COMBINING ABILITY STUDIES IN TOMATO
[Lycopersicon esculentum Mill.]

By

SEEJA G.

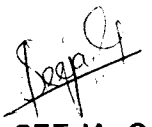
THESIS
Submitted in partial fulfilment of the requirement
for the degree of

MASTER OF SCIENCE IN AGRICULTURE
(PLANT BREEDING AND GENETICS)
FACULTY OF AGRICULTURE
Kerala Agricultural University

DEPARTMENT OF PLANT BREEDING AND GENETICS
COLLEGE OF AGRICULTURE
VELLAYANI
THIRUVANANTHAPURAM
1995

DECLARATION

I hereby declare that this thesis, entitled Combining ability studies in tomato (Lycopersicon esculentum Mill.) is a bonafide record of the research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar titles of any University or Society.



SEEJA G.

College of Agriculture,
Vellayani, 16 - 3 -1995.

CERTIFICATE

Certified that this thesis, entitled Combining ability studies in tomato (Lycopersicon esculentum Mill.) is a record of research work done independently by Kum. SEEJA G. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Dr. D.Chandramony,
Chairman,
Advisory Committee,
(Associate Professor)
Dept. of Agricultural
Botany).

College of Agriculture,
Vellayani, 16-3-1995

APPROVED BY :

CHAIRMAN :

Dr. D.CHANDRAMONY

MEMBERS :

Dr. P.D. VIJAYAGOPAL.

Dr. R. GOPIMONY.

Dr.(Mrs) P. SARASWATHY.

EXTERNAL EXAMINER :

A. Seetharam

Dedicated to

my loving Parents

ACKNOWLEDGEMENT

I wish to express my sincere and deep sense of gratitude to Dr. D.Chandramony, Associate Professor of Agricultural Botany and Chairman of my Advisory Committee for the valuable guidance and efficient supervision throughout the investigation and preparation of this thesis.

I am thankful to Dr. R.Gopimony, Professor and Head of Agricultural Botany for the valuable guidance and advice rendered during my research work.

I am extremely grateful to Dr.P.D.Vijayagopal, Professor and Head of Plant breeding and Genetics for valuable suggestions and help during this study. I also express my sincere thanks to Dr.V.Gopinathan Nair, former Professor and Head of Plant breeding and Genetics for his candid suggestions in formulating this research work.

I express my whole hearted thanks to Dr.P.Saraswathy, Professor and Head of Agricultural Statistics for her constant encouragement, creative criticism and valuable suggestions in designing the experiment, conducting the statistical analysis and interpreting the results.

My sincere thanks are due to C.E. Ajith Kumar, Junior Programmer of the Department of Agricultural Statistics for the help rendered during the analysis of the data and P. Sreekumar, Athira and Ranees Computers for their help in the preparation of this thesis.

I have pleasure to keep in mind the Co-operation and assistance obtained from Rani, Madhura, Deepa, Sindhu and Suresh and also Juniors of the Department of Plant breeding and Genetics. I also express my thanks to all Staff members of the Department for their timely help and Co-operation.

My heartful thanks are due to the Centre for Plant Molecular Biology, TNAU, Coimbatore and the Department of Biotechnology, New Delhi for providing me the relevant literature for the successful completion of this thesis.

I am thankful to the Kerala Agricultural University for awarding the K.A.U Fellowship.

Above all, I am very grateful to the Eternal Power guiding me through out this course programme.

SEEJA G.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

For the development of hybrid (F_1) variety suitable parents must be identified first. In this respect a basic knowledge on the combining ability of parents and gene action governing the yield characters is a pre-requisite for launching the hybridization programme.

As far as Kerala is concerned bacterial wilt caused by Pseudomonas solanacearum is a handicap which practically prevents the tomato cultivation. So to suit the condition of Kerala the high yielding varieties must necessarily be resistant to bacterial wilt. Only a very few varieties are reported so far as resistant to bacterial wilt.

Taking into consideration all the above points the present study was undertaken in a line x tester model with an objective of estimating the combining ability of parental varieties and nature of gene action involved in the inheritance of different yield attributes and heterosis that can be achieved in the hybrids. For the hybridization programme three well adapted bacterial wilt resistant varieties were used as lines and five popular varieties were used as testers. Basic information on combining ability, gene action, heterosis and disease resistance derived from this study will be useful for identifying suitable parents for the development of high yielding wilt resistant hybrid varieties.

INTRODUCTION

Tomato (Lycopersicon esculentum Mill.) belonging to the family Solanaceae is an important vegetable crop of Tropical American origin. It is the world's largest vegetable crop after potato. Moreover it is one of the most important protective foods because of its special nutritive value. Tomato is a rich source of Vitamins A, B and C.

In India, tomato is cultivated in an area of 0.29 million hectares with a production of 4.6 million tonnes. The average yield of tomato is only 15.85 tonnes per hectare. (Chhabra, 1992.)

The phenomenon of heterosis in crop plants is common and its exploitation for higher production is one of the plant breeding strategies. Choudhury et al. (1965) reported manifestation of hybrid vigour in F_1 and F_2 generations of tomatoes. In fact the culture of hybrid vegetables in the country started with the evolution of the hybrid tomato 'Karnataka' in 1973. Hybrid tomatoes offer a very high yield of 70-80t/ha. So development of hybrid variety is an ideal method to tackle the problem of low productivity.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Information on combining ability, gene action and heterosis for yield attributes in relation to wilt resistance is essential to chalk out efficient breeding programmes in tomato. A review of literature on these aspects are presented below.

Plant height

a. Combining ability and gene action

Svanosio and Vandoni (1974) studied combining ability involving eight lines from intervarietal hybrids of tomato in the F_4, F_5 and F_6 generations and reported significant sca effects for plant height.

In a study of intervarietal hybrids of tomato Rema Bai (1975) reported dominance for tall stature over medium stature of plant.

Combining ability analysis for plant height was carried out by Singh and Singh (1980). They reported that the gca variances were higher than sca variances in the F_1 and F_2 generations. Additive gene action was predominant for this character.

Govindarasu et al. (1981) from a line x tester analysis reported that sca variances were higher than gca variances. They suggested the involvement of non-additive gene action for this character.

Combining ability analysis of pear shaped tomato was done by Sidhu et al. (1981). They reported higher estimates of gca than those of sca. They also showed the importance of additive and non additive gene effects for plant height with a predominance of non additive gene effects. High gca was exhibited by the variety Chico grande.

Moya et al. (1986) in an estimation of combining ability of nine tomato varieties significant gca and sca effects were reported for fruiting height.

Sonone et al. (1986), in a combining ability analysis for yield and its components in tomato revealed that non additive effects were important for plant height.

Younis et al. (1987) reported that two gene pairs with dominance was involved in the inheritance of tallness in tomato.

Combining ability analysis of tomato involving several crosses revealed the significance of positive sca effects in six crosses for plant height (Chandrasekhar and Rao, 1989).

Combining ability for plant height was studied in a six parent diallel cross of tomato by Ali *et al*. (1989) and they reported highly significant gca and sca variances and involvement of additive and non additive gene effects.

The inheritance of plant height in tomato was studied in the parental, F_1, F_2, BC_1 and BC_2 generations of two crosses involving three parents by Brahma *et al*. (1991). They reported that in the cross Jap x CTI, the dominance effects were pronounced. Combining ability analysis of tomato including nine parents and their 36 F1's was carried out by Ghosh and Symal (1994) and they recorded high gca variance and predominant additive gene action for plant height. They suggested that crosses involving poor and good general combiners could give better expression for this trait.

b. Heterosis

Rema Bai (1975) studied heterosis in intervarietal hybrids of tomato and reported that all the hybrids exhibited heterotic effects for plant height.

Babu (1978), in a 6 x 6 diallel cross of tomato including parents and F_1 hybrids, reported heterosis for plant height.

Govindarasu *et al*. (1982) studied heterosis in tomato involving 11 lines, four testers and their hybrids and reported that heterosis was moderate for plant height.

Ahmed et al. (1988) in a study of heterosis in tomato reported that most of the hybrids showed positive heterosis over the better parent for plant height.

Brahma et al. (1991) studied the inheritance of plant height in the parental, F_1, F_2, BC_1 and BC_2 generations of tomato and reported heterosis for this trait.

In a 12 x 12 diallel cross involving parents and $66F_1$ hybrids in tomato Dod et al. (1992) reported pronounced heterosis for plant height.

Number of branches/plant

a. Combining ability and gene action

In an estimation of combining ability in tomato Gurdalbir Singh and Nandpuri (1974) reported that additive gene effects were important for branch number per plant. They also suggested that the cultivars Sutton's, Best of All, Pusa Ruby and Red Belt exhibited high gca for this trait.

Dudi et al. (1979) in a line x tester analysis in tomato reported that certain varieties exhibited high gca for this trait.

Singh and Singh (1980), in a combining ability analysis indicated that gca variances were higher than sca variances in

the F_1 and F_2 generations for number of primary branches/plant indicating predominance of additive gene action.

From a line x tester analysis Govindarasu *et al*. (1981) reported that sca variances were higher than gca variances indicating predominance of non additive gene action.

In a study of combining ability analysis of pear shaped tomato, Sidhu *et al*. (1981) reported high sca values and predominance of non additive gene effects for number of branches/plant.

Younis *et al*. (1987) reported that four gene pairs with dominance was involved in the inheritance of low number of branches/plant.

In a study of combining ability in tomato Lonkar and Borikar (1988) reported predominance of gca effects for this trait.

Combining ability analysis in a six parent diallel cross of tomato revealed significant gca and sca variance and additive and non additive gene effects for number of branches/plant. (Ali *et al*., 1989).

Diallel analysis in tomato was conducted by Ghosh and Symal (1994) and they reported that gca variances were greater than sca variances and additive gene action was predominant for number of

primary branches. They suggested that crosses involving poor and average general combiners could give better expression for this trait.

b. Heterosis

Rema Bai (1975) studied heterosis in intervarietal hybrids and revealed that all the hybrids exhibited heterotic effects for number of branches/plant.

From a study of heterosis in pear shaped tomato Sidhu et al. (1981) reported that the crosses Gamed x Chico Grande and Punjab Chhuhara x KAL exhibited heterotic effect for this trait.

Growth habit and Spread of the plant

Inheritance of growth habit components was studied by Daskaloff et al. (1975). They revealed that self pruning in tomato, which is controlled by the gene species is independent of growth habit components such as the number and length of internodes. The number of leaves/stem was partially dominant and more than 3 genes control growth habit.

Chandrasekhar and Rao (1989) noticed significant positive sca effects for spread of the plant in 6 crosses from a combining ability analysis of tomato.

Period of harvest

a. Combining ability and gene action

Svanosio and Vandoni (1974), studied the date of maturity in the F_4, F_5 and F_6 generation of tomato involving eight lines from intervarietal hybrids and noticed that there were significant gca and sca effects for this trait.

Nandpuri et al. (1975) studied the combining ability aspects in a set of top crosses of male sterile lines x pollinators and reported that gca and sca variances were important for earliness.

In a daillel cross involving six cultivars of tomato, Trinklein (1975) reported highly significant gca and sca effects for early yield and also reported that dominance and epistasis were involved in the inheritance of this character.

Maggiore et al. (1976) studied combining ability of tomato for early yield and observed significant gca and sca effects for this trait.

Diallel analysis on morphological and production traits in elongated and round types of tomato was done by Scossiroli et al. (1976) and they recorded that fruit maturity had significant additive and dominance effects.

Dudi *et al*. (1979) studied combining ability aspects of tomato in a line x tester model and reported that certain varieties exhibited high gca for early yield.

In a study of inheritance of earliness in first generation of tomato hybrids Egiyan and Luk'yanenko (1979) reported that earliness was dominant.

Khatyleva (1980) proposed that intervarietal hybridization in tomato using the lines with the best combining ability should be employed to produce early hybrids.

Singh and Singh (1980) studied combining ability of tomato and suggested that non additive variance was involved for number of days to fruit maturity in the F_1 generation.

F_1 hybrids of tomato cultivars were evaluated by Gibrel *et al* (1982) at three growth stages. They reported that gca variance was larger than sca variance for earliness from first fruit set to first ripe fruit stage.

In a combining ability analysis of tomato, Swamy and Mathai (1982) reported significant gca effects and predominant additive gene action for early fruit yield/plant.

In a diallel analysis of tomato including 7 cultivars and 21 F_1 hybrids Kalf-Allah and Kaseem (1985) reported that Pace setter 502 had the highest gca for early yield. They also suggested

the involvement of additive, dominance and epistatic effects in the expression of this character.

Lopez - Rivares and Cuartero (1985) studied the genetic aspects of earliness in yield in tomato and recorded that gca was highest in the varieties Oxheart, Fortuna and Floradel. They also reported partial dominance for this character and suggested that in order to get F_1 population with higher early yields, a parent which bears a large number of early fruits must be crossed with one which bears heavy fruits.

Younis *et al*. (1987) reported that additive gene action was important in the inheritance of earliness. They suggested that two gene pairs with dominance was involved for early ripening in tomato.

Ali *et al*. (1989) from their studies on combining ability for harvesting period in a 6 parent diallel cross of tomato, reported that gca and sca variances were significant and the additive and non additive gene effects were also significant for this trait.

Four tomato lines were crossed in a complete diallel design by Szwadiak and Kordus, (1992) and they reported significant gca and sca variances for early yield and they suggested the involvement of additive-dominance model of gene action for this trait.

Diallel analysis for combining ability in tomato was conducted by Ghosh and Symal (1994). They reported that gca variances were greater than sca variances and hence additive gene action was predominant for days to ripening. They suggested that crosses involving poor general combiners could show better expression.

b. Heterosis

Heterosis was reported for earliness in certain tomato hybrids by Zubeldia and Nuez (1974).

In a study of seven inbred lines and their 21 F_1 hybrids of tomato, Lobo and Marin (1975) reported heterosis for harvesting period.

In an estimation of combining ability and reciprocal effects for several characters in tomato Trinklein (1975) reported that heterotic effects were significant for early yield in tomato.

Egiyan and Luk'yanenko (1979) reported heterosis for earliness in some hybrids of intervarietal crosses of tomato. Heterosis for earliness was exhibited by the hybrids V729 x Cross 525, Cross 525 x Sort 123 and Sort 123 x Podarok 105.

Govindarasu et al. (1982) studied heterosis in tomato involving 11 lines, four testers and their hybrids and reported that heterosis was moderate for earliness.

Narcisco and Rosario (1988) studied processing quality of tomato hybrids and reported that hybrids exhibited heterosis and heterobeltiosis for days to first harvest.

Heterosis was studied for harvesting period in a six parent diallel cross of tomato by Ali et al. (1989) and they suggested that the crosses Japanese x World Champion, World Champion x FR 2 and World Champion x CTI exhibited high heterosis for this trait.

In a 12 x 12 diallel cross involving parents and 66 F_1 hybrids in tomato Dod et al. (1992) reported pronounced heterosis for days to first harvest.

Individual fruit weight

a. Combining ability and gene action

Gurdalbir Singh and Nandpuri (1974) conducted combining ability analysis of tomato crosses involving two male sterile lines 19-5 and 26-5 and 8 cultivars and recorded that the cultivars and the line 19-5 exhibited high gca for fruit weight. Crosses obtained from cultivars with high gca showed high sca for this trait. They suggested the importance of additive as well as non additive gene effects for this trait.

Svanosio and Vandoni (1974) studied combining ability in the F_4, F_5 and F_6 generation of intervarietal hybrids of tomato and indicated significant gca effects for mean fruit weight.

Milkova (1975) reported that gca for fruit weight was stable and it was higher in the cultivars than in the lines obtained by crossing different species of tomato. They also reported the involvement of both additive and non additive effects for this trait.

In a diallel cross involving 6 cultivars of tomato Trinklein (1975) found significant sca effect and also involvement of dominance and epistasis in the inheritance of fruit weight.

In a 6 x 6 reciprocal diallel cross using inbred lines of tomato Trinklein and Lambeth (1975) reported that small fruited PJ 118785 showed the largest negative gca effect for fruit weight and hence suggested that dominance controlled this trait.

In a line x tester analysis of tomato Dixit et al. (1980) revealed that gca and sca variances were significant and gca variances were higher than sca variances and hence the predominance of additive gene action for average fruit weight.

Progeny from diallel crosses among 9 inbred lines were evaluated by Swamy and Mathai (1982) and they reported significant gca effects and predominant additive gene action for fruit weight.

Combining ability for fruit weight was studied in a 6 x 6 diallel cross of tomato by Dholaria and Qadri (1983) and they

revealed highly significant gca and sca variances and predominant additive gene action for the above character.

Khalil et al (1983) studied heritability of fruit weight in tomato and indicated that this trait is quantitatively inherited with predominance of additive effects.

Kalf-Allah and Kaseem (1985) in the study of combining ability consisting of 7 cultivars and 21 F_1 hybrids as a diallel set in tomato revealed that the variety VFN 8 had high gca for fruit weight. They reported significant additive and dominance effects and epistasis for mean fruit weight.

In an estimation of gca and sca of 9 tomato varieties including 36 F_1's derived from a diallel cross Moya et al. (1986) reported that the gca and sca effects were significant for fruit weight.

Sonone et al. (1986) studied combining ability effects of tomato crosses derived from 13 lines and four testers and reported high gca effects and predominant additive gene action for this trait.

Lonkar and Borikar (1988), while analysing combining ability in tomato found predominant gca effects for fruit weight.

Omara et al. (1988) reported that in a 6 x 6 diallel cross of tomato gca and sca effects were significant in the parents and

F_1 hybrids. The components of variance analysis revealed predominant additive gene effects for fruit weight.

Chandrasekhar and Rao (1989) reported significant positive sca effects for fruit weight in eight crosses of tomato.

Combining ability analysis in six parent diallel cross for fruit weight was done by Ali et al. (1989) and they reported significant gca and sca variances and hence suggested the involvement of additive and non additive gene effects in the inheritance of this trait.

Szwadiak and Kordus (1992) crossed four tomato lines in complete diallel design and reported significant gca and sca variances for single fruit weight.

Diallel analysis for combining ability in tomato was conducted by Ghosh and Symal (1994). They reported that the variety Flora Dade was the best general combiner. They suggested that crosses involving poor general combiners could give better expression for this trait.

b. Heterosis

Sidhu et al. (1981) studied heterosis in pear shaped tomato involving seven varieties and their hybrids from a non reciprocal diallel cross and reported that the hybrid from the cross Roma x Punjab Chhuhara exhibited high heterosis for average fruit weight.

Heterosis for fruit weight was studied in tomato by Alvarez (1985) and he reported significant positive heterosis for this trait. The hybrid from the cross INCA 21 x INCA 3 was superior to the better parent.

Ahmed et al. (1988) studied heterosis in tomato and reported that most of the hybrids showed positive heterosis over the better parent for fruit weight.

Number of fruits/plant

a. Combining ability and gene action

Conti (1974) reported that for the character total number of fruits/plant in tomato dominance effects accounted for most of the genetic variance in tomato.

In an estimation of combining ability in tomato Gurdalbir Singh and Nandpuri (1974) reported that the male sterile line 19-5, the cultivars and their crosses exhibited high gca and sca effects. They also suggested that both additive and non additive effects were important for fruit number/plant.

Svanosio and Vandoni (1974) studied combining ability in tomato involving 8 lines from intervarietal hybrids in the F_4, F_5 and F_6 generations and reported significant gca effects for this trait.

In tomato combining ability analysis in a set of top crosses of male sterile lines x pollinators was conducted by Nandpuri et al. (1975). They reported significant gca and sca variances for number of fruits/plant.

Trinklein and Lambeth (1975), while analysing combining ability of tomato hybrids derived from a 6 x 6 reciprocal diallel set found that the small fruited line, PJ 118 785, showed the greatest gca effect for fruit number and it was mainly controlled by additive effects.

Combining ability in tomato was studied by Maggiore et al. (1976) and they reported that gca effects were significant for this trait and they suggested the involvement of additive gene effects.

Singh and Mital (1978) in a combining ability analysis of tomato reported significant gca variance for fruit number/bunch in the F_1 generation.

Combining ability analysis for five yield components in the winter and summer seasons was conducted by Dhillon et al. (1979) and they reported significant gca variances in the male and female parents in both seasons for fruit number.

Dudi et al. (1979) carried out line x tester analysis and reported that, of the 21 crosses, certain hybrids showed high sca for number of fruits/plant.

In a line x tester analysis Dixit et al. (1980) revealed that gca variances and sca variances were significant for this trait. But gca variances were higher than sca variances indicating that additive gene action was predominant.

Analysis of variance for combining ability in tomato conducted by Singh and Singh (1980) showed that the gca variances were higher than sca variances in the F_1 and F_2 generations for number of fruits/plant and number of fruits/bunch indicating the predominance of additive gene action.

Govindarasu et al. (1981) reported from a line x tester analysis, that sca variances were higher than gca variances for number of fruits/plant and hence non additive gene action was involved in the inheritance of this trait.

In a study of combining ability in pear shaped tomato Sidhu et al. (1981) reported predominance of non additive gene effects for number of fruits/plant.

Combining ability analysis of tomato involving progenies from a diallel set of crosses was conducted by Swamy and Mathai (1982) and they reported significant gca effect and predominant additive gene action for this character.

In an analysis of combining ability, Dholaria and Qadri (1983) recorded significant gca and sca variances and predominant additive gene effects for the character number of fruits/plant.

Khalil et al. (1983) studied heritability of number of fruits/plant and indicated that the character was quantitatively inherited with predominance of additive effects and partial dominance.

Combining ability analysis of 9 tomato varieties including $36F_1$'s of a diallel set indicated significant gca and sca effects for this trait. (Moya et al., 1986).

Sonone et al. (1986) estimated combining ability in a 13 x 4 line x tester combination in tomato and reported high gca effects and predominant additive gene action for fruit number.

Genetics of yield components in tomato were investigated by Dhaliwal and Nandpuri (1988) and they reported the involvement of digenic interaction and additive and dominance effects in the inheritance of this trait.

Combining ability analysis in a line x tester model, was done by Lonkar and Borikar (1988) and they reported that high gca for fruit yield was associated with high or medium gca for fruit number.

Omara et al. (1988) in a 6 x 6 diallel analysis of tomato showed that both gca and sca effects were high in the F_1 hybrids. Additive and non-additive gene effects were found to be significant with predominant role of additive component of genetic variance for this trait.

