ESTIMATION OF COMBINING ABILITY AND HETEROSIS IN SNAKEGOURD

(Trichosanthes anguina L.)

By
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DECLARATION

I hereby declare that this thesis entitled **"Estimation of combining ability and heterosis in snakegourd (*Trichosanthes anguina* L.)"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"Estimation of combining ability and heterosis in snakegourd (*Trichosanthes anguina* L.)"** is a record of research work done independently by **Mrs. Radhika. V.S** (97-11-26) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship of any other University or Society.

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**DEDICATED TO
MY BELOVED FAMILY**

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INTRODUCTION

I. INTRODUCTION

Attainment of food sufficiency to provide a healthy life to the human population is perhaps the greatest challenge before mankind in the 21st century. Vegetables play a vital role in the health and nutrition of people throughout the world. The food experts and nutritionists have realised and appreciated the food value of vegetables because of the low calorific value, high contents of protein, vitamins and minerals.

Several cucurbitaceous crops constitute a principal group of cross fertilized vegetables. Snakegourd *(Trichosanthes anguina* L.), vipergourd or serpent cucumber occupies a prominent position among these crops in India especially in south India including Kerala. It is cultivated throughout the year. It is considered as a good source of minerals, fibre and other nutrients. It contains 94.1 per cent water, 4.4 per cent carbohydrate, 0.5 per cent protein, 0.3 per cent fat, 0.7 per cent mineral matter, 0.035 per cent sulphur and 1601 IU of vitamin A (Aykroyd, 1958).

In spite of its nutritional, dietary and economic importance in the country, systematic efforts have not been so far taken to improve the productivity and acceptability of the crop. Hence varieties/hybrids with high yield potential and acceptability characters are not available at present. Most of the cultivars grown are non-descript and uneconomical. This is one of the major constraints in the cultivation of snakegourd. This calls for an immediate crop improvement programme for developing superior varieties/hybrids suited to the agroclimatic conditions of the country in general and Kerala in particular.

Snakegourd is a monoecious crop and is typically cross pollinated one. Hence there is immense scope for commercial exploitation of hybrid vigour in this crop. Fairly good amount of diversity was found to exist in the crop in south India. The genetic divergence in the population was estimated and the genotypes were clustered into distinct groups in a previous research programme in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani (Mathew, 1996).

Identification of specific parental combinations heterotic for economic characters forms the basis for commercial production of acceptable hybrids. With this end in view the present investigation was taken up with the following objectives.

1. Estimation of general combining ability of parents identified as most divergent in the previous study.
2. Estimation of specific combining ability of specific single crosses
3. Estimation of relative heterosis, heterobeltiosis and standard heterosis for different characters.
4. Identifying the gene actions governing different characters in the crop.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

The literature on crop improvement in snakegourd (*Trichosanthes anguina* L.) is limited when compared to other cucurbits. The lack of progress might be partially due to inadequate breeding efforts. But being a cross pollinated crop, due to monoecy there exists considerable scope for exploitation of heterosis in snakegourd. An attempt has been made to review the available literature on various aspects of important cucurbitaceous crops.

2.1 Variance

Variability is the sum total of genotypic and environmental effects. To undertake the plant improvement programmes and to get a better idea of the variability, it is necessary to assess the components of variance. High genotypic variance indicates wider genetic basis for those characters. On the other hand, wide difference between the phenotypic and genotypic variance reveal the dominant role played by the environment.

In a study using 25 lines of **bittergourd** by Ramachandran (1978), the estimates of phenotypic, genotypic and the environmental variance of the character, primary branches per plant, indicated the predominant influence of the genetic component over the environmental effect on its phenotype.

Sarkar *et al.* (1990) observed high phenotypic and genotypic variances for fruits per plant and fruit volume in a study with 16 divergent genotypes of **pointedgourd.**

Abusaleha and Dutta (1990) used 75 pure genotypes and observed high magnitude of genotypic and phenotypic variances for all the characters studied in **cucumber.**

Presence of inherent genetic variability in the 20 genotypes of **pumpkin** (Borthakur and Shadeque, 1990) were evident from the high estimates of genotypic and phenotypic variance for main creeper length, leaves per plant and fruit size index. High genotypic and phenotypic variance for seeds per fruit among 12 lines of **watermelon** was observed by Kumar and Singh (1997).

2.1.1 Co-efficient of variation

To apportion the observed variability to the component factors, parameters such as genotypic coefficient of variation (GCV) and phenotypic co-efficient of variation (PCV) may be more suitable. This gives a better picture of the extent of genetic variability within the genotypes for each trait and suggests that the characters with high GCV possess better potential for improvement through selection. The existence of fairly large differences between PCV and GCV predicts that the traits were much influenced by non-heritable portion and therefore, the phenotypic values as such cannot be used for making selection. But, if there is minimum difference between the two, there is stability for such traits.

In his study using 25 genotypes of **snakegourd** Joseph (1978) recorded highest GCV for fruit weight (28.29 per cent) and fruit length (29.81 per cent). But 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 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.

Studies conducted by Srivastava and Srivastava (1976) using 10 lines and Singh *et al.* (1977) using 25 varieties of **bittergourd** showed maximum GCVfor fruits per plant followed by yield per plant (37.45 and 39.00 per cent, respectively). Lowest GCV for days to flower (4.00 and 9.17 percent, respectively) was reported by Singh *et al.* (1977) and Mangal *et al.* (1981), Ramachandran (1978) and Ramachandran and Gopalakrishnan (1979) evaluated 25 types and observed 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. Six lines were examined and GCV was moderate to high for all the characters except number of fruits per plant and percentage fruit set (Suribabu *et al.* 1986). Chaudhary (1987) and Vahab (1989) also recorded highest 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.

Data collected from 189 local varieties of **pointedgourd** by Singh *et al.* (1986) showed that GCV varied from 1.70 (days to first fruit set) to 42.27 per cent (fruits per plant). The GCV was also high for yield per plant and fruit length. High GCV for yield and fruits per plant were also reported.

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.

In **ridgegourd,** Reddy and Rao (1984) found that PCV ranged from 14.38 to 162.32 per cent and GCV from 13.56 to 112.03 per cent for days to first marketable fruit and yield per plant. However, days to first picking and fruit diameter had least values of PCV and GCV. Varalakshmi *et al.* (1995) evaluated 58 genotypes for 19 characters which revealed high PCV and GCV for fruits per plant, fruit weight, seeds per fruit and yield per plant. The values of PCV and GCV were also almost equal for most of the characters indicating minimum influence of environment.

Arora *et al.* (1983) evaluated thirteen lines of **spongegourd** for 10 traits and observed high GCV and PCV for yield per plant and fruits per plant.

In a collection of **cucumber** genotypes, Solanki and Seth (1980) observed maximum PCV and GCV estimates for plant height (71.80 and 69.02 per cent) and minimum for fruits per plant (10.43 and 6.00 per cent). Significant environmental co-efficient of variation (ECV) was also noticed which ranged from 6.90 (days to maturity) to 71.20 per cent (yield per plant). In the study by Prasunna and Rao (1988) with five F_1 progenies, the GCV ranged from 5.14 to 73.35 per cent while the PCV ranged from 8.52 to 80.13 per cent. Mariappan and Pappiah (1990) evaluated 45 diverse genotypes and recorded the highest PCV for seeds per fruit followed by weight of seeds per fruit. The difference between PCV and GCV was, however, invariably low for all characters studied. Rastogi and Deep (1990a and b) also got similar results but they recorded the highest PCV and GCV estimates for days to fruit maturity and lowest for fruit yield per plant.

Gopalakrishnan (1979) studied variability for 25 quantitative characters among 18 genotypes of **pumpkin** and found the maximum GCV for male flowers per plant (56.23 per cent) followed by fruits per plant (50.32 per cent). But, Doijode and Sulladmath (1986) and Rana *et al.* (1986) reported highest PCV and GCV for fruit weight compared to other characters. 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. Sureshbabu (1989) pointed out highest GCV for seeds per fruit (37.37 per cent) and 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.

Variability among 25 varieties of **watermelon** was studied by Thakur and Nandpuri (1974) and recorded maximum GCV for seeds per kg of fruit (41.31 per cent) and minimum for days to first picking (6.46 per cent). Prasad *et al.* (1988) evaluating nine germplasm lines 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. Similar observation was also made by Rajendran and Thamburaj (1994) except for fruits per plant. They also recorded the highest PCV and GCV for yield per vine (88.34 and 67.60 per cent).

In **muskmelon**, Deol *et al.* (1981) and Kalloo *et al.* (1981) found high GCV for yield per plant and fruits per plant. Chacko (1992) also observed moderate to high GCV for yield while Swamy *et al.* (1985) with 45 genotypes recorded the highest PCV as well as GCV for marketable yield per plant (62.56 and 35.29 per cent) followed by total yield per plant and average fruit weight. They also found that the magnitude of environmental influence (PCV-GCV) ranged from 2.50 for days to first harvest to 27.27 per cent for marketable fruit yield.

2.2 Heritability and genetic advance

The components of variation do not reveal the heritable portion of variability which is ascertained through heritability. The extent of improvement further depends upon the intensity of selection and genetic advance obtained from the population.

2.2.1 Heritability

In crop improvement, only the genetic component of variation is important since only this component is transmitted to the next generation. The magnitude of heritable variability is an important aspect of genetic constitution of breeding material which has a close bearing on selection. Those traits with high heritability are considered to be dependable from breeding point of view.

In **snakegourd,** Joseph (1978) evaluated 25 varieties for heritability and observed the highest estimate for fruit length (99.19 per cent) followed by fruit girth. Yield per plant had a comparatively low estimate of heritability whereas fruits per plant had the lowest value. Varghese (1991) and Varghese and Rajan (1993a) reported maximum heritability estimate for total duration of the crop (99.80 per cent). Fruit length, fruits per plant and yield per plant also had high values but that of seeds per fruit was low.

Mangal *et al.* (1981) noted high heritability values for average fruit weight, fruits per plant, yield per plant and seeds per fruit among 21 varieties of **bittergourd** while Indiresh (1982) studying 24 lines reported high estimates for all the characters except yield per plant and days for fruit development.

With 18 lines of **pointedgourd,** Singh *et al.* (1986) observed high heritability for days to first picking and flowering, yield per plant, fruit length and diameter, average fruit weight and fruits per plant.

In **bottlegourd,** narrow sense heritability was high for days to first male and female flower, fruit length, girth and 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.

Evaluating six parents and seven hybrids of **ridgegourd** Reddy and Rao (1984) observed highest heritability for average fruit weight (49.74 per cent) and lowest for days to first harvest (4.00 per cent). High estimates were also recorded for fruit length, days to first female flower, yield (by number as well as weight) and fruit diameter. Varalakshmi *et al.*(1995) also reported high heritability values using 58 genotypes for seeds per fruit, fruit weight, days to first female and male flower, fruit length, 100-seed weight and fruits per plant while it was low for fruit diameter.

In a study with 13 lines of **spongegourd,** Arora *et al.* (1983) observed high values of heritability for days to first male and female flower, yield per plant and number of fruits per plant and moderate values for length and diameter of fruit. Prasad *et al.* (1984) found that yield per plant and four other traits had heritability estimates of 10.00 per cent.

In **cucumber,** moderately high heritability was observed for days to first female flower (Miller and Quisenberry, 1976) whereas Mariappan and Pappiah (1990) reported high values for fruit girth and length, days to first staminate flower, number of seeds per fruit and fruit weight also. While Prasunna and Rao (1988) recorded high estimates for fruits per vine and average fruit weight only, Rastogi and Deep (1990a) recorded high heritability for yield per plant and days to fruit maturity as well.

Flesh thickness and fruit weight had high heritability in **pumpkin** (Singh *et al.*, 1988 and Borthakur and Shadeque, 1990). While Singh *et al.* (1988) observed high heritability for yield, Sureshbabu (1989) recorded the lowest for the same. Evaluating six quantitative characters, Doijode and Sulladmath (1985 and 1986) showed high narrow sense heritability for most of the characters.

The magnitudes of heritability of nine lines of **watermelon** were quite high for all the characters except days to first picking and branches per plant (Prasad *et al.*, 1988). Rajendran and Thamburaj (1994) recorded high heritability estimates for 100-seed weight, average fruit weight, yield per vine and number of seeds per fruit.

In a study of Kalloo *et al.* (1981) in **muskmelon,** the estimates of heritability ranged from 11.00 to 73.98 per cent with characters such as fruit length, fruit weight, yield and number of fruits registering high values. The heritability estimates were found to be invariably moderate to high for all the characters in a study by Swamy *et al.* (1985) while Singh *et al.* (1989) observed moderate estimates of narrow sense heritability for all the traits except number of primary branches.

2.2.2 Heritability and genetic advance

Studies by many workers revealed that heritability estimates depend upon the specific material studied, the characters chosen and the environmental condition and therefore, information may be lost if based on heritability estimates alone. This reveals that heritability merely aids as a tool in selection, but to know the progress of selection genetic advance is to be taken into consideration.

For a breeding programme aimed at improving a particular trait through selection, only that section of heritable portion is desirable which is due to additive gene effect. According to Panse (1957), if the heritability is mainly due to this effect, a high genetic advance may be expected.

In **snakegourd,** high heritability in association with high magnitude of genetic advance was observed for fruits per plant (Varghese, 1991 and Varghese and Rajan, 1993a).

Fruits per plant had the highest estimates of genetic advance (71.75 per cent) and heritability (99.31 per cent) in **bittergourd** (Srivastava and Srivastava, 1976) although many workers have reported high estimates of both for yield per plant as well (Ramachandran, 1978; Chaudhary, 1987 and Chaudhary *et al.* 1991). Suribabu *et al.* (1986) found that seeds per fruit, days to first female flower and yield per plant exhibited moderate to high genetic advance over mean.

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

Prasad and Prasad (1979) using 40 lines of **bottlegourd** recorded high heritability coupled with high genetic advance for fruit length and fruit diameter. While Sharma and Dhankhar (1990) made similar observation for fruits per plant.

Following a study by Reddy and Rao (1984) in **ridgegourd,** high heritability was associated with high magnitude of genetic gain for yield, individual fruit weight, number of fruits and fruit length. In addition to these traits, Varalakshmi *et al.* (1995) observed high estimates for seeds per fruit and 100-seed weight. However, Kadam and Kale (1987) found high heritability and genetic advance for days to flowering.

In **spongegourd,** broad sense heritability and genetic advance were high for fruit length, days to flowering (Panwar *et al.,* 1977 and Prasad *et al.* (1984), yield per plant and fruits per plant (Arora *et al.* (1983).

Many workers reported high heritability coupled with high genetic advance for fruit yield (Solanki and Seth, 1980 and Rastogi and Deep, 1990a) and fruits per vine (Abusaleha and Dutta, 1990 and Rastogi and Deep, 1990a) and fruit weight (Mariappan and Pappiah, 1990 and Rastogi and Deep, 1990a) in **cucumber.** The estimates were also high for days to maturity (Solanki and Seth, 1980), days to first female flower (Prasunna and Rao, 1988), fruit length (Abusaleha and Dutta, 1990) and pulp thickness (Mariappan and Pappiah, 1990).

Studying 20 cultivars of **pumpkin** of Indian and foreign origin, Mangal *et al.* (1979) pointed out that estimates of heritability and genetic advance were high for yield and fruits per plant. High heritability in conjunction with genetic gain was observed for fruits number (Rana *et al.*, 1986) and fruit weight (Singh *et al.* 1988 and Borthakur and Shadeque, 1990). While Singh *et al.* (1988) reported high values for yield and 100-seed weight, Sureshbabu (1989) found high genetic gain for seeds per fruit (73.05 per cent).

In **watermelon,** Sachan and Tikka (1971) noticed that the average fruit weight and yield exhibited high heritability and genetic advance. In addition to these characters, number of fruits per plant, number of seeds per fruit and 100-seed weight exhibited high estimates in the study by Prasad *et al.* (1988) and Rajendran and Thamburaj (1994).

Association of high heritability along with high genetic gain was observed for yield per vine (Kalloo *et al.*, 1981; Swamy *et al.*, 1985 and Chacko, 1992), for fruits per plant (Deol *et al.*, 1981 and Kalloo *et al.*, 1981) and for fruit weight (Kalloo *et al.*, 1981 and Swamy *et al.*, 1985) in **muskmelon.**

In **roundmelon,** Dahiya *et al.* (1989) revealed the presence of high heritability and genetic advance in the 45 lines studied.

High value of heritability is not always an indication of high genetic advance (Johnson *et al.*, 1955 and Swarup and Chaugale, 1962). Certain characters may have moderate to high heritability but low genetic advance, suggesting that high heritability of these traits were due to non-additive gene effects such as dominance, over dominance, epistasis and their interaction (Panse, 1957).

In **snakegourd,** yield per plant, fruit length, total crop duration, days to first harvest and first male flower exhibited high heritability estimate coupled with low genetic gain (Varghese, 1991 and Varghese and Rajan, 1993a).

Fruits per plant registered moderate heritability and low genetic advance in the study by Suribabu *et al.* (1986) in **bittergourd.**

High heritability and low expected genetic advance was recorded in **cucumber** by Solanki and Seth (1980) for average fruit weight and number of fruits harvested per plant.

The heritability was high while genetic gain was low for days to first fruit harvest (Deol *et al.*, 1981 and Swamy *et al.*, 1985) and moderate for average fruit weight (Deol *et al.*, 1981) in **muskmelon.**

2.3 Combining ability and heterosis

2.3.1 Combining ability

Selection of parents and hybrids on the basis of general combining ability (gca) and specific combining ability (sca) are prerequisites to develop high yielding varieties and hybrids respectively. The term gca was coined by Sprague and Tatum

(1942) to designate the average performance of a line in a number of hybrid combinations. They used sca to designate those cases in which certain hybrid combinations did relatively better or worse than would be expected on the basis of the average performance of the lines involved.

In an estimation of combining ability in a 8 x 3, line x tester cross in **snakegourd,** Varghese and Rajan (1994) observed high and significant gca and sca variances for yield per plant and fruits per plant.

Sirohi and Choudhary (1977) while estimating the combining ability in **bittergourd** in a diallel cross involving 8 varieties observed that the variance due to gca was much higher than sca variance indicating the predominance of additive gene action for yield and its components.

In bittergourd, observations were recorded by Singh and Joshi (1979) on yield, stem length, primary branches per plant, fruit length and number and weight of fruits per plant for 5 inbreds and their 10 hybrids produced by diallel crossing. All characters were governed mainly by additive gene action. High gca was recorded in the parent, BWL_1 for fruit length, number and weight of fruits per plant. Hybrids BWL_1, x BB_1 and BWM_1 x BS_1, had high sca values for weight of fruit per plant.

In a diallel cross involving 10 varieties of bittergourd Srivastava *et al.* (1983) observed significant gca and sca effects for days to flowering, fruits per plant, fruit weight per plant and total yield per plant. In a line x tester analysis of bittergourd varieties, Pal *et al.* (1985) revealed that gca effects were high for days to floral initiation than sca effects indicating the importance of additive gene effects. An analysis of diallel cross using 9 varieties of bittergourd by Mishra *et al.* (1994) indicated the existence of both additive and non additive gene action for fruits per plant and length, breadth and weight of fruit and yield. The sca effects were high for the hybrids, Coimbatore Long x Gadabeta and Tiansi x Gadabeta.

In **bottlegourd** Sivakami *et al.* (1987) reported the significance of both gca and sca effects for yield characters in a diallel cross involving 10 varieties. Also the gca effects predominated over sca effects suggesting that recurrent selection would be effective in improving them. In a combining ability of quantitative characters in a 10 x 10 diallel cross of round fruited bottlegourd, the estimated components of variance of gca were larger than those for all characters except days to opening of first male and female flowers and fruit polar diameter (Janakiram and Sirohi, 1988).

Estimation of combining ability in a line x tester cross in bottlegourd, Kumar and Singh (1997) observed that variance due to sca was highly significant for yield and yield components indicating that non additive gene components were important.

Om *et al.* (1978) reported in a half diallel cross of several varieties of **cucumber,** significant general and specific combining ability indicating that both additive and non additive components of genetic variation were important, and the former were the more important for early yield per plant. Smith *et al.* (1978) observed node to first female flower per vine, branches per vine, fruits per vine, average fruit weight, fruit length to diameter ratio and total yield per vine to have high gca variances indicating the role of additive gene action for the expression of these characters in cucumber.

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. In a study of 36 combinations involving 16 parents of cucumber Wang and Wang (1980) found that both gca and sca effects were significant for a number of yield and maturity characters.

Ghaderi and Lower (1981) carried out breeding investigations in cucumber and reported significant additive and or dominance variance in certain crosses for fruit weight per plant, fruits per plant and average fruit weight. In cucumber, significant gca variance was observed by Shawaf and Baker (1981) 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).

While studying the combining ability for 60 F_1 hybrids in cucumber Dolgikh and Siderova (1983) reported general combining ability to be important for early and total yield and for fruit number per plant. They also reported a line W as promising for producing hybrids with high early yield. 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) while studying combining ability in the production of cucumber hybrids found high gca effects for parthenocarpy and disease resistance. The lines, Zh L 745 and PML 761 were reported as best combiners for parthenocarpy and high yield.

Analysis of data on the yields of the parental lines and F_1 populations from a 5 line diallel cross in cucumber by Prudek (1984) showed that both general and specific combining abilities were significant in determining both fruit number and fruit weight per plant, but gca was more important. The sca was not important with regard to earliness and mean single fruit weight. Line PS 66 was a good combiner for many characters.

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.

Prudek and Wolf (1985) reported lines and crosses with high gca and sca estimates on the basis of a diallel analysis of data on four yield components in crosses involving five lines of cucumber. The Lines, PS 66 and PS 13 were reported as best combiners for all the characters. The sca variance was significant for mean fruit weight.

Seven cultivars of cucumber were crossed in all possible combinations by Musmade and Kale (1986) and observed that both gca and sca variances were significant for all the characters except yield per vine. Frederick and Staub (1989) following evaluation of nine cucumber lines for six traits reported significant gca estimates for all the traits. The sca was significant for days to anthesis. The lines, W

12963 and 4H 261 had the highest gca estimates as male and female parents, respectively, for total yield and primary branches, but gca estimate for fruit size was the lowest. In cucumber Hormuzdi and More (1989) studied combining ability on nine yield components in twelve genotypes and their F_1 hybrids and reported that SR 551 F as the best combiner for a number of characters. The genotypes SR 551 F and Japanese Long Green were the best combiners for highest yield.

Rastogi and Deep (1990a) reported the role of non additive genes for the expression of traits *viz.* vine length, primary branches per plant, male flower per plant and days to fruit maturity in cucumber. Solanki and Shah (1990) revealed significant contribution of gca and sca variances at varied proportions and magnitudes for yield contributing characters in cucumber Balam Kheera and Hinrekha were good combiners. 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 gca for all the characters except for branches per vine, specific leaf weight, specific leaf area and cavity size in cucumber. The sca was significant 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.

Combining ability of 10 quantitative characters were estimated from parents and F_1 data of a diallel set of 10 **muskmelon** cultivars. Both gca and sca variance seemed to be important, however gca variance contributed major part of genetic variation indicating the predominance of additive genetic variance (Chadha and

Nandpuri, 1980). Kalb and Davis (1984) crossed 6 cultivars of bush muskmelon in all possible combinations and observed that gca variance exceeded sca variance for all fruit quality traits. In a diallel cross involving 10 varieties, Swamy and Dutta (1985) observed the significance of gca and sca effects for fruit ascorbic acid content indicating the importance of both additive and non additive gene effects. A ten parent diallel cross excluding reciprocals was carried out to study the control of TSS content in muskmelon by Swamy and Dutta (1993) indicating the importance of both additive and dominance affect, the latter being predominant. Kuti and Ng (1989) observed significance of gca variance for muskmelon tolerance to disease and toxin and significance of sca for inoculations involving pathogen.

In **watermelon** gca variance exceeded sca variance for yield and yield characters suggesting control by additive genes. Dominance and epistatic effects were important for length of growth period and for seed number and weight (Dyustin and Prosvirnin, 1979). In a preliminary analysis of combining ability in watermelon Li and Shu (1985) observed that for Brix value, fruit weight, fruit number per plant, pericarp thickness and hardness, gca effects were significant. Significant sca effects were also seen for Brix value and fruit weight. In a study of crosses among 14 lines of watermelon by Gill and Kumar (1988), 'Shipper' was a good combiner for yield and fruit weight and 'Sugarbaby' for days to maturity and fruit number per plant.

