HETEROSIS AND COMBINING ABILITY IN MELON (*Cucumis melo* (L.) var. *conomon*)

By

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2000

Dedicated

to

Achan and Amma

DECLARATION

I hereby declare that this thesis entitled "Heterosis and combining ability in melon (*Cucumis melo* (L.) var. *conomon*)" 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.

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CERTIFICATE

Certified that this thesis entitled "Heterosis and combining ability in melon (*Cucumis melo* (L.) var. *conomon*)" is a record of research work done independently by Ms. Deepthy R. (98-11-25) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Introduction

1. INTRODUCTION

Melon (*Cucumis melo*) is a member of the family Cucurbitaceae, subfamily Cucurbitoideae with 2n number 24. The origin of the crop is in dispute. Some researchers suggest that India is the centre of domestication, because melon has been cultivated here for centuries and inedible forms grow wild in India (Robinson and Walters, 1997). It has high moisture content of 95 per cent and is a fairly good source of vitamin A (169 μg/100g of fruit).

Cucumis melo var.*conomon* (commonly referred as Vellari) is one among the ten botanical varieties of the species, *Cucumis melo* (Naudin, 1859). It is a unique warm season vegetable which possess both aesthetic and religious significance. Its immature fruits can be eaten raw or used as salad, whereas mature fruit is an unavoidable part of many South Indian dishes. The cultivation of the crop is limited to Kerala and parts of Tamil Nadu. Regional variations in preference is noticed for the crop in Kerala i.e., golden yellow fruits with long storage period is preferred in North, while green fruits with short shelf life is the choice of South.

Two improved varieties have been developed in this crop through selection. Hybridisation works have not yet been attempted. They are highly cross pollinated due to monoecy. The technique of hand pollination being easy and the base population being much variable, there is considerable scope for commercial exploitation of heterosis in the crop. For the improvement of any character information about the nature of gene action is important. Combining ability analysis will be useful in selecting suitable hybrid combinations. The present study was undertaken in this context with the following objectives.

(i) Estimation of relative heterosis, heterobeltiosis and standard heterosis.

(ii) Estimation of general combining ability of parents.

(iii) Estimation of specific combining ability of single crosses.

(iv) Identification of gene actions governing different characters in the crop.

Review of Literature

2. REVIEW OF LITERATURE

The cultivation of *Cucumis melo* var. *conomon* is confined to Kerala and parts of Tamil Nadu. Crop improvement works done in this crop are limited. So the review of literature includes most of the important cucurbits grown in India like muskmelon, cucumber, bittergourd, bottlegourd, pumpkin and squashes, snakegourd and watermelon. The available literature are reviewed under the following headings.

2.1 Variance, coefficient of variation, heritability and genetic advance

2.2 Heterosis

2.3 Combining ability

2.1 Variance, coefficient of variation, heritability and genetic advance

The efficiency of selection in crop improvement programmes largely depends on the extent of genetic variability present in the population. The variation present in the plant population is of three types, viz., phenotypic, genotypic and environmental. Of these the genetic variance can be further partitioned to additive, dominance and epistatic variance components.

The variability present in breeding populations can be assessed by variance component analysis. The phenotypic, genotypic and environmental co-efficient of variation (PCV, GCV and ECV respectively) give an idea about the magnitude of variability present in the population.

Heritability and genetic advance are important selection parameters. The ratio of genotypic variance to the phenotypic variance is known as heritability. The difference between the mean phenotypic value of the progeny of selected plants and the base or parental population is called genetic advance (GA). High heritability means that the character is least influenced by environment. High genetic advance shows that the character is governed by additive genes and low genetic advance shows that, non-additive gene action exist. Heritability along with genetic advance help us in predicting the gene action and the method of breeding to be practiced.

2.1.1 Muskmelon

Deol *et al.* (1981) observed high GCV for yield per plant and fruits per plant in muskmelon. High heritability and high genetic advance has been reported for fruits per plant.

Kalloo *et al.* (1981) also reported high GCV for yield per plant and fruits per plant. The estimates of heritability ranged from 11.00 to 73.98 per cent with characters like fruit length, weight, yield and number of fruits. High heritability accompanied by high genetic advance has been reported for yield per vine, fruits per plant and fruit weight.

Abadia *et al.* (1985) conducted studies on the mode of inheritance of fruit characters in melon. They reported that dominance effects towards the better parent were detected for fruit characters like weight, width, skin thickness index and yield. Dominance in the opposite direction was detected for central cavity index. Gene interaction effects were detected for fruit cracking. Swamy and Dutta (1985) studied the inheritance of ascorbic acid in muskmelon and observed that the heritability was 0.32.

Swamy *et al.* (1985) performed variability studies in muskmelon and they found that heritability was high for presence or absence of sutures and netting, fruit shape, flesh thickness, average weight per fruit, total yield per plant and titrable acidity. Highest GCV and PCV were recorded for marketable yield per plant followed by total yield per plant and average fruit weight. The magnitude of environmental influence (i.e., PCV - GCV) ranged from 2.5 for days to first harvest to 27.27 for marketable fruit yield. High heritability coupled with high GA was observed for yield per vine and fruit weight. Chacko (1992) also observed moderate to high GCV for yield.

2.1.2 Cucumber

Miller and Quisenberry (1976) reported that variance was primarily due to additive gene action for early flowering. This character showed high heritability also. Partial dominance was observed for early flowering and low nodal position of the first female flower.

Smith *et al.* (1978) observed that the variance components for six fruit characters were additive in cucumber. The heritability for yield was in the range of 0.17 to 0.25.

Solanki and Seth (1980) reported that PCV varied from 10.43 for fruits per plant to 71.8 for plant height. GCV was the lowest for fruits per plant (5.996) and the highest for plant height (69.026) whereas ECV ranged from 6.896 for days to fruit maturity to 71.202 for yield per plant. High heritability and high GA was also observed for the above characters and low GA was recorded for average fruit weight, duration of flowering, primary branches per plant, fruits per plant and secondary branches per plant.

Choudhary *et al.* (1985) reported significant genotypic variance for several yield components in cucumber. Secondary branches per vine, yield per vine, primary branches per vine, vine length and fruits per vine had high GA along with high heritability. High heritability and low GA has been reported for days to first female flower appearance, flowers per vine and fruit length indicating the role of non-additive gene effects.

High heritability (0.8) has been reported for yield in cucumber by Owens *et al.* (1985). Heritability for fruit yield ranged from 0.03 to 0.25 and for fruit quality traits from zero to 0.3 (Strefeler and Wehner, 1986) in cucumber.

Globerson *et al.* (1987) reported significant variance for seed weight with a broad sense heritability of 26 to 56 per cent. In the study by Prasunna and Rao (1988) with five F_1 progenies the GCV values ranged from 5.14 to 73.35 per cent while PCV values ranged from 8.52 to 80.13. High heritability for fruits per vine and average fruit weight was also recorded.

Abusaleha and Dutta (1990) examined 75 pure genotypes of cucumber and observed high magnitude of genotypic and phenotypic variance for all the characters studied. High heritability and genetic advance were associated with fruit length and fruits per vine.

After studying 45 diverse genotypes in cucumber, Mariappan and Pappiah (1990) reported that, PCV was the highest for seeds per fruit followed by weight of seeds per fruit. The difference between PCV and GCV was invariably low for all the characters. High heritability along with high GA was observed for fruit girth, days to first male flower opening, number and weight of seeds per fruit indicating additive gene effect.

Rastogi and Deep (1990a and b) recorded higher PCV and GCV for fruit yield per plant and fruit weight and the lowest for days to fruit maturity. High heritability was observed for yield per plant, days to fruit maturity, fruits per vine and fruit weight. Characters like vine length, primary branches per plant, male flowers per plant and days to fruit maturity showed high heritability but low genetic advance.

Study of 23 genotypes of cucumber by Prasad and Singh (1992) revealed that, the heritability estimates ranged from 0.02 per cent for fruits per plot to 48 per cent for fruit length. High heritability coupled with high GA was observed for fruit length, fruit breadth and fruit weight. High heritability and high GA for more than 12 growth and yield attributes was also observed in another collection of cucumber (Prasad and Singh, 1994 b).

Wehner and Cramer (1996) reported genetic variance for total yield, early yield and marketable fruits per plot, fruit shape and fruit weight in three slicing cucumber populations. They also reported low to moderate heritability for fruit yield, earliness and quality.

Paiva and Paiva (1997) derived information on variation and heritability from 36 half sib progenies in cucumber and reported that, heritability was the lowest for fruit number and the highest for number of fruits. Serquen *et al.* (1997) conducted genetic analysis of yield components in cucumber and indicated that, mainstem length and multiple lateral branching exhibited mostly additive genetic variance. For sex expression, additive and dominant genetic variance were important. Gayathri (1997) has reported that yield per plant, fruits per plant, average fruit weight and node to first female flower had the highest GCV with high heritability and genetic advance.

2.1.3 Bittergourd

Srivastava and Srivastava (1976) studied variability in 10 lines of bittergourd and obtained significant differences for all the characters except for male flowers per plant. The highest GCV (37.45) was observed for fruits per plant followed by yield per plant (32.13) and weight of fruit (30.02). Fruits per plant had highest GA (71.75 per cent) and heritability (99.31 per cent).

In a study using 25 lines of bittergourd by Ramachandran (1978), the estimates of phenotypic, genotypic and environmental variance of the character, primary branches per plant, indicated the predominant influence of the genetic component over the environmental effect on its phenotype. He also reported lowest GCV for days to flower. Ramachandran and Gopalakrishnan (1979) evaluated 25 types and observed the highest PCV and GCV for yield per plant (39.88 and 37.82 per cent).

Indiresh (1982) found high GCV for fruit fresh weight, yield per plant and fruit length among the 24 lines assessed. Sirohi and Chaudhary (1983) analysed variability in bittergourd and indicated additive gene action with partial dominance for stem length, days to first harvest, fruit length and diameter, fruit flesh thickness, fruits per plant and fruit weight.

Six lines were examined by Suribabu *et al.* (1986) and they observed that GCV was moderate to high for all the characters except number of fruits per plant and percentage of fruit set. The characters seeds per fruit, days to first female flower and yield per plant exhibited moderate to high genetic advance over mean. Fruits per plant registered moderate heritability and low GA in the study. Chaudhary (1987) and Vahab (1989) also recorded high PCV and GCV for yield per plant, fruits per plant and fruit weight while it was moderate for fruit length and low for early flower formation.

Study conducted by Rajput *et al* . (1996) in bittergourd revealed that, there was a large variation for yield and its components at the phenotypic and genotypic level. Heritability estimates were high for almost all the characters studied. Joint consideration of GA and heritability suggested that all the characters were controlled by additive gene effects, except days to first harvest which was under non additive gene action.

2.1.4 Bottlegourd

Tyagi (1972) conducted a study in bottlegourd using 25 inbreds and noted that fruits per plant exhibited the highest GCV (48.26 per cent) followed by fruit length and girth.

Prasad and Prasad (1979) worked on 40 genetically diverse lines of bottlegourd. They recorded high estimates of heritability for vine length (98.4 per cent), fruit length (98.03 per cent) and fruit diameter (96.27 per cent). Maximum value of genetic advance was found for fruit thickness (78.99 per cent) and fruit length (78.2 per cent).

In bottlegourd, narrow sense heritability was reported to be high for days to first male and female flower opening, fruit length, girth, weight and fruits per plant (Sirohi *et al.*, 1986). But Sirohi *et al.* (1988) reported low estimates for all the characters except fruit length and weight.

Sharma and Dhankhar (1990) reported high heritability coupled with high GA for fruits per plant. Pitchaimuthu and Sirohi (1997) conducted genetic analysis of fruit characters in bottlegourd and reported that all the interacting crosses showed a duplicate type of epistasis. Predominance of dominance x dominance gene effect was observed in majority of crosses for all four characters studied. Kumar and Singh (1997) reported high genotypic and phenotypic variance for seeds per fruit among 12 lines of bottlegourd.

2.1.5 Pumpkin and squashes

Kubiaki and Walezak (1976) reported high heritability estimates for beta-carotene content and total soluble solids in pumpkin.

Gopalakrishnan (1979) reported the highest estimates of heritability for male flowers per plant (99.14 per cent), per cent of female flowers (97.77 per cent) and female flowers per plant (97.45 per cent) in pumpkin. Lowest heritability estimates were noted for fruit set (76.97 per cent). The highest GA as per cent of mean was observed for male flowers per plant (115.33) followed by fruits per plant (98.82). The lowest GA was obtained for days to first female flower anthesis (12.19).

Mangal *et al.* (1979) pointed out that, estimates of heritability and GA were high for yield and fruits per plant. Doijode and Sulladmath (1986) reported highest PCV and GCV for fruit weight compared to other characters.

Rana *et al.* (1986) reported high heritability in conjunction with genetic gain for fruit number. High GCV and PCV was reported for fruit weight.

In the study by Singh *et al.* (1988) using 20 genotypes the PCV was comparatively high for yield and 100 seed weight, moderate for fruit weight, seeds per fruit and flesh thickness and low for early female flower while the

GCV was high for yield, fruit weight, seeds per fruit and flesh thickness. There existed fairly large differences between PCV and GCV as well. High heritability and high GA was observed for fruit weight.

Sureshbabu (1989) pointed out the highest GCV for seeds per fruit (37.37 per cent) and the lowest for node number to first female flower (12.77 per cent) whereas the highest and lowest PCV were exhibited by yield per plant (58.00 per cent) and days to first male flower (13.08 per cent) respectively. High GA was obtained for seeds per fruit (73.05 per cent).

Presence of inherent genetic variability in the 20 genotypes of pumpkin were evident from the high estimates of genotypic and phenotypic variance for main creeper length, leaves per plant and fruit size index. Flesh thickness and fruit weight had high heritability. Fruit weight showed high heritability and high genetic advance (Borthakur and Shadeque, 1990).

2.1.6 Snakegourd

Joseph (1978) worked on 25 snakegourd types and recorded the highest GCV for fruit length (29.87) and phosphorus content (29.55) followed by fruit weight (28.69) and minimum for days to opening of first male flower (3.16). The highest heritability was observed for fruit length (99.19 per cent), girth of fruit (98.6) and vitamin C content (97.59 per cent). The lowest heritability was for fruits per plant (21.2 per cent). The highest GA was for female flowers per pant (47.62 per cent).

Varghese (1991) and Varghese and Rajan (1993a) observed that, the PCV and GCV were the highest for fruiting nodes on main vine (70.05 and

62.99 per cent) and the lowest for total crop duration (9.25 and 9.24 per cent). The PCV and GCV were also observed to be high for yield per plant, fruits per plant, fruit length and girth, seeds per fruit and average fruit weight while days to first male flower, female flower and fruit picking had low estimates of PCV and GCV. Maximum heritability estimate was for total duration of the crop (99.8 per cent). High heritability and high GA was observed for fruits per plant.

2.1.7 Watermelon

Thakur and Nandpuri (1974) observed variability for vine length, branches per plant, sex ratio, days to fruit picking, fruits per vine, average fruit weight, yield per vine, seeds per kg 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). The GCV values also showed the same trend.

Prasad *et al.* (1988) evaluated nine germplasm lines and observed high values of PCV and GCV for fruits per plant, average fruit weight, seeds per fruit, 100 seed weight and fruit yield per plant. The magnitude of heritability was high for all the above characters except days to first picking and branches per plant. High heritability coupled with high GA has been observed for fruits per plant, number of seeds per fruit and 100 seed weight.

Rajendran (1989) reported that GA and heritability were 27.76 per cent and 38 per cent respectively for vine length. Low heritability (25 per cent) and moderate GA (47.4 per cent) was seen for leaves per vine, moderate heritability (49 per cent) and high GA (87.46 per cent) for sex ratio, low heritability (4 per cent) and GA (6.97 per cent) for crop duration were also observed.

Rajendran and Thamburaj (1994) recorded the highest GCV and PCV for yield per vine (67.6 and 88.34 per cent) in watermelon. They also reported high heritability estimates for 100 seed weight, average fruit weight, yield per vine and number of seeds per fruit.

2.2 Heterosis

The superiority of a hybrid in one or more characters over its parents is known as heterosis. The term heterosis was first used by Shull (1914). Existence of significant amount of dominance variance is essential for undertaking heterosis breeding programme. Dominance effects are associated with heterozygosity. Therefore, in plant populations, dominance effects are expected to be maximum in cross pollinated crops (Frey, 1966). For this reason, occurrence of heterosis is more in cross pollinated crops than in self pollinated crops. Cucurbits are highly cross pollinated and heterosis has been reported for most of the traits. The available literature on heterosis in cucurbits is presented in a crop wise manner.

2.2.1 Muskmelon

Lippert and Legg (1972) observed significant and favourable heterosis for days to first fruit harvest, average weight of first three fruits and weight of all fruits harvested in crosses between muskmelon cultivars.

Shakhanov (1972) studied heterosis in complex melon hybrids and mentioned three multiple combinations showing heterosis for yield. Heterosis for number of fruits per plant and size of fruit was observed in most single crosses while hybrids from complex crosses displayed heterosis for number of fruits only.

More and Seshadri (1980) conducted works in muskmelon involving two monoecious lines as female parents to study the performance of F_1 hybrids. It was revealed that, heterosis was significant for days to first harvest, average fruit weight per plant, total yield and earliness.

Dixit and Kalloo (1983) analysed data on yield and yield related traits in 28 F_1 hybrids in muskmelon and reported that heterosis over better parent was the highest for fruit number per plant. The highest negative (favourable) heterosis over better parent for cavity length (-12.3 per cent) occurred in the cross, Arka Jeet x Sarada Melon.

Seshadri *et al.* (1983) suggested that in breeding for heterosis in melons, greater emphasis should be placed on fruit quality and early maturity in F_1 hybrid than on total yield.

Kalb and Davis (1984) crossed six cultivars of muskmelon in all possible combinations and observed that favourable heterosis over mid parental value was shown for total soluble solids, net density and to a lesser extent for amount of flesh, rind thickness, amount of cavity and cavity dryness.

Mishra and Seshadri (1985) crossed two genetically male sterile lines of muskmelon with 32 cultivars. The greatest heterosis over better parent was observed for early yield. Heterosis was also observed for total soluble solids and early fruits. But for proportion of flesh, the hybrids were generally intermediate between the parents.

Velich (1985) conducted experiments in muskmelon using marker genes and reported that the cross YG x Ch F_1 equalled the standard parent in earliness and exceeded in yield and quality. Significant heterosis for total soluble solids (6.38 per cent) and flesh firmness (8.53 per cent) was reported in oriental pickling melon by Om *et al.* (1987).

Liou *et al.* (1995) reported significant average heterosis for yield (41.56 per cent) in muskmelon. Heterosis was non significant for skin thickness and soluble solids content. Kim *et al.* (1996) observed favourable mid parent heterosis in muskmelon for fruit weight, fruit width, fruit length and sugar content.

Study of six parental lines and 15 F_1 hybrid of muskmelon revealed appreciable heterosis over better parent and top parent for all the characters studied except total soluble solids. The best performing hybrid recorded 28.15 per cent higher yield over best commercial check (Munshi and Verma, 1997).

2.2.2 Cucumber

Heterosis was reported for the first time in cucumber by Hayes and Jones (1916). They reported that hybrid vigour was expressed in total yield, the increased yield being due to large number of fruits per plant. The highest yielding hybrid outyielded the better parent by 30 per cent.

Gill *et al.* (1973) developed an F_1 hybrid "Pusa Sanyog" in cucumber by crossing a Japanese variety Kaga Aomoga Fushinari with Green Long Naples. This F_1 hybrid outyielded the better parent by 23.05 to 128.78 per cent and was about 10 days earlier.

Imam *et al.* (1977) reported that heterosis ranged from 15.34 per cent for fruit diameter to 59.22 per cent for fruit shape index in cucumber. Pyzhenkov and Kosareva (1979) made hybrids between four male and four female parents in cucumber and reported that heterosis for yield was reflected as increased number of fruits per plant. The mean fruit weight of the hybrids was not more than parents.

Lower *et al.* (1982) reported significant heterobeltiosis for fruit weight per plant and main stem length in cucumber. Also F_1 deviation from mid parent was observed for lateral branches per plant.

Solanki *et al.* (1982 a and b) observed heterosis over better parent for primary branches (25.26 per cent) secondary branches (43.60 per cent), female flowers (50.95 per cent) average fruit weight (33.33 per cent), fruits per plant (42.12 per cent) and fruit yield (83.81 per cent). The character days to maturity had maximum negative heterosis while plant height had no heterosis.

Significant relative heterosis and heterobeltiosis for total and marketable yield, earliness and fruit quality traits of cucumber were reported in two varying environments by Rubino and Wehner (1986). Aleksandrova (1988) noticed two hybrids Vikhra (Ts 1 x 13) and Lora (Ts 3 x 13) showing significant heterosis for fruit yield, fruit size and other quality traits, among the progenies from crosses between gynoecious maternal lines and hermaphrodite pollen parents.

Pyzhenkov *et al.* (1988) reported heterosis for vine length, branches per plant, fruit yield and disease resistance in the F_1 hybrid MOVIR-1 in cucumber. Hormuzdi and More (1989) observed heterosis for various economic characters except for total yield in crosses involving gynoecious, monoecious and gynomonoecious lines of cucumber.

Kasem and Somsak (1991) evaluated the hybrid performance of crosses among 21 mini-cucumber lines and reported significant heterosis for characters like flowering habits, yield and fruit characters like fruit length, fruit width and average fruit weight.

Satyanarayana (1991) reported a mean heterosis of 61.1 per cent and 52.2 per cent over mid parent and better parent respectively for total yield/vine in a 9 x 9 diallel analysis in cucumber.

Study of heterosis over better parent and superiority over top parent for earliness, yield and its components in tropical and temperate gynoecious hybrids in cucumber revealed a maximum heterosis over better parent with 77.6 per cent superiority over top parent in a tropical gynoecious hybrid 304 x RKS 296 (Vijayakumari *et al.*, (1993).

Fang *et al.* (1994) developed a hybrid 'Zhongnong 8' from a cross between line 90271 and line 90211 which was heterotic over standard variety for early and total yield vine length, average fruit weight, fruit quality and disease resistance.

Li *et al.* (1995) conducted genetic analysis of major agronomic characters in cucumber and reported significant positive heterosis for total yield, early yield, fruit number, average fruit weight, leaf area, fruit ratio and fruit shape index. Vine length had negative heterosis i.e., shorter vines produced greater yield.

Musmade *et al.* (1995) made studies on heterosis in cucumber and reported significant positive heterosis over better parent for yield and its contributing characters. The percentage of heterosis for yield per vine ranged from -46.79 to 106.37.

El Hafez *et al.* (1997) performed genetic analysis of cucumber yield and its components by diallel crossing and reported that heterosis over mid and better parent was absent or insignificant for all studied traits except marketable and total yield on number basis. Gayathri (1997) reported all the three types of heterosis for days to first female flower opening in cucumber.

2.2.3 Bittergourd

Aiyadurai (1951) conducted preliminary studies in bittergourd and reported significant heterosis for earliness, fruits per plant, fruit size, fruit flesh thickness and total yield. Srivastava (1970) reported that, 45 out of 90 F_1 hybrids studied, produced female flowers significantly earlier than better parents and concluded that days to female flower formation could be reduced to 16.7 per cent.

Lal *et al.* (1976) observed significant heterosis for internodal length, petiole length, leaf length, leaf width, branches per plant, shoot length, fruits per plant, length, girth and weight of fruits and total yield in bittergourd. In the case of days to flower, there was 7.02 per cent negative heterosis in one of the hybrids studied.

Lawande and Patil (1990) reported that heterosis for yield per vine was 86.1 per cent in bittergourd. Ranpise *et al.* (1992) derived information on heterosis from diallel analysis of 8 lines and 28 F_1 hybrids in bittergourd and reported 64 per cent heterosis for yield in the most promising hybrids.

Mishra *et al.* (1994) indicated a high level of heterosis for fruits per plant, fruit length, breadth, weight and yield in bittergourd after performing a diallel analysis using nine varieties. Kennady *et al.* (1995) reported a heterosis of 65.7 per cent over standard parent and 49.0 per cent over better parent in yield in the cross Pusa Visesh x MC 13.

According to Celine and Sirohi (1996) remarkable heterosis for yield and yield attributes were observed over better parent, top parent and commercial check in bittergourd.

Ram *et al.* (1997) observed negative heterosis (desirable) for days to male flower anthesis, days to female flower anthesis and plant height. Fruits per plant and yield per plant were the most heterotic characters. Positive heterosis was absent for fruit length, fruit diameter and fruit weight.

2.2.4 Bottlegourd

Analysis of F_1 data from crosses between a South African line and four Indian lines of bottlegourd revealed that, the hybrids showed heterosis for characters like rapid germination, earlier fruit maturity, node to first female flower, flesh thickness, early yield and length of harvesting period (Pal *et al.*, 1984).

Janakiram and Sirohi (1988) in their studies on heterosis in round fruited bottlegourd reported that the best performing hybrid S 46 x S 54 gave 148.97 per cent higher yield over the commercial cultivar Pusa Summer Prolific Round and 84.5 per cent over best parental line. In another study by Janakiram and Sirohi (1992) on heterosis for quantitative characters, significant heterobeltiosis was observed for eight plant characters.

Sharma *et al.* (1995) gathered information on heterosis in bottlegourd from a line x tester cross and observed that, the cross Summer Long Green Selection 2 x Faizabadi Long had the largest heterosis over control cultivar

Pusa Summer Prolific Long for number of fruits (106.63 per cent) and total yield per plant (110.33 per cent). Another cross showed 22.93 per cent heterosis for fruit length.

Rajesh *et al.* (1999) reported significant heterosis over better parent and standard parent for fruit yield and in component characters like fruit weight, number of fruits per plant, fruit length and diameter and for traits deciding earliness in bottlegourd.

2.2.5 Pumpkin and squashes

Doijode and Sulladmath (1982) reported significant heterosis for vine length (59 per cent), node to first female flower (11.7 per cent) and number of female flower per plant (52.0 pre cent) in pumpkin. In a study of seed characters in pumpkin using 7 x 7 diallel cross, significant heterosis was observed for seed number, seed weight per fruit, 100 seed weight and seed size index (Doijode *et al.*, 1983).

Sirohi (1993) noticed appreciable heterosis for important quantitative characters including yield in pumpkin. The F_1 'Pusa Hybrid 1' showed significant heterosis for yield over the commercial check Pusa Vishwas.

Kasrawi (1994) studied heterosis for quantitative traits in summer squash and noticed significant heterosis over mid parent for yield traits but was negative for flowering traits. Estimated heterosis over the superior parent was negative for flowering but positive for yield, fruit number and fruit set.

