heterosis but these were not significant. Fifteen hybrids recorded significant negative values. The highest negative value was exhibited by P_3 x P_4 (-53.79) (Fig. 25).

4.5.13 Duration of the crop

Fifteen hybrids showed significant negative relative heterosis. The hybrid P_5 x P_7 (-20.16) had the highest negative value which was on par with P_2 x P_3 (-19.83).

Significant negative heterobeltiosis was exhibited by sixteen hybrids, of which the hybrid P_5 x P_7 (-21.69) recorded the highest value and the hybrid P_2 x P_3 (-21.32) was on par with it.

Significant negative standard heterosis was shown by thirteen hybrids. The hybrids P_5 x P_7 (-17.16) and P_2 x P_3 (-15.12) were found to be on par with regard to the duration of the crop (Fig. 26).

DISCUSSION

5. DISCUSSION

The diallel mating system without reciprocals 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 heterosis breeding programme. This method also enables to estimate the nature of gene action governing the different characters based on which appropriate breeding methodology can be adopted.

In the present investigation seven diverse parents of bittergourd, their 21 hybrids and a check variety (Preethi) were subjected to diallel analysis without reciprocals for studying the combining ability, gene action and heterosis.

5.1 Mean performance

Mean performance gives an idea about the relative importance of the different genotypes. For the selection of superior parents for hybridisation programme, the GCA effects also should be considered along with the mean performance. The mean performance of the different genotypes are discussed below.

The parent P_6 (32.67) and P_7 (33.07) were the earliest for days to first male flower while among the hybrids, $P_2 \times P_6$ (25.67) was the earliest and six crosses were on par with it. The check variety took 33.87 days to first male flower. All the hybrids recorded less number of days to first male flower compared to that of the parents and the check variety.

With respect to the character days to first female flower, P_6 took minimum number of days (44.53) among the parents and none of the parents were on par with P_6. The hybrid P_2 x P_6 recorded the minimum number of days (35.27) which was on par with three other hybrids while in the check variety it was 43.20 days. All the hybrids recorded less number of days to first female flower compared to the parents and the check variety.

The minimum number of days for first fruit harvest was observed in the parent P_7 (71.07) and P_6 (72.00) and P_4 (72.73) were equally good. The hybrid P_2 x P_4 was the earliest for the character (62.00) and 14 other hybrids were found to be equally good. The check variety took 73 days to first fruit harvest. So compared to the parents and the check variety, all the hybrids were early yielders.

Among the parents, P_5 produced maximum number of female flowers per plant (82.67) along with P_3 (82.00) and P_4 (78.93), whereas in the hybrids, the maximum number of female flowers were produced by P_3 x P_5 (89.93) which was on par with P_6 x P_7 and P_2 x P_6. All the hybrids produced more number of female flowers compared to the check variety (58.67).

The parents P_3 (32.33), P_5 (32.27) and P_4 (31.60) produced the maximum number of fruits per plant while among the hybrids, P_3 x P_5 (41.73) was significantly superior to all others. All the hybrids except one (P_4 x P_5) produced more number of fruits per plant than the check variety (23.27).

The highest mean fruit weight was recorded in P_6 (248.98 g) and P_1 (246.60 g) among the parents and P_2 x P_6 (324.77 g) among the hybrids. No other hybrid was on par with P_2 x P_6. Eight hybrids recorded a mean fruit weight higher than that of the check variety (223.60 g). Apart from P_2 x P_6, other hybrids with good performance were P_1 x P_6 (276.29 g) and P_2 x P_7 (253.93 g).

The highest fruit yielders were P_1 (6.70 kg) among the parents and P_2 x P_6 (10.41 kg) among the hybrids. The parent P_1 and the cross P_2 x P_6 were significantly superior to all other parents and hybrids respectively. However, 13 hybrids out yielded the check variety (5.18 kg). Some crosses with high mean performance were P_1 x P_6 (9.08 kg), P_1 x P_7 (7.39 kg), P_6 x P_7 (7.29 kg) and P_2 x P_7 (7.06 kg).

Among the parents, P_6 (24.08 cm) and P_1 (23.25 cm) produced the longest fruits while in the hybrids, the fruits of P_2 x P_6 (28.00 cm) were the longest and no other hybrid was on par with it. However, seven other hybrids also had longer fruits than the check variety (20.99 cm).

The fruits of P_1 (18.10 cm) and P_6 (17.39 cm) among the parents and P_2 x P_6 (22.69 cm) among the hybrids recorded the maximum girth. The hybrid P_2 x P_6 was significantly superior to all other hybrids. Nine hybrids had fruit girth higher than the check variety (18.07 cm).

Maximum flesh thickness was recorded by the fruits of the parents P_1 (0.45 cm), P_4 (0.43 cm) and P_7 (0.42 cm). Among the hybrids, P_6 x P_7 (0.61 cm) produced fruits with maximum flesh thickness. The hybrid P_2 x P_6 (0.59 cm) was found to be equally good. The fruits of 15 hybrids had a flesh thickness higher than that of check variety (0.48 cm).

The parent P_7 had the maximum number of seeds (31.53) per fruit along with P_1 (30.20), whereas in the hybrids, P_2 x P_6 recorded the maximum number (44.40) and was significantly superior to all the others. However, 11 hybrids recorded higher values than the check variety (28.53).

The 100 seed weight was maximum in P_7 (24.96 g) with no other parents on par. Among hybrids P_2 x P_7 (27.47) recorded maximum 100 seed weight and five hybrids were found to be on par with P_2 x P_7. Four hybrids had 100 seed weight higher than the check variety (26.55 g).

Among the parents, the duration of the crop was minimum in P_4 (129.60 days) and P_5 (130.07 days) and P_2 (132.80 days) were on par with P_4. Among the hybrids, P_5 x P_7 (105.93 days) had the shortest duration and the hybrid P_2 x P_3 (108.53 days) was on par with it. The check variety recorded a duration of 127.87 days while 14 hybrids had shorter duration compared to the check variety.

In conclusion it can be stated that among the parents P_1 (MC 17) and P_6 (MC 40) and among the hybrids P_2 x P_6 (MC 18 x MC 40), P_1 x P_6 (MC 17 x MC 40), P_1 x P_7 (MC 17 x MC 53), P_6 x P_7 (MC 40 x MC 53) and P_2 x P_7 (MC 18 x MC 53) showed high mean performance for yield and most of the yield attributes.

5.2 Coefficient of variation

In a genetic population, the phenotypic variation is contributed by genotypic and environmental variations. Genotypic variation is inherent and is more useful to a plant breeder for exploitation in selection or hybridisation programmes. The relative values of PCV, GCV and ECV give an idea about the magnitude of variability present in a genetic population. If the difference between PCV and GCV is less, it indicates that the influence of environment on the expression of the character is less. Selection for improvement of such character will be rewarding.

In the present study, PCV was highest for fruit yield per plant (29.83) and lowest for days to first fruit harvest (7.82). The characters, mean weight of fruit, fruit length and number of seeds per fruit also had high values for PCV. This is in conformity with the results of Ramachandran and Gopalakrishnan (1979), Chaudhary (1987) and Vahab (1989) in bittergourd ; Radhika (1999) in snakegourd ; Reddy and Rao (1984) and Varalakshmi *et al.* (1995) in ridgegourd ; Arora *et al.* (1983) in spongegourd ; Sureshbabu (1989) in pumpkin ; Abusaleha and Dutta (1990), Mariappan and Pappiah (1990) and Gayathri (1997) in cucumber ; Thakur and Nandpuri (1974), Prasad *et al.* (1988) and Rajendran and Thamburaj (1994) in watermelon and Swamy *et al.* (1985) in muskmelon.

With regard to GCV, the highest value was observed for fruit yield per plant (29.18) and the lowest for days to first fruit harvest (7.56). High GCV values were also noticed for mean weight of fruit, fruit length and number of seeds per fruit. These results were in agreement with the findings of Srivastava and Srivastava (1976), Singh *et al.* (1977), Ramachandran and Gopalakrishnan (1979), Mangal *et al.* (1981), Indiresh (1982), Chaudhary (1987) and Vahab (1989) in bittergourd ; Joseph (1978), Varghese (1991) and Radhika (1999) in snakegourd ; Tyagi (1972) and Kumar *et al.* (1999) in bottlegourd ; Singh *et al.* (1986) in pointedgourd ; Reddy and Rao (1984) and Varalakshmi *et al.* (1995) in ridgegourd ; Arora *et al.* (1983) in spongegourd ; Sureshbabu (1989) in pumpkin ; Abusaleha and Dutta (1990), Mariappan and Pappiah (1990) and Gayathri (1997) in cucumber ; Thakur and Nandpuri

(1974), Prasad *et al.* (1988) and Rajendran and Thamburaj (1994) in watermelon ; Swamy *et al.* (1985) and Chacko (1992) in muskmelon.

There was not much difference between the PCV and GCV values for all the 13 characters studied, indicating the importance of genetic component on the expression of characters. Hence, selection based on phenotype will be effective for the characters with high GCV values since it reflects the actual genotype. Similar trend in PCV and GCV values were earlier reported by Vahab (1989) in bittergourd ; Mathew (1996) and Radhika (1999) in snakegourd and Gayathri (1997) in cucumber.

Fruit yield per plant had the highest GCV indicating maximum variability for the character. In short, all the characters, except days to first fruit harvest and duration of the crop, had comparatively high GCV values, suggesting good scope for improvement through selection.

5.3 Heritability and genetic advance

Heritability and genetic advance are the important selection parameters. A character can be improved only if it is highly heritable. The magnitude of heritability indicates the effectiveness with which the selection of the genotypes can be made based on phenotypic performance. If the heritability of a character is high, there would be close correspondence between genotype and phenotype due to relatively smaller contribution of environment to the phenotype thereby favouring selection for the improvement of the trait.

Eventhough the heritability values give an indication of the effectiveness of selection based on the phenotypic performance, it does not necessarily mean a high genetic advance for a particular character. Hence, heritability along with genetic advance should be considered while making selection.

In the study, all the 13 characters showed high heritability estimates which ranged from 80.5 per cent (number of fruits per plant) to 99.4 per cent (mean weight of fruit).