In a six parent diallel cross of tomato, combining ability was estimated by Ali et al. (1989) and revealed significant gca and sca variances and involvement of both additive and non additive genetic effects for this trait.

A diallel cross with five cultivars of tomato revealed that the parents IPA-3 and Roma VFN showed high gca and hybrids with Roma VFN as one of the parents showed high sca for total number of fruits/plant (Araujo and Campos, 1991).

The inheritance of number of fruits per plant was studied in the parental, F_1, F_2, BC_1 and BC_2 generation of two crosses involving three parents and reported that in the cross Jap x CTI, the dominance and the additive x dominant gene effects were predominant (Brahma et al., 1991).

Szwadiak and Kordus (1992), in a study of combining ability four tomato lines were crosed in a complete diallel design and recorded significant gca and sca variances for this trait.

Ghosh and Symal (1994) from their studies on combining ability reported that the variety BT-1 was the best general combiner for number of fruits/plant. They suggested that for getting better of this trait good and poor general combiners should be crossed.

b. Heterosis

Conti (1974) from his studies on tomato hybrids reported that among several traits maximum heterosis was observed for total number of fruits/plant.

Heterosis was reported for number of fruits in tomato hybrids by Zubeldia and Nuez (1974) and they recorded that the hybrid from the cross Marmande x Tonda Sioux exhibited high heterosis for this trait.

Trinklein (1975) reported that heterotic effects were significant for fruit number in tomato.

Babu (1978) studied heterosis in a 6 x 6 diallel cross of tomato including parents and F_1 hybrids and showed heterosis for fruit number.

In tomato a line x tester analysis was carried out by Anbu *et al*. (1981) and they estimated the relative heterosis and heterobeltiosis for number of fruits/plant.

Sidhu et al. (1981) studied heterosis in pear shaped tomato and reported that the hybrid from the cross Sel 152 x Roma, exhibited high heterosis for number of fruits per plant.

In a preliminary estimation of hybrid vigourin tomato Sonone et al. (1981) reported heterotic effect for this trait.

Govindarasu et al. (1982) studied heterosis in tomato involving 11 lines, four testers and their hybrids and reported that heterosis was high for fruits/plant.

Jamwal et al. (1984) reported hybrid vigour for fruit number/plant in a line x tester analysis of tomato involving ten foreign lines and three local testers.

Ahmed et al. (1988) studied heterosis in tomato and reported that most of the hybrids showed positive heterosis over the better parent for fruits/plant.

Brahma et al. (1991) studied the inheritance of number of fruits/plant in the parental, F_1, F_2, BC_1 and BC_2 generations of tomato and reported heterosis for this trait.

In a 12 x 12 diallel cross involving parents and F_1 hybrids in tomato Dod et al. (1992) reported pronounced heterosis for number of fruits/plant.

Fruit yield/plant

a. Combining ability and gene action.

Diallel analysis using eight varieties of tomato was carried out by Betlach and Novak (1968-69). They reported that the combining ability effects were not significant for total yield/plant.

Gurdalbir Singh and Nandpuri (1974) analysed the combining ability of 8 tomato cultivars and two male sterile lines 19-5 and 26-5 and observed that the cultivars and the line 19-5 showed significant gca for yield. The results indicated the importance of additive gene effects.

Combining ability analysis, using a set of top crosses of male sterile lines with pollinators in tomato for yield components showed the importance of gca and sca effects for yield. (Nandpuri et al., 1975).

Trinklein (1975) reported highly significant gca effects and involvement of additive gene action in the inheritance of total yield in tomato through diallel analysis.

Trinklein and Lambeth (1975) recorded from a 6 x 6 reciprocal diallel cross using inbred lines of tomato, that the line Mosage had the greatest gca effect for total yield and this trait was mainly controlled by additive effects. Maggiore et

al. (1976) reported significant gca effects and additive gene action for total yield.

Singh and Mital (1978) in a combining ability analysis of tomato involving parents, F_1 and F_2 generations recorded significant gca and sca variances for yield/plant.

Dudi et al. (1979) conducted a line x tester analysis in tomato with parents and their 21 crosses and reported that certain varieties and hybrids showed high gca and sca for total yield.

In a line x tester analysis, Dixit et al. (1980) revealed that gca variances of the female parent were significant and higher than sca variances with regard to yield/plant in tomato. The variety HS 120 had the highest gca for yield.

Combining ability studies in tomato by Singh and Singh (1980) indicated the significance of non additive variances for yield/plant in both F_1 and F_2 generations.

According to Govindarasu et al. (1981), sca variances were higher than gca variances for this trait. They also reported a preponderance of non additive gene action here.

Sidhu et al. (1981) studied combining ability in pear shaped tomato involving seven varieties and their hybrids from a non reciprocal diallel cross and reported high values for both gca and sca. They also reported significant additive and non additive gene effects with predominance of non additive gene effects for total yield/plant.

In a line x tester analysis of tomato Borikar et al. (1982) reported high gca in the tester Pusa Ruby and in four lines and high sca in ten cross combinations for yield.

Combining ability analysis of 44 F_1 hybrids using 11 lines and four testers in tomato done by Govindarasu et al. (1983). They suggested that the two lines LE 758 and LE 68 were good general combiners for yield.

Combining ability analysis of tomato for yield was carried out by Dholaria and Qadri (1983). They reported that both gca and sca variances were significant and additive gene action was predominant for the expression of this trait.

Kalf-Allah and Kaseem (1985) from their studies on combining ability using seven cultivars and 21 F_1 hybrids of a diallel set in tomato, suggested that the cultivar VFN 8 was a good general combiner for total yield. They reported significant additive, dominance and epistatic effects for total yield.

Raijadhav and Kale (1985) conducted combining ability analysis of tomato in a line x tester model and reported that parents and hybrids exhibited significant gca and sca effects for yield.

In an estimation of combining ability with 36 F_1's derived from a diallel set of crosses involving nine varieties of tomato Moya *et al*. (1986) reported significant gca and sca effects for yield.

Sonone *et al*. (1986) reported significant sca effects and predominant non additive gene action for yield/plant in tomato in a line x tester analysis using 13 lines and four testers.

Lonkar and Borikar (1988), in a line x tester analysis involving 16 male sterile lines and three pollinators recorded predominance of gca effects and they suggested that Pusa Ruby was a good general combiner for yield in tomato. They also reported that in general high gca for fruit yield was associated with high or medium gca for fruit number.

Genetics of yield components in tomato was studied by Dhaliwal and Nandpuri (1988) and they recorded the involvement of additive and dominant gene action together with the digenic interaction in the inheritance of the total yield.

In a genetic analysis of yield and its components in tomato using parents, F_1 and F_2's of a 6 x 6 diallel set Omara *et al*. (1988) recorded that both additive and non additive effects were significant and there was predominance for the additive component of genetic variance for the total yield/plant.

Chandrasekhar and Rao (1989) reported significant sca effect for yield in seven crosses of tomato and identified Pusa Early Dwarf as the best general Combiner for yield.

Combining ability estimation from a triallel cross of tomato Singh *et al*. (1989) reported that (Pusa Ruby x HS 110) x Ostenkinskii showed the greatest sca effects for yield.

Combining ability analysis for fruit yield per plant in a six parent diallel cross of tomato was carried out by Ali *et al*. (1989) and they indicated that gca and sca variances were highly significant and additive and non additive gene effects were involved for the inheritance of this trait. The best general combiners identified were CI-143-0-10-3 and World Champion.

Combining ability for yield was studied in a diallel set involving 11 varieties and their hybrids by Kryuchkov *et al*. (1992) and they indicated that yield was polygenically controlled with predominance of dominant genes.

Four tomato lines were crossed in a complete diallel design by Szwadiak and Kordus (1992) and they reported significant gca and sca variances suggesting the involvement of an additive-dominance model of gene action for the total yield.

Ghosh and Symal (1994) conducted combining ability analysis in tomato and reported that sca variance was significant for fruit yield/plant and hence the involvement of non additive gene action. Flora Dade, BT-1, Punjab Chhuhara and Arka Vikash showed excellent gca for fruit yield. Crosses involving poor x poor general combiners gave high fruit yield/plant.

b. Heterosis

Avdeev (1974) recorded positive heterosis for fruit yield in tomato and also observed that certain hybrids with low yield could show positive heterosis for other characters.

Conti (1974) from his studies on tomato hybrids reported that the hybrids gave a mean increase in yield per ha of 8.2%.

Swadiak (1974) reported that heterosis for yield/plant observed in the tomato hybrids was due to the increase in the number of fruits/plant and not at all due to the large fruit size.

Lobo and Marin (1975) studied heterosis for yield in tomato including seven inbred lines and their 21 F_1 hybrids. They reported that the average value of heterosis for yield per plant based on the highest yielding parent was 120%.

Rema Bai (1975) studied heterosis in intervarietal hybrids of tomato and reported that all the hybrids exhibited heterotic effects for yield per plant.

Trinklein (1975) reported that heterotic effects were significant for total yield in tomato.

Babu (1978) studied heterosis in a 6 x 6 diallel cross of tomato including parents and F_1 hybrids and reported heterosis for fruit yield. The yield was maximum in the hybrid Pusa Ruby x Tiny Tim (723.54 q/ha).

Palaniappan *et al*. (1981) conducted growth analysis for fruit yield in tomato involving six lines and their nine F_1 hybrids and reported heterosis for this trait. The best hybrid identified was LE 719 x LE 573.

Sidhu *et al*. (1981) studied heterosis in pear shaped tomato involving seven varieties and their hybrids and reported that high heterosis for yield was shown by Gamed x Chico Grande, Roma x Punjab Chhuhara, Punjab Chhuhara x KAL and Sel 152 x Roma.

In a preliminary estimation of hybrid vigour in tomato Sonone et al. (1981) found that out of 197 hybrids, 13 gave 80-155% higher yield than the control Pusa Ruby.

Govindarasu et al. (1982) studied heterosis in tomato involving 11 lines, four testers and their hybrids and reported that heterosis was high for yield and the best hybrid was LE 758 x LE 413.

Jamwal et al. (1984) reported hybrid vigour for fruit yield/plant in the hybrids obtained from line x tester cross involving ten foreign lines and three local testers of tomato. The hybrids EC 6050 x Lalmani, EC 122156 x Lalmani and EC 121193 x Gola were having very good yield.

In a study of tomato involving seven parental cultivars and their 21 F_1's derived from a diallel set Bhuiyan et al. (1986) observed that Fujuki x World Champion exhibited maximum heterosis for yield/plant.

Ahmed et al. (1988) studied heterosis in tomato including six varieties and their 15 F_1's and reported that most of the hybrids showed positive heterosis over the better parent for yield per plant.

Narcisco and Rosario (1988) studied the processing qualities of tomato hybrids and reported that the hybrids exhibited heterosis and heterobeltiosis for the fruit yield.

Kanthaswamy and Balakrishnan (1989) reported that among the different hybrids studied the hybrid from the cross LE 3 x LE 1036 was outstanding giving the highest yield of 1.646 kg per plant with a relative heterosis estimate of 29.81%.

Mandal *et al*. (1989) observed heterobeltiosis for fruit yield and quality and reported that the hybrid from the cross Pusa Early Dwarf x KS1 was the highest yielding hybrid having 46.9 fruits/plant on an average.

Ali *et al*. (1989) studied heterosis for fruit yield per plant in a six parent diallel cross of tomato and reported that the crosses Japanese x World Champion, World Champion x FR_2 and World Champion x CT1 exhibited high heterosis for this trait.

In a 12 x 12 diallel cross involving parents and 66 F_1's in tomato Dod *et al*. (1992) reported pronounced heterosis for yield per plant.

Kryuchkov *et al*. (1992) reported that maximum heterosis for fruit yield in tomato was achieved by a successful combination of high gca and high sca effects.

Bora et al. (1993), in a study of eight parental tomato varieties and their 19 F_1's recorded significant heterosis for yield over the better parent in 11 hybrids. The hybrid from the cross $BT_{10} \times K_{10}$ showed highest heterosis for yield.

Hybrids from a diallel set of crosses between 11 varieties of tomato were evaluated by Sidhu and Surjan Singh (1993) for yield and they reported that heterosis ranged from 0.7% to 71.7%.

Kanthaswamy (1994), in a study of hybrid vigour in tomato reported that the F_1 hybrid of cross E (LE 3 x LE 1036) was the outstanding giving highest yield of 1.6 kg/plant with the high relative heterosis estimate of 29.8%.

Number of leaves/plant

a. Combining ability and gene action.

From a diallel cross involving six lines, Konstantinova et al. (1990) reported that leaf number between inflorescences was affected by growing conditions. Dominance and epistasis were found in the inheritance of this character.

b. Heterosis

Rema Bai (1975) studied heterosis in intervarietal hybrids of tomato and indicated that all the hybrids exhibited heterotic effects for number of leaves per plant.

Pericarp thickness

a. Combining ability and gene action.

Combining ability analysis of 10 varieties of tomato conducted by Patil and Bojappa (1968) and they indicated significant gca and sca variances. Higher sca effect for pericarp thickness was observed in the cross San Merzano x NTDR-1.

Nandpuri and Tyagi (1976) in a study of inheritance of pericarp thickness in tomato showed that thick pericarp was partially dominant to thin pericarp and they suggested the importance of additive effects for the control of this trait.

The combining ability analysis of 36 hybrids from the crosses of three testers and 12 lines in tomato revealed significant gca and sca differences, for pericarp thickness. The best general combiners identified were Gamed, Sioux and Improved Meeruti and the best specific combiner was Gamed x Sioux (Bagrawat Singh et al., 1980).

Combining ability analysis of 15 varieties of tomato from a line x tester cross revealed significant sca variances for pericarp thickness. (Dixit et al., 1980).

Bhutani (1981) conducted combining ability analysis in tomato and recorded predominant role of non additive gene action and partial dominance for the pericarp thickness in both F_1 and F_2 generations.

Sidhu et al. (1981) studied combining ability in pear shaped tomato involving seven varieties and their hybrids on a diallel set and reported that estimate of sca was higher than that for gca indicating the predominance of non additive gene action for pericarp thickness. The best general combiner for this trait was Roma and the best specific combiner was ChicoGrande x Labonita.

Combining ability analysis from a line x tester cross involving two testers and 10 lines revealed that the contribution of gca variance was more prominent for pericarp thickness. The best general combiner was the line `SM' for this trait (Patil and Patil, 1988).

Combining ability analysis involving parents and their F_1's was conducted by Ghosh and Symal (1994) and they reported greater gca variances and predominant additive gene action for the inheritance of pericarp thickness. They suggested that crosses involving poor x average general combiners gave better expression for this trait.

b. Heterosis

Nandpuri and Tyagi (1976) reported heterosis for pericarp thickness in the F_1 hybrids of tomato.

In a line x tester study of tomato involving 10 lines, two testers and 20 crosses, Patil and Patil (1988) recorded high heterosis for pericarp thickness in most of the hybrids.

Locules/fruit

a. Combining ability and gene action.

Nandpuri and Tyagi (1976) in a study of inheritance of locule number in tomato showed that low number of locules per fruit was dominant to high number and he suggested that dominance effects were more important in the control of locule number.

Singh and Mital (1978) studied combining ability in tomato and reported that gca variance was greater than sca variance and the parent K.Kuber exhibited high gca for this trait.

The combining ability analysis of 36 hybrids from a line x tester cross of tomato revealed significant gca and sca differences for locule number per fruit. PH 14, SL120 and Pusa Ruby were the best general combiners and Punjab Tropic x SL120 was the best specific combiner for this trait. (Bagrawat Singh et al., 1980).

Combining ability analysis of tomato involving parents, F_1's and F_2's was carried out by Singh and Singh (1980) and they observed that gca variances were higher than sca variances in the F_1 and F_2 generations for number of locules per fruit. They reported the predominance of additive gene action for this trait.

Combining ability analysis involving eight parents, F_1's and F_2's of a diallel set of tomato indicated predominance of non additive gene action and partial dominance for locule number per fruit in both F_1 and F_2 generations (Bhutani, 1981).

Govindarasu *et al*. (1981) reported from a line x tester analysis of tomato that additive gene action was involved in the inheritance of locule number per fruit.

In a study of combining ability in pear shaped tomato Sidhu *et al*. (1981) reported predominance of non additive gene effects for number of locules per fruit.

Dholaria and Qadri (1983) from a 6 x 6 diallel cross of tomato reported significant gca and sca variances and predominant additive gene effects for number of locules/fruit.

Tarrega and Nuez (1983) conducted combining ability analysis of parents and F_1's of a 7 x 7 half diallel cross of tomato and reported that gca and sca variances were highly significant for number of lobes in the fruit.

In an estimation of combining ability of nine tomato varieties including 36 F_1's derived from a diallel cross, it was indicated that additive effects were significant for number of carpels per fruit. (Moya et al., 1986).

Younis et al. (1988) reported that additive gene effects were greater than non additive effects and partial dominance was involved for higher number of locules per fruit.

Inheritance of locule number was studied by Bhutani and Kalloo (1991) in tomato including 28 F_1's and F_2's from a diallel cross and reported that additive gene action was highly significant for this trait.

b. Heterosis

In a study of heterotic effects on parental, F_1, F_2, BC_1 and BC_2 populations of tomato Ahmed and Petrescu (1983) reported positive heterosis for locules/fruit.

In a combining ability analysis of tomato Ghosh and Symal (1994) reported greater gca variances and predominant additive gene action for number of locules per fruit. Crosses with poor general combiners gave higher expression for this trait.

Size of fruits

a. Combining ability and gene action

Combining ability analysis with a set of top crosses of male sterile lines and pollinators was conducted by Nandpuri et al. (1975). They reported significant role of gca and sca variances for fruit size.

Dominance was noticed for large size of fruit over small size in a study of intervarietal hybrids of tomato conducted by Rema Bai (1975).

Inheritance of fruit size in tomato was studied by Nandpuri and Tyagi (1976) in the cross EC 55055 x Punjab Tropic and they reported that small fruit size was partially dominant over large fruit size. They suggested the predominance of additive effects in the inheritance of this trait.

Dudi et al. (1979) conducted a line x tester analysis in tomato involving parents and their 21 crosses and reported that gca was high for fruit diameter.

Inheritance of fruit shape in tomato was studied by Hanna and Hernandez (1979). They reported that fruit diameter was controlled by a minimum of two pairs of genes.

Singh and Singh (1980) in a combining ability analysis of tomato involving parents, F_1's and F_2's of line x tester crosses reported that gca variances were higher than sca variances in the F_1 and F_2 generations for fruit size. They also reported predominance of additive gene action for this trait.

Govindarasu et al. (1981) reported from a line x tester analysis of tomato that additive gene action was involved in the inheritance of fruit size.

Combining ability analysis conducted on a diallel set of crosses in tomato by Dholaria and Qadri (1983) recorded that the gca and sca variances were significant for the character fruit volume. They indicated that the character is predominantly controlled by additive gene action.

Combining ability analysis using the parents, and F_1's of a 7 x 7 half diallel cross of tomato was carried out by Tarrega and Nuez (1983) and they reported that gca and sca variances were highly significant for fruit diameter.

In an estimation of combining ability of nine tomato varieties and their 36 F_1's as a diallel set significant gca and sca effects were reported by Moya et al. (1986).

Combining ability analysis of tomato was carried out by Ghosh and Symal (1994). They reported that for polar fruit

diameter Flora Dade was the best general combiner. Crosses with poor x average general combiners gave better expression for this trait.

b. Heterosis

In a preliminary estimation of hybrid vigour in tomato Sonone et al. (1981) reported that certain hybrids exhibited heterotic effect for fruit size.

Alvarez (1985) reported heterosis for equatorial diameter of fruit.

Bacterial wilt resistance

Singh (1961) and AVRDC (1975) reported that bacterial wilt resistance is controlled by multiple recessive genes in tomato.

Ferrer (1976) studied inheritance of resistance to Pseudomonas solanacearum in tomato and suggested that resistance was polygenically inherited and the genes involved were additive and no dominance was involved.

Graham and Yap (1976) studied inheritance of resistance to Pseudomonas solanacearum in tomato in a diallel cross of six cultivars and indicated that the gca was more important than sca. They suggested that inheritance of resistance was mainly due to additive gene action.

Cinar (1978) reported that differences in resistance were related to the number of bacteria present in the leaf cells four days after infection.

Rema devi (1978) reported that Pseudomonas solanacearum existed in different races coming under either race 1 or race 3.

Sunarjono (1980) reported that the breeding lines AVRDC 33, AVRDC 15 and CL 32-d-0-1-25 were resistant to Pseudomonas solanacearum.

Sonoda et al. (1980) observed that the better sources of resistance to Pseudomonas solanacearum are Hawaii 7997, CRA 66 and PI 126408A.

Bell (1981) stated that the factors which influence resistance to bacterial wilt include intensity, duration and quality of light, moisture levels, nutrient levels and agricultural and industrial chemicals.

Celine (1981) reported that CL-32-d-0-19GS is a bacterial wilt resistant variety. A resistant line viz. Sakthi has been developed in the horticultural College, Vellanikkara.

Rajan (1985) reported that in Kerala bacterial wilt caused by the soil borne pathogen Pseudomonas solanacearum EF Smith was a handicap which affected the tomato cultivation very seriously.

Performance of local tomato varieties against bacterial wilt disease was conducted by Ho (1988) and he reported that disease incidence in the field peaked in approximately the ninth week after transplanting. High rainfall, especially towards the middle and end of the growing season favoured high disease incidence.

Narcisco and Rosario (1988) studied bacterial wilt resistance of tomato hybrids and reported that hybrids exhibited heterosis and heterobeltiosis in bacterial wilt resistance.

Varietal resistance to bacterial wilt in tomato was carried out by Kapoor et al. (1991) and they reported that of the 62 varieties screened, 9 were immune, 26 were resistant, 5 were moderately resistant, 4 were moderately susceptible and 18 were susceptible. Environmental factors were found to be involved in the stability of resistance.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present study was undertaken in the Division of Plant Breeding and Genetics, College of Agriculture, Vellayani during 1993-94 with the objective of estimating the combining ability and gene action for yield and bacterial wilt resistance in tomato.