Combining ability analysis in **Pumpkin** using 10 parental diallel cross by Sirohi *et al.* (1988) the sca variance exceeded gca variance components for all characters except vine length. It is concluded that the superior performance of hybrid with high sca was due to epistatic effects. Diallel analysis of 36 F_1 hybrids of pumpkin showed overdominance for vine length, fruits per plant, fruit size index and fruit flesh thickness and dominant gene action for fruit weight and yield per plant (Sirohi, 1993).

Korzeniewska and Nierricrowicz (1994) studied the combining ability in **wintersquash** and observed high gca values for all yield components while significant sca were noted for fruit yield. Semibush line 144 (Ispanskaya x Emerald Squash) was the best combiner for dry matter content.

In a diallel cross of six varieties of **orientalmelon,** Om *et al.* (1987) observed that gca was important for fruit weight, soluble solids content, flesh firmness, days to maturity and yield per plant. Non allelic interaction was evident in the control of total soluble solids.

2.3.2 Heterosis

Varghese and Rajan (1993b) studied the heterosis of 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.

In **bittergourd** Lawande and Patil (1990) found heterosis for yield per vine and other yield related characters. An analysis of diallel cross using nine varieties of bittergourd by Mishra *et al.* (1994) indicated a high level of heterosis for fruits per plant, fruit length, breadth, weight and yield. The hybrid Coimbatore Long x Gadabeta and Tiansi x Gadabeta had high heterosis over the better parental value.

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. In an experiment conducted by Ram *et al.* (1997) with 11 parents and 24 F_1's in bittergourd the performance of cultivated lines were superior to the wild lines. The result indicated that fruits per plant and yield per plant were the most heterotic characters. High positive heterosis over better parent was observed in the cross IC – 50516 x VRBT-77 for fruits per plant and in crosses Narendra x VRBT-47 and IC 50516 x VRBT-77 for yield per plant.

The manifestation of heterosis in **bottlegourd** was observed by Pal *et al.* (1984) for rapid germination , earlier fruit maturity, flesh thickness, higher early yields and long harvesting period. Studies on heterosis for quantitative characters in bottlegourd by Janakiram and Sirohi (1992) revealed significant values over the better parent for yield and yield attributes. Heterosis for yield components was estimated in a 11 line x 3 tester cross of bottlegourd varieties and the cross Summer Long Green Sel 2 x Faizabadi Long had the highest heterosis over the control cultivar PSPL for number of fruits and total yield per plant. For fruit length Hisar Local 2 Sel x PSPL had the highest heterosis over the control cultivar.[Sharma *et al.* (1995)].

Hayes and Jones (1916) were the first to observe heterosis in **cucumber.** Hybrid vigour was expressed in total yield and the increased yield was due to large number of fruits per plant. The highest yielding hybrid out yielded the better parent by 30 percent.

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

Heterosis ranged from 15.34 per cent for fruit diameter to 59.22 per cent for fruit shape index in cucumber (Imam *et al.*, 1977). Heterobeltiosis was observed for fruit weight per plant and main stem length.

Solanki *et al.* (1982) observed heterosis in cucumber over better parent for primary branches (25.26%), secondary branches (43.60%), female flowers (50.95%), average fruit weight (33.33%), fruits per plant (42.12%) and fruit yield (83.81%). They also observed pronounced heterosis over better parent in a similar study for the above characters. Days to maturity had maximum negative heterosis, while plant height had no heterosis.

Nikulenkova (1984) studied heterosis in cucumber and reported heterosis over standard parent for earliness and fruit yield. Musmade and Kale (1986) reported heterosis in cucumber and the hybrids P_1 x P_6 , P_3 x P_4 and P_5 x P_7 were the most promising since these hybrids recorded 135.47, 56.42 and 54.72 per cent higher yield per vine over better parent respectively.

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). Delancy and Lower (1987) reported significant heterosis of the F_1 over the mean parental values for fruit yield and four plant traits in cucumber. Heterosis over better parent was observed for average internode length.

Among the progenies from crosses between gynoecious maternal lines and hermaphrodite pollen parents, Aleksandrova (1988) noticed 2 hybrids of cucumber Vikhra (TS 1 x 13) and Lora (TS 3 x 13) showing significant heterosis for fruit yield, fruit size and other quality traits.

Hormuzdi and More (1989) reported heterosis for various economic characters except for total yield in crosses involving gynoecious, monoecious and gynomonoecious lines of cucumber in both summer and rainy seasons. Good combinations were W 12757 x RK 5295 and Poinsette x RK 5300 for the rainy season and SR 551F x Balam, SR 551F x Japanese Long Green and SR 551 F x Poanakhera for the summer season. Lack of heterosis for total yield was attributed to inability of the F_1 hybrids to sustain production over late period of harvesting.

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 fruit yield per vine in a 9 x 9 diallel analysis in cucumber.

In a study of heterosis over better parent and superiority over top parent for earliness, yield and its components in cucumber, maximum heterosis over better parent with 77.6 per cent superiority over top parent was evidenced in 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, heterotic over standard variety for early and total yield, vine length, average fruit weight, fruit quality and disease resistance. Heterosis for early and total yield was over 30 per cent. Musmade *et al.* (1995) evaluated 54 F_1 hybrids along with parents to study the extent of heterosis and observed significant and positive heterosis for yield and its contributing characters. They reported greatest heterosis over better parent for yield and its contributing characters. It was greatest for yield per vine and least for flesh thickness. The percentage of heterosis for yield per vine ranged from –46.79 to 106.37. The hybrid L_6 x T_3 recorded the highest per cent heterosis for yield per vine over better parent.

Shakhanov (1973) studied heterosis in complex **melon** hybrids and observed heterosis for number of fruits per plant and size of fruits in most single crosses and for number of fruits per plant in complex crosses.

In **muskmelon,** More and Seshadri (1980) studied the performance of F_1 hybrids involving 2 monoecious lines as female parents and 6 hybrids showed significant heterosis over better parent for earliness, yield and quality. Dixit and Kalloo (1983) in muskmelon, observed heterosis over the better parent for fruit number per plant and stem length. The highest negative favourable heterosis was observed over the better parent for cavity length in Arka Jeet x Sarada Melon. 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 solvents, net density and to a lesser extent amount of flesh, rind thickness, amount of cavity and cavity dryness. F_1 hybrids derived from a half diallel cross among six genotypes in muskmelon were grown along with their parents and evaluated for yield and its contributing characters and appreciable heterosis was recorded over better parent and top parent for all characters studied except total soluble sugar (Munshi and Verma, 1997).

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

Doijode *et al.* (1983) studied certain seed characters in a 7 x 7 diallel cross of **pumpkin** and observed heterosis for seed number, seed weight per fruit, 100 seed weight and seed size index. Additive gene action was also found predominant for all four characters. In a study on heterosis in pumpkin Doijode and Sulladmath (1984) reported that the cross IHR 6 x CM 12 showed heterosis for fruit characters.

In **summersquash** Kasrawi (1994) studied yield and yield components and heterosis was observed over the midparental value for yield traits but was negative for flowering traits. Heterosis over superior parent was also negative for flowering and positive for yield, fruit number and fruit set.

MATERIALS AND METHODS

III. MATERIALS AND METHODS

The present study was conducted to estimate the combining ability and heterosis in snakegourd and thereby to identify suitable parental lines for production of commercial hybrid varieties in snakegourd. The investigation was carried out at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during the period from 1997 to 1999.

3.1 Materials

The experimental material consisted of 6 varieties identified as most divergent in a D^2 analysis by Mathew (1996) previously conducted in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani. The varieties are

P_1. Nedumangad local

P_2. Thrikkannapuram local

P_3 Kanhangad local – 3

P_4 Vlathankara local

P_5 Kaumudi

P_6 Idukki local

Selfed seeds of these varieties were utilized for producing single crosses by crossing in diallel fashion excluding reciprocals.

3.1.1 Production of seed materials

Hybrid seeds were produced, by first covering the mature male and female flower buds with butter paper cover on the previous day of its anthesis. Then on the following day between 6.30 and 9.00 am pollen was collected from the protected male flowers of one variety and used to pollinate the protected female flowers in another variety. Thus hybrid seeds were produced in all possible combinations except reciprocals. Selfing was also done in the six parents by collecting the pollen from the protected male flowers and dusting them on the stigma of the protected female flowers of the same plant. After crossing and selfing, the butter paper cover was replaced over the female flower and labelled. The cover was removed after 2-3 days. The mature fruits were harvested, seeds extracted, cleaned, dried and stored in separate packets.

Crossed seeds of fifteen single crosses and selfed seeds of the parents were used for evaluating combining ability and estimation of heterosis.

3.2 Experimental techniques

3.2.1 Design and layout

The six parents and fifteen hybrids were evaluated in a randomised block design with three replications. In each replication four pits per treatment spaced 2 m apart were taken. The sowing was taken up on 27/11/1998. Single plant was grown in each pit.

3.2.2 Cultural practices

The cultural and management practices were followed according to the package of practice recommendations (KAU, 1996) of the Kerala Agricultural University.

3.2.3 Biometric observations

The following observations were made in each plant adopting standard procedures and average was worked out for each replication.

3.2.3.1 Days to first male flower

Number of days taken from sowing to the bloom of the first male flowers in each plant was recorded.

3.2.3.2 Days to first female flower

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

3.2.3.3 Days to first fruit harvest

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

3.2.3.4 Number of female flowers

Total number of female flowers bloomed during the life of each plant.

3.2.3.5 Number of fruits per plant

Total number of fruits produced on a single plant was recorded.

3.2.3.6 Mean weight of fruit

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

3.2.3.7 Fruit yield per plant

The total fruit yield of four treatment plants in each replication was computed and the average was worked out and expressed in kilograms.

3.2.3.8 Fruit length

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

3.2.3.9 Fruit girth

The girth of fruits were measured from fruits selected for recording fruit length, mean worked out and expressed in centimetres.

3.2.3.10 Flesh thickness

Each fruit taken to record the above two observations was cut at the middle, the thickness of the flesh measured and the mean recorded is centimetres.

3.2.3.11 Number of seeds per fruit

The seeds were taken from fifteen fruits at random and the total number was counted and averaged and recorded.

3.2.3.12 100 seed weight

One hundred well dried seeds taken at random from each treatment were weighed and expressed in grams.

3.2.3.13 Duration of the crop

The number of days taken by the plant from germination to the harvest of the last fruit was recorded to get the duration of the crop.

3.2.3.14 Vine length

The length of the vine of each plant was recorded at the time of the last harvest and expressed in centimetres.

The colour of fruits was graded on a scale from 1 (full white) to 6 (full green) (Table 4). Control measures were adopted as and when required and hence incidence of pest and disease was less and no scoring was done.

3.3 Statistical analysis

Data from the parents and hybrids were subjected to statistical analysis.

Preliminary analysis was carried out as in the case of RBD experiment, making use of 15 treatments consisting of p = 6 parents and p (p-1) / 2 = 6 x 5/2 = 15 F_1s. The data collected were subjected to Analysis of variance. If the genotypic differences were significant, combining ability analysis was performed with mean values.

Table: 1 Analysis of variance for each character

Source of variation	Degrees of freedom	Mean squares	F
Replication	(r-1)	MSR	MSR/MSE
Treatments	(v-1)	MST	MST/MSE
Error	(r-1) (v-1)	MSE	
Total	(vr-1)		

Where

r = Number of replications

v = Number of treatments

MSR = Replication mean square

MST = Treatment mean square

MSE = Error variance and

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

where t_α is the students t table value for α(0.5 or 0.1) per cent level of significance corresponding to the error degrees of freedom.

3.3.1 Estimation of variance components

The variance components were calculated according to the method of Johnson *et al.* (1955).

a) Genotypic variance σ_g^2 = $\frac{MST - MSE}{r}$

b) Environmental variance σ_e^2 = MSE

c) Phenotypic variance σ_p^2 = $\sigma_g^2 + \sigma_e^2$

3.3.2 Coefficient of variation

Phenotypic and genotypic coefficients of variation (PCV and GCV) were estimated to study the variability that existed in the population (Singh and Chaudhary, 1985).

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

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

Where σ_g = Genotypic standard deviation

σ_p = Phenotypic standard deviation

$\bar{x}$ = Population mean

3.3.3 Heritability (broad sense)

To estimate the proportion of heritable component of variation heritability (h^2) was calculated.

$$h^2 = \frac{\sigma_g^2 \times 100}{\sigma_p^2}$$

Where h^2 is the heritability expressed in percentage

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

To estimate the change in the mean genotypic level of the population brought about by selection genetic advance (GA) is calculated as

$$GA = kh^2 \frac{\sigma_p}{\bar{X}} \times 100$$

Where k is the selection differential with values 2.06 at 5% and 1.76 at 10%, selection intensity.

3.3.4 Combining ability analysis

The combining ability analysis was carried out after arranging the data on per unit basis.

Table 2. Analysis of variance of combining ability

Source	df	MS	E(Ms) Expectation of mean squares
genotypes	$p + p\frac{(p-1)}{2} - 1$	M	$\sigma^2 e + \sigma^2 g$
gca	p-1	Mg	$\sigma^2 e + \sigma^2 sca + (p+2)\, \sigma^2\, gca$
sca	$p\frac{(p-1)}{2}$	Ms	$\sigma^2 e + \sigma^2 sca$
Error	$\left(p + \frac{p(p-1)}{2} - 1\right)(r-1)$	Me	$\sigma^2 e$

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

MSE = Error mean square

r = Number of replications

p = Parents

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

General combing ability (g_i) = $\frac{1}{p+2} \left\{ \Sigma (y_{i\cdot} + y_{ii}) - \frac{2y_{..}}{p} \right\}$

Specific combing ability effect of ixjth cross,

$$S_{ij} = Y_{ij} - \frac{1}{p+2} [y_{i\cdot} + y_{ii} + y_{\cdot j} + y_{jj}] + \frac{2y_{..}}{(p+1)(p+2)}$$

Where y_{ij} = Mean of character with respect to $(_{ixj})^{th}$ cross over the three replication

$y_{i\cdot}$ = Total of mean value (over replication) corresponding to $_i^{th}$ parent over the other crosses involving $_i^{th}$ parent

$y_{\cdot j}$ = Total of mean values corresponding to $_j^{th}$ parent over the other crosses involving $_j^{th}$ parent.

$y_{..}$ = Total of all mean values.

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

$$SE\,[g_i] = \left(\frac{p-1}{p\,(p+2)} Me \right) ½$$

$$SE\,(s_{ij}) = \left(\frac{2\,(p-1}{(p+1)\,(p+2)} Me \right) ½$$

SE for the difference of gca and sca effects are

$$SE\,(g_i\text{-}g_j) = \left(\frac{2}{(p+2)} Me \right) ½$$

$$SE\,(s_{ii}\text{-}s_{jj}) = \left(\frac{2\,(p-2)}{p+2} Me \right) ½$$

$$SE\,(s_{ij}\text{-}s_{ik}) = \left(\frac{2 \times (p+1)}{(p+2)} Me \right) ½$$

$$SE\,(s_{ij}\text{-}s_{kl}) = \left(\frac{2p}{(p+2)} Me \right) ½$$

CD = SE x t (table value at error df)

The significance of gca effect implies that additive heritable variance is responsible for variation for the observed character. The significance of sca effect reveals the importance of non-additive variance for the inheritance of the character.

Components of variance for the gca and sca effects were estimated as

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

$$\sigma^2 sca = Ms - Me$$

The additive variance $\sigma^2 a = 2\sigma^2 gca$

dominance variance $\sigma^2 d = \sigma^2 sca$

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

3.3.5 Heterosis

The mean values over the three replications of each parent and hybrid for each character were taken for the estimation of heterosis. Heterosis was calculated as the percent deviation of the mean performance of F_1s from its midparent (MP), better parent (BP) and standard parent, (SP) for each cross combination

(1) Deviation of the hybrid mean from the mid parent value

$$\text{(Relative heterosis) [RH]} = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

(2) Deviation of the hybrid mean from the better parental value

(Heterobeltiosis) HB = $\frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$

(3) Deviation of the hybrid mean from the standard parental value

(Standard heterosis) SH = $\frac{\overline{F_1} - \overline{SP}}{\overline{SP}} \times 100$

For each character, the average value of the two parents involved in each cross combination was taken as the mid parental value (MP) and the superior one between the parents in each cross as better parental value (BP). The variety Kaumudi was taken as standard parent (SP).

To test the significance of difference of F_1 mean over mid and better parent, critical difference (CD) was calculated from their standard error of differences as mentioned below.

To test the significance over mid parent

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

To test the significance over better parent and standard parent

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

Where t_α = table value for error df

MSE = Error mean square

r = Number of replications.

RESULTS

IV RESULTS

The data on all the characters in snakegourd recorded from the experiment except colour of fruit and pest and disease incidence was statistically analysed.

4.1 Mean Performance

The analysis of variance of different characters was done and the genotypes exhibited significant difference with respect to all the characters. The mean performance of the six parents and fifteen hybrids for various characters are presented in Table 3.

4.1.1 Days to first male flower

The mean ranged from 28.75 (P_6) to 35.17 (P_3) among the parents. Among hybrids the mean in the character ranged from 25.5 (P_4 x P_6) to 28.75 (P_4 x P_5). The hybrids P_1 x P_6 (25.67), P_3 x P_6 (26.17) and P_2 x P_6 (26.42) were on par with P_4 x P_6.

4.1.2 Days to first female flower

The mean ranged from 44.42 (P_6) to 54.92 (P_3) among the parents. Among hybrids the minimum number of days to first female flower was recorded in P_4 x P_6 (36.58) and the maximum in P_1 x P_3 (41.25). The hybrids P_5 x P_6 (36.83), P_2 x P_6 (36.75) and P_3 x P_6 (37.00) were on par with P_4 x P_6.

Table 3. Mean performance of genotypes

Treatments	Days to first male flower	Days to first female flower	Days to first fruit harvest	No. of female flowers	No. of fruits per plant	Mean weight of fruits	Fruit yield per plant	Fruit length	Fruit girth	Flesh Thickness	No. of seeds per fruit	100 seed weight	Duration of Crop	Vine length
P1	32.58	50.83	77.50	49.00	17.33	973.7	19.01	100.75	21.76	1.09	73.92	27.96	121.07	5.71
P2	33.92	52.67	76.67	60.00	16.92	959.5	18.11	83.31	25.81	1.24	83.07	31.77	123.80	6.02
P3	35.17	54.92	79.17	48.5	17.58	953.2	18.67	75.69	22.82	1.84	70.81	25.39	119.50	5.23
P4	30.75	48.58	75.33	54.67	16.58	960.8	18.81	92.59	21.79	1.44	78.27	24.3	98.80	6.20
P5	32.25	49.67	76.17	41.08	17.67	1064.2	20.81	93.72	18.38	1.44	104.12	26.05	120.97	5.94
P6	28.75	44.42	73.33	47.38	15.17	924.5	17.14	119.42	17.32	0.95	104.35	23.1	148.43	6.71
P1 X P2	26.58	41.00	70.17	63.75	24.25	1030.9	25.44	98.87	25.59	2.25	96.23	32.4	114.57	6.26
P1 X P3	27.93	41.25	67.00	66.08	26.25	1085.2	27.81	94.96	24.73	2.17	118.88	23.02	115.30	7.61
P1 X P4	26.08	37.92	72.83	64.17	25.25	1068.2	28.52	106.24	21.66	2.21	111.62	31.67	103.60	5.59
P1 X P5	26.92	40.92	70.17	68.33	26.58	1245.2	31.79	109.51	26.98	2.10	90.88	32.42	117.10	6.40
P1 X P6	25.67	38.08	67.50	66.00	25.25	1094.3	26.78	124.73	26.22	2.01	113.12	28.58	128.20	7.10
P2 X P3	27.42	41.00	70.83	55.33	22.17	1119.2	26.56	100.46	25.70	2.16	95.16	31.86	121.40	5.79
P2 X P4	27.75	40.08	68.83	67.17	22.75	1141.9	26.50	100.53	28.39	2.01	84.04	31.97	106.52	5.71
P2 X P5	27.75	38.92	70.83	69.08	27.17	1208.4	30.06	112.75	28.09	2.27	116.92	32.58	118.30	5.19
P2 X P6	26.42	36.75	70.67	72.75	25.67	1095.7	29.78	125.30	25.01	2.28	105.51	32.22	129.17	6.34
P3 X P4	27.67	40.42	70.67	76.17	26.00	1090.5	28.75	100.30	27.18	2.21	104.95	31.84	108.87	5.51
P3 X P5	28.00	38.58	70.33	65.50	25.50	1,243.00	29.73	100.52	27.32	2.18	114.79	31.42	118.03	5.49
P3 X P6	26.17	37.00	72.00	67.33	25.17	1075.1	28.41	123.06	27.19	2.15	118.41	25.15	124.93	6.03
P4 X P5	28.75	40.25	68.00	66.67	24.58	1040.1	25.66	113.51	27.97	2.10	113.53	23.18	113.67	7.30
P4 X P6	25.50	36.58	68.83	67.92	23.33	1025.8	24.72	123.37	23.68	2.01	106.45	29.31	125.23	6.72
P5 X P6	26.75	36.83	71.17	54.00	26.92	1119.2	28.82	124.02	25.44	1.94	103.35	25.11	124.53	5.67
MSE	0.33	0.599	7.195	10.014	1.347	0.21	1.156	20.791	1.898	0.004	54.966	1.274	10.623	0.3487
CD	0.952	1.277	4.426	5.222	1.915	0.756	1.774	7.526	2.274	0.110	12.233	1.862	5.379	0.974

4.1.3 Days to first fruit harvest

Among the parents, the mean values of days to first fruit harvest ranged from 73.33 in P_6 to 79.17 in P_3. The hybrid P_1 x P_3 had the lowest number of days to first fruit harvest (67.00) and P_1 x P_4 had the highest (72.83). The hybrids P_1 x P_6 (67.50), P_4 x P_5 (68.00), P_2 x P_4 (68.83), P_4 x P_6 (68.83), P_1 x P_2 (70.17), P_1 x P_5 (70.17), P_3 x P_5 (70.33), P_2 x P_6 (70.67), P_3 x P_4 (70.67), P_2 x P_3 (70.83), P_2 x P_5 (70.83), P_5 x P_6 (71.17), P_3 x P_6 (72.00) were on par with P_1 x P_3.

4.1.4 Number of female flowers

The mean value for the minimum number of female flowers was observed on the parent P_5 (41.08) and the maximum in P_2 (60.00). The hybrid P_3 x P_4 (76.17) had the maximum number of female flowers and the minimum number was observed in P_5 x P_6 (54.00). The hybrid P_2 x P_6 (72.75) was on par with P_3 x P_4.

4.1.5 Number of fruits per plant

The parent P_5 (17.67) produced the maximum number of fruits per plant whereas the parent P_6 (15.17) showed the minimum number of fruits per plant. The hybrid P_2 x P_5 (27.17) was the largest producer of fruits and the hybrids P_5 x P_6 (26.92), P_1 x P_5 (26.58), P_3 x P_4 (26.00), P_2 x P_6 (25.67) and P_3 x P_5 (25.50) were on par with this. The hybrid P_2 x P_3 (22.17) produced the lowest number of fruits per plant. All the hybrids had more number of fruits than their parents.

Parents P_1 and P_3 with their hybrids

Parents P_1 and P_4 with their hybrids

Parents P_1 and P_5 with their hybrids

4.1.6 Mean weight of fruits

The average individual fruit weight was found to be highest in the parent P_5 (1064.2g) and the lowest in the parent P_6 (924.5g). The fruits in the hybrid P_1 x P_5 weighed the highest (1245.2 g) and the hybrid P_4 x P_6 (1025.8g) had the lowest mean fruit weight. The mean weight of fruits of all hybrids were superior to those of the parents.

4.1.7 Fruit yield per plant

The parent P_6 (17.14 kg) was the lowest yielder and the parent P_5 (20.81 kg) was the highest yielder. The hybrid P_1 x P_5 (31.79kg) showed the maximum fruit yield per plant and P_4 x P_6 (24.72kg) showed the minimum fruit yield per plant. The hybrid P_2 x P_5 alone (30.06kg) was on par with the hybrid P_1 x P_5. All the hybrids were better yielders where compared to the parents.

4.1.8 Fruit length

Among parents, the fruits in P_3 (75.69 cm) were the shortest and that in P_6 (119.42 cm) were the longest. Among the hybrids P_1 x P_3 (94.96 cm) showed the minimum fruit length and the hybrid P_2 x P_6 (125.30 cm) had the maximum fruit length. The hybrids P_1 x P_6 (124.73 cm), P_5 x P_6 (124.02 cm), P_4 x P_6 (123.37 cm), P_4 x P_6 (123.06 cm) and P_1 x P_2 (119.42 cm) were on par with P_2 x P_6.