Several authors reported similar results earlier. In bittergourd high heritability values were reported by Srivastava and Srivastava (1976) for fruits per plant ; Singh *et al.* (1977) for yield, fruits per plant and fruit length ; Ramachandran (1978) for yield per plant ; Ramachandran and Gopalakrishnan (1979) for fruits per plant ; Mangal *et al.* (1981) for average fruit weight, fruits per plant, yield per plant and seeds per fruit ; Indiresh (1982) for all the characters except yield per plant and days for fruit development ; Vahab (1989) for fruit weight, yield and fruits per plant and Chaudhary *et al.* (1991) for yield per plant. In snakegourd, high estimates of heritability were reported by Varghese (1991) for male flowers per plant, sex ratio and fruiting nodes on main vine ; Varghese and Rajan (1993 a) for fruits per plant, yield per plant, fruit length, crop duration, days to first harvest and days to first male flower ; Mathew (1996) for all characters except flesh thickness and Radhika (1999) for all the characters except days to first fruit harvest and vine length. In bottlegourd, high estimates of heritability were reported by Prasad and Prasad (1979) for fruit length and fruit diameter ; Sirohi *et al.* (1986) for days to first male and female flower, fruit length, girth and weight and fruits per plant ; Sharma and Dhankar (1990) for fruits per plant and Kumar *et al.* (1999) for all the characters studied. Singh *et al.* (1986) reported high heritability for fruits per plant and yield per plant in pointed gourd. In ridgegourd, Varalakshmi *et al.* (1995) observed high heritability values for seeds per fruit, fruit weight, days to first male and female flower, fruit length, 100 seed weight and fruits per plant. In spongegourd, Prasad *et al.* (1984) reported high heritability estimates for yield per plant and four other traits. In pumpkin, high heritability was reported by Rana *et al.* (1986) for fruit number and Singh *et al.* (1988) and Borthakur and Shadeque (1990) for fruit weight. In cucumber, high heritability estimates were reported by Solanki and Seth (1980) for average fruit weight, number of fruits per plant and fruit yield ; Prasunna and Rao (1988) for fruits per vine and average fruit weight ; Mariappan and Pappiah (1990) for fruit length, fruit girth, days to first staminate flower, number of seeds per fruit and fruit weight ; Rastogi and Deep (1990 a) for fruits per vine, fruit weight, yield per plant and days to fruit maturity and Gayathri (1997) for yield per plant, fruits per plant, average fruit weight and node to first female flower. Prasad *et al.* (1988) observed high heritability estimates for all the characters studied except for days to first picking and branches per plant whereas Rajendran and Thamburaj (1994) reported high heritability for 100 seed weight, number of fruits per plant, average fruit weight, yield per vine and number of seeds per fruit in watermelon. In muskmelon, high heritability values were reported by Chonkar *et al.* (1979) for pulp thickness and fruit weight ; Kalloo *et al.* (1981) for fruit length, fruit weight, yield and number of fruits ; Swamy *et al.* (1985) for yield per vine, fruit weight and days to first fruit harvest and Vijay (1987) for fruits per vine, flesh thickness, yield per vine, fruit weight and days to flower.

In the present investigation, all the characters except days to first fruit harvest and duration of the crop had high estimates of genetic advance (>20 per cent) the values ranging from 15.07 per cent for days to first fruit harvest to 58.73 per cent for fruit yield per plant.

This was in conformity with the results of Chaudhary (1987), Vahab (1989) and Chaudhary *et al.* (1991) in bittergourd ; Varghese (1991), Varghese and Rajan (1993 a), Mathew (1996) and Radhika (1999) in snakegourd ; Prasad and Prasad (1979), Sharma and Dhankar (1990) and Kumar *et al.* (1999) in bottlegourd ; Singh *et al.* (1986) in pointedgourd ; Reddy and Rao (1984), Kadam and Kale (1987) and Varalakshmi *et al.* (1995) in ridgegourd ; Arora *et al.* (1983) and Prasad *et al.* (1984) in spongegourd; Gayathri (1997) in cucumber ; Prasad *et al.* (1988) and Rajendran and Thamburaj (1994) in watermelon and Kalloo *et al.* (1981), Swamy *et al.* (1985) and Vijay (1987) in muskmelon.

The characters days to first male flower, days to first female flower, number of female flowers per plant, number of fruits per plant, mean weight of fruit, fruit yield per plant, fruit length, fruit girth, flesh thickness, number of seeds per fruit and 100 seed weight had high estimates of heritability and genetic advance. It indicates that these characters are governed by additive gene action and selection will be rewarding for improvement of these traits.

Several reports were in agreement with this finding. In bittergourd, high estimates of heritability and genetic advance were reported by Srivastava and Srivastava (1976) for fruits per plant ; Singh *et al.* (1977) for yield, fruits per plant and fruit length; Ramachandran (1978) for yield per plant ; Vahab

(1989) for fruit weight, yield per plant and fruits per plant and Chaudhary *et al.* (1991) for yield per plant. In snakegourd, high heritability coupled with high genetic advance were noticed by Varghese and Rajan (1993 a) for fruits per plant ; Mathew (1996) for all the characters except flesh thickness and Radhika (1999) for days to first female flower, number of female flowers, number of fruits per plant, fruit yield per plant, fruit length, fruit girth, flesh thickness, number of seeds per fruit and 100 seed weight. In bottlegourd, high estimates of both heritability and genetic advance were reported by Prasad and Prasad (1979) for fruit length and diameter ; Sharma and Dhankar (1990) for fruits per plant and Kumar *et al.* (1999) for yield per plant and number of fruits per plant. Singh *et al.* (1986) noticed high heritability and genetic advance for fruits per plant and yield per plant in pointedgourd. Similarly, high heritability coupled with high genetic advance were reported by Reddy and Rao (1984) for yield, individual fruit weight, number of fruits and fruit length ; Kadam and Kale (1987) for days to flowering ; Prasad and Singh (1989) for yield in quintals per hectare, yield per plant and number of fruits and Varalakshmi *et al.* (1995) for seeds per fruit and 100 seed weight in ridgegourd ; Arora *et al.* (1983) for yield per plant and fruits per plant and Prasad *et al.* (1984) for fruit length, diameter and yield per plant in spongegourd ; Rana *et al.* (1986) for fruit number, Singh *et al.* (1988) and Borthakur and Shadeque (1990) for fruit weight in pumpkin ; Solanki and Seth (1980) for fruit yield, Abusaleha and Dutta (1990) for fruits per vine, Mariappan and Pappiah (1990) for fruit weight, Rastogi and Deep (1990 a) for fruit weight and fruits per vine and Gayathri (1997) for yield per plant, fruits per plant, average fruit weight and node to first female flower in cucumber ; Prasad *et al.* (1988) and Rajendran and Thamburaj (1994) for number of fruits per plant, number of seeds per fruit and 100 seed weight in watermelon ; Chonkar *et al.* (1979) for pulp thickness and fruit weight ; Kalloo *et al.* (1981) for yield per vine, fruits per plant and fruit weight ; Swamy *et al.* (1985) for yield per vine and fruit weight and Vijay (1987) for fruits per vine, flesh thickness, yield per vine, fruit weight and days to flower in muskmelon.

The characters days to first fruit harvest and duration of the crop exhibited high heritability and low genetic advance. It indicates that these characters are governed by non-additive gene action. The high heritability exhibited may be due to favourable influence of environment rather than genotype and selection for these traits may not be rewarding. Heterosis breeding may be useful for the improvement of these traits.

This result was in agreement with the findings of Varghese (1991) and Varghese and Rajan (1993 a) in snakegourd and Swamy *et al.* (1985) in muskmelon.

5.4 Combining ability and gene action

In a crop improvement programme for evolving heterotic hybrid varieties, one of the major criterion is the choice of suitable parents. The combining ability analysis helps in selecting suitable genotypes as parents for hybridisation programme and also gives information about the nature and magnitude of gene action. If the GCA variance is higher than the SCA variance for a trait, it denotes that there is preponderance of additive gene action and selection will be effective for the improvement of the trait. If the SCA variance is higher than GCA variance, it indicates that there is predominance of non-additive gene action (dominance and epistasis) for the trait, hence heterosis breeding may be rewarding. If both GCA and SCA variances are of equal magnitude, it shows that additive and non-additive genes are equally important in the expression of the character. In such a situation, reciprocal recurrent selection may be resorted to for population improvement.

The analysis of variance for combining ability revealed that both the GCA and SCA variances were significant for all the 13 characters studied. This indicates the involvement of both additive and non-additive gene actions in the inheritance of these characters. Hence selection as well as hybridisation will be effective for the genetic improvement of these traits.

For days to first male flower significant GCA and SCA variances were noticed for parents and hybrids indicating both additive and non-additive gene action. However, the SCA variance was much higher than GCA variance suggesting predominance of non-additive gene action. The dominance variance was also much higher than additive variance thereby confirming the predominance of non-additive gene action. Similar to this finding preponderance of non-additive gene action for days to first male flower was reported by Radhika (1999) in snakegourd and Janakiram and Sirohi (1988) in bottlegourd, whereas Gayathri (1997) observed predominance of additive gene action in cucumber.

Among the parents, significant negative GCA effects were shown by P_6 and P_1, while P_3 and P_4 showed significant positive GCA effects. The parents

P_6 and P_1 were found to be the best general combiners for days to first male flower. The hybrid P_6 x P_7 showed significant positive SCA effect, while all the other hybrids except P_1 x P_6, P_2 x P_7 and P_3 x P_7 showed significant negative SCA effects. The hybrid P_2 x P_6 had the highest significant negative SCA effect and this hybrid had parents with positive and negative GCA effects. Eight other hybrids were found to be on par with P_2 x P_6.

The analysis of variance for combining ability revealed that the variances due to parents and hybrids were significant for days to first female flower, indicating the involvement of both additive and non-additive gene actions in the expression of the trait. But the SCA variance was much higher than GCA variance implying the predominant role of non-additive gene action. The high value of dominance variance compared to additive variance also indicated non-additive gene action for the trait. In agreement to this, involvement of both additive and non-additive gene actions with predominance of non-additive gene action for days to first female flower was reported by Radhika (1999) in snakegourd. However, contrary to this, preponderance of additive gene action was reported by Pal *et al.* (1985) in bittergourd ; Gayathri (1997) in cucumber ; Chadha and Nandpuri (1980) and Kalb and Davis (1984) in muskmelon.

The parents P_6 and P_7 showed significant negative GCA effects while P_4 and P_3 showed significant positive GCA effects. The parent P_6 was the best general combiner for days to first female flower since it had the highest negative GCA effect. Among hybrids only P_6 x P_7 showed significant positive SCA effect and all the other hybrids except P_2 x P_7 and P_2 x P_3 had significant negative SCA effects. The highest significant negative SCA effect was shown by the hybrid P_5 x P_7 and in this hybrid, one parent was a good negative general combiner. Seven hybrids were on par with P_5 x P_7.