Firpo *et al.* (1998) reported heterosis for total and precocious fruit number, days from sowing to first harvest, number of leaves and plant height in a diallel cross involving 10 parents in summer squash. According to Ghai *et al.* (1998) F_1 hybrids in summer squash showed significant heterosis for earliness and yield.

2.2.6 Snakegourd

Varghese and Rajan (1993b) studied heterosis for growth characters and earliness in snakegourd and found 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) reported manifestation of heterosis for all the characters studied. Among the hybrids, Thrikkannapuram Local x Kaumudi had maximum standard heterosis (73.28 per cent) for yield and yield related characters.

2.2.7 Watermelon

Sachan and Nath (1974) observed appreciable heterosis for fruit yield (87 per cent), fruit weight (16 per cent), fruit number (41.8 per cent), total soluble solids (21 per cent) and also flesh weight, 100 seed weight and number of female flowers in watermelon. Sidhu and Brar (1977) noticed that in watermelon maximum heterosis for yield was 46.76 per cent over mid parent and 28.87 per cent over better parent. Negative (favourable) heterosis was observed for number of seeds per fruit.

Reddy *et al.* (1987) evaluated six watermelon cultivars with their 15 F_1 hybrids in a diallel analysis and reported that, hybrids showed significant heterosis for yield per plant, total soluble solids, number of fruits per plant, average fruit weight and edible flesh content.

Galaev (1988) estimated heterosis in watermelon and found that all 14 F_1 hybrids exhibited heterosis exceeding the parental forms in seedling characters like length of main root, number of lateral roots and root weight and had a relatively better root than shoot development.

2.3 Combining ability

The concept of combining ability as a measure of gene action was proposed by Sprague and Tatum (1942). Combining ability analysis helps in the evaluation of inbreds in terms of their genetic value and in the selection of suitable parents for hybridization.

2.3.1 Muskmelon

Lippert and Legg (1972) performed diallel analysis for yield and maturity characteristics in muskmelon and reported significant general combining ability (GCA) and specific combining ability (SCA) effects for the characters days to first fruit harvest and average weight of first three fruits. GCA was more important than SCA for explaining difference among crosses.

Estimation of combining ability of ten quantitative characters in muskmelon by Chadha and Nandpuri (1980) revealed highly significant GCA and SCA variances for all the characters. However, GCA variance contributed major part of genetic variation indicating the predominance of additive genetic variance.

Evaluation of combining ability, for yield, maturity and plant characteristics in bush muskmelon by Kalb and Davis (1984) revealed that, GCA variance was greater than SCA for all traits.

Kendall (1985) reported significant levels of GCA and SCA for maturity characteristics, fruit traits, storage life and climacteric patterns with GCA being predominant for all traits except flesh firmness. Genetic control was predominantly additive for soluble solids content, both additive and non-additive effects were important for fruit weight and flesh firmness. Swamy and Dutta (1985) observed significant GCA and SCA effects for fruit ascorbic acid content indicating the importance of both additive and non-additive gene effects.

Om *et al.* (1987) evaluated heterosis and combining ability in oriental melon and reported that GCA was significant for fruit weight, total soluble solids, flesh firmness, days to maturity and yield per plant. A ten parent diallel cross excluding reciprocals was carried out to study the control of total soluble solids content in muskmelon by Swamy and Dutta (1993) indicated the importance of both additive and dominance effect, the latter bei predominant.

Kim *et al.* (1996) analysed the combining ability of fruit yiel quantitative characters in muskmelon and reported that, GCA effects w for leaf length, leaf width, fruit width, fruit length, sugar conten ratio, days to flowering and days to maturity. SCA effects wer leaf width, fruit set ratio, days to flowering and days to maturit

Munshi and Verma (1999) studied combining ability i observed high GCA and SCA effects for most of the char importance of both additive and non-additive genetic cor

2.3.2 Cucumber

Om *et al.* (1978) reported significant GCA and SCA effects in cucumber indicating the importance of both additive and non additive components of genetic variation and the former was the most important for early yield per plant. After estimating variance components in pickling cucumber, Smith *et al.* (1978) reported that, the characters node to first female flower, female flower per vine, branches per vine, fruits per vine, average fruit weight, fruit length to diameter ratio and total yield per vine have high GCA variance indicating the role of additive gene action for their expression.

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 in cucumber as evidenced by high SCA variance over GCA variances.

Wang and Wang (1980) in a study of 36 combinations involving 16 parents of cucumber found that both GCA and SCA effects were significant for a number of yield and maturity characters. Additive variance was of importance in phenotypic variation.

Significant additive and dominance variance for fruit weight per plant, fruits per plant and average fruit weight were reported in cucumber by Ghaderi and Lower (1981). Shawaf and Baker (1981) reported significant GCA variance for yield and associated components except for gynoecious expression indicating the importance of additive gene effects. Combining ability studies in cucumber revealed that GCA effects were important for total yield and marketable yield and the predominance of additive gene effects for both yield and femaleness (Tasdighi and Baker, 1981).

Dolgikh and Siderova (1983) while studying the combining ability for 50 F_1 hybrids in cucumber reported GCA to be important for early and total yield and for fruit number per plant. They also reported that total yield, fruits per plant and fruit weight were controlled mainly by additive genes while early yield was controlled by non additive genes. Guseva and Mospan (1984) reported significant GCA effects for parthenocarpy and disease resistance.

Prudek (1984) analysed the yield data from a five line diallel cross and noticed that both GCA and SCA were of significance in determining both the number and the 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) conducted biometrical investigations in cucumber and reported that GCA and SCA estimates were significant for fruit length and weight indicating the importance of both additive and non additive effects for fruit expression. Musmade and Kale (1986) observed that both GCA and SCA variances were significant for all the characters studied in cucumber. The GCA variance were greater than SCA variance for all characters except yield per vine.

Frederick and Staub (1989) reported significant GCA estimates for all traits studied and significant SCA for days to anthesis. Rastogi and Deep (1990a) reported the role of non additive genes for the expression of traits viz., vine length, primary branches per plant, male flowers per plant and days to fruit maturity in cucumber.

Solanki and Shah (1990) revealed significant contribution of GCA and SCA variance at varied proportions and magnitudes for yield contributing characters in cucumber. 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) observed significant SCA for all the 27 characters studied except for branches per vine. Variance due to SCA was more than GCA variance indicating the role of non additive gene effects.

Diallel analysis of yield components was performed in cucumber by Prasad and Singh (1994a) and reported, significant GCA effect indicating the existence of genetic difference among the parents selected for hybridization. Additive gene action seemed to be responsible for the expression of yield components. Crosses showing maximum GCA effects were the resultants of high and poor combinations.

Li *et al.* (1995) conducted genetic analysis of major agronomic characters in cucumber and reported that, among the parents, line 112 had the greatest GCA for average fruit weight and fruit number and hybrid 111 x 112 had the greatest SCA for fruit number, average fruit weight, vine length, fruit length to fruit diameter ratio and leaf area.

El Hafez *et al.* (1997) performed genetic analysis of cucumber yield and its components and observed that the ratio of GCA, SCA variance for these characters based on weight and number indicated the predominance of additive gene action in the expression of these characters. On the other hand, this ratio for the first female flower anthesis revealed that additive and non-additive gene effects are of the same magnitude in the inheritance of this character.

Gayathri (1997) reported significant GCA and SCA variances for all the traits studied. She identified CS_{12} and CS_9 as good general combines for yield.

2.3.3 Bittergourd

Sirohi and Chaudhary (1977) conducted a study on combining ability in bittergourd in a 8 x 8 diallel cross and reported that the variance due to GCA was more than due to SCA for yield and its component characters indicating the predominance of additive gene action.

Singh and Joshi (1979) conducted studies on heterosis and combining ability in bittergourd. Observations were recorded on yield, stem length and number of primary branches per plant. All the characters were found to be governed mainly by additive gene action.

Srivastava and Nath (1983) presented the data on GCA and SCA effects for days to flowering, fruits per plant, fruit weight per plant and total yield per plant in bittergourd. Several parental breeding lines showed significant GCA and SCA effects for the four traits.

Yield and seven yield related characters were investigated in a line x tester crosses in bittergourd by Pal *et al.* (1985). GCA was found to be high for days to female flower initiation and fruits per plant.

Estimation of heterosis and combining ability in bittergourd by Mishra *et al.* (1994) revealed that both additive and non additive gene action were involved in the expression of fruits per plant, fruit length, breadth, weight and yield. At least one parent with high GCA was involved in most of the hybrids showing high SCA effects.

Devadas *et al.* (1995) analysed combining ability for seed yield and quality parameters in bittergourd and reported that the cultivar MC 13 was a good general combiner for 100 seed weight and MC 84 was a good general combiner for field emergence, seedling length and seedling dry weight.

Analysis of combining ability of quantitative characters in bittergourd revealed that the variance due to SCA was higher than GCA for all characters studied indicating the predominance of non additive gene effects (Ram *et al.*, 1999).

2.3.4 Bottlegourd

Sivakami *et al.* (1987) performed combining ability analysis in bottlegourd and reported significant GCA and SCA effects for yield per plant and eight yield related characters. GCA effects were predominated over SCA effects for these characters. In an incomplete diallel cross of ten bottlegourd lines, the estimated components of variance of GCA were larger than those for SCA for all the characters studied except days to opening of first male and female flowers and fruit polar diameter (Janakiram and Sirohi, 1988).

Reyes *et al.* (1993) estimated combining ability for yield and yield components in bottlegourd and reported highly significant GCA effects for all traits except for number of pickings while significant SCA effects were detected for days to first fruit harvest, length and diameter.

Kumar and Singh (1997) reported that the variance due to SCA was highly significant for the metric traits they studied indicating the importance of non-additive gene effects.

2.3.5 Pumpkin and squashes

Bhagchandani *et al.* (1980) conducted combining ability analysis in 5 x 5 diallel cross in summer squash for vine length, branches, fruits and yield per plant. Additive gene effect was responsible for vine length, whereas non additive for yield. However, additive and non additive effects were prevalent for branches as well as fruits per plant.

Sirohi *et al.* (1986) studied nine agronomic characters in a diallel cross of ten lines and reported that SCA variance exceeded GCA variance components for all characters except vine length. It was concluded that, the superior performance of hybrids with high SCA was due to epistatic effects.

Information on combining ability and heterosis was derived from data on five yield components in winter squash. High GCA values were obtained for all yield components while significant SCA was noted for fruit yield (Korzeniewska and Nierricrowicz, 1993).

Arora *et al.* (1996) studied combining ability in summer squash and significant GCA and SCA effects were reported for yield per plant, fruit per plant, fruit weight, fruit shape index and days to maturity.

Anido *et al.* (1998) derived information on combining ability from data on total and precocious fruit number, days to first harvest, leaf number, leaf diameter and plant height in parents and hybrids from a diallel cross involving 10 selected inbreds lines derived from a highly variable summer squash population.

2.3.6 Snakegourd

Information on combining ability was derived from data on seven yield components in 8 lines and 3 testers in snakegourd and their 24 F_1 hybrids. Significant GCA and SCA effects were reported for yield per plant and fruits per plant (Varghese and Rajan, 1994).

Radhika (1999) reported that the variance due to GCA and SCA was significant in almost all the characters studied indicating the significance of both additive and non additive gene action in the characters. The SCA variance was found to be more than GCA variance in most of the characters studied indicating the predominance of non additive gene action. The ratio of additive to dominance variance was less than one in most of the characters again indicating predominant influence of non additive gene action.

2.3.7 Watermelon

Dyustin and Prosvirnin (1979) reported that GCA variance exceeded SCA variance for almost all the characters studied, suggesting the predominance of additive genes. Dominance and epistatic effects were important for length of growing period and for seed number and weight. In a preliminary analysis of combining ability in watermelon, GCA effects were found to be significant for brix value, fruit weight, fruit number per plant, pericarp thickness and hardness. Also significant SCA effects were observed for brix value and fruit weight (Li and Shu, 1985). Gill and Kumar (1988) reported that 'Shipper' was a good combiner for yield and fruit weight and 'Sugar Baby' for days to maturity and fruit number per plant.

Materials and Methods

3. MATERIALS AND METHODS

The current research programme is aimed at the estimation of heterosis and combining ability in melon (*Cucumis melo* (L.) var. *conomon*) and thereby selection of parents having good combining ability for the production of hybrid seeds. The work was conducted at the department of Plant Breeding and Genetics, College of Agriculture, Vellayani, during the period from 1998 to 2000.

3.1 Materials

The experimental material comprised of seven homozygous lines of melon (*cucumis melo* (L.) var. *conomon*) selected as parents based on D^2 analysis conducted among 33 genotypes collected from different sources. Seven parents selected from genetically divergent clusters were used for the production of hybrids. The list of parental lines are presented in Table 1.

Table 1. List of parental lines used for hybridisation

Sl. No.	Parents	Name of cultivar	Source
1.	P_1	CS - 26 -3	College of Horticulture, Vellanikkara
2.	P_2	CS - 114 - 3	College of Horticulture, Vellanikkara
3.	P_3	CS - 111 - 1	College of Horticulture, Vellanikkara
4.	P_4	Chiramanangad local	Local collection
5.	P_5	Kuttipuram local	Local collection
6.	P_6	CS - 4	Vegetable Research Station, TNAU, Palur
7.	P_7	Mudicode local	College of Horticulture, Vellanikkara

3.1.1 Collection of seed materials

Selfed seeds were collected from seven homozygous lines maintained in the Department of Plant Breeding and Genetics for raising the parental lines for hybridisation. The whole investigation was carried out as two separate experiments.

3.1.2 Experiment I : Production of F_1 seeds

The parents for hybrid seed production were raised in the field. Staggered sowing was done to facilitate synchronous flowering and to ensure successful production of hybrids in all possible combinations.

Seven parents (Plates 1 and 2) were crossed in a diallel fashion without reciprocals to get hybrid seeds. Mature male and female flower buds in the desired parents were kept covered with a brown paper cover on the previous day of anthesis. On the following day, hand pollination was done between 8.30 am to 10 am (peak anthesis time) and pollinated female flowers were kept covered and labelled. Crossing was done in all possible combinations without reciprocals among seven parents. The parents were selfed along with production of hybrid seeds. The procedure followed in selfing of parents was same as that given above, except that, both male and female buds were selected from the same plant in selfing (Plates 3 and 4). The cover kept over female flower was removed after two to three days. Mature fruits were harvested, seeds extracted, cleaned, dried and this was used as the source material for experiment 2.

Plates 1 & 2. Seven genotypes used as parents in hybrid seed production

Plate 1

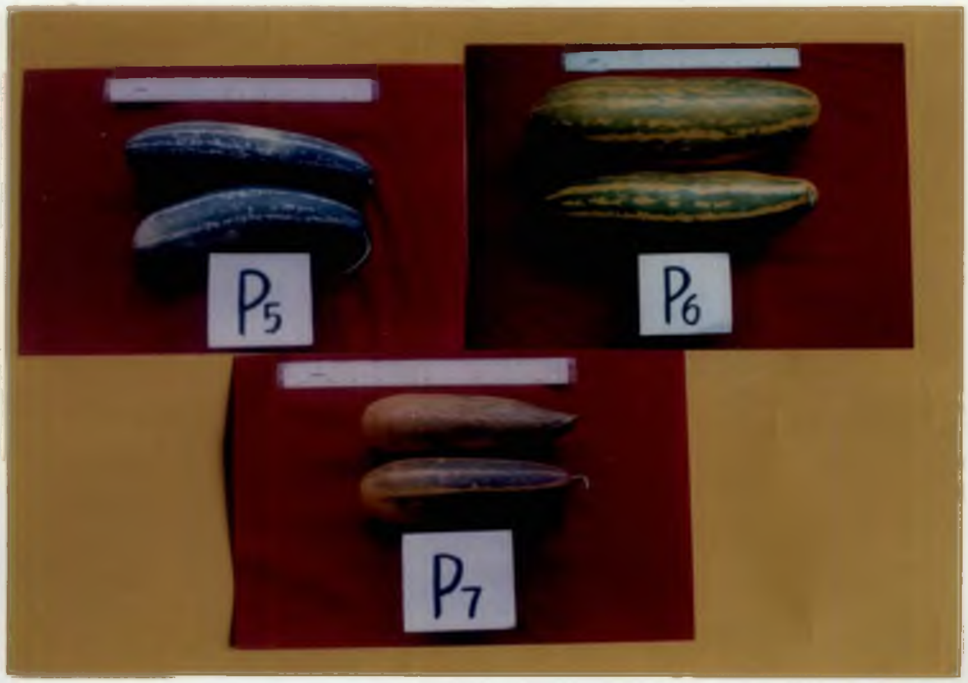


Plate 2

Plate 3. Covering selected male and female flowers in selfing

Plate 4. The technique of selfing

Plate 3

Plate 4

3.1.3 Experiment 2 : Evaluation of F_1 hybrids

Twenty one F_1 hybrids obtained by crossing seven parents in all possible combinations without reciprocals along with the parents were evaluated for estimating heterosis and combining ability.

3.2 Methods

3.2.1 Design and layout

The experiment was laid out in randomised block design (RBD) with 28 treatments (21 hybrids and seven parents) in three replications (Plate 5). In each replication five pits per treatment each with two plants were taken at a spacing of 2 x 1.5 m.

3.2.2 Cultural practices

All cultural and management practices as per Package of Practices Recommendations (KAU, 1998) of Kerala Agricultural University were followed all through the experiment.

3.2.3 Biometric observations

Biometric observations were taken from five plants selected randomly in each treatment adopting standard procedures and average was worked out for each replication.

Plate 5. A view of the experimental field

Plate 5

3.2.3.1 Days to first male flower opening

Number of days taken from sowing to anthesis of first male flower in each plant was recorded.

3.2.3.2 Days to first female flower opening

Number of days taken from sowing to anthesis of first female flower in each plant was recorded.

3.2.3.3 Node to first female flower

The node at which first female flower was produced was recorded in each plant. Nodes were counted from the collar region to the tip.

3.2.3.4 Male flowers per plant

The total number of male flowers produced in the period between bloom of first male flower to last harvest was recorded per plant.

3.2.3.5 Female flowers per plant

The total number of female flowers produced in the period between bloom of first female flower to last harvest was recorded per plant.

3.2.3.6 Fruits per plant

Total number of fruits produced per plant was recorded.

3.2.3.7 Productive branches per plant

The number of branches which bear fruits were recorded in each plant. This included primary, secondary and even tertiary branches.

3.2.3.8 Node at first fruiting

The node on the main vine at which first fruit was produced was recorded in each plant. Nodes were counted from the collar region to the tip.

3.2.3.9 Mean fruit weight

The weight of five randomly selected fruits were taken from each plant and was averaged to obtain the mean fruit weight. Observations were recorded in kilograms.

3.2.3.10 Yield per plant

Total weight of fruits obtained from each plant was recorded and expressed in kilograms.

3.2.3.11 Fruit diameter

Each fruit taken to record the mean fruit weight was cut at the middle to obtain the fruit diameter, mean worked out and expressed in centimeters.

3.2.3.12 Flesh thickness

The thickness of the flesh of the fruits which were cut for taking fruit diameter was measured, mean worked out and expressed in centimeters.

3.2.3.13 Fruit length

The length of the fruits were measured from the fruits used for recording fruit weight, mean worked out and expressed in centimeters.

3.2.3.14 Vine length

Length of the vine from collar region to the tip of the main vine was taken at the time of last harvest in each plant and expressed in meters.

3.2.3.15 Internodal length

The length of five internodes selected randomly was measured in each plant, mean worked out and expressed in centimeters. The observation was taken at the time of last harvest of the crop.

3.2.3.16 Seeds per fruit

The number of seeds in the fruits used for recording other fruit characters, were counted and recorded the average number of seeds per fruit.

3.2.3.17 100 seed weight

A random sample of 100 mature seeds per fruit from each plant was taken and weighed using an electronic precision balance and expressed in grams.

3.2.3.18 Days to first fruit harvest

Number of days taken from sowing to harvest of the first fruit was recorded in each plant.

3.2.3.19 Sex ratio

The ratio of total number of male flowers to the total number of female flowers produced per plant was worked out.

3.2.3.20 Crop duration

The number of days from sowing to last harvest in each plant was recorded.

3.2.3.21 Keeping quality

Two fruits from each replication without any bruises or insect attack, harvested for vegetable purpose, were kept under room conditions for one month. Keeping quality was expressed as the number of days from harvest till the day when the flesh just begin to loose its firmness which was tested by pressing the fruit with the fingers.

3.2.3.22 Incidence of pests and diseases

Mosaic was the only disease observed and hence grading based on visual observations was done for mosaic alone for each plant. The three grades given were low, medium and high depending up on the severity of the disease. No scoring was done for pests since there was no pest incidence because of effective control measures.

3.3 Statistical analysis

The data collected were subjected to statistical analysis.

3.3.1 Analysis of variance for each character

Analysis of variance (Anova) was done for the experiment in RBD with 28 treatments (7 parents and 21 F_1's) in three replications. When the genotypic variances were found to be significant for each character, combining ability analysis was performed with mean values.

Table 2 Analysis of variance for each character

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

where, r = Number of replication

v = Number of treatments

MSR = Replication mean square

MST = Treatment mean square

MSE = Error mean square

When the treatments differed significantly by the F test, the pair wise comparison of the treatment means are made by using critical difference as

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

Where, t_α is the students 't' table value for α (5 per cent or 1 per cent) level of significance corresponding to the error degrees of freedom.

If the difference between means of any two treatments for a particular character is greater than the calculated critical difference value, then those treatment means differ significantly for that character.

3.3.2 Components of variance

The mean squares between treatment consists of variances attributable to genotype, environment and phenotype (Singh and Chaudhary, 1985).

The components are estimated as

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

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

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

3.3.3 Coefficient of variation

It is a unit free measurement used for comparison of variation of different characters measured in different units.

a) Phenotypic Coefficient of Variation (PCV)

$$= \frac{\sqrt{\sigma^2_p}}{\text{Mean}} \times 100$$

b) Genotypic Coefficient of Variation (GCV)

$$= \frac{\sqrt{\sigma^2_g}}{\text{Mean}} \times 100$$

3.3.4 Heritability (Broad sense)

It is the ratio of genotypic variance to phenotypic variance and it gives an estimate of the heritable component of variation. It is expressed in percentage as

$$\text{Heritability, } H^2 = \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

3.3.5 Genetic advance (Johnson *et al.*, 1955 and Allard, 1960)

This measures the change in mean genotypic level of the population brought about by selection.

$$\text{Genetic advance} = kh^2 \sigma_p$$

$$\text{Genetic advance (GA) as per cent of mean} = \frac{kh^2 \sigma_p}{\text{Mean}} \times 100$$

where, k is the selection differential whose value is 2.06 at five per cent and 1.76 at 10 per cent selection intensity.

3.3.6 Heterosis

Heterosis can be estimated in three different ways.

(i) As the percentage deviation of the mean performance of F_1's from its mid parent which is referred as **relative heterosis** or **average heterosis**.

(ii) As the percentage deviation of the mean performance of F_1's from better parent which is referred as **heterobeltiosis**.

(iii) As the percentage deviation of mean performance of F_1's from a standard parent which is referred as **standard heterosis**. The standard parent used in this experiment was 'Mudicode local' which was parent No. 7.

a) Relative heterosis (RH) = $\frac{\bar{F}_1 - \bar{MP}}{\bar{MP}} \times 100$

b) Heterobeltiosis (HB) = $\frac{\bar{F}_1 - \bar{BP}}{\bar{BP}} \times 100$

c) Standard heterosis (SH) = $\frac{\bar{F}_1 - \bar{SP}}{\bar{SP}} \times 100$

To test the significance of $\bar{F}_1 - \bar{MP}$ observed in relative heterosis, critical difference is calculated as

$$C.D\ (0.05) = t_\alpha \times \sqrt{\frac{3\ MSE}{2\ r}}$$

To test the significance of $\bar{F}_1 - \bar{BP}$ and $\bar{F}_1 - \bar{SP}$ observed in heterobeltiosis and standard heterosis respectively, critical difference is worked out as

$$C.D\ (0.05) = t_\alpha \times \sqrt{\frac{2\ MSE}{r}}$$

where, t_α = 't' value for error degrees of freedom

MSE = Error mean square

r = Number of replication

3.3.7 Combining ability analysis

Combining ability analysis was performed only when the genotypic differences were found to be significant in the anova of individual characters. Since the experimental material comprised of parents and F_1's only (no reciprocals), Griffing's Approach Model I, Method II (1956) was used and estimation was done using the mean value of each treatment over replication.

Table 3 Analysis of variance for combining ability

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

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

MSE = Error mean square obtained from first anova
n = Number of parents
r = Number of replications
GCA = General combining ability
SCA = Specific combining ability

If the F value for GCA and SCA was found to be significant, then their effects were estimated using the following formulae.

$$\text{GCA effect } (gi) = \frac{1}{n+2}\left[\Sigma (Xi. + Xii) - \frac{2X..}{n}\right]$$

$$\text{sca effect } (sij) = Xij - \frac{(Xi. + Xii + Xj. + Xjj)}{n+2} + \frac{2X..}{(n+1)(n+2)}$$

where, Xij = Mean of character with respect to $(i \times j)^{th}$ cross over 3 replication

Xi. = Total of mean value (over replication) corresponding to i^{th} parent over the other crosses involving i^{th} parent.

Xj. = Total of the mean values corresponding to j^{th} parent over the other crosses involving j^{th} parent

X.. = Total of all mean values

The comparison of GCA and SCA effects were made by computing the respective critical difference based on the following estimates of variances.

$$\text{Var (gi)} = \frac{(n - 1)\ Me}{n\,(n + 2)}$$

$$\text{Var (sij)} = \frac{n\,(n - 1)\ Me}{(n + 1)\,(n + 2)}$$

$$\text{Var (Sii)} = \frac{(n^2 + n + 2)\ Me}{(n + 1)\,(n + 2)}$$

$$\text{Var (gi - gj)} = \frac{2\ Me}{n + 2}$$

$$\text{Var (Sii - Sjj)} = \frac{2\,(n-2)\ Me}{(n + 2)}$$

$$\text{Var (Sij - Sik)} = \frac{2\,(n + 1)\ Me}{(n + 2)}$$

$$\text{Var (Sij - Skl)} = \frac{2n\ Me}{(n + 2)}$$

The significance of gi and sij values were tested using 't' test. For making pair wise comparisons, critical differences were worked out using corresponding estimates of variances.

$$CD = t_{\alpha} \times \sqrt{\text{Variance}}$$

where, t_{α} = 't' value for error degree of freedom

Significant GCA implied that additive genotypic variance was operating while significant SCA effect revealed the importance of non-additive variance for the inheritance of the character.