MATERIALS

The first part of the experiment consisted of pot culture where the selected varieties were grown for hybridization. The materials consisted of eight varieties of tomato, of which three were bacterial wilt resistant ones already identified and five were popular high yielders. The high yielders were used as testers and resistant ones were used as lines. The details of these varieties are given in table 1.

Three lines and five testers were crossed in a line x tester fashion. These 15 hybrid combinations are listed in table 2.

Table - 1. Details of parental varieties

Lines/ Testers	Treatment Number	Name of variety	Source
Lines	L_1	Arka Abha	11HR, Bangalore
	L_2	Arka Alok	11HR, Bangalore
	L_3	Sakthi	Department of Olericulture, Horticultural College, Vellanikkara.
Testers	T_1	LE 312	Department of Olericulture, Horticultural College, Vellanikkara.
	T_2	LE 370	"
	T_3	LE 373	"
	T_4	RFH-1	"
	T_5	PKM-1	"

METHODOLOGY

A. Pot culture

All the eight varieties were grown in pots for collection of selfed and hybrid seeds. For hybrid seed production ten plants each of the eight varieties were grown in pots following the standard pot culture method. Staggered planting was followed to obtain synchronised flowering for crossing. Sufficient number of flowers in each variety were selfed to produce true to type plants for the experiment. The techniques followed for the production of selfed and crossed seeds were as follows.

Selfing

For getting selfed seeds mature flower buds which would open on the next day were covered with paperbags and labelled in the evening. The paper bags were retained till the end of fruit setting.

Crossing

For hybridization programme the three lines were used as female parents and five testers were used as male parents. From the lines mature flower buds which would open on the next day were selected in the evening and emasculation was done by standard manual method using forceps. The emasculated flower buds were covered with paperbag. Next morning between 9 and 10

am. the emasculated flowers were pollinated by pollen collected from the male parent. For collecting pollen grains, the anther walls were split open with a needle and pollen grains were scooped out and transferred to the stigmatic surface. After pollination the flowers were protected with paper bags. Labels with the details of crossing were attached and kept till the fruits ripen.

The fully ripened fruits of both selfed and crossed flowers were harvested and seeds were extracted separately. For collection of seeds, pulp with seeds were kept for fermentation in separate containers for one day, and seeds were separated by washing with water eight to ten times to remove slimy materials. Seeds were dried in shade for one day and then under sun for two to three days before storing.

B. Field experiment

In the second part of the programme the evaluation of the line x tester hybrids and parents was carried out as a replicated field trial in a wilt free area with further precautions taken to avoid wilt through heat sterilization of each planting pit and application of higher dose of organic manure.

Well developed good quality seeds of eight parents and 15 hybrids were sown in nursery and 30 days after sowing the

seedlings were transplanted to the main field in Randomised Block Design with three replications. In a replication, each treatment consisted of 10 plants planted at a spacing of 60 x 60cm. The cultural and management practices were done as per package of practices (KAU, 1993) except the heat treatment and higher dose of organic manure applied to avoid wilt.

Observations on the following characters were recorded.

1. Plant height
2. Number of branches/Plant
3. Growth habit

    a) Determinate (dwarf)
    b) Indeterminate
    c) Semi determinate.

4. Spread of the plant
5. Period of harvest
6. Individual fruit weight
7. Number of fruits/plant
8. Fruit yield/plant
9. Number of leaves/plant
10. Pericarp thickness
11. Locules/fruit
12. Size of fruits
13. Observation on pests and diseases.

Observations from all the 10 plants were taken in each plot.

The details of observations are given below.

1. Plant height.

The height of plant was measured in centimeters from the base of the main shoot to the tip of leaf bud of the largest branch using a meter scale and the mean plant height was estimated.

2. Number of branches/plant.

Total number of primary, secondary and tertiary branches were counted and the mean was estimated.

3. Growth habit

The plants were classified into any one of the following three types as per description given.

a) Determinate

Inflorescence occurs more frequently in every internode until terminal ones are formed and elongation ceases at this point. The main axis terminates with a flower cluster.

b) Indeterminate

Inflorescence cluster occurs at every third internode and the main axis continues growing indefinitely.

c) Semi determinate

It is intermediate between determinate and indeterminate one.

4. Spread of the plant

Measured between the farthest two opposite leaf buds in the side branches in centimeters and average was worked out.

5. Period of harvest

Number of days from first to final fruit harvest and the mean was estimated.

6. Individual fruit weight

Weight of five fruits from each plant was taken and the mean weight was recorded as the mean single fruit weight in gram.

7. Number of fruits/plant

The number of fruits of each plant in a plot was noted and average was estimated.

8. Fruit yield/plant

Total weight of all the fruits harvested periodically from each plant in a plot was recorded and the mean yield in gram per plant was estimated.

9. Number of leaves/plant

Number of leaves from each plant in a plot was counted and the average number of leaves/plant was estimated.

10. Pericarp thickness

The pericarp thickness was measured in millimeters from five random fruits from each plant in a plot after cutting the fruits transversely.

11. Locules/fruit

From each plant, five random fruits were selected and number of locules was counted and mean number of locules/fruit was estimated.

12. Size of fruits

Five random fruits from each plant was taken and their volume was measured by the water displacement method using a measuring cylinder. The mean volume of fruit/plant was estimated in cubic centimeter.

13. Observation on pests and diseases

a) Tomato fruit borer (Heliothis armigera)

The number of fruits attacked by the fruit borer in a plot was recorded and expressed as percentage.

b) Mosaic

The number of plants infected by mosaic in a plot was recorded and expressed as percentage.

c) Leaf curl

The number of plants infected by leaf curl in a plot was recorded and expressed as percentage.

Statistical analysis

Analysis of variance was conducted for the characters under study to test for the significant differences among genotypes including both crosses and parents (Singh and Chaudhary, 1977). ANOVA for line x tester mating design is presented in table 3.

Line x tester analysis

Combining ability and gene action were estimated from the ANOVA of the line x tester model (Dabholkar, 1992).

$$\text{Contribution of testers} = \frac{SST}{SSC} \times 100$$

$$\text{Contribution of line x testers} = \frac{SSLT}{SSC} \times 100$$

Where SSL = sum of squares due to lines

SST = sum of squares due to testers

SSLT = sum of squares due to line x testers

SSC = sum of squares due to crosses

Heterosis

The three types of heterosis namely relative heterosis, heterobeltiosis, and standard heterosis along with the standard error (SE_d) were estimated as following:

$$\text{Relative heterosis (RH)} = \frac{\overline{XF1} - \overline{MP}}{\overline{MP}} \times 100$$

$$SE_d = \sqrt{\frac{3\ Me}{2\ r}}$$

$$\text{Heterobeltiosis (HB)} = \frac{\overline{XF1} - \overline{BP}}{\overline{BP}} \times 100$$

$$SE_d = \sqrt{\frac{2\ Me}{r}}$$

Table - 3 ANOVA for line x tester mating design

Source	df	MS	Expected mean square
Replication	(r-1)		
Treatments	(v-1)		
Parents	(l+t)-1		
Crosses	lt-1		
Parents Vs crosses	1		
Lines	l-1	ML	$\sigma^2e + r \times \sigma^2sca + rt \times \sigma^2gca$
Testers	t-1	MT	$\sigma^2e + r \times \sigma^2sca + rl \times \sigma^2gca$
Line x Tester	(l-1)(t-1)	MLT	$\sigma^2e + r \times \sigma^2sca$
Error	(r-1)(v-1)	Me	σ^2e
Total	vr-1		

Where r = number of replications

v = number of genotypes

l = number of lines

t = number of testers

σ^2sca = sca variance

σ^2gca = gca variance

σ^2e = error variance

Estimation of gca and sca effects

gca effects of lines

$$gi = \frac{li}{rt} - \text{mean}$$

$$\text{Mean} = \frac{G'}{ltr}$$

Where gi = gca effect of i^{th} line

li = sum total of observations with respect to i^{th} line.

G' = total of observations with respect to all hybrids

$$SE\ (gi-gj) = \sqrt{\frac{2\ Me}{rt}}$$

gca effects of testers

$$gj = \frac{tj}{rl} - \text{mean}$$

Where gj = gca effect of j^{th} tester

tj = sum total of observations with respect to j^{th} tester

$$SE\ (gi-gj) = \sqrt{\frac{2\ Me}{rl}}$$

sca effects of line x testers

$$Sij = \frac{(lt)\ ij}{r} - \frac{li}{rt} - \frac{tj}{rl} + \text{mean}$$

Where Sij = sca effect of i x j^{th} cross

(lt) ij = value corresponding to ixj^{th} cross

$$SE\ (Sij\text{-}Sil) = \sqrt{\frac{2\ Me}{r}}$$

$$SE\ (Sij\text{-}Skl) = \sqrt{\frac{2\ Me}{r}}$$

Estimation of genetic components of variance

$$\sigma^2 gca = \frac{(1+F)}{4}\ \sigma^2\ a$$

$$\sigma^2 sca = \frac{(1+F)^2}{2}\ \sigma^2\ d$$

When F = 0

$$\sigma^2 gca = 1/4\ \sigma^2 a$$

$$\sigma^2 sca = 1/4\ \sigma^2 d$$

where F = Coefficient of inbreeding

$\sigma^2 a$ = additive variance

$\sigma^2 d$ = dominance variance

Proportional contribution of lines, testers and line x testers to total variance

$$\text{Contribution of lines} = \frac{SSL}{SSC} \times 100$$

$$\text{Standard heterosis (SH)} = \frac{XF1 - \overline{SC}}{\overline{SC}} \times 100$$

$$SE_d = \sqrt{\frac{2\ Me}{r}}$$

Where $\overline{X}F1$ = F1 mean

$\overline{MP}$, $\overline{BP}$ and $\overline{SC}$ respectively

are the mean of mid parent, better parent and

standard cultivar

Me = Mean square for error

r = number of replications

RESULTS

RESULTS

The experiment was conducted using three lines, five testers and their resultant fifteen hybrids in RBD with three replications. The mean performance, combining ability and gene action of the lines, testers and line x tester hybrids were analysed. The heterosis of the line x tester hybrids was also analysed and the results are presented below.

4.a. MEAN PERFORMANCE

The mean performance of lines, testers and line x tester hybrids for the different characters is given in table 4.

The mean plant height was minimum in Sakthi (45.38 cm) and maximum in Arka Alok (52.66 cm) among lines. Among testers the height was minimum in PKM-1 (48.82 cm) and was maximum in LE 373 (105.39 cm). In hybrids the minimum and maximum plant height were recorded by Arka Abha x RFH-1 (51.33 cm) and Arka Abha x LE 373 (95.52 cm) respectively.

The lowest mean number of branches/plant was recorded in Arka Alok (6.58) and highest number of branches was recorded in Sakthi (13.54). The tester RFH-1 produced minimum number of branches/plant (3.9) and LE 373 produced maximum number of branches/plant (17.93). Among the hybrids the minimum and maximum number of branches/plant were recorded by Arka Abha x RFH-1 (5.33) and Sakthi x LE 370 (18.56) respectively.

Table - 4 Mean performance of lines, testers and hybrids for different morphological characters.

Parents/Hybrids	Plant height (cm)	Number of branches/ plant	Spread of the plant (cm)	Period of harvest (days)	Individual fruit weight (g)	Number of fruits/ plant	Fruit yield/ plant (g)	Pericarp thickness (mm)	Number of leaves/ plant	Locules/ fruit	Size of fruit (cc)
1	2	3	4	5	6	7	8	9	10	11	12
Arka Abha	45.42	7.1	20.83	23.5	54.34	7.5	424.17	4.82	74.71	4.93	51.92
Arka Alok	52.66	6.58	24.92	19.0	46.65	7.67	321.01	3.37	95.44	3.92	43.75
Sakthi	45.38	13.54	23.87	17.38	30.59	35.17	1261.33	3.28	65.48	3.74	28.17
LE 312	62.82	15.67	24.0	19.5	38.45	11.30	439.43	3.31	138.9	4.93	35.22
LE 370	72.47	15.96	34.53	25.25	22.02	20.22	445.4	3.02	200.58	3.68	19.17
LE 373	105.39	17.93	44.98	21.5	37.53	7	263.77	4.28	207.73	4.63	34.71
RFH-1	49.42	3.9	18.31	10.67	34.35	4.67	192.95	4.15	75.4	3.94	41.72
PKM-1	48.82	7.56	23.02	20.82	43.34	13.43	598.50	3.63	106.67	4.59	39.16
Arka Abha x LE 312	69.52	12.82	59.47	14.87	44.77	11.57	517.95	3.45	222.6	4.90	41.62
Arka Abha x LE 370	89.43	17.41	48.39	17.0	47.76	13.42	680.27	4.02	219.67	4.50	44.22
Arka Abha x LE 373	95.52	13.67	71.28	14.28	49.44	8.83	435.86	4.21	208.51	4.87	47.68

Table - 4 Continued .....

1	2	3	4	5	6	7	8	9	10	11	12
Arka Abha x RFH-1	51.33	5.33	21.0	27.67	43.8	14.33	438.65	4.38	54.0	4.98	45.69
Arka Abha x PKM-1	75.83	7.78	34.57	12.44	52.92	16.67	362.64	4.67	93.83	3.75	51.56
Arka Alok x LE 312	67.50	10.82	43.36	11.88	61.67	10	616.33	4.46	148.73	4.42	59.36
Arka Alok x LE 370	61.23	9.13	28.5	11.52	46.16	13.08	570.22	3.15	143.25	5.05	42.29
Arka Alok x LE 373	84.26	9.49	40.17	6.47	46.17	6	560.33	3.83	163.53	4.99	43.35
Arka Alok x RFH-1	56.74	5.75	24.72	16.25	71.38	7.17	512.60	5.92	58.23	4.24	69.54
Arka Alok x PKM-1	86.37	10.70	54.11	15.56	56.67	15.17	678	3.71	217.83	5.11	51.91
Sakthi x LE 312	86.08	14.69	75.63	14.65	31.92	19.8	634.65	3.38	201.07	3.97	28.18
Sakthi x LE 370	83.78	18.56	70.36	21.77	26.12	25.14	659.43	3.41	170.02	3.78	22.60
Sakthi x LE 373	89.83	15.98	42.2	18.02	33.14	18.67	618.67	3.89	159.87	4.22	31.38
Sakthi x RFH-1	58.78	7.68	44.89	25.37	39.90	20.67	823.27	4.21	68	3.57	37.63
Sakthi x PKM-1	66.56	11.32	50.0	15.92	43.86	14.97	655.80	3.81	127.56	4.01	40.5
F (22,44)	21.81**	6.61**	10.17**	8.62**	65.72**	24.83**	16.01**	5.07**	37.67**	4.01**	20.96**
SE	3.77	1.72	5.48	1.79	1.42	1.09	54.73	0.29	9.61	0.26	2.51
CD(5%)	10.75	4.90	15.62	5.10	4.03	8.22	167.34	0.84	27.38	0.75	7.17

For spread of the plant wide variation was observed among the lines, testers and line x tester hybrids. The line Arka Abha exhibited minimum spread of 20.83 cm and Arka Alok exhibited maximum spread of 24.92 cm. Among testers it was minimum in RFH-1 (18.31 cm) and was maximum in LE 373 (44.98 cm) while in hybrids minimum and maximum spread was recorded by Arka Abha X RFH-1 (21 cm) and Sakthi x LE 312 (75.63 cm) respectively.

Mean duration from first to final harvest varied from 17.38 days in Sakthi to 24.92 days in Arka Abha among lines. But in testers it ranged from 10.67 days in RFH-1 to 25.25 days in LE 370. Among the hybrids this period ranged from 6.47 days in Arka Alok x LE 373 to 27.67 days in Arka Abha x RFH-1.

Individual fruit weight was minimum in Sakthi (30.59 g) and maximum in Arka Abha (54.34 g) among the lines. Testers showed a variation from 22.02 g in LE 370 to 43.34 g in PKM-1. In the hybrids this range was from 26.12 g in Sakthi x LE 370 to 71.38 g in Arka Alok x RFH-1.

Average number of fruits/plant was minimum in Arka Abha (7.5) among the lines and in LE 373 (7) among the testers and was maximum in Sakthi (35.17) among the lines and in LE 370 (20.22) among the testers. Among hybrids the lowest and highest values were recorded by Arka Alok x LE 373 (6) and Sakthi x LE 370 (25.14) respectively.

Among lines average fruit yield/plant ranged from 321.01 g/plant in Arka Alok to 1261.33 g/plant in Sakthi. In the testers it ranged from 192.95 g/plant in RFH-1 to 598.50 g/plant in PKM-1. This range was from 362.64 g/plant in Arka Abha x PKM-1 to 823.27 g/plant in Sakthi x RFH-1 among the hybrids.

The minimum and maximum pericarp thickness were recorded by Sakthi (3.28 mm) and Arka Abha (4.82 mm) respectively among the lines. In the testers the pericarp thickness ranged from 3.02 mm in LE 370 to 4.28 mm in LE 373. Arka Alok x LE 370 recorded the minimum pericarp thickness of 3.15 mm and Arka Alok x RFH-1 recorded the maximum pericarp thickness of 5.92 mm among the hybrids.

The average number of leaves/plant varied from 65.48 in Sakthi to 95.44 in Arka Alok among the lines and from 75.4 in RFH-1 to 207.73 in LE 373 among the testers. Number of leaves/plant ranged from 54 in Arka Abha x RFH-1 to 222.6 in Arka Abha x LE 312 in the hybrids.

The mean number of locules/fruit among lines was minimum in Sakthi (3.74) and maximum in Arka Abha (4.93). Among testers number of locules/fruit was minimum in LE 370 (3.68) and maximum in LE 312 (4.93). Minimum and maximum value in hybrids were shown by Sakthi x RFH-1 (3.57) and Arka Alok x PKM-1 (5.11) respectively.

Size of fruit in the lines ranged from 28.17 cc in Sakthi to 51.92 cc in Arka Abha. In the testers the variation ranged from 19.17 cc in LE 370 to 41.72 cc in RFH-1. In the hybrids it was from 22.60cc in Sakthi x LE 370 to 69.54cc in Arka Alok x RFH-1.

4.b. COMBINING ABILITY AND GENE ACTION

Analysis of variance of different morphological characters studied are presented in table 5.

Highly significant differences were observed among the genotypes for all the characters, hence proceeded to combining ability analysis in a line x tester model and the results are presented below.

The general combining ability (gca) effects of parents and the specific combining ability (sca) effects of hybrids for eleven characters are given in table 6 and table 7.

Combining ability analysis of plant height revealed that variance due to testers and hybrids was significant. But for the lines it was not significant. The gca effect was negative and significant in Arka Alok (-3.56) among the lines. Among testers LE 373 had significant positive gca effect (15.08) and RFH-1 had negative effect (-19.17) and both of them were significantly different from the rest. Significant positive sca effect was shown by hybrids Arka Alok x PKM-1 (14.01), Arka Abha x LE 370

Table 5 ANOVA of lines, testers and line x tester hybrids

Source	df	Mean squares										
		Plant height	Number of branches/ plant	Spread of the plant	Period of harvest	Individual fruit weight	Number of fruits/ plant	Fruit yield/ plant	Pericarp thickness	Number of leaves/ plant	Locules/ fruit	Size of fruit
Replication	2	267.22**	100.89**	922.76**	48.91*	35.96**	0.77	25021	0.49	114.94	0.26	1.03
Treatments	22	930.13**	58.67**	916.19**	82.89**	394.88**	87.76**	139088.6**	1.31**	10429.59**	0.82**	397.60**
Parents	7	1260.35**	84.74**	239.95*	58.82**	297.06**	80.45**	335783.2**	1.16**	95730.38**	0.84**	299.53**
Hybrids	14	596.78**	49.66**	841.05**	87.47**	400.97**	84.01**	41919.43**	1.38**	10607.55**	0.85**	418.53**
Parents vs Hybrids	1	3285.58**	2.24	6702.08**	187.16**	994.34**	191.34**	129593.5**	1.41*	13931.56**	0.26	791.04**
Lines	2	143.68	74.86*	1276.52	185.33**	1741.51**	365.32**	137335.5*	0.98	971.63	3.06**	1750.92**
Testers	4	1367.09**	104.54**	1035.71	150.30**	232.97	45.69	11904.75	2.19	25362.94**	0.26	300.31
Line x tester	8	324.90**	15.92	634.85**	31.59**	149.83**	32.84**	32198.25**	1.08**	5638.83**	0.59*	144.55**
Error	44	42.65	8.87	90.10	9.62	6.01	3.53	8687.137	0.26	276.88	0.20	18.97

* Significant at 5% level
** Significant at 1% level

(9.74) and Sakthi x LE 312 (9.69). Hybrids Arka Abha x LE 370 (-13.35) and Sakthi x PKM-1 (-12.38) exhibited significant negative sca effect. The gca and sca effects for plant height are presented in figure 1.

The gca and sca effects for number of branches/plant are presented in figure 2. Variance for number of branches/plant was significant only among lines and testers. The maximum positive and negative gca effects were recorded by the lines Sakthi (2.24) and Arka Alok (-2.23) respectively and among the testers LE 373 (3.63), and RFH-1 (-5.16) respectively. None of the hybrids exhibited significant positive sca effect but only Arka Alok x LE 370 (-3.67) exhibited significant negative sca effect.

Analysis of variance for spread of the plant showed significant differences among hybrids only. The gca effects differed significantly among the lines and the testers. The lines Sakthi and Arka Alok recorded gca effect of 9.37 and -9.08 respectively. Only LE 312 (12.23) and RFH-1 (-17.05) recorded significant gca effect among testers. The sca effect was positive and high in hybrids, Arka Abha x LE 373 (20.35), Arka Alok x PKM-1 (16.93) and Sakthi x LE 370 (11.91) and negative in Sakthi x LE 373 (-18.38), Arka Abha x PKM-1 (-11.30) and Arka Alok x LE 370 (-11.51). The gca and sca effects for this trait are presented in figure 3.

Table - 6 Gca effects of parents (lines and testers) with respect to different morphological characters.