Significant GCA and SCA variances due to parents and hybrids were recorded for days to first fruit harvest. This indicated that both additive and non-additive gene actions were involved in the expression of the trait. Similar results was reported in muskmelon by Chadha and Nandpuri (1980). But the SCA variance was much higher than GCA variance suggesting preponderance of non-additive gene action for the trait. The value of dominance variance was much higher than additive variance and this also indicated the predominance of non-additive gene action for the character. Non-additive gene action for days to first fruit harvest was earlier reported by Pal *et al.* (1983) in bittergourd and Radhika (1999) in snakegourd. However, Sirohi and Choudhury (1977) and Vahab (1989) in bittergourd and Gayathri (1997) in cucumber observed additive gene action for the character.

The parents P_6 and P_5 had significant negative GCA effects, while P_1 had significant positive GCA effect. The parents P_6 and P_5 were the best general combiners for the trait. Among hybrids, only P_6 x P_7 had a significant positive SCA effect, while all other hybrids except P_1 x P_4 recorded significant negative SCA effects. The highest negative SCA effect was observed in the hybrid P_1 x P_5. In this hybrid, one parent was a positive general combiner and the other was a negative general combiner. Seven hybrids recorded high negative SCA effects which were on par with P_1 x P_5.

GCA and SCA variances were significant for number of female flowers per plant and this indicated that both additive and non-additive gene actions were involved in the expression of the trait. Here, the SCA variance was slightly higher than GCA variance. However, the value of dominance variance was much higher than additive variance. This indicated the preponderance of non-additive gene action for the character. Similar findings were reported by Vahab (1989) in bittergourd and Radhika (1999) in snakegourd.

The parents, P_5 and P_3 had significant positive GCA effects whereas P_1, P_7 and P_2 had significant negative GCA effects. The parents P_5 and P_3 were the best general combiners for number of female flowers per plant. Ten hybrids showed significant positive SCA effects, of which the hybrid P_1 x P_6 recorded the highest positive SCA effect and P_2 x P_6 and P_6 x P_7 were on par with it and hence these three hybrids were the best specific combiners for the trait. In these three crosses one parent was a positive general combiner.

Significant GCA and SCA variances were observed for number of fruits per plant, indicating the involvement of both additive and non-additive gene action for the expression of the character. The SCA variance was slightly higher than GCA variance while the dominance variance was much higher than additive variance. This indicated the predominance of non-additive gene action for the trait. Radhika (1999) in snakegourd and Solanki and Seth (1980) in cucumber reported predominance of non-additive gene action for the trait while several others observed preponderance of additive gene action [Singh and Joshi, (1979), Pal *et al.* (1983) and Vahab (1989) in bittergourd ; Smith *et al.* (1978), Dolgikh and Siderova (1983), Prudek (1984) and Gayathri (1997) in cucumber; Chadha and Nandpuri (1980) in muskmelon and Dyustin and Prosvirnin (1979) in watermelon].

Among the parents, P_3 and P_5 showed significant positive GCA effects, whereas P_7, P_4 and P_1 showed significant negative GCA effects. The parent P_3

was the best general combiner for number of fruits per plant. Six hybrids showed significant positive SCA effects of which P_3 x P_5 recorded the maximum positive value and hence was the best specific combiner for the character. In this hybrid, both the parents had positive GCA effects. No other hybrid was on par with P_3 x P_5.

The parents and hybrids exhibited significant combining ability variances for mean weight of fruit, indicating that both additive and non-additive gene actions were involved in the inheritance of the trait. The GCA variance was much higher than SCA variance implying a major role of additive gene action for the character which was also confirmed by the higher additive variance than the dominance variance. The results were in conformity with the findings of Vahab (1989) in bittergourd ; Gayathri (1997) in cucumber and Chadha and Nandpuri (1980) in muskmelon who reported both additive and non-additive gene action for the trait with the preponderance of additive gene action. Additive gene action was also reported by Smith *et al.* (1978) and Prudek (1984) in cucumber ; Dyustin and Prosvirnin (1979) in watermelon and Om *et al.* (1987) in orientalmelon whereas Pal *et al.* (1983) in bittergourd ; Radhika (1999) in snakegourd ; Solanki and Seth (1980) and Prudek and Wolf (1985) in cucumber reported non-additive gene action for the character.

All the parents showed significant GCA effects of which P_6, P_1, P_2 and P_7 had significant positive GCA effects while P_4, P_5 and P_3 had significant negative GCA effects. The parent P_6 was the best general combiner for the trait. All the hybrids except P_5 x P_6 showed significant SCA effects, of which 11 hybrids showed significant positive values. The hybrid P_2 x P_6 was the best specific combiner for mean weight of fruit since it had the highest positive SCA effect and no other hybrid was on par with it. The hybrid P_2 x P_6 had both the parents with positive GCA effects.

For fruit yield per plant, the combining ability analysis showed that the variances due to parents and hybrids were significant indicating the involvement of both additive and non-additive gene action. The value of the additive and dominance variances revealed the preponderance of non-additive gene action since the additive to dominance variance was less than unity. Similar to this finding Pal *et al.* (1983) in bittergourd ; Radhika (1999) in snakegourd and Bhagchandani *et al.* (1980) in summersquash reported predominance of non-additive gene action, while several authors reported predominance of additive gene action for the trait [Singh and Joshi (1979) and Vahab (1989) in bittergourd ; Smith *et al.* (1978), Tasdighi and Baker (1981), Dolgikh and Siderova (1983), Frederick and Staub (1989) and Gayathri (1997) in cucumber ; Kalb and Davis (1984) in muskmelon and Om *et al.* (1987) in orientalmelon].

Among the parents, P_6, P_2 and P_1 had significant positive GCA effects of which P_6 was the best general combiner for the trait. The parents P_4, P_5 and P_3 had significant negative GCA effects. Of the nine hybrids which showed significant positive SCA effects, P_2 x P_6 was the best specific combiner for the character and was significantly superior to P_1 x P_6, P_3 x P_7 and P_1 x P_7 which also showed high significant positive SCA effects. Both the parents of the hybrid P_2 x P_6 were good positive general combiners.

GCA and SCA variances due to parents and hybrids were significant for fruit length, indicating the involvement of both additive and non-additive gene action for the expression of the trait. The GCA variance was much higher than SCA variance and also the ratio of additive to dominance variance was more than unity suggesting the predominance of additive gene action. The reports by Singh and Joshi (1979) and Vahab (1989) in bittergourd; Radhika (1999) in snakegourd and Gayathri (1997) in cucumber support the present findings.

All the parents exhibited significant GCA effects of which P_6, P_1, P_2 and P_7 had significant positive effects while P_5, P_4 and P_3 had significant negative effects. The parent P_6 was the best general combiner and the hybrids P_2 x P_6, P_1 x P_5 and P_3 x P_7 were the best specific combiners out of the seven hybrids with significant positive SCA effects. In the hybrid P_2 x P_6 both the parents were positive general combiners, whereas in other two hybrids only one of the parent was a positive general combiner.

The combining ability analysis showed that the variances due to parents and hybrids were significant for fruit girth, indicating the role of both additive and non-additive gene action for the inheritance of the trait. However, the dominance variance was slightly higher than the additive variance indicating the preponderance of non-additive gene action. Radhika (1999) reported similar findings in snakegourd. But contrary to this, Vahab (1989) in bittergourd and Gayathri (1997) in cucumber reported preponderance of additive gene action.

All the parents showed significant GCA effects with P_2, P_6, P_1 and P_7 having positive effects and P_3, P_4 and P_5 with negative effects. The parents P_2, P_6, P_1 and P_7 were the best general combiners for fruit girth. Eight hybrids showed significant positive SCA effects of which the hybrids P_2 x P_6 and P_2 x

P_4 were the best specific combiners. In the hybrid P_2 x P_6 both the parents were positive general combiners while in P_2 x P_4 one of the parent alone was a positive general combiner.

For the character flesh thickness, the GCA and SCA variances due to parents and hybrids were significant. This showed that both additive and non-additive gene actions were involved in the inheritance of the trait. The additive to dominance ratio revealed the predominance of non-additive gene action for flesh thickness since the dominance variance was slightly higher than the additive variance. In conformity to this, Radhika (1999) in snakegourd, reported predominance of non-additive gene action, while Vahab (1989) in bittergourd, Chadha and Nandpuri (1980) and Kalb and Davis (1984) in muskmelon and Om *et al.* (1987) in orientalmelon observed preponderance of additive gene action.

Among the parents, P_6, P_2 and P_7 had significant positive GCA effects while P_3, P_5 and P_4 had significant negative GCA effects. The parents P_6, P_2 and P_7 with high significant positive GCA effects were the best general combiners for flesh thickness. Among the hybrids, 13 showed significant positive SCA effects of which P_6 x P_7 recorded the highest value with both the parents being positive general combiners.The cross P_3 x P_5 was on par with it and both the parents were negative general combiners.

The inheritance of number of seeds per fruit was controlled by both additive and non-additive gene action as indicated by the significant combining ability variances due to parents and hybrids. However, the additive variance was slightly higher than the dominance variance indicating the preponderance of additive gene action for the character. This was in conformity with the results of Vahab (1989) in bittergourd and Gayathri (1997) in cucumber. However, Radhika (1999) reported predominance of non-additive gene action for the trait in snakegourd.

Significant GCA effect was exhibited by all the parents of which P_6, P_2, P_7 and P_1 had positive effects while P_5, P_4 and P_3 had negative effects. The parents P_6, P_2 and P_7 were the best general combiners for the trait. Among the 11 hybrids which showed significant positive SCA effects, the hybrid $P_2 \times P_6$ was significantly superior to all others and was the best specific combiner for the character. Both the parents of $P_2 \times P_6$ showed positive GCA effects.

The GCA and SCA variances due to parents and hybrids were significant for 100 seed weight, indicating the role of additive and non-additive gene action. The estimated value of dominance variance was higher than additive variance suggesting the preponderance of non-additive gene action for the trait. Non-additive gene action for 100 seed weight was earlier reported by Radhika (1999) in snakegourd ; Gayathri (1997) in cucumber and Dyustin and Prosvirnin (1979) in watermelon.

The parents P_7 and P_5 showed significant positive GCA effects, with P_7 being the best general combiner, while P_4, P_3 and P_6 showed significant negative GCA effects. Ten hybrids recorded significant positive SCA effects of which the hybrid $P_3 \times P_5$ had the maximum SCA effect and the hybrids $P_2 \times P_6$ and $P_3 \times P_6$ were on par with it. In the hybrids $P_3 \times P_5$ and $P_2 \times P_6$, one of the parent was a positive general combiner while in $P_3 \times P_6$ both the parents were negative general combiners.