Components of variance for GCA and SCA effects can be estimated as:

$$\sigma^2_{gca} = \frac{Mg - Ms}{n + 2}$$

$$\sigma^2_{sca} = MS - Me$$

Additive variance σ^2_a = $2\ \sigma^2_{gca}$

Dominance variance σ^2_d = σ^2_{sca}

Additive to dominance ratio was worked out and if it was more than unity, then there was predominance of additive gene action. Less than unity value for the ratio revealed the predominance of non-additive gene action for the character.

Results

4. RESULTS

Observations on 21 biometrical characters were subjected to statistical analysis. Analysis of variance revealed significant differences among all the 28 treatments for all the characters (Table 4).

4.1 Mean performance

Mean performance of seven parents and 21 F_1 hybrids was calculated and are displayed in Table 5. Character wise analysis of all the 28 genotypes is given below.

4.1.1 Days to male flower opening

The mean of parents ranged from 25.73 days in P_6 to 35.40 days in P_2. Among hybrids, P_4 x P_5 was the earliest (22.60 days) whereas the P_5 x P_6 was the latest (34.40 days). None of the hybrids were on par with P_4 x P_5.

4.1.2 Days to female flower opening

The parental means ranged from 37.20 (P_6) to 44.93 (P_2). Among the hybrids the mean ranged from 33.07 in P_1 x P_7 to 41.40 in P_2 x P_7. The hybrids P_1 x P_3 (36.00), P_2 x P_4 (36.20), P_2 x P_6 (36.53), P_4 x P_5 (34.27), P_4 x P_6 (35.40) and P_6 x P_7 (36.07) were on par with P_1 x P_7 in earliness for days to female flower opening.

4.1.3 Node to first female flower

The parent P_6 produced first female flower at the lowest node (4.67) whereas P_3 at the highest node (9.20). Among hybrids P_2 x P_3 produced first

Table 4 Analysis of variance for various characters

Character	Mean Squares		
	Treatment	Replication	Error
1. Days to first male flower opening	21.40**	9.40	3.56
2. Days to first female flower opening	14.98**	0.83	2.74
3. Node to first female flower	5.66**	1.42	2.15
4. Male flowers per plant	10036.81**	720.99	109.91
5. Female flowers per plant	11.47**	0.44	0.45
6. Fruits per plant	10..65**	0.64	0.43
7. Productive branches per plant	4.04**	0.39	0.31
8. Node at first fruiting	3.91**	2.28	1.39
9. Mean fruit weight	336732.73**	13686.01	14577.02
10. Yield per plant	28182330.00**	2596304	1387450.50
11. Fruit diameter	5.52**	1.12	0.62
12. Flesh thickness	0.24**	0.11	0.32
13. Fruit length	42.68**	7.15	2.26
14. Vine length	0.24**	0.03	0.05
15. Internodal length	1.46**	1.64	0.32
16. Seeds per fruit	117719.89**	256.90	648.87
17. 100 seed weight	0.34**	0.0002	0.0003
18. Days to first fruit harvest	6.58**	22.47	2.03
19. Sex ratio	285.76**	5.18	5.60
20. Crop duration	64.26**	4.85	2.73
21. Keeping quality	110.25**	9.56	0.37

** Significant at 1 per cent level

Table 5 Mean values of individual characters

	Days to firts male flower opening	Days to first female flower opening	Node to first female flower	Male flowers per plant	Female flowers per plant	Fruits per plant	Productive branches per plant	Node at first fruiting
P_1	32.20	40.67	8.80	134.80	7.67	6.40	3.47	10.67
P_2	35.40	44.93	6.40	197.80	5.40	4.53	3.47	6.80
P_3	32.20	39.67	9.20	224.63	6.47	5.53	3.80	9.67
P_4	30.87	38.87	6.53	198.93	8.73	6.47	5.20	7.50
P_5	31.93	37.73	8.33	125.73	8.67	7.00	3.27	9.53
P_6	25.73	37.20	4.67	192.20	6.53	3.80	3.40	7.00
P_7	31.53	37.60	4.93	76.40	7.87	6.93	5.20	7.47
P_1 x P_2	29.60	38.27	5.40	118.33	9.47	8.20	4.33	5.53
P_1 x P_3	29.13	36.00	8.20	205.73	8.07	6.27	5.87	9.27
P1 x P4	27.60	39.13	6.33	150.00	7.13	5.73	6.40	7.00
P1 x P5	29.87	38.60	8.20	202.20	10.67	10.00	6.37	8.60
P1 x P6	31.13	37.07	6.07	118.07	7.87	7.20	5.33	7.20
P1 x P7	28.93	33.07	5.93	87.33	5.33	4.87	3.40	6.93
P2 x P3	29.60	37.67	3.67	334.40	8.60	7.00	5.53	6.73
P2 x P4	26.73	36.20	6.67	158.60	11.53	6.27	4.47	7.07
P2 x P5	29.07	37.53	8.00	116.73	8.27	7.40	3.60	8.53
P2 x P6	27.80	36.53	6.93	232.13	7.60	6.33	2.80	7.33
P2 x P7	31.60	41.40	8.13	217.87	6.60	4.13	3.13	8.73
P3 x P4	32.73	39.00	9.00	247.33	11.27	9.87	4.93	9.47
P3 x P5	33.67	38.60	7.93	195.00	8.20	7.80	3,60	9.27
P3 x P6	30.2	38.47	5.67	269.93	6.67	6.27	3.73	8.40
P3 x P7	30.73	38.07	7.87	173.87	5.73	5.27	3.87	8.50
P4 x P5	22.60	34.27	6.87	109.20	13.13	11.53	6.13	8.03
P4 x P6	30.07	35.40	6.80	143.53	8.60	6.20	3.27	7.80
P4 x P7	29.07	35.20	7.67	157.33	8.97	7.87	4.53	8.00
P5 x P6	34.40	37.47	7.93	167.27	7.27	6.47	4.53	8.93
P5 x P7	30.20	37.13	6.20	217.87	5.00	3.93	2.93	7.40
P6 x P7	32.40	36.07	7.13	178.73	10.07	9.80	6.53	8.27
MST	21.40	14.98	5.66	10036.81	11.47	10.66	4.04	3.91
F	6.02**	5.47**	2.64**	91.32**	25.52**	24.48**	13.21**	2.80**
SE	1.54	1.35	1.20	8.56	0.55	0.54	0.45	0.96
CD (5 %)	3.08	2.71	2.40	17.15	1.10	1.11	0.90	1.93
CD (1 %)	4.11	3.01	3.20	22.85	1.46	1.44	1.20	2.57

Table 5 Contd...

	Mean fruit weight (kg)	Yield per plant (kg)	Fruit diameter (cm)	Flesh thickness (cm)	Fruit length (cm)	Vine length (m)	Internodal length (cm)
P_1	0.44	2.82	7.10	1.77	23.30	1.93	8.47
P_2	0.35	1.59	6.33	1.72	22.27	1.40	8.27
P_3	1.12	6.17	9.83	2.28	31.90	2.53	11.20
P_4	0.82	5.28	7.93	1.98	27.16	2.07	9.47
P_5	0.55	3.85	6.60	1.62	27.22	2.27	10.73
P_6	0.65	2.49	7.83	2.17	30.92	1.73	8.60
P_7	0.75	5.18	7.43	2.12	27.36	1.80	9.20
P_1 x P_2	0.73	6.00	8.83	1.97	33.47	1.73	8.87
P_1 x P_3	0.98	6.16	8.97	2.17	28.80	2.47	9.73
P1 x P4	0.55	3.12	9.57	2.37	23.99	1.93	8.53
P1 x P5	1.01	10.20	8.80	2.07	30.97	2.47	10.00
P1 x P6	0.69	4.94	7.20	2.00	26.27	2.20	8.67
P1 x P7	0.74	3.63	7.87	1.80	27.73	1.80	9.40
P2 x P3	1.40	9.77	12.30	2.30	35.58	1.80	9.93
P2 x P4	0.96	6.07	7.97	2.02	31.11	2.33	10.00
P2 x P5	0.82	6.09	8.77	1.77	31.20	2.00	9.20
P2 x P6	1.60	10.14	11.30	2.28	36.69	1.93	9.07
P2 x P7	0.59	2.44	6.93	1.77	25.26	1.93	9.33
P3 x P4	1.21	11.97	9.27	2.37	31.90	2.33	9.73
P3 x P5	1.51	11.83	8.70	2.38	33.55	2.20	8.80
P3 x P6	1.27	7.94	8.93	1.89	29.60	2.53	9.73
P3 x P7	0.82	4.32	6.70	1.71	24.18	1.87	8.67
P4 x P5	0.67	7.70	8.17	1.98	26.02	2.33	9.07
P4 x P6	0.64	3.92	7.97	2.03	27.06	1.93	8.43
P4 x P7	1.29	10.16	9.50	2.80	30.78	2.20	8.87
P5 x P6	1.30	8.47	7.43	1.73	34.44	2.27	9.27
P5 x P7	1.18	4.67	8.97	1.49	30.28	1.93	8.73
P6 x P7	1.11	10.90	7.77	2.00	27.56	1.87	9.07
MST	336.73	28182.33	5.52	0.25	42.69	0.24	1.46
F	23.10**	20.31**	8.92**	7.83**	18.87**	4.81**	4.56**
SE	98.58	961.75	0.64	0.15	1.23	0.18	0.46
CD (5 %)	0.19	1.93	1.29	0.29	2.45	0.37	0.92
CD (1 %)	0.26	2.57	1.72	0.39	3.28	0.49	1.23

Table 5 Contd...

	Seeds per fruit	100 seed weight (g)	Days to first fruit harvest	Sex ratio	Crop duration	Keeping quality (days)
P_1	641.33	1.67	59.47	17.82	75.40	4.33
P_2	496.13	1.43	57.47	36.76	72.47	4.67
P_3	1109.37	1.70	61.13	35.09	86.87	5.83
P_4	662.27	1.40	60.73	22.78	89.00	8.83
P_5	634.27	1.26	59.33	14.52	71.13	7.83
P_6	982.07	1.13	59.73	29.61	74.60	10.67
P_7	881.47	1.50	59.47	9.72	75.27	31.00
P_1 x P_2	922.20	2.00	59.93	12.53	74.67	15.17
P_1 x P_3	969.27	1.75	60.93	25.53	73.93	14.83
P1 x P4	1248.33	1.60	56.93	21.14	70.47	3.83
P1 x P5	861.20	2.08	61.20	19.00	74.27	11.67
P1 x P6	903.00	1.40	59.40	15.01	73.40	3.67
P1 x P7	988.93	1.39	58.07	16.43	73.40	14.50
P2 x P3	1107.93	1.52	61.40	39.06	72.13	4.83
P2 x P4	591.00	1.52	61.33	13.85	73.00	3.83
P2 x P5	820.40	1.84	58.73	14.29	76.63	4.83
P2 x P6	1095.93	1.46	55.47	30.70	69.00	5.17
P2 x P7	756.27	1.63	58.87	33.02	72.47	4.17
P3 x P4	849.20	1.74	59.93	21.99	69.47	7.83
P3 x P5	984.33	1.21	60.13	23.96	69.87	5.17
P3 x P6	621.77	2.67	59.40	40.60	74.20	6.00
P3 x P7	701.53	1.50	61.13	30.52	74.20	4.83
P4 x P5	956.93	1.82	58.27	8.35	70.93	4.67
P4 x P6	667.40	1.58	61.13	16.71	73.33	6.00
P4 x P7	658.53	1.96	59.80	17.78	68.07	9.83
P5 x P6	804.90	2.09	61.33	23.02	74.40	8.83
P5 x P7	466.53	1.53	60.80	43.56	75.27	5.00
P6 x P7	922.13	2.25	60.73	17.79	67.87	19.5.0
MST	117719.89	0.34	6.58	285.76	64.26	110.25
F	181.42**	989.33**	3.24**	51.02**	23.56**	296.88**
SE	20.80	0.02	1.16	1.93	1.35	0.50
CD (5 %)	41.68	0.03	2.33	3.87	2.70	1.00
CD (1 %)	55.51	0.04	3.10	5.16	3.60	1.33

** Significant at 1 per cent level

female flower at lowest node (3.67) and P_3 x P_4 at the highest node (9.00). The hybrids P_1 x P_2 (5.40), P_1 x P_4 (6.33), P_1 x P_6 (6.07), P_1 x P_7 (5.93), P_2 x P_4 (6.67), P_3 x P_6 (5.67), P_4 x P_6 (6.80) and P_5 x P_7 (6.20) were on par with P_2 x P_3.

4.1.4 Male flowers per plant

Among parents, P_3 produced maximum number of male flowers (224.63), whereas P_7 produced the minimum (76.40). Among hybrids the mean number ranged from 87.33 (P_1 x P_7) to 334.40 (P_2 x P_3). No other hybrid was on par with P_2 x P_3.

4.1.5 Female flowers per plant

Number of female flowers varied from 5.40 (P_2) to 8.73 (P_4) in the parents. The hybrid P_4 x P_5 had maximum female flowers (13.13) whereas, P_5 x P_7 had the minimum (5.00).

4.1.6 Fruits per plant

The mean of parents ranged from 3.80 in P_6 to 7.00 in P_5. In hybrids, mean varied from 3.93 in P_5 x P_7 to 11.53 in P_4 x P_5. No other hybrid was on par with P_4 x P_5.

4.1.7 Productive branches per plant

The parent P_5 had the minimum productive branches (3.27) whereas P_4 and P_7 had the maximum (5.20). The hybrid with least number of productive branches was P_2 x P_6 (2.80) whereas P_6 x P_7 produced the highest number

(6.53). The hybrids P_1 x P_3 (5.87), P_1 x P_4 (6.40), P_1 x P_5 (6.37), P_4 x P_5 (6.13), P_1 x P_6 (5.33) and P_2 x P_3 (5.53) were on par with P_6 x P_7.

4.1.8 Node at first fruiting

Among parents P_2 produced fruits at the lowest node (6.80) while P_1 produced fruits at the highest node (10.67). Among hybrids P_1 x P_2 bore fruits at the lowest node of 5.53 and P_3 x P_4 at the highest node of 9.47. P_1 x P_4 (7.00), P_1 x P_6 (7.20), P_1 x P_7 (6.93), P_2 x P_3 (6.73), P_2 x P_4 (7.07), P_2 x P_6 (7.33) and P_5 x P_7 (7.40) were found to be on par with P_1 x P_2.

4.1.9 Mean fruit weight

The parent P_3 produced fruits with maximum mean weight (1.12 kg) while P_2 produced fruits with minimum weight (0.35 kg). Among hybrids, P_2 x P_6 produced fruits with a maximum weight of 1.60 kg while P_1 x P_4 produced fruits with minimum weight of 0.55 kg. The hybrids P_2 x P_3 (1.40 kg) and P_3 x P_5 (1.51 kg) were on par with P_2 x P_6.

4.1.10 Yield per plant

The parent P_3 recorded the highest mean yield of 6.17 kg and P_2 the lowest of 1.59 kg. The cross P_3 x P_4 recorded a maximum mean yield of 11.97 kg, while the cross P_2 x P_7 produced a minimum mean yield of 2.44 kg. The hybrids P_1 x P_5 (10.20 kg), P_2 x P_3 (9.77 kg), P_2 x P_6 (10.14 kg), P_3 x P_5 (11.83 kg), P_4 x P_7 (10.16 kg) and P_6 x P7 (10.90 kg) were on par with the highest yielding hybrid P_3 x P_4. All high yielding hybrids out yielded the highest yielding parent P_3.

4.1.11 Fruit diameter

The mean of parents ranged from 6.33 cm (P_2) to 9.83 cm (P_3). The mean of hybrids varied from 6.70 cm (P_3 x P_7) to 12.30 cm (P_2 x P_3). The hybrid P_2 x P_6 (11.30) was on par with P_2 x P_3.

4.1.12 Flesh thickness

The least flesh thickness of 1.62 cm was recorded by P_5 while P_3 recorded the maximum of 2.28 cm among parents. Among hybrids, the mean flesh thickness ranged from 1.49 cm in P_5 x P_7 to 2.80 cm in P_4 x P_7.

4.1.13 Fruit length

The mean of parents ranged from 22.27 cm (P_2) to 31.90 cm (P_3). Fruit length of hybrids varied between 23.99 cm (P_1 x P_4) and 36.69 cm (P_2 x P_6). The hybrids P_2 x P_3 (35.58 cm) and P_5 x P_6 (34.44 cm) were on par with P_2 x P_6 which has maximum fruit length.

4.1.14 Vine length

Among parents, P_2 had the shortest vines (1.40 m), while P_3 had the longest vines (2.53 m). The best performing hybrid P_3 x P_6 also recorded the same mean length as that of P_3 (2.53 m) while P_1 x P_2 recorded the lowest vine length (1.73 m). The hybrids P_1 x P_3 (2.47 m), P_1 x P_5 (2.7 m), P_1 x P_6 (2.20 m), P_2 x P_4 (2.33 m), P_3 x P_4 (2.33 m), P_3 x P_5 (2.20 m), P_4 x P_5 (2.33 m), P_4 x P_7 (2.20 m) and P_5 x P_6 (2.27 m) were on par with P_3 x P_6.

4.1.15 Internodal length

In parents, the internodal length ranged from 8.27 cm (P_2) to 11.20 cm (P_3). The hybrids P_1 x P_5 and P_2 x P_4 had longest internodes of 10.00 cm. The hybrids P_1 x P_2 (8.87 cm), P_1 x P_3 (9.73 cm), P_1 x P_7 (9.40 cm), P_2 x P_3 (9.93 cm), P_2 x P_5 (9.20 cm), P_2 x P_6 (9.07 cm), P_2 x P_7 (9.33 cm), P_3 x P_4 (9.73 cm), P_3 x P_5 (8.80 cm), P_3 x P_6 (9.73 cm), P_4 x P_5 (9.07 cm), P_4 x P_7 (8.87 cm), P_5 x P_6 (9.27 cm) and P_6 x P_7 (9.07 cm) were on par with P_1 x P_5 and P_2 x P_4. The hybrid P_4 x P_6 had the shortest internodal length of 8.43 cm.

4.1.16 Seeds per fruit

The parent P_2 had the minimum seeds per fruit (496.13) and P_3 the maximum (1109.37). Among hybrids, P_1 x P_4 produced maximum seeds per fruit (1248.33) and P_5 x P_7 the minimum (466.53).

4.1.17 100 seed weight

Among parents, 100 seed weight was maximum for P_3 (1.70 g) and minimum for P_6 (1.13 g). Among hybrids, it was maximum for P_3 x P_6 (2.67 g) and minimum for P_3 x P_5 (1.21 g).

4.1.18 Days to first fruit harvest

The parent P_2 was the earliest for first harvest (57.47 days) and P_3 the latest (61.13 days). The hybrid early for harvest was P_2 x P_6 which took only 55.47 days. P_1 x P_4 (56.93) was on par with P_2 x P_6. The hybrid P_2 x P_3 took maximum number of days for first harvest (61.40).

4.1.19 Sex ratio

Sex ratio was lowest for P_7 (9.72) and highest for P_2 (36.76) among parents. The hybrid P_4 x P_5 showed the lowest sex ratio of 8.35. P_1 x P_2 (12.53) was observed to be on par with P_4 x P_5. P_5 x P_7 showed the highest sex ratio of 43.56.

4.1.20 Crop duration

Among parents, P_5 was the earliest with a duration of 71.13 days, while P_4 had the longest duration of 89.00 days. Among hybrids P_6 x P_7 was the earliest with the duration of 67.87 days. P_1 x P_4 (70.47), P_2 x P_6 (69.00), P_3 x P_4 (69.47), P_3 x P_5 (69.87), P_4 x P_5 (70.93) and P_4 x P_7 (68.07) were on par with the earliest hybrid P_6 x P_7. The hybrid P_2 x P_5 had the longest duration of 76.63 days.

4.1.21 Keeping quality

The parent P_7 had the maximum keeping quality (31.00 days) while P_1 showed the minimum keeping quality of 4.33 days. Among hybrids, P_6 x P_7 remained fresh till 19.5 days after harvest and P_1 x P_7 showed least keeping quality of just 3.67 days. None of the hybrids overtook the best parent P_7 in this character.

4.1.22 Incidence of pests and disease

Mosaic was the only disease that affected the crop. Hence scoring was done for mosaic only. Generally, none of the hybrids showed high incidence of the disease. Among hybrids, P_1 x P_2, P_1 x P_3, P_2 x P_3. P_2 x P_4, P_2 x P_5, P_2 x P_6,

P_4 x P_5 and P_4 x P_7 showed low disease incidence in all the three replications. Pests were not at all a problem during the crop period.

4.2 Phenotypic Coefficient of Variation, Genotypic Coefficient of Variation, heritability and genetic advance

The estimates of genetic parameters for various characters are presented in Table 6. The character days to first fruit harvest showed minimum PCV and GCV i.e., 3.15 and 2.06 respectively while the character keeping quality showed maximum values of PCV and GCV i.e., 71.76 and 71.40 respectively, among the 21 characters studied.

There was no marked differences between PCV and GCV for almost all the characters except node to first female flower (10.59) and node at first fruiting (7.19). The two values varied slightly for 100 seed weight, number of seeds, keeping quality, crop duration and number of male flowers per plant.

High heritability (i.e., above 60 per cent) was observed in characters like days to male flower opening, male flowers per plant, female flowers per plant, fruits per plant, productive branches per plant, mean fruit weight, yield per plant, fruit diameter, flesh thickness, fruit length, number of seeds, 100 seed weight, sex ratio, crop duration and keeping quality. The highest heritability was observed for 100 seed weight (99.70 per cent) followed by keeping quality (99.00 per cent). Heritability was the lowest for node to first female flower (35.30 per cent).

High value of genetic advance was observed in male flowers, female flowers and fruits per plant, productive branches per plant, mean fruit weight, yield per plant, number of seeds, 100 seed weight, sex ratio and keeping quality. All the

Table 6 PCV, GCV, heritability and genetic advance (as per cent of mean) of different characters

Character	PCV	GCV	H^2	GA
1. Days to first male flower opening	10.19	8.06	62.60	13.12
2. Days to first female flower opening	6.90	5.34	59.80	8.51
3. Node to first female flower	26.10	15.51	35.30	19.05
4. Male flowers per plant	33.06	32.53	96.80	65.92
5. Female flowers per plant	25.01	23.60	89.10	45.94
6. Fruits per plant	29.02	27.32	88.70	53.04
7. Productive branches per plant	28.31	25.37	80.30	46.86
8. Node at first fruiting	18.55	11.36	37.60	14.40
9. Mean fruit weight	37.99	35.64	88.00	68.90
10. Yield per palnt	50.60	47.07	86.60	19.21
11. Fruit diameter	17.89	15.23	72.50	26.70
12. Flesh thickness	15.94	13.28	69.50	22.77
13. Fruit length	13.60	12.59	85.60	24.00
14. Vine length	16.36	12.23	55.90	18.90
15. Internodal length	9.03	6.65	54.30	10.05
16. Seeds per fruit	23.93	23.73	98.40	48.50
17. 100 seed weight	20.25	20.22	99.70	41.44
18. Days to first fruit harvest	3.15	2.06	42.70	2.78
19. Sex ratio	42.78	41.56	94.30	83.17
20. Crop duration	6.53	6.14	88.20	11.87
21. Keeping quality	71.76	71.40	99.00	146.30

above characters, showed high values of heritability also. Maximum GA was observed for keeping quality (146.30 per cent) and minimum for days to first fruit harvest (2.78).

4.3 Heterosis

Superior hybrids in relation to mid parental value (relative heterosis) better parent (heterobeltiosis) and standard parent (standard heterosis) were estimated for all the 21 characters and are presented in Table 7. Mudicode local (P_7) was chosen as the standard parent. The graphical representation of standard heterosis for all characters and heterobeltiosis for some selected characters are given in Fig. 1 to 6.

4.3.1 Days to first male flower opening

Significant negative heterosis was observed in nine hybrids over the mid parents, three hybrids over better parent and four over the standard parent. The cross P_4 x P_5 (Plate 6) showed maximum negative relative heterosis (-28.03), heterobeltiosis (-26.79) and standard heterosis (-28.32) for this trait. P_2 x P_4 showed a relative heterosis of –19.33 which was on par with P_4 x P_5.

The cross P_5 x P_6 showed maximum positive heterosis over mid parent (19.32) and better parent (33.70). None of the hybrids showed significant positive standard heterosis. Two hybrids showed significant positive relative heterosis and five showed significant positive heterobeltiosis.

4.3.2 Days to first female flower opening

The hybrid P_1 x P_7 exhibited maximum negative values with a relative heterosis of –15.50, heterobeltiosis and standard heterosis of –12.05 each.

Table 7 Estimates of percentage heterosis over mid, better and standard parents for various characters

	(i) Days to first male flower opening				(ii) Days to first female flower opening			
	Mean	R H	HB	SH	Mean	R H	HB	SH
P_1	32.20	-	-	-	40.67	-	-	-
P_2	35.40	-	-	-	44.93	-	-	-
P_3	32.20	-	-	-	39.67	-	-	-
P_4	30.87	-	-	-	38.87	-	-	-
P_5	31.93	-	-	-	37.73	-	-	-
P_6	25.73	-	-	-	37.20	-	-	-
P_7	31.53	-	-	-	37.60	-	-	-
P_1 x P_2	29.60	-12.43**	-8.08	-6.12	38.27	-10.58**	-5.90	1.78
P_1 x P_3	29.13	-9.53*	-9.53	-7.61	36.00	-10.38**	-9.25**	-4.26
P_1 x P_4	27.60	-12.48**	-10.59*	-12.46*	39.13	-1.61	0.67	4.07
P_1 x P_5	29.87	-6.85	-6.45	-5.27	38.60	-1.53	2.31	2.66
P_1 x P_6	31.13	7.48	20.99**	-1.27	37.07	-4.79	-0.35	-1.41
P_1 x P_7	28.93	-9.21*	-8.25	-8.25	33.07	-15.50**	-12.05**	-12.05**
P_2 x P_3	29.60	-12.43**	-8.08	-6.12	37.67	-10.95**	-5.04	0.19
P_2 x P_4	26.73	-19.33**	-13.41**	-15.22**	36.20	-13.60**	-6.87	-3.72
P_2 x P_5	29.07	-13.65**	-8.96	-7.80	37.53	-9.19**	-0.53	-0.19
P_2 x P_6	27.80	-9.05*	8.05	-11.83*	36.53	-11.04**	-1.80	-2.85
P_2 x P_7	31.60	-5.57	0.22	0.22	41.40	0.33	10.11**	10.11**
P_3 x P_4	32.73	3.79	6.03	3.81	39.00	-0.69	0.33	3.72
P_3 x P_5	33.67	5.01	5.45	6.79	38.60	-0.26	2.31	2.66
P_3 x P_6	30.20	4.26	17.37**	-4.22	38.47	0.09	3.41	2.31
P_3 x P_7	30.73	-3.56	-2.44	-2.54	38.07	-1.46	1.27	1.25
P_4 x P_5	22.60	-28.03**	-26.79**	-28.32**	34.27	-10.52**	-9.17*	-8.86*
P_4 x P_6	30.07	6.25	16.88**	-4.63	35.40	-6.93*	-4.84	-5.85
P_4 x P_7	29.07	-6.83	-5.83	-7.80	37.20	-2.70	1.06	-1.06
P_5 x P_6	34.40	19.32**	33.70**	9.10	37.47	0.01	0.73	-0.35
P_5 x P_7	30.20	-4.82	-4.22	-4.21	37.13	-1.42	-1.25	-1.25
P_6 x P_7	32.40	13.17**	25.92**	2.76	36.07	-3.56	-3.04	-4.07
$ CD (5 %)	-	2.67	3.09	3.09	-	2.35	2.71	2.71
CD (1 %)	-	3.56	4.11	4.11	-	3.12	3.61	3.61

RH - Relative Heterosis HB - Heterobeltiosis SH - Standard Heterosis
** Significant at one per cent level * Significant at five per cent level

$ CD for comparing difference of means as in section 3.6

Table 7 Contd...