Parents P_1 and P_6 with their hybrids

Parents P_2 and P_4 with their hybrids

Parents P_2 and P_5 with their hybrids

4.1.9 Fruit girth

The girth of fruit was maximum in the parent P_2 (25.81 cm) and the girth was minimum in P_6 (17.32 cm). Among hybrids P_1 x P_4 recorded the least mean value for fruit girth (21.66 cm) and P_2 x P_4 had the highest value (28.39 cm). The hybrids P_1 x P_5 (26.98 cm), P_2 x P_4 (28.39 cm), P_2 x P_5 (28.09cm), P_4 x P_5 (27.97 cm), P_3 x P_5 (27.32 cm), P_3 x P_6 (27.19 cm), P_3 x P_4 (27.18 cm) and P_1 x P_6 (26.22 cm) were on par with P_2 x P_4.

4.1.10 Flesh thickness

The fruits in the parent, P_3, had the thickest flesh (1.84 cm) while those in P_6 were the thinnest (0.95 cm). In the hybrids, P_2 x P_6 had the maximum thickness (2.28cm) whereas P_5 x P_6 had the minimum thickness (1.94 cm). The hybrids P_2 x P_5 (2.27cm), P_1 x P_2 (2.25 cm), P_1 x P_4 (2.21 cm), P_3 x P_4 (2.21 cm), P_3 x P_5 (2.18 cm) and P_1 x P_3 (2.17 cm) and were on par with P_2 x P_6.

4.1.11 Number of seeds per fruit

Among parents the number of seeds produced per fruit was minimum in P_3 (70.81) and the maximum in P_6 (104.35). Among the hybrids, P_2 x P_4 showed the lowest number of seeds per fruit (84.04) whereas P_1 x P_3 showed the maximum (118.88). The hybrids P_3 x P_6 (118.41), P_2 x P_5 (116.92), P_3 x P_5 (114.79), P_4 x P_5 (113.53), P_1 x P_6 (113.12) and P_1 x P_4 (111.62) were on par with P_1 x P_3.

Parents P_2 and P_6 with their hybrids

Parents P_3 and P_4 with their hybrids

Parents P_3 and P_5 with their hybrids

Parents P_3 and P_6 with their hybrids

4.1.12 100 seed weight

Among the parents P_6 recorded the minimum 100 seed weight (23.10g) and P_2 recorded the maximum (31.77g). The minimum 100 seed weight was observed in P_1 x P_3 (23.02g) and the highest in the hybrid P_2 x P_5 (32.58 g). The hybrids P_1 x P_5 (32.42g), P_1 x P_2 (32.40g), P_2 x P_6 (32.22g), P_2 x P_4 (31.97g), P_2 x P_3 (31.86g), P_3 x P_4 (31.84g), P_1 x P_4 (31.67g) and P_3 x P_5 (31.42g) were on par with P_2 x P_5.

4.1.13 Duration of the crop

The parent P_6 took the maximum number of days (148.43) from germination to harvest of the last fruit while P_4 (98.80) recorded the minimum days. Longest duration (129.17 days) was recorded in the hybrid P_2 x P_6 and the shortest duration (103.6 days) in P_1 x P_4. The hybrids P_2 x P_4 (106.52) and P_3 x P_4 (108.87) were on par with P_1 x P_4.

4.1.14 Colour of the fruit

The genotypes were graded for fruit colour according to a score ranging from 1 to 6. The score of each parent and hybrid are given in the table:

Table 4. Colour of the Fruit

Treatments	Score		
P_1	1	1.	Full white
P_2	1	2.	White with <25% green
P_3	5	3.	White with 25 - 50% green
P_4	2	4.	Green with 25 - 50% white
P_5	1	5.	Green with <25% white
P_6	2	6.	Full green
$P_1 \times P_2$	1		
$P_1 \times P_3$	5		
$P_1 \times P_4$	2		
$P_1 \times P_5$	1		
$P_1 \times P_6$	2		
$P_2 \times P_3$	2		
$P_2 \times P_4$	2		
$P_2 \times P_5$	1		
$P_2 \times P_6$	1		
$P_3 \times P_4$	1		
$P_3 \times P_5$	2		
$P_3 \times P_6$	2		
$P_4 \times P_5$	2		
$P_4 \times P_6$	2		
$P_5 \times P_6$	2		

4.1.15 Pest and disease score

Control measures against pests and diseases were taken up as and when required. Thus scoring for pests or diseases was not carried out.

4.1.16 Vine length

The parent P_6 had the longest vine (6.71m) and P_3 the shortest (5.23m). Among hybrids P_1 x P_3 had the longest vine length (7.61m) and the hybrids P_4 x P_5 (7.3 m), P_1 x P_6 (7.1), P4 x P_6 (6.72 m) and P_1 x P_2 (6.71 m) and were on par with this. The hybrid P_2 x P_5 had the least vine length (5.19 m).

4.2 PCV, GCV Heritability and Genetic Advance

PCV ranged from 5.63 for days to first fruit harvest to the maximum of 21.83 for flesh thickness. The characters, number of fruits per plant, mean weight of fruit and fruit yield per plant had the PCV values 18.23, 9.19 and 18.52 respectively. The character days to first fruit harvest (4.22) had the lowest GCV value and the character flesh thickness (21.56) had the highest GCV value. For all the characters studied, the closer values of PCV and GCV were observed indicating the predominant influence of genetic component over the environmental effect in its phenotype.

The highest heritability value was recorded in the character days to first female flower (98.152). The lowest heritability value was recorded in the character vine length (48.37).

Days to first male flower (95.863) days to first female flower (98.152) fruit length (90.33) fruit yield per plant (94.75), flesh thickness (97.35), number of fruit per plant (22.22), 100 seed weight (91.12) and duration of crop (90.79) had high heritability values. All these characters also have high genetic advance values indicating that selection for these characters will be effective.

The maximum genetic advance at 5% was observed in the character flesh thickness (43.78) and the least genetic advance was observed in days to first fruit harvest (6.5).

4.3 Genetic components of variance

The genetic components of variance viz. additive variance (σ^2A) and dominance variance (σ^2D) are presented in table 7.

For all characters except fruit length and duration of crop, dominance variance was greater than additive variance. The ratio of additive to dominance ratio was more than unity for fruit length (1.16) and duration of crop (7.38).

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

No.	CHARACTERS	PCV	GCV	H^2	GA
1.	Days to first male flower	9.91	9.70	95.86	19.57
2.	Days to first female flower	13.49	13.36	98.15	27.27
3.	Days to first fruit harvest	5.63	4.22	56.03	6.50
4.	Number of female flowers	15.72	14.85	89.28	28.91
5.	Number of fruits per plant	18.23	17.50	92.22	34.63
6.	Mean weight of the fruit	9.19	8.14	78.42	14.85
7.	Fruit yield per plant	18.52	18.03	94.75	36.15
8.	Fruit length	13.85	13.16	90.33	25.77
9.	Fruit girth	13.32	12.09	82.5	22.64
10.	Flesh thickness	21.83	21.54	97.35	43.78
11.	Number of seeds per fruit	16.11	14.32	78.98	26.21
12.	100 seed weight	13.20	12.60	91.12	24.78
13.	Duration of crop	9.01	8.59	90.79	16.86
14.	Vine Length	13.41	9.33	48.37	13.37

Table 6. Analysis of variance for combining ability effects for various characters

No.	Character	Mean Squares		
		gca	sca	Error
1.	Days to first male flower	5.78*	8.42*	0.11
2.	Days to first female flower	17.82*	36.75*	0.19
3.	Days to first fruit harvest	2.21^{NS}	14.69*	2.39
4.	Number of female flowers	26.14*	103.55*	3.34
5.	Number of fruits/plant	2.31*	20.99*	0.45
6.	Mean weight of fruit	8.513*	8.247*	0.69
7.	Fruit yield per plant	4.22*	26.9*	0.38
8.	Fruit length	512.22*	97.43*	6.93
9.	Fruit girth	7.22*	10.36*	0.63
10.	Flesh thickness	0.069*	0.20*	0.0015
11.	Number of seeds/fruit	190.27*	236.4*	18.32
12.	100 seed weight	21.39*	10.79*	0.42
13.	Duration of crop	384.88*	16.04*	3.54
14.	Vine length	0.386*	0.46*	0.12

Table 7. Genetic components of variance for various yield components in snakegourd

Sl. No.	Characters	Additive variance (σ^2A)	Dominance variance (σ^2D)	(σ^2A)/ σ^2D
1.	Days to first male flower	-0.661	8.3087	-
2.	Days to first female flower	-4.731	36.5482	-
3.	Days to first fruit harvest	-3.1179	12.2881	-
4.	No. of female flowers	-16.8586	100.2091	-
5.	No. of fruits/plant	-4.6723	20.5487	-
6.	Mean weight of fruit	5.3324	75.4813	0.0707
7.	Fruit yield per plant	-5.6697	26.5179	-
8.	Fruit length	103.6977	90.4925	1.1459
9.	Fruit girth	-6.2906	9.7297	-
10.	Flesh thickness	-0.0355	0.2028	-
11.	No. of seeds/fruit	-11.5339	218.0834	-
12.	100 seed weight	2.6488	10.3699	0.2554
13.	Duration of crop	92.2096	12.4983	7.377
14.	Vine length	-0.0185	0.3444	-

Table 8. The general combining ability effects of parents for various characters

Character	P1	P2	P3	P4	P5	P6	SE (gi)	CD (5%)	CD (1%)	SE (gi-gj)	CD (5%)	CD (1%)
Days to first male flower	-0.15	0.52**	0.99**	-0.29**	0.38**	-1.45**	0.107	0.216	0.289	0.166	0.335	0.448
Days to first female flowe	0.66**	0.94**	1.57**	-0.39*	-0.09	-2.68**	0.144	0.292	0.389	0.223	0.452	0.602
Days to first fruit harvest	0	0.25	0.81	-0.35	0.02	-0.73	0.499	1.01	1.347	0.774	1.565	2.09
Number of female flowers	-0.49	2.22**	-0.36	2.64**	-3.07**	-0.94	0.59	1.192	1.593	0.914	1.846	2.468
Number of fruits/plant	0.36	-0.44*	0.11	-0.53*	0.84**	-0.34	0.216	0.437	0.583	0.335	0.677	0.905
Mean weight of fruit	-0.065	0.015	0.021	-0.27**	0.602**	-0.305**	0.085	0.172	0.23	0.132	0.267	0.357
Fruit yield per plant	0.13	-0.34	0.16	-0.69**	1.30**	-0.56	0.2	0.405	0.54	0.31	0.627	0.837
Fruit length	-0.67	-4.58**	-8.82**	-1.51	0.82	14.76**	0.85	1.717	2.295	1.316	2.661	3.553
Fruit girth	-0.54	1.42**	0.59*	-0.69*	-0.06	-1.35*	0.257	0.519	0.694	0.398	0.804	1.075
Flesh thickness	-0.05*	0.01	0.15**	0.01	0.01	-0.13**	0.028	0.057	0.076	0.019	0.039	0.051
Number of seeds/fruit	-3.03*	-4.84**	-1.12	-3.2*	5.61**	6.59**	1.381	2.792	3.729	2.14	4.325	5.778
100 seed weight	0.45*	3.02**	-0.80**	-0.48*	-0.45*	-1.73**	0.21	0.425	0.567	0.326	0.658	0.88
Duration of the Crop	-1.64**	0.45	-0.81	-9.81**	-0.06	11.87**	0.607	1.227	1.639	0.941	1.901	2.541
Vine Length	0.19	-0.19	-0.24*	0.05	0.11	0.31**	0.11	0.222	0.297	0.171	0.345	0.462

Table 9. Specific combining ability effects of hybrids

Hybrids	1 Days to first male flower	2 Days to first female flower	3 Days to first fruit harvest	4 No. of female flowers	5 No. of fruits per plant	6 Mean weight of fruit	7 Fruit yield per plant	8 Fruit length	9 Fruit girth	10 Flesh thickness	11 No. of seeds per fruit	12 100 seed weight	13 Duration of Crops	14 Vine Length
P1 x P2	-2.29**	-2.82**	-1.89**	0.55*	1.56**	-0.36**	0.32**	-1.76**	-0.01NS	0.39**	3.71**	0.30**	-3.39**	0.14**
P1 x P3	-1.42**	-3.20**	-5.62**	5.47**	3.01**	0.18**	2.19**	-1.44**	-0.04NS	0.16**	22.63**	-5.26**	-1.40**	1.54**
P1 x P4	-1.98**	-4.57**	1.38**	0.55*	2.66**	0.29**	3.75**	2.53**	-2.45**	0.35**	17.46**	3.07**	-4.10**	-0.77**
P1 x P5	-1.83**	-1.88**	-1.66**	10.43**	2.62**	1.19**	5.03**	3.48**	2.86*	0.23**	-12.09**	3.79**	-0.35NS	0.2**
P1 x P6	-1.24**	-2.11**	-3.58**	5.97**	2.46**	0.59**	1.88**	4.75**	3.40**	0.29**	9.17**	1.23**	-1.17**	0.48**
P2 x P3	-2.61**	-3.73**	-2.04**	-8.00**	-0.27**	0.44**	1.41**	7.97**	-1.03**	0.09**	0.73NS	1.01**	2.62**	0.11*
P2 x P4	-0.99**	-2.69**	-2.87**	0.83**	0.96**	0.95**	2.21**	0.73*	2.32**	0.08**	-8.30**	0.80**	-3.22**	-0.27**
P2 x P5	-0.67**	-4.16**	-1.25**	8.46**	4.00**	0.75**	3.77**	10.63**	2.01**	0.33**	15.76**	1.38**	-1.24**	-0.63**
P2 x P6	-1.17**	-3.73**	-0.66**	10.00**	3.68**	0.53**	5.36**	9.24**	0.23*	0.49**	3.38**	2.30**	-2.29**	0.1*
P3 x P4	-1.54**	-2.98**	-1.60**	12.42**	3.66**	0.43**	3.95**	4.74**	1.94**	0.14**	8.87**	4.49**	0.34NS	-0.42**
P3 x P5	-1.89**	-5.11**	-2.31**	7.46**	1.78**	1.09**	2.94**	2.63**	2.06**	0.11**	9.91**	4.03**	-0.25NS	-0.27**
P3 x P6	-1.89**	-4.10**	0.11NS	7.16**	2.63**	0.32**	3.48**	11.23**	3.23**	0.22**	12.55**	-0.96**	-5.27**	-0.15**
P4 x P5	0.14NS	-1.49**	-3.48**	5.62**	1.51**	-0.65**	-0.28**	8.32**	3.38**	0.17**	10.73**	-4.52**	4.39**	1.24**
P4 x P6	-1.27**	-2.56**	-1.89**	4.75**	1.44**	0.11**	0.65**	4.23**	0.39**	0.23**	2.67**	2.89**	4.03**	0.25**
P5 x P6	-0.70*	-2.61**	0.07NS	-3.46**	3.65**	0.18**	2.76**	2.55**	2.14**	0.15**	-9.34**	-1.34**	-6.42**	-0.64**
SE (sij)	0.1407	0.0036	0.0428	0.0596	0.008	0.0125	0.0069	0.1238	0.0113	0.00003	0.3272	0.0076	0.0632	0.0021
CD (5%)	0.2845	0.1207	0.4183	0.4935	0.181	0.0714	0.1677	0.7112	0.2148	0.0104	1.1561	0.176	0.5082	0.0921
CD (1%)	0.3799	0.161	0.5600	0.6600	0.2420	0.0955	0.2240	0.9520	0.2870	0.0140	1.5470	0.2350	0.6800	0.1230
SE (sij-sik)	0.4410	0.5913	2.0486	2.4170	0.8864	0.3496	0.8212	3.4831	1.0521	0.0510	5.6624	0.862	2.4893	0.451
CD (5%)	0.8906	1.1949	4.1403	4.8850	1.7913	0.7066	1.6597	7.0393	2.1263	0.1030	11.4440	1.7422	5.031	0.9114
CD (1%)	1.191	1.5965	5.5312	6.526	2.3933	0.944	2.2172	9.4044	2.8407	0.1377	15.2885	2.3274	6.7211	1.2177
SE (sij-skl)	0.4080	0.5474	1.8967	2.2377	0.821	0.3237	0.7603	3.2247	0.9741	0.0472	5.2424	0.7981	2.304	0.4175
CD (5%)	0.8244	1.1064	3.8331	4.5223	1.6585	0.6542	1.5366	6.5172	1.9686	0.0953	10.5950	1.1613	4.6577	0.8438
CD (1%)	1.102	1.478	5.1211	6.0418	2.2167	0.874	2.0528	8.7067	2.6301	0.1274	14.1545	2.1549	6.2224	1.1273

4.4 Combining ability analysis

The analysis of variance of combining ability effects for various characters is presented in Table. 6

Significant differences were observed among treatments for all characters studied (Table 6). Hence the data were subjected to combining ability analysis.

The general combining ability (gca) of parents and specific combining ability (sca) of the hybrids for various characters are presented in Table 8 and Table 9 respectively.

4.4.1 Days to first male flower

Combining ability analysis of the character days to first male flower, showed that variance due to parents and hybrids were significant. Significant positive gca effects were shown by parents P_3 (0.99) P_2 (0.52) and P_5 (0.38).

Significant negative gca effects was shown by parents P_4 ($^-$0.29) and P_6 ($^-$1.45). All hybrids except P_4 x P_5 showed significant negative sca effects (Fig. 1).

4.4.2 Days to first female flower

Variance for the character was significant for both gca and sca effects. Significant positive gca effects were shown by parents P_3 (1.57) P_2 (0.94) and P_1 (0.66) significant negative gca effects were shown by parents P_6 ($^-$2.68) and P_4 ($^-$0.39). All the hybrids showed significant negative sca effects (Fig. 2).