Parents		Plant height	Number of branches/ plant	Spread of the plant	Period of harvest	Individual fruit weight	Number of fruits/ plant	Fruit yield/ plant	Pericarp thickness	Number of leaves/ plant	Locules/ fruit	Size of fruit
Lines	1	1.54	-0.006	-0.29	1.01	1.36*	-1.40*	-97.24*	0.11	9.28*	0.17	2.32**
	2	-3.56*	-2.23*	-9.08*	-3.91*	10.03*	-4.08*	3.19	0.18	-4.13	0.34*	9.46*
	3	2.02	2.24*	9.37*	2.90*	-11.39*	5.98*	94.05*	-0.29*	-5.14	-0.51*	-11.78*
	F	0.44	4.70*	2.01	5.87**	11.62**	11.12**	4.27*	0.91	0.17	5.16**	12.1**
	SE	1.69	0.77	2.45	0.80	0.63	0.49	24.07	0.13	4.30	0.12	1.13
	CD	4.81	2.19	6.99	2.28	1.81	1.38	68.65	0.38	12.26	0.33	3.21
Testers												
	4	-0.42	1.37	12.23*	-2.45*	-0.26	-0.58	5.33	-0.27	40.35*	0.01	-0.78
	5	3.36	3.63*	1.84	0.52	-6.36	2.85*	52.33	-0.51*	27.20*	0.02	-7.46*
	6	15.08*	1.64	3.97	-3.32*	-3.46*	-3.20*	-46.02	-0.06	26.86*	0.27	3.03*
	7	-19.17*	-5.16*	-17.05*	6.85*	5.31*	-0.31	7.20	0.80*	-90.37*	-0.16	7.12*
	8	1.14	-1.48	-0.99	-1.60	4.77*	1.24*	-18.83	0.03	-4.04	-0.13	4.16*
	F	4.21**	6.57**	1.63	4.76**	1.56	1.39	0.37	2.04	4.50**	0.45*	2.08
	SE	2.18	0.99	3.16	1.03	0.82	0.63	31.07	0.17	5.55	0.15	1.45
	CD	6.21	2.83	9.03	2.95	2.33	1.79	88.62	0.48	15.82	0.43	4.14

Table - 7 Sca effects of hybrids

Line x tester hybrids	Plant height	Number of branches/ plant	Spread of the plant	Period of harvest	Individual fruit weight	Number of fruits/ plant	Fruit yield/ plant	Pericarp thickness	Number of leaves/ plant	Locules/ fruit	Size of fruit
L_1T_1	-6.39	0.05	0.27	0.06	-2.71	-0.82	25.54	-0.43	22.53*	0.30	-3.75
L_1T_2	9.74*	2.38	-0.40	-0.77	6.39*	-2.40*	140.87*	0.38	32.74*	-0.12	5.53*
L_1T_3	4.11	0.63	20.35*	0.35	5.16*	-0.93	-5.19	0.12	21.93*	-0.002	4.56
L_1T_4	-5.83	-0.91	-8.92	3.57*	-9.26*	1.68	-55.62	-0.57	-15.35	0.54*	7.58*
L_1T_5	-1.63	-2.15	-11.30*	-3.21	0.41	2.47*	-105.61*	0.49	-61.85*	-0.72*	1.25
L_2T_1	-3.30	0.28	-7.05	1.99	5.52*	0.29	23.50	0.52	-37.94*	-0.35	6.85*
L_2T_2	-13.35*	-3.67*	-11.51*	-1.33	-3.68*	-0.05	-69.61	-0.56	-30.27*	0.27	3.53
L_2T_3	-2.04	-1.33	-1.97	-2.55	-6.78*	-1.08	18.86	-0.32	-9.04	-0.04	-6.91*
L_2T_4	4.69	1.73	3.60	-2.94	9.66*	-2.81*	-82.09	0.89*	2.29	-0.36	9.13*
L_2T_5	14.01*	2.99	16.93*	4.82*	-4.51*	3.65*	109.33*	-0.53	75.56*	0.48	-5.54*
L_3T_1	9.69*	-0.32	6.78	-2.05	-2.81	0.53	-49.05	-0.09	15.41	0.06	-3.09
L_3T_2	3.61	1.29	11.91*	2.10	-2.50	2.44*	-71.26	0.18	-2.48	-0.15	-1.99

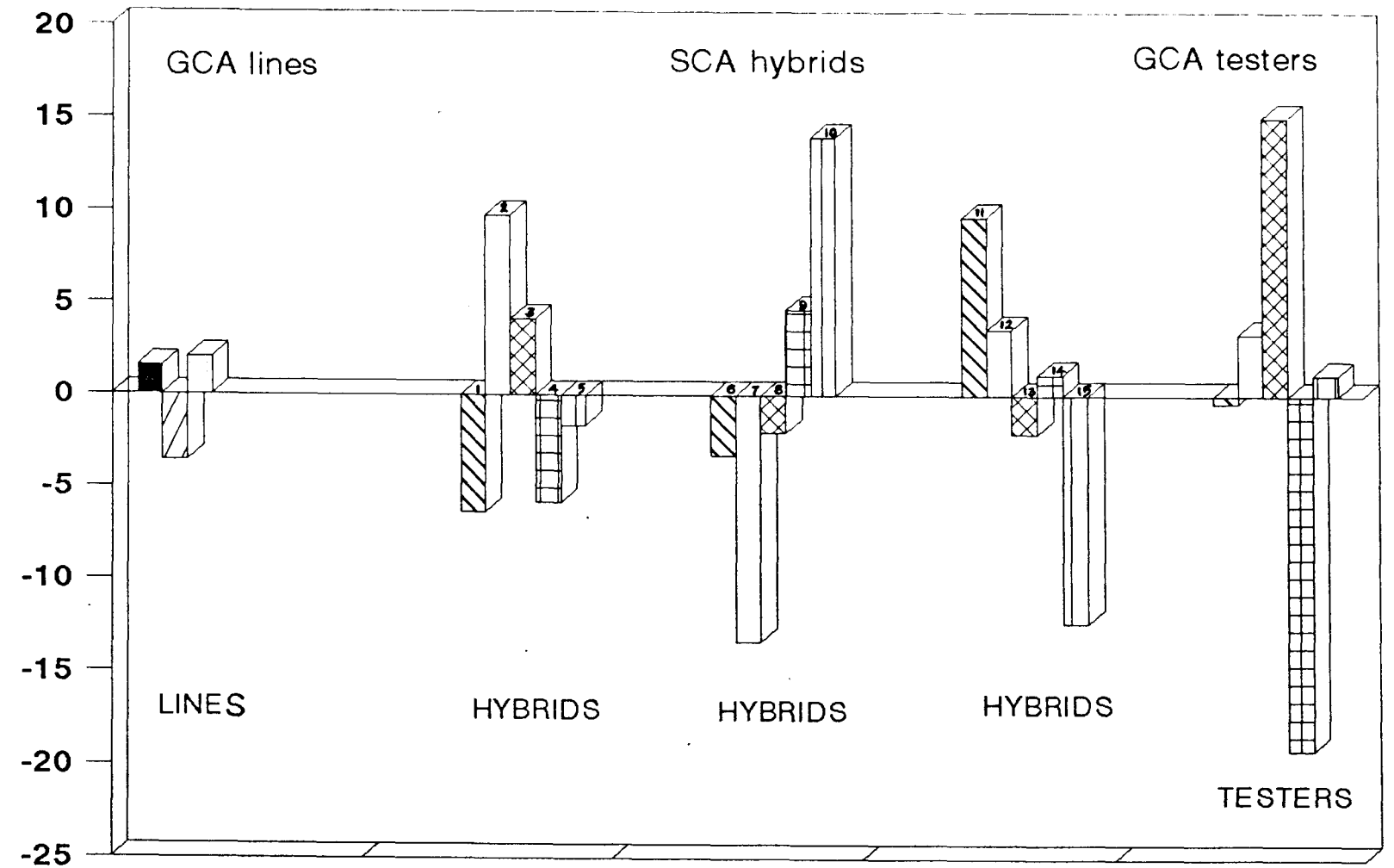


Fig. 1. GCA and SCA-plant height

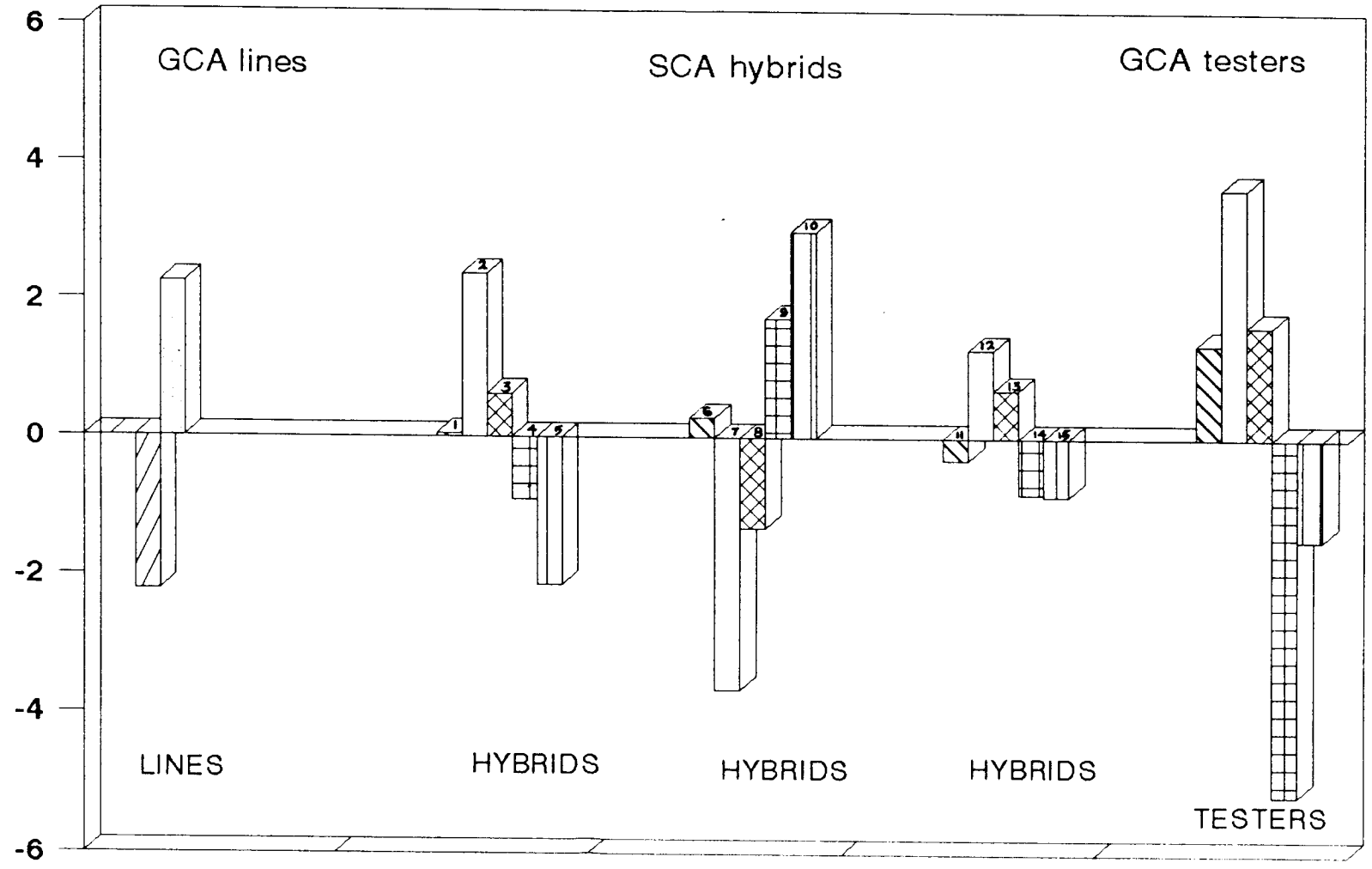


Fig. 2. GCA and SCA - number of branches/plant

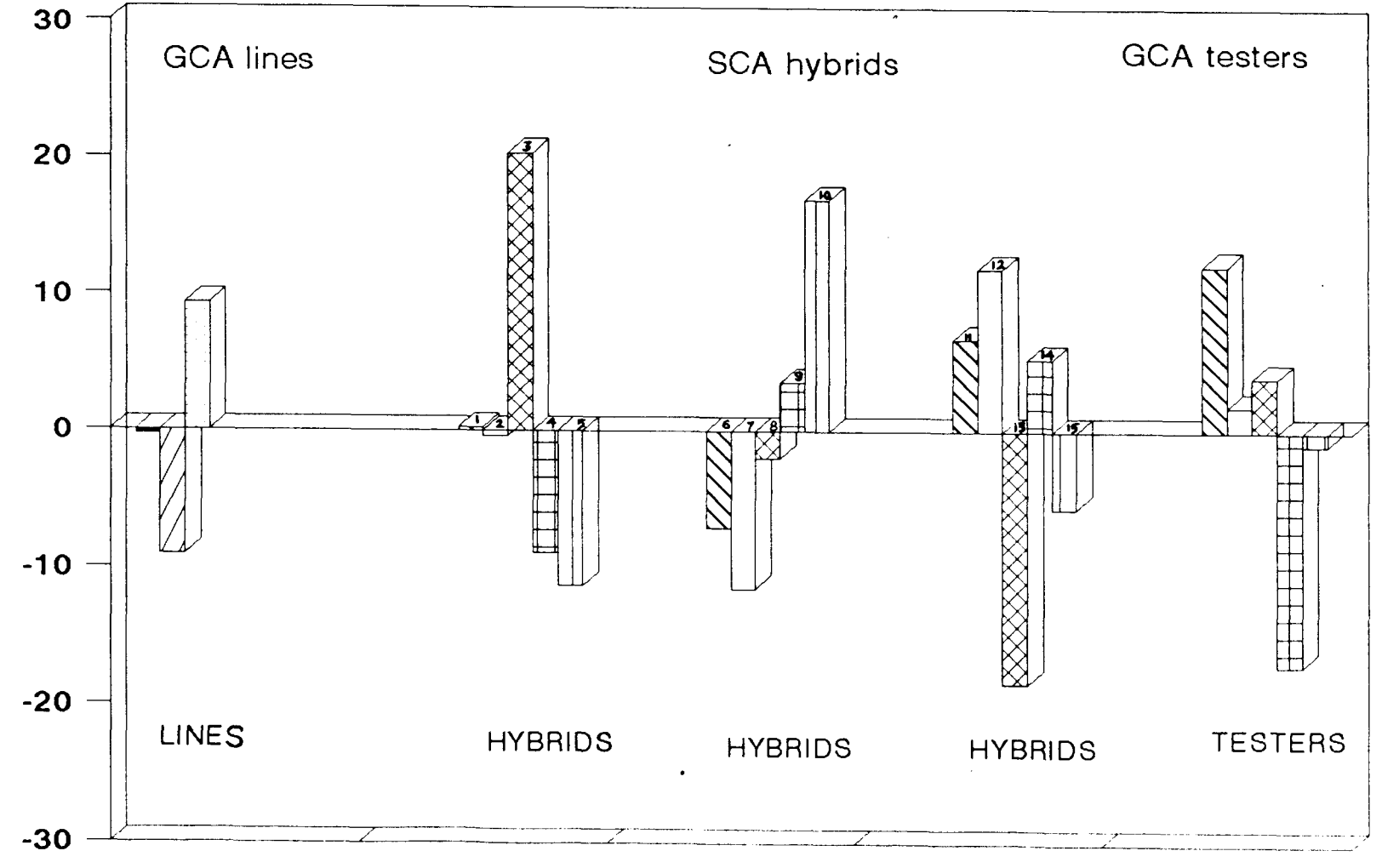


Fig. 3. GCA and SCA - spread of the plant

Fig. 1.GCA and SCA - Plant height

SCA hybrids

1. Arka Abha x LE 312
2. Arka Abha x LE 370
3. Arka Abha x LE 373
4. Arka Abha x RFH-1
5. Arka Abha x PKM-1
6. Arka Alok x LE 312
7. Arka Alok x LE 370
8. Arka Alok x LE 373
9. Arka Alok x RFH-1
10. Arka Alok x PKM-1
11. Sakthi x LE 312
12. Sakthi x LE 370
13. Sakthi x LE 373
14. Sakthi x RFH-1
15. Sakthi x PKM-1

Fig. 2. GCA and SCA - number of branches/plant

SCA hybrids

1. Arka Abha x LE 312
2. Arka Abha x LE 370
3. Arka Abha x LE 373
4. Arka Abha x RFH-1
5. Arka Abha x PKM-1
6. Arka Alok x LE 312
7. Arka Alok x LE 370
8. Arka Alok x LE 373
9. Arka Alok x RFH-1
10. Arka Alok x PKM-1
11. Sakthi x LE 312
12. Sakthi x LE 370
13. Sakthi x LE 373
14. Sakthi x RFH-1
15. Sakthi x PKM-1

Fig. 3. GCA and SCA - Spread of the plant

SCA hybrids

1. Arka Abha x LE 312
2. Arka Abha x LE 370
3. Arka Abha x LE 373
4. Arka Abha x RFH-1
5. Arka Abha x PKM-1
6. Arka Alok x LE 312
7. Arka Alok x LE 370
8. Arka Alok x LE 373
9. Arka Alok x RFH-1
10. Arka Alok x PKM-1
11. Sakthi x LE 312
12. Sakthi x LE 370
13. Sakthi x LE 373
14. Sakthi x RFH-1
15. Sakthi x PKM-1

Fig. 4. GCA and SCA - Period of harvest

SCA hybrids

1. Arka Abha x LE 312
2. Arka Abha x LE 370
3. Arka Abha x LE 373
4. Arka Abha x RFH-1
5. Arka Abha x PKM-1
6. Arka Alok x LE 312
7. Arka Alok x LE 370
8. Arka Alok x LE 373
9. Arka Alok x RFH-1
10. Arka Alok x PKM-1
11. Sakthi x LE 312
12. Sakthi x LE 370
13. Sakthi x LE 373
14. Sakthi x RFH-1
15. Sakthi x PKM-1

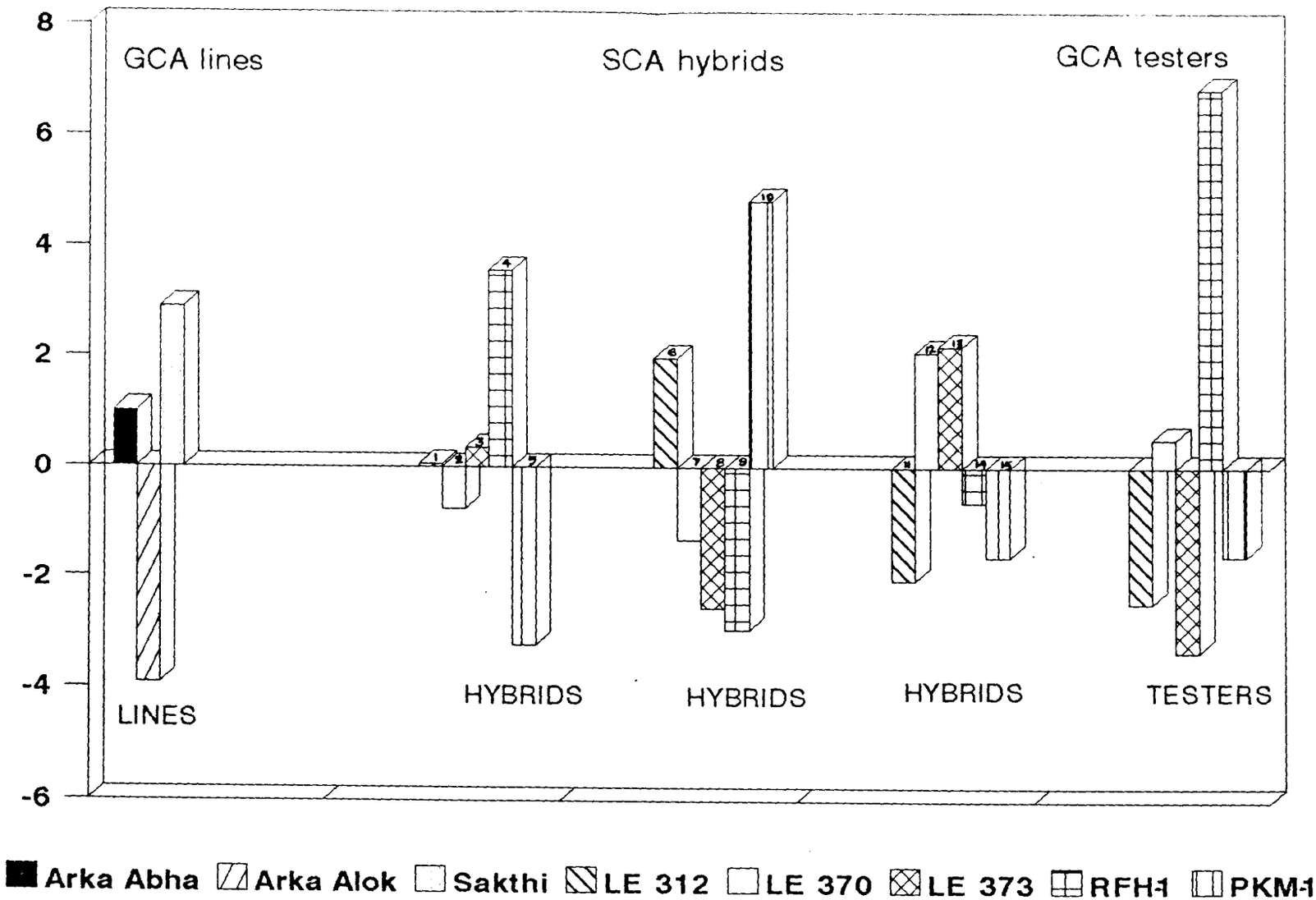


Fig. 4. GCA and SCA - period of harvest

Fig .5. GCA and SCA - Individual fruit weight

SCA hybrids

1. Arka Abha x LE 312
2. Arka Abha x LE 370
3. Arka Abha x LE 373
4. Arka Abha x RFH-1
5. Arka Abha x PKM-1
6. Arka Alok x LE 312
7. Arka Alok x LE 370
8. Arka Alok x LE 373
9. Arka Alok x RFH-1
10. Arka Alok x PKM-1
11. Sakthi x LE 312
12. Sakthi x LE 370
13. Sakthi x LE 373
14. Sakthi x RFH-1
15. Sakthi x PKM-1