	(iii) Node to first female flower				(iv) Male flowers per plant			
	Mean	R H	HB	SH	Mean	R H	HB	SH
P_1	8.80	-	-	-	134.80	-	-	-
P_2	6.40	-	-	-	197.80	-	-	-
P_3	9.20	-	-	-	224.63	-	-	-
P_4	6.53	-	-	-	198.93	-	-	-
P_5	8.33	-	-	-	125.73	-	-	-
P_6	4.67	-	-	-	192.20	-	-	-
P_7	4.93	-	-	-	76.40	-	-	-
P_1 x P_2	5.40	-28.95*	-15.63	9.53	118.33	-28.85**	-40.18**	54.88**
P_1 x P_3	8.20	-8.89	-6.82	66.33**	205.73	14.48**	-8.41**	169.28**
P_1 x P_4	6.33	-17.42	-3.06	29.40	150.00	-10.11*	-24.60**	96.34**
P_1 x P_5	8.20	-4.26	-1.56	66.33**	202.20	55.22**	50.00**	160.66**
P_1 x P_6	6.07	-9.87	29.98	23.12	118.07	-27.79**	-38.57**	54.54**
P_1 x P_7	5.93	-13.62	20.28	20.28	87.33	-17.30*	-35.22**	14.31
P_2 x P_3	3.67	-52.95**	-42.66*	-25.56	334.40	58.32**	48.87**	337.70**
P_2 x P_4	6.67	3.17	4.22	35.29	158.60	-20.05**	-20.27**	107.59**
P_2 x P_5	8.00	8.62	25.00	62.27*	116.73	-27.84**	-40.99**	52.79**
P_2 x P_6	6.93	25.20	48.39	40.57	232.13	19.04**	17.36**	203.84**
P_2 x P_7	8.13	43.51*	64.91	64.91**	217.87	29.46**	10.18*	185.17**
P_3 x P_4	9.00	14.43	37.83	82.56**	247.33	16.79**	10.11*	223.73**
P_3 x P_5	7.93	-9.53	-4.80	60.85*	195.00	11.31**	-13.19	155.24**
P_3 x P_6	5.67	-18.24	21.41	15.01	269.93	29.52**	20.17**	253.31**
P_3 x P_7	7.87	11.39	59.63*	59.63*	173.87	15.52**	-22.60**	127.58**
P_4 x P_5	6.87	-7.54	5.21	39.35	109.20	-32.73**	-45.11**	42.93**
P_4 x P_6	6.80	21.43	45.61	37.93	143.53	-26.61**	-27.85**	87.87**
P_4 x P_7	7.67	33.86	55.58*	55.58*	157.33	14.29*	-20.91**	105.93**
P_5 x P_6	7.93	22.00	69.81**	60.85*	167.27	5.22	-12.97**	118.94**
P_5 x P_7	6.20	-6.49	25.76	25.76	217.87	115.57**	73.28**	185.17**
P_6 x P_7	7.13	48.54*	52.68*	44.63	178.73	33.08**	-7.01	133.81**
CD (5 %)	-	2.08	2.40	2.40	-	14.86	17.15	70.15
CD (1 %)	-	2.77	3.19	3.19	-	19.79	22.85	22.85

Table 7 Contd...

	(v) Female flowers per plant				(vi) Fruits per plant			
	Mean	R H	HB	SH	Mean	R H	HB	SH
P_1	7.67	-	-	-	6.40	-	-	-
P_2	5.40	-	-	-	4.53	-	-	-
P_3	6.47	-	-	-	5.53	-	-	-
P_4	8.73	-	-	-	6.47	-	-	-
P_5	8.67	-	-	-	7.00	-	-	-
P_6	6.53	-	-	-	3.80	-	-	-
P_7	7.87	-	-	-	6.93	-	-	-
P_1 x P_2	9.47	44.91**	23.47**	20.33**	8.2	50.05**	28.13**	18.33*
P_1 x P_3	8.07	14.14*	5.22	2.54	6.27	5.11	-2.03	-9.52
P_1 x P_4	7.13	-13.05*	-18.33**	-9.40	5.73	-10.96	-11.44	-17.32
P_1 x P_5	10.67	30.60**	23.07**	35.58**	10.00	49.25**	42.86**	44.30**
P_1 x P_6	7.87	10.85	2.61	0.00	7.20	41.18**	12.50	3.89
P_1 x P_7	5.33	-31.40**	-32.27**	-32.27**	4.87	-26.93**	-29.73**	-29.73**
P_2 x P_3	8.60	44.90**	32.92**	9.28	7.00	39.17**	26.58**	1.01
P_2 x P_4	11.53	63.20**	32.07**	46.51**	6.27	14.00	-3.09	-9.52
P_2 x P_5	8.27	17.56*	-4.61	5.08	7.40	28.36**	5.71	6.78
P_2 x P_6	7.60	27.50**	16.39	-3.43	6.33	51.98**	39.74**	-8.66
P_2 x P_7	6.60	-0.53	-16.14*	-16.04*	4.13	-27.92**	-40.40**	-40.40**
P_3 x P_4	11.27	48.29**	29.20**	43.20**	9.87	64.50**	52.55**	42.42**
P_3 x P_5	8.20	8.32	-5.42	4.19	7.80	24.50**	11.43	12.55
P_3 x P_6	6.67	2.62	2.14	-15.25*	6.27	34.41**	13.38	-9.52
P_3 x P_7	5.73	-20.08**	-27.19**	-27.19**	5.27	-15.41**	-23.95**	-23.95**
P_4 x P_5	13.13	50.92**	50.40**	66.84**	11.53	71.20**	64.71**	66.38**
P_4 x P_6	8.60	12.71*	45.62**	9.28	6.20	20.74*	-4.17	-10.53
P_4 x P_7	8.97	8.07	2.75	13.98*	7.87	17.46*	13.56	13.56
P_5 x P_6	7.27	-4.34	-16.15*	-7.62	6.47	19.82*	-7.57	-6.64
P_5 x P_7	5.00	-39.54**	-42.33**	-36.47**	3.93	-43.58**	-43.86**	-43.29**
P_6 x P_7	10.07	39.86**	27.95**	27.95**	9.80	82.67**	41.41**	41.41**
CD (5 %)	-	0.95	1.20	1.20	-	0.94	1.08	1.08
CD (1 %)	-	1.27	1.46	1.46	-	1.25	1.44	1.44

Table 7 Contd...

	(vii) Productive branches per plant				(viii) Node at first fruiting			
	Mean	R H	HB	SH	Mean	R H	HB	SH
P_1	3.47	-	-	-	10.67	-	-	-
P_2	3.47	-	-	-	6.80	-	-	-
P_3	3.80	-	-	-	9.67	-	-	-
P_4	5.20	-	-	-	7.50	-	-	-
P_5	3.27	-	-	-	9.53	-	-	-
P_6	3.40	-	-	-	7.00	-	-	-
P_7	5.20	-	-	-	7.47	-	-	-
$P_1 \times P_2$	4.33	24.78*	24.78	-16.73	5.53	-36.69**	-18.68	-25.97*
$P_1 \times P_3$	5.87	61.49**	54.47**	21.89	9.27	-8.85	-4.14	24.10
$P_1 \times P_4$	6.40	47.64**	23.08**	23.08**	7.00	-22.95**	-6.68	-6.29
$P_1 \times P_5$	6.37	89.02**	83.57**	22.50*	8.60	-14.85	-9.80	15.13
$P_1 \times P_6$	5.33	55.17**	53.60**	2.50	7.20	-18.51	2.86	-3.61
$P_1 \times P_7$	3.40	-21.57**	-34.62**	-34.62**	6.93	-23.59*	-7.23	-7.23
$P_2 \times P_3$	5.53	52.13**	45.53**	6.35	6.73	-18.28	-1.03	-9.91
$P_2 \times P_4$	4.47	3.11	-14.04	14.04	7.07	-1.12	3.97	-5.36
$P_2 \times P_5$	3.60	6.83	3.75	-30.77**	8.53	4.47	25.44	14.19
$P_2 \times P_6$	2.80	-18.49	-19.31	-46.15**	7.33	6.23	7.79	-1.87
$P_2 \times P_7$	3.13	-27.80**	-39.81*	-39.81**	8.73	22.36	28.32*	16.87
$P_3 \times P_4$	4.93	9.56	-5.19	-5.19	9.47	10.31	26.27*	26.77
$P_3 \times P_5$	3.60	1.84	-5.26	-30.77**	9.27	-3.44	-2.73	24.10
$P_3 \times P_6$	3.73	3.61	-1.84	-28.27**	8.40	0.78	20.00	12.45
$P_3 \times P_7$	3.87	-14.00	-25.58**	-25.58**	8.50	-0.82	13.79	13.79
$P_4 \times P_5$	6.13	44.75**	17.85*	17.89*	8.03	-5.70	7.07	7.50
$P_4 \times P_6$	3.27	-23.95*	-37.12**	-37.12**	7.80	7.59	11.43	4.42
$P_4 \times P_7$	4.53	-12.89	-12.89	-12.89	8.00	6.88	7.10	7.10
$P_5 \times P_6$	4.53	35.83**	33.24*	-12.89	8.93	8.05	27.57*	19.55
$P_5 \times P_7$	2.93	-30.82**	-43.65**	-43.65**	7.40	-12.94	-0.94	-0.94
$P_6 \times P_7$	6.53	51.86**	25.58**	25.58**	8.27	14.31	-18.14	10.71
CD (5 %)	-	0.78	0.91	0.91	-	1.67	1.93	1.93
CD (1 %)	-	1.05	1.21	1.21	-	2.23	2.57	2.57

Table 7 Contd...

	(ix) Mean fruit weight				(x) Yield per plant			
	Mean	R H	HB	SH	Mean	R H	HB	SH
P_1	0.44	-	-	-	2.82	-	-	-
P_2	0.35	-	-	-	1.59	-	-	-
P_3	1.12	-	-	-	6.17	-	-	-
P_4	0.82	-	-	-	5.28	-	-	-
P_5	0.55	-	-	-	3.85	-	-	-
P_6	0.65	-	-	-	2.49	-	-	-
P_7	0.75	-	-	-	5.18	-	-	-
P_1 x P_2	0.73	83.37**	64.90**	-2.92	6.00	172.46**	113.00**	15.89
P_1 x P_3	0.98	25.33*	-12.72	30.80*	6.16	37.19*	-0.69	19.01
P_1 x P_4	0.55	-13.26	-33.41**	-26.80*	3.12	-22.90	-40.88*	-39.71*
P_1 x P_5	1.01	104.85**	84.27**	35.75**	10.20	206.06**	165.10**	96.95**
P_1 x P_6	0.69	26.96	6.64	-7.66	4.94	86.52**	75.45*	-4.55
P_1 x P_7	0.74	25.49	-0.32	-0.32	3.63	-9.10	-29.82	-29.82
P_2 x P_3	1.40	89.75**	24.64**	86.79**	9.77	151.94**	58.40**	88.65**
P_2 x P_4	0.96	64.61**	17.51	29.16*	6.07	76.71**	14.92	17.20
P_2 x P_5	0.82	81.42**	48.60**	9.47	6.09	124.25**	58.40*	17.68
P_2 x P_6	1.60	220.62**	147.35**	114.18**	10.14	398.40**	308.56**	95.90**
P_2 x P_7	0.59	7.52	-20.97	-20.97	2.44	-27.99	-52.96**	-52.96**
P_3 x P_4	1.21	25.36**	8.65	62.82**	11.97	109.12**	94.09**	131.16**
P_3 x P_5	1.51	80.89**	34.90**	102.17**	11.83	136.25**	91.81**	128.44**
P_3 x P_6	1.27	43.75**	13.41	69.95**	7.94	83.68**	28.82	53.42**
P_3 x P_7	0.82	-12.20	-26.81**	9.68	4.32	-23.80	-29.91	-16.53
P_4 x P_5	0.67	-2.70	-18.74	-10.69	7.70	68.75**	45.84*	48.74*
P_4 x P_6	0.64	-0.90	-22.62	-14.95	3.92	1.00	-25.76	-24.29
P_4 x P_7	1.29	64.55**	57.13**	72.71**	10.16	94.36**	92.47**	96.29**
P_5 x P_6	1.30	118.05**	101.77**	74.72**	8.47	167.66**	120.20**	63.60**
P_5 x P_7	1.18	82.58**	58.54**	58.54**	4.67	3.50	-9.80	-9.80
P_6 x P_7	1.11	59.08**	48.42**	48.42**	10.90	184.65**	110.57**	110.57**
CD (5 %)	-	0.171 09	0.197 55	0.197 55	-	1.669 14	1.927 35	1.927 35
CD (1 %)	-	0.227 86	0.263 11	0.263 11	-	2223.02	2566.92	2566.92

Table 7 Contd...

	(xi) Fruit diameter				(xii) Flesh thickness			
	Mean	R H	HB	SH	Mean	R H	HB	SH
P_1	7.10	-	-	-	1.77	-	-	-
P_2	6.33	-	-	-	1.72	-	-	-
P_3	9.83	-	-	-	2.28	-	-	-
P_4	7.93	-	-	-	1.98	-	-	-
P_5	6.60	-	-	-	1.62	-	-	-
P_6	7.83	-	-	-	2.17	-	-	-
P_7	7.43	-	-	-	2.12	-	-	-
P_1 x P_2	8.83	31.50**	24.37**	18.84*	1.97	12.89	11.30	-7.08
P_1 x P_3	8.97	5.97	-8.75	20.73*	2.17	7.16	-4.83	2.36
P_1 x P_4	9.57	27.35**	20.68*	28.80**	2.37	26.40**	19.70**	11.79
P_1 x P_5	8.80	28.47**	23.94*	18.44*	2.07	22.12**	16.95*	-2.36
P_1 x P_6	7.20	-3.55	-8.05	-3.09	2.00	1.52	-7.83	-5.66
P_1 x P_7	7.87	8.33	5.92	5.92	1.80	-7.46	-15.09*	-15.09
P_2 x P_3	12.30	52.23**	25.13**	65.55**	2.30	15.00*	0.88	8.49
P_2 x P_4	7.97	11.78	0.50	7.27	2.02	9.19	2.02	-4.72
P_2 x P_5	8.77	35.65**	32.88**	18.04*	1.77	5.99	2.91	-16.51
P_2 x P_6	11.30	59.61**	44.32**	52.09**	2.28	17.22**	5.07	7.55
P_2 x P_7	6.93	0.73	-6.73	-6.73	1.77	-7.81	-16.51*	-16.51
P_3 x P_4	9.27	4.39	-5.70	24.76**	2.37	11.27	3.95	11.79
P_3 x P_5	8.70	5.90	-11.50	17.09	2.38	22.05**	4.39	12.26
P_3 x P_6	8.93	1.13	-9.16	20.19*	1.89	-15.06**	-17.11**	-10.85
P_3 x P_7	6.70	-22.36**	-31.84**	-9.83	1.71	-22.27**	-25.00**	-19.34**
P_4 x P_5	8.17	12.46	3.03	9.96	1.98	10.00	0.00	-6.60
P_4 x P_6	7.97	1.14	0.50	7.27	2.03	-2.17	-6.45	-4.25
P_4 x P_7	9.50	23.70**	19.80*	27.86**	2.80	36.59**	32.08**	32.08**
P_5 x P_6	7.43	2.98	-5.11	0.00	1.73	-8.71	-20.28**	-18.40**
P_5 x P_7	8.97	27.87**	20.73*	20.73*	1.49	-20.32**	-29.72**	-29.72**
P_6 x P_7	7.77	1.84	-0.77	4.58	2.00	-6.76	-7.83	-5.66
CD (5 %)	-	1.12	1.29	1.29	-	0.25	0.29	0.29
CD (1 %)	-	1.49	1.72	1.72	-	0.34	0.39	0.39

Table 7 Contd...

	(xiii) Fruit length				(xiv) Vine length			
	Mean	R H	HB	SH	Mean	R H	HB	SH
P_1	23.30	-	-	-	1.93	-	-	-
P_2	22.27	-	-	-	1.40	-	-	-
P_3	31.90	-	-	-	2.53	-	-	-
P_4	27.16	-	-	-	2.07	-	-	-
P_5	27.22	-	-	-	2.27	-	-	-
P_6	30.92	-	-	-	1.73	-	-	-
P_7	27.36	-	-	-	1.80	-	-	-
$P_1 \times P_2$	33.47	46.90**	43.65**	22.33**	1.73	2.98	-10.36	-3.89
$P_1 \times P_3$	28.80	4.35	-9.72*	5.26	2.47	10.76	-2.37	37.22**
$P_1 \times P_4$	23.99	-4.92	-11.67*	-12.32**	1.93	-3.50	6.76	7.22
$P_1 \times P_5$	30.97	22.61**	13.78**	13.19**	2.47	17.62*	-8.81	37.22*
$P_1 \times P_6$	26.27	-3.10	-15.04**	-3.98	2.20	20.22*	13.99	22.22*
$P_1 \times P_7$	27.73	-9.48*	1.35	1.35	1.80	-3.49	-6.74	0.00
$P_2 \times P_3$	35.58	31.36**	11.54**	30.04**	1.80	-8.40	-28.85**	0.00
$P_2 \times P_4$	31.11	25.88**	14.54**	13.71**	2.33	34.29**	12.56	29.44**
$P_2 \times P_5$	31.20	26.09**	14.62**	14.04**	2.00	8.99	-11.89	11.11
$P_2 \times P_6$	36.69	37.96**	18.66**	34.10**	1.93	23.32*	11.56	7.22
$P_2 \times P_7$	25.26	1.79	-7.68	-7.68	1.93	20.63*	7.22	7.22
$P_3 \times P_4$	31.90	8.03*	0.00	16.59**	2.33	1.30	-7.91	29.44**
$P_3 \times P_5$	33.55	13.50**	5.17	22.62**	2.20	-8.33	-13.04	22.22*
$P_3 \times P_6$	29.60	-5.76	-7.21	8.19	2.53	18.78*	0.00	40.56**
$P_3 \times P_7$	24.18	-18.39**	-24.22**	-11.62*	1.87	-13.63	-26.09**	3.89
$P_4 \times P_5$	26.02	-4.30	-4.41	-4.90	2.33	7.37	2.64	29.44**
$P_4 \times P_6$	27.06	-6.82	-12.48**	-1.09	1.93	1.58	-6.76	7.22
$P_4 \times P_7$	30.78	12.91**	12.50**	12.50**	2.20	13.70	6.28	22.22*
$P_5 \times P_6$	34.44	18.47**	11.38**	25.88**	2.27	13.50	0.00	26.11*
$P_5 \times P_7$	30.28	10.96**	10.67*	10.67**	1.93	-5.16	-14.98	7.22
$P_6 \times P_7$	27.56	-5.42	-10.87**	0.73	1.87	5.95	3.89	3.89
CD (5 %)	-	2.13	2.46	2.46	-	0.32	0.37	0.37
CD (1 %)	-	2.84	3.28	3.28	-	0.42	0.49	0.49

Table 7 Contd...

	(xvii) 100 seed weight				(xviii) Days to first fruit harvest			
	Mean	R H	HB	SH	Mean	R H	HB	SH
P_1	1.67	-	-	-	59.47	-	-	-
P_2	1.43	-	-	-	57.47	-	-	-
P_3	1.70	-	-	-	61.13	-	-	-
P_4	1.40	-	-	-	60.73	-	-	-
P_5	1.26	-	-	-	59.33	-	-	-
P_6	1.13	-	-	-	59.73	-	-	-
P_7	1.50	-	-	-	59.47	-	-	-
P_1 x P_2	2.00	29.03**	19.76**	33.33**	59.93	2.50	4.28*	0.77
P_1 x P_3	1.75	3.86**	2.94**	16.67**	60.93	1.05	2.46	2.46
P_1 x P_4	1.60	4.24**	-4.19**	6.67**	56.93	-5.28**	-4.27*	-4.27*
P_1 x P_5	2.08	41.98**	24.55**	38.67**	61.20	3.03	3.15	2.91
P_1 x P_6	1.40	0.00	-16.17**	-6.67**	59.40	-0.34	-0.12	-0.12
P_1 x P_7	1.39	-12.30**	-16.77**	-7.33**	58.07	-2.35	-2.35	-2.35
P_2 x P_3	1.52	-2.88**	-10.59**	1.33	61.40	3.54*	6.84**	3.25
P_2 x P_4	1.52	7.42**	6.29**	1.33	61.33	3.77*	6.72**	3.13
P_2 x P_5	1.84	36.80**	28.67**	22.67**	58.73	0.57	2.19	1.24
P_2 x P_6	1.46	14.06**	2.10*	-2.67**	55.47	-5.34**	-3.48	-6.73**
P_2 x P_7	1.63	11.26**	8.67**	8.67**	58.87	0.68	-2.44	-1.01
P_3 x P_4	1.74	12.26**	2.35**	16.00**	59.93	-1.64	-1.32	0.77
P_3 x P_5	1.21	-18.24**	-28.82**	-19.33**	60.13	-0.17	1.35	1.11
P_3 x P_6	2.67	88.69**	57.06**	78.00**	59.40	-0.85	-0.55	-0.12
P_3 x P_7	1.50	-6.29**	11.76**	0.00	61.13	1.38	2.79	2.79
P_4 x P_5	1.82	36.84**	30.00**	21.33**	58.27	-2.93	-1.79	-2.02
P_4 x P_6	1.58	24.90**	12.86**	5.33**	61.13	1.49	2.34	2.79
P_4 x P_7	1.96	35.17**	30.67**	30.67**	59.80	-0.50	0.56	0.56
P_5 x P_6	2.09	74.90**	65.87**	39.33**	61.33	3.03	-3.37	3.13
P_5 x P_7	1.53	10.87**	2.00*	2.00*	60.80	2.36	2.48	2.24
P_6 x P_7	2.25	71.10**	50.00**	50.00**	60.73	1.90	2.12	2.12
CD (5 %)	-	0.03	0.03	0.03	-	2.03	2.33	2.33
CD (1 %)	-	0.03	0.04	0.04	-	2.69	3.11	3.11

Table 7 Contd...

	(xix) Sex ratio				(xx) Crop duration			
	Mean	R H	HB	SH	Mean	R H	HB	SH
P_1	17.82	-	-	-	75.40	-	-	-
P_2	36.76	-	-	-	72.47	-	-	-
P_3	35.09	-	-	-	86.87	-	-	-
P_4	22.78	-	-	-	89.00	-	-	-
P_5	14.52	-	-	-	71.13	-	-	-
P_6	29.61	-	-	-	74.60	-	-	-
P_7	9.72	-	-	-	75.27	-	-	-
P_1 x P_2	12.53	-54.09**	-29.69**	28.91	74.67	0.99	3.04	-0.80
P_1 x P_3	25.53	3.50	43.27**	162.65**	73.93	-8.88**	-1.95	-1.78
P_1 x P_4	25.14	4.14	18.63	117.49**	70.47	-14.27**	-6.54**	-6.38**
P_1 x P_5	19.00	17.50	30.85*	95.47**	74.27	1.37	4.41*	-1.33
P_1 x P_6	15.01	-36.71**	-15.77	54.42**	73.40	-2.13	-1.61	-2.48
P_1 x P_7	16.43	19.32	70.06**	69.03**	73.40	-2.57	-2.48	-2.48
P_2 x P_3	39.06	8.73	11.31*	301.85**	72.13	-9.46**	-0.47	-4.17*
P_2 x P_4	13.85	-53.48**	-39.20**	42.49*	73.00	-9.58**	-0.73	-3.02
P_2 x P_5	14.29	-44.27**	-1.58	47.01*	76.63	6.73**	7.73**	1.81
P_2 x P_6	30.70	-7.49	3.68	21.84**	69.00	-6.17**	-4.79*	-8.33**
P_2 x P_7	33.02	42.08**	239.72**	239.71**	72.47	-1.90	0.00	-3.72*
P_3 x P_4	21.99	-23.99**	-3.47	126.23**	69.47	-20.91**	-20.03**	-7.71**
P_3 x P_5	23.96	-3.41	65.01**	146.50**	69.87	-11.56**	-1.77	-7.17**
P_3 x P_6	40.60	25.50**	37.12**	3.18**	74.20	-8.09**	-0.54	-1.42
P_3 x P_7	30.52	36.22**	213.99**	213.99**	74.20	-8.47**	-1.42	-1.42
P_4 x P_5	8.35	-55.23**	-42.49**	-14.0	70.93	-11.41**	-0.28	-5.77**
P_4 x P_6	16.71	-36.21**	-26.65**	71.91**	73.33	-10.36**	-1.70	-2.58
P_4 x P_7	17.78	9.42	82.92**	82.92**	68.07	-17.12**	-9.57**	-9.57**
P_5 x P_6	23.02	4.33	58.54	136.83**	74.40	2.11	4.59*	-1.16
P_5 x P_7	43.56	259.41**	348.15	348.15**	75.27	2.83	5.82**	0.00
P_6 x P_7	17.79	-9.54	83.02	83.03**	67.87	-9.44**	-9.10**	-9.83**
CD (5 %)	-	3.35	3.87	3.87	-	2.34	2.70	2.70
CD (1 %)	-	4.47	5.16	5.16	-	3.12	3.60	3.60

Table 7 Contd...