For duration of the crop, the parents and hybrids exhibited significant GCA and SCA variances suggesting the involvement of both additive and non-additive gene action for the inheritance of the character. However, the SCA variance was higher than GCA variance indicating the preponderance of non-additive gene action for the trait which was also confirmed by the ratio of dominance variance to additive variance which was greater than unity. Dyustin and Prosvirnin (1979) in watermelon reported non-additive gene action for duration of the crop. In contrary to this, Radhika (1999) in snakegourd ; Gayathri (1997) in cucumber and Gill and Kumar (1988) in watermelon reported preponderance of additive gene action.

Among the parents significant positive GCA effects were noticed in P_1, P_6, P_4 and P_2 and significant negative GCA effects in P_5 and P_7. The parent P_5 was the best general combiner because it had the highest negative GCA effect and no other parent was on par with it. Twelve hybrids showed significant negative SCA effects of which the hybrid P_2 x P_3 which had the highest negative value was on par with P_2 x P_4. Hence, P_2 x P_3 and P_2 x P_4 were the best specific combiners for the trait. The parents of both these hybrids were positive general combiners.

In general, it was observed that among parents P_6 (MC 40), P_2 (MC 18) and P_1 (MC 17) had high GCA effects and among hybrids P_2 x P_6 (MC 18 x MC 40), P_1 x P_6 (MC 17 x MC 40), P_3 x P_7 (MC 21 x MC 53), P_1 x P_7 (MC 17 x MC 53) and P_2 x P_7 (MC 18 x MC 53) had high SCA effects for yield and related characters.

5.5 Heterosis

Exploitation of hybrid vigour to increase the yield of fruits has become one of the most important techniques in vegetable breeding. In the present study the three types of heterosis - relative heterosis, heterobeltiosis and standard heterosis were estimated for the identification of desirable hybrids and to find out the magnitude of heterosis on yield and its components. The findings are discussed below.

For the character days to first male flower, all the 21 hybrids recorded significant negative heterosis over mid parent, better parent and standard variety. High relative heterosis and heterobeltiosis observed in the hybrid P_4 x P_5 could be attributed to the high negative SCA effect of the hybrid. The hybrid P_2 x P_6 recorded the highest standard heterosis, in which one parent (P_6) was a good general combiner. The same hybrid had the highest negative SCA effect in combining ability analysis. Six hybrids were found to be on par with P_2 x P_6. Negative heterosis for days to first male flower was earlier reported by Ram *et al.* (1997) in bittergourd ; Radhika (1999) in snakegourd ; Gayathri (1997) in cucumber and Kasrawi (1994) in summersquash.

All the hybrids showed significant negative relative heterosis and heterobeltiosis for days to first female flower and the hybrid P_1 x P_5 had the highest value for these two types of heterosis. Fifteen hybrids recorded significant negative standard heterosis, in which the hybrid P_2 x P_6 had the highest value and the hybrids P_4 x P_6, P_5 x P_7 and P_5 x P_6 were found to be equally good. These significant heterosis may be due to the high negative GCA effect of one of the parent and high negative SCA effects of hybrids. Negative heterosis for the character was earlier reported by Agrawal *et al.* (1957), Srivastava and Nath (1983), Chaudhari (1987), Vahab (1989), Ranpise *et al.* (1992), Ram *et al.* (1997) in bittergourd ; Radhika (1999) in snakegourd ; Gayathri (1997) in cucumber and Kasrawi (1994) in summersquash.

Significant negative relative heterosis, heterobeltiosis and standard heterosis were exhibited by all the hybrids for days to first fruit harvest. Highest relative heterosis was observed in the hybrid P_1 x P_5, whereas the hybrid P_2 x P_5 had the maximum heterobeltiosis. It was observed that, in these two hybrids, one of the parent (P_5) had high negative GCA effect and both the hybrids had high negative SCA effects. The hybrid P_2 x P_4 exhibited the maximum standard heterosis. Here, eventhough the parents had non-significant negative GCA effects, the SCA effect of hybrid was high and it may have contributed to the high heterosis estimate. Fifteen hybrids recorded on par values. Vahab (1989) and Ranpise *et al.* (1992) in bittergourd ; Varghese and Rajan (1993 b) and Radhika (1999) in snakegourd and Ghai *et al.* (1998) in summersquash observed negative heterosis for the character. In contrary to this, Gayathri (1997) reported no significant heterosis for the character in cucumber.

For number of female flowers per plant, significant positive relative heterosis and heterobeltiosis were shown by 16 and six hybrids respectively. Highest values for these two types of heterosis were shown by the hybrid P_6 x P_7 and it could be attributed to the high SCA effect of the hybrid. All the hybrids exhibited significant positive standard heterosis and the hybrid P_3 x P_5 had the maximum value. The high estimate of standard heterosis in this hybrid could be due to the involvement of two good general combiners as the parents along with the high SCA effect of the hybrid. The hybrids P_2 x P_6 and P_6 x P_7 were on par with P_3 x P_5 and these two hybrids had high SCA effects. Pronounced heterosis for this trait was reported earlier by Pal and Singh (1946) and Vahab (1989) in bittergourd and Radhika (1999) in snakegourd.

Significant positive heterosis over mid parent, better parent and standard variety were shown by eight, four and nineteen hybrids respectively for number of fruits per plant. Highest relative heterosis and heterobeltiosis were exhibited by the cross P_6 x P_7. In this cross, eventhough the parents had negative GCA effects, the SCA effect of the hybrid was positive and highly significant. Maximum positive standard heterosis was shown by the hybrid P_3 x P_5 which was significantly superior to all others. This could be attributed to the involvement of two positive general combiners as parents and the highest positive SCA effect of the hybrid. Several authors reported significant heterosis for the trait. [Aiyadurai (1951), Srivastava (1970), Srivastava and Nath (1983), Ranpise (1985), Vahab (1989), Ranpise *et al.* (1992), Mishra *et al.* (1994), Kennedy *et al.* (1995), Celine and Sirohi (1996) and Ram *et al.* (1997) in bittergourd ; Radhika (1999) in snakegourd ; Kumar (1999) in bottlegourd and Kasrawi (1994) in summersquash]. But contrary to this, Gayathri (1997) reported negative standard heterosis for the character in cucumber.

For mean weight of fruit, ten hybrids for relative heterosis, four hybrids for heterobeltiosis and five hybrids for standard heterosis were found to be positively significant. The maximum value for the three types of heterosis was shown by the hybrid P_2 x P_6 which was significantly superior to all the others. This could be attributed to the highly significant positive GCA effects of the parents, the high positive SCA effect of the hybrid and the high *per se* performance of the hybrid. P_1 x P_6 was the other hybrid with a high value for standard heterosis. Here also both the parents were good positive general combiners and the SCA effect of the hybrid was positive and high. Significant positive heterosis for the trait was earlier reported by Srivastava (1970), Lal *et al.* (1976), Vahab (1989), Mishra *et al.* (1994) and Kennedy *et al.* (1995) in bittergourd ; Radhika (1999) in snakegourd ; Kumar *et al.* (1999) in bottlegourd and Gayathri (1997) in cucumber.

Studies on heterosis revealed that significant positive relative heterosis, heterobeltiosis and standard heterosis were exhibited by 11, seven and 12 hybrids respectively for fruit yield per plant. The cross P_2 x P_6 exhibited highest value for the three types of heterosis and was significantly superior to all the other crosses. The significant heterosis could be attributed to the high and positive GCA effects of parents and SCA effect of the hybrid. High standard heterosis for the character was also noticed in P_1 x P_6, P_1 x P_7 and P_6 x P_7. Many workers reported heterosis for the character [Pal and Singh (1946), Aiyadurai (1951), Srivastava (1970), Lal *et al.* (1976), Singh and Joshi (1979), Srivastava and Nath (1983), Ranpise *et al.* (1985), Vahab (1989), Lawande and Patil (1990), Ranpise *et al.* (1992), Mishra *et al.* (1994), Devadas *et al.* (1995), Kennedy *et al.* (1995), Celine and Sirohi (1996) and Ram *et al.* (1997) in bittergourd ; Varghese (1991) and Radhika (1999) in snakegourd ; Janakiram and Sirohi (1992) in bottlegourd ; Musmade *et al.* (1995) and Ram *et al.* (1995) in cucumber ; More and Seshadri (1980) and Munshi and Verma (1997) in muskmelon and Kasrawi (1994) and Ghai *et al.* (1998) in summersquash]. However, Gayathri (1997) observed no significant positive standard heterosis for fruit yield per plant in cucumber.

For fruit length, eight hybrids showed significant positive relative heterosis, one showed significant positive heterobeltiosis and four hybrids showed significant positive standard heterosis. The hybrid P_2 x P_6 showed the maximum positive significant values for the three types of heterosis and no other hybrid was on par with $P_2 \times P_6$. It was observed that, in the cross $P_2 \times P_6$ both the parents were good positive general combiners and the hybrid had the highest positive SCA effect for the character. Significant heterosis for the trait was earlier reported by Srivastava (1970), Lal *et al.* (1976), Singh and Joshi (1979), Vahab (1989), Ranpise *et al.* (1992), Mishra *et al.* (1994) and Kennedy *et al.* (1995) in bittergourd ; Radhika (1999) in snakegourd; Gayathri (1997) in cucumber and Kumar *et al.* (1999) in bottlegourd.

For fruit girth, significant positive values were shown by 12, seven and three hybrids for relative heterosis, heterobeltiosis and standard heterosis respectively. The maximum positive relative heterosis, heterobeltiosis and standard heterosis were shown by the cross $P_2 \times P_6$, which could be attributed to the high positive GCA effects of parents and the high positive SCA effect of the cross. This hybrid was found to be significantly superior to all other hybrids. Srivastava (1970), Lal *et al.* (1976) and Vahab (1989) in bittergourd and Radhika (1999) in snakegourd have also reported heterotic effects for the trait.

Out of 21 hybrids, significant positive values were exhibited by 20, 17 and 11 hybrids over mid parent, better parent and standard variety respectively for the character flesh thickness. The hybrid $P_6 \times P_7$ recorded the highest positive value for relative heterosis and standard heterosis. This may be due to the positive GCA effect of parents and high SCA effect of the hybrid. The hybrid $P_2 \times P_6$ showed the maximum positive heterobeltiosis and it was observed that both the parents were good general combiners and the hybrid had high positive SCA effect. The hybrid $P_6 \times P_7$ was on par with $P_2 \times P_6$. Heterosis for flesh thickness was reported earlier by Aiyadurai (1951), Vahab

(1989), Ranpise *et al.* (1992) and Kennedy *et al.* (1995) in bittergourd ; Radhika (1999) in snakegourd and Pal *et al.* (1984) in bottlegourd.