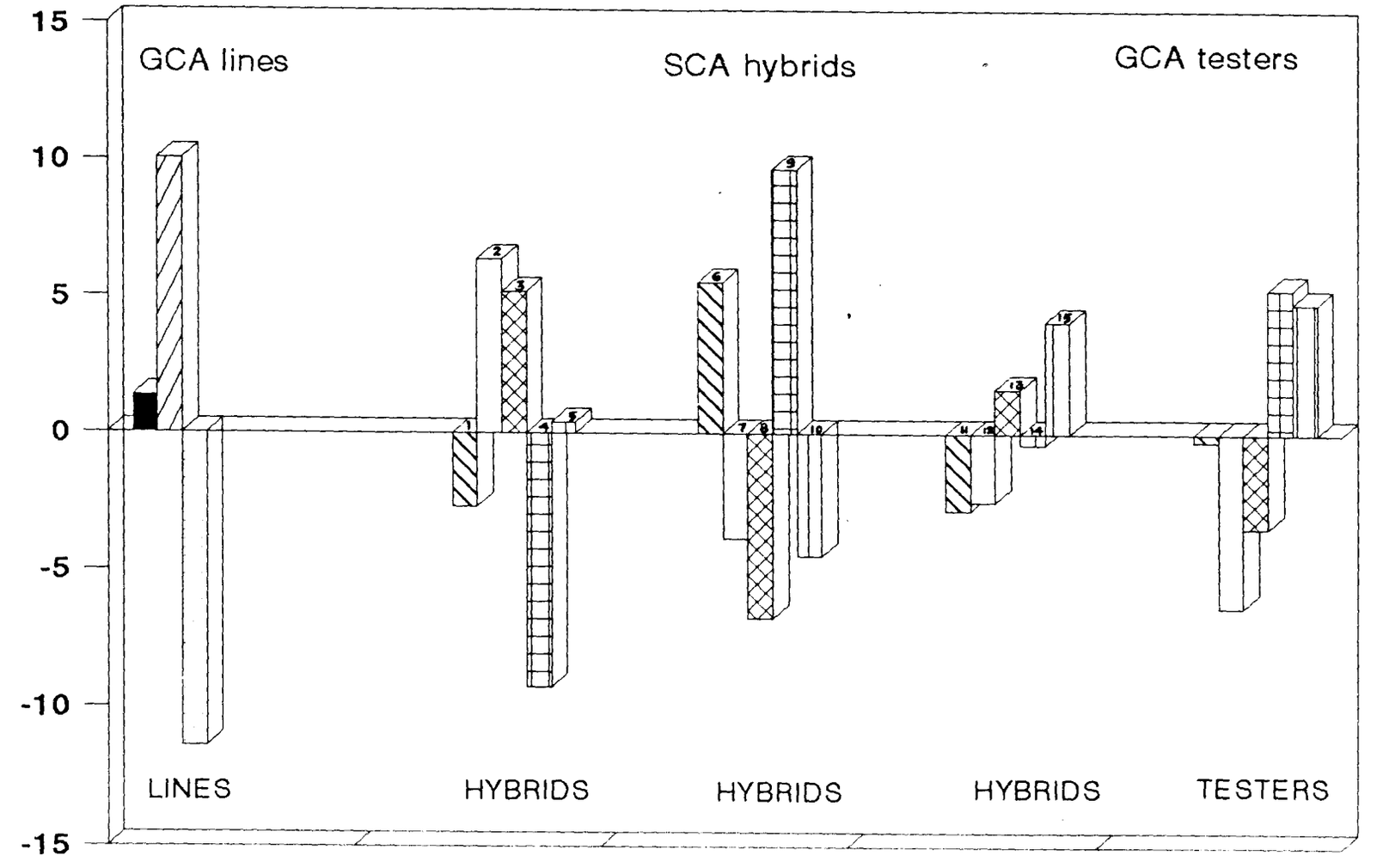


Fig. 5. GCA and SCA - Individual fruit weight

The gca and sca effects for number of fruits/plant are given in figure 6. Both lines and hybrids showed significant variances for number of fruits per plant but in testers it was insignificant. Significant gca effect was observed in the lines but only Sakthi exhibited positive gca effect (5.48). The testers LE 370 and PKM-1 showed positive gca effect of 2.85 and 1.24 and LE 373 showed negative gca effect of -3.20. Significant sca effect was observed in six hybrids. Among these Arka Alok x PKM-1 (3.65), Arka Abha x PKM-1 (2.47) and Sakthi x LE 370 (2.44) exhibited positive sca effect and Sakthi x PKM-1 (-6.11) had negative sca effect.

Analysis of variance showed significant genotypic differences for fruit yield/plant in both the lines and hybrids. The line Sakthi showed positive gca effect of 94.05 and Arka Abha showed negative gca effect of -97.24. None of the testers showed significant gca effect. Significant sca effect was recorded in the four hybrids viz., Arka Abha x LE 370 (140.87), Arka Alok x PKM-1 (109.33), Sakthi x RFH-1 (137.71) and Arka Abha x PKM-1 (-105.61). The gca and sca effects for fruit yield/plant are represented graphically in figure 7.

Pericarp thickness differed significantly among hybrids only. The line Sakthi exhibited negative gca effect of -0.29. But in testers RFH-1 showed positive gca effect (0.80) and LE 370 showed negative gca effect (-0.51). Only one hybrid exhibited

Fig. 6. GCA and SCA - number of fruits/plant

SCA hybrids

1. Arka Abha x LE 312
2. Arka Abha x LE 370
3. Arka Abha x LE 373
4. Arka Abha x RFH-1
5. Arka Abha x PKM-1
6. Arka Alok x LE 312
7. Arka Alok x LE 370
8. Arka Alok x LE 373
9. Arka Alok x RFH-1
10. Arka Alok x PKM-1
11. Sakthi x LE 312
12. Sakthi x LE 370
13. Sakthi x LE 373
14. Sakthi x RFH-1
15. Sakthi x PKM-1

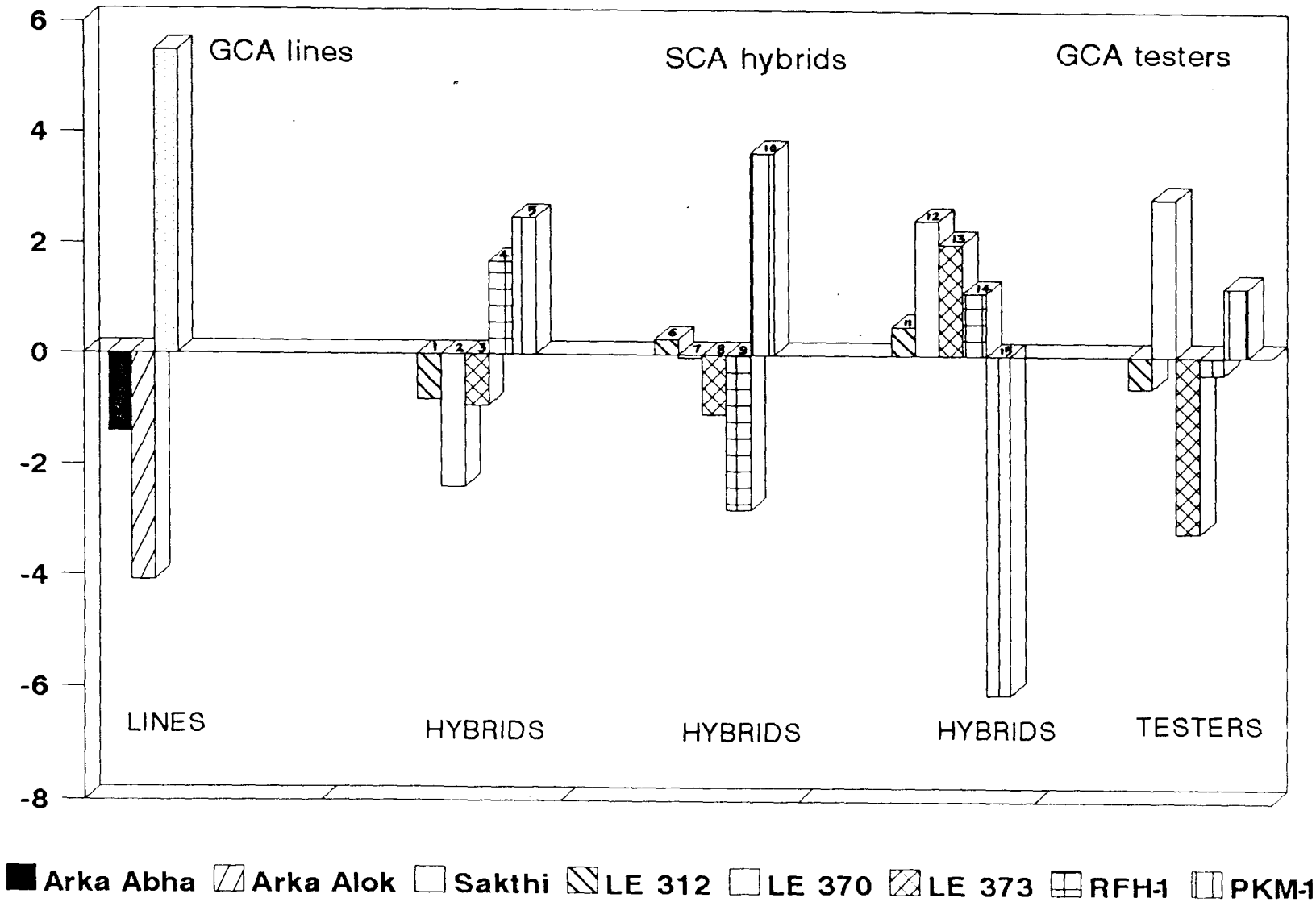


Fig. 6. GCA and SCA - number of fruits/plant

Fig. 7. GCA and SCA - fruit yield/plant

SCA hybrids

1. Arka Abha x LE 312
2. Arka Abha x LE 370
3. Arka Abha x LE 373
4. Arka Abha x RFH-1
5. Arka Abha x PKM-1
6. Arka Alok x LE 312
7. Arka Alok x LE 370
8. Arka Alok x LE 373
9. Arka Alok x RFH-1
10. Arka Alok x PKM-1
11. Sakthi x LE 312
12. Sakthi x LE 370
13. Sakthi x LE 373
14. Sakthi x RFH-1
15. Sakthi x PKM-1

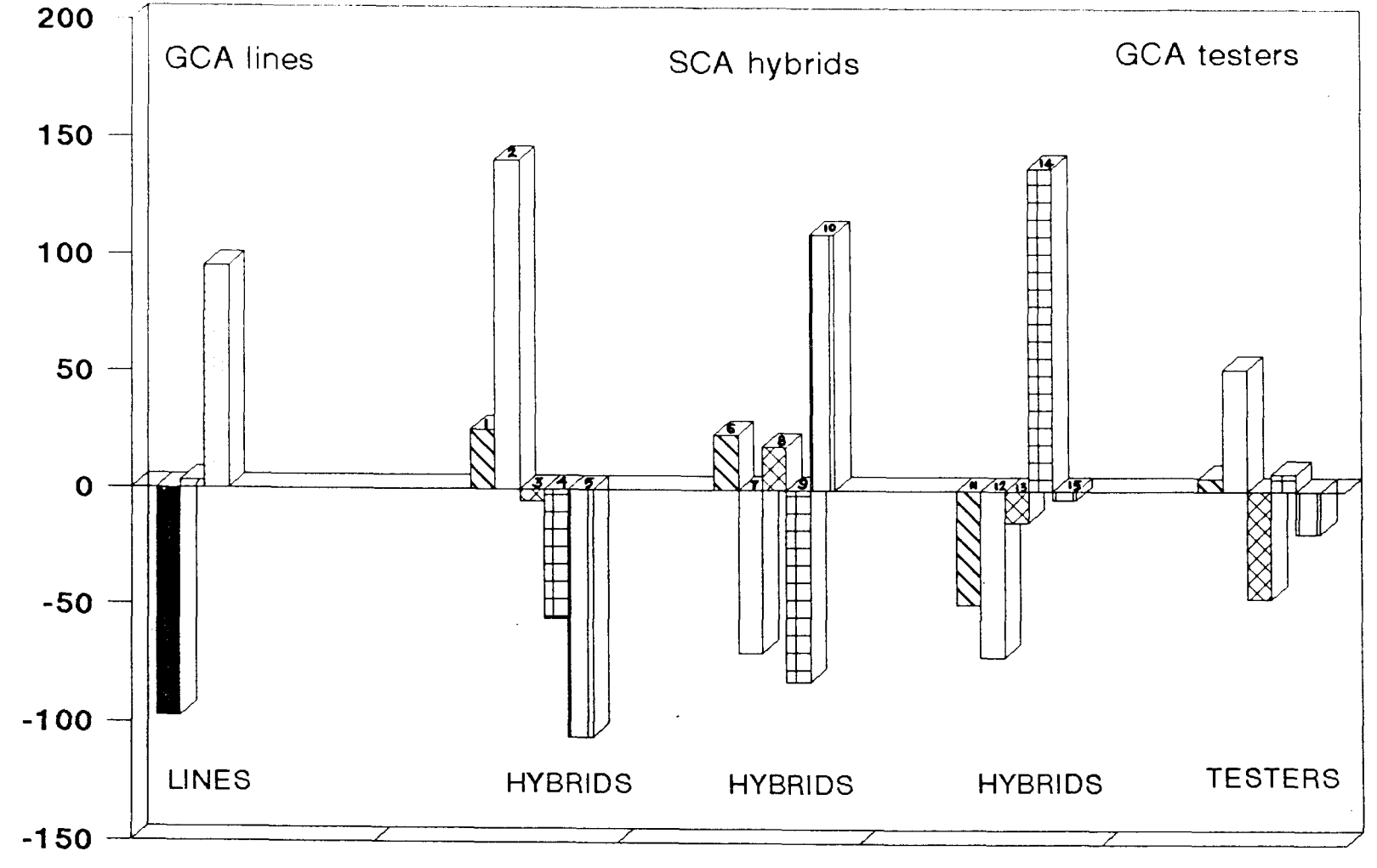


Fig. 7. GCA and SCA - fruit yield/plant

significant positive sca effect. That was Arka Alok x RFH-1 (0.89). The gca and sca effects are represented graphically in figure 8.

Number of leaves/plant varied significantly among testers and hybrids. Only the line Arka Abha showed significant gca effect (9.28). But among testers all the varieties except one exhibited significant gca effect viz., LE 312 (40.35), LE 370 (27.20), LE 373 (26.86) and RFH-1 (-90.37). Significant positive sca effects were observed in Arka Abha x LE 312 (22.53), Arka Abha x LE 373 (21.93), Arka Abha x LE 370 (32.74) and Arka Alok x PKM-1 (75.56) while negative sca effects were seen in Arka Abha x PKM-1 (-61.85), Arka Alok x LE 312 (-37.94) and Arka Alok x LE 370 (-30.27). The gca and sca effects are presented in figure 9.

The gca and sca effects for locules/fruit are graphically represented in figure 10. Variance due to lines, testers and hybrids were significant for locules/fruit. Lines Arka Alok (0.34) showed significant positive gca effect and Sakthi (-0.51) showed significant negative gca effect. None of the testers exhibited significant gca effect. Among the hybrids Arka Abha x RFH-1 (0.54) and Arka Abha x PKM-1 (-0.72) expressed significant sca effect.

Analysis of variance for size of fruits showed significant differences among the lines and hybrids. The lines Arka Alok and

Fig. 8. GCA and SCA - Pericarp thickness

SCA hybrids

1. Arka Abha x LE 312
2. Arka Abha x LE 370
3. Arka Abha x LE 373
4. Arka Abha x RFH-1
5. Arka Abha x PKM-1
6. Arka Alok x LE 312
7. Arka Alok x LE 370
8. Arka Alok x LE 373
9. Arka Alok x RFH-1
10. Arka Alok x PKM-1
11. Sakthi x LE 312
12. Sakthi x LE 370
13. Sakthi x LE 373
14. Sakthi x RFH-1
15. Sakthi x PKM-1

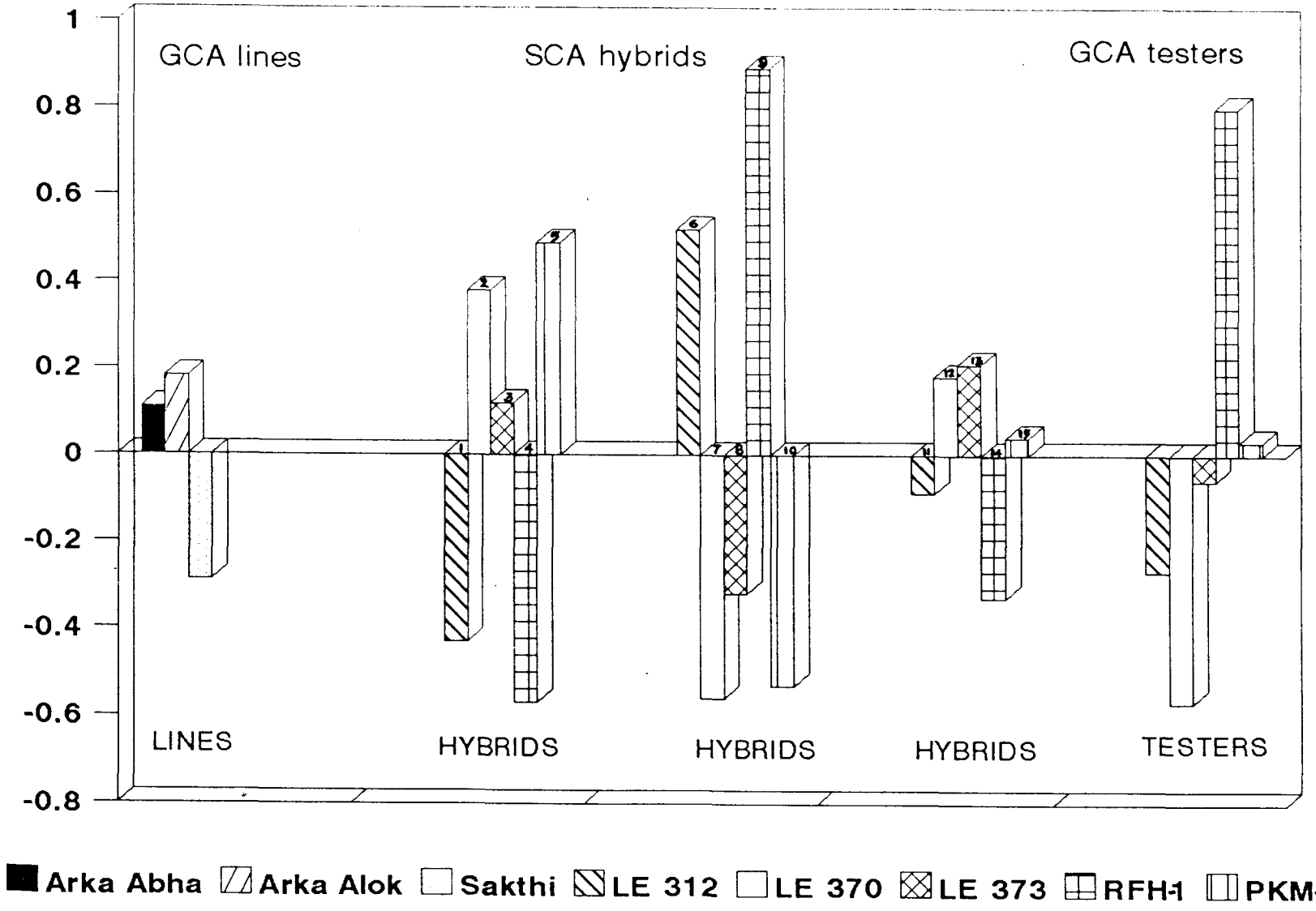


Fig. 8. GCA and SCA - pericarp thickness

Fig. 9. GCA and SCA - number of leaves/plant

SCA hybrids

1. Arka Abha x LE 312
2. Arka Abha x LE 370
3. Arka Abha x LE 373
4. Arka Abha x RFH-1
5. Arka Abha x PKM-1
6. Arka Alok x LE 312
7. Arka Alok x LE 370
8. Arka Alok x LE 373
9. Arka Alok x RFH-1
10. Arka Alok x PKM-1
11. Sakthi x LE 312
12. Sakthi x LE 370
13. Sakthi x LE 373
14. Sakthi x RFH-1
15. Sakthi x PKM-1