	(xxi) Keeping quality			
	Mean	R H	HB	SH
P_1	4.33	-	-	-
P_2	4.67	-	-	-
P_3	5.83	-	-	-
P_4	8.83	-	-	-
P_5	7.83	-	-	-
P_6	10.67	-	-	-
P_7	31.00	-	-	-
P_1 x P_2	15.17	237.11**	224.84**	-51.07**
P_1 x P_3	14.83	191.93**	154.37**	-52.16**
P_1 x P_4	3.83	-41.79**	-56.63**	-87.65**
P_1 x P_5	11.67	91.94**	49.04**	-62.36**
P_1 x P_6	3.67	-51.07**	-65.60**	-88.16**
P_1 x P_7	14.50	-26.88**	-53.23**	-53.23**
P_2 x P_3	4.83	-8.00	-17.15*	-84.42**
P_2 x P_4	3.83	-43.26**	56.63**	87.65**
P_2 x P_5	4.83	-22.72**	-38.31**	-84.42**
P_2 x P_6	5.17	-32.60**	-51.55**	-83.32**
P_2 x P_7	4.17	-76.62**	-86.55**	-86.55**
P_3 x P_4	7.83	6.82	-11.33*	-74.74**
P_3 x P_5	5.17	-24.31**	-33.97**	-83.32**
P_3 x P_6	6.00	-27.27**	-43.77**	-80.65**
P_3 x P_7	4.83	-73.77**	-84.42**	-84.42**
P_4 x P_5	4.67	-43.94**	-47.11**	-84.94**
P_4 x P_6	6.00	-38.46**	-43.77*	-80.65**
P_4 x P_7	9.83	-50.64**	-68.29**	-68.29**
P_5 x P_6	8.83	-4.54	-17.25**	-71.52**
P_5 x P_7	5.00	-74.25**	-83.87**	-83.87**
P_6 x P_7	19.50	-6.41**	-31.10**	-37.10**
CD (5 %)	-	0.86	1.00	1.00
CD (1 %)	-	1.15	1.33	1.33

Fig. 1 Standard heterosis for various characters

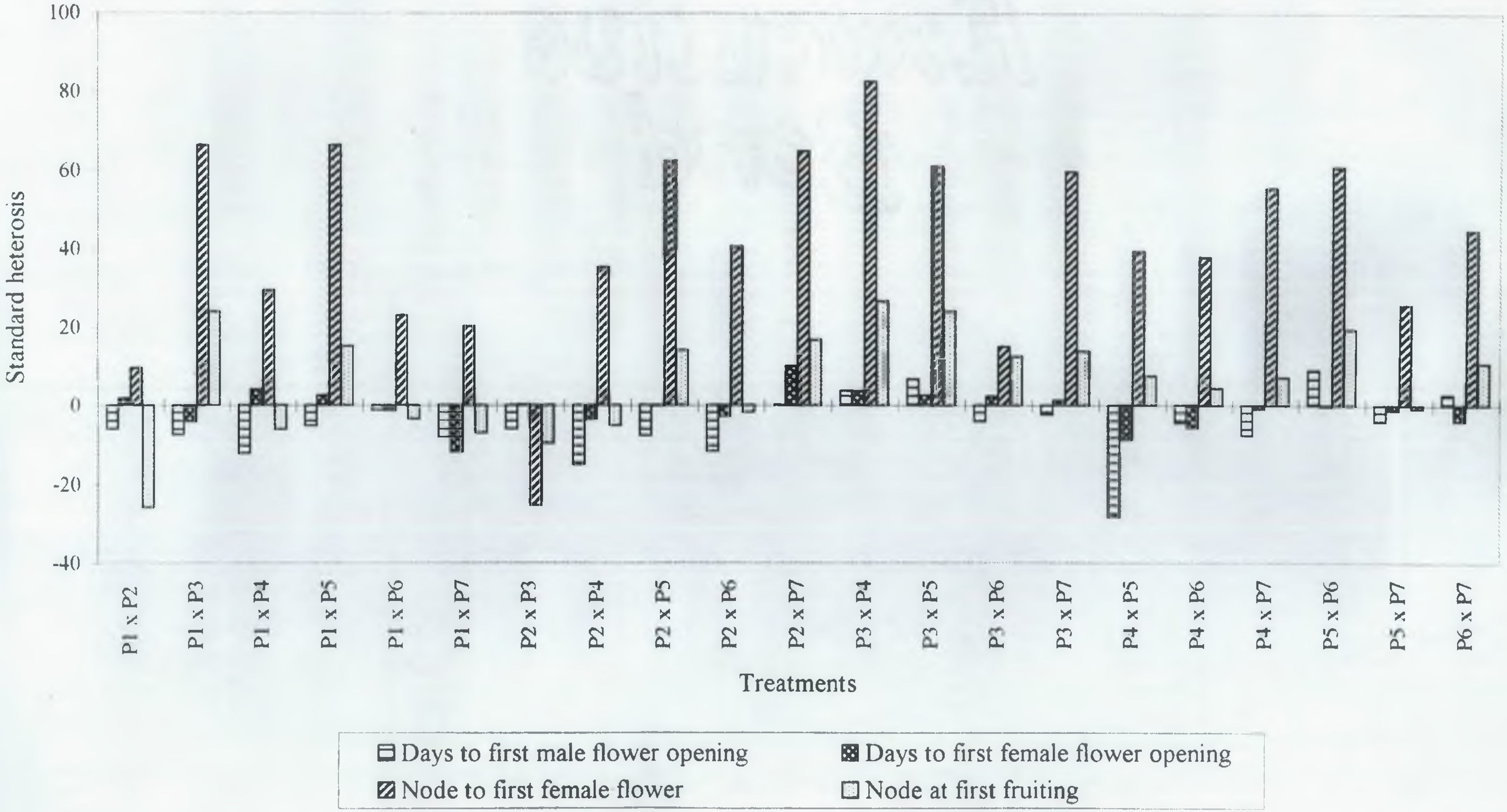


Fig. 2 Standard heterosis for various characters

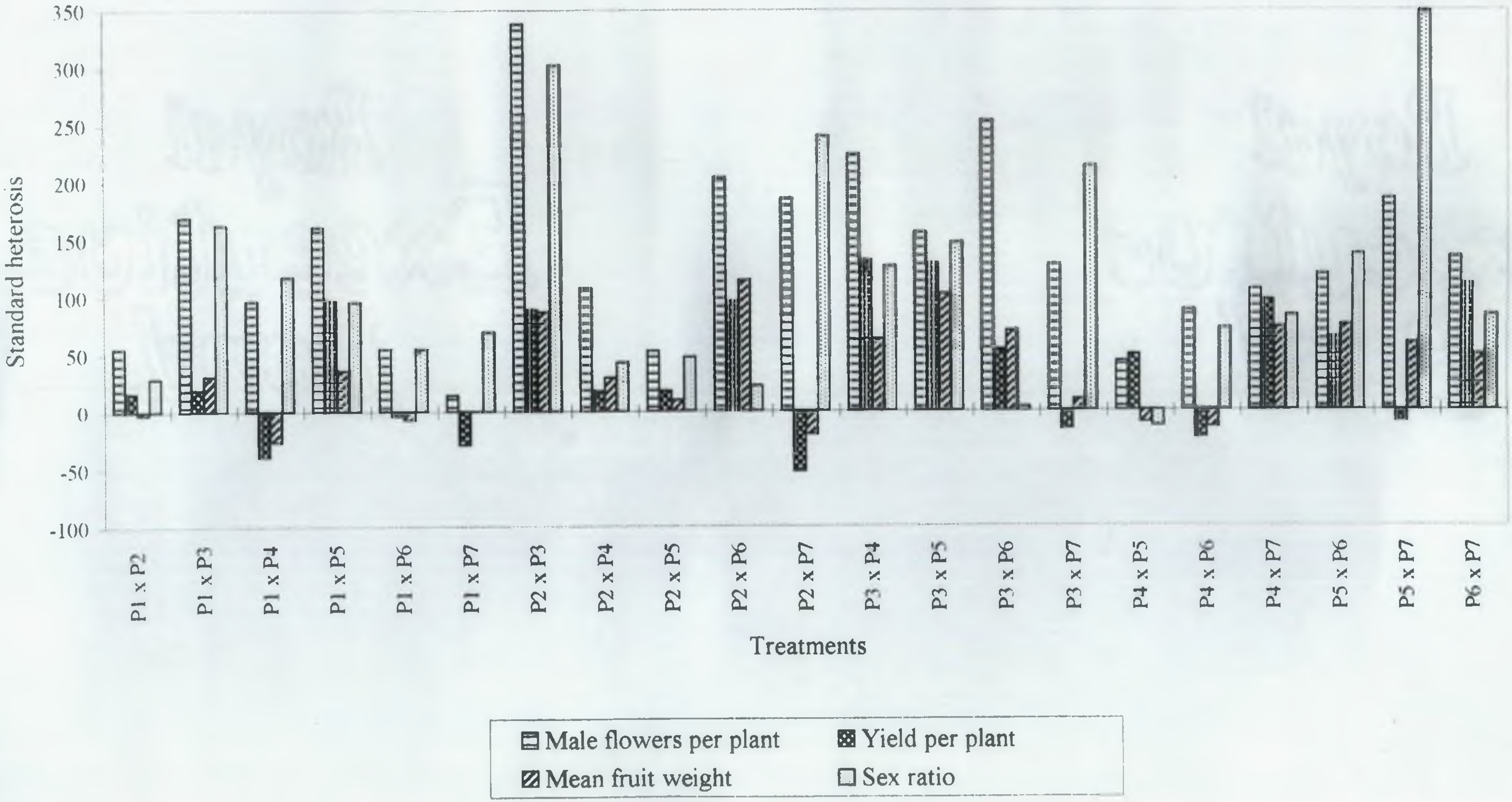


Fig. 3 Standard heterosis for various characters

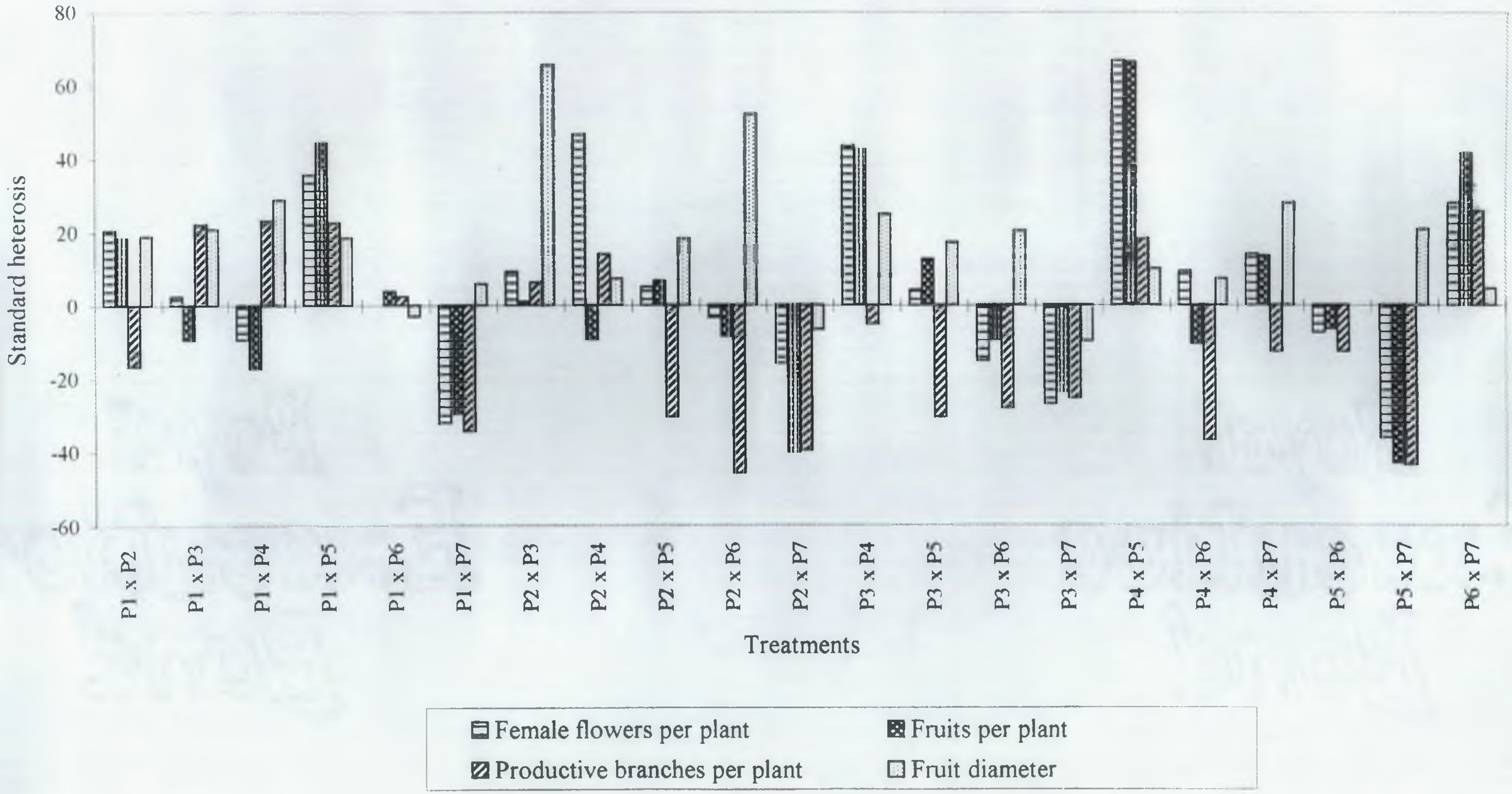


Fig. 4 Standard heterosis for various characters

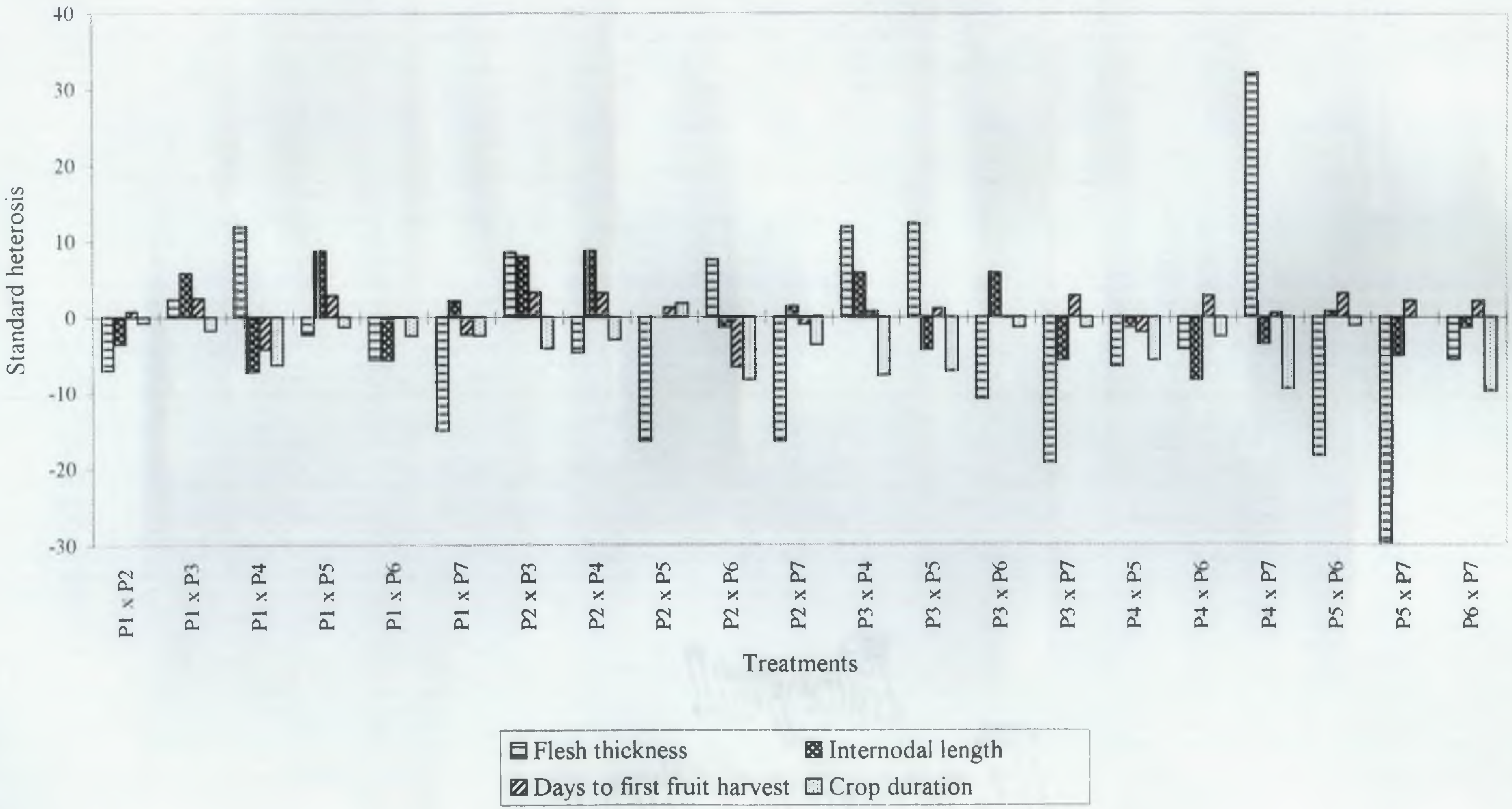


Fig. 5 Standard heterosis for various characters

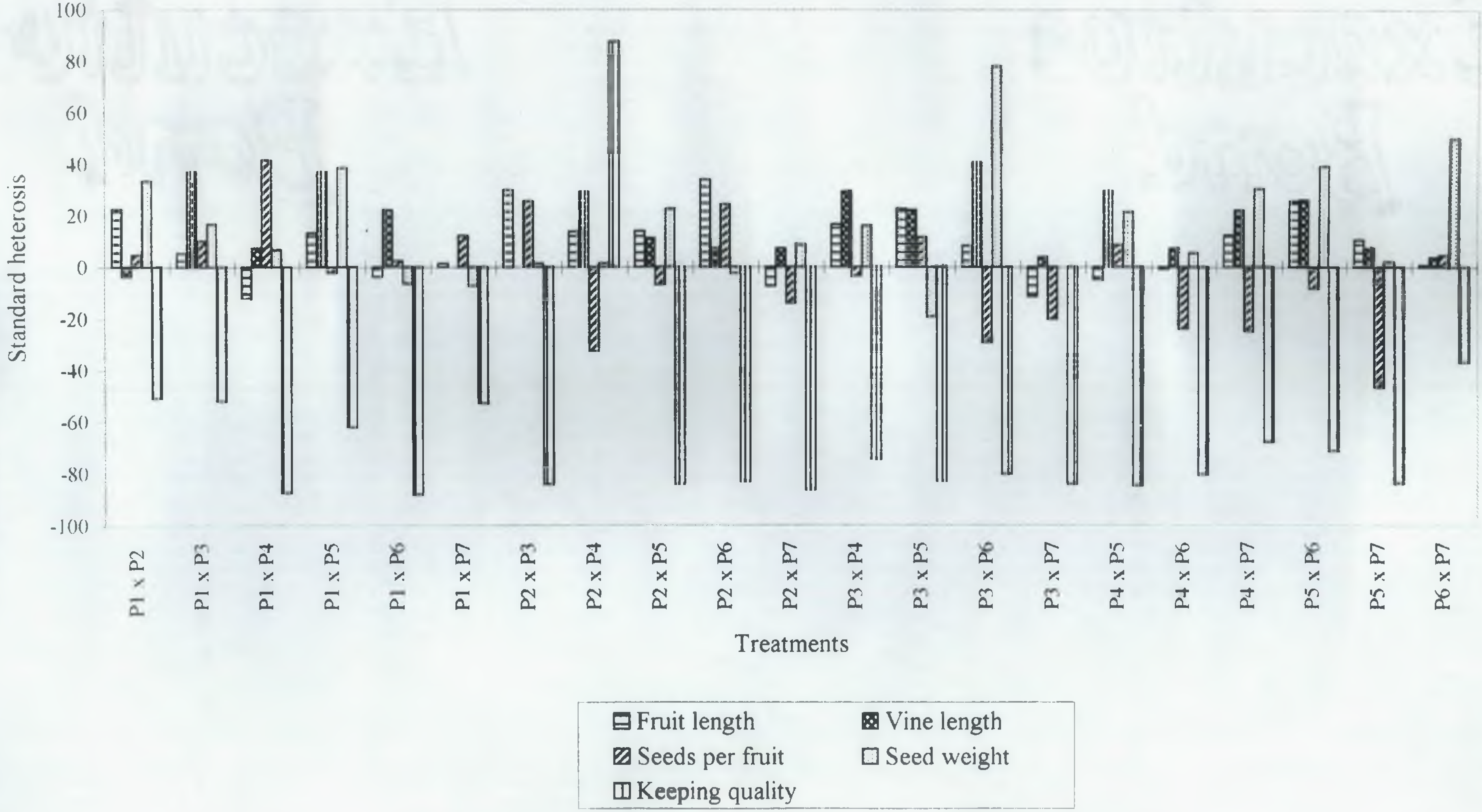
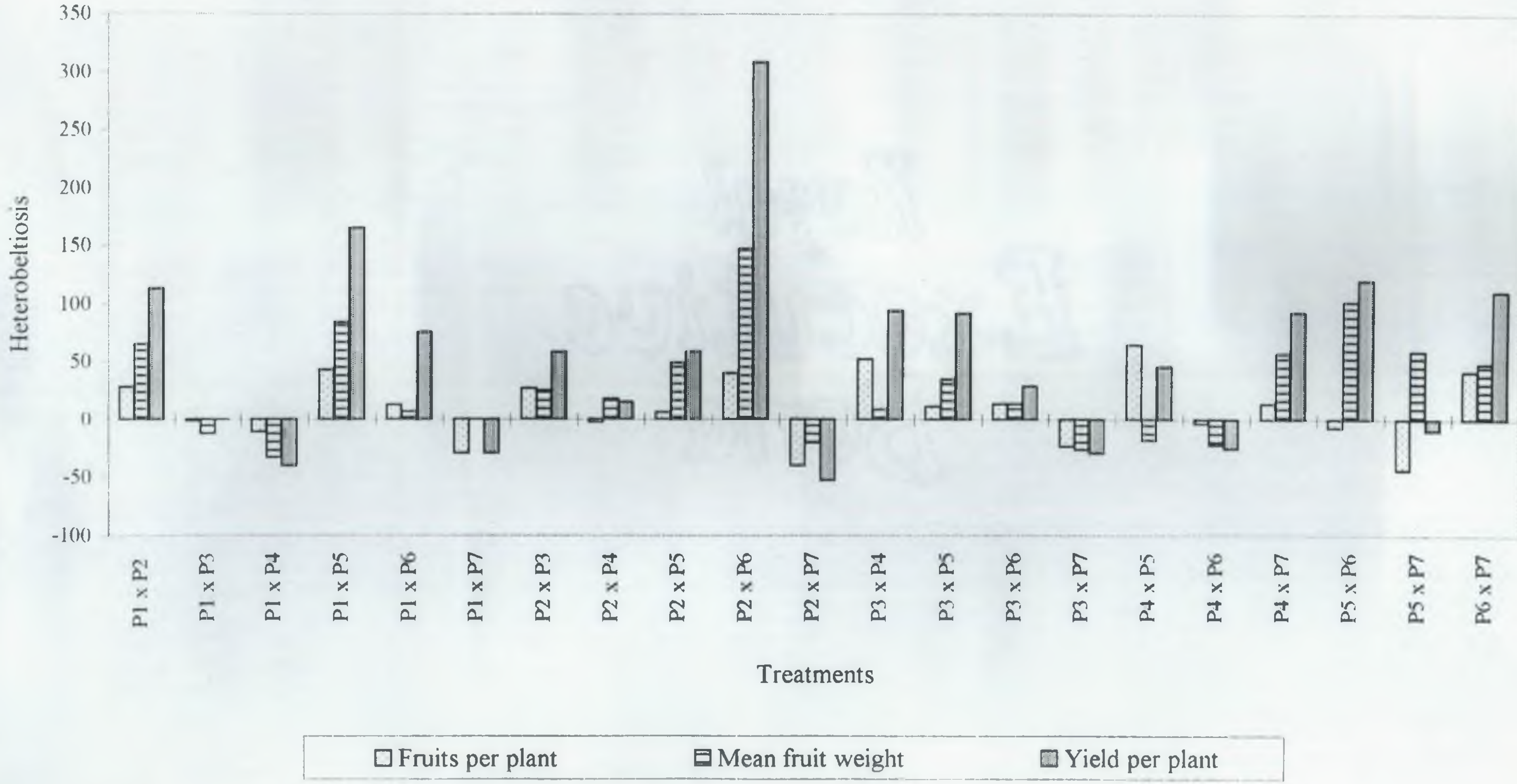


Fig. 6 Heterobeltiosis for yield and two yield related characters



Nine hybrids showed significant negative relative heterosis of which P_2 x P_4 (-13.60) was on par with that of P_1 x P_7. This was followed by P_2 x P_3 (-10.95), P_1 x P_2 (-10.58), P_4 x P_5 (-10.52) and P_1 x P_3 (-10.38). Three hybrids showed significant negative heterobeltiosis. Among them P_1 x P_3 (-9.25) and P_4 x P_5) (-9.17) were on par with P_1 x P_7. Also P_4 x P_5 showed a standard heterosis of –8.86 which was on par with P_1 x P_7. Significant positive heterosis was observed only in P_2 x P_7 over both better and standard parent (10.11 each).

4.3.3 Node to first female flower

The hybrid P_2 x P_3 was superior over both mid parent (-52.95) and better parent (-42.66). P_1 x P_2 (-28.95) also showed significant negative relative heterosis which was on par with P_2 x P_3. None of the hybrids showed significant negative standard heterosis while 9 showed significant positive values. Maximum significant positive heterosis was shown by P_6 x P_7 (48.54) over mid parent, P_5 x P_6 (69.81) over better parent and P_3 x P_4 (82.56) over standard parent.

4.4.4 Male flowers per plant

Twelve hybrids possessed significant positive relative heterosis of which P_5 x P_7 had the maximum value of 115.57. Out of the seven hybrids with significant positive heterobeltiosis, P_5 x P_7 ranked first (73.28) followed by P_2 x P_3 (48.87). 20 hybrids showed significant positive standard heterosis with a maximum value for P_2 x P_3 (337.70). P_4 x P_5 showed maximum significant negative relative heterosis (-32.73) and heterobeltiosis (-45.11). None of the crosses showed negative standard heterosis

4.3.5 Female flowers per plant

Among 11 hybrids with significant positive heterosis over mid parent P_2 x P_4 showed maximum value of 63.20, followed by P_4 x P_5 (50.92) and P_3 x P_4 (48.29) which were on par with P_2 x P_4. Out of eight positively heterobeltiotic hybrids P_4 x P_5 ranked first (50.40), followed by P_4 x P_6 (45.62). P_4 x P_5 showed maximum positive standard heterosis of 66.84. P_5 x P_7 showed significantly negative relative heterosis (-39.54), heterobeltiosis (-42.33) and standard heterosis (-36.47).