For number of seeds per fruit, significant positive heterosis was shown by 14 hybrids over the mid parent, eight hybrids over the better parent and nine hybrids over the standard variety. The cross P_2 x P_6 recorded the highest positive value for the three types of heterosis and this could be attributed to the high and positive GCA effects of parents and the high positive SCA effect of the cross. The hybrid P_2 x P_6 was significantly superior to all other hybrids. Vahab (1989) in bittergourd ; Radhika (1999) in snakegourd ; Gayathri (1997) in cucumber and Doijode *et al.* (1983) in pumpkin observed similar results.

Significant positive relative heterosis and heterobeltiosis were observed in 16 and 13 hybrids respectively for 100 seed weight while none of the hybrids showed significant positive standard heterosis. The highest positive value for relative heterosis and heterobeltiosis shown by the hybrid P_2 x P_6 may be due to the high positive SCA effect of the hybrid. The hybrid P_3 x P_6 was on par with P_2 x P_6 for relative heterosis, while the hybrids P_3 x P_6 and P_1 x P_6 were on par with P_2 x P_6 for heterobeltiosis. These hybrids also had high positive SCA effects. Vahab (1989) in bittergourd, Radhika (1999) in snakegourd, Gayathri (1997) in cucumber and Doijode *et al.* (1983) in pumpkin observed heterosis for the trait.

Negative heterosis is important for the character duration of the crop. Significant negative heterosis was recorded by 15 hybrids over the mid parent, 16 hybrids over the better parent and 13 hybrids over the standard variety. The hybrid P_5 x P_7 recorded the highest significant negative relative heterosis, heterobeltiosis and standard heterosis. This was due to the negative GCA effects of the parents and the high negative SCA effect of the hybrid. The hybrid P_2 x P_3 was on par with P_5 x P_7 for all the three types of heterosis. Eventhough the parents of P_2 x P_3 had positive GCA effects, the hybrid had the highest SCA effect in the combining ability analysis for the character. Negative heterosis for the character was earlier reported by Kennedy *et al.* (1995) in bittergourd ; Varghese and Rajan (1993 b) and Radhika (1999) in snakegourd.

In general, the general combining ability analysis revealed that the parent P_6 (MC 40) was the best general combiner for several traits including days to first male flower, days to first female flower, days to first fruit harvest, mean weight of fruit, fruit yield per plant, fruit length, fruit girth, flesh thickness and number of seeds per fruit. The parents P_2 (MC 18) and P_1 (MC 17) were also good general combiners for yield and its attributes. These three parents also had good *per se* performance for most of the characters indicating that the combining ability of parents was related to *per se* performance as well.

A number of crosses showed significant specific combining ability effects for various characters. In almost all the crosses having high SCA effects for the different characters, one or both of the parents were good general combiners for the character and was manifested in their combinations. The cross P_2 x P_6 (MC 18 x MC 40) showed the highest mean performance, SCA effect and standard heterosis for yield and related characters and hence it was the best hybrid (Plate 2). The other promising hybrids were P_1 x P_6 (MC 17 x MC 40) (Plate 3), P_1 x P_7 (MC 17 x MC 53) and P_2 x P_7 (MC 18 x MC 53) (Plate 4).

Plate 2 The parents P_2 (MC 18) and P_6 (MC 40) along with the hybrid P_2 x P_6 (MC 18 x MC 40)

Plate 2

Plate 3 The parents P_1 (MC 17) and P_6 (MC 40) along with the hybrid P_1 x P_6 (MC 17 x MC 40)

Plate 4 The parents P_2 (MC 18) and P_7 (MC 53) along with the hybrid P_2 x P_7 (MC 18 x MC 53)

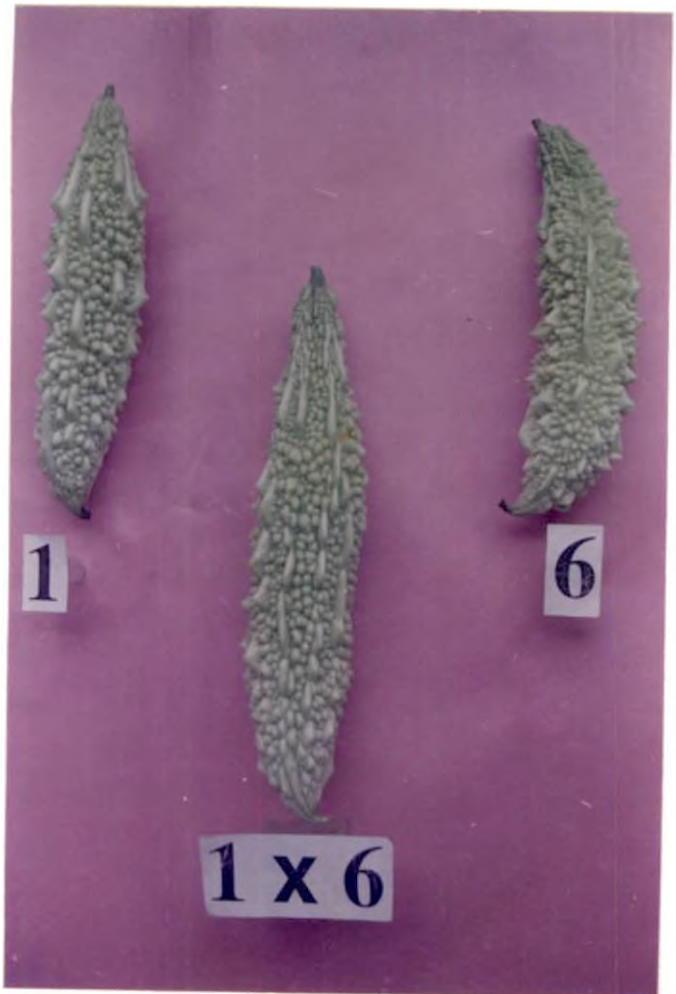


Plate 3

Plate 4

SUMMARY

6. SUMMARY

The present investigation to study the combining ability, gene action and heterosis in bittergourd was undertaken in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani involving seven parents and their 21 hybrids without reciprocals, along with the check variety, Preethi. The observations were recorded on yield and important yield attributes. The salient findings are given below.

With regard to mean performance, all the 29 genotypes showed significant differences for the 13 characters studied. Among the parents, P_1 was the highest fruit yielder with maximum flesh thickness and fruit girth while P_3, P_4 and P_5 produced the maximum numbers of fruits per plant. The parent P_4 (along with P_2 and P_5) had the shortest duration and the parents P_5, P_3 and P_4 produced the maximum number of female flowers. However, P_6 exhibited the minimum number of days to first male and female flower production, maximum mean fruit weight and the longest fruit whereas P_7 was the earliest fruit yielder having maximum number of seeds per fruit and 100 seed weight.

Among the hybrids, $P_2 \times P_6$ recorded the minimum number of days to first male and female flower along with several other hybrids on par with it. For days to first fruit harvest, the cross $P_2 \times P_4$ along with 14 other hybrids were the earliest. $P_3 \times P_5$ produced maximum number of female flowers with $P_6 \times P_7$ and $P_2 \times P_6$ being equally good, while $P_3 \times P_5$ produced the maximum number of fruits and was significantly superior to all others. The hybrid $P_2 \times P_6$ had the maximum mean weight of fruit, fruit yield, fruit length, fruit girth and number of seeds per fruit and was significantly superior to all other hybrids. Maximum flesh thickness was recorded by the fruits of P_6 x P_7 and P_2 x P_6. The hybrid P_2 x P_7 along with five other hybrids had the maximum 100 seed weight. The shortest duration of the crop was recorded by P_5 x P_7 and P_2 x P_3. Several other hybrids, in general, exhibited good performance compared to the check variety.

All the characters except days to first fruit harvest and duration of the crop had comparatively high GCV values and high genetic advance, whereas all the 13 characters showed high heritability indicating that majority of the characters in bittergourd can be improved through selection.

The variances due to general and specific combining abilities were significant for all the characters indicating the involvement of both additive and non-additive gene actions for the expression of all the characters. However, dominance variances were high compared to additive variances in all the characters studied except mean weight of fruit, fruit length and number of seeds per fruit, suggesting the preponderance of non-additive gene action and thereby indicating the scope of heterosis breeding for improving the crop.

The parent, P_6 was the best general combiner for several traits including days to first male flower, days to first female flower, days to first fruit harvest, mean weight of fruit, fruit yield per plant, fruit length, fruit girth, flesh thickness and number of seeds per fruit. The parents P_5 and P_3 were the best general combiners for number of female flowers per plant while P_5 was the best general combiner for duration of the crop. For the characters number of fruits per plant and 100 seed weight the best general combiners were P_3 and P_7 respectively.

The hybrid P_2 x P_6 along with eight other hybrids were good specific combiners for days to first fruit harvest. P_5 x P_7 together with seven other hybrids showed high SCA effects for days to first female flower. Highest SCA effect for days to first fruit harvest was shown by P_1 x P_5 and seven other hybrids. P_1 x P_6, P_2 x P_6 and P_6 x P_7 were the best specific combiners for number of female flowers per plant and P_3 x P_5 for number of fruits per plant. The hybrid P_2 x P_6 was the best specific combiner for mean weight of fruit, fruit yield per plant, number of seeds per fruit, fruit length (along with P_1 x P_5 and P_3 x P_7) and fruit girth (along with P_2 x P_4). High SCA effects were also exhibited by the hybrids P_6 x P_7 and P_3 x P_5 for flesh thickness, P_3 x P_5 along with P_2 x P_6 and P_3 x P_6 for 100 seed weight and P_2 x P_3 and P_2 x P_4 for duration of the crop.

Several hybrids showed significant relative heterosis, heterobeltiosis and standard heterosis for all the 13 characters studied except significant standard heterosis for 100 seed weight. Maximum negative standard heterosis to first male and female flower was recorded by P_2 x P_6 and for days to first fruit harvest, by P_2 x P_4 along with several other hybrids. The hybrids P_3 x P_5, P_2 x P_6 and P_6 x P_7 recorded the maximum positive standard heterosis for number of female flowers per plant, P_3 x P_5 for number of fruits per plant and P_2 x P_6 for mean weight of fruit, fruit yield per plant, fruit length, fruit girth and number of seeds per fruit, P_6 x P_7 and P_2 x P_6 for flesh thickness while P_5 x P_7 along with P_2 x P_3 recorded the maximum negative standard heterosis for duration of the crop.