Fig. 1 gca and sca. Days to first male flower

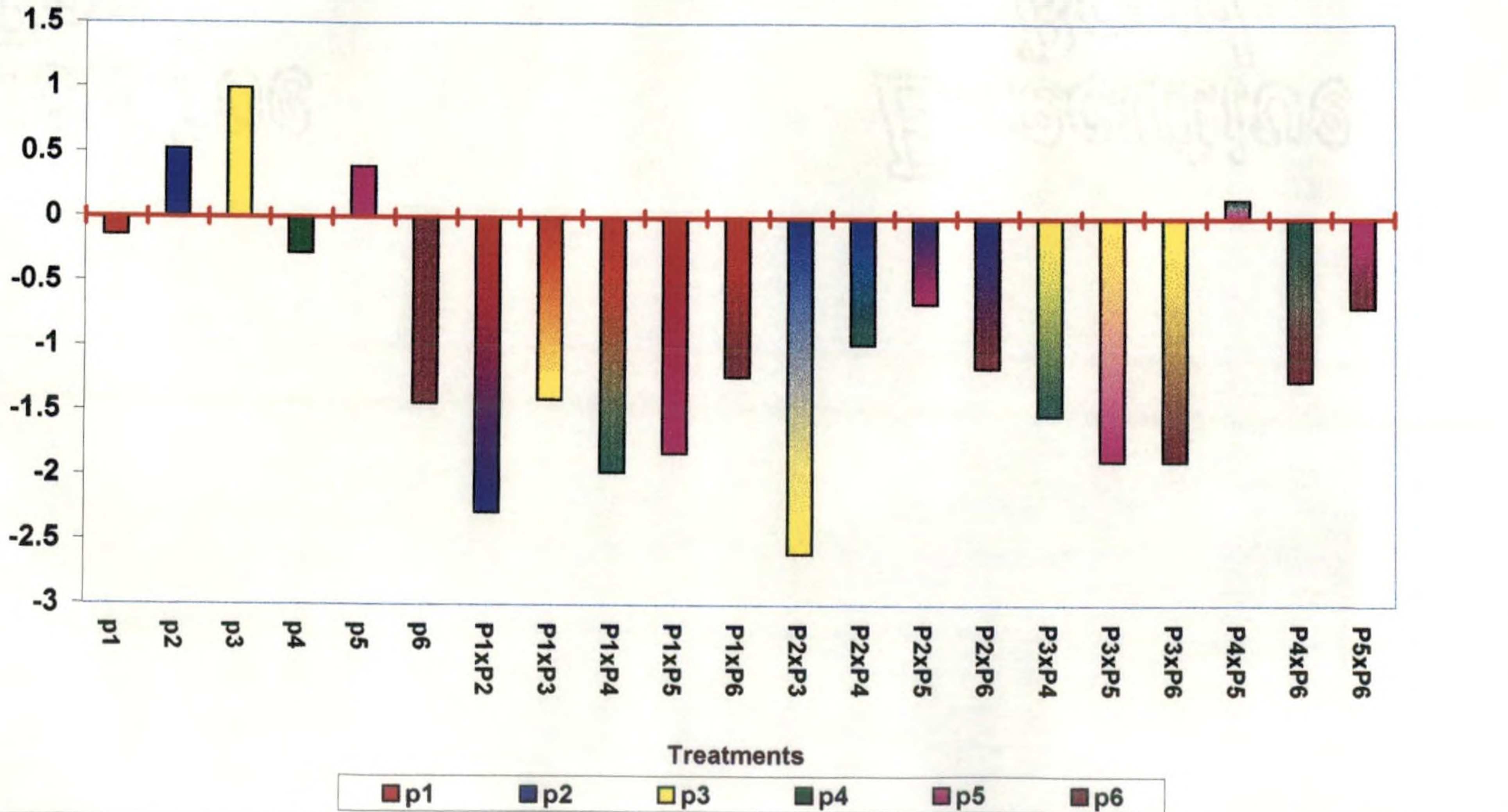


Fig. 2. gca and sca. Days to first female flower

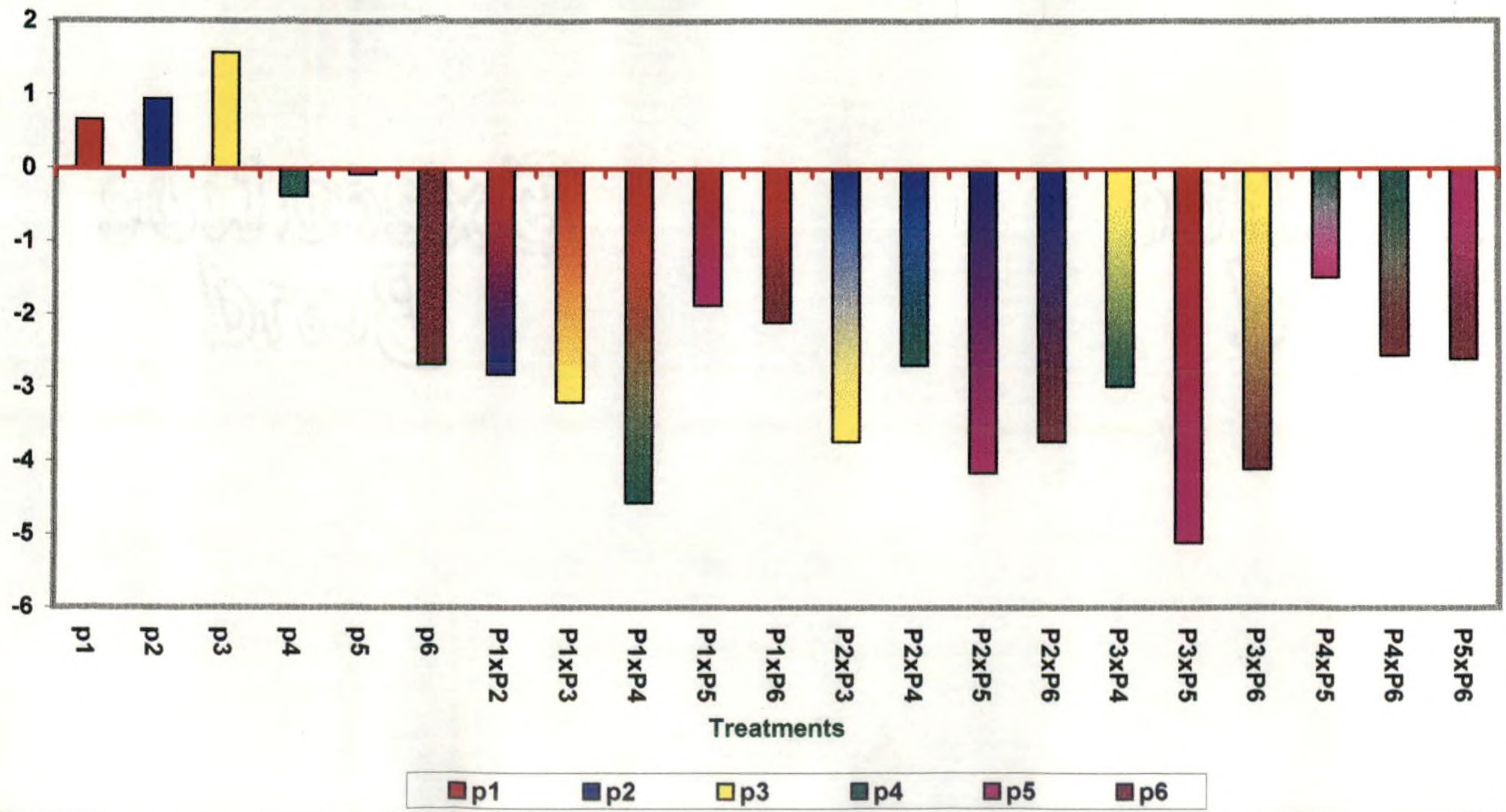


Fig. 3. gca and sca. Days to first fruit harvest

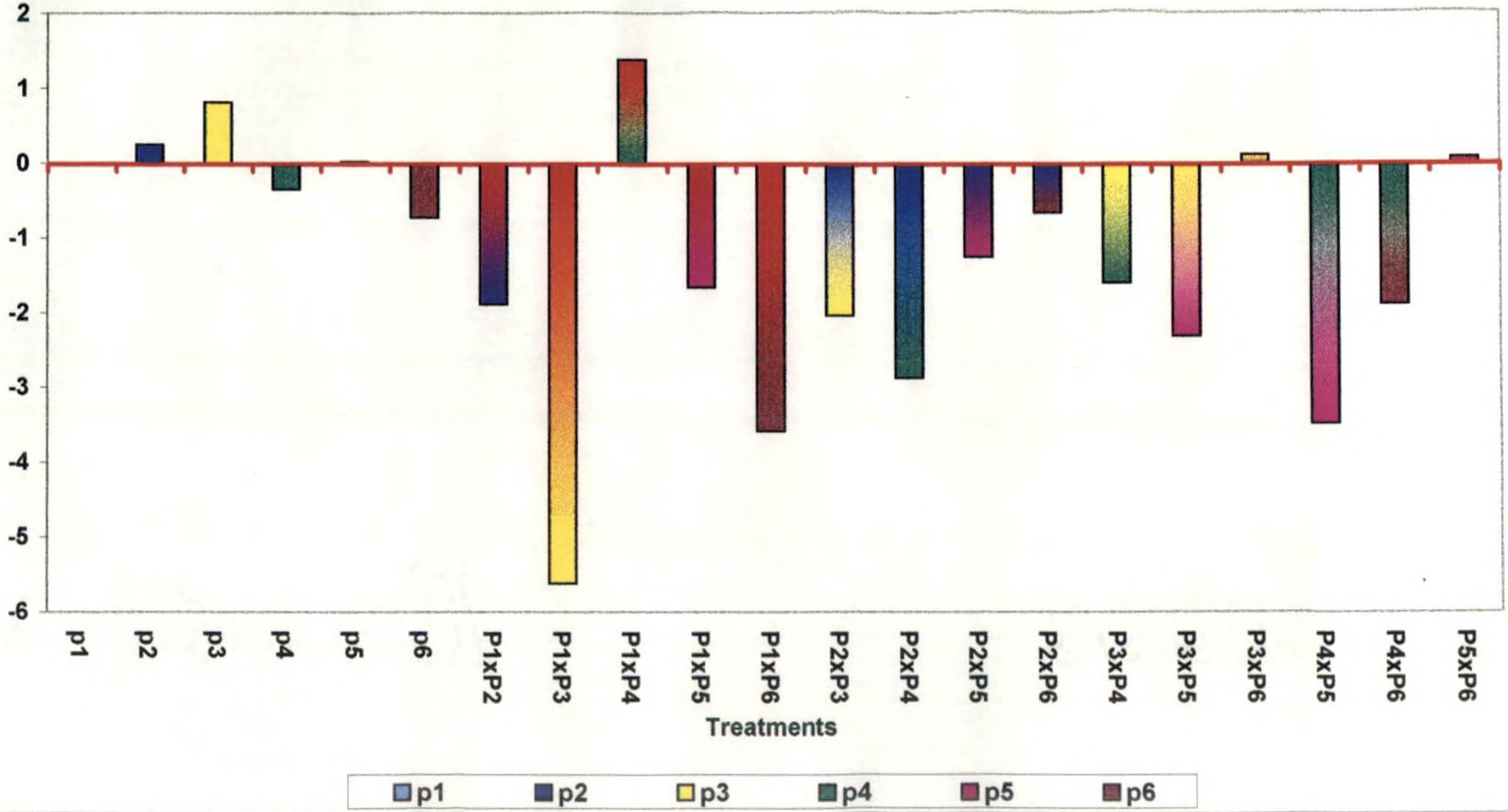


Fig. 4. gca and sca. No. of female flowers

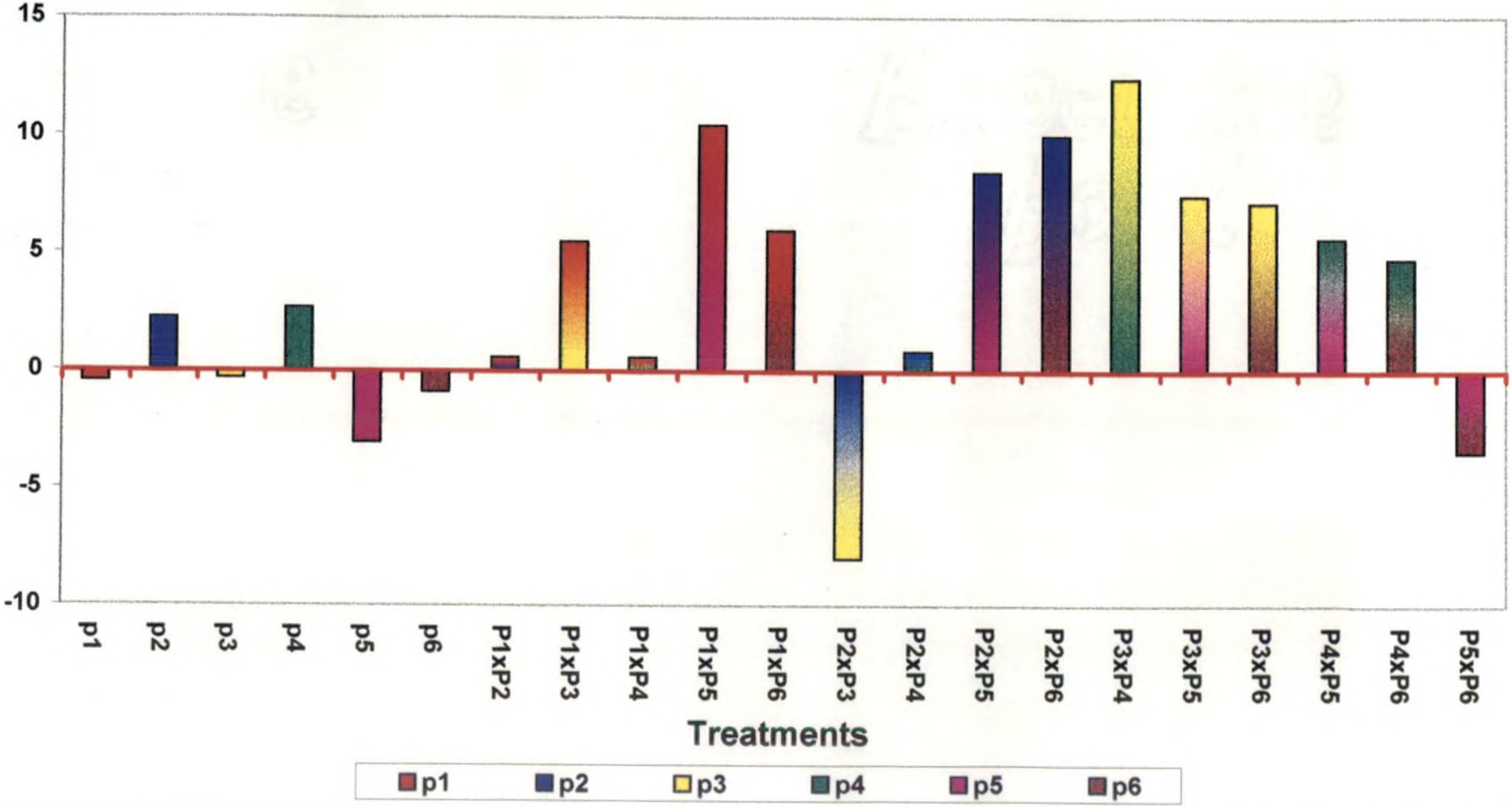
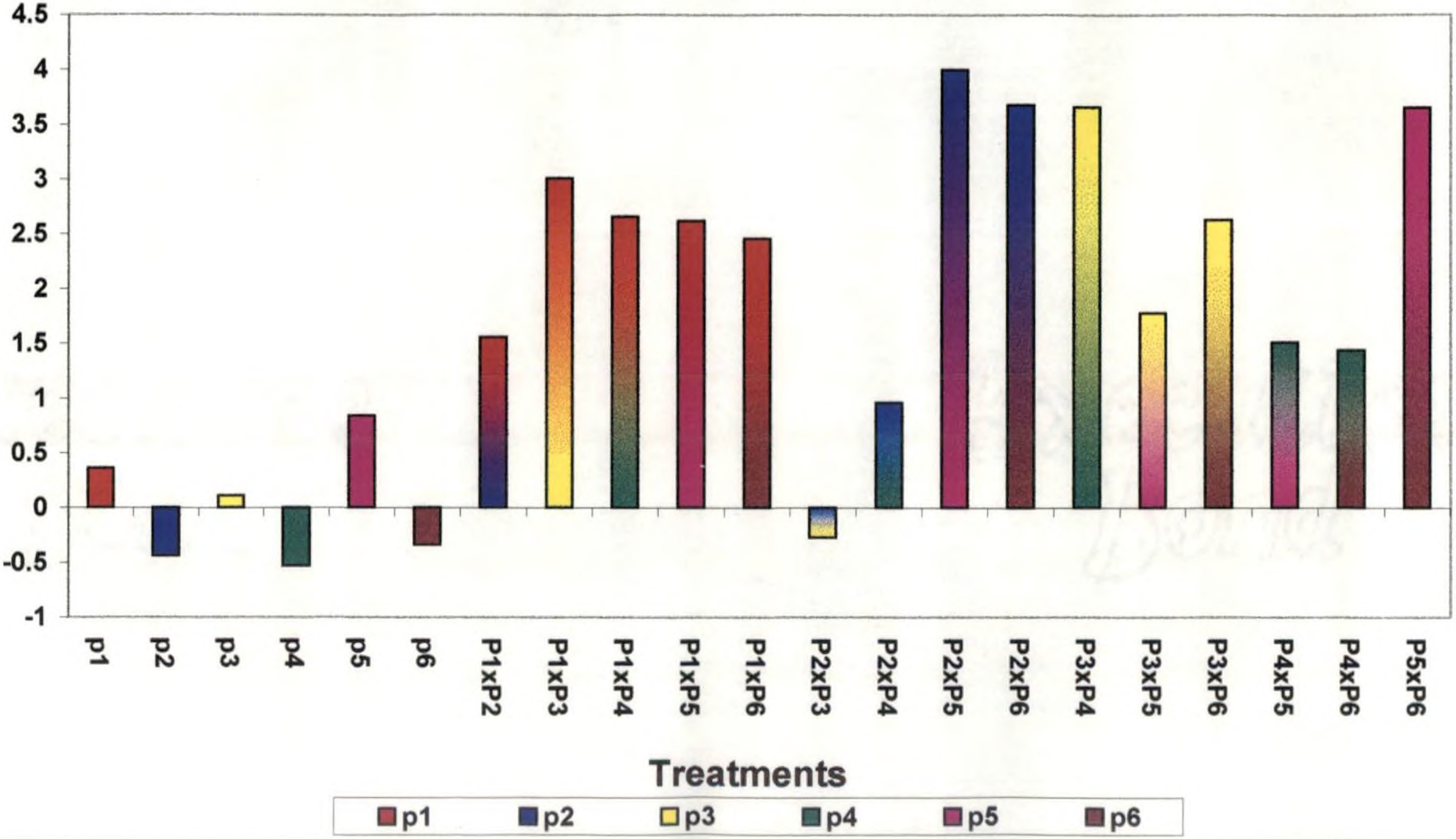


Fig. 5. gca and sca. No. of fruits per plant



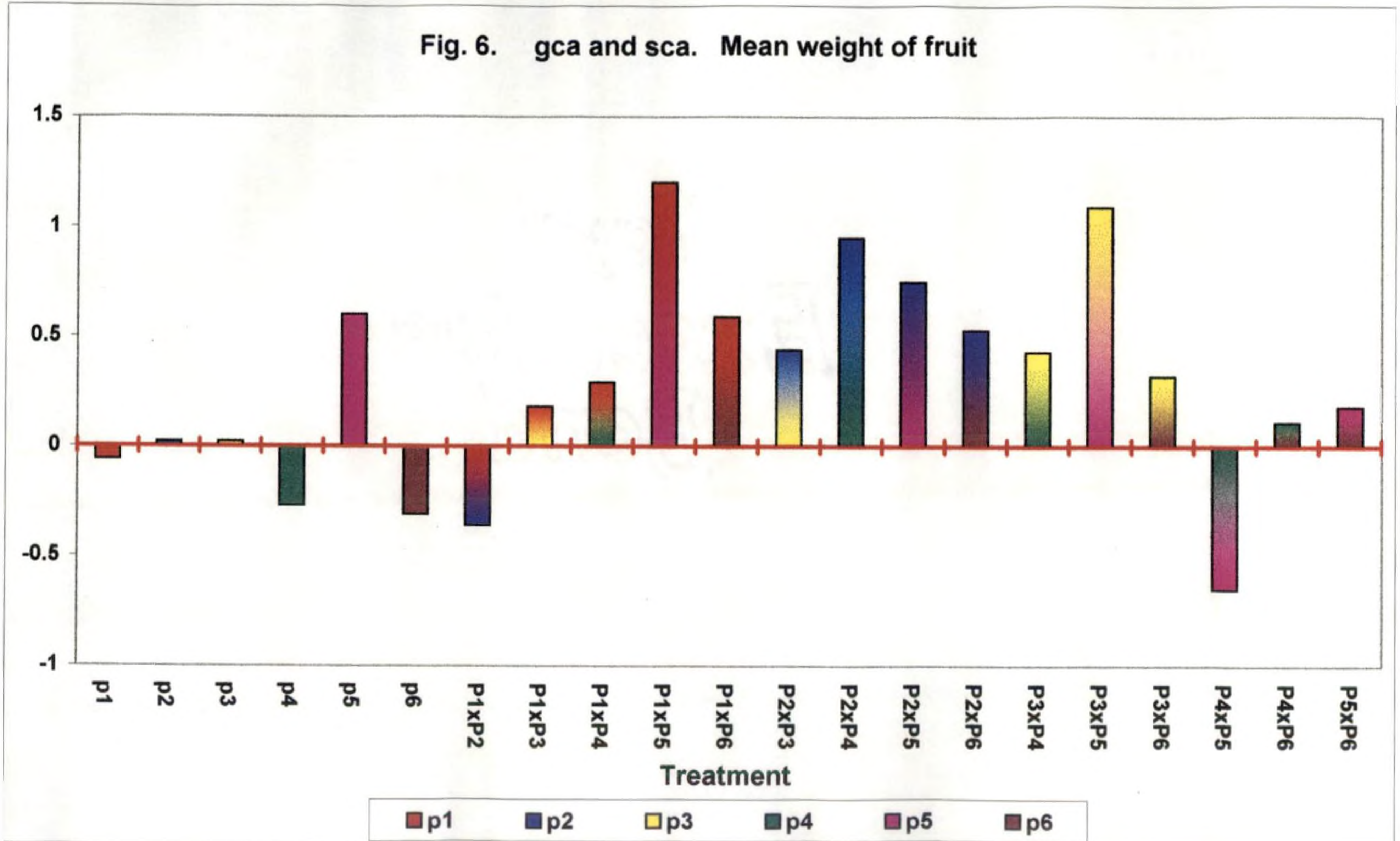


Fig. 6. gca and sca. Mean weight of fruit
1.5
1
0.5
0
-0.5
-1
p1
p2
p3
p4
p5
p6
P1xP2
P1xP3
P1xP4
P1xP5
P1xP6
P2xP3
P2xP4
P2xP5
P2xP6
P3xP4
P3xP5
P3xP6
P4xP5
P4xP6
P5xP6
Treatment
p1
p2
p3
p4
p5
p6

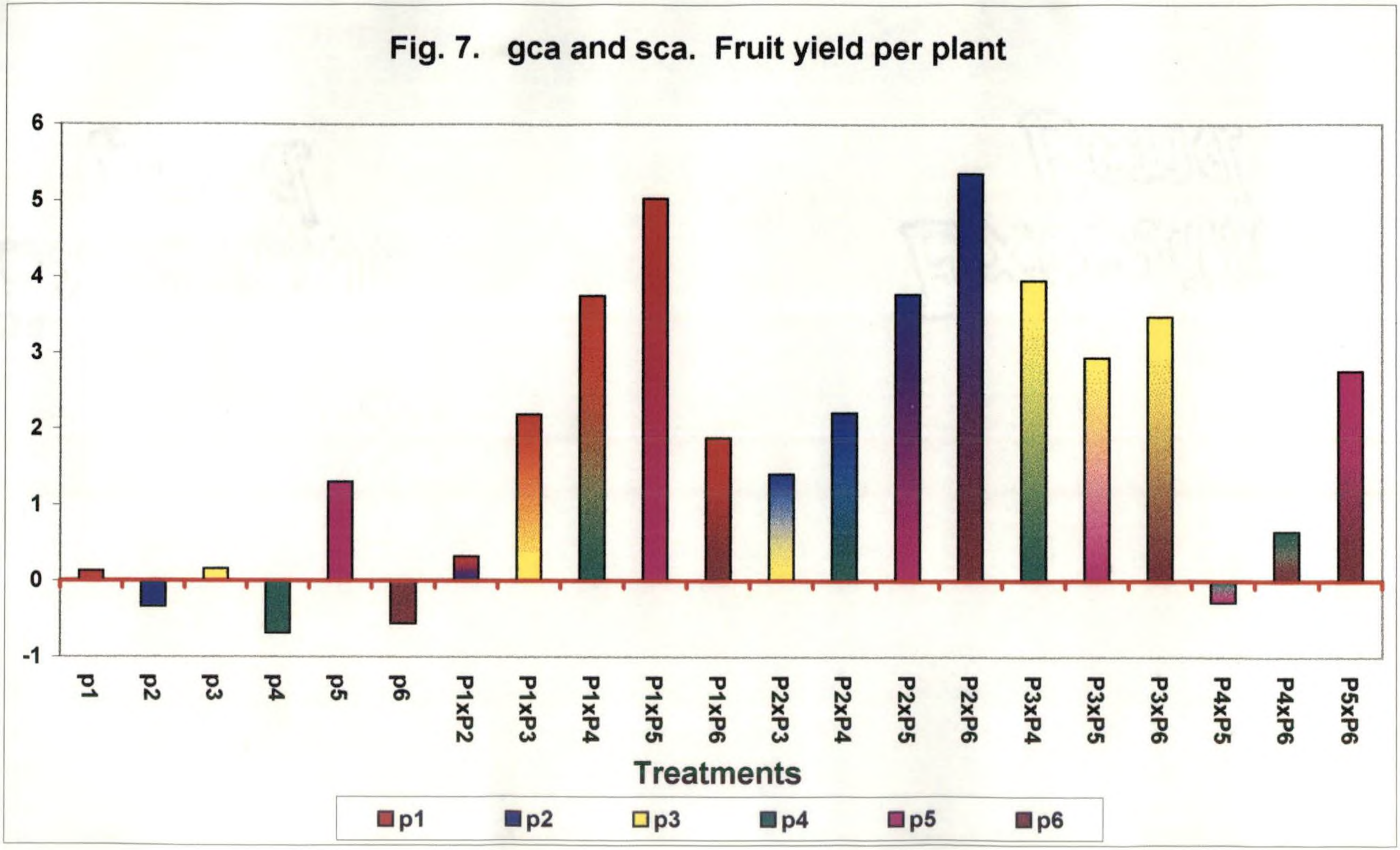


Fig. 7. gca and sca. Fruit yield per plant
6
5
4
3
2
1
0
-1
p1
p2
p3
p4
p5
p6
P1xP2
P1xP3
P1xP4
P1xP5
P1xP6
P2xP3
P2xP4
P2xP5
P2xP6
P3xP4
P3xP5
P3xP6
P4xP5
P4xP6
P5xP6
Treatments
p1
p2
p3
p4
p5
p6

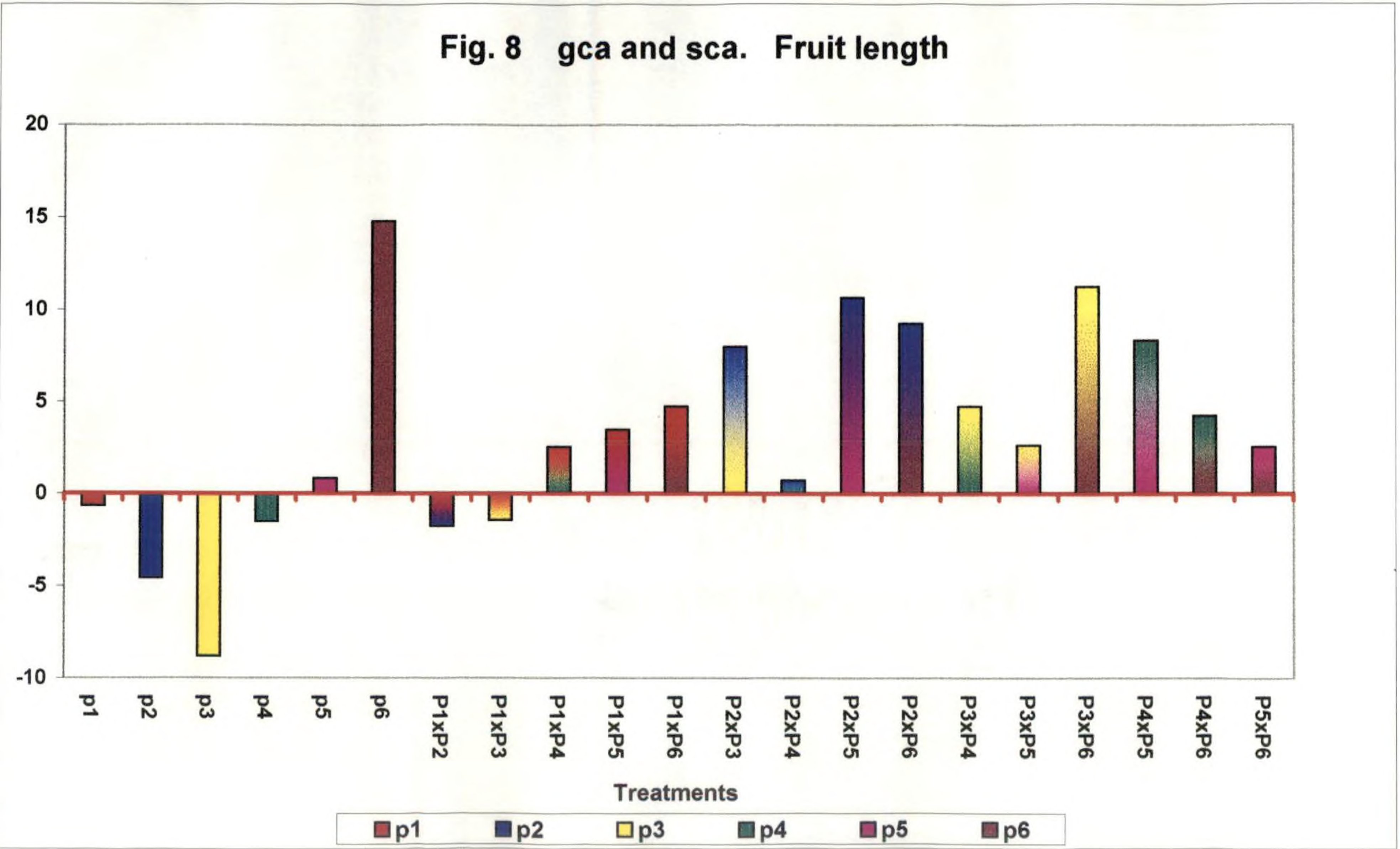


Fig. 8 gca and sca. Fruit length
20
15
10
5
0
-5
-10
p1
p2
p3
p4
p5
p6
P1xP2
P1xP3
P1xP4
P1xP5
P1xP6
P2xP3
P2xP4
P2xP5
P2xP6
P3xP4
P3xP5
P3xP6
P4xP5
P4xP6
P5xP6
Treatments
p1
p2
p3
p4
p5
p6