4.3.6 Fruits per plant

Maximum significant positive relative heterosis was shown by P_6 x P_7 (82.67) (Plate 9) which was on par with P_4 x P_5 (71.20) and P_3 x P_4 (64.50). The hybrid P_4 x P_5 showed maximum positive heterobeltiosis (64.71) and standard heterosis (66.38). Altogether 14 hybrids showed significant positive relative heterosis, seven showed significant positive heterobeltiosis and five showed significant positive standard heterosis. P_5 x P_7 showed maximum significant negative values for all three types of heterosis (-43.58, -43.86, -43.29 respectively) P_1 x P_7 and P_2 x P_7 also showed significant and high negative values for all the three types of heterosis.

4.3.7 Productive branches per plant

Out of the 13 crosses with significant relative heterosis, P_1 x P_5 possessed maximum positive value (89.02). P_5 x P_7 (-30.82) showed maximum negative value and the crosses P_1 x P_3 (61.49) and P_6 x P_7 (51.86) were on par with this. P_1 x P_5 and P_5 x P_7 possessed maximum significant positive and negative heterobeltiosis of 83.57 and –43.65 respectively. P_1 x P_3 (54.47) was on par with P_1 x P_5. Among the four crosses which showed significant positive standard heterosis, P_6 x P_7 showed maximum value of 25.58. P_2 x P_6 showed maximum negative standard heterosis (-46.15).

4.3.8 Node at first fruiting

Only three crosses showed significant relative heterosis and all were on par with each other. Among them P_1 x P_2 ranked first (-36.69) followed by P_1 x P_7 (-23.59) and P_1 x P_4 (-22.95). None of the hybrids showed significant negative heterobeltiosis but three showed significant positive values of which P_2 x P_7 (28.38) had maximum. The only hybrid with significant standard heterosis was P_1 x P_2 with a value of –25.97.

4.3.9 Mean fruit weight

The cross P_2 x P_6 (Plate 7) exhibited maximum significant positive heterosis over mid parent (220.62), better parent (147.35) and standard parent (114.18). Significant positive values were shown by 14 hybrids over mid parent, 10 over better parents and 12 over standard parent. Standard heterosis of P_3 x P_5 (102.17) (Plate 11) was on par with P_2 x P_6. None of the hybrids were on par with P_2 x P_6 in terms of relative heterosis and heterobeltiosis. No hybrid showed significant negative relative heterosis whereas two showed significant negative values for heterobeltiosis and one for standard heterosis. P_1 x P_4 showed maximum significant negative heterobeltiosis (-33.41) and standard heterosis (-26.80).

4.3.10 Yield per plant

The cross P_2 x P_6 ranked first in terms of positive relative heterosis and heterobeltiosis (398.40 and 308.56 respectively). Out of the 15 hybrids with significant positive relative heterosis, P_1 x P_5 (206.06), P_3 x P_5 (136.25) and P_6 x P_7 (184.65) were on par with P_2 x P_6. Among the 12 hybrids with significant positive heterobeltiosis. P_1 x P_5 (165.10), P_3 x P_4 (94.09) and P_6 x P7 (110.57) were on par with P_2 x P_6. The cross P_3 x P_4 (Plate 8) showed maximum significant positive standard heterosis (131.16). This was on par with P_1 x P_5 (96.95), P_2 x P_6 (95.90), P_3 x P_5 (128.44), P_4 x P_7 (96.29) and P_6 x P_7 (110.57). None of hybrids showed significant negative relative heterosis. P_1 x P_4 and P_2 x P_7 showed significant negative heterobeltiosis and standard heterosis. Of the two, P_2 x P_7 showed maximum value for both (-52.96 each). P_1 x P_5 and P_6 x P_7 are two superior crosses with respect to yield which exhibited high values for all the three types of heterosis, whereas P_2 x P_6, P_3 x P_5 and P_3 x P_5 showed high values for standard heterosis and relative heterosis / heterobeltiosis.

4.3.11 Fruit diameter

The hybrid P_2 x P_6 showed maximum significant positive relative heterosis (59.61) and heterobeltiosis (44.32). P_2 x P_3 showed a relative heterosis of 52.23 and a heterobeltiosis of 25.31 and was on par with P_2 x P_6 for both. Out of the nine hybrids significant for both relative heterosis and heterobeltiosis only one showed negative value (P_3 x P_7, -22.36 and -31.84 respectively). Out of the 11 hybrids with significant standard heterosis P_2 x P_3 (65.55) (Plate 12) ranked first followed by P_2 x P_6 (52.09) which were on par and none showed negative values.

4.3.12 Flesh thickness

Out of the nine hybrids with significant relative heterosis, maximum positive value was observed in P_4 x P_7 (36.59) (Plate 10) followed by P_1 x P_4 (26.40) which were on par with each other and maximum negative value was observed in P_3 x P_7 (-22.27). Among the nine hybrids with significant heterobeltiosis, P_4 x P_7 had maximum positive value (32.08) and P_5 x P_7 had maximum negative value (-29.72). Out of the four hybrids significant for standard heterosis, only one showed positive value i.e., P_4 x P_7 (32.08). Maximum negative value was shown by P_5 x P_7 (-29.72).

4.3.13 Fruit length

The cross P_1 x P_2 (Plate 13) showed maximum positive heterosis over mid parent (46.90) and better parent (43.65). Among the 13 hybrids with significant relative heterosis only P_3 x P_7 (-18.39) showed negative value. P_2 x P_6 (37.96) had relative heterosis which was on par with that of P_1 x P_2. Maximum negative heterobeltiosis was in P_3 x P_7 (-24.22). Among 11 hybrids with significant positive standard heterosis maximum was for P_2 x P_6 (34.10) and P_2 x P_3 (30.04) which were on par. Maximum negative value for standard heterosis was shown by P_1 x P_4 (-12.32).

4.3.14 Vine length

Among six hybrids significant for relative heterosis, maximum positive value was for P_2 x P_4 (34.29) and none had significant negative value. None of the hybrids had significant positive heterobeltisos, but P_2 x P_3 showed maximum significant negative value (-28.85). Out of the 10 hybrids significant for standard heterosis, P_3 x P_6 recorded maximum positive value (40.56) and none showed significant negative values. P_1 x P_3 and P_1 x P_5 (both 37.22) were on par with P_3 x P_6 in standard heterosis.

4.3.15 Internodal length

Out of the five hybrids with significant relative heterosis, only P_2 x P_4 showed positive value (12.74). Maximum negative heterosis was shown by P_3 x P_5 (-19.75). None of the hybrids exhibited significant positive heterosis over better parent. Maximum negative heterobeltiosis was shown by P_3 x P_7 (-22.59). Standard heterosis was not significant in any of the crosses.

4.3.16 Seeds per fruit

The cross P_1 x P_4 exhibited maximum significant positive heterosis over mid (91.52) better (88.49) and standard parents (41.62). Maximum negative relative heterosis was observed for P_3 x P_6 (-40.54) while P_5 x P_7 showed maximum negative values for heterobeltiosis (-88.94) and standard heterosis (-47.07).

4.3.17 100 seed weight

All hybrids except P_1 x P_6 showed significant relative heterosis. Heterobeltiosis was significant in all hybrids. Eighteen hybrids showed significant standard heterosis. P_3 x P_7 showed no standard heterosis at all. Maximum positive relative and standard heterosis was shown by P_3 x P_6 (88.69 and 78.00 respectively). Positive heterobeltiosis was maximum in P_5 x P_6

(65.87). The cross P_3 x P_5 showed maximum negative values for relative heterosis (-18.24) heterobeltiosis (-28.82) and standard heterosis (-19.33).

4.3.18 Days to first fruit harvest

Out of the four hybrids with significant relative heterosis, P_2 x P_6 and P_1 x P_4 showed significant negative relative heterosis (-5.34 and –5.28 respectively) while P_2 x P_3 and P_2 x P_4 exhibited significant positive relative heterosis (3.54 and 3.77 respectively). P_1 x P_4 was the only cross which showed significant negative heterosis (-4.27) over better parent. P_2 x P_3 (6.84) showed maximum positive heterobeltiosis. P_2 x P_6 (-6.73) and P_1 x P_4 (-4.27) were only two hybrids with significant standard heterosis.

4.3.19 Sex ratio

The cross P_4 x P_5 showed maximum significant negative values of relative heterosis (-55.23) and heterobeltiosis (-42.49). The hybrid P_5 x P_7 showed maximum positive heterosis over mid parent (259.41), better parent and standard parent (348.15 each). Seven hybrids showed significant negative relative heterosis while four showed significant negative heterobeltiosis and none of the hybrids showed significant negative standard heterosis.

4.3.20 Crop duration

Out of the 14 hybrids significant for relative heterosis, 13 showed negative values with P_3 x P_4 having a maximum of –20.91, while P_2 x P_5 showed maximum positive value of 6.73. Among the five hybrids significant for negative heterobeltiosis P_3 x P_4 possessed a maximum value of –20.03. Maximum

Plate 6. P_4 x P_5 **: heterotic for days to first male and female flower opening, number of female flowers and number of fruits**

Plate 7. P_2 x P_6 **: heterotic for yield, mean fruit weight, fruit diameter, fruit length, days to first harvest and crop duration**

Plate 6

Plate 7

Plate 8. P_3 x P_4 : heterotic for yield (maximum), number of female flowers and fruits per plant

Plate 9. P_6 x P_7 : heterotic for yield, fruits per plant, productive branches per plant and crop duration

Plate 8

Plate 9

Plate 10. P_4 x P_7 : heterotic for yield and flesh thickness

Plate 11. P_3 x P_5 : heterotic for yield and mean fruit weight

Plate 10

Plate 11

Plate 12. P_2 x P_3 **: heterotic for fruit diameter, fruit length, male flowers per plant**

Plate 13. P_1 x P_2 **: heterotic for fruit length and node to first fruiting**

Plate 12

Plate 13

significant positive heterobeltiosis was shown by P_2 x P_5 (7.73). Nine hybrids showed significant negative standard heterosis with a maximum of –9.83 for P_6 x P_7 followed by P_4 x P_7 (-9.57) and P_2 x P_6 (-8.33) which were on par.

4.3.21 Keeping quality

The crosses P_1 x P_2, P_1 x P_3 and P_1 x P_5 showed significant positive relative heterosis (237.11, 191.93 and 91.94 respectively) and heterobeltiosis (224.84, 154.37 and 49.04 respectively). All the hybrids exhibited significant negative standard heterosis. P_1 x P_6 (-88.16) showed maximum negative standard heterosis while P_2 x P_7 showed maximum negative relative heterosis (-76.61) and heterobeltiosis (-86.55).

4.4 Combining ability analysis

Analysis of variance for combining ability revealed significance of general combining ability and specific combining ability variance for all the 21 characters (Table 8). GCA effect of parents and SCA effect of all the crosses were estimated and are presented in Table 9 and 10 respectively.

4.4.1 Days to first male flower opening

Both GCA and SCA variances were significant for the trait and SCA variance was higher than GCA variance. The parent P_4 showed significant negative GCA (-1.27) while P_3 showed significant positive GCA (0.94).

The cross P_4 x P_5 showed maximum significant SCA value of -6.56. This was followed by P_2 x P_4 (-2.60) and P_2 x P_6 (-2.30). The cross P_5 x P_6 showed maximum significant positive SCA (4.47)

Table 8 Mean squares of GCA and SCA for individual characters

Character	GCA	SCA	Error
1. Days to first male flower opening	4.71**	7.83**	1.19
2. Days to first female flower opening	6.29**	4.62**	0.91
3. Node to first female flower	2.34**	1.76**	0.72
4. Male flowers per plant	7265.33**	2225.67**	36.64
5. Female flowers per plant	5.30**	3.40**	0.15
6. Fruits per plant	2.96**	3.72**	0.15
7. Productive branches per plant	1.16**	1.40	0.10
8. Node at first fruiting	2.50**	0.96**	0.47
9. Mean fruit weight	153543.55**	100444.41**	4859.00
10. Yield per plant	7726606.50**	9870530.90**	462683.50
11. Fruit diameter	1.72**	1.88**	0.21
12. Flesh thickness	0.12**	0.07**	0.01
13. Fruit length	15.74**	13.80**	0.75
14. Vine length	0.20**	0.05**	0.02
15. Internodal length	0.84**	0.39**	0.11
16. Seeds per fruit	31078.47**	41571.91**	216.29
17. 100 seed weight	0.02**	0.14**	0.0001
18. Days to first fruit harvest	2.13*	2.21**	0.68
19. Sex ratio	177.13**	71.86**	1.88
20. Crop duration	13.27**	23.74**	0.91
21. Keeping quality	67.72**	27.90**	0.12

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

Table 9 General combining ability effects of parents for various characters

Character	P_1	P_2	P_3	P_4	P_5	P_6	P_7	SE (g_i)	SE (g_i - g_j)	CD (g_i - g_j)	
										5 %	1 %
1. Days to first male flower opening	-0.15	0.36	0.94**	-1.27**	0.19	-0.50	0.44	-0.34	0.51	1.03	1.37
2. Days to first female flower opening	0.07	1.63**	0.48	-0.43	-0.41	-0.82**	-0.52	0.30	0.45	0.90	1.20
3. Node to first female flower	0.21	-0.47	0.54*	0.06	0.66*	-0.66*	-0.34	0.26	0.40	0.80	1.06
4. Male flowers per plant	-29.29**	17.65**	51.19**	-5.66**	-17.23**	8.80**	-25.45**	1.87	2.85	5.72	7.62
5. Female flowers per plant	-0.12	-0.23	-0.39**	1.46**	0.54**	-0.43**	-0.84**	0.12	0.18	0.37	0.49
6. Fruits per plant	0.12	-0.62**	-0.05	0.71**	0.79**	-0.46**	-0.48**	0.12	0.18	0.36	0.48
7. Productive branches per plant	0.38**	-0.49**	0.00	0.55**	-0.16	-0.24**	-0.04	0.10	0.15	0.30	0.40
8. Node at first fruiting	0.16	-0.77**	0.72**	-0.23	0.60**	-0.28	-0.19	0.21	0.32	0.64	0.86
9. Mean fruit weight	-197.69**	-62.28**	229.99**	-43.73*	26.97	60.63**	-13.89	21.51	32.86	65.85	87.70
10. Yield per palnt	-1234.39**	-791.01**	1501.98**	299.89	649.92**	53.67	-480.05*	209.87	320.58	642.45	855.64
11. Fruit diameter	-0.19	0.18	0.82**	0.13	-0.34*	-0.10	-0.50**	0.14	0.21	0.43	0.57
12. Flesh thickness	-0.03	-0.07*	0.14**	0.15**	-0.17**	0.01	-0.04	0.03	0.05	0.10	0.13
13. Fruit length	-1.72**	0.50	1.57**	-0.90**	0.84**	1.13**	-1.42**	0.27	0.41	0.82	1.09
14. Vine length	-0.01	-0.22**	0.19**	0.08	0.14**	-0.03	-0.15**	0.04	0.06	0.12	0.16
15. Internodal length	-0.21*	-0.12	0.55**	-0.05	0.28**	-0.29**	-0.17	0.10	0.15	0.31	0.41
16. Seeds per fruit	57.46**	-41.39**	88.26**	-40.28**	-55.07**	35.64**	-44.62**	4.54	6.93	13.89	18.50
17. 100 seed weight	0.03**	-0.06**	0.05**	-0.03**	-0.03**	0.04**	-0.01**	0.01	0.01	0.01	0.01
18. Days to first fruit harvest	-0.27	-0.79**	0.82**	0.12	0.15	-0.10	0.06	0.25	0.39	0.78	1.04
19. Sex ratio	-4.53**	3.44**	7.31**	-4.52**	-2.76**	1.89**	-0.83	0.42	0.64	1.29	1.72
20. Crop duration	0.08	-0.82**	1.93**	1.45**	-0.73*	-0.98**	-0.93**	0.29	0.45	0.90	1.20
21. Keeping quality	0.50**	-2.28**	-1.40**	-1.57**	-1.33**	0.30**	5.78**	0.11	0.17	0.33	0.44

** Significant at 1 per cent level

* Significant at 5 per cent level

Table 10 Specific combining ability of crosses for various characters

Cross	Days to first male flower opening	Days to first female flower opening	Node to first female flower	Male flowers per plant	Female flowers per plant	Fruits per plant	Productive branches per plant	Node at first fruiting
P_1 x P_2	-0.86	-1.29	-1.32*	-46.88**	1.70**	1.96**	0.04	-1.91**
P_1 x P_3	-1.91*	-2.41**	0.47	6.98	0.46	-0.55	1.09**	0.33
P_1 x P_4	-1.23	1.64*	-0.92	8.10	-2.32**	-1.84**	1.07**	-0.98
P_1 x P_5	-0.42	1.09	0.35	71.87**	2.12**	2.34**	1.75**	-0.21
P_1 x P_6	1.54	-0.04	-0.46	-38.30**	0.29	0.79**	0.79**	-0.73
P_1 x P_7	-1.61	-4.34**	-0.92	-34.79**	-1.83**	-1.53**	-1.34**	-1.09*
P_2 x P_3	-1.95*	-2.29**	-3.39**	88.71**	1.10**	0.93**	1.63**	-1.28*
P_2 x P_4	-2.60**	-2.85**	0.10	-30.24**	2.19**	-0.57	0.00	0.01
P_2 x P_5	-1.72*	-1.53*	0.83	-60.53**	-0.17	0.48	-0.15	0.65
P_2 x P_6	-2.30**	-2.12**	1.09	28.83**	0.14	0.67*	-0.87**	0.33
P_2 x P_7	0.55	2.44**	1.96**	48.81**	-0.45	-1.52**	-0.74**	1.63**
P_3 x P_4	2.82**	1.10	1.41*	24.95**	2.07**	2.46**	-0.01	0.92
P_3 x P_5	2.29**	0.68	-0.25	-15.81**	-0.08	0.31	0.63*	-0.11
P3 x P_6	-0.49	0.96	-1.19	33.09**	-0.64*	0.03	-0.42	-0.10
P_3 x P_7	-0.90	0.25	0.68	-28.73**	-1.16**	-0.96**	-0.48	-0.09
P_4 x P_5	-6.56**	-2.74**	-0.84	-44.76**	3.01**	3.28**	1.35**	-0.39
P_4 x P_6	1.59	-1.20	0.42	-36.46**	-0.55	-0.80**	-1.44**	0.26
P_4 x P_7	-0.35	0.30	0.96	11.59*	0.22	0.88**	-0.37	0.36
P_5 x P_6	4.47**	0.85	0.96	-1.16	-0.97**	-0.61*	0.54*	0.56
P_5 x P_7	-0.68**	0.22	-1.10	83.70**	-2.83**	-3.13**	-1.26**	-1.07*
P_6 x P_7	2.21**	-0.44	1.16	18.53**	3.21**	3.99**	2.42**	0.68
SE (sij)	0.83	0.73	0.65	4.62	0.30	0.29	0.24	0.52
SE (sij - sij)	1.45	1.27	1.13	8.07	0.52	0.51	0.43	0.91
CD (5 %)	2.91	2.55	2.26	16.17	1.03	1.02	0.85	1.82
CD (1 %)	3.88	3.40	3.01	21.54	1.38	1.36	1.14	2.43
SE (sij-skl)	1.36	1.19	1.06	7.55	0.48	0.48	0.40	0.85
CD (5 %)	2.72	2.39	2.11	15.13	0.97	0.95	0.80	1.70
CD (1 %)	3.62	3.18	2.82	20.15	1.29	1.27	1.06	2.27

Table 10 Contd...

Cross	Mean fruit weight	Yield per plant	Fruit diameter	Flesh thickness	Fruit length	Vine length	Internodal length	Seeds per fruit
P_1 x P_2	65.61	1675.32**	0.45	0.04	5.52**	-0.11	-0.06	73.82**
P_1 x P_3	25.18	-455.83	-0.06	0.04	-0.21	0.21*	0.14	-8.76
P_1 x P_4	-131.27*	-2293.64**	1.23**	0.22**	-2.55**	-0.20*	-0.46	398.85**
P_1 x P_5	265.19**	4430.79**	0.94**	0.24**	2.68**	0.27**	0.68**	26.50*
P_1 x P_6	-92.66	-227.10	-0.91*	0.00	-2.30**	0.18	-0.09	-22.41
P_1 x P_7	36.65	-1001.87	0.17	-0.15	1.71*	-0.11	0.53*	143.79**
P_2 x P_3	307.97**	2705.44**	2.90**	0.21**	4.35**	-0.24*	0.25	228.75**
P_2 x P_4	151.21	208.79	-0.74*	-0.09	2.35**	0.41**	0.92**	-159.64**
P_2 x P_5	-66.48	-116.14	0.54	-0.02	0.69	0.02	-0.21	84.55**
P_2 x P_6	681.94**	4528.88**	2.82**	0.32**	5.90**	0.12	0.22	269.37**
P_2 x P_7	-252.95**	-2642.80**	-1.14**	-0.14	-2.99**	0.24*	0.37	9.97
P_3 x P_4	110.42*	3814.93**	-0.08	0.06	2.07**	0.00	-0.20	-31.08**
P_3 x P_5	333.58**	3324.44**	-0.17	0.40**	1.98**	-0.19	-1.29**	118.84**
P3 x P_6	59.33	36.94	-0.18	-0.27**	-2.26**	0.31**	0.21	-334.44**
P_3 x P_7	-316.29**	-3050.01**	-2.01**	-0.41**	-5.13**	-0.25*	-0.97**	-174.41**
P_4 x P_5	-235.56**	400.58	-0.01	-0.02	-3.09**	0.06	-0.42	219.98**
P_4 x P_6	-301.08**	-2783.28**	-0.46	-0.15	-2.33**	-0.17	-0.48	-160.27**
P_4 x P_7	428.16**	3991.81**	1.48**	0.67**	3.95**	0.21*	-0.16	-88.87**
P_5 x P_6	297.97**	1415.91**	-0.52	-0.14	3.30**	0.10	0.02	-7.98
P_5 x P_7	251.59**	-1849.65**	1.42**	-0.32**	1.70*	-0.12	-0.63*	-266.08**
P_6 x P_7	142.34**	4977.33**	-0.03	0.01	-1.31	-0.02	0.27	98.80**
SE (sij)	53.24	519.41	0.35	0.08	0.66	0.10	0.24	11.23
SE (sij - sik)	92.94	906.75	0.61	0.14	1.16	0.17	0.46	19.61
CD (5 %)	186.26	1817.12	1.21	0.27	2.32	0.35	0.87	39.50
CD (1 %)	248.06	2420.11	1.62	0.37	3.09	0.46	1.16	52.34
SE (sij-skl)	86.94	848.19	0.57	0.13	1.08	0.16	0.41	18.34
CD (5 %)	174.23	1699.76	1.14	0.26	2.17	0.32	0.82	36.76
CD (1 %)	232.04	2263.81	1.51	0.34	2.89	0.43	1.09	48.96

Table 10 Contd...

Cross	100 seed weight	Days to first fruit harvest	Sex ratio	Crop duration	Keeping quality
P_1 x P_2	0.36**	1.27*	-9.63**	1.63*	8.46**
P_1 x P_3	0.01	0.65	-0.51	-1.85*	7.26**
P_1 x P_4	-0.06**	-2.64**	6.93**	-4.84**	-3.57**
P_1 x P_5	0.41**	1.59*	3.03**	1.14	4.02**
P_1 x P_6	-0.33**	0.04	-5.60**	0.52	-5.61**
P_1 x P_7	-0.30**	-1.45*	-1.46	0.48	-0.2
P_2 x P_3	-0.15**	1.64*	5.06**	-2.75**	0.04
P_2 x P_4	-0.06**	2.28**	-8.32**	-1.41	-0.80**
P_2 x P_5	0.26**	-0.35	-9.65**	4.41**	-0.04
P_2 x P_6	-0.19**	-3.37**	2.12*	-2.98**	-1.33**
P_2 x P_7	0.02**	-0.13	7.16**	0.44	-7.81**
P_3 x P_4	0.06**	-0.73	-4.06**	-7.69**	2.33**
P_3 x P_5	-0.48**	-0.56	-3.85**	-5.10**	-0.57*
P3 x P_6	0.91**	-1.05	8.15**	-0.52	-1.37**
P_3 x P_7	-0.21**	0.53	0.79	-0.57	-8.02**
P_4 x P_5	0.21**	-1.73**	-7.63**	-3.56**	-0.91**
P_4 x P_6	-0.10**	1.39*	-3.92**	-0.92	-1.20**
P_4 x P_7	0.33**	-0.10	-0.13	-6.23**	-2.85**
P_5 x P_6	0.41**	1.56*	0.63	2.33**	1.39**
P_5 x P_7	-0.10**	0.87	23.89**	3.15**	-7.93**
P_6 x P_7	0.55**	1.04	-6.52**	-4.00**	4.94**
SE (sij)	0.01	0.63	1.04	0.73	0.27
SE (sij - sik)	0.01	1.20	1.82	1.27	0.47
CD (5 %)	0.03	2.20	3.65	2.55	0.94
CD (1 %)	0.04	2.93	4.86	3.40	0.25
SE (sij-skl)	0.01	1.03	1.70	1.19	0.44
CD (5 %)	0.03	2.06	3.42	2.93	0.88
CD (1 %)	0.04	2.74	4.55	3.18	1.17

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

4.4.2 Days to first female flower opening

Combining ability analysis revealed that GCA and SCA variances were significant with a high value for GCA variance than SCA variance. The only parent which showed significant negative GCA was P_6 (-0.82) whereas P_2 showed significant positive GCA (1.63).

The hybrid P_1 x P_7 showed maximum significant negative SCA of -4.34 followed by P_2 x P_4 (-2.85), P_4 x P_5 (-2.74), P_1 x P_3 (-2.41) and P_2 x P_3 (-2.29). But none of the above said hybrids were found to be on par with P_1 x P_7. The cross P_2 x P_7 exhibited maximum significant positive SCA for the trait.

4.4.3 Node to first female flower

Both GCA and SCA variances were significant for the character and GCA variance exceeded SCA variance. Only one parent P_6 recorded significant negative GCA (-0.66) whereas P_5 (0.66) and P_3 (0.54) showed significant positive GCA.