In conclusion it can be stated that the parent P_6 (MC 40) was the best general combiner for most of the characters studied. The cross P_2 x P_6 (MC 18 x MC 40) which had the highest mean performance was the best specific combiner and also exhibited significant standard heterosis for yield and most of the yield attributes. However, the hybrids P_1 x P_6 (MC 17 x MC 40), P_1 x P_7 (MC 17 x MC 53) and P_2 x P_7 (MC 18 x MC 53) were also found to be heterotic and promising with respect to yield and related characters.

REFERENCES

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REFERENCES

Abusaleha, A. and Dutta, O. P. 1990. Studies on variability, heritability and scope of improvement in cucumber. *Haryana J. Hort. Sci.* **19** (3-4) : 349-352

Agrawal, J. S., Khanna, A. N. and Singh, S. P. 1957. Studies on floral biology and breeding in *Momordica charantia* L. *Indian J. Hort.* **14** : 42-44

Aiyadurai, S. G. 1951. Preliminary studies in bittergourd. *Madras agric. J.* **38** : 245-246

*Aleksandrova, M. 1988. Results of breeding heterotic hybrid varieties of green house cucumber. *Rasteniev "dni-Nauki"* **25** (5) : 60-63

Arora, S. K., Pandita, M. L., Pratap, P. S. and Sindhu, A. S. 1983. Variability and correlation studies in spongegourd (*Luffa cylindrica* Roem). *Haryana Agric. Univ. J. Res.* **13** (1) : 146-149

Bhagchandani, P. M., Singh, N.and Thakur, P. C. 1980. Combining ability in summersquash (*Cucurbita pepo* L.). *Indian J. Hort* **37**: 62-65

Borthakur, U. and Shadeque, A. 1990. Genetic variability studies in pumpkin (*Cucurbita moschata* Poir). *Veg. Sci.* 17 (2) : 221-223

Brar, J. S. and Sukhija, B. S. 1977. Line x Tester analysis of combining ability in watermelon. *Indian J. Hort.* **34** : 410-414

Burton, G. W. 1952. Quantitative inheritance in grasses. *6th Int. Grass Land Cong.* **1** : 277-283

Celine, V. A. and Sirohi, P. S. 1996. Heterosis in bittergourd (*Momordica charantia* L.). *Veg. Sci.* **23** (2) : 180-185

Chacko, E. 1992. Evaluation of dessert type of muskmelon (*Cucumis melo* L.) for southern region of Kerala. M.Sc. (Hort.) thesis, Kerala Agricultural University, Thrissur, Kerala

Chadha, M. L. and Nandpuri, K. S. 1980. Combining ability in muskmelon (*Cucumis melo* L.). *Indian J. Hort.* **37** : 55

Chaudhary, S. M. 1987. Studies on heterosis, combining ability and correlation in bittergourd (*Momordica charantia* L.). Ph.D. thesis, Mahatma Phule Agricultural University, Rahuri, Maharashtra

Chaudhary, S. M., Kale, P. N. and Desai, U. T. 1991. Variability studies and scope of improvement for fruit yield in bittergourd. *J. Maharashtra Agric. Univ.* **16** (1) : 15-17

Chonkar, V. S., Singh, D. N. and Singh, R. L. 1979. Genetic variability and correlation studies in muskmelon. *Indian J. agric. Sci.* **49** : 361-363

Delancy, D. E. and Lower, R. L. 1987. Generation mean analysis of plant characters in crosses between two determinate cucumber lines and *Cucumis sativus* var. *hardwickii*. *J. Amer. Soc. Hort. Sci.* **112** : 707-711

Devadas, V. S., Seemanthini, R. and Ramadas, S. 1995. Combining ability of seed yield and quality parameters in bittergourd (*Momordica charantia* L.). *Indian J. Genet. Plant Breed.* **55** (1) : 41-45

Dixit, J. and Kalloo, G. 1983. Heterosis in muskmelon (*Cucumis melo* L.). *Haryana Agric. Univ. J. Res.* **13** (4) : 549-553

Doijode, S. D. and Sulladmath, U. V. 1984. Preliminary studies on heterosis in pumpkin (*Cucurbita moschata* Poir.). *Mysore J. agric. Sci.* **18** (1) : 30-34

Doijode, S. D. and Sulladmath, U. V. 1986. Genetic variability and correlation studies in pumpkin (*Cucurbita moschata* Poir). *Mysore J. agric. Sci.* **20** (1) : 59-61

Doijode, S. D., Sulladmath, U. V. and Kulkarni, R. S. 1983. Heterosis for certain seed characters in pumpkin (*Cucurbita moschata* Poir). *Indian J. Hered.* **15** (1/4) : 8-13

*Dolgikh, S. T. and Siderova, A. M. 1983. Combining ability of induced mutants and partially dioecious forms of cucumber. *Genetica.* **19** : 1292-1300

*Dyustin, K. E. and Prosvirnin, V. J. 1979. Diallel analysis of economically useful characters in watermelon and melon. *Tsitologiya i genetica.* **13** (6) : 456-462

*Fang, X. J., Gu, X. F. and Han, X. 1994. New cucumber cultivar. 'Zhongnong 8' for outdoor cultivation. *Chinese Veg.* **3** : 2

Frederick, L. R. and Staub, J. E. 1989. Combining ability analysis of fruit yield and quality in near homozygous lines derived from cucumber. *J. Amer. Soc. Hort. Sci.* **144** (2) : 332-338

*Garrison, W. 1977. The world crops plant germplasm and endangered resources. *The Bulletin of the Atomic Scientists* **33** : 9-16

Gayathri, K. 1997. Genetic variability and heterosis in cucumber (*Cucumis sativus* L.). M.Sc. thesis, Kerala Agricultural University, Thrissur, Kerala

Ghaderi, A. and Lower, R. L. 1981. Estimates of genetic variance for yield in pickling cucumber. *J. Amer. Soc. Hort. Sci.* **106** : 237-238

Ghai, T. R., Singh, J., Arora, S. K. and Singh, J. 1998. Heterosis studies for earliness and yield in summersquash (*Cucurbita pepo* L.). *Punjab Vegetable Grower*, **33** : 35-40

Gill, B. S. and Kumar, J. C. 1988. Combining ability analysis in watermelon (*Citrullus lanatus*). *Indian J. Hort.* **45** (2) : 104-109

Gopalan, C., Sastri, B. V. R. and Balasubramanian, S. C. 1982. Nutritive value of Indian foods, ICMR, National Institute of Nutrition, Hyderabad

Griffing, B. 1956. Concepts of general and specific combining ability in relation to diallel crossing systems. *Aust. J. Biol. Sci.* **9** : 463-493

*Guseva, L. T. and Mospan, M. V. 1984. Studying of combining ability in the production of cucumber hybrids. *Geneticheske Osnovy Seleitsii Selskokh Zyaistvennykh rastenii i Zhinotnykh* **28** : 29

Hormuzdi, S. G. and More, T. A. 1989. Heterotic studies in cucumber (*Cucumis sativus* L.). *Indian J. Hort.* **46** (1) : 73-79

Imam, M. K., Abobaker, M. A. and Yacoub, H. M. 1977. Inheritance of some characters in cucumber ; some quantitative characters. *Libyan J. Agric.* **6** : 115-125

Indiresh, B. T. 1982. Studies on genotypic and phenotypic variability in bittergourd (*Momordica charantia* L.). *Thesis abstracts* **8** (1) : 52

Janakiram, T. and Sirohi, P. S. 1988. Combining ability of quantitative characters in 10 x 10 diallel cross of round fruited bottlegorud. *Annals. agric. Res.* **9** (2) : 207-214

Janakiram, T. and Sirohi, P. S. 1992. Studies on heterosis for quantitative characters in bottlegourd. *J. Maharashtra Agric. Univ.* **17** (2) : 204-206

Johnson, H. W., Robinson, H. D. and Comstock, R. E. 1955. Estimates of genetical and environmental variability in soybeans. *Agron. J.* **47** : 314-318

Joseph, S. 1978. Genetic variability and correlation studies in snakegourd (*Trichosanthes anguina* L.). M.Sc. thesis, Kerala Agricultural University, Thrissur, Kerala

Kadam, P. Y. and Kale, P. N. 1987. Genetic variability in ridgegourd. *J. Maharashtra Agric. Univ.* **12** (2) : 242-243

Kalb, T. J. and Davis, D. W. 1984. Evaluation of combining ability, heterosis and genetic variability for fruit quality characteristics in bush muskmelon. *J. Amer. Soc. Hort. Sci.* **109** (3) : 411-415

*Kale, P. B. and Seshadri, V. S. 1988. Studies on combining ability in watermelon (*Citrullus lanatus* (Mastumura) Nakai). *PKV Research Journal* **12** (1) : 45-48

Kalloo, G., Dixit, J. and Sidhu, A. S. 1981. Studies on genetic variability and character association on muskmelon (*Cucumis melo* L.). *Indian J. Hort.* **38** (1 & 2) : 79-85

Kalyanasundaram, P. 1976. Evaluation of three muskmelon cultivars (*Cucumis melo* L.). *South Indian Hort.* **24** : 18-23

Kasrawi, M. A. 1994. Heterosis and reciprocal differences for quantitative traits in summersquash (*Cucurbita pepo* L.). *J. Genet. Breed.* **48** (4) : 399-403

KAU. 1996. *Package of Pracitces Recommendations Crops.* Kerala Agricultural University, Directorate of Extension, Mannuthy, Thrissur

Kennedy, R. R., Arumugam, R., Kandasamy, G. and Suresh, S. 1995. Heterosis studies in bittergourd (*Momordica charantia* L.). *Madras agric. J.* **82** (2) : 121-123

Kohle, A. K. 1972. Exploitation of hybrid vigour in cucurbits. *Indian J. Hort.* **29** : 17-21

*Korzeniewska, A. and Nierricrowicz - Sczezytt, K. 1994. Combining ability and heterosis effect in wintersquash (*Cucurbita maxima*). *Genetica Polonica* **34** (3) : 259-272

Kumar, R., Singh, D. K. and Ram, H. H. 1999. Manifestation of heterosis in bottlegourd (*Lagenaria siceraria* (Mol.) standl). *Annals. agric. Res.* **20** (2) : 177-179

Kuti, J. O. and Ng, T. J. 1989. Combining ability estimates for muskmelon tolerance to *Myrothecium roridum* and its toxic metabolite roridin E. *J. Amer. Soc. Hort. Sci.* **114** (2) : 319-321