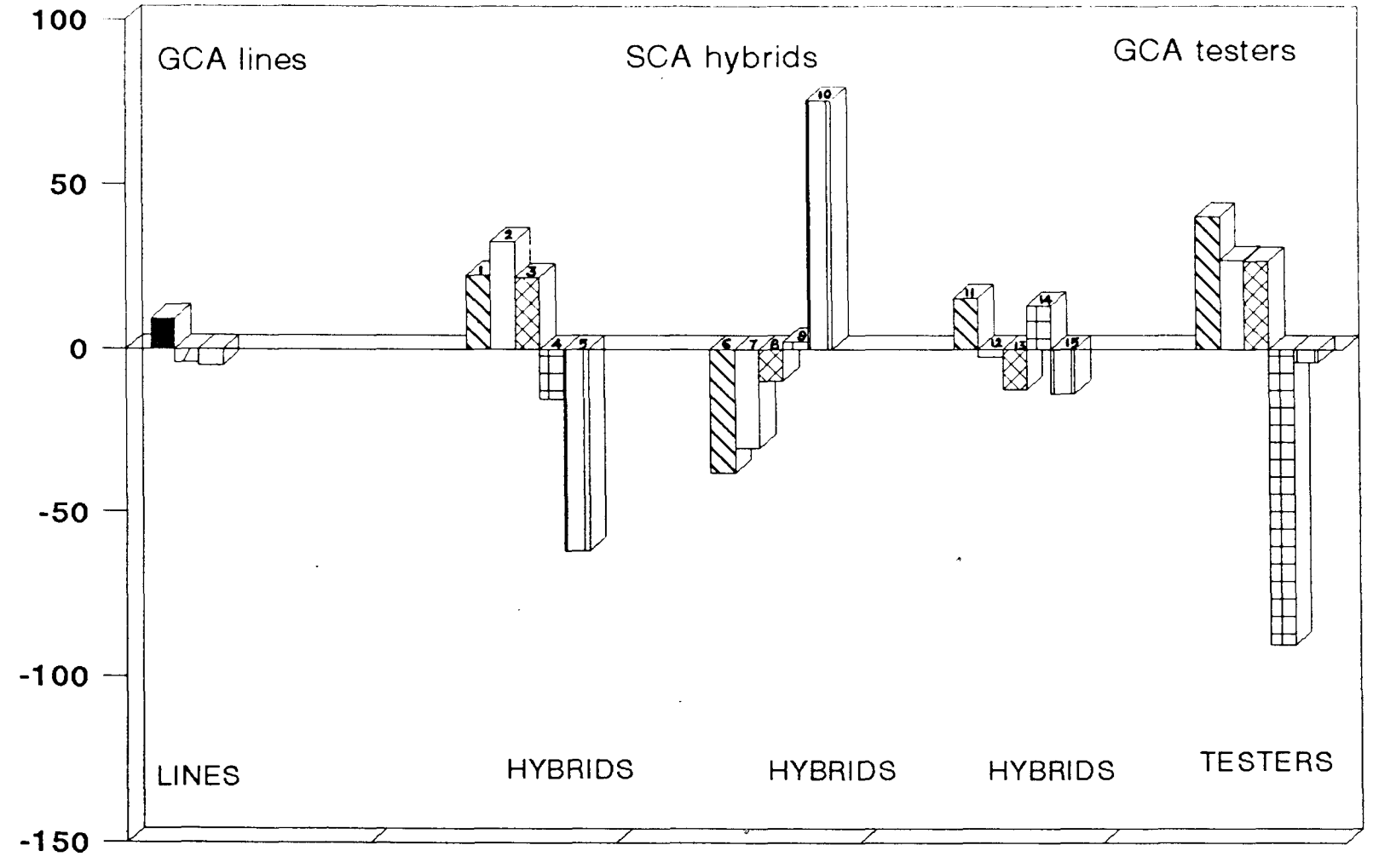


Fig. 9. GCA and SCA - number of leaves/plant

Fig. 10. GCA and SCA - locules/fruit

SCA hybrids

1. Arka Abha x LE 312
2. Arka Abha x LE 370
3. Arka Abha x LE 373
4. Arka Abha x RFH-1
5. Arka Abha x PKM-1
6. Arka Alok x LE 312
7. Arka Alok x LE 370
8. Arka Alok x LE 373
9. Arka Alok x RFH-1
10. Arka Alok x PKM-1
11. Sakthi x LE 312
12. Sakthi x LE 370
13. Sakthi x LE 373
14. Sakthi x RFH-1
15. Sakthi x PKM-1

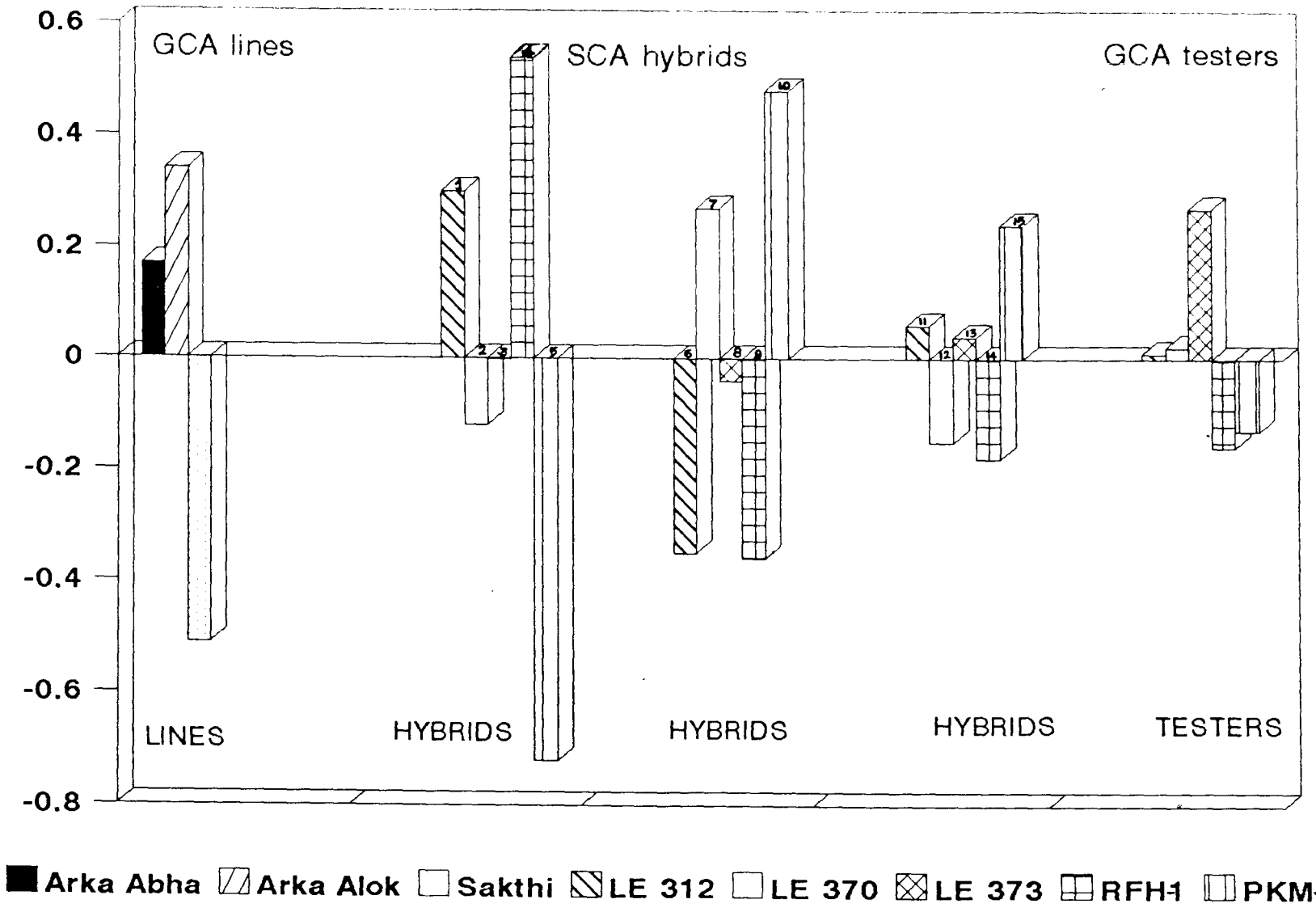


Fig. 10. GCA and SCA - locules/fruit

Arka Abha showed positive gca effect of 9.46 and 2.32 respectively and the line Sakthi showed negative gca effect of -11.78. Among testers RFH-1 (7.12) and PKM-1 (4.16) showed positive gca effect and LE 370 (-7.46) and LE 373 (-3.03) showed negative effect. Only three hybrids Arka Alok x RFH-1 (9.13), Arka Abha x LE 370 (5.53), and Arka Alok x LE 312 (6.85) showed significant positive sca effects. The gca and sca effects are represented graphically in figure 11.

4.c. GENETIC COMPONENTS OF VARIANCE

The genetic components of variance such as additive variance (σ^2a) and dominance variance (σ^2d) were estimated and they are presented in table 8 and in figure 12.

For all the characters under study dominance variance was greater than additive variance.

The additive to dominance variance ratio ranged from a minimum of 0.03 for pericarp thickness to a maximum of 0.50 for number of branches/plant. The ratio was low for five characters such as spread of the plant (0.04), fruit yield/plant (0.04), pericarp thickness (0.03), number of leaves/plant (0.09) and locules/fruit (0.07). Medium values were observed for plant height (0.10), period of harvest (0.26), individual fruit weight (0.18), number of fruits/plant (0.18) and size of fruits (0.23).

Fig. 11. GCA and SCA - size of fruits

SCA hybrids

1. Arka Abha x LE 312
2. Arka Abha x LE 370
3. Arka Abha x LE 373
4. Arka Abha x RFH-1
5. Arka Abha x PKM-1
6. Arka Alok x LE 312
7. Arka Alok x LE 370
8. Arka Alok x LE 373
9. Arka Alok x RFH-1
10. Arka Alok x PKM-1
11. Sakthi x LE 312
12. Sakthi x LE 370
13. Sakthi x LE 373
14. Sakthi x RFH-1
15. Sakthi x PKM-1

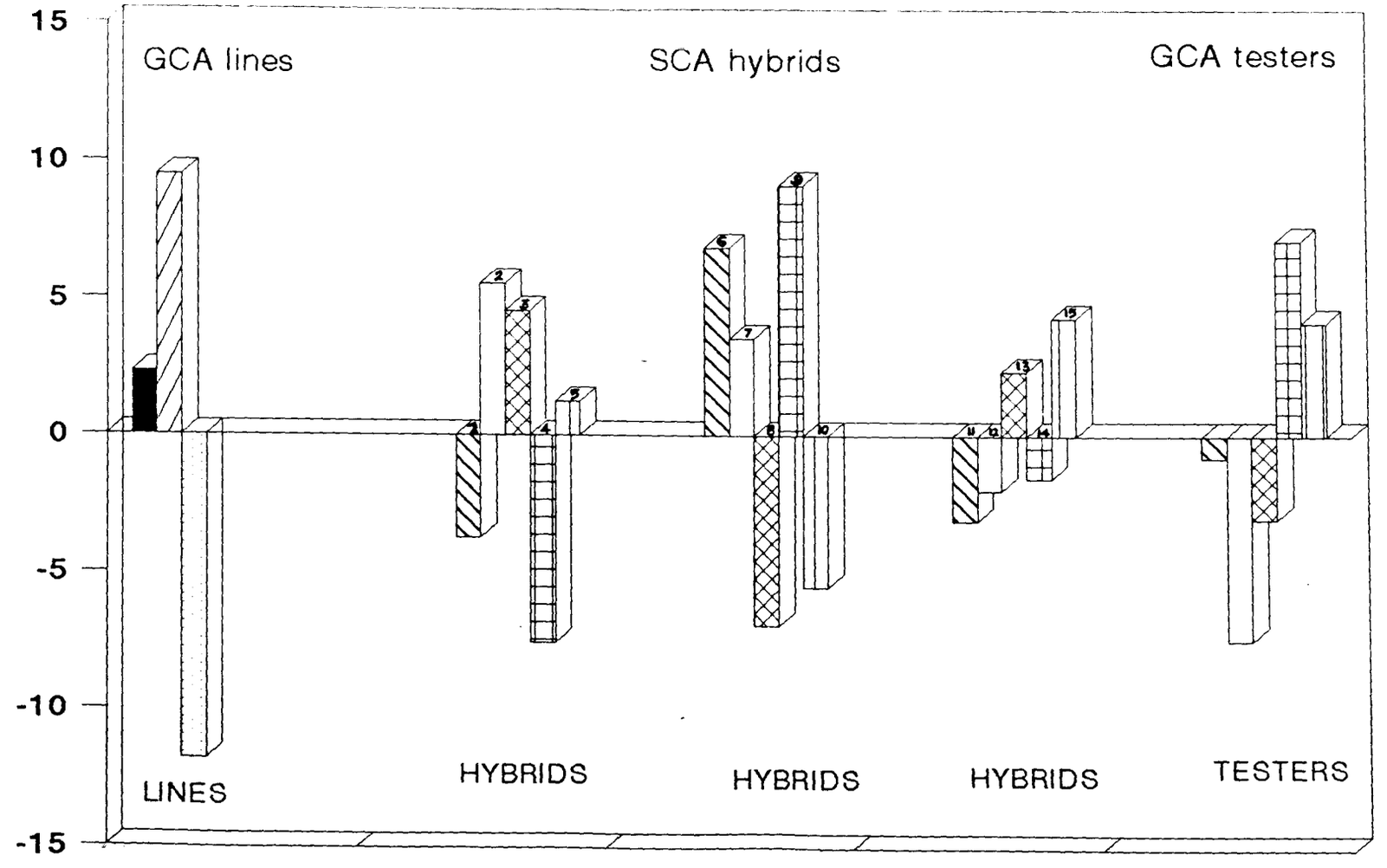


Fig. 11. GCA and SCA - size of fruits

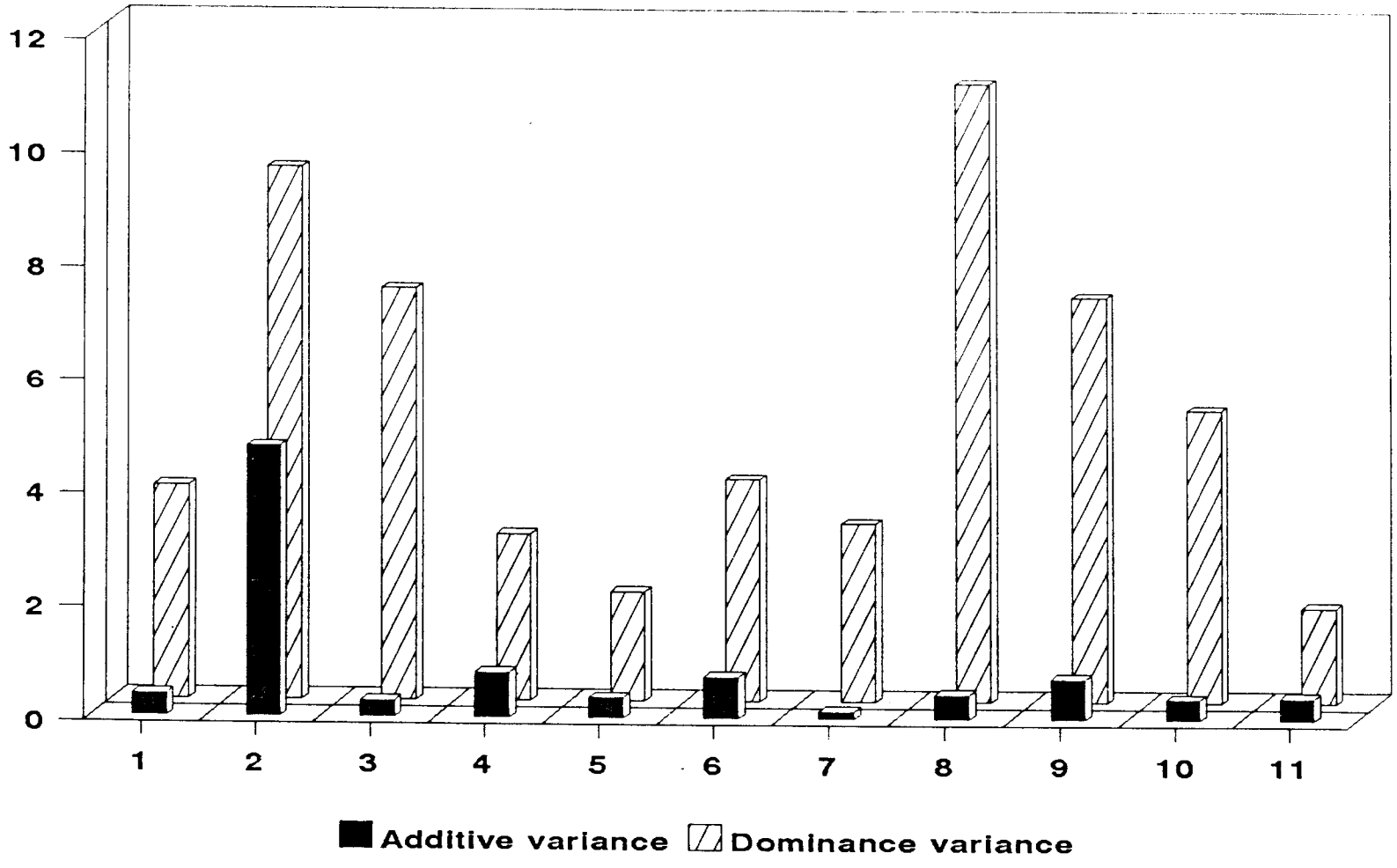


Fig. 12. Genetic components of variance

1 - Plant height (y x 10^2) 2 - Branches (y) 3 - Spread of plant (y x 10^2) 4 - Period (y x 10)

5 - Fruit weight (y x 10^2) 6 - Fruit number (y x 10) 7 - Fruit yield (y x 10^4) 8 - Pericarp thickness (y x 10^{-1})

9 - Number of leaves (y x 10^3) 10 - Locules/fruit (y x 10^{-1}) 11 - Size of fruits (y x 10^2)

Among the different characters, the proportional contributions of lines, ranged very widely from a minimum of 1.30 per cent for number of leaves/plant to a maximum of 62.12 per cent for number of fruits/plant. In the testers also the proportional contribution varied very widely from a minimum of 8.21 per cent for fruit yield/plant to a maximum of 68.32 per cent for number of leaves/plant. In the line x tester hybrids this range was from 18.32 per cent for number of branches/plant to 44.50 per cent for pericarp thickness.

Contribution of lines to the total variance was high for the characters viz., individual fruit weight, number of fruits/plant, fruit yield/plant, locules/fruit and size of fruits having the values 62.05, 62.12, 47.37, 51.33 and 59.76 per cent respectively. Contribution of lines was less for plant height (3.44 %), spread of the plant (21.68 %), pericarp thickness (16.12%) and number of leaves/plant (1.30%). The contribution of lines was medium for number of branches/plant (21.53%) and period of harvest (30.27%).

Contribution of testers was very high for plant height (65.45%), number of branches/plant (60.15%), period of harvest (49.09%), pericarp thickness (45.38%) and number of leaves/plant (68.32%). Contribution of testers was less for individual fruit weight (16.60%), number of fruits/plant (15.54%), fruit yield/plant (8.21%) and locules/fruit (8.90%). For the rest of

the characters viz., spread of the plant and size of fruits the proportion being 35.18 and 20.50 per cent respectively.

Contribution of the line x tester hybrids to the total variance was less for the characters branches/plant (18.32%), size of fruits (19.74%) and period of harvest (20.64%). It was high for the character spread of the plant (43.14%). For the remaining characters such as plant height, individual fruit weight, fruits/plant, fruit yield/plant, pericarp thickness, leaves/plant and locules/fruit the contribution of the hybrids was medium, the proportion being 31.11, 21.35, 22.34, 44.42, 44.50, 30.38 and 39.77 per cent respectively.

Table - 9, Proportional contribution of lines, testers and line x tester to total variance.

Sl. No.	Characters	Contributions (%)		
		Lines	Testers	Line x tester
1.	Plant height	3.44	65.45	31.11
2.	Number of branches/plant	21.53	60.15	18.32
3.	Spread of the plant	21.68	35.18	43.14
4.	Period of harvest	30.27	49.09	20.64
5.	Individual fruit weight	62.05	16.60	21.35
6.	Number of fruits/plant	62.12	15.54	22.34
7.	Fruit yield/plant	47.37	8.21	44.42
8.	Pericarp thickness	10.12	45.38	44.50
9.	Number of leaves/plant	1.30	68.32	30.38
10.	Locules/fruit	51.33	8.90	39.77
11.	Size of fruits	59.76	20.50	19.74

4.e. HETEROSIS

Percentage of relative heterosis, heterobeltiosis and standard heterosis were assessed from the mean value of parents and hybrids for the different morphological characters and the results are presented below:

Plant height

The mean value of parents and hybrids and percentage of heterosis for plant height are given in table 10.

The hybrids exhibited significant heterosis for plant height. Relative heterosis varied from -2.13 to 70.23 per cent. Except one, all the hybrids exhibited positive heterosis and it was significant in eleven hybrids viz., Arka Alok x LE 312 (16.91), Sakthi x LE 373 (19.16), Sakthi x RFH-1 (24.02), Arka Abha x LE 373 (26.67), Arka Abha x LE 312 (28.46), Sakthi x PKM-1 (39.21), Sakthi x LE 370 (42.18), Arka Abha x LE 370 (51.72), Sakthi x LE 312 (59.11), Arka Abha x PKM-1 (60.94) and Arka Alok x PKM-1 (70.23). Heterobeltiosis varied from -14.77 to 64.02 among the fifteen hybrids. Significant positive heterosis was noticed in Sakthi x LE 370 (15.60), Arka Abha x LE 370 (23.40), Sakthi x PKM-1 (34.31), Sakthi x LE 312 (37.02), Arka Abha x PKM-1 (55.34) and Arka Alok x PKM-1 (64.02). Standard heterosis was measured using LE 373 as check variety. None of the hybrids exhibited significant positive standard heterosis. The hybrid Arka Alok x PKM-1 recorded highest significant relative heterosis as well as heterobeltiosis.

Number of branches/plant

The mean value of parents and hybrids and heterosis for number of branches/plant are given in table 10.

The hybrids exhibited significant heterosis for branches/plant. Significant positive relative heterosis was observed only in one hybrid, ie. Arka Abha x LE 370 (50.99).

Table - 10 Mean value of parents and hybrids and heterosis percentage for plant height and number of branches/plant.

Parents/Hybrids	Plant height					Number of branches/plant				
	Mean (cm)	$\overline{MP}$	Heterosis (%)			Mean	$\overline{MP}$	Heterosis (%)		
			RH	HB	SH			RH	HB	SH
Arka Abha	45.42					7.10				
Arka Alok	52.66					6.58				
Sakthi	45.38					13.54				
LE 312	62.82					15.67				
LE 370	72.47					15.96				
LE 373	105.39					17.93				
RFH-1	49.42					8.9				
PKM-1	48.82					7.56				
Arka Abha x LE 312	69.52	54.12	28.46*	10.67	-34.03*	12.82	11.39	12.62	-18.17	-28.49*
" x LE 370	89.43	58.95	51.72*	23.40*	-15.14*	17.41	11.53	50.99*	9.09	-2.88
" x LE 373	95.52	75.41	26.67*	-9.37	-9.37	13.67	12.52	9.22	-28.76	-28.76
" x RFH-1	51.33	47.42	8.26	3.88	-51.29*	5.33	5.5	-3.03	-24.88	-70.25*
" x PKM-1	75.83	47.12	60.94*	55.34*	-28.05*	7.78	7.33	6.07	2.82	-56.62*
Arka Alok x LE 312	67.50	57.74	16.91*	7.46	-35.95*	10.82	11.13	-2.71	-30.92	-39.62*
" x LE 370	61.23	62.57	-2.18	-15.51*	-41.90*	9.13	11.27	-19.00	-42.80*	-49.07*
" x LE 373	84.26	79.03	6.63	-20.05*	-20.05*	9.49	12.26	-22.59	-47.08*	-47.08*
" x RFH-1	56.74	51.04	11.18	7.76	-46.16	5.75	5.24	9.63	-12.71	-67.94*
" x PKM-1	86.37	48.82	70.23*	64.02*	-18.05*	10.70	7.07	51.23	41.43	-40.33*
Sakthi x LE 312	86.08	54.10	59.11*	37.02*	-18.33*	14.69	14.61	0.61	-6.23	-18.06
" x LE 370	83.78	58.93	42.18*	15.60*	-20.51*	18.56	14.75	25.85	16.2	3.53
" x LE 373	89.83	75.39	19.16*	-14.77	-14.77*	15.98	15.74	1.58	-10.86	-10.86
" x RFH-1	58.78	47.4	24.02*	18.96	-44.23*	7.68	8.72	-11.95	-43.29*	-57.18*
" x PKM-1	65.56	47.1	39.21*	34.31*	-37.79*	11.32	10.55	7.27	-16.40	-36.87*
CD (0.5			9.31	10.75	10.75			4.24	4.90	4.90

* 5% level of significance.