Maximum negative SCA was exhibitedby P_2 x P_3 (-3.39) followed by P_1 x P_2 (-1.32). P_2 x P_7 showed maximum positive SCA of 1.96.

4.4.4 Male flowers per plant

Anova for combining ability revealed significant GCA and SCA variances for the trait. GCA variance was much higher than SCA variance. All the parents showed significant GCA values for the trait with P_3 having maximum positive value (51.19) followed by P_2 (17.65). P_1 had maximum negative value (-29.29)

All crosses except P_1 x P_3, P_1 x P_4 and P_5 x P_6 showed significant SCA effect. P_2 x P_3 expressed maximum positive SCA effect (88.71) followed by P_5 x P_7 (83.70) which were on par with each other. P_2 x P_5 possessed maximum negative SCA of -60.53.

4.4.5 Female flowers per plant

GCA and SCA variance were found to be significant with a higher value for GCA variance than SCA variance. The parents P_4 and P_5 exhibited significant positive GCA effect of 1.46 and 0.54 respectively. P_7 showed maximum negative GCA effect of -0.84.

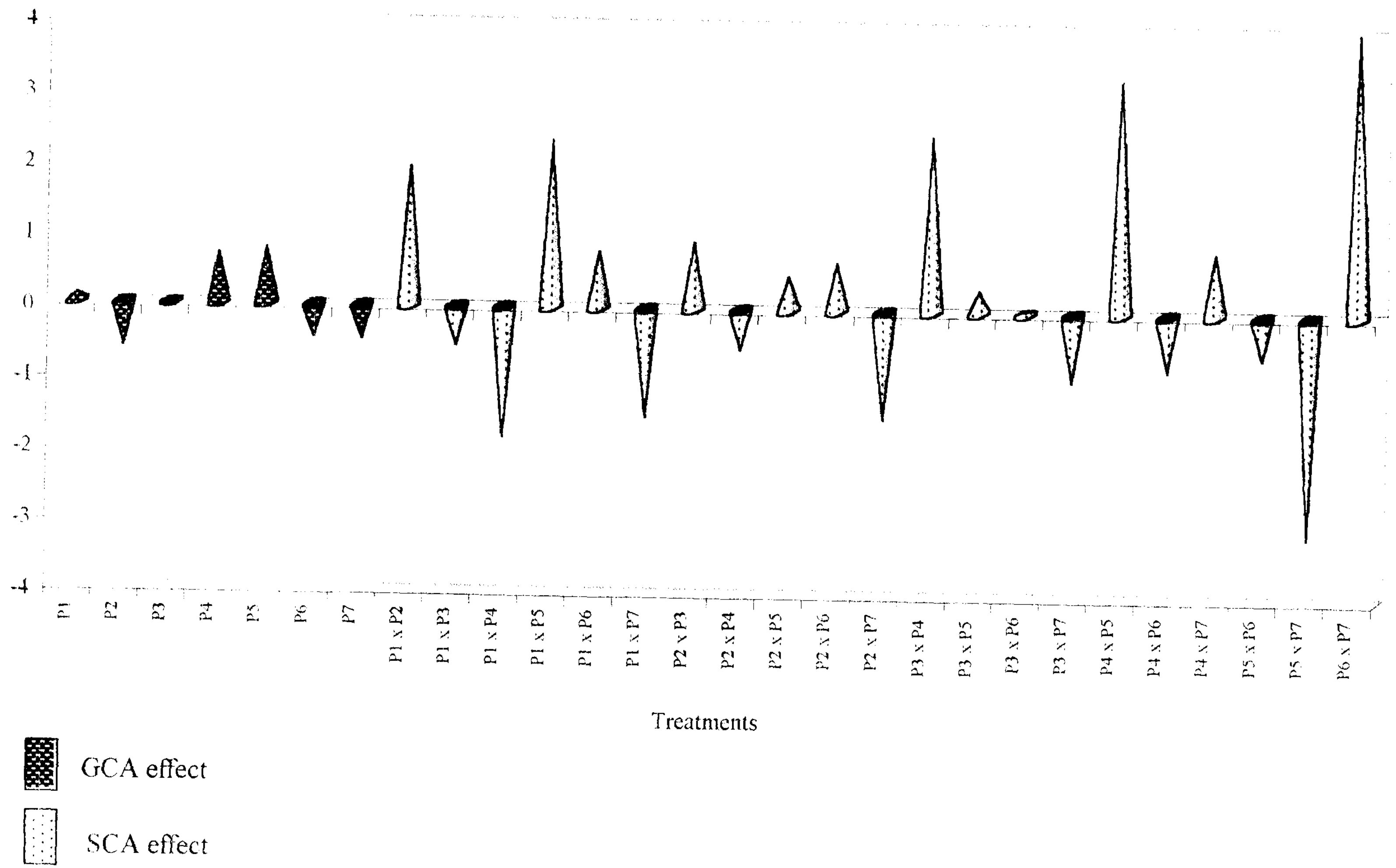
The crosses P_6 x P_7 and P_4 x P_5 showed maximum significant positive SCA effects of 3.21 and 3.01 respectively. These were on par with each other. These were followed by P_2 x P_4 (2.19) and P_1 x P_5 (2.12). The cross P_5 x P_7 exhibited maximum negative SCA effect of -2.83 for the character.

4.4.6 Fruits per plant

Anova of combining ability revealed significant GCA and SCA variances for number of fruits per plant. SCA variance was higher than variance due to GCA. The parent P_5 showed maximum significant positive GCA effect of 0.79. This was on par with P_4 (0.71). P_2, P_6 and P_7 showed negative GCA effects of which P_2 had a maximum of -0.62.

Maximum significant positive SCA effect of 3.99 was observed for P_6 x P_7. This was followed by P_4 x P_5 (3.28) and P_3 x P_4 (2.46). P_5 x P_7 had maximum negative SCA effect of -3.13 (Fig. 7).

Fig. 7 GCA and SCA : Fruits per plant



4.4.7 Productive branches per plant

Both GCA and SCA variances were significant for the trait with SCA variance almost equal to that of GCA variance. Parent P_4 showed maximum significant positive GCA effect (0.55). This was on par with P_1 (0.38). P_2 and P_6 showed significant negative GCA effects of -0.49 and -0.24 respectively.

Maximum positive SCA effect was shown by P_6 x P_7 (2.42) followed by P_1 x P_5 (1.75) and P_2 x P_3 (1.63). The hybrid P_4 x P_6 showed maximum negative SCA effect of -1.44.

4.4.8 Node at first fruiting

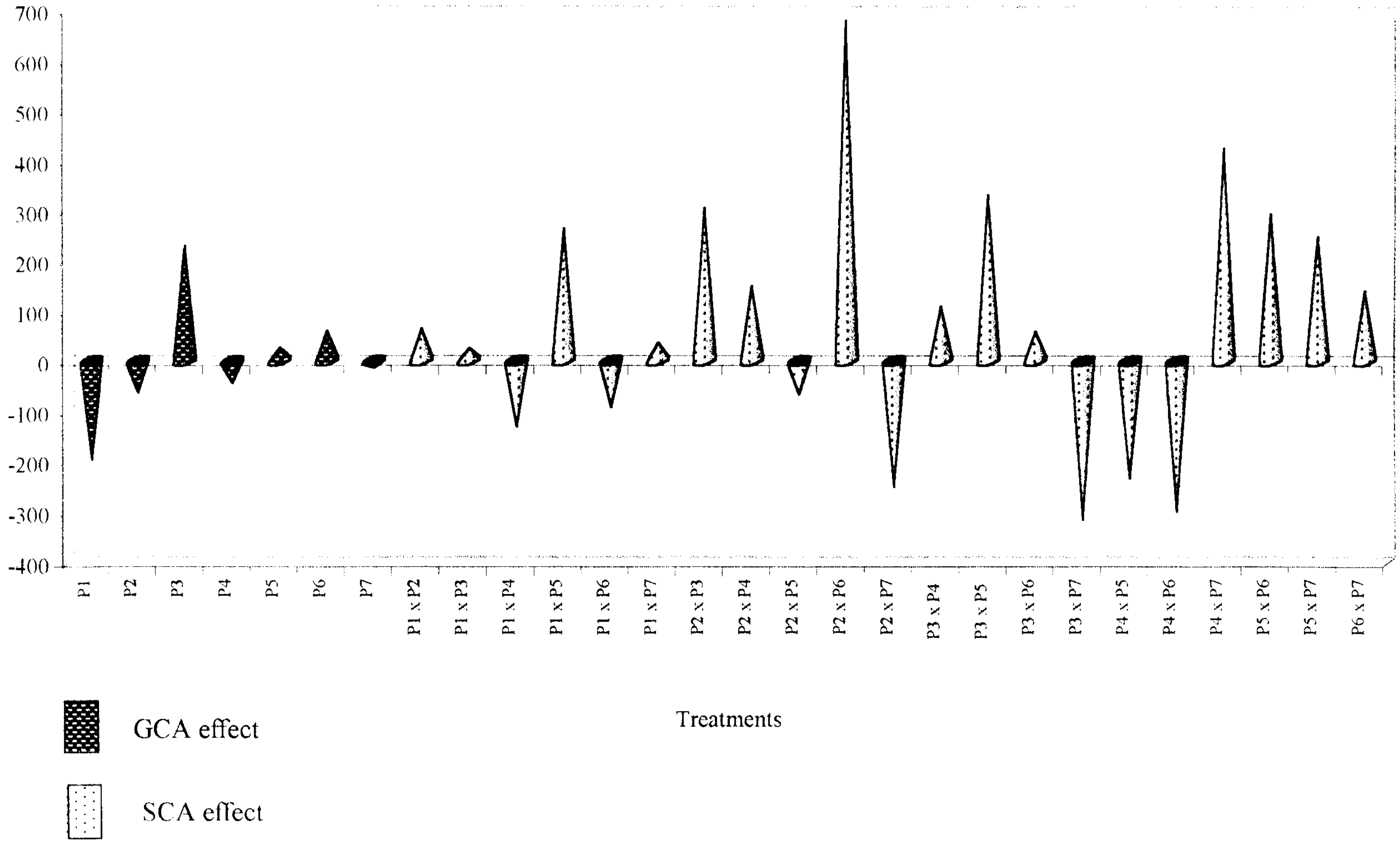
Combining ability analysis showed that both GCA and SCA variances were significant with a high value for GCA variance than the other. The parent P_2 was the only parent with significant negative GCA effect (-0.77) while P_3 and P_5 showed significant positive GCA of 0.72 and 0.60 respectively.

Maximum negative SCA effect for the trait was shown by P_1 x P_2 (-1.91), P_2 x P_3 (-1.28), P_1 x P_7 (-1.09) and P_5 x P_7 (-1.07) were on par with P_1 x P_2. The hybrid P_2 x P_7 showed significant positive SCA effect of 1.63.

4.4.9 Mean fruit weight

Variance due to GCA and SCA were found to be significant with a high value for GCA when compared to SCA. Significant GCA effect was observed in all parents except P_5 and P_7. P_3 had maximum positive GCA effect of 229.99 whereas P_1 had maximum negative GCA effect of -197.69.

Fig. 8 GCA and SCA : Mean fruit weight



Out of the ten crosses with significant positive SCA effects, P_2 x P_6 ranked first with a maximum of 681.94, followed by P_4 x P_7 (428.16) and P_3 x P_5 (333.58). The cross P_3 x P_7 (-316.29) showed maximum negative SCA for the trait (Fig. 8).

4.4.10. Yield per plant

Combining ability analysis revealed that variance due to GCA and SCA were significant for yield with high values for SCA variance when compared with GCA. All parents except P_4 and P_6 showed significant GCA effect for yield. P_3 and P_5 showed significant positive effect of 1501.98 and 649.92 respectively. The maximum negative GCA observed was -1234.39 for P_1.

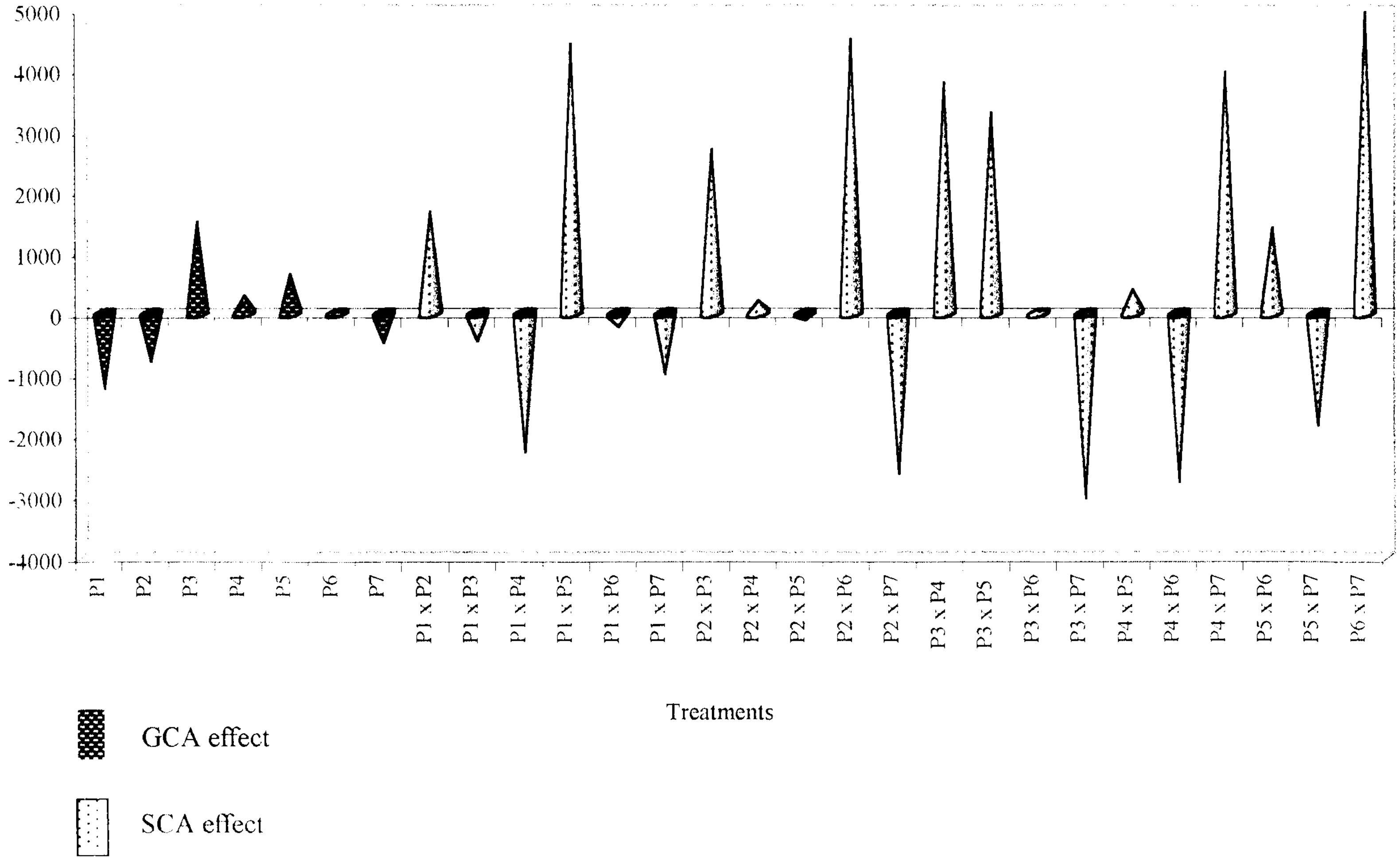
Out of the nine hybrids significant for positive SCA effect, P_6 x P_7 stood first (4977.33). This was on par with P_2 x P_6 (4528.88), P_1 x P_5 (4430.79), P_4 x P_7 (3991.81), P_3 x P_4 (3814.93) and P_3 x P_5 (3324.44). The crosses P_2 x P_3 (2705.44), P_1 x P_2 (1675.32) and P_5 x P_6 (1415.91) also showed significant positive SCA effects for yield. P_3 x P_7 (-3050.01) showed maximum negative SCA value for yield (Fig. 9).

4.4.11 Fruit diameter

Significant GCA and SCA variances were observed for the trait with almost same values for both. The only parent with significant positive GCA for fruit diameter was P_3 (0.82). P_7 and P_5 showed significant negative values of -0.50 and -0.34 respectively.

P_2 x P_3 showed maximum significant positive SCA effect (2.90), which was on par with P_2 x P_6 (2.82). The cross P_3 x P_7 (-2.01) showed maximum negative SCA effect

Fig. 9 GCA and SCA : Yield per palnt



4.4.12. Flesh thickness

Variance due to GCA and SCA were significant and GCA variance was slightly higher than SCA variance. The parent P_3 and P_4 showed significant positive GCA effects of 0.14 and 0.15 respectively and they were on par with each other. P_5 and P_2 showed significant negative GCA effect of -0.17 and -0.07 respectively.

The hybrid P_4 x P_7 showed maximum positive SCA effect of 0.67 was followed by P_3 x P_5 (0.40). P_3 x P_7 showed maximum negative SCA effect of -0.41 for flesh thickness.

4.4.13 Fruit length

Analysis of variance for combining ability revealed significant GCA and SCA variances for fruit length. GCA variance was found to be slightly higher than SCA variance. All parents except P_2 showed significant GCA for the trait. P_3 showed maximum positive GCA effect (1.57) which was on par with P_6 (1.13) and P_5 (0.84). Maximum negative GCA was shown by P_1 (-1.72).

Out of the 11 hybrids with significant positive SCA effect, P_2 x P_6 stood first (5.90). Also P_1 x P_2 (5.52), P_2 x P_3 (4.35) and P_4 x P_7 (3.95) were found to be on par with this. Maximum negative SCA effect was observed for P_3 x P_7 (-5.13).

4.4.14 Vine length

Variance due to GCA and SCA were significant with almost similar values for both variances. Both the values were less than one. Maximum positive GCA was obtained for P_3 (0.19) followed by P_5 (0.14) which were on par with each other. Maximum negative GCA of -0.22 was shown by P[illegible]

The hybrid P_2 x P_4 showed maximum positive SCA of 0.41. This was on par with P_3 x P_6 (0.31), P_1 x P_5 (0.27), P_2 x P_7 (0.24), P_1 x P_3 (0.21) and P_4 x P_7 (0.21). The cross P_3 x P_7 exhibited maximum negative SCA (-0.25) for the trait followed by P_2 x P_3 (-0.24).

4.4.15 Internodal length

Significant variances due to GCA and SCA were observed for this character but both the variances were less than one. The parent P_3 showed maximum positive GCA effect (0.55) which was on par with P_5 (0.28). P_6 showed maximum negative GCA effect of -0.29).

Only three hybrids showed significant positive SCA effect. They were P_2 x P_4 (0.92), P_1 x P_5 (0.68) and P_1 x P_7 (0.53). All these were on par with each other. The hybrid P_3 x P_5 exhibited maximum negative SCA effect of -1.29.

4.4.16 Seeds per fruit

Variance due to GCA and SCA were highly significant for this trait. SCA variance was higher than GCA variance. All the hybrids showed significant GCA effect. Maximum positive value was observed for P_3 (88.26) which was significantly higher than P_1 (57.46) and P_6 (35.64). Maximum negative GCA was shown by P_5 (-55.07).

Out of the 17 hybrids with significant SCA effects, P_1 x P_4 had the maximum of 398.85 followed by P_2 x P_6 (269.37) and P_2 x P_3 (228.75). The hybrid P_3 x P_6 showed maximum negative SCA of -334.44.

4.4.17 100 seed weight

Small but significant values were obtained for GCA and SCA variances as per combining ability analysis. All the seven parents showed significant GCA effects with P_3 having a maximum positive value of 0.05 which was on par with P_6 (0.04). These were followed by P_1 (0.03). The parent P_2 showed maximum negative GCA (-0.06).

All the hybrids except $P_1 \times P_3$ showed significant SCA effect. Out of the ten hybrids, with significant positive SCA effect $P_3 \times P_6$ showed a maximum positive value of 0.91, followed by $P_6 \times P_7$ (0.55). $P_3 \times P_5$ showed maximum negative SCA (-0.48) for 100 seed weight.

4.4.18 Days to first fruit harvest

Variance due to GCA and SCA were found to be significant with almost similar values for both. GCA effect was found to be significant for two parents only, of which P_2 showed a negative GCA of -0.79 while P_3 showed a positive GCA of 0.82.

Only four hybrids exhibited significant negative SCA for the trait, of which $P_2 \times P_6$ stood first (-3.37) while the other three i.e., $P_1 \times P_4$ (-2.64), $P_4 \times P_5$ (-1.73) and $P_1 \times P_7$ (-1.45) were on par with it. The hybrid $P_2 \times P_4$ showed maximum significant positive SCA of 2.28.

4.4.19 Sex ratio

Both GCA and SCA variances were significant of which GCA variance was more than twice as that of SCA variance. All the parents except P_7 showed significant GCA effects. The parents P_1 (-4.53) and P_4 (-4.52) showed maximum negative GCA and were on par while P_3 (7.31) showed the highest positive GCA effect.

Out of the nine hybrids with significant negative SCA effect, P_2 x P_5 (-9.65) showed maximum value which was on par with P_1 x P_2 (-9.63), P_2 x P_4 (-8.32), P_4 x P_5 (-7.63) and P_6 x P_7 (-6.52). The hybrid P_5 x P_7 exhibited maximum positive SCA (23.89) which was significantly higher than all other hybrids.

4.4.20 Crop duration

Significant variances due to GCA and SCA were observed for crop duration. SCA variance was higher than GCA variance. All the parents except P_1 showed significant GCA effects. P_6 showed the maximum negative value of -0.98 which was on par with P_7 (-0.93), P_2 (-0.82) and P_5 (-0.73). The parent P_3 showed a maximum positive GCA of 1.93.

Maximum negative SCA was shown by P_3 x P_4 (-7.69) which was on par with P_4 x P_7 (-6.23). The hybrids P_1 x P_4 (-4.84), P_2 x P_3 (-2.75), P_2 x P_6 (-2.98), P_3 x P_5 (-5.10), P_4 x P_5 (-3.56) and P_6 x P_7 (-4.00) also showed significant negative SCA effects for crop duration. The cross P_2 x P_5 showed maximum positive SCA of 4.41 for crop duration.

4.4.21 Keeping quality

Combining ability analysis revealed the presence of significant GCA and SCA variance for the trait. GCA variance was much higher than SCA variance. All the parents showed significant GCA effects. The parent P_7 showed highest positive effect of 5.78 while P_2 showed the highest negative effect of -2.28.

All the hybrids except P_1 x P_7, P_2 x P_3 and P_2 x P_5 showed significant SCA effect for the character. P_1 x P_2 showed the highest positive SCA of 8.46 which was significantly higher than all other hybrids. This was followed by P_1 x P_3 with 7.26. The hybrids P_3 x P_7 showed the highest negative SCA (-8.02) for keeping quality.

4.5 Genetic components of variance

Additive variance, dominance variance and the ratio of additive to dominance variance for all the 21 characters are presented in Table 11. The ratio of additive to dominance variance was positive for 12 characters, of which vine length alone possessed a greater than unity value (1.17). The characters, node at first fruiting (0.69), male flowers per plant (0.51), internodal length (0.36), sex ratio (0.33) and keeping quality (0.32) showed considerably high (but less than unity) values for the ratio.

Table 11 Genetic components of variance for various characters

Character	σ^2A	σ^2D	σ^2A/σ^2D
1. Days to first male flower opening	-0.69	6.64	-
2. Days to first female flower opening	0.37	3.71	0.10
3. Node to first female flower	0.13	1.04	0.12
4. Male flowers per plant	1119.92	2189.03	0.51
5. Female flowers per plant	0.42	3.25	0.13
6. Fruits per plant	-0.17	3.57	-
7. Productive branches per plant	-0.05	1.30	-
8. Node at first fruiting	0.34	0.50	0.69
9. Mean fruit weight	11799.81	95585.40	0.12
10. Yield per palnt	-476427.60	9408047.40	-
11. Fruit diameter	-0.04	1.67	-
12. Flesh thickness	0.01	0.06	0.15
13. Fruit length	0.43	13.04	0.03
14. Vine length	0.034	0.029	1.17
15. Internodal length	0.10	0.28	0.36
16. Seeds per fruit	-2331.88	41355.62	-
17. 100 seed weight	-0.03	0.14	-
18. Days to first fruit harvest	-0.02	1.53	-
19. Sex ratio	23.39	69.99	0.33
20. Crop duration	-2.33	22.84	-
21. Keeping quality	8.85	27.78	0.32

Discussion

5. DISCUSSION

The crop melon (*Cucumis melo* (L.) var. *conomon*) commonly referred to as 'Vellari' is confined mainly to Kerala and parts of Tamil Nadu in terms of cultivation and consumption. Breeding works in this crop were attempted earlier and two varieties has been released so far, through selection. But heterosis breeding as a means of crop improvement was not yet tried in the crop. Much variability is present in the crop within Kerala itself with respect to colour of fruit, size, stage of harvest, keeping quality, splitting nature of mature fruits etc. So, there is much scope for exploitation of heterosis. The basic steps in heterosis breeding programme include selection of desirable parents, evaluation of parents and hybrid seed production. In the present study the selected seven inbreds were evaluated in a diallel cross without reciprocals. The heterosis and combining ability effects of single crosses were studied and superior crosses were identified. A brief discussion regarding the results obtained is furnished herein.

5.1 Mean performance

In the early days of breeding research, methods like selection was purely based on the mean performance of the concerned genotypes. Subsequently breeders began paying attention to other genetic parameters like heritability and genetic advance also along with the mean performance while practicing selection. Hybridisation programmes also require rigorous selection for the identification of suitable parents. But in these experiments, combining ability of the parents and the *per se* performance are given due consideration rather than the aforesaid genetic parameters.

The parent early to produce first male and female flower was P_6. Among hybrids P_4 x P_5 was the earliest in the production of first male flower and it was the only hybrid, earlier than the early parent. But with respect to earliness in production of first female flower P_1 x P_7 was the best hybrid. Six other hybrids were also earlier than the early parent P_6. The same parent produced first female flower at the lowest node, P_2 x P_3 was the hybrid which produced first female flower at lowest node.

Maximum number of male flowers was produced by P_3 among parents and by P_2 x P_3 among hybrids. P_4 was the best parent for female flowers while, P_4 x P_5 was the best hybrid. The performance of the hybrid P_4 x P_5 was better than that of the best parent P_4. The same hybrid produced maximum number of fruits per plant while its male parent P_5 performed best among parents for this character.