Fig. 9.   gca and sca.   Fruit girth

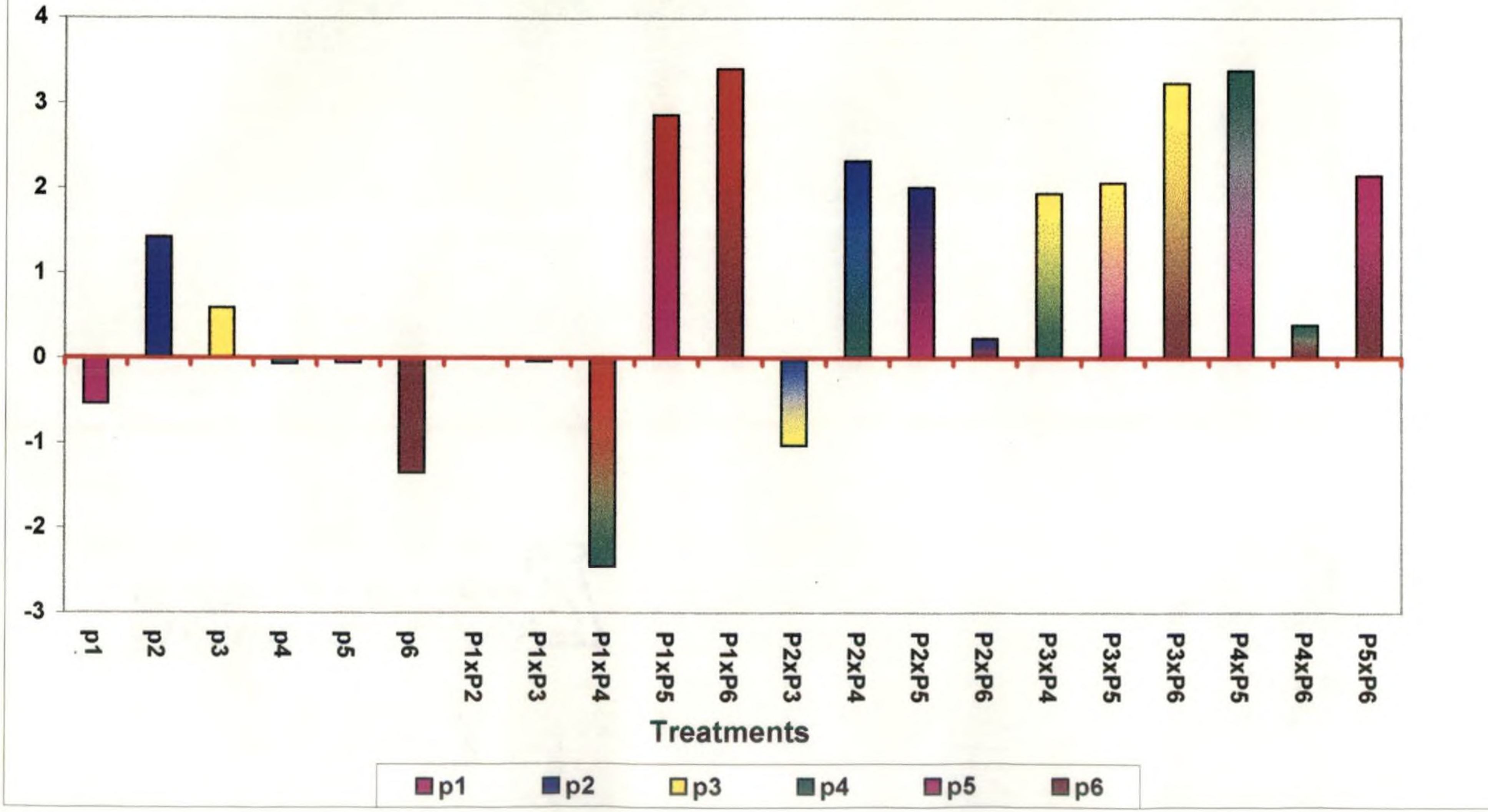


Fig. 10. gca and sca. Flesh thickness

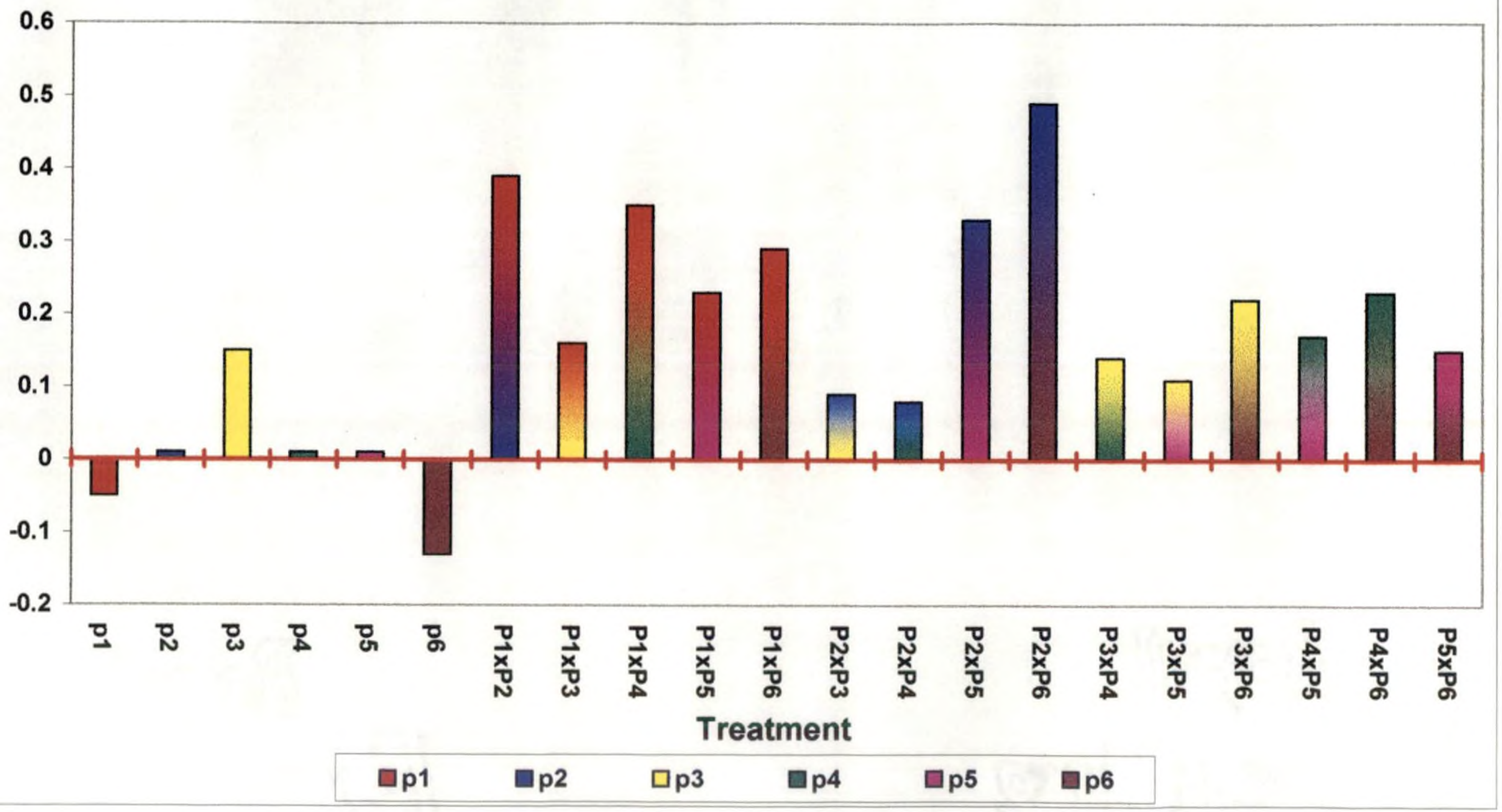


Fig. 11. gca and sca. No. of seeds/fruit

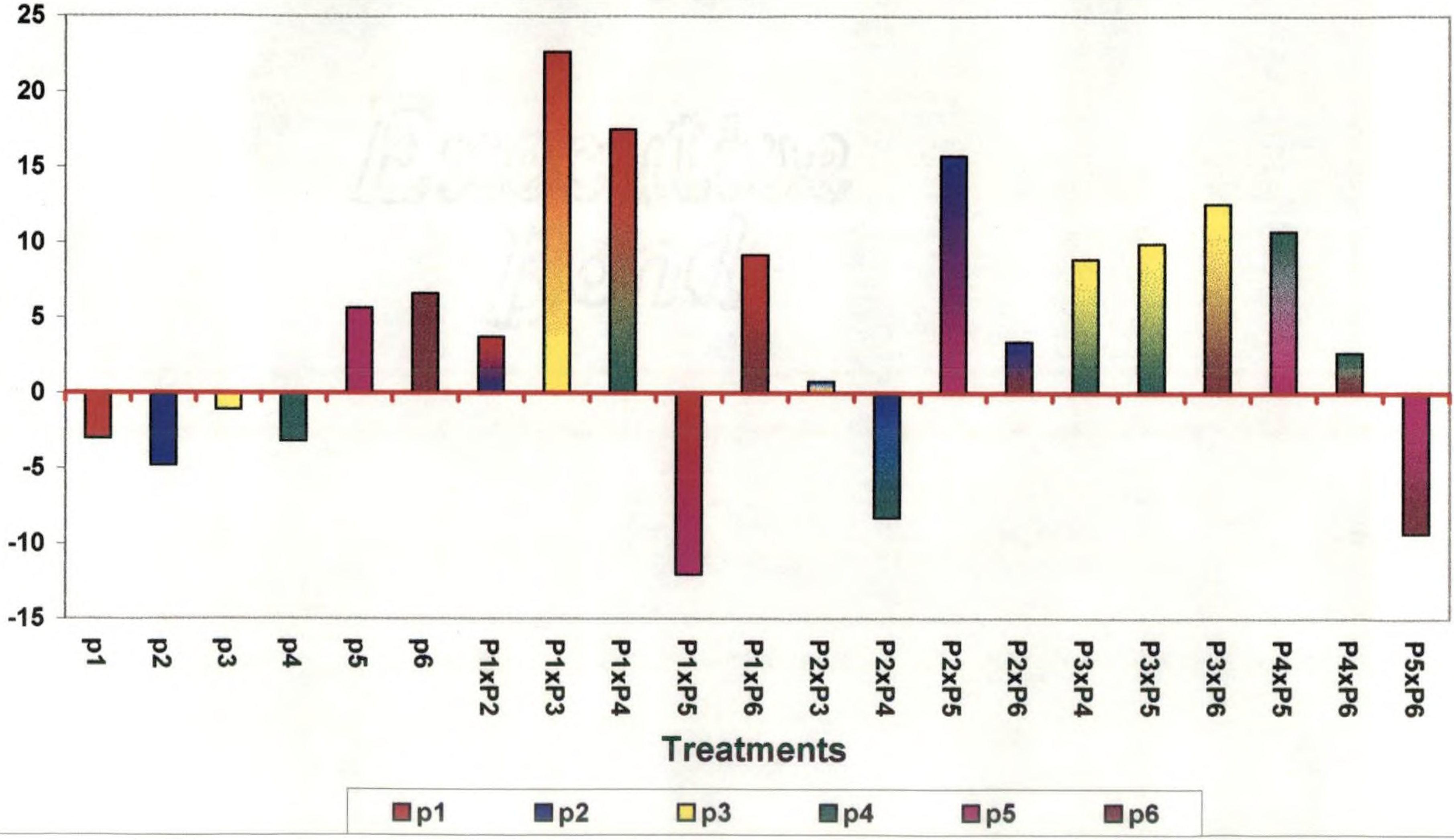


Fig. 12. gca and sca. 100 seed weight

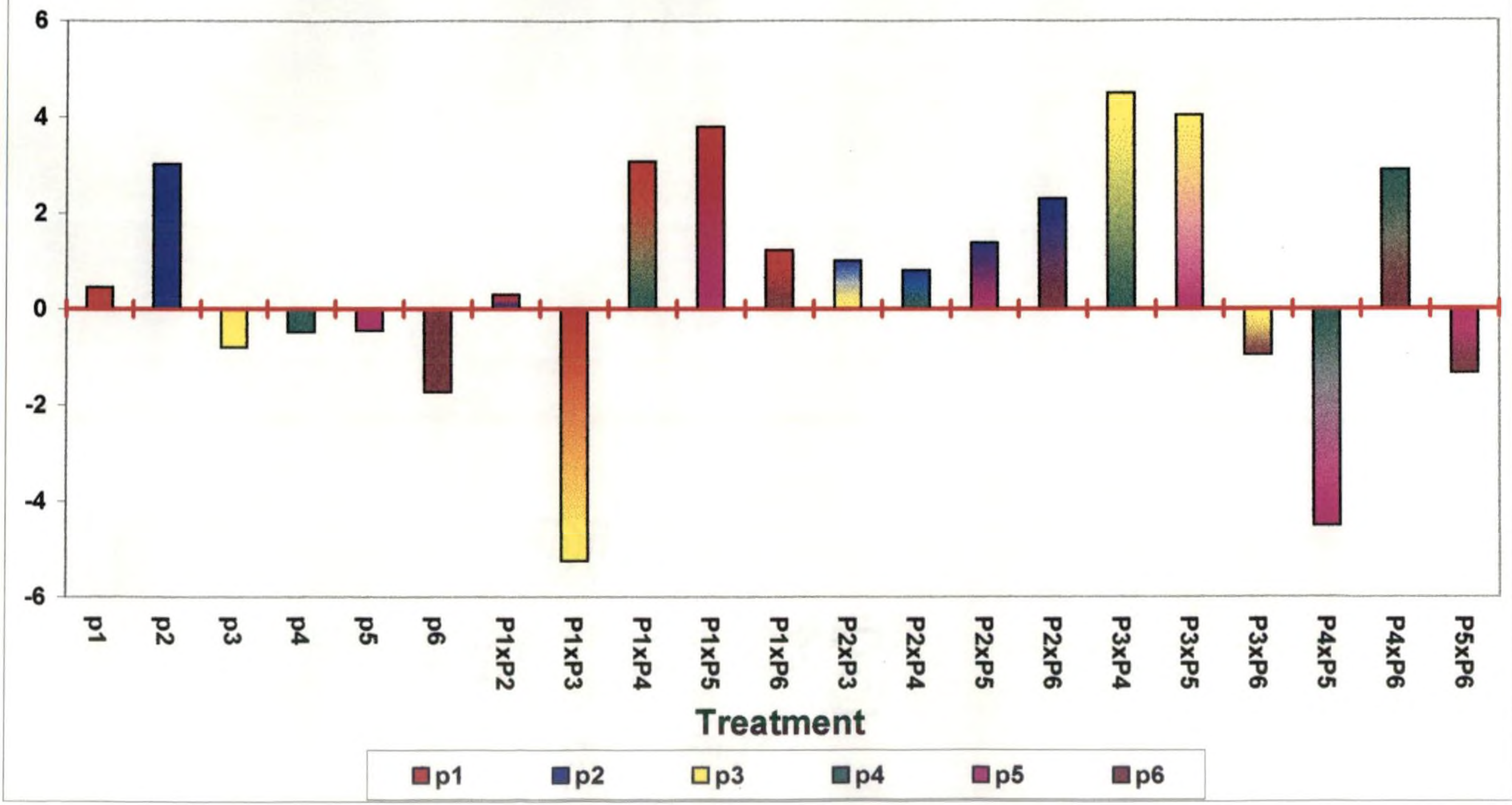


Fig. 13. gca and sca. Duration of the crop

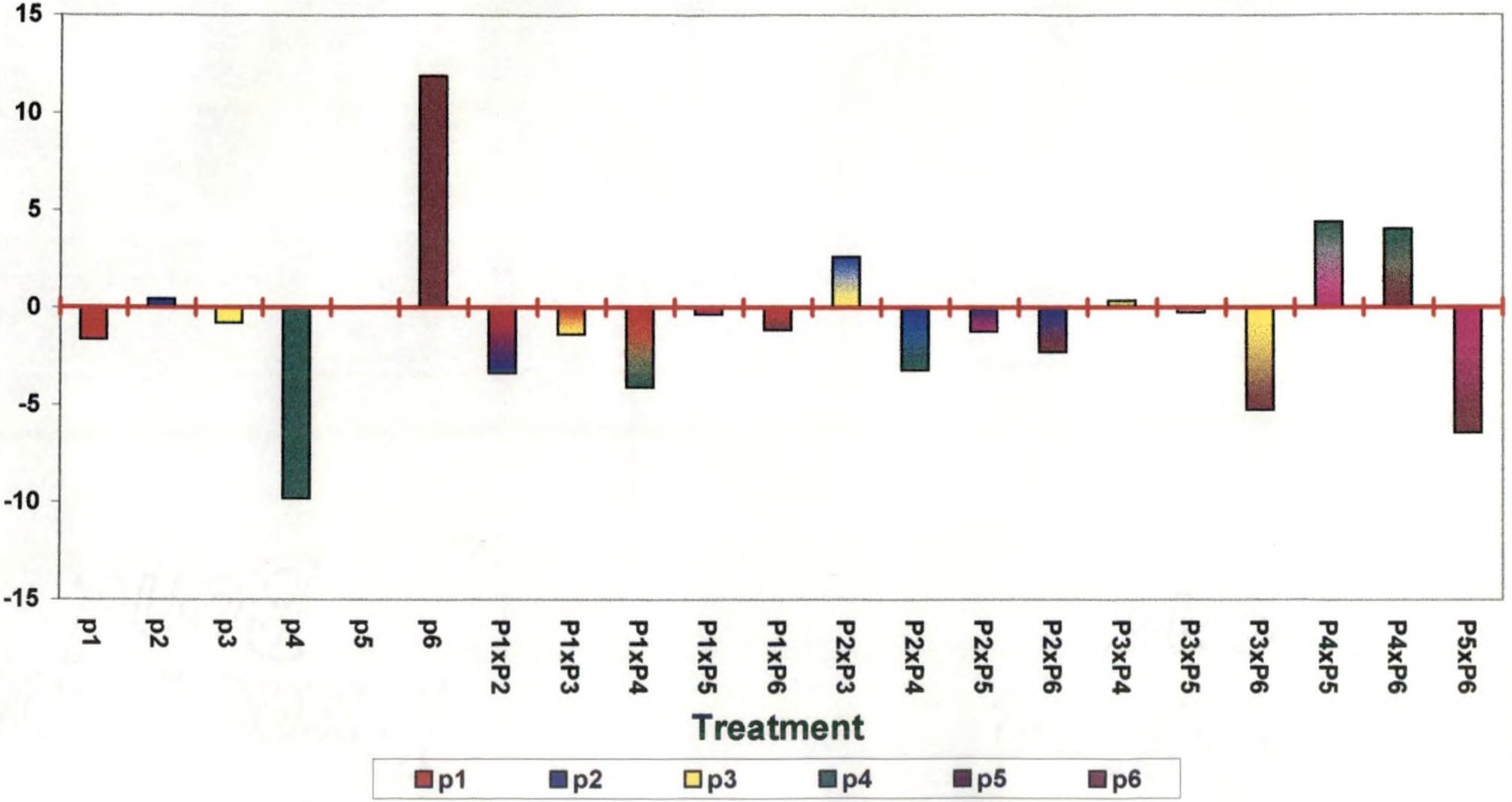
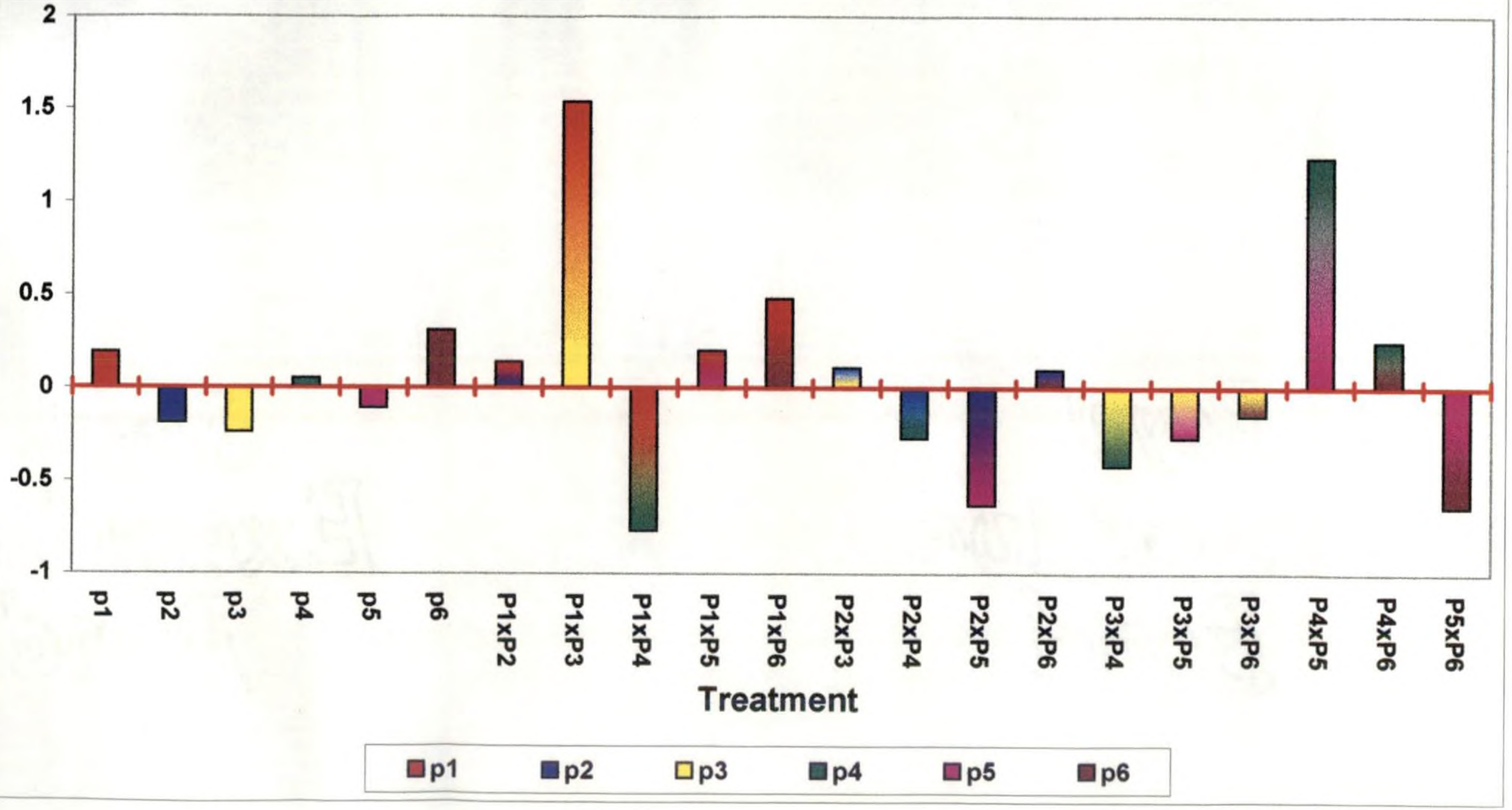


Fig. 14. gca and sca. Vine length



4.4.3 Days to first fruit harvest

Variance for the character days to first fruit harvest was not significant for gca effects of parents, but it was found significant for sca effects of hybrids. Among the hybrids, P_1 x P_4 showed significant positive sca effects (1.38). All other hybrids except P_3 x P_6 and P_5 x P_6 showed significant negative sca values (Fig. 3).

4.4.4 Number of female flowers

Variance for the combining ability effects for the number of female flowers was significant for both parents and hybrids. Significant positive gca effects were shown by parents P_4 (2.64) and P_2 (2.22). P_5 (-3.07) had significant negative gca values. All hybrids had significant sca effects of which P_2 x P_3 (-8.00) and P_5 x P_6 (-3.46) had significant negative values and all other hybrids had significant positive values (Fig. 4). The hybrid P_3 x P_4 showed the highest positive significant sca effect (12.42).

4.4.5 Number of fruits per plant

Variance for combining ability effects for number of fruits per plant was significant for both parents and hybrids. The parent P_5 (0.84) had significant positive gca values. The parents P_4 (-0.53) and P_2 (-0.44) had significant negative values. All the hybrids except P_1 x P_3 showed significant positive sca effects (Fig. 5).

4.4.6 Mean weight of fruits

Variance for combining ability effects for mean weight of fruit was significant for both parents and hybrids. P_5 (0.602) showed significant positive gca effect and P_6 (-0.305) and P_4 (-0.27) showed significant negative gca effect. Significant sca effects were exhibited by all the hybrids. P_4 x P_5 (-0.65) and P_1 x P_5 (-0.36) had significant negative sca effect and all other hybrids had significant positive sca effects (Fig. 6).