None of the hybrids recorded significant positive hetero beltiosis and standard heterosis. Standard heterosis was estimated using LE 373 as a check variety.

Spread of the Plant

The mean value of parents and hybrids and heterosis expressed for spread of the plant are given in table 11.

The hybrids exhibited significant heterosis for spread of the plant. Relative heterosis, heterobeltiosis and standard heterosis recorded significant value. All the hybrids except one showed positive relative heterosis. But only ten hybrids viz., Arka Abha x PKM-1 (65.67), Arka Alok x LE 312 (77.28), Arka Abha x LE 370 (81.36), Sakthi x RFH-1 (112.88), Sakthi x PKM-1 (113.30), Arka Abha x LE 373 (123.40), Arka Alok x PKM-1 (125.77), Sakthi x LE 370 (140.96), Arka Abha x LE 312 (177.67) and Sakthi x LE 312 (215.99) recorded significant relative heterosis. Heterobeltiosis was positive and significant in eight hybrids viz. Arka Abha x LE 373 (58.47), Arka Alok x LE 312 (74.02), Sakthi x RFH-1 (88.09), Sakthi x LE 370 (103.75), Sakthi x PKM-1 (109.50), Arka Alok x PKM-1 (117.16), Arka Abha x LE 312 (147.78) and Sakthi x LE 312 (215.11). Standard heterosis was significant and positive in three hybrids. They were Sakthi x LE 370 (56.41), Arka Abha x LE 373 (58.47) and Sakthi x LE 312 (68.12). Relative heterosis, heterobeltiosis and standard heterosis were maximum in Sakthi x LE 312.

Period of harvest

Period of harvest was recorded as number of days from first to last harvest. The mean value of parents and hybrids and heterosis for period of harvest are given in table 11.

Significant heterosis was recorded by the different hybrids for this trait. Relative heterosis was positive and significant in two hybrids, Arka Abha x RFH-1 (61.95) and Sakthi x RFH-1 (80.91) and it was significantly negative in seven hybrids. Heterobeltiosis was significant and negative in eight hybrids viz., Arka Alok x PKM-1 (-25.27), Arka Abha x LE 370 (-32.67), Arka Abha x LE 312 (-36.74), Arka Alok x LE 312 (-39.09), Arka Abha x LE 373 (-39.25), Arka Abha x PKM-1 (-47.05), Arka Alok x LE 370 (-54.36) and Arka Alok x LE 373 (-69.92) whereas standard heterosis was significant and negative in 12 hybrids. Maximum heterosis was shown by Arka Alok x LE 373 (-74.39). Here LE 370 was used as a check variety. In all the three types of heterosis the hybrid Arka Alok x LE 373 recorded maximum significant negative values.

Individual fruit weight

The mean value of parents and hybrids and heterosis percentage for individual fruit weight are presented in table 12.

Table - 11 Mean value of parents and hybrids and heterosis percentage for spread of the plant and period of harvest.

Parents/Hybrids	Spread of the plant					Period of harvest				
	Mean (cm)	$\overline{MP}$	Heterosis (%)			Mean (days)	$\overline{MP}$	Heterosis (%)		
			RH	HB	SH			RH	HB	SH
Arka Abha	20.83					23.50				
Arka Alok	24.92					19.00				
Sakthi	23.87					17.38				
LE 312	24.00					19.50				
LE 370	34.53					25.25				
LE 373	44.98					21.50				
RFH-1	18.31					10.67				
PKM-1	23.02					20.82				
Arka Abha x LE 312	59.47	21.42	177.67*	147.78*	32.20	14.87	21.5	-30.85*	-36.74*	-41.12*
" x LE 370	48.39	26.68	81.36*	40.14	7.58	17.00	24.38	-30.26*	-32.67*	-32.67*
" x LE 373	71.28	31.91	123.40*	58.47*	58.47*	14.28	22.50	-36.55*	-39.25*	-43.46*
" x RFH-1	21.00	18.57	13.09	11.50	-53.32*	27.67	17.09	61.95*	17.73	9.57
" x PKM-1	34.57	20.93	65.67*	50.62	-22.93	12.44	17.97	-43.84*	-47.05*	-50.72*
Arka Alok x LE 312	43.36	24.46	77.28*	74.02*	-3.61	11.88	19.25	-38.30*	-39.09*	-52.96*
" x LE 370	28.5	29.73	-4.12	-17.47	-36.64*	11.52	22.13	-47.92*	-54.36*	-54.36*
" x LE 373	40.17	34.95	14.93	-10.71	-10.71	6.47	20.25	-68.07*	-69.92*	-74.39*
" x RFH-1	24.72	21.62	14.40	-0.78	-45.04*	16.25	14.84	9.55	-14.47	-35.64*
" x PKM-1	54.11	23.97	125.77*	117.16*	20.29	15.56	19.91	-21.86	-25.27*	-38.39*
Sakthi x LE 312	75.63	23.94	215.99*	215.11*	68.12*	14.65	18.44	-20.55	-24.87	-41.98*
" x LE 370	70.36	29.20	140.96*	103.75*	56.41*	21.77	21.32	2.13	-13.80	-13.80
" x LE 373	42.20	34.43	22.59	-6.19	-6.19	18.02	19.44	-7.31	-16.20	-28.65*
" x RFH-1	44.89	21.09	112.88*	88.09*	-0.21	25.37	14.03	80.91*	45.98*	0.46
" x PKM-1	50.00	23.45	113.30*	109.50*	11.15	15.92	19.10	-16.62	-23.51	-36.94*
CD (0.05)			13.52	15.62	15.62			4.42	5.10	5.10

Significant heterosis was recorded in the hybrids for individual fruit weight. Ten hybrids viz., Arka Abha x LE 373 (7.63), Arka Abha x PKM-1, (8.36), Arka Alok x LE 373 (9.69), Sakthi x PKM-1 (18.65), Sakthi x RFH-1 (22.88), Arka Abha x LE 370 (25.10), Arka Alok x PKM-1 (25.95), Arka Alok x LE 370 (34.46), Arka Alok x LE 312 (44.93) and Arka Alok x RFH-1 (76.26) exhibited significant positive relative heterosis. Four hybrids, Sakthi x RFH-1 (16.15), Arka Alok x PKM-1 (21.48), Arka Alok x LE 312 (32.20) and Arka Alok x RFH-1 (53.03) exhibited positive heterobeltiosis. Standard heterosis was measured by using Arka Abha as a check variety. 13 out of 15 hybrids recorded significant standard heterosis. But positive heterosis was exhibited by Arka Alok x LE 312 (13.48) and Arka Alok x RFH-1 (31.36). Among the 15 hybrids Arka Alok x RFH-1 recorded maximum significant positive relative heterosis, heterobeltiosis and standard heterosis.

Number of fruits/plant

The mean value of parents and hybrids and heterosis percentage for number of fruits/plant are presented in table 12.

Significant heterosis was recorded in the hybrids for number of fruits/plant. Out of 15 hybrids seven of them expressed significant positive relative heterosis. They were Sakthi x LE 370 (42.11), Arka Alok x PKM-1 (43.76), Sakthi x LE

Table - 12 Mean value of parents and hybrids and heterosis percentage for individual fruit weight and number of fruits/plant

Parents/Hybrids	Individual fruit weight					Number of fruits/plant				
	Mean (g)	$\overline{MP}$	Heterosis (%)			Mean	$\overline{MP}$	Heterosis (%)		
			RH	HB	SH			RH	HB	SH
Arka Abha	54.34					7.5				
Arka Alok	46.65					7.67				
Sakthi	30.59					35.17				
LE 312	38.45					11.30				
LE 370	22.02					20.22				
LE 378	37.53					7				
RFH-1	34.35					4.67				
PKM-1	43.34					13.43				
Arka Abha x LE 312	44.77	46.40	-3.50	-17.61*	-17.61*	11.57	9.4	23.05	2.36	-42.80*
" x LE 370	47.76	38.18	25.10*	-12.11*	12.11*	13.42	13.86	-3.20	-33.65*	-33.65*
" x LE 378	49.44	45.94	7.63*	-9.02*	-9.02	8.83	7.25	21.84	17.78	-56.31*
" x RFH-1	43.80	44.35	-4.24	-19.40*	-19.40*	14.33	6.09	135.62*	91.11*	-29.11*
" x PKM-1	52.92	48.84	8.36*	-2.61	-2.61	16.67	10.47	59.24*	24.07*	-17.57*
Arka Alok x LE 312	61.67	42.55	44.93*	32.20*	13.48*	10	9.49	5.45	-11.50	-50.54*
" x LE 370	46.16	34.34	34.46*	-1.04	-15.05*	13.08	13.95	-6.17	-35.30*	-35.30*
" x LE 378	46.17	42.09	9.69	-1.03	-15.05*	6	7.34	-18.18	-21.74	-70.33*
" x RFH-1	71.38	40.50	76.26*	53.03*	31.36*	7.17	6.17	16.22	-6.52	-64.56*
" x PKM-1	56.67	44.99	25.95*	21.48*	4.28	15.17	10.55	43.76*	12.90	-24.99*
Sakthi x LE 312	31.92	34.52	-7.54	-16.99*	-41.27*	19.8	13.24	49.62*	30.55*	-2.08
" x LE 370	26.12	26.31	-0.68	-14.60*	-51.93*	25.14	17.70	42.11*	24.35*	24.35*
" x LE 378	33.14	34.06	-2.70	-11.70*	-39.01*	18.67	11.09	68.42*	23.08*	-7.68
" x RFH-1	39.90	32.47	22.88*	16.15*	-26.58*	20.67	9.92	108.40*	36.26*	2.21
" x PKM-1	43.86	36.97	18.65*	1.20	-19.29*	14.97	14.30	4.71	-1.28	-25.95*
CD (0.05)			3.49	4.03	4.03			2.68	3.09	3.09

312 (49.62), Arka Abha x PKM-1 (59.24), Sakthi x LE 373 (68.42), Sakthi x RFH-1 (108.40) and Arka Abha x RFH-1 (135.62). Heterobeltiosis was significant and positive in six hybrids viz., Sakthi x LE 373 (23.08), Arka Abha x PKM-1 (24.07), Sakthi x LE 370 (24.35), Sakthi x LE 312 (30.55), Sakthi x RFH-1 (36.26) and Arka Abha x RFH-1 (91.11). LE 370 was used as a check variety for measuring standard heterosis. Only one hybrid Sakthi x LE 370 exhibited significant standard heterosis. The hybrid Arka Abha x RFH-1 recorded significant positive relative heterosis as well as heterobeltiosis.

Fruit yield/plant

The mean value of parents and hybrids and heterosis percentage are given in table 13.

For fruit yield/plant the percentage ranged from -29.48 to 99.47 in relative heterosis from -50.95 to 74.56 in heterobeltiosis and from -71.25 to -34.73 in standard heterosis. Five hybrids such as Arka Alok x PKM-1 (47.47), Arka Alok x LE 370 (48.80), Arka Alok x LE 312 (62.10), Arka Alok x LE 373 (91.64) and Arka Alok x RFH-1 (99.47) exhibited significant positive heterosis over mid parent. Four hybrids viz., Arka Alok x LE 312 (40.26), Arka Abha x LE 370 (52.73), Arka Alok x RFH-1 (59.69) and Arka Alok x LE 373 (74.56) expressed significant positive heterosis over better parent, whereas none of the

hybrids exhibited significant positive heterosis over check variety. Sakthi was used as a check variety. The hybrid Arka Alok x LE 373 recorded maximum significant positive relative heterosis and heterobeltiosis.

Pericarp thickness

The mean value of parents and hybrids and heterosis percentage of hybrids for pericarp thickness are given in table 13.

The hybrids exhibited significant heterosis for pericarp thickness. Relative heterosis ranged from -15.16 to 57.43 per cent. But significant positive heterosis was recorded in Arka Alok x LE 312 (33.60) and Arka Alok x RFH-1 (57.43). Three out of 15 hybrids recorded significant heterobeltiosis. Only two hybrids exhibited positive heterosis. They were Arka Alok x LE 312 (32.48) and Arka Alok x RFH-1 42.57. Only one hybrid Arka Alok x RFH-1 (22.67) exhibited significant positive standard heterosis. Arka Abha was used as a check variety. For pericarp thickness the hybrid Arka Alok x RFH-1 recorded maximum significant relative heterosis, heterobeltiosis and standard heterosis.

Table - 13 Mean value of parents and hybrids and heterosis percentage for fruit yield/plant and pericarp thickness.

Parents/Hybrids	Fruit Yield/plant					Pericarp thickness				
	Mean (g)	$\overline{MP}$	Heterosis (%)			Mean (mm)	$\overline{MP}$	Heterosis (%)		
			RH	HB	SH			RH	HB	SH
Arka Abha	424.17					4.82				
Arka Alok	321.01					3.37				
Sakthi	1261.33					3.28				
LE 312	439.43					3.31				
LE 370	445.40					3.02				
LE 373	263.77					4.28				
RFH-1	192.95					4.15				
PKM-1	598.50					3.63				
Arka Abha x LE 312	517.95	431.80	19.95	17.87	-58.94*	3.45	4.07	-15.16	-28.47*	-28.47*
" x LE 370	680.27	552.22	56.46	52.73*	-46.07*	4.02	3.92	2.55	-16.59	-16.59
" x LE 373	435.86	343.97	26.72	2.76	-65.44*	4.21	4.55	-7.54	-12.72	-12.72
" x RFH-1	438.65	308.56	42.16	3.41	-65.22*	4.38	4.49	-2.30	-9.12	-9.12
" x PKM-1	362.64	511.34	-29.08*	-39.41*	-71.25*	4.67	4.23	10.41	-3.25	-3.25
Arka Alok x LE 312	616.33	380.22	62.10*	40.26*	-51.14*	4.46	3.34	33.60*	32.48*	-7.53
" x LE 370	570.22	383.21	48.80*	28.02	-54.79*	3.15	3.20	-1.41	-6.44	-34.69*
" x LE 373	560.33	292.39	91.64*	74.56*	-55.58*	3.83	3.83	0.22	-10.51	-20.53*
" x RFH-1	512.60	256.98	99.47*	59.69*	-59.36*	5.92	3.76	57.43*	42.57*	22.67*
" x PKM-1	678.00	459.76	47.47*	13.28	-46.25*	3.71	3.5	6.05	2.20	-23.08*
Sakthi x LE 312	634.65	850.38	-25.37*	-49.68*	49.68	3.38	3.30	2.63	2.22	-29.86*
" x LE 370	659.43	853.37	-22.73*	-47.72*	47.72*	3.41	3.15	8.14	3.86	-29.30*
" x LE 373	618.67	762.55	-18.87*	-50.95*	-50.95*	3.89	3.78	2.82	-9.18	-19.35*
" x RFH-1	823.27	727.14	13.22	-34.73*	-34.73*	4.21	3.72	13.27	1.45	-12.72
" x PKM-1	655.80	929.92	-29.48*	-48.01*	-48.01*	3.81	3.46	10.32	5.05	-20.94*
CD (0.05)			132.80	153.34	153.34			0.72	0.84	0.84

Number of leaves/plant.

The mean value of parents and hybrids and heterosis percentage of hybrids for number of leaves/plant are given in table 14.

Hybrids exhibited significant relative heterosis, heterobeltiosis and standard heterosis for this trait. Eight hybrids, Arka Alok x LE 312 (26.94), Sakthi x LE 370 (27.81), Arka Abha x LE 373 (47.65), Sakthi x PKM-1 (48.20), Arka Abha x LE 370 (59.59), Sakthi x LE 312 (96.76), Arka Abha x LE 312 (108.42) and Arka Alok x PKM-1 (115.56) recorded significant positive relative heterosis. Only three hybrids recorded significant positive heterobeltiosis. They were Sakthi x LE 312 (44.76), Arka Abha x LE 312 (60.26) and Arka Alok x PKM-1 (104.22). None of the hybrids showed significant positive standard heterosis. With regard to number of leaves/plant the hybrid Arka Alok x PKM-1 expressed significant relative heterosis as well as heterobeltiosis.

Locules/fruit

The mean value of parents and hybrids and percentage of heterosis for locules/fruit are given in table 14.

The hybrids exhibited significant relative heterosis, heterobeltiosis and standard heterosis. Relative heterosis was

Table - 14 Mean value of parents and hybrids and heterosis percentage for No.of leaves/plant and locules/fruit.

Parents/Hybrids	Number of leaves/plant					Locules/fruit				
	Mean	$\overline{MP}$	Heterosis (%)			Mean	$\overline{MP}$	Heterosis (%)		
			RH	HB	SH			RH	HB	SH
Arka Abha	74.71					4.93				
Arka Alok	95.44					3.92				
Sakthi	65.48					3.74				
LE 312	138.90					4.93				
LE 370	200.58					3.68				
LE 373	207.73					4.63				
RFH-1	75.4					3.94				
PKM-1	106.67					4.59				
Arka Abha x LE 312	222.6	106.81	108.42*	60.26*	7.16	4.90	4.93	-0.61	-0.61	-0.61
" x LE 370	219.67	137.65	59.59*	9.52	5.75	4.50	4.31	4.45	-8.85	-8.85
" x LE 373	208.51	141.22	47.65*	0.37	0.37	4.87	4.78	1.74	-1.35	-1.85
" x RFH-1	54	150.11	-28.05*	-28.38	-74.01*	4.98	4.44	12.13	0.88	0.88
" x PKM-1	93.83	90.69	3.47	-12.03	-54.83*	3.75	4.76	-21.22*	-23.99*	-23.99*
Arka Alok x LE 312	148.73	117.17	26.94*	7.08	-28.40*	4.42	4.43	-0.19	-10.47	-10.47
" x LE 370	143.25	148.01	-3.21	-28.58*	-31.04*	5.05	3.8	33.10*	29.02*	2.43
" x LE 373	163.53	151.59	7.88	-21.28*	-21.28*	4.99	4.28	16.88*	7.84	1.28
" x RFH-1	58.23	85.42	-31.83*	-38.99*	-71.97*	4.24	3.93	7.97	7.61	-13.99
" x PKM-1	217.83	101.06	115.56*	104.22*	4.86	5.11	4.26	20.19*	11.41	3.58
Sakthi x LE 312	201.07	102.19	96.76*	44.76*	-3.21	3.97	4.34	-8.41	-19.46*	-19.46*
" x LE 370	170.02	133.03	27.81*	-15.23*	-18.15*	3.78	3.71	1.98	1.07	-23.31*
" x LE 373	159.87	136.61	17.03	-23.04*	-23.04*	4.22	4.19	0.84	-8.85	-14.39
" x RFH-1	68	70.44	-3.46	-9.81	-67.27*	3.57	3.84	-7.11	-9.47	-27.64*
" x PKM-1	127.56	86.08	48.20*	19.58	-38.60*	4.01	4.17	-3.64	-12.5	-18.65*
CD (0.05)			23.71	27.38	27.38			0.65	0.75	0.75

significant in four hybrids. Out of these, three hybrids showed positive values. They were Arka Alok x LE 373 (16.88), Arka Alok x PKM-1 (20.19) and Arka Alok x LE 370 (33.10). Three hybrids exhibited significant heterobeltiosis. Among these only one Arka Alok x LE 370 (29.02) expressed positive heterosis. None of the hybrids expressed significant positive standard heterosis. The hybrid Arka Alok x LE 370 expressed maximum significant relative heterosis and heterobeltiosis.

Size of fruits

The mean value of parents and hybrids and percentage of heterosis for size of fruits are given in table 15.

Relative heterosis, heterobeltiosis and standard heterosis were significant in the hybrids. Relative heterosis was significant and positive in six hybrids, viz., Sakthi x PKM-1 (20.32), Arka Abha x LE 370 (24.41), Arka Alok x PKM-1 (25.23), Arka Alok x LE 370 (34.44), Arka Alok x LE 312 (50.33) and Arka Alok x RFH-1 (62.73). Three hybrids viz., Arka Alok x PKM-1 (18.65), Arka Alok x LE 312 (35.67) and Arka Alok x RFH-1 (58.96) exhibited significant positive heterobeltiosis. Only two hybrids viz., Arka Alok x LE 312 (14.33) and Arka Alok x RFH-1 (33.95) showed significant positive standard heterosis. Heterosis was maximum in the hybrid Arka Alok x RFH-1.

Table - 15 Mean value of parents and hybrids and heterosis percentage for size of fruits.

Parents/Hybrids	Size of fruits				
	Mean (cc)	$\overline{MP}$	Heterosis (%)		
			RH	HB	SH
Arka Abha	51.92				
Arka Alok	43.75				
Sakthi	28.17				
LE 312	35.22				
LE 370	19.17				
LE 373	34.71				
RFH-1	41.72				
PKM-1	39.16				
Arka Abha x LE 312	41.62	43.57	-4.47	-19.83*	-19.83*
" x LE 370	44.22	35.55	24.41*	-14.83*	-14.83*
" x LE 373	47.68	43.32	10.09	-8.15	-8.15
" x RFH-1	45.69	46.82	-2.41	-11.99	-11.99
" x PKM-1	51.56	45.54	13.23	-0.69	0.69
Arka Alok x LE 312	59.36	39.49	50.33*	35.67*	14.33*
" x LE 370	42.29	31.46	34.44*	-3.33	-18.54*
" x LE 373	43.35	39.23	10.50	-0.91	-16.50*
" x RFH-1	69.54	42.74	62.73*	58.96*	33.95*
" x PKM-1	51.91	41.46	25.23*	18.65*	-0.01
Sakthi x LE 312	28.18	31.70	-11.07	-19.97	-45.71*
" x LE 370	22.60	23.67	-4.49	-19.75	-56.46*
" x LE 373	31.38	31.44	-0.19	-9.59	-39.56*
" x RFH-1	37.63	34.95	7.68	-9.81	-27.52*
" x PKM-1	40.5	33.67	20.32*	3.43	-21.99*
CD (0.05)			6.21	7.17	7.17

4.f. DISEASE AND PEST INCIDENCE

Diseases

Observations were made on the incidence of diseases-mosaic, leaf curl and bacterial wilt. There was no natural incidence of bacterial wilt. The percentage of mosaic and leaf curl infected plants in the lines, testers and line x tester hybrids is presented in the table 16.