Among parents, both P_4 and P_7 produced maximum number of productive branches while the hybrid P_6 x P_7 along with six other hybrids were significantly superior and on par with each other for the trait. The parent P_2 produced first fruit at the lowest node while the best hybrid P_1 x P_2 produced the first fruit at a node still lower than that of P_2. Seven other hybrids were on par with the best hybrid.

The best parent for fruit weight, yield, fruit diameter, flesh thickness fruit length, vine length, internodal length and number of seeds was P_3. The highest yielding hybrid was P_3 x P_4 which was on par with P_1 x P_5, P_2 x P_3,

P_2 x P_6, P_3 x P_5, P_4 x P_7 and P_6 x P_7. P_3 x P_4 exhibited maximum vine length also. P_4 x P_7 had maximum flesh thickness and was on par with P_3 x P_6 which had maximum vine length. Both P_1 x P_5 and P_2 x P_4 produced maximum internodal length and they had high values for vine length also. P_1 x P_4 produced maximum number of seeds per fruit. The hybrid P_2 x P_6 was the best for fruit weight and fruit length. It was on par with the superior hybrid for internodal length and yield. P_2 x P_3 had maximum fruit diameter and was on par with the best hybrid for yield, internodal length, fruit length etc.

Hundred seed weight was maximum for P_1, among parents and P_3 x P_6 among crosses. This hybrid exceeded the best performing parent for the character. For days to first harvest, P_2 was the best parent (early) while P_2 x P_6 was the best hybrid. P_1 x P_4 was on par with P_2 x P_6. Both these hybrids were earlier than the best parent P_2. Lowest sex ratio was observed in P_7 among parents and in P_4 x P_5 among crosses. P_1 x P_2 was on par with P_4 x P_5.

In terms of crop duration, P_5 was the best parent (earliest) while, P_6 x P_7 was the superior hybrid. There were six other hybrids viz., P_1 x P_4, P_2 x P_6, P_3 x P_4, P_3 x P_5, P_4 x P_5 and P_4 x P_7, which had duration less than that of the best parent P_5. Keeping quality was maximum for the parent P_7. No other parent could attain a long storage period as that of P_7. Among hybrids maximum keeping quality was observed for P_6 x P_7. Among the superior hybrids obtained so far in the present study, only P_2 x P_3, P_4 x P_5, P_1 x P_2, P_2 x P_6 and P_4 x P_7 showed field tolerance to mosaic disease in the field.

From the above discussion it can easily be comprehended that all hybrids are not equally superior for various characters. Based on the mean performance, a few hybrids can be projected as best in terms of their economic traits. They include P_2 x P_6 (superior in fruit weight, fruit length, yield internodal length, field tolerance to mosaic, days to first fruit harvest, crop duration), P_2 x P_3 (superior in fruit diameter, yield, internodal length, fruit length, field tolerance to mosaic and node at first female flower), P_3 x P_4 (superior in yield, vine length, crop duration), P_6 x P_7 (superior in keeping quality, yield, number of productive branches per plant) and P_4 x P_5 (superior in days to first female and male flower opening, number of female flowers, days to first fruit harvest, field tolerance to mosaic). P_3 was observed to be the best parent on the basis of mean performance for yield and other yield attributes. The standard parent (P_7) was superior in keeping quality and sex ratio.

5.2 Phenotypic coefficient of variation, genotypic coefficient of variation, heritability and genetic advance

The variability present in breeding populations can be assessed in different ways like simple measures of variability, components of variance and genetic diversity. Among these three, measures of variability like, range, standard deviation, standard error and coefficient of variation are the simplest and the easiest method. Within the four, coefficient of variation is more efficient than the other three, because it is a unit free measurement, and hence comparisons can be made among various characters that are measured in different units.

Phenotypic coefficient of variation (PCV) gives an idea about the extent of variation present in the expression of the trait. This can be due to genotypic effect and environmental influence. In the present study, highest values of PCV was observed for keeping quality (71.76) followed by yield per plant (50.6) sex ratio (42.78) and mean fruit weight (37.99). This evinces that much variability is present in the phenotypic expression of these characters. This result is in line with the earlier reports of Rajendran and Thamburaj (1994) in watermelon. Low PCV estimates were observed for days to first fruit harvest (3.15), crop duration (6.53), days to first female flower opening (6.9), internodal length (9.03) and days to first male flower opening (10.19). This means that, the phenotypic expression of these characters does not show much variability. Similar results were reported by Singh *et al.* (1988) and Sureshbabu (1989) in pumpkin.

Phenotypic coefficient of variation does not give an estimate of the heritable component of variation. In this context, genotypic coefficient of variation (GCV) gains significance. GCV estimates were higher for keeping quality (71.4), yield per plant (47.07), sex ratio (41.56) and mean fruit weight (35.64). PCV was also high for all these characters. This indicates that total as well as heritable variability were higher for these traits, and selection can be effectively practiced for improving these characters. This result was in conformity with the results of Suribabu *et al.* (1986) in bittergourd, Singh *et al.* (1988) in pumpkin and Gayathri (1997) in cucumber. GCV was the lowest for days to first fruit harvest (2.06) followed by days to female flower opening (5.34), crop duration (6.14), internodal length (6.65) and days to first male flower opening (8.06) i.e., the genetic variability in these traits are very less. Reports of Sureshbabu (1989) in pumpkin is in conformity with the result.

The difference between PCV and GCV was very less for all the traits except two which indicates the negligible influence of environment in the expression of the characters. For 100 seed weight, number of seeds, keeping quality, crop duration and number of male flowers per plant, approximately cent per cent of phenotypic variability was due to genotype itself. Selection for improvement of these characters will be rewarding. Similar results were reported by Mariappan and Pappiah (1990) and Rastogi and Deep (1990 a and b) in cucumber. Fairly good amount of environmental influence has been observed for only two characters, node to first female flower (10.59) and node to first fruiting (7.19). Works of Singh *et al.* (1988) in pumpkin also draw a similar conclusion.

In crop improvement, the heritable component of variation is important because only this component is transmitted to the next generation. The magnitude of heritability indicates the effectiveness with which, selection of genotypes can be made based on the phenotype. If heritability of a character is high, selection for such character will be effective because of the close correspondence between genotype and phenotype otherwise not.

Highest estimate of heritability was observed for 100 seed weight (99.7) followed by keeping quality (99.0), number of seeds (98.4) and number of male flowers per plant (96.8). High heritability values were also observed for days to first male flower opening, female flowers per plant, fruits per plant, productive branches per plant, mean fruit weight, yield per plant, fruit diameter, flesh thickness, fruit length and crop duration. Similar results were reported by Swamy *et al.* (1985) in musmkelon, Owens *et al.* (1985 a), Prasunna and Rao (1988) and Abusaleha and Dutta (1990) in cucumber, Borthakur and Shadeque (1990) in pumpkin, Rastogi and Deep (1990 a and b) in cucumber, Rajendran and Thamburaj (1994) in watermelon and Rajput *et al.* (1996) in bittergourd. Lowest estimate of heritability was observed for node to first female flower (35.3) and days to first fruit harvest (42.7). The report of Prasad *et al.* (1988) in watermelon also confirms this result. None of the characters showed very low heritability.

High values of heritability does not always mean a good genetic gain under selection. Hence, along with heritability estimates, expected genetic advance also should be considered while making selection (Johnson *et al.*, 1955). Those characters with high heritability and high genetic advance are under the control of additive gene action and selection is effective in improving them. But, those having high heritability but low genetic advance are controlled by dominance gene action and methods like heterosis breeding should be resorted to in improving them.

Both heritability and genetic advance were high for keeping quality (99.00 and 146.30 respectively), yield per plant (86.60 and 90.21), seeds per fruit (98.40 and 48.49), 100 seed weight (99.7 and 41.44) mean fruit weight (88.00 and 68.90), male flowers per plant, (96.8 and 65.92), female flowers per plant (89.9 and 45.94), fruits per plant (88.7 and 53.04), productive branches per plant (80.3 and 46.86) and sex ratio (94.3 and 83.17). This shows that, the variation in these characters are due to additive gene action and they can be effectively improved through selection. This result is in conformity with the results obtained by Chaudhary *et al.* (1985) in cucumber, Swamy *et al.* (1985) in muskmelon, Mariappan and Pappiah (1990) in cucumber, Sharma and Dhankhar (1990) in bottlegourd, Prasad and Singh (1992, 1994 b) in cucumber, Varghese (1991) and Varghese and Rajan (1993 a) in snakegourd and Gayathri (1997) in cucumber. High heritability accompanied by low genetic advance was observed in days to first male flower opening (62.60 and 13.12 respectively), fruit diameter (72.5 and 26.70), flesh thickness (69.50 and 22.77), fruit length (35.60 and 24.00) and crop duration (88.20 and 11.87). This signals that, these characters are under the control of non-additive gene action and scope for selection in the improvement of these characters are less. The reports of Chaudhary *et al.* (1985) in cucumber supports this view.

5.3 Heterosis and combining ability

The most important step in any heterosis breeding programme is the choice of suitable parents. This requires the joint consideration of combining ability effects and the *per se* performance of both parents and hybrids. With this intention a partial diallel with seven parents was designed in the crop.

Analysis of variance for combining ability gives an estimate of the variance due to GCA and SCA, which is an indication of the type of gene action responsible for the variation in each character. Significant and high GCA variance indicates that additive gene action is operative, while significant and high SCA variance shows that non-additive gene action (dominance and epistasis) is controlling the character.

The existence of significant amount of dominance variance is a prerequisite for the exploitation of heterosis (Singh and Narayanan, 1993). The SCA variance is a measure of dominance gene action. For a better hybrid it is desirable to have high heterosis, high SCA effect, high GCA effect for at least one of its parents and appreciable *per se* performance.

Both GCA and SCA variance were found to be significant for all the characters studied. This reveals the role of both additive and non-additive gene action in the control of all these characters. Significance of GCA and SCA variances were observed earlier by Kendall (1985) in muskmelon, Owens *et al.* (1985) and Musmade and Kale (1986) in cucumber, Solanki and Shah (1990) in cucumber, Mishra *et al.* (1994) in bittergourd, Varghese and Rajan (1994) in snakegourd, Arora *et al.* (1996) in summersquash, Gayathri (1997) in cucumber, Munshi and Verma (1999) in muskmelon and Radhika (1999) in snakegourd.

GCA variance was higher than SCA variance for the characters days to first female flower opening, node to first female flower, male flowers per plant, female flowers per plant, node at first fruiting, mean fruit weight, fruit length, sex ratio and keeping quality. This result points to the fact that, these characters are governed by additive gene action and selection will be effective for the genetic improvement of these traits. This is in agreement with the results of Om *et al.* (1987) in muskmelon, Frederick and Staub (1989) and Kim *et al.* (1996) in cucumber.

Days to first male flower opening, fruits per plant, yield, seeds per fruit and crop duration showed higher SCA variances than GCA variances. This implies that, there is preponderance of non-additive gene action in these characters and therefore heterosis breeding will be effective than selection. The reports of Janakiram and Sirohi (1988) in bottlegourd, Frederick and Staub (1989), Satyanarayana (1991) in cucumber and Reyes *et al.* (1993) in bottlegourd support this view. In the present study, yield was observed to be controlled by non-additive gene action. Results in this line were presented earlier by Musmade and Kale (1986), Solanki and Shah (1990) and Satyanarayana (1991) in cucumber and Korzeniewska and Nierricrowicz (1993) in wintersquash. But this results is contradictory with the results of Om *et al.* (1987) in muskmelon, Sivakami *et al.* (1987) in bottlegourd and El Hafez *et al.* (1997) in cucumber.

The ratio of additive to dominance variance was greater than unity for vine length which shows the predominance of additive gene action. Almost equal values for GCA and SCA variances were observed for productive branches per plant, flesh thickness, fruit diameter, 100 seed weight, internodal length and days to first fruit harvest. This shows that additive and non-additive gene action are equally important in the expression of the character. In this situation, reciprocal recurrent selection may be resorted to for population improvement. Kendall (1985) has reported in a similar manner in muskmelon.

In the present study all the parents with high GCA effect had the highest *per se* performance also for the respective character. But, three cases were noticed as an exception to this. It includes, the parents, P_4 (for days to first male flower opening), P_1 (for sex ratio) and P_6 (for crop duration).

From the study conducted using seven diverse parents, good crosses can be identified by taking into consideration, the heterosis, SCA effect and GCA of parents. A character-wise analysis revealed that parents producing heterotic crosses for a trait had high and significant SCA effect for that trait, in all the characters studied. Musmade and Kale (1986) and Satyanarayana (1991) had similar results in cucumber.

Significant values of relative heterosis, standard heterosis and heterobeltiosis was shown by P_4 x P_5 for days to first male flower opening. This cross possessed maximum negative SCA effect for the trait and it had the lowest (favourable) mean value. P_2 x P_4 was on par with this in terms of relative heterosis and it too had high negative SCA effect. High heterosis may be attributed to the presence of P_4 which had maximum GCA effect as one of the parents in both the crosses. Ram *et al.* (1997) has reported heterosis for this trait in bittergourd.

For days to first female flower opening, all the three types of heterosis were significant in P_1 x P_7. This had maximum negative SCA effect and the lowest favourable mean value. The crosses P_4 x P_5 and P_2 x P_4 also showed significant heterosis and SCA effect. This heterosis may be due to the negative GCA effect of at least one of the parents involved in the cross. Heterosis for this character was reported earlier in cucumber by Gayathri (1997).

Both relative heterosis and heterobeltiosis were maximum in the cross P_2 x P_3 for the trait node to first female flower. It possessed maximum significant SCA effect (negative) and the lowest mean value. None of the crosses showed significant negative standard heterosis. This may be attributed to the negative GCA effect of the parent P_2. Pal *et al.* (1984) has also reported similar results in bottlegourd.

The F_1 hybrid P_5 x P_7 showed maximum relative heterosis and heterobeltiosis for male flowers per plant. Maximum standard heterosis was shown by P_2 x P_3. These two crosses had maximum SCA effect and *per se* performance also. Maximum GCA effect for this character was observed in P_3.

Significant values for all the three types of heterosis was exhibited by P_4 x P_5 for female flowers per plant. Other hybrids with significant heterosis were P_2 x P_4 and P_3 x P_4. The reports of Doijode and Sulladmath (1982) in pumpkin and Solanki *et al.* (1982 a and b) in cucumber go parallel to this. All these crosses possessed significant and high SCA effects and mean values and had P_4, which had maximum GCA effect as one of its parents.

Maximum values for all the three types of heterosis was exhibited by the cross P_4 x P_5 for fruits per plant. This result is in agreement with the results of Mishra *et al.* (1994) in bittergourd, Li *et al.* (1995) in cucumber, Sharma *et al.* (1995) in bottlegourd and Rajesh *et al.* (1999) in bottlegourd. This had the highest SCA effect and *per se* performance. Other crosses with significant and high relative heterosis and SCA effect were P_6 x P_7 and P_3 x P_4. Both the parents of the superior hybrid P_4 x P_5 had significant and high GCA effects which were on par with each other. Its superiority can be attributed to this reason.

For productive branches per plant, significant and high relative heterosis and heterobeltiosis were shown by P_1 x P_5 and P_1 x P_3. The hybrid P_6 x P_7 showed maximum significant standard heterosis. Similar results were reported by Solanki *et al.* (1982 a and b) and Pyzhenkov *et al.* (1988) in cucumber. All the above crosses had significant and high SCA effects and *per se* performance. The superiority of these could be assigned to the significant and high GCA effect of the parent P_1.

Relative heterosis and standard heterosis were maximum in the cross P_1 x P_2 for the character node at first fruiting. P_1 x P_7 and P_1 x P_4 also showed significant relative heterosis. SCA effect and mean value were high (negative) for these three crosses. None of the crosses showed significant heterobeltiosis. The superiority of the cross P_1 x P_2 may be attributed to the maximum significant GCA effect of P_2.

Maximum significant values for all the three types of heterosis for mean fruit weight was shown by P_2 x P_6. P_3 x P_5 also showed standard heterosis which was on par with P_2 x P_6. Similar results were reported earlier by Kasem and Somsak (1991) in cucumber, Mishra *et al.* (1994) in bittergourd, Li *et al.* (1995) in cucumber, Kim *et al.* (1996) in muskmelon, Ram *et al.* (1997) in bittergourd and Rajesh *et al.* (1999) in bottlegourd. SCA effects and *per se* performance of the above two crosses were significant and maximum. GCA effect was maximum for the parent P_3.

Maximum heterosis, over mid parent and better parent was exhibited by P_2 x P_6 for yield per plant. The hybrid P_3 x P_4 showed maximum significant standard heterosis. Other crosses with significant standard heterosis were P_3 x P_5 and P_6 x P_7. Simlar results were presented by Satyanarayana (1991) in cucumber, Sirohi (1993) in pumpkin, Musmade *et al.* (1995) and Li *et al.* (1995) in cucumber, Ghai *et al.* (1998) in summersquash and Rajesh *et al.*

(1999) in bottlegourd. All the above crosses had significant and high SCA effect. The *per se* performance of all these crosses were also very high. GCA effect was significant for both P_3 and P_5.

The F_1 hybrid P_2 x P_6 showed high values for all the three types of heterosis for fruit diameter. P_2 x P_3 showed maximum standard heterosis for this. Supporting literature were presented by Kasem and Somsak (1991) in cucumber and Rajesh *et al.* (1999) in bottlegourd. Contradictory result i.e., absence of positive heterosis for the trait was reported by Ram *et al.* (1997) in bittergourd. The above two crosses possessed high SCA effect and mean performance also for the character.

Maximum values of all the three types of heterosis for flesh thickness was exhibited by the cross P_4 x P_7. Significant relative heterosis was shown by P_1 x P_4 also. They had high SCA effect and better *per se* performance. The superiority may be attributed to the high GCA effect of the common parent P_4. Reports on heterosis for this character was presented earlier by Pal *et al* (1984) in bottlegourd.

Heterosis with respect to mid-parent and better parent was highest in P_1 x P_2 for the character, fruit length. Maximum significant standard heterosis was shown by P_2 x P_6 and P_2 x P_3. Results in this regard were reported earlier by Mishra *et al.* (1994) in bittergourd, Sharma *et al.* (1995) bottlegourd, Kim *et al.* (1996) in muskmelon, Ram *et al.* (1997) in bittergourd and Rajesh *et al.* (1999) in bottlegourd. The above hybrids had high *per se* performance and SCA effects.

Maximum significant relative heterosis was observed in P_2 x P_4 for the character vine length. The crosses P_3 x P_6, P_1 x P_3 and P_1 x P_5 showed maximum significant values for standard heterosis. Fang *et al.* (1994) and Varghese and Rajan (1993 b) have also reported heterosis for this in the crops cucumber and snakegourd respectively. All these had significant and high SCA effect also. The superiority of these crosses may be ascribed to the significant positive GCA effect of the parents P_3, P_4 and P_5. These crosses possessed better mean values also.

Significant heterosis was observed only with reference to the mid parent for the character internodal length, the heterotic cross being P_2 x P_4. It had the highest SCA effect and mean value.

Maximum values for all the three types of heterosis were exhibited by P_1 x P_4 which had the highest SCA effect and mean value for the character seeds per fruit. Similar results were documented earlier by Doijode *et al.* (1983) in pumpkin.

For 100 seed weight maximum positive relative and standard heterosis was shown by P_3 x P_6 and maximum heterobeltiosis by P_5 x P_6. Results of this kind was reported earlier by Doijode *et al.* (1983) in pumpkin. All these had significant and high SCA effects and *per se* performance. The superiority of these crosses may be attributed to the high GCA effects of the parents, P_3 and P_6.

All the three types of heterosis were minimum (favourable) in P_1 x P_4 and P_2 x P_6 for days to first fruit harvest. Similar result was reported by Varghese and Rajan (1993 b) in snakegourd and Firpo *et al.* (1998) in summer squash. Maximum GCA effect was observed in the parent P_2. This may be a reason for the superiority of P_2 x P_6. Both these had high SCA effects and better *per se* performance.

The F_1 hybrid P_4 x P_5 showed maximum negative values of relative heterosis and heterobeltiosis for sex ratio. None of the hybrid showed significant standard heterosis. The above said cross had significant and high SCA effect and better mean performance. Its superiority may be attributed to the high GCA effect of the parent P_4.

Relative heterosis and heterobeltiosis was maximum in the cross P_3 x P_4 for crop duration. Standard heterosis was high in P_6 x P_7 followed by P_4 x P_7 and P_2 x P_6. All these had significant SCA effect and good *per se* performance. Significant GCA effect was observed in the parents P_2, P_6 and P_7. This may be reason for the superiority of the aforesaid crosses.

The study revealed that none of the crosses was better than the standard parent (P_7) in terms of keeping quality. However significant relative heterosis and heterobeltiosis was shown by P_1 x P_2, P_1 x P_3 and P_1 x P_5. SCA effect and *per se* performance of these crosses were better than other hybrids. Though P_7 had the highest GCA effect and mean performance, none of its crosses, had a positive SCA effect for the trait. The superiority of the above said crosses may be due to the significant GCA effect of P_1.

In general, three crosses could be identified as superior with multiple heterosis for economically important traits. They had high heterosis, high SCA effect and better *per se* performance. The hybrid P_4 x P_5 was identified as superior in terms of flowering traits like days to first male and female flowers and sex ratio. For yield and other fruit characters like mean weight, diameter, length and days to first fruit harvest, the hybrid P_2 x P_6 was observed to be the superior. The cross P_1 x P_2 was the best in terms of keeping quality, node to first female flower, node to first fruiting and fruit length. These three crosses showed very low incidence of mosaic disease in the field, which may be regarded as an added advantage to the superior crosses.

From the present investigation it is evident that heterosis can be exploited in this crop for yield and yield attributes. For getting uniform F_1 population the homozygosity of the parental lines is to be maintained by inbreeding. The production and evaluation of the hybrids is to be repeated for confirmity of the results.

Summary

6. SUMMARY

The present investigation 'Heterosis and combining ability in melon (*Cucumis melo* (L.) var. *conomon*) was conducted at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 1998-2000. The experiment was carried out with seven parents and their 21 F_1 hybrids (without reciprocals) designed in a Randomised Block Design with three replications. Major objectives of the study were estimation of genetic variability, heritability and genetic advance ; identification of superior F_1 hybrids and the estimation of combining ability effects of parents and hybrids in melon.

Observations were recorded on various biometric traits viz., days to first male and female flower opening, node to first female flower, male flowers, female flowers and fruits per plant, productive branches per plant, node at first fruiting, mean fruit weight, yield, fruit diameter, length, flesh thickness, vine length, internodal length, seeds per fruit, 100 seed weight, days to first harvest, sex ratio, crop duration, keeping quality and incidence of pests and diseases.

All the 28 genotypes showed significant difference for all the 21 characters studied. The genotype P_3 topped in mean performance for yield per plant, male flowers per plant, fruit weight, fruit diameter, flesh thickness, vine length, internodal length and seeds per fruit while the standard parent P_7 was first in keeping quality and sex ratio. The parent superior in fruits per plant and crop duration was P_5.

The hybrids P_2 x P_6 and P_2 x P_3 were superior with respect to yield, fruit characters, earliness and resistance to mosaic disease. The hybrid P_6 x P_7 was the best for keeping quality, yield and crop duration while P_4 x P_5 was superior in earliness traits like days to first male and female flower opening, days to first fruit harvest and number of female flowers.

High values of phenotypic and genotypic coefficient of variation (PCV and GCV) were observed for keeping quality, yield per plant, sex ratio and mean fruit weight. Heritability and genetic advance were also high for the above traits and also for seeds per fruit, 100 seed weight, male flowers per plant, fruits per plant and productive branches per plant. The difference between PCV and GCV was considerably large for node to first female flower and node to first fruiting.

Significant heterosis was observed for all the 21 characters studied. Altogether, nine hybrids possessed all the three types of heterosis for yield. Maximum standard heterosis for yield was shown by P_3 x P_4. Relative heterosis and heterobeltiosis was maximum for P_2 x P_6. This cross also showed highest standard heterosis for mean fruit weight, fruit diameter, fruit length, days to first fruit harvest and crop duration. The hybrid P_4 x P_5 showed maximum standard heterosis for days to first male and female flower opening, female flowers and fruits per plant and sex ratio.

Analysis of variance for combining ability revealed significant GCA and SCA variance for all the characters studied. The parent P_3 was the best general combiner for yield, fruit diameter, mean fruit weight and fruit length. P_4 was the best combiner for female flowers and fruits per plant, days to first male flower opening, flesh thickness, vine length and sex ratio, whereas P_2 was the best for node to first female flower, node to first fruiting and crop duration. The hybrid P_6 x P_7 was the best specific combiner for yield and fruits per plant.

All the hybrids with high estimates of standard heterosis were found to be good specific combiners for that trait with better *per se* performance. Combining all the three, P_2 x P_6 was identified as superior in yield, mean fruit weight, fruit diameter, fruit length and days to first harvest whereas P_4 x P_5 was the best in days to first male and female flower anthesis, female flowers and fruits per plant and sex ratio. These crosses also showed field tolerance to mosaic disease. The findings of this investigation is to be confirmed by repeated experiments.

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*Original not seen

HETEROSIS AND COMBINING ABILITY IN MELON (*Cucumis melo* (L.) var. *conomon*)

By

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ABSTRACT OF THE THESIS
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ABSTRACT

The current research programme on 'Heterosis and combining ability in melon (*Cucumis melo* (L.) var. *conomon*) was carried at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 1998-2000. The objectives were estimation of various genetic parameters, heterosis and combining ability effects of parents and hybrids. The experimental material consisted of seven parents and their 21 F_1 hybrids (without reciprocals).

Analysis of variance revealed highly significant difference among the genotypes for all the 21 characters studied. The genotype P_3 topped in mean performance for yield and many yield attributes. The hybrids $P_2 \times P_6$ and $P_2 \times P_3$ were superior in yield and fruit characters, whereas $P_6 \times P_7$ was the best for keeping quality, yield and crop duration.

Genetic parameters like PCV, GCV, heritability and genetic advance were high for keeping quality, yield, sex ratio and mean fruit weight. Environmental component of variation was negligible for majority of traits.

Significant heterosis was observed for all the characters studied. $P_3 \times P_4$ showed maximum standard heterosis for yield whereas, $P_2 \times P_6$ showed maximum relative heterosis and fruit characters and earliness traits.

Variance due to GCA and SCA were significant for all the traits studied. P_3 was the best general combiner for yield, fruit diameter, mean fruit weight

and fruit length and P_2 was the best for node characters and crop duration. The hybrid P_6 x P_7 was the best specific combiner for yield.

Combining the mean performance, SCA effects and standard heterosis, P_2 x P_6 was identified as the superior cross in terms of yield and yield attributes whereas P_4 x P_5 was the best for various flowering traits.