4.4.7 Fruit yield per plant

Variance for combining ability effects for the fruit yield per plant was significant for both parents and hybrids. Among parents significant positive gca effect was shown by P_5 (1.30) and significant negative gca effect was shown by P_4 (-0.69). All hybrids showed significant sca effects among which the cross P_4 x P_5 showed significant negative sca (-0.28). All other hybrids showed significant positive sca effects, the hybrid P_2 x P_6 having the highest value (5.36) (Fig. 7).

4.4.8 Fruit length

Analysis of variance of the character fruit length showed that variance for combining ability effect was significant for both parents and hybrids. Among parents P_3 (-8.82) and P_2 (-4.58) showed significant negative gca values. The parent P_6 (14.76) showed significant positive gca effect. All hybrids had significant sca effects of which the hybrids P_1 x P_2 (-1.76) and P_1 x P_3 (-1.44) showed significant negative sca values. All the other hybrids showed significant positive sca effects (Fig. 8).

4.4.9 Fruit girth

Combining ability analysis for fruit girth exhibited significant variances among the parents and hybrids. The parents P_2 (1.42) and P_3 (0.59) exhibited significant positive gca effect and P_6 (-1.35) showed significant negative gca effect. Among hybrids P_1 x P_4 (-2.45) and P_2 x P_3 (-1.03) showed significant negative sca effect. All the other hybrids except P_1 x P_2 and P_1 x P_3 showed significant positive sca effect (Fig. 9).

4.4.10 Flesh thickness

Both parents and hybrids showed significant variance for combining ability effects for the character flesh thickness. Significant positive gca effect was shown by P_3 (0.15) and significant negative gca effects by P_6 (-0.13) and P_1 (-0.05). All the hybrids showed significant positive sca values (Fig. 10).

4.4.11 Number of seeds per fruit

Combining ability analysis for number of seeds per fruit revealed that variance due to parents and hybrids were significant. Among parents P_6 (6.59) and P_5 (5.61) showed significant positive gca effect and the parents P_2 (-4.84), P_4 (-3.2) and P_1 (-3.03) had significant negative gca values. All hybrids except P_2 x P_3 were significant. The hybrids P_1 x P_5 (-12.09), P_5 x P_6 (-9.34) and P_2 x P_4 (-8.30) showed significant negative sca values. The others exhibited significant positive sca effects. The hybrid P_1 x P_3 had the highest sca effect (22.63) which was significantly superior to all other hybrids (Fig. 11).

4.4.12 100 Seed weight

Combining ability analysis of 100 seed weight showed significant variance due to parents and hybrids. Among parents significant positive gca effect was shown by parent P_2 (3.02) and P_1 (0.45). Significant negative gca effect was shown by P_6 (-1.73) and P_3 (-0.8) P_4 (-0.48) and P_5 (-0.45). Among hybrids P_1 x P_3 (-5.26), P_4 x P_5 (-4.52), P_5 x P_6 (-1.34) and P_3 x P_6 (-0.96) showed significant negative sca effects. All other hybrids showed significant positive sca effect (Fig. 12).

4.4.13 Duration of the crop

Analysis of variance of combining ability effects for duration of crop showed significant variances for both parents and hybrids. The parent, P_6 showed significant positive gca effect (11.87) and P_4 (-9.81) and P_1 (-1.64) showed significant negative effect. Among the hybrids P_4 x P_5 (4.39), P_4 x P_6 (4.03) and P_2 x P_3 (2.62) showed significant positive sca effect other hybrids had significant negative sca effects except P_1 x P_5, P_3 x P_4 and P_3 x P_5 (Fig. 13).

4.4.14 Vine length

Analysis of variance for combining ability for vine length showed significant effects. Among parents P_6 (0.31) had significant positive gca effect and P_3 (0.24) significant negative effects. All hybrids had significant sca effects. Of this seven hybrids had significant negative sca effects others had significant positive sca effects (Fig. 14).

Table 10. Percentage heterosis over mid parent, better parent and standard parent

Parents/ Hybrids	Days to first male flower				Days to first female flower			
	Mean	RH	HB	SH	Mean	RH	HB	SH
P_1	32.58	--	--	--	50.83	--	--	--
P_2	33.92	--	--	--	52.67	--	--	--
P_3	35.17	--	--	--	54.92	--	--	--
P_4	30.75	--	--	--	48.58	--	--	--
P_5	32.25	--	--	--	49.67	--	--	--
P_6	28.75	--	--	--	44.42	--	--	--
$P_1 \times P_2$	26.58	-20.06**	-21.64**	-17.58**	41.00	-20.77*	-22.16**	-17.46**
$P_1 \times P_3$	27.93	-17.55**	-20.59**	-13.39**	41.25	-21.98**	-24.89**	-16.95**
$P_1 \times P_4$	26.08	-17.63**	-19.95**	-19.13**	37.92	-23.71**	-25.40**	-23.66**
$P_1 \times P_5$	26.92	-16.95**	-17.37**	-16.53**	40.92	-18.57**	-19.50**	-17.62**
$P_1 \times P_6$	25.67	-16.29**	-21.21**	-20.40**	38.08	-20.04**	-25.08**	-23.33**
$P_2 \times P_3$	27.42	-20.62**	-22.04**	-14.98**	41.00	-23.78**	-25.35**	-17.46**
$P_2 \times P_4$	27.75	-14.18**	-18.19**	-13.95**	40.08	-20.83**	-23.90**	-19.31**
$P_2 \times P_5$	27.75	-16.12**	-18.19**	-13.95**	38.92	-23.94**	-26.11**	-21.64**
$P_2 \times P_6$	26.42	-15.68**	-22.11**	-18.08**	36.75	-24.29**	-30.23**	-26.01**
$P_3 \times P_4$	27.67	-16.05**	-21.32**	-14.20**	40.42	-21.89**	-26.40**	-18.62**
$P_3 \times P_5$	28.00	-16.94**	-20.39**	-13.18**	38.58	-26.22**	-29.75**	-22.33**
$P_3 \times P_6$	26.17	-18.12**	-25.59**	-18.85**	37.00	-25.51**	-32.63**	-25.51**
$P_4 \times P_5$	28.75	-8.73**	-10.85**	-10.85**	40.25	-18.06**	-18.97**	-18.97**
$P_4 \times P_6$	25.50	-14.29**	-20.93**	-20.93**	36.38	-21.33**	-24.70**	-26.35**
$P_5 \times P_6$	26.75	-12.30**	-17.05**	-17.05**	36.83	-21.71**	-25.85**	-25.85**
CD (0.05)		0.825	0.952	0.952		1.106	1.277	1.277
CD (0.01)		1.104	1.274	1.274		1.48	1.71	1.71

RH - Relative Heterosis

HB - Hetero Beltiosis

SH - Standard Heterosis

Table: 10 Continued.

Parents/ Hybrids	Days to first fruit harvest				Number of female flowers			
	Mean	RH	HB	SH	Mean	RH	HB	SH
P_1	77.50	--	--	--	49.00	--	--	--
P_2	76.67	--	--	--	60.00	--	--	--
P_3	79.19	--	--	--	48.50	--	--	--
P_4	75.33	--	--	--	54.67	--	--	--
P_5	76.17	--	--	--	41.08	--	--	--
P_6	73.33	--	--	--	47.38	--	--	--
$P_1 \times P_2$	70.17	-8.98**	-10.45**	-7.88**	63.75	16.97*	6.25^{NS}	55.19**
$P_1 \times P_3$	67.00	-14.47**	-15.37**	-12.04**	66.08	35.55**	34.86**	60.86**
$P_1 \times P_4$	72.83	-4.69*	-6.03	-4.38^{NS}	64.17	23.79**	17.38**	56.21**
$P_1 \times P_5$	70.17	-8.67**	-9.46**	-7.88**	68.33	51.71**	39.45**	66.33**
$P_1 \times P_6$	67.50	-10.49**	-12.90**	-11.88**	66.00	36.96**	34.69**	60.66**
$P_2 \times P_3$	70.83	-9.10**	-10.53**	-7.01**	55.33	1.99^{NS}	7.78**	34.69**
$P_2 \times P_4$	68.83	-9.43**	-10.23**	-9.64**	67.17	17.15**	11.95**	63.51**
$P_2 \times P_5$	70.83	-7.31**	-7.62**	-7.01**	69.08	36.68**	15.13**	68.16**
$P_2 \times P_6$	70.67	-5.77*	-7.83**	-7.22**	72.75	35.5**	21.25**	77.09**
$P_3 \times P_4$	70.67	-8.52**	-10.74**	-7.22**	76.17	47.64**	39.33**	85.42**
$P_3 \times P_5$	70.33	-9.45**	-11.17**	-7.66**	65.50	46.24**	35.05**	59.44**
$P_3 \times P_6$	72.00	-5.57*	-9.06**	-5.47^{NS}	67.33	40.45**	38.82**	63.89**
$P_4 \times P_5$	68.00	-10.23**	-10.73**	-10.73**	66.67	39.25**	21.95**	62.29**
$P_4 \times P_6$	68.83	-7.40**	-8.63**	-9.64**	67.92	33.11**	24.24**	65.34**
$P_5 \times P_6$	71.17	-4.79^{NS}	-6.56	-6.56*	54.00	22.09**	13.97**	31.45**
CD (0.05)		3.833	4.426	4.426		4.522	5.222	5.222
CD (0.01)		5.13	5.92	5.92		6.05	6.99	6.99

Table 10. Continued.

Parents/ Hybrids	Number of fruits/plant				Mean weight of fruit			
	Mean	RH	HB	SH	Mean	RH	HB	SH
P_1	17.33	--	--	--	96.37	--	--	--
P_2	16.92	--	--	--	95.95	--	--	--
P_3	17.58	--	--	--	95.32	--	--	--
P_4	16.58	--	--	--	96.08	--	--	--
P_5	17.67	--	--	--	106.42	--	--	--
P_6	15.17	--	--	--	92.45	--	--	--
P_1 x P_2	24.25	41.59**	39.93**	37.24**	103.09	7.21*	6.97^{NS}	-3.12^{NS}
P_1 x P_3	26.25	50.37**	49.32**	48.56**	108.52	13.22**	12.61**	1.97^{NS}
P_1 x P_4	25.25	48.91**	45.70**	42.89**	106.82	11.01**	10.84**	0.38^{NS}
P_1 x P_5	26.58	51.89**	50.42**	50.42**	124.52	22.81**	17.01**	17.00**
P_1 x P_6	25.25	55.38**	45.7**	42.89**	109.43	15.91**	13.55**	2.83^{NS}
P_2 x P_3	22.17	28.52**	26.11**	25.47**	111.92	17.03**	16.64**	5.17^{NS}
P_2 x P_4	22.75	35.82**	34.46**	28.75**	114.19	19.69**	18.85**	7.3^{NS}
P_2 x P_5	27.17	57.08**	53.76**	53.76**	120.84	19.42**	13.55**	13.55**
P_2 x P_6	25.67	59.97**	51.71**	45.27**	109.57	16.32**	14.19**	2.96^{NS}
P_3 x P_4	26.00	52.22**	47.90**	47.14**	109.05	13.95**	13.5**	2.47^{NS}
P_3 x P_5	25.50	44.67**	45.05**	44.31**	124.30	23.23**	16.8**	16.8**
P_3 x P_6	25.17	53.69**	43.17**	25.47^{NS}	107.51	14.51**	12.79**	1.02^{NS}
P_4 x P_5	24.58	43.52**	39.11**	39.11**	104.01	2.73^{NS}	-2.26^{NS}	-2.26^{NS}
P_4 x P_6	23.33	46.95**	40.71**	32.03**	102.58	8.82*	6.77^{NS}	-3.61^{NS}
P_5 x P_6	26.92	63.95**	52.35**	52.35**	111.92	12.56**	5.17^{NS}	5.17^{NS}
CD (0.05)		1.659	1.915	1.915		6.542	7.552	7.552
CD (0.01)		2.22	2.56	2.56		8.75	10.10	10.10

Table 10 Continued.

Parents/ Hybrids	Fruit yield per plant				Fruit Length			
	Mean	RH	HB	SH	Mean	RH	HB	SH
P_1	19.01	--	--	--	100.75	--	--	--
P_2	18.11	--	--	--	83.31	--	--	--
P_3	18.67		--	--	75.69	--	--	--
P_4	18.81	--	--	--	92.59	--	--	--
P_5	20.81	--	--	--	93.72	--	--	--
P_6	17.14	--	--	--	119.42	--	--	--
$P_1 \times P_2$	25.44	37.07**	33.82**	22.25**	98.87	-0.94^{NS}	-1.87^{NS}	5.49^{NS}
$P_1 \times P_3$	27.81	47.61**	46.29**	33.64**	94.96	1.15^{NS}	-5.74^{NS}	1.32^{NS}
$P_1 \times P_4$	28.52	50.82**	50.03**	37.05**	106.24	9.90**	5.45^{NS}	13.36**
$P_1 \times P_5$	31.79	59.67**	52.76**	52.76**	109.51	12.62**	8.69*	16.85**
$P_1 \times P_6$	26.78	48.15**	40.87**	28.69**	124.73	13.30**	4.45^{NS}	33.09**
$P_2 \times P_3$	26.56	44.43**	42.26**	27.63**	100.46	26.36**	20.59**	7.19^{NS}
$P_2 \times P_4$	26.50	43.55**	40.88**	27.34**	100.53	14.30**	8.58*	7.27^{NS}
$P_2 \times P_5$	36.06	85.30**	73.28**	73.28**	112.75	27.38**	20.31**	20.31**
$P_2 \times P_6$	29.78	68.94**	64.44**	43.10**	125.30	23.61**	4.92^{NS}	33.69 **
$P_3 \times P_4$	28.75	53.42**	52.84**	38.15**	100.30	19.21**	8.32*	7.21^{NS}
$P_3 \times P_5$	29.73	50.61**	42.86**	42.86**	100.52	18.67**	7.26^{NS}	7.25^{NS}
$P_3 \times P_6$	28.41	58.65**	52.17**	36.52*	123.06	26.14**	3.05^{NS}	31.31**
$P_4 \times P_5$	25.66	29.53**	23.31**	23.31**	113.51	21.85**	21.12**	21.12**
$P_4 \times P_6$	24.72	37.51**	31.42**	18.79**	123.37.	16.38**	3.31^{NS}	31.64**
$P_5 \times P_6$	28.82	51.87**	38.49**	38.49**	124.02	16.37**	3.85^{NS}	32.33**
CD (0.05)		1.536	1.774	1.774		6.517	7.526	7.526
CD (0.01)		2.06	2.37	2.37		8.72	10.07	10.07

Table 10 Continued.

Parents/ Hybrids	Fruit Girth				Flesh Thickness			
	Mean	RH	HB	SH	Mean	RH	HB	SH
P_1	21.76	--	--	--	1.09	--	--	--
P_2	25.81	--	--	--	1.24	--	--	--
P_3	22.82		--	--	1.84	--	--	--
P_4	21.79	--	--	--	1.44	--	--	--
P_5	18.38	--	--	--	1.44	--	--	--
P_6	17.32	--	--	--	0.95	--	--	--
$P_1 \times P_2$	25.59	7.59**	-0.85^{NS}	39.23**	2.25	92.31**	81.45**	56.25**
$P_1 \times P_3$	24.73	10.95**	8.37**	34.55**	2.17	70.5**	17.93**	50.69**
$P_1 \times P_4$	21.66	-0.53^{NS}	-0.60^{NS}	17.85**	2.21	74.02**	53.47**	53.47**
$P_1 \times P_5$	26.98	34.43**	23.99**	46.79**	2.10	65.35**	45.83**	45.83**
$P_1 \times P_6$	26.22	34.19**	20.49**	42.66**	2.01	97.06**	84.40**	39.58**
$P_2 \times P_3$	25.70	5.69**	-0.43^{NS}	39.83**	2.16	40.26**	17.39**	50.00**
$P_2 \times P_4$	28.39	19.29**	9.99**	54.46**	2.01	50.00**	39.58**	40.00**
$P_2 \times P_5$	28.09	27.13**	8.83**	52.83**	2.27	69.40**	57.64**	57.64**
$P_2 \times P_6$	25.01	15.97**	-3.10**	36.07**	2.28	107.73**	83.87**	58.33**
$P_3 \times P_4$	27.18	21.85**	19.11**	47.88**	2.21	34.76**	20.11**	53.47**
$P_3 \times P_5$	27.32	32.62**	19.72**	48.64**	2.18	32.93**	51.39**	51.38**
$P_3 \times P_6$	27.19	35.48**	19.15**	47.93**	2.15	53.93**	16.85**	49.31**
$P_4 \times P_5$	27.97	39.25**	28.36**	52.18**	2.10	45.83**	45.83**	45.83**
$P_4 \times P_6$	23.68	21.09**	8.67**	28.84**	2.01	67.92**	39.58**	39.58**
$P_5 \times P_6$	25.44	42.52**	38.41**	38.41**	1.94	61.67**	34.72**	34.72**
CD (0.05)		1.969	2.274	2.274		0.090	0.11	0.11
CD (0.01)		2.63	3.04	3.04		0.12	0.15	0.15

Table 10. Continued.

Parents/ Hybrids	Number of Seeds Per Fruit				100 Seed Weight			
	Mean	RH	HB	SH	Mean	RH	HB	SH
P_1	73.91	--	--	--	27.96	--	--	--
P_2	83.07	--	--	--	31.77	--	--	--
P_3	70.81		--	--	25.39	--	--	--
P_4	78.27	--	--	--	24.30	--	--	--
P_5	104.12	--	--	--	26.05	--	--	--
P_6	104.35	--	--	--	23.1	--	--	--
P_1 x P_2	96.23	22.60**	15.83*	-7.58^{NS}	32.4	8.49**	1.98^{NS}	24.38
P_1 x P_3	118.88	64.29**	60.84**	14.18*	23.02	-13.7*	-17.67**	-11.63**
P_1 x P_4	111.62	46.69**	42.61**	7.2^{NS}	31.67	21.2**	13.27**	21.57**
P_1 x P_5	90.88	2.09^{NS}	12.72*	72.72**	32.42	20.05**	15.95**	24.45**
P_1 x P_6	113.12	26.92**	8.40^{NS}	8.64^{NS}	28.58	11.95**	2.22^{NS}	9.71**
P_2 x P_3	95.16	23.68**	14.55*	-8.6^{NS}	31.86	11.48**	0.28^{NS}	22.3**
P_2 x P_4	84.04	4.18^{NS}	1.17^{NS}	-19.28**	31.97	14.03**	0.63^{NS}	22.73**
P_2 x P_5	116.92	24.92**	12.29*	12.29*	32.58	12.69**	2.55^{NS}	25.07**
P_2 x P_6	105.51	12.59*	1.11^{NS}	1.33^{NS}	32.22	17.44**	1.42^{NS}	23.69**
P_3 x P_4	104.95	40.8**	34.09**	0.79^{NS}	31.84	28.15**	25.40**	22.22**
P_3 x P_5	114.79	31.24**	10.25^{NS}	10.25^{NS}	31.42	22.16**	20.61**	20.61**
P_3 x P_6	118.41	35.20**	13.47*	13.72**	25.15	3.73^{NS}	-0.95^{NS}	-3.45^{NS}
P_4 x P_5	113.53	24.49**	9.04^{NS}	9.04^{NS}	23.18	-7.92*	-11.02**	11.02**
P_4 x P_6	106.45	16.58**	2.01^{NS}	2.24^{NS}	29.31	23.67**	20.62**	12.51**
P_5 x P_6	103.25	-0.95^{NS}	-1.05^{NS}	-0.84^{NS}	25.11	2.18^{NS}	3.33^{NS}	-3.61^{NS}
CD (0.05)		10.595	12.233	12,233		1.613	1.862	1.862
CD (0.01)		14.18	16.37	16.37		2.16	2.49	2.49

Table 10. Continued.

Parents/ Hybrids	Duration of Crop				Vine Length			
	Mean	RH	HB	SH	Mean	RH	HB	SH
P_1	121.07	--	--	--	5.71	--	--	--
P_2	123.80	--	--	--	6.02	--	--	--
P_3	119.50		--	--	5.23	--	--	--
P_4	98.80	--	--	--	6.20	--	--	--
P_5	120.97	--	--	--	5.94	--	--	--
P_6	148.43	--	--	--	6.71	--	--	--
$P_1 \times P_2$	114.57	-6.42**	-7.46^{NS}	-5.29^{NS}	6.26	6.73^{NS}	3.99^{NS}	5.39^{NS}
$P_1 \times P_3$	115.30	-4.14**	-4.77^{NS}	-4.69^{NS}	7.61	39.12**	33.27**	28.11**
$P_1 \times P_4$	103.60	-5.76**	-14.43**	-14.36**	5.59	-6.12^{NS}	-9.84^{NS}	-5.89^{NS}
$P_1 \times P_5$	117.10	-3.24**	-3.28^{NS}	-3.19^{NS}	6.4	9.86^{NS}	7.74^{NS}	7.74^{NS}
$P_1 \times P_6$	128.20	-4.86**	-13.63**	5.98*	7.1	10.76^{NS}	5.81^{NS}	19.53*
$P_2 \times P_3$	121.40	-0.21^{NS}	-1.94^{NS}	0.36^{NS}	5.79	-2.93^{NS}	-3.82^{NS}	-2.52^{NS}
$P_2 \times P_4$	106.57	-4.25**	-13.92**	-11.9**	5.71	-6.54^{NS}	-7.9^{NS}	-3.87^{NS}
$P_2 \times P_5$	118.3	-3.34*	-4.44^{NS}	-2.21^{NS}	5.19	-13.21^{NS}	-13.79**	-12.63^{NS}
$P_2 \times P_6$	129.17	-5.10**	-12.98**	6.78*	6.34	-0.39^{NS}	-5.51^{NS}	6.73^{NS}
$P_3 \times P_4$	108.87	-0.26^{NS}	-8.90**	-1^{NS}	5.51	-3.58^{NS}	-11.13^{NS}	-7.24^{NS}
$P_3 \times P_5$	118.03	-1.84**	-2.43^{NS}	-2.4^{NS}	5.49	-1.69^{NS}	-7.58^{NS}	-7.58^{NS}
$P_3 \times P_6$	124.93	-6.74**	-15.83**	3.27^{NS}	6.03	1.01^{NS}	-10.13^{NS}	1.52^{NS}
$P_4 \times P_5$	113.67	3.44*	-6.03*	-6.03*	7.30	20.26**	17.74*	22.89**
$P_4 \times P_6$	125.23	1.31^{NS}	-15.63**	3.52^{NS}	6.72	4.10^{NS}	0.15^{NS}	13.13^{NS}
$P_5 \times P_6$	124.53	-7.55**	-16.1**	2.94^{NS}	5.67	-10.35^{NS}	-15.5*	-4.54^{NS}
CD (0.05)		3.314	5.379	5.379		0.844	0.974	0.974
CD (0.01)		4.43	7.2	7.2		1.13	1.3	1.3

4.4 Heterosis

The heterosis was estimated for various yield components in snakegourd. The superiority of hybrids were estimated in comparison with the mean value of the parents [Relative heterosis (RH)], better parent [Heterobeltiosis (HB)] and standard parent (Standard heterosis (SH)]. The standard parent taken was P_5 (Kaumudi). The parental values and the percentage heterosis over mid parent, better parent and standard parent are presented in Table 10.

4.4.1 Days to first male flower

All the hybrids exhibited significant negative heterosis in comparison with mean value of mid parent, better parent and standard parent. Maximum negative relative heterosis was exhibited by the hybrid P_2 x P_3 (-20.62) and the hybrid P_1 x P_2 (-20.06) was on par with this. The hybrid P_3 x P_6 (-25.59) recorded the highest negative heterobeltiosis. This was significantly superior to all other hybrids. The hybrid P_4 x P_6 (-20.93) recorded the highest negative standard heterosis and P_1 x P_6 (-20.40) was on par with this (Table 10).

4.4.2 Days to first female flower

All the hybrids exhibited significant negative relative heterosis, heterobeltiosis and standard heterosis for days to first female flower (Table 10). Maximum negative relative heterosis was observed in the hybrid P_3 x P_5 (-26.22) which was on par with P_3 x P_6 (-25.51). In heterobeltiosis, the hybrid P_3 x P_6 (-32.63) had the highest negative heterosis. This was significantly superior to all other crosses. Highest negative standard heterosis was recorded in the hybrid P_4 x P_6 (-26.35). The hybrids P_2 x P_6 (-26.01), P_3 x P_6 (-25.51) and P_5 x P_6 (-25.85) were on par with this.