Lal, S. D., Seth, T. N. and Solanki, S. S. 1976. Note on heterosis in bittergourd (*Mormordica charantia* L.). *Indian J. agric. Res.* **10** (3) : 195-197

Lawande, K. E. and Patil, A. V. 1990. Heterosis in bittergourd. *Haryana J. Hort. Sci.* **19** (3-4) : 342-348

Li, P. J. and Shu, J. H. 1985. A preliminary analysis of combining ability for several quantitative characters in watermelon. *Shanghai Agric. Sci. Technol.* **3** : 1-3

Mangal, J. L., Dixit, J., Pandita, M. L. and Sindhu, A. A. 1981. Genetic variability and correlation studies in bittergourd (*Momordica charantia* L.). *Indian J. Hort.* **38** (1 & 2) : 94-99

Mariappan, S. and Pappiah, C. M. 1990. Genetic studies in cucumber (*Cucumis sativus* L.). *South Indian Hort.* **38** (2) : 70-74

Mathew, S. S. 1996. Evaluation of genetic divergence in snakegourd (*Trichosanthes anguina*). M.Sc. thesis, Kerala Agricultural University, Thrissur, Kerala

Mishra, H. N., Mishra, R. S., Mishra, S. N. and Parhi, G. 1994. Heterosis and combining ability in bittergourd. *Indian J. agric. Sci.* **64** (5) : 310-313

More, T. A. and Seshadri, V. S. 1980. Studies on heterosis in muskmelon. *Veg. Sci.* **7** (1) : 27

Munshi, A. D. and Verma, V. K. 1997. Studies on heterosis in muskmelon (*Cucumis melo*). *Veg. Sci.* **24** (2) : 103-106

Musmade, A. M. and Kale, P. N. 1986. Heterosis and combining ability in cucumber (*Cucumis sativus* L.). *Veg. Sci.* **13** : 60-68

Musmade, A. M., Kale, P. N., Desai, U. T. and Lawande, K. E. 1995. Heterosis in cucumber (*Cucumis sativus* L.). National Symposium on Recent Developments in Vegetable Improvement, Abstracts, 2-5 Feb. 1995. Raipur. *Indian Society of Vegetable Science* : 11

*Nikulenkova, E. F. 1984. New hybrid cucumbers from the Netherlands for winter green houses. *Genetike i Seleksii* **90** : 104-108

*Om, Y. H., Choi, K. S., Lee, C. H. and Choi, C. I. 1978. Diallel analysis of several characters in cucumber (*Cucumis sativus* L.). *Korean J. Breed.* **10** : 44-50

*Om, Y. H., Oh, D. G. and Hong, K. H. 1987. Evaluation of heterosis and combining ability for several major characters in orientalmelon. *Research Reports of the Rural Development Administration,* Horticulture Korea Republic **29** (1) : 74-76

Owens, K. W., Bliss, F. S. and Peterson, C. E. 1985. Genetic analysis of fruit length and weight in two cucumber populations using inbred backcross line method. *J. Amer. Soc. Hort. Sci.* **110** : 431-436

Pal, A. B., Doijode, S. D. and Biswas, S. R. 1983. Line x Tester analysis of combining ability in bittergourd (*Momordica charantia* L.). *South Indian Hort.* **31** (2/3) : 72-76

Pal, A. B., Shivanandappa, D. J. and Vani, A. 1984. Manifestation of heterosis in bottlegourd. *South Indian Hort.* **32** (1) : 33-38

Pal, A. B. and Singh, H. 1946. Studies in hybrid vigour II. Notes on the manifestation of hybrid vigour in brinjal and bittergourd. *Indian J. Genet. Pl. Breed.* **6** : 19-33

Prasad, L., Gautam, N. C. and Singh, S. P. 1988. Studies on genetic variability and character association in watermelon (*Citrullus lanatus* (Thumb) Mansf.) *Veg. Sci.* **15** (1) : 86-94

Prasad, R. and Prasad, A. 1979. A note on heritability and genetic advance in bottlegourd (*Lagenaria siceraria* (Mol.) Standl). *Indian J. Hort.* **36** (4) : 446-448

Prasad, A., Sind, P. D. and Nalini, K. 1984. Heritability and genetic advance in *Luffa cylindrica* L. *Prog. Hort.* **16** : 312-315

Prasad, V. S. R. K. and Singh, D. P. 1989. Studies on heritability, genetic advance and correlation in ridgegourd. *Indian J. Hort.* **46** : 390-394

Prasad, V. S. R. K. and Singh, D. P. 1994. Diallel analysis of yield components in slicing cucumber (*Cucumis sativus* L.). *J. Res.* **6** : 151-154

Prasunna, M. N. and Rao, M. R. 1988. Variability studies in cucumber (*Cucumis* sp.). *South Indian Hort.* **36** (5) : 237-241

*Prudek, M. 1984. Diallel analysis of combining ability for yield components in field grown salad cucumber. *Acta Universitatis Agriculturae Brno A.* **32** (4) : 349-355

*Prudek, M. and Wolf, J. 1985. Combining ability and phenotypic stability for yield components in field grown salad cucumber. *Acta Universitatis Agriculturae Brno A.* **33** (4) : 91-98

Radhika, V. S. 1999. Estimation of combining ability and heterosis in snakegourd (*Trichosanthes anguina* L.). M.Sc. thesis, Kerala Agricultural University, Thrissur, Kerala

Rai, B. 1979. Heterosis breeding. Agro Biological Publications, Delhi, p. 183

Rajendran, P. C. and Thamburaj, S. 1994. Genetical variability in biometrical traits in watermelon (*Citrullus lanatus*). *Indian J. agric. Sci.* **64** (1) : 5-8

Ram, D., Kalloo, G. and Singh, M. 1997. Heterosis in bittergourd (*Momordica charantia* L.). *Veg. Sci.* **24** (2) : 99-102

Ram, H. H., Singh, D. K. and Rai, P. N. 1995. Prospects of hybrid breeding in cucurbits. In : National Symposium on Recent Developments in Vegetable Improvement, Abstracts. 2-5 Feb, 1995. Raipur. *Indian Society of Vegetable Science*, p. 12

Ramachandran, C. 1978. Genetic variability, correlation studies and path coefficient analysis in bittergourd (*Momordica charantia* L.). M.Sc. thesis, Kerala Agricultural University, Thrissur, Kerala

Ramachandran, C. and Gopalakrishnan, P. K. 1979. Correlation and regression studies in bittergourd. *Indian J. agric. Sci.* **49** : 850-854

Ramachandran, C. and Gopalakrishnan, P. K. 1980. Variability studies for biochemical traits in bittergourd. *Agric. Res. J. Kerala* **18** : 27-32

Rana, T. K., Vashista, R. N. and Pandita, M. L. 1986. Genetic variability and heritability studies in pumpkin (*Cucurbita moschata* Poir). *Haryana J. Hort. Sci.* **15** (1-2) : 71-75

Randhawa, K. S. and Singh, M. J. 1990. Assessment of combining ability, heterosis and genetic variance for fruit quality characters in muskmelon (*Cucumis melo* L.). *Indian J. Genet. Pl. Breed.* **50** (2) : 127-130

Ranpise, S. A. 1985. Heterosis and combining ability studies in bittergourd (*Momordica charantia* L.). M.Sc. thesis, Mahatma Phule Agricultural University, Rahuri, Maharashtra

Ranpise, S. A., Kale, P. N., Desale, G. Y. and Desai, U. T. 1992. Heterosis in bittergourd (*Momordica charantia* L.). *South Indian Hort.* **40** (6) : 313-315

Rastogi, K. B. and Deep, A. 1990 a. A note on interrelationship between yield and important plant characters of cucumber (*Cucumis sativus* L.). *Veg. Sci.* **17** (1) : 102-104

Rastogi, K. B. and Deep, A. 1990 b. Variability studies in cucumber (*Cucumis sativus* L.). *Veg. Sci.* **17** (2) : 224-226

Reddy, K. S. S. and Rao, M. R. 1984. Studies on heritability, genetic advance and character association in ribbedgourd. *South Indian Hort.* **32** (2) : 97-100

Rubino, D. B. and Wehner, T. C. 1986. Effect of inbreeding on horticultural performance of lines developed from an open pollinated pickling cucumber population. *Euphytica* **35** : 459-464

Sarkar, S. K., Maity, T. K., Roy, K. and Som, M. G. 1990. Studies on genetic variability of pointedgourd (*Trichosanthes dioica* Roxb.). *Exp. Genet.* **6** (1 & 2) :68-73

Satyanarayana, N. 1991. Genetical studies in cucumber (*Cucumis sativus* L.). Ph.D. thesis, University of Agricultural Sciences, Bangalore

Sharma, N. K. and Dhankhar, B. S. 1990. Variability studies in bottlegourd (*Lagenaria siceraria* Standl). *Haryana J. Hort. Sci.* **19** (3-4) : 305-312

Sharma, N. K., Dhankar, B. S. and Jowatia, A. S. 1995. Heterosis in bottlegourd. *Haryana Agric. Univ. J. Res.* **23** (1) : 8-14

*Shawaf, I. I. S. and Baker, L. R. 1981. Combining ability and genetic variance in G x H F_1 hybrids for parthenocarpic yield in gynoecious pickling cucumber for once over mechanical harvest. *J. Amer. Soc. Hort. Sci.* **106** (3) : 15

Singh, B. and Joshi, S. 1979. Heterosis and combining ability in bittergourd. *Indian J. agric. Sci.*, **50** (7) : 558-560

Singh, J., Kumar, J. C. and Sharma, J. R. 1988. Genetic variability and heritability of some economic traits of pumpkin in different seasons. *Punjab Hort. J.* **28** (3-4) : 238-242

Singh, M. J., Randhawa, K. S. and Lal, T. 1989. Genetic analysis for maturity and plant characteristics in muskmelon. *Veg. Sci.* **16** (2) : 181-184

Singh, V. P., Singh, K. and Jaiswal, R. C. 1986. Genetic variability and correlation studies in pointedgourd (*Trichosanthes dioica* Roxb.). *Narendra Deva J. Agric. Res.* **1** : 120-124

Singh, H. N., Srivastava, J. P. and Prasad, R. 1977. Genetic variability and correlation studies in bittergourd. *Indian J. agric. Sci.* **47** : 604-607

Sirohi, P. S. 1993. Genetic diversity in cucurbits - pumpkin. *Indian Hort.* **38** (2) : 35-37

Sirohi, P. S. and Choudhury, B. 1977. Combining ability in bittergourd. *Veg. Sci.* **4** (3) : 6-7

Sirohi, P. S. and Choudhury, B. 1979. Gene effects in bittergourd (*Momordica charantia* L.). *Veg. Sci.* **6** : 106-112

Sirohi, P. S. and Choudhury, B. 1983. Diallel analysis for variability in bittergourd. *Indian J. agric. Sci.* **53** : 880-888

Sirohi, P. S., Kumar, T. S. and Choudhury, B. 1986. Studies on combining ability in pumpkin (*Cucurbita moschata* Duch. expoir). *Indian J. Hort.* **43** (1-2) : 98-104

Sirohi, P. S., Sivakami, N. and Choudhury, B. 1986. Genetic analysis in long fruited bottlegourd. *Indian J. agric. Sci.* **56** (9) : 623-625

Sirohi, P. S., Sivakami, N. and Choudhury, B. 1988. Genetic studies in bottlegourd. *Annals. agric. Res.* **9** (1) : 1-5

Sivakami, N., Sirohi, P. S. and Choudhury, B. 1987. Combining ability analysis in long fruited bottlegourd. *Indian J. Hort.* **44** (3-4) : 213-219

*Smith, O. S., Lower, R. L. and Moll, R. H. 1978. Estimates of heritability and variance components in pickling cucumber. *J. Amer. Soc. Hort. Sci.* **103** : 222-225

Solanki, S. S. and Seth, J. N. 1980. Studies on genetic variability in cucumber (*Cucumis sativus* L.). *Prog. Hort.* **12** (1) : 43-49

Solanki, S. S., Seth, J. N. and Lal, S. D. 1982. Heterosis and inbreeding depression in cucumber (*Cucumis sativus* L.). *Prog. Hort.* **14** : 121-125

Solanki, S. S. and Shah, A. 1990. Line x Tester analysis of combining ability for yield and its component in cucumber. *Prog. Hort.* **13** : 40-44

Srivastava, V. K. 1970. Studies on hybrid vigour, combining ability and inheritance of some quantitative characters in bittergourd (*Momordica charantia* L.). Ph.D. thesis, University of Udaipur, India

Srivastava, V. K. and Nath, P. 1983. Studies on combining ability on *Momordica charantia* L. *Egyptian J. Genet. Cytology* **12** (1) : 207-224

Srivastava, V. K. and Srivastava, L. C. 1976. Genetic parameter, correlation coefficients and path coefficient analysis in bittergourd (*Momordica charantia* L.). *Indian J. Hort.* **33** : 66-70

Sureshbabu, V. 1989. Divergence studies in pumpkin. M.Sc. thesis, Kerala Agricultural University, Thrissur, Kerala

Suribabu, B., Reddy, E. N. and Rao, M. R. 1986. Inheritance of certain quantitative and qualitative characters in bittergourd (*Momordica charantia* L.). *South Indian Hort.* **34** (6) : 380-386

*Swamy, K. R. M. and Dutta, O. P. 1985. Inheritance of ascorbic acid content in muskmelon. *SABRAO J.* **17** (2) : 157-163

Swamy, K. R. M. and Dutta, O. P. 1993. Inheritance of fruit dry matter content in muskmelon (*Cucumis melo* L.). *Indian J. agric. Res.* **27** (2) : 87-95

Swamy, K. R. M., Dutta, O. P., Ramachander, P. R. and Wahi, S. D. 1985. Variability studies in muskmelon (*Cucumis melo* L.). *Madras agric. J.* **72** (1) : 1-5

*Tasdighi, M. and Baker, L. R. 1981. Combining ability for femaleness and yield in single and three way crosses of pickling cucumbers intended for once over harvest. *Euphytica* **30** (1) : 183-192

Thakur, J. C. and Nandpuri, K. S. 1974. Studies on variability and heritability of some important quantitative characters in watermelon (*Citrullus lanatus* Thumb Mansf.). *Veg. Sci.* **1** : 1-8

Tyagi, J. D. 1972. Variability and correlation studies in bottlegourd (*Lagenaria siceraria*). *Indian J. Hort.* **29** : 219-222

Vahab, M. A. 1989. Homeo static analysis of components of genetic variance and inheritance of fruit colour, fruit shape and bitterness in bittergourd (*Momordica charantia* L.). Ph.D. thesis, Kerala Agricultural University, Thrissur, Kerala

Varalakshmi, B., Rao, P. V. and Reddy, Y. N. 1995. Genetic variability and heritability in ridgegourd (*Luffa acutangula*). *Indian J. agric. Sci.* **65** (8) : 608-610

Varghese, P. 1991. Heterosis in snakegourd (*Trichosanthes anguina* L.) M.Sc. thesis, Kerala Agricultural University, Thrissur, Kerala.

Varghese, P. and Rajan, S. 1993a. Genetic variability and heritability studies in snakegourd (*Trichosanthes anguina* L.) J. *Tropic. Agric.* **31**(1): 13-17

Varghese, P. and Rajan, S. 1993 b. Heterosis of growth characters and earliness in snakegourd (*Trichosanthes anguina* L.). *J. Tropic. Agric.* **31** (1) : 22-23

Varghese, P. and Rajan, S. 1994. Line x Tester analysis of combining ability in snakegourd (*Trichosanthes anguina* L.). *Indian J. Genet. Plant Breed.* **54** (2) : 188-191

Vijay, O. P. 1987. Genetic variability, correlation and path coefficient analysis in muskmelon (*Cucumis melo* L.). *Indian J. Hort.* **44** : 223-238

Vijayakumari, P., More, T. A. and Seshadri, V. S. 1993. Heterosis in tropical and temperate gynoecious hybrids in cucumber. *Veg. Sci.* **20**: 152-157

*Wang, Y. J. and Wang, X. S. 1980. Preliminary analysis of combining ability in autumn cucumber. *Scientea Agriculture Sinica.* **3** : 52-57

* Original not seen

I

Appendix I Analysis of variance for various characters in 29 bittergourd genotypes

Sl. No.	Character	Mean squares		
		Replication d.f. = 2	Treatments d.f. = 28	Error d.f. = 56
1	Days to first male flower	2.02	39.12**	0.99
2	Days to first female flower	3.41	90.09**	1.16
3	Days to first fruit harvest	2.08	78.55**	1.75
4	Number of female flowers per plant	6.92	316.65**	5.46
5	Number of fruits per plant	9.04	48.11**	3.58
6	Mean weight of fruit	97.00	8430.89**	16.85
7	Fruit yield per plant	0.73	8.44**	0.13
8	Fruit length	1.82	62.89**	0.46
9	Fruit girth	0.32	22.01**	0.32
10	Flesh thickness	0.002	0.013**	0.001
11	Number of seeds per fruit	2.52	138.37**	3.33
12	100 seed weight	14.10	52.79**	0.78
13	Duration of the crop	2.13	354.03**	4.08

** Significant at 1 per cent level

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Appendix II Analysis of variance for various characters in 28 bittergourd genotypes

Sl. No.	Character	Mean squares		
		Replication d.f. = 2	Treatments d.f. = 27	Error d.f. = 54
1	Days to first male flower	1.84	38.93**	1.003
2	Days to first female flower	3.19	93.29**	1.15
3	Days to first fruit harvest	2.42	77.16**	1.77
4	Number of female flowers per plant	8.58	299.85**	5.32
5	Number of fruits per plant	7.66	46.16**	3.67
6	Mean weight of fruit	90.13	8667.90**	17.39
7	Fruit yield per plant	0.645	8.72**	0.127
8	Fruit length	1.52	64.44**	0.468
9	Fruit girth	0.322	22.58**	0.335
10	Flesh thickness	0.003	0.014**	0.0003
11	Number of seeds per fruit	1.92	143.46**	3.36
12	100 seed weight	13.02	52.10**	0.802
13	Duration of the crop	3.20	366.89**	4.04

** Significant at 1 per cent level

Appendix III Analysis of variance for combining ability for various characters in bittergourd

Sl. No.	Character	Mean squares		
		GCA	SCA	Error
1	Days to first male flower	2.36**	16.01**	0.33
2	Days to first female flower	13.48**	36.13**	0.38
3	Days to first fruit harvest	7.92**	30.81**	0.59
4	Number of female flowers per plant	98.49**	100.36**	1.77
5	Number of fruits per plant	14.76**	15.57**	1.22
6	Mean weight of fruit	9597.96**	972.53**	5.79
7	Fruit yield per plant	7.33**	1.64**	0.042
8	Fruit length	74.84**	6.24**	0.16
9	Fruit girth	19.78**	4.03**	0.11
10	Flesh thickness	0.0044**	0.0045**	0.000097
11	Number of seeds per fruit	130.37**	24.24**	1.12
12	100 seed weight	32.89**	12.93**	0.27
13	Duration of the crop	102.87**	127.87**	1.35

** Significant at 1 per cent level

COMBINING ABILITY AND HETEROSIS IN BITTERGOURD (*Momordica charantia* L.)

By

ISWARA PRASAD C. M.

ABSTRACT OF THE THESIS
SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE

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ABSTRACT

The present investigation "**Combining ability and heterosis in bittergourd (*Momordica charantia* L.)**" was conducted in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani, involving seven parents, 21 hybrids without reciprocals and the check variety Preethi with a view to assess the general and specific combining abilities, the nature of gene action and to estimate the extent of heterosis for 13 characters in bittergourd.

Significant differences were noticed among the 29 genotypes for all the characters studied with respect to the mean performance. Among the parents MC 17 (P_1) and MC 40 (P_6) and among the hybrids MC 18 x MC 40 (P_2 x P_6) had the high mean performance for yield and most of the yield attributes. The estimates of PCV and GCV for most of the traits were comparatively high with very high estimates of heritability and genetic advance indicating the scope of improvement through selection.

The combining ability analysis revealed that both GCA and SCA variances were significant for all the characters indicating the involvement of both additive and non-additive gene action. However, the ratio of additive to dominance variance was less than unity for most of the characters indicating the predominance of non-additive gene action and thereby suggesting the importance of heterosis breeding programme in crop improvement. The parent MC 40 (P_6) and the hybrid MC 18 x MC 40 (P_2 x P_6) were the best general and specific combiners respectively for yield and most of the yield related components.

Several hybrids possessed significant relative heterosis, heterobeltiosis and standard heterosis for all the characters except significant standard heterosis for 100 seed weight. The hybrid MC 18 x MC 40 (P_2 x P_6) recorded the maximum positive standard heterosis for yield and most of the yield attributes. However, the hybrids MC 17 x MC 40 (P_1 x P_6), MC 17 x MC 53 (P_1 x P_7) and MC 18 x MC 53 (P_2 x P_7) also exhibited good performance with regard to yield and related characters.