4.4.3 Days to first fruit harvest

Significant negative relative heterosis was exhibited by all the hybrids except P_5 x P_6. The hybrid P_1 x P_3 (-14.47) recorded the maximum negative value and was significantly superior to all other hybrids. Significant negative heterobeltiosis was exhibited by all hybrids and the highest negative value was observed in the hybrid P_1 x P_3 (-15.37). The hybrid P_1 x P_6 (-12.90) was on par with this.

All hybrids exhibited negative standard heterosis of which three were not significant. For days to first fruit harvest the hybrid P_1 x P_3 (-12.04) had the maximum value. The hybrids P_1 x P_6 (-11.88), P_4 x P_5 (-10.73), P_2 x P_4 (-9.64), P_4 x P_6 (-9.64), P_1 x P_2 (-7.88) P_1 x P_5 (-7.88) and P_3 x P_5 (-7.66) were on par with this (Table 10).

4.4.4 Number of female flowers

Significant positive relative heterosis was exhibited by all hybrids except one (P_2 x P_3) for number of female flowers. The hybrid P_1 x P_5 (51.71) showed the maximum relative heterosis value. The hybrid P_3 x P_4 (47.64) was on par with this. All hybrids except P_1 x P_2 showed positive significant heterobeltiosis and the hybrid P_1 x P_5 (39.45) had the maximum value. The hybrids P_3 x P_4 (39.33) P_3 x P_6 (38.82), P_3 x P_5 (35.05), P_1 x P_3 (34.86) and P_1 x P_6 (34.69) were on par with this.

All hybrids exhibited significant standard heterosis with the hybrid P_3 x P_4 (85.42) having the maximum value. This was significantly superior to all other crosses (Table 10).

4.4.5 Number of fruits per plant

All the hybrids exhibited significant positive relative heterosis, heterobeltiosis and standard heterosis for the character. The hybrid P_5 x P_6 (63.95) showed the highest positive RH and was superior to all other hybrids. The hybrid P_2 x P_5 (53.76) had the maximum positive heterobeltiosis and the hybrid P_3 x P_6 (52.35) was on par with this. The hybrid P_2 x P_5 (53.76) had the highest standard heterosis and the hybrid P_5 x P_6 (52.35) was on par with this (Table 10).

4.4.6 Mean weight of fruit

All hybrids exhibited significant positive heterosis in comparison with mean value of mid parent (RH). Only one hybrid P_4 x P_5 (2.73) showed non-significant value. Maximum value of relative heterosis was expressed by the hybrid P_3 x P_5 (23.23) and the hybrids P_1 x P_5 (22.81), P_2 x P_4 (19.69), P_2 x P_5 (19.42) and P_2 x P_3 (17.05) were on par with this.

Significant heterobeltiosis was exhibited by eleven hybrids of which the hybrid P_2 x P_4 (18.85) had the maximum value and the hybrids P_1 x P_5 (17.01) P_3 x P_5 (16.8), P_2 x P_3 (16.64), P_2 x P_6 (14.19), P_1 x P_6 (13.55), P_2 x P_5 (13.55), P_3 x P_4 (13.50), P_3 x P_6 (12.79) and P_1 x P_3 (12.61) were on par with this. Of the other four hybrids, P_1 x P_2 (6.97), P_4 x P_6 (6.77) and P_5 x P_6 (5.17) showed non-significant positive values and the hybrid P_4 x P_5 (-2.26) showed non-significant negative value.

Only three hybrids P_1 x P_5 (17.00), P_2 x P_5 (13.55) and P_3 x P_5 (16.8) showed significant positive standard heterosis and these three hybrids were on par with each other. All other hybrids had non significant values when compared with mean value of standard parent (Table 10).

4.4.7 Fruit yield per plant

All hybrids exhibited significant positive values with respect to the character, when hybrids were evaluated from the values of mid parent better parent and standard parent. The hybrid P_2 x P_5 exhibited the maximum value for relative heterosis (85.30), heterobeltiosis (73.28) and standard heterosis (73.28). This hybrid was significantly superior to all others in the three types of heterosis (Table 10).

4.4.8 Fruit length

All hybrids except 2 expressed significant positive relative heterosis. Highest value was shown by the hybrid P_2 x P_5 (27.38) and the hybrids P_2 x P_3 (26.36), P_3 x P_6 (26.14), P_2 x P_6 (23.61) and P_4 x P_5 (21.85) were on par with this.

Six hybrids showed significant positive heterobeltiosis for fruit length and the maximum value was expressed by hybrid P_4x P_5 (21.12) which was on par with P_2 x P_3 (20.59) and P_2 x P_5 (20.31).

Nine hybrids showed significant positive values for standard heterosis and P_2 x P_6 (33.69) had the maximum value. The hybrids P_5 x P_6 (32.33), P_1 x P_6 (33.09), P_4 x P_6 (31.64) and P_3 x P_6 (31.31) were on par with this (Table 10).

4.4.9 Fruit girth

Significant positive relative heterosis was exhibited by all hybrids except one (P_1 x P_4). The hybrid P_5 x P_6 (42.52) exhibited the highest value and was superior to all other hybrids.

When compared with mean values of better parent 11 hybrids showed significant values of which 10 hybrids had significant positive values and one hybrid had significant negative value i.e. P_2 x P_6 (-3.00). The hybrid P_5 x P_6 (38.41) expressed the highest value and was significantly superior to all other hybrids.

All hybrids exhibited significant positive standard heterosis and the highest value was shown by P_2 x P_4 (54.46) and P_2 x P_5 (52.83) was on par with this (Table 10).

4.4.10 Flesh thickness

All hybrids exhibited significant positive values for relative heterosis, heterobeltiosis and standard heterosis. The highest value was shown by hybrid P_2 x P_6 (107.73) when compared with the values of mid parent and was significantly superior to all other hybrids. The hybrid P_1 x P_6 (84.40) showed the highest value for heterobeltiosis and the hybrid P_2 x P_6 (83.87) was on par with this. When compared with standard parent, the highest value was recorded in P_2 x P_6 (58.33) and this was significantly superior to the rest of the hybrids compared (Table 10).

4.4.11 Number of seeds per fruit

Twelve out of 15 hybrids exhibited significant positive relative heterosis for seeds per fruit. The hybrid P_1 x P_3 (64.29) exhibited the maximum value of relative heterosis and no other hybrid was on par with this. Eight hybrids showed significant positive heterobeltiosis and P_1 x P_3 (60.84) had the maximum value, with none other hybrid being on par with this.

Only five hybrids were significant when compared with mean value of standard parent. The hybrid P_1 x P_5 recorded the maximum value of standard heterosis (72.72) and this was significantly superior to the rest of the hybrids compared. The hybrid P_2 x P_4 (-19.28) exhibited negative significant standard heterosis (Table 10).

4.4.12 100 seed weight

All hybrids except two recorded significant values of relative heterosis for the character 100 seed weight. The hybrids P_1 x P_3 (-13.7) and P_4 x P_5 (-7.92) had significant negative values and the other hybrids had significant positive values. The hybrid P_3 x P_4 (28.15) had the maximum value of relative heterosis and was significantly superior to all other hybrids compared.

When compared with mean values of better parent 5 hybrids showed significant positive heterosis. The hybrids P_1 x P_3 (-17.67) and P_4 x P_5 (-11.02) had significant negative values. The maximum positive heterobeltiosis was observed in the hybrid P_3 x P_4 (25.40) which was significantly superior to the rest of the hybrids compared.

Eleven hybrids recorded significant positive standard heterosis. The hybrids P_1 x P_3 (-11.63) and P_4 x P_5 (-11.02) had significant negative heterosis. The hybrid P_2 x P_5 (25.07) had the highest positive standard heterosis and P_2 x P_6 (23.69) was on par with this (Table10).

4.4.13 Duration of crop

Ten hybrids expressed significant negative relative heterosis and the hybrid P_4 x P_5 alone (3.44) had significant positive relative heterosis. The hybrid P_5 x P_6 (-7.55) had the maximum negative relative heterosis and the hybrids P_3 x P_6 (-6.74), P_1 x P_2 (-6.42), P_1 x P_4 (-5.76), P_2 x P_6 (-5.10) and P_1 x P_6 (-4.86) were on par with this.

Eleven hybrids recorded significant negative heterobeltiosis. The hybrid P_5 x P_6 (-16.1) had the maximum negative heterobeltiosis and the hybrids P_3 x P_6 (-15.83), P_4 x P_6 (-15.63), P_1 x P_4 (-14.43), P_2 x P_4 (-13.92), P_1 x P_6 (-13.63) and P_2 x P_6 (-12.98) were on par with this.

Three hybrids showed significant negative standard heterosis. Maximum negative standard heterosis was shown by P_1 x P_4 (-14.36) and the hybrid P_2 x P_4 (-11.9) was on par with this. Two hybrids P_2 x P_6 (6.78) and P_1 x P_6 (5.98) showed significant positive, standard heterosis (Table 10).

4.4.14 Vine length

Only two hybrids showed significant relative heterosis. Both the hybrids showed significant positive values and the hybrid P_1 x P_3 (39.12) had the highest value.

Four hybrids showed significant values when compared with mean values of better parent. The hybrids P_1 x P_3 (33.27) and P_4 x P_5 (17.74) showed significant positive values, the former being significantly superior. Two hybrids P_2 x P_5 (-13.79) and P_5 x P_6 (-15.5) had significant negative heterobeltiosis.

Only three hybrids had significant positive standard heterosis values and the hybrid P_1 x P_3 (28.11) had the maximum heterosis and was significantly superior to others. This hybrid had maximum value for the three types of heterosis (Table 10).

DISCUSSION

V. DISCUSSION

The present research programme was carried out at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani, to identify suitable parental lines for production of commercial hybrid varieties in snakegourd. The success of crop improvement programme, aimed at the production of superior varieties depends solely on the selection of suitable genotypes to be used as parents in the hybridization programme. Combining ability analysis provides useful information on the nature of inheritance of quantitative characters and also helps in identifying superior parents and cross combinations likely to yield better F_1 progeny. Estimate of heterosis along with combining ability effects will yield reliable information on the best performing hybrid combination which could be commercially exploited.

5.1 Mean performance

Earlier plant breeders used to select the parents for hybridisation on the basis of their mean performance alone. Now the ability of a genotype to transmit desirable traits to its progeny is given importance. However, based on the mean performance, potential and desirable genotypes can be selected for crop improvement.

Among parents, P_6 and among hybrids P_4 x P_6, P_3 x P_1 and P_2 x P_6 were identified as the best (earliest) genotype for the characters days to first male flower and days to first female flower production.

The parent P_6 and the hybrid P_1 x P_3 were the best (earliest) genotype for the character days to first fruit harvest. Thirteen other crosses were on par with P_1 x P_3 .

Number of female flowers was highest for the parent P_2 and the hybrids P_3 x P_4 and P_2 x P_6.

The parent, P_5 recorded the highest values for number of fruits per plant, mean weight of fruits and fruit yield per plant. As regards the number of fruits per plant, the hybrid P_2 x P_5 along with five other hybrids gave the highest value and for the other two characters the hybrid P_1 x P_5 recorded the highest values. This shows that the parent P_5 was superior in yield and in major yield contributing characters and it was also found to be a good combiner since all the three superior hybrids had the common parent P_5.

The parent P_6 had the longest fruit and the hybrid P_2 x P_6 along with other six hybrids recorded the maximum fruit length.

Parent P_2 had the maximum fruit girth and the hybrid P_2 x P_4 with other eight hybrids recorded the maximum value for this character.

The fruits in the parent P_3 and the hybrid P_2 x P_6 and other six hybrids had the maximum values for flesh thickness.

In the case of number of seeds per fruit, among parents P_6 had the maximum value and the hybrid P_1 x P_3 along with six other hybrids had superior performance.

Among the parents P_2 recorded the maximum 100 seed weight and the hybrid P_2 x P_5 and eight other hybrids had the highest value for this character.

Parent P_4 availed the minimum number of days from germination to harvest of last fruit and among hybrids P_1 x P_4, P_2 x P_4 and P_3 x P_4 had the shortest duration.

For the character vine length, the parent, P_6 and the hybrid P_1 x P_3 and other three hybrids recorded the maximum values.

With regard to the mean performance the parent P_5 (Kaumudi) was found to be a good combiner for yield and yield contributing characters and the hybrids involving this parent was superior for these characters.

Assessment of variability

To choose the most suitable breeding method for the improvement of yield and its components knowledge on the available variability, heritability of the character and genetic advance under selection are highly necessary. Study of variability is important as it provides the basis for effective selection. The observed variability is the total variation that arise in the population due to genotypic and environmental effects.

In the present study, the PCV values ranged from 5.63 to 21.83 per cent (Table 5). The PCV for flesh thickness was the highest followed by fruit yield per plant and number of fruits per plant. These results were in agreement with the results of Varghese (1991) and Varghese and Rajan (1993a) in snakegourd; Arora *et al.* (1983) in spongegourd; Chaudhary (1987) and Chaudhary *et al.* (1991) in bittergourd; Sarkar *et al.* (1990) in pointed gourd; Reddy and Rao (1984) and Varalakshmi *et al.* (1995) in ridgegourd; Solanki and Seth (1980), Mariappan and Pappiah (1990)

Rastogi and Deep (1990 a and b) in cucumber; Doijode and Sulladmath (1986), Rana *et al.* (1986), Singh *et al.* (1988), Suresh Babu (1989) and Borthakur and Shadeque (1990) in pumpkin, Thakur and Nandpuri (1974), Prasad *et al.* (1988), Rajendran and Thamburaj (1994) in watermelon.

Crop improvement programme cannot be undertaken solely on phenotypic performance as the phenotype constitute both genotypic effect and environmental influence. The GCV provides a more precise measure of genetic variability. Closer values of phenotypic and genotypic variances for all the characters under study suggested the predominant influence of genetic component over the environmental effect in its phenotype. It indicates that the selection on phenotypic basis will hold good for genotypic basis also.

The reports by Ramachandran (1978) in bittergourd; Sarkar *et al.* (1990) in pointedgourd; Solanki and Seth (1980); Abusaleha and Dutta (1990) in cucumber and Borthakur and Shadeque (1990) in pumpkin recorded similar results.

In the study the GCV value ranged from 4.22 (days to first fruit harvest) to 21.54 (flesh thickness) per cent. Fruit yield per plant and number of fruits per plant also had high values of GCV. These findings were similar to those of Joseph (1978), Varghese (1991) and Varghese and Rajan (1993a) in snakegourd; Srivastava and Srivastava (1976), Singh *et al.* (1977), Ramachandran and Gopalakrishnan (1979) Mangal *et al.* (1981), Indiresh (1982), Suribabu *et al.* (1986), Chaudhary (1987) and Chaudhary *et al.* (1991) in bittergourd; Arora *et al.* (1983) in spongegourd, Reddy and Rao (1984) and Varalakshmi *et al.* (1995) in ridgegourd; Singh *et al.* (1986) and

Sarkar *et al.* (1990) in pointedgourd; Solanki and Seth (1980), Mariappan and Pappiah (1990) and Rastogi and Deep (1990 a and b) in cucumber; Gopalakrishnan (1979), Doijode and Sulladmath (1986), Rana *et al.* (1986), Singh *et al.* (1988), Sureshbabu (1989) and Borthakur and Shadeque (1990) in pumpkin; Thakur and Nandpuri (1974), Prasad *et al.* (1988) and Rajendran and Thamburaj (1994) in watermelon; Deol *et al.* (1981) and Chacko (1992) in muskmelon; and Dahiya *et al.* (1989) in roundmelon.

The comparatively high values of GCV suggests good scope for improvement through selection.

5.3 Heritability and Genetic Advance

After assessing the relative amount of variability in a population, it is necessary to divide the overall variability into heritable and non-heritable components. The magnitude of heritability indicates the effectiveness with which the selection of genotypes can be made based on phenotypic performance (Johnson *et al.* 1955). High value of heritability indicated that the phenotype of the trait strongly reflected the genotype and suggests the major role of genetic constitution in the expression of that character. Such traits are considered dependable from breeding point of view. But for characters with low heritability, selection may be considerably ineffective due to masking effect of environment on the genotypic effects.

Here the highest and lowest values for heritability were recorded for days to first female flower and vine length respectively. High heritability values indicated that they can be selected since it will be repeated in the next generation. So selection can be made for characters with high heritability values like days to first female flower, flesh thickness, days to first male flower, fruit yield per plant, number of fruits per plant, 100 seed weight, duration of crop and fruit length. Similar results were reported by several authors. In snakegourd, Joseph (1978) reported high heritability for fruit length and fruit girth, but low heritability for yield per plant and fruits per plant. In bittergourd, high estimate of heritability was reported by Srivastava and Srivastava (1976) for fruits per plant and fruit length, by Ramachandran (1978) for fruits per plant and yield per plant; by Mangal *et al.* (1981) for average fruit weight, fruits per plant, yield per plant and seeds per fruit; and by Indiresh (1982) for all the characters except yield per plant and days for fruit development. Arora *et al.* (1983) also reported high heritability for all the characters except fruit diameter in spongegourd while Prasad *et al.* (1984) reported high heritability for fruit length and fruit diameter but low heretability for yield per plant.

High heritability estimate gives indication of effectiveness of selection based on phenotypic performance. But it does not necessarily mean a high genetic advance for a particular character. Johnson *et al.* (1955) stated that heritability and genetic advance are more useful than heritability alone in predicting the resultant effect of selecting the best individuals. However Hanson . (1961) concluded that both heritability and genetic advance are complementary aspects. Estimates of genetic advance together with heritability helps in assessing the nature of gene action.

In this study the genetic advance percentage varied from 6.5 for the character days to first fruit harvest to 43.78 for the character flesh thickness. All the characters having high heritability like days to first male flower, days to first female flower, fruit length, fruit yield per plant, flesh thickness, number of fruits per plant, 100 seed weight had high genetic advance values indicating that selection for these characters will be effective, since it will be repeated in the next generation.

It also indicates that such characters are governed by additive gene action suggesting a realistic possibility of improvement through selection for the development of high yielding varieties (Briggle, 1963 and Panse, 1957).

The findings are similar to several results reported earlier. Some of them are Srivastava and Srivastava (1976), Ramachandran (1978), Mangal *et al.* (1981) and Chaudhary *et al.* (1991) in bittergourd; Panwar *et al.* (1977) in spongegourd; Varghese (1991) and Varghese and Rajan (1993a) in snakegourd; Reddy and Rao (1984) and Varalakshmi *et al.* (1995) in ribbedgourd; Singh and Choudhary (1985) and Sarkar *et al.* (1990) in pointedgroud; Sharma and Dhankar (1990) in bottlegourd, Solanki and Seth (1980), Prasunna and Rao (1988), Abusaleha and Dutta (1990) and Rastogi and Deep (1990 a) in cucumber, Mangal *et al.* (1979) and Rana *et al.* (1986) in pumpkin; Sachan and Tikka (1971) in watermelon; and Dahiya *et al.* (1989) in roundmelon.

The characters number of female flowers and number of seeds per fruit had moderately high heritability values but had high genetic advance. The character days to first fruit harvest and vine length had low heritability and low genetic advance values revealing the non-additive gene action for these traits. Varghese (1991) and Varghese and Rajan (1993a) in snakegourd and Suribabu *et al.* (1986) in bittergourd observed similar results.

Mean performance and general combining ability effect can indicate the superiority of a genotype. In judging the genetic potentiality of a genotype that can be selected as parents for breeding programmes, combining ability assumes importance. Evaluation based on the mean performance and gca effect may result in the identification of different superior genotypes. Hence evaluating the parents using both the criteria would be more relevant.

5.4 Combining ability and Heterosis

The concept of combining ability was introduced by Sprague and Tatum (1942). According to them, combining ability is the relative ability of a biotype to transmit desirable performance to its crosses. 'General combining ability' (gca) refers to the average performance of a strain in a series of crosses, whereas 'specific combining ability' (sca) indicates those cases in which certain combinations do relatively better or worse than would be expected on the basis of average performance of the lines involved.

In almost all major crops, combining ability analysis has been used to estimate gca and sca variances and effects and also to assess the nature of gene action involved in the expression of various quantitative traits. Higher magnitude of gca variances indicate the predominant role of additive gene action and higher sca variances indicate non-additive gene action (dominance and epistatic effects).

The diallel mating system involved in the present study is an effective method of determining the combining ability of the parents which enables a rational choice of the parental material to be used in a heterosis breeding programme. 'This method also helps to study the nature of gene action governing the different characters based on which an appropriate breeding methodology can be adopted. In the present study six parental lines and their 15 hybrids were subjected to diallel analysis for studying combining ability and gene action and heterosis.

Analysis of variance for combining ability effects revealed that the general combining ability effects due to parents were significant for all the fourteen characters studied except days to first fruit harvest. The sca effects were significant for all the fourteen characters. This indicated the importance of both gca and sca for these traits which in turn suggests the involvement of both additive and non-additive gene action in the inheritance of the characters. Hence these characters are amenable for improvement through selection as well as hybridization.

To exploit the phenomenon of hybrid vigour, knowledge on the magnitude and direction of heterosis is of paramount importance. Heterosis is the superiority of an F_1 hybrid over both its parents. It may be positive or negative. The common measures of heterosis are relative heterosis, heterobeltiosis and standard heterosis. Hence all these three measures are considered for identification of desirable combination for commercial exploitation.

5.4.1 Days to first male flower

Significant variance was recorded by parents and hybrids for days to first male flower. Both gca and sca effects were significant for the character suggesting the involvement of both additive and non-additive gene action. The estimate of dominance variance was much higher than additive variance indicating the predominant role of dominance gene action (Table 7).

The estimates of combining ability revealed that among the parents P_3, P_2 and P_5 recorded significant positive gca effects and P_4 and P_6 showed significant negative gca effects. Significant negative sca effect was shown by all hybrids except P_4 x P_5. The hybrid P_2 x P_3 recorded the maximum negative sca effect where both the parents P_2 and P_3 had positive gca values. The variance for sca effects was more than gca effects. So the character can be predominantly under the control of non-additive gene action.

Significant sca effect and non-additive gene action for the character was also reported by Sivakami *et al.* (1987) and Janakiram and Sirohi (1988) in bottlegourd; Srivastava *et al.* (1983) and Pal *et al.* (1985) in bittergourd; and by Solanki and Seth (1980) in cucumber.

Observations on heterosis in the hybrids, well supported the results of combining ability analysis. Significant negative heterosis was recorded by all the fifteen hybrids over mid parent, better parent and standard parent. The hybrid P_2 x P_3 recorded the highest negative relative heterosis. The hybrid P_3 x P_6 had the highest negative heterobeltiosis and the hybrid P_4 x P_6 the highest negative standard heterosis for days to first male flower. Negative heterosis for this trait was reported earlier by Kasrawi (1994) in summersquash.

5.4.2 Days to first female flower

Significant gca and sca variances were recorded for parents and hybrids for days to first female flower suggesting the involvement of both additive and non-additive gene action. Here the gca effects of parents were significant and all hybrids showed significant negative sca effects. The dominance variance was more than additive variance indicating the predominance of non-additive gene action (Table 7).

Among parents P_3, P_2 and P_1 showed significant positive effects and the parents P_4 and P_6 showed significant negative gca effects. All the hybrids showed significant negative sca effects. The sca effects were more than gca effects indicating the significance of non-additive gene action. The finding is in agreement with the results of Srivastava *et al.* (1983) and Pal *et al.* (1985) in bittergourd; and Solanki and Seth (1980) in cucumber. The hybrid P_3 x P_5 recorded the maximum negative sca effect.

The hybrids had a very high degree of heterosis for days to first female flower. All the fifteen hybrids exhibited significant relative heterosis, heterobeltiosis and standard heterosis. The maximum negative relative heterosis was observed in the hybrid P_3 x P_5 and the hybrid P_3 x P_6 had the highest negative heterobeltiosis. The hybrid P_4 x P_6 had the highest negative standard heterosis. Similar report was given by Kasrawi (1994) in summersquash.

5.4.3 Days to first fruit harvest

For this character the gca variance due to parents was not significant but the variance due to hybrids was significant. This indicated the significant role of sca effects. The much dominance variance was higher than additive variance indicating the predominant effect of non-additive genes (Table 7). The result is in conformity with the findings of Dolgikh and Siderova (1983); and Rastogi and Deep (1990a) in cucumber.

Among hybrids only P_1 x P_4 showed significant positive sca effects. All other hybrids except P_3 x P_6 and P_5 x P_6 showed significant negative sca values. The hybrid P_1 x P_3 had the maximum negative value. Similar studies were reported by Om *et al.* (1978); Wang and Wang (1980); and Prudek (1984) in cucumber where both general and specific combining abilities were significant.

The predominance of sca variance was well reflected in the expression of heterosis. The hybrid P_1 x P_3 recorded the maximum significant negative heterosis when compared with mid parent, better parent and standard parent which also had the maximum negative sca effect in combining ability analysis. Similar results were reported by Varghese and Rajan (1993b) in snakegourd; Pal *et al.* (1984) in bottlegourd; and Cizov (1945) in cucumber.

5.4.4 Number of female flowers

Significant combining ability effects were noticed for parents and hybrids for number of female flowers indicating significant gca and sca effects and the involvement of additive and non-additive genetic components in the expression of this trait. The dominance variance was greater than additive variance indicating the predominant role of non-additive gene action (Table 7).

Among parents P_2 and P_4 had significant positive gca values and the parent P_5 had significant negative value. The highest positive sca effect was observed in the hybrid P_3 x P_4 where one parent (P_4) is a positive general combiner and the other parent P_3 had negative gca value. Similar results were reported by Solanki and Shah (1990) and Tasdighi and Baker (1981) in cucumber.

Significant positive heterosis which is desirable for the character number of female flowers was observed in almost all the hybrids. The hybrid P_1 x P_5 was the best when compared with mid parent and better parent. The hybrid P_3 x P_4 had the highest standard heterosis which had the maximum positive sca effect also in combining ability analysis. Significant heterotic effects for number of female flowers was reported by Solanki *et al.* (1982) in cucumber.

5.4.5 Number of fruits per plant

Variance for combining ability for parents and hyrbids were significant for number of fruits per plant. This indicated that both additive and non-additive gene actions were involved in the expression of the trait. The involvement of both additive and non-additive gene action was reported by Varghese and Rajan (1994) in snakegourd; Srivastava *et al.* (1983) and Mishra *et al.* (1994) in bittergourd; Sivakami *et al.* (1987) in bottlegourd; and Ghaderi and Lower (1981); Prudek (1984); Prudek and Wolf (1985); and Solanki and Shah (1990) in cucumber.

This trait was found to be controlled predominantly by non-additive gene action since dominance variance was more than additive variance (Table 7). The sca variance was more than gca variance. Non-additive gene action for this character was reported by Kumar and Singh (1997) in bottlegourd; and Sirohi *et al.* (1988) in pumpkin; and Solanki and Seth (1980) in cucumber.

Among the parents, P_5 had significant positive gca values and the parents P_2 and P_4 had significant negative value. All the hybrids showed significant sca effects of which only one (P_2 x P_3) had negative effect. Similar studies were reported by Singh and Joshi (1979) in bittergourd; Shawaf and Baker (1981) and Dolgikh and Siderova (1983) in cucumber; Li and Shu (1985) and Gill and Kumar (1988) in watermelon, where gca variance was more predominant.

All hybrids exhibited significant positive relative heterosis, heterobeltiosis and standard heterosis for the character. The hybrid P_2 x P_5 had the maximum positive heterobeltiosis and standard heterosis, which also had the maximum sca value in the combining ability analysis. Significant heterotic effects for number of fruits per plant was reported by Lawande and Patil (1990), Mishra *et al.* (1994), Celine and Sirohi (1996) and Ram *et al.* (1997) in bittergourd; Sharma *et al.* (1995) in bottlegourd; Hayes and Jones (1916); Solanki *et al.* (1982), Dalaney and Lower (1987) Vijayakumari *et al.* (1993) and Musmade *et al.* (1995) in cucumber; Shakhanov (1973) in melon; More and Seshadri (1980) and Dixit and Kalloo (1983) in muskmelon; and Kasrawi (1994) in summersquash.

5.4.6 Mean weight of fruit

Variance due to combining ability effects with respect to parents and hybrids was significant for individual fruit weight. This showed that both additive and non-additive gene actions were involved in the inheritance of this trait. This is in conformity with the results of Srivastava *et al.* (1983) and Mishra *et al.* (1994) in bittergourd; Sivakami *et al.* (1987) in bottlegourd; Ghaderi and Lower (1981) Prudek (1984), and Owens *et al.* (1985) in cucumber. Here also predominance of non-additive gene action were indicated since dominance variance is more than additive variance (Table 7). Non-additive gene action for this character was reported by Kumar and Singh (1997) in bottlegourd and Prudek and Wolf (1985) in cucumber.

Two parents (P_4 and P_6) showed significant negative gca and one (P_5) showed significant positive gca effect. All hybrids exhibited significant sca effects with only two (P_4 x P_5 and P_1 x P_5) showing negative effects. Similar studies were reported by Singh and Joshi (1979) in bittergourd; Smith *et al.* (1978); Shawaf and Baker (1981) and Dolgikh and Siderova (1983) in cucumber; Li and Shu (1985) and Gill and Kumar (1988) in watermelon; and Om *et al.* (1987) in oriental melon.

Most of the hybrids were significant for relative heterosis and heterobeltiosis. However only three hybrids were significant for standard heterosis for the character. Significant heterosis expressed in the hybrids for mean weight of fruit supported the results of combining ability analysis. The hybrid P_1 x P_5 exhibited maximum heterobeltiosis and standard heterosis had maximum sca values as well. The hybrid showing maximum relative heterosis (P_3 x P_5) also had similar values for sca.

Similar reports were given by Lawande and Patil (1990), Mishra *et al.* (1994) and Celine and Sirohi (1996) in bittergourd, Janakiram and Sirohi (1992) in bottlegourd; Imam *et al.* (1977), Solanki *et al.* (1982), Vijayakumari *et al.* (1993), Fang *et al.* (1994), and Musmade *et al.* (1995) in cucumber; More and Seshadri (1980) in muskmelon; and Kasrawi (1994) in summersquash

5.4.7 Fruit yield per plant

For fruit yield per plant the combining ability variance was significant for both parents and hybrids. Hence both gca and sca were significant suggesting the involvement of both additive and non-additive gene action. In agreement to this, significance of gca and sca effects were reported by Varghese and Rajan (1994) in snakegourd; Srivastava *et al.* (1983) and Mishra *et al.* (1994) in bittergourd; Sivakami *et al.* (1987) in bottlegourd; Ghaderi and Lower (1981); Prudek and Wolf (1985) and Solanki and Shah (1990) in cucumber. Here also the dominance variance was greater than additive variance indicating the predominance of non-additive gene action (Table 5). Similar reports were given by Kumar and Singh (1977) in bottlegourd, Solanki and Seth (1980) in cucumber.

Only two parents (P_5 and P_4) had significant positive gca values others being non-significant. All hybrids (except one) showed significant positive sca values. Results in the line were also reported by Sirohi and Choudhary (1977) in bittergourd; Smith *et al.* (1978) Shawaf and Baker (1981) Dolgikh and Siderova (1983) and Frederick and Staub (1989) in cucumber; Gill and Kumar (1988) in watermelon;

Korzeniewska and Nierricrowicz (1994) in wintersquash; and Om *et al.* (1987) in oriental melon.

Highly significant positive heterosis was exhibited by all hybrids. The hybrid P_2 x P_5 exhibited maximum values for all the three types of heterosis. Similar studies were reported by Lawande and Patil (1990), Mishra *et al.* (1994), Celine and Sirohi (1996) and Ram *et al.* (1997) in bittergourd; Pal *et al.* (1984), Janakiram and Sirohi (1992) and Sharma *et al.* (1995) in bottlegourd; Hayes and Jones (1916), Solanki *et al.* (1982), Rubino and Wehner (1986), Daleney and Lower (1987), Aleksandrova (1988), Satyanarayana (1991), Vijayakumari *et al.* (1993), Fang *et al.* (1994) and Musmade *et al.* (1995) in cucumber; More and Seshadri (1980) in muskmelon. Lack of heterosis for fruit yield was reported by Hormuzdi and More (1989) in cucumber.

5.4.8 Fruit length

In the analysis for fruit length, significant combining ability effects of gca and sca were recorded for parents and hybrids indicating the importance of both types of combining ability for the trait. The ratio of additive to dominance variance was more than unity indicating that the character was predominantly under the control of additive gene action. Similarly gca variance was considerably higher than sca variance (Table 7). This was in agreement to the study by Kalb and Davis (1984) in muskmelon. Singh and Joshi (1979) and Mishra *et al.* (1994) in bittergourd; and Owens *et al.* (1985) in cucumber reported the existence of both additive and non-additive gene action for this trait.

Combining ability analysis revealed that among parents, P_3 and P_2 had significant negative values and P_6 had significant positive value. All the hybrids had significant values and the hybrid P_3 x P_6 had the maximum positive value with one of its parent (P_3) with significant negative value and the other (P_6) with significant positive value.

Out of the fifteen hybrids, thirteen hybrids expressed significant positive relative heterosis, six hybrids showed significant positive heterobeltiosis and nine hybrid had significant positive standard heterosis. P_2 x P_6 along with other hybrids involving P_6 had higher standard heterosis and the hybrid P_4 x P_5 had the highest heterobeltiosis. The hybrid, P_2 x P_5 had the highest relative heterosis. Significant heterosis for fruit length was also reported by Mishra *et al.* (1994) in bittergourd; Sharma *et al.* (1995) in bottlegourd; Aleksandrova (1988) in cucumber; Shakhanov (1973) in melon and Doijode and Sulladmath (1984) in pumpkin.

5.4.9 Fruit girth

Analysis of variance for fruit girth showed significant gca and sca variance for parents and hybrids showing the significance of both additive and non-additive genetic components. Since dominance variance more than additive variance non-additive gene action was predominant in the trait (Table 7). Likewise sca variance was slightly higher than the gca variance (Table 7).

Among parents P_2 and P_3 gca effects were positive and significant and P_6 was negatively significant. Among hybrids, thirteen hybrids showed significant values of which two hybrids P_1 x P_4 and P_2 x P_3 had negatively significant values and all others were positively significant. Similar results were reported by Mishra *et al.* (1994) in bittergourd; Frederick and Staub (1989) in cucumber; and Kalb and Davis (1984) in muskmelon. The hybrid P_1 x P_6 had the maximum value.

Significant positive relative heterosis was shown by all hybrids except one (P_1 x P_4) and the hybrid P_5 x P_6 had the highest value. Eleven hybrids had significant heterosis when compared with better parent, here also P_5 x P_6 had the maximum value. All hybrids exhibited significant positive standard heterosis and the highest value was shown by P_2 x P_4.

Heterosis for fruit girth was also reported by Mishra *et al.* (1994) in bittergourd; Iman *et al.* (1977) and Aleksandrova (1988) in cucumber, Shakhanov (1973) in melon; Doijode and Sulladmath (1984) in pumpkin.

5.4.10 Flesh thickness

The variance due to gca and sca effects for both parents and hybrids were significant for flesh thickness. This indicated significant additive and non-additive gene action for the trait. The dominance variance was more than additive variance (Table 7) thereby revealing the predominant role of non-additive gene action. Similarly sca variance was higher than gca variance (Table 7). In agreement to this non-additive gene action was reported by Sirohi (1993) in pumpkin. Predominance of additive gene action was reported by Kalb and Davis (1984) in muskmelon; and Om *et al.* (1987) in oriental melon.

Significant positive gca effect was shown by parent P_3 and significant negative gca effect by P_6 and P_1. All the hybrids showed significant positive sca values, the hybrid P_2 x P_6 having maximum value.

The observations on heterosis in the hybrids well supported the results of combining ability analysis. All hybrids exhibited significant positive values for relative heterosis, heterobeltiosis and standard heterosis. The hybrid P_2 x P_6 recorded maximum positive relative heterosis and standard heterosis. With respect to heterobeltiosis this hybrid alone was on par with P_1 x P_6 which had the maximum values (Table 10). Manifestation of heterosis for flesh thickness was reported earlier by Pal *et al.* (1984) in bottlegourd; Aleksandrova (1988) and Musmade *et al.* (1995) in cucumber; Shakhanov (1973) in melon; Kalb and Davis (1984) in muskmelon; and Doijode and Sulladmath (1984) in pumpkin.

5.4.11 Number of seeds per fruit

For number of seeds per fruit, combining ability variance due to parents and hybrids were significant suggesting the involvement of both additive and non-additive gene action. (Table 7). The dominance variance was more than additive variance indicating the predominance of non-additive gene action (Table 7)

Among the parents P_6 and P_5 showed significant positive gca effect and the parents P_2, P_4 and P_1 had significant negative gca values. All hybrids except one (P_2 x P_3) were significant. Three hybrids (P_1 x P_5, P_5 x P_6 and P_2 x P_4) showed significant negative sca values, while others exhibited significant positive sca effects. The hybrid P_1 x P_3 had the maximum sca value, which was significantly superior to all others.

Predominance of non-additive gene action was reported by Kalb and Davis (1984) in muskmelon; and Dyustin and Prosvirnin (1979) in watermelon.

Twelve out of fifteen hybrids exhibited significant positive relative heterosis, eight hybrids showed significant positive heterobeltiosis and five showed significant standard heterosis. The hybrid P_1 x P_3 had the maximum values of relative heterosis and heterobeltiosis. The hybrid P_1 x P_5 had the highest standard heterosis and was superior to all others (Table 10). Doijode *et al.* (1983) also reported significant heterosis for this trait.

5.4.7 100 Seed weight

The combining ability variance due to both parents and hybrids was significant for 100 seed weight suggesting the importance of both additive and non-additive gene action for the expression of this trait. The ratio of additive to dominance variance was less than unity indicating the predominant role of non-additive gene action (Table 7). This finding was in agreement with the results of Dyustin and Prosvirnin (1979) in watermelon where the predominance of dominance and epistatic gene action is seen. However here the gca variance was higher than the sca variance.

Out of six parents P_2 and P_1 showed significant positive gca effect and the rest showed significant negative effects. Among fifteen hybrids eleven showed significant positive sca effects, the remaining four having significant negative effects. The hybrid P_3 x P_4 had the maximum positive sca value.

All hybrids except two recorded significant relative heterosis, five hybrids showed significant heterobeltiosis and eleven hybrids recorded significant positive standard heterosis. The hybrid P_3 x P_4 had the maximum value of relative heterosis and heterobeltiosis. The hybrid P_2 x P_5 had the highest standard heterosis along with the other three hybrids (Table 10). Significant heterotic effects for 100 seed weight was reported by Doijode *et al.* (1983) in pumpkin.

5.4.13 Duration of the crop

General and specific combing ability variances of parents and hybrids were significant for period of harvest. This indicated that both additive and non-additive gene actions were involved in the expression of the trait. The involvement of both additive and non-additive gene action was reported earlier by Om *et al.* (1978) in cucumber. However, the character was found to be controlled predominantly by additive gene action since the ratio of additive to dominance variance is more than unity. Similarly gca variance was considerably higher than sca variance for the character (Table 7). This was in agreement with the reports of Gill and Kumar (1988) in watermelon. Dyustin and Prosvirnin (1979) reported that in watermelon the trait was controlled by non-additive genes.

Among the parents,.P_6 showed significant positive gca effect and P_4 and P_1 showed significant negative effect. Among the hybrids three (P_4 x P_5, P_4 x P_6 and P_2 x P_3) showed significant positive sca effect and other hybrids except three (P_1 x P_5,

P_3 x P_4 and P_3 x P_5) had significant negative sca effects. The hybrid P_5 x P_6 had the maximum value.

Significant negative relative heterosis, heterobeltiosis and standard heterosis was exhibited by different hybrids. The maximum value was recorded in the hybrid P_5 x P_6 for relative heterosis and heterobeltiosis which was in accordance with the combining ability results. Negative heterosis is preferable for period of harvest, since it gives earliness and compactness for harvest. The hybrid P_1 x P_4 along with P_2 x P_4 gave maximum negative standard heterosis. Significant heterotic effects for duration of crop was given by Varghese and Rajan (1993b) in snakegourd; Pal *et al.* (1984), Rubino and Wehner (1986) and Vijayakumari *et al.* (1993) in cucumber and More and Seshadri (1980) in muskmelon.

5.4.14 Vine length

For vine length the combining ability variance was significant for both parents and hybrids. Hence both gca and sca were significant, suggesting the involvement of both additive and non-additive gene action. Significance of both additive and non-additive gene effects were reported by Solanki and Shah (1990) in cucumber. Here dominance variance was far greater than additive variance (Table 7) indicating the preponderance of non-additive gene action. The sca variance was more than gca variance (Table 7). Rastogi and Deep (1990b) in cucumber; and Sirohi (1993) in pumpkin reported the role of non-additive genes for the expression of this trait.

Among parents only one (P_6) had significant positive gca and P_3 significant negative gca effects. All the hybrids had significant sca effects where seven of them had significant negative sca effect and others had significant positive sca effects. The hybrid P_1 x P_3 had the maximum positive sca value.

Only a few hybrids showed significant heterosis values. Only two hybrids showed significant relative heterosis, four hybrids showed significant heterobeltiosis and three hybrids had significant standard heterosis values. The hybrid P_1 x P_3 had maximum heterotic value for all the three types of heterosis. Varghese and Rajan (1993b) reported standard heterosis and heterobeltiosis for the character in snakegourd and Fang *et al.* (1994) reported heterosis over standard variety for this character in cucumber.

Thus, it is evident from the above discussion that in the present material there exists considerable amount of genetic variability with respect to different characters as evident from the highly significant differences and close values of PCV and GCV. Heritability and genetic advance of most of the characters like days to first male flower, days to first female flower, fruit length, fruit yield per plant, flesh thickness, number of fruits per plant and 100 seed weight were high indicating that selection for these characters will be effective.

The variance due to general and specific combining ability 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 the gca variance in most of the characters studied which indicates the predominance of non-additive gene action.

Among parents, P_6 was found to be a good general combiner for characters like days to first male flower, days to first female flower, fruit length, number of seeds per fruit and vine length. For yield and yield related characters P_5 was a good general combiner. Among hybrids P_1 x P_5, P_2 x P_5 and P_2 x P_6 were superior specific combiners in yield characters like mean weight of fruit, number of fruits per plant and fruit yield per plant respectively. Manifestation of heterosis was observed for all the characters studied. Among the hybrids, P_2 x P_5 had the maximum standard heterosis for yield and yield related characters. The cross P_1 x P_5, P_5 x P_6 and P_3 x P_5 also exhibited significant standard heterosis for these characters. In general the hybrids involving the parent P_5 (Kaumudi) was found to be more heterotic.

The observations and findings obtained in this research programme may be confirmed by repeating the experiment before being commercially exploited.

SUMMARY

VI. SUMMARY

A diallel analysis in snakegourd was carried out in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 1997-1999 in order to determine the combining ability, to study the nature of gene action and also to estimate the heterosis for different characters. The experimental material consisted of six parental lines and their fifteen F_1 hybrids (without reciprocals). The experiment was laid out in Randomised Block Design with three replications. The observations were recorded on 14 characters including yield.

Significant differences were detected among the mean performance of the genetypes, for all the characters studied. Among the parents, P_6 was the earliest to produce male flowers, female flowers and to first fruit harvest. However the parent P_4 was the earliest in duration of the crop. The parent P_6 produced the longest fruits and largest number of seeds per fruit and had maximum vine length. In yield characters viz. number of fruits per plant, mean weight of fruits and fruit yield per plant, P_5 recorded the maximum values. The parent P_2 produced maximum number of female flowers and recorded maximum fruit girth and 100 seed weight. The parent P_3 had flesh with maximum thickness.

All the hybrids, with P_6 as male parent took least number of days to first male and female flowers. In days to first fruit harvest, P_1 x P_3 along with other 10 hybrids were shortest and on par. The hybrids P_3 x P_4 and P_2 x P_6 produced maximum number of female flowers. In duration of the crop, P_1 x P_4, P_2 x P_4 and P_3 x P_4 were shortest and on par. In yield characters viz. number of fruits per plant (P_2 x P_5 along

with other five hybrids), mean weight of fruits (P_1 x P_5) and fruit yield per plant (P_1 x P_5 and P_2 x P_5) the influence of P_5 parent is apparent. In number of female flowers, P_3 x P_4 and P_2 x P_6 were superior. Fruit length were maximum in the hybrid P_2 x P_6 along with other six hybrids and fruit girth was the highest in P_2 x P_4 along with other eight hybrids. In flesh thickness P_2 x P_6 recorded maximum value along with six hybrids. In number of seeds per fruit, P_1 x P_3 with other six hybrids and in 100 seed weight P_2 x P_5 along with other eight hybrids and in vine length P_1 x P_5 and other three hybrids recorded maximum mean values.

The variance due to general and specific combining ability 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 the gca variance in all the studied except mean weight of fruit, fruit length, number of seeds per fruit and duration of the crop where the trend was reverse. This indicated the predominance of non-additive gene action in most of the characters except the above four. Similarly ratio of additive variances to dominant variances was less than one in all the characters except fruit length and duration of the crop. Here also the predominant influence of non-additive gene action is very clear. These results very strongly substantiates the validity of the heterosis breeding method in improving the crop.

The parent, P6 was found to a good general combiner for characters like, days to first male flower, days to first female flower, fruit length, number of seeds per fruit; and vine length. The P_5 was superior, in this aspect with respect to number of fruits per plant, mean weight of fruit; and fruit yield per plant. Likewise P_4 was superior in number of female flowers and duration of the crop. In fruit girth and 100 seed weight P_2 was a good general combiner and P_3 was superior in gca only in flesh thickness.

The hybrid P_1 x P_3 showed good specific combining ability in days to first fruit harvest, number of seeds per fruit, and vine length. The hybrid P_2 x P_5 was a superior specific combiner in number of fruits per plant, P_1 x P_5 in mean weight of fruit and P_2 x P_6 in fruit yield per plant, the hybrid P_3 x P_6 and P_2 x P_5 were superior specific combiners in fruit length, P_1 x P_6, P_3 x P_6 and P_4 x P_5 in fruit girth; P_2 x P_6 in flesh thickness, P_3 x P_4 in 100 seed weight and P_5 x P_6 in duration of the crop. Hybrids P_1 x P_5; P_2 x P_5 and P_2 x P_6 were superior specific combiners in yield characters like mean weight of fruit; number of fruits per plant and fruit yield per plant respectively. The hybrid P_4 x P_6 and P_1 x P_6 recorded the maximum standard heterosis for least number of days to male flower; P_4 x P_6; P_2 x P_6 P_3 x P_6 and P_5 x P_6 for days to first female flower; P_1 x P_3 (and 7 other hybrids) for days to first fruit harvest, P_3 x P_4 for number of female flowers, P_2 x P_6 (and 4 others) for fruit length, P_2 x P_4 and P_2 x P_5 for fruit girth, P_2 x P_6 for flesh thickness; P_1 x P_5 and P_2 x P_6 for 100 seed weight; P_1 x P_4 and P_2 x P_4 for duration of the crop and P_1 x P_3 for vine length. In yield character, P_2 x P_5 and P_5 x P_6 exhibited maximum standard heterosis for number of fruits per plant; P_1 x P_5; P_2 x P_5 and P_3 x P_5 for mean weight of fruit and P_2 x P_5 for fruit yield per plant.

Hence it can be seen that in general the crosses involving the P_5 (Kaumudi) performed superior with respect to yield and yield contributing characters – in the mean performance, combining ability and heterosis.

The observations and findings on general and specific combining ability and heterosis realised in the present research programme may be confirmed by repeating the experiment before they are commercially exploited.

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ESTIMATION OF COMBINING ABILITY AND HETEROSIS IN SNAKEGOURD

(*Trichosanthes anguina.* L)

BY

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ABSTRACT OF THE THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURE (PLANT BREEDING AND GENETICS)
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ABSTRACT

A diallel analysis in snakegourd (*Trichosanthes anguina.* L.) was carried out in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during the period 1997-1999. The research work was taken up to assess the general and specific combining abilities, nature of gene action and also to estimate the heterosis for various characters. The six parents involved were selected from a previous D^2 analysis conducted in the Department and were the most divergent ones. They are P_1 (Nedumangad local), P_2 (Thrikkannapuram local), P_3 (Kanhangad local – 3), P_4 (Vlathankara local), P_5 (Kaumudi) and P_6 (Idukki local). The observations were recorded on yield and yield attributing characters.

Significant differences were detected among the mean performance of the genotypes, for all the characters studied. The combining ability analysis revealed that the parent P_5 (Kaumudi) was the best general combiner for most of the yield and and yield contributing traits. The hybrids P_1 x P_5, P_2 x P_5 and P_2 x P_6 were superior specific combiners in yield characters like mean weight of fruit, number of fruits per plant and fruit yield per plant respectively. The crosses involving P_5 and P_6 were found to be good specific combiners for yield and yield contributing characters.

The variance due to general and specific combining ability 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 the predominant influence of non additive

gene action which strongly substantiated the validity of the heterosis breeding method in improving the crop.

Manifestation of heterosis was seen for all the characters studied. Among the hybrids, P_2 x P_5 had the maximum standard heterosis for yield and yield related characters. The crosses P_1 x P_5, P_5 x P_6 and P_3 x P_5 also exhibited significant standard heterosis for these characters. In general the hybrids involving the parent P_5 was found to be more heterotic.