(a) Mosaic

In the lines the percentage of infected plants ranged from 20.67 in Arka Abha to 30 in Arka Alok while in the testers it ranged from 0 in LE 370 to 23.67 in PKM-1. In the hybrids the range was from 0 to 20 per cent. Maximum infection was recorded in Arka Alok x PKM-1 (20%) among the hybrids. The hybrids Arka Abha x LE 370, Sakthi x LE 370, Arka Abha x RFH-1, Sakthi x LE 373 and Sakthi x RFH-1 were free from mosaic infection.

(b) Leaf Curl

The percentage of plants infected by leaf curl in the two lines Arka Abha and Arka Alok were 20 and 15 respectively. The line Sakthi was free from the disease. Among the five testers, only RFH-1 and PKM-1 showed symptoms of leaf curl and the percentage of plants showing infection was 25 and 10 respectively in the two varieties. Among the 15 hybrids only five hybrids

Abha x LE 312, Arka Abha x LE 370, Arka Abha x LE 373, Arka Abha x RFH-1, Arka Abha x PKM-1, Arka Alok x 312, Sakthi x LE 312, Sakthi x LE 370, Sakthi x RFH-1 and Sakthi x PKM-1 were free from this disease.

Insect pest

The major insect pest noticed was fruit borer. The percentage of tomato fruits attacked by fruit borer in the lines, testers and hybrids is presented in table 16.

Table 16. Percentage of plants infected by diseases - mosaic and leaf curl and percentage of fruits attacked by fruit borer.

Parents/ Hybrids	Mosaic (%)	Leaf curl (%)	fruits attacked by borer (%)
Arka Abha	20.67	20	13.04
Arka Alok	30	15	12.15
Sakthi	23.33	0	0.68
LE 312	15	0	3.46
LE 370	0	0	0
LE 373	10	0	3.45
RFH-1	20	25	0
PKM-1	23.67	10	7.41
Arka Abha x LE 312	10	0	9.87
Arka Abha x LE 370	0	0	0
Arka Abha x LE 373	10	0	5.56
Arka Abha x RFH-1	0	0	0
Arka Abha x PKM-1	10	0	0
Arka Alok x LE 312	15	0	8.35
Arka Alok x LE 370	10	20	6.38
Arka Alok x LE 373	10	10	4
Arka Alok x RFH-1	10	16.67	6.95
Arka Alok x PKM-1	20	20	4.35
Sakthi x LE 312	10	0	9.8
Sakthi x LE 370	0	0	6.51
Sakthi x LE 373	0	10	0
Sakthi x RFH-1	0	0	7.46
Sakthi x PKM-1	10	0	4.85

In the lines the percentage of fruits showing pest attack ranged from 0.68 (Sakthi) to 13.04 (Arka Abha). In the testers the range was from 0 to 8.46. Testers LE 370 and RFH-1 were found to be free from the fruit borer attack. In the hybrids the percentage of fruits showing the pest attack ranged from 0 to 9.87. Among the five hybrids in which Arka Abha was used as the female parent, three hybrids recorded no incidence of fruit borer attack. They were Arka Abha x LE 370, Arka Abha x RFH-1 and Arka Abha x PKM-1. Sakthi x LE 373 was also free from this infestation.

Growth habit

Growth habit of the lines, testers and line x tester hybrids are given in table 17.

According to the growth habit tomatoes were classified into three viz., determinate, semideterminate and indeterminate types.

All the three lines Arka Alok, Arka Abha and Sakthi were having semi determinate growth. Among the five testers RFH-1 and PKM-1 were semi determinate types while LE 370, LE 373 and LE 312 were indeterminate types. Among the hybrids all the three lines crossed to the three tester varieties LE 312, LE 370 and LE 373 produced indeterminate types and the three lines crossed to the tester varieties RFH-1 and PKM-1 produced either determinate or semideterminate types.

Table 17. Growth habit of parents and hybrids

Parents/Hybrids		Growth habit
Arka Abha	-	Semideterminate
Arka Alok	-	Semideterminate
Sakthi	-	Semideterminate
LE 312	-	Indeterminate
LE 370	-	Indeterminate
LE 373	-	Indeterminate
RFH-1	-	Semideterminate
PKM-1	-	Semideterminate
Arka Abha x LE 312	-	Indeterminate
Arka Abha x LE 370	-	Indeterminate
Arka Abha x LE 373	-	Indeterminate
Arka Abha x RFH-1	-	Determinate
Arka Abha x PKM-1	-	Determinate
Arka Alok x LE 312	-	Indeterminate
Arka Alok x LE 370	-	Indeterminate
Arka Alok x LE 373	-	Indeterminate
Arka Alok x RFH-1	-	Semideterminate
Arka Alok x PKM-1	-	Determinate
Sakthi x LE 312	-	Indeterminate
Sakthi x LE 370	-	Indeterminate
Sakthi x LE 373	-	Indeterminate
Sakthi x RFH-1	-	Determinate
Sakthi x PKM-1	-	Determinate

DISCUSSION

DISCUSSION

Before launching any hybridization programme it is necessary to choose the parents carefully. The common approach of selecting the parents on the basis of per se performance does not necessarily lead to fruitful results. Hence proper identification of the genetically superior parents is done on the basis of the performance of the hybrids which in turn is dependent on the information obtained from the analysis of the combining ability, in terms of gca of the parents and sca of the hybrids. The concept of combining ability was first proposed by Sprague and Tatum (1942). Combining ability analysis is aimed at getting information about the general combining ability (gca) of parents and specific combining ability (sca) of hybrids. Combining ability is the ability of a biotype to transmit desirable performance to its crosses. General combining ability is the average performance of a strain in a series of crosses. Specific combining ability is used to designate those cases in which certain combinations do relatively better or worse than that would be expected on the basis of average performance of the lines involved.

In almost all major field 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 indicates the predominant role of additive gene action which is fixable and higher sca variances indicate dominance deviation and epistatic effect.

Line x tester analysis is one of the methods for evaluating the performance of varieties or strains in terms of their combining ability. It is a modified form of top cross and was proposed by Kempthorne (1957). This method has some advantage over diallel analysis in that interaction among males and females can be avoided and the number of cross combinations can be reduced without affecting the accuracy of the results. The present study was carried out in a line x tester model using eight varieties of tomato to estimate the general combining ability of the parents and specific combining ability of the hybrids. The three bacterial wilt resistant varieties were used as lines (female parents) to ensure the production of hybrid seeds on the mother plants.

Analysis of variance had shown that the treatments were significant for all the characters, suggesting that there was significant differences among the genotypes. The mean square due to parents were significant for number of branches/plant, indicating that the parents differed significantly for this trait. The mean squares due to lines, testers and line x tester

hybrids were significant for the characters viz., plant height, number of leaves/plant, period of harvest, individual fruit weight, number of fruits/plant, fruit yield/plant, locules/fruit and size of fruits. For the two characters viz., spread of the plant and pericarp thickness only the line x tester hybrids showed significance.

The results obtained from the line x tester analysis are discussed below:

Combining ability and gene action

The analysis of variance revealed that the mean squares due to lines and testers were significant for number of branches/plant. This indicated the importance of gca alone for the expression of this trait which inturn reflects the importance of additive gene action. The mean square due to lines, testers and line x tester interactions were significant for the characters viz., plant height, number of leaves/plant, period of harvest, individual fruit weight, number of fruits/plant, fruit yield/plant, locules/fruit and size of fruits. This showed the importance of both gca and sca for these traits which inturn suggest the involvement of both additive and non-additive gene action in the inheritance of these characters. Hence these characters are amenable to selection as well as hybridization. However the variance due to line x tester interaction alone was

significant for spread of the plant and pericarp thickness, suggesting the involvement of sca alone for the inheritance of these characters.

Plant height

For plant height significant variance was recorded by testers and line x testers. So both gca and sca effects were significant for this character, suggesting the involvement of both additive and non additive gene action for the expression of this trait. But the ratio of additive to dominance variance was less than unity. This revealed the predominant role of non additive gene action. In agreement to this non additive gene action was reported by Govindarasu et al. (1981), Sidhu et al. (1981), Sonone et al. (1986) and Brahma et al. (1991) in tomato. Predominance of additive gene action was reported by Singh and Singh (1980) and Ghosh and Symal (1994). However the involvement of both additive and non additive effects were also reported by Moya et al. (1986) and Ali et al. (1989) in tomato.

The estimates of combining ability revealed that, among the three lines only Arka Alok had significant negative gca effect. Among the five testers, LE 373 recorded significant positive gca effect while RFH-1 recorded significant negative gca effect. Significant positive sca effects were shown by the hybrids, Arka Abha x LE 370, Arka Alok x PKM-1 and Sakthi x LE 312. But

maximum sca effect was shown by the hybrid Arka Alok x PKM-1, where one parent had negative gca effect and the other parent had positive gca effect. In the hybrid Arka Abha x LE 370 both parents had positive gca effects. The hybrid Sakthi x LE 312 had one parent with positive gca effect and other parent with negative gca effect.

Observations on heterosis in the hybrids, well supported the results of combining ability analysis. Since there were predominant non additive gene action and significant sca effects; heterosis was pronounced in the hybrids. Positive heterosis was recorded by 14 hybrids out of the fifteen. Significant positive heterosis over mid parent was recorded by 11 hybrids. Of these six hybrids recorded significant positive heterosis over the better parent. The hybrid Arka Alok x PKM-1 recorded significant positive heterobeltiosis also exhibiting significant sca effects in the combining ability analysis. Positive heterosis for this trait was reported earlier by Rema Bai (1975), Babu (1978), Ahmed et al. (1985), Brahma et al. (1991) and Dod et al. (1992).

Number of branches/plant

For number of branches/plant, variance due to lines and testers were significant, suggesting the major involvement of additive gene action. More over the contribution of testers was maximum here. For line x tester interaction the variance was not

significant which implied that the sca effect was not significant. However crosses should be selected on the basis of gca effect of parents, unless sca variance exceeds twice gca variance. Here sca variance does not exceed twice gca variance. Hence selection should be based on the gca effect of parents.

Predominance of additive gene action for the above trait was reported by Gurdalbir Singh and Nandpuri (1974), Singh and Singh (1980), Lonkar and Borikar (1988) and Ghosh and Symal (1994) in tomato which supported the present findings. But contrary to this, predominance of non additive gene action was reported by Govindarasu et al. (1981) and Sidhu et al. (1981). Involvement of both additive and non additive gene actions were reported for this trait by Ali et al. (1989).

Among the lines, Arka Alok showed significant negative gca effect while Sakthi showed positive gca effect. Among testers, LE 370 alone showed significant positive gca effect. None of the hybrids showed significant positive sca effect. But significant negative sca effect was observed in Arka Alok x LE 370, where one of the parents is having significant negative gca effect and the other parent is having positive gca effect.

Significant positive heterosis over mid parent was recorded only in one hybrid Arka Abha x LE 370. Rema Bai (1975) and Sidhu et al. (1981) also reported significant heterosis for this trait.

Spread of the plant

The mean squares for line x tester interaction alone was significant for the character, spread of the plant. This indicated significant sca effect. The proportional contribution of line x tester hybrids was also maximum for this character. The ratio of additive to dominance variance was less than unity. All these suggested the involvement of non-additive gene action alone for the expression of this trait. It is in agreement with the result of Chandrasekhar and Rao (1989) in tomato.

The lines Arka Alok and Sakthi exhibited significant negative and positive gca effects respectively for spread of the plant. Among testers , LE 312 and RFH-1 showed significant positive and negative gca effects respectively. Significant positive sca effect was observed in three hybrids viz., Arka Abha x LE 373, Arka Alok x PKM-1 and Sakthi x LE 370. Among these Arka Abha x LE 373 had parents with negative x positive gca effects, Sakthi x LE 370 had parents with positive x positive gca effects and Arka Alok x PKM-1 with negative x negative gca effects.

The heterosis expressed in the hybrids for spread of the plant was also studied. It was found that a very high degree of heterosis was manifested among the hybrids. Out of the 15 hybrids 14 recorded positive relative heterosis. Significant

positive heterosis was recorded by ;ten hybrids over mid parent, eight hybrids over better parent and three hybrids over standard parent. The maximum heterosis was expressed by Sakthi x LE 312.

Period of harvest

Variance due to lines, testers and line x tester interaction was significant for period of harvest. This indicated that both additive and non-additive gene actions were involved in the expression of this trait. However this trait was found to be controlled predominantly by non-additive gene action since the additive to dominance variance ratio was less than one. In agreement to this, non-additive gene action was reported by Egiyan and Luk'yanenko (1979) and Singh and Singh (1980). But predominance of additive gene action was reported by Swamy and Mathai (1982) and Ghosh and Symal (1994). The involvement of both additive and non-additive gene action was reported by Nandpuri et al. (1975), Trinklein (1975), Scossiroli et al. (1976), Ali et al. (1989) and Swadiak and Kordus (1992).

Among the parents, the line Arka Alok and the testers LE 312 and LE 373 exhibited significant negative gca effect. The highest negative sca effect was observed in the hybrid Arka Abha x PKM-1, where both the parents were positive general combiners.

The predominance of sca variance is well reflected in the hybrids. Significant heterosis was recorded by the different hybrids. Positive heterosis was significant in Arka Abha x RFH-1 and Sakthi x RFH-1 while it was significantly negative and maximum in the hybrid Arka Alok x LE 373. Negative heterosis is preferable for period of harvest since it gives earliness and compactness for harvest.

Significant heterotic effects for early yield were reported by Zubeldia and Nuez (1974), Trinklein (1975) and Egiyan and Luk'yanenko (1979) in tomato. Moderate heterosis for earliness was also reported by Govindarasu et al. (1982).

Individual fruit weight

Variance due to lines and line x tester interactions were 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 confirmity with the results of Gurdalbir Singh and Nandpuri (1974), Moya et al. (1986), Ali et al. (1989) and Szwadiak and Kordus (1992). Predominance of additive gene action was reported by Dixit et al. (1980), Sonone et al. (1986) and Omara et al. (1988) for this trait. In the present study predominance of non-additive gene action was indicated since the additive to dominance variance ratio was less than unity.

All the lines showed significant gca effect for individual fruit weight. Maximum gca effect was exhibited by Arka Alok. But Sakthi showed significant negative gca effect. All the testers, except LE 312 exhibited significant gca effect. REH-1 showed maximum gca effect. Nine hybrids exhibited significant sca effects. But significant positive sca effect was expressed by five hybrids. Maximum sca effect was observed in Arka Alok x RFH-1, where both parents were having significant positive gca effects. The hybrids Arka Abha x LE 370, Arka Alok x LE 312 and Arka Abha x LE 373 had parents with positive x negative general combiners. The hybrid Sakthi x PKM-1 had parents with negative x positive general combiners.

Significant heterosis expressed in the hybrids for individual fruit weight supported the results of combining ability analysis. Ten hybrids recorded significant positive relative heterosis, of which the four viz., Arka Alok x LE 312, Arka Alok x RFH-1, Arka Alok x PKM-1 and sakthi x RFH-1 recorded significant positive heterobeltiosis also. The hybrid Arka Alok x RFH-1 which had the highest sca effect recorded maximum positive heterosis for fruit weight. Similar findings were also reported for this trait by Ahmed et al. (1988).

Number of fruits/plant

For number of fruits/plant the variance was significant for lines and line x tester hybrids Hence both gca and sca were significant, suggesting the involvement of both additive and non-additive gene actions. Here the ratio of additive to dominance variance was found to be less than one indicating the preponderance of non-additive gene action. This finding was in agreement with the results of Govindarasu et al. (1981) and Sidhu et al. (1981). But contrary to this, Singh and Singh (1980), Omara et al. (1988) and Sonone et al. (1986) reported predominant additive gene action for this trait. Significance of both additive and non-additive gene effects were reported by Moya et al. (1986). Dhaliwal and Nandpuri (1988). Ali et al. (1989) and Szwadiak and Kordus (1992).

All the lines recorded significant gca effect. Two lines Arka Abha and Arka Alok exhibited significant negative gca effect. Among testers LE 370 and PKM-1 exhibited significant positive gca effect. whereas LE 373 exhibited significant negative gca effect. Among hybrids significant sca effect was observed in six hybrids - three with positive sca effect and three with negative sca effect. High sca effect was observed in the hybrids Arka Alok x PKM-1. Arka Abha x PKM-1 and Sakthi x LE 370. Hybrids Arka Alok x PKM-1 and Arka Abha x PKM-1 had parents

with negative x positive gca effect while Sakthi x LE 370 had positive x positive gca effect.

Positive heterosis expressed by the hybrids supports the predominance of sca effect. Out of 15, 12 hybrids showed positive heterosis. Heterosis was significantly positive in seven hybrids over mid parent viz., Arka Abha x RFH-1, Arka Abha x PKM-1, Sakthi x LE 312, Sakthi x LE 373, Sakthi x LE 370, Sakthi x RFH-1 and Arka Alok x PKM-1. These hybrids showed significant heterobeltiosis also. The hybrid Sakthi x LE 370 exhibited significant standard heterosis for this trait.

Pronounced heterosis for this trait was reported earlier by Sonone et al. (1981). Govindarasu et al. (1982). Brahma et al. (1991) and Dod et al. (1992). Heterobeltiosis was reported by Ahmed et al. (1988).

Fruit yield / plant

Significance of gca and sca was revealed from the analysis of variance for fruit yield/plant; as the mean squares due to lines and line x tester interactions were significant. This trait is therefore controlled by both additive and non-additive gene actions. But the ratio of additive to dominance variance was less than unity indicating that non-additive gene action is predominantly involved in the expression of this trait. This is in accordance with the findings of Govindarasu et al. (1981).

Sidhu et al. (1981), Sonone et al. (1986) and Kryuchkov et al. (1992). But predominance of additive gene effects were reported by Dholaria and Qadri (1983), Lonkar and Borikar (1988) and Omara et al. (1988).

The gca effect was positively significant only in one line ie. Sakthi where as it was insignificant among testers. The sca effect was significant in four hybrids. Maximum positive sca effect was shown by Arka Abha x LE 370 obtained from parents with negative x positive gca effect. It was followed by Sakthi x RFH-1, where both parents were having positive gca effects. In the hybrid Arka Alok x PKM-1, the sca effect was significant and positive; while the parents were having positive x negative gca effects. In the hybrid Arka Abha x PKM-1, sca effect was significant and negative; where both parents were negative general combiners.

The expression of heterosis in the hybrids was estimated and it was found that out of 15, five hybrids showed significant positive heterosis over mid parent and four hybrids over better parent. The hybrids Arka Alok x RFH-1 and Arka Alok x LE 373 exhibited high significant positive relative heterosis and heterobeltiosis. Earlier reports by Avdeev (1974), Ahmed et al. (1988), Narcisco and Rosario (1988) and Mandal et al. (1989) indicated that there was significant positive heterobeltiosis expressed for this trait in tomato.

Pericarp thickness

Variance due to line x tester interaction alone was significant for pericarp thickness suggesting the importance of non-additive gene action for the expression of this trait. Moreover the ratio of additive to dominance variance was less than one. So only non-additive gene action is involved in the inheritance of this trait. This finding was in agreement with the results of Dixit et al. (1980), Bhutani (1981) and Sidhu et al. (1981). But the predominance of additive gene action was reported by Nandpuri and Tyagi (1976), Patil and Patil (1988) and Ghosh and Symal (1994) in tomato.

The line Arka Alok showed maximum positive gca effect and Sakthi showed significant negative gca effect. But significant positive gca effect was observed in the tester RFH-1 alone. Significant positive sca effect was found in the hybrid Arka Alok x RFH-1, where both parents were having maximum gca effect. Eight hybrids had significant positive sca effect. Of these three hybrids were having parents with positive x negative gca effects, two hybrids were having parents with positive x positive gca effects, two hybrids were having parents with negative x negative gca effects and one hybrid was having parents with negative x positive gca effect.

exhibited significant negative sca effects. The maximum sca effect was expressed by Arka Alok x PKM-1, where both the parents were having negative gca effects. In the three hybrids Arka Abha x LE 370, Arka Abha x LE 312 and Arka Abha x LE 373; all the parents were having positive gca effects.

Since the character is predominantly under the control of non-additive gene action the heterosis also was significant in the hybrids. Significant positive heterosis was observed in eight hybrids over mid parent and three hybrids over better parent. Maximum positive heterosis was recorded by the hybrid, Arka Alok x PKM-1 which showed high sca effect in the combining ability analysis.

Locules/fruit

Significant mean sum of squares due to lines and line x tester interactions were recorded for locules/fruit. This indicated significant gca and sca effects and the involvement of additive and non-additive genetic components in the expression of this trait. But the ratio of additive to dominance variance was found to be less than one, indicating the predominant role of non-additive gene action. This is in agreement with the results of Bhutani (1981) and Sidhu et al (1981) in tomato. Predominance of additive gene effects were reported by Singh and Singh (1980), Moya et al. (1986), Bhutani and Kalloo (1991) and Ghosh and Symal

Pericarp thickness

Variance due to line x tester interaction alone was significant for pericarp thickness suggesting the importance of non-additive gene action for the expression of this trait. Moreover the ratio of additive to dominance variance was less than one. So only non-additive gene action is involved in the inheritance of this trait. This finding was in agreement with the results of Dixit et al. (1980), Bhutani (1981) and Sidhu et al. (1981). But the predominance of additive gene action was reported by Nandpuri and Tyagi (1976), Patil and Patil (1988) and Ghosh and Symal (1994) in tomato.

The line Arka Alok showed maximum positive gca effect and Sakthi showed significant negative gca effect. But significant positive gca effect was observed in the tester RFH-1 alone. Significant positive sca effect was found in the hybrid Arka Alok x RFH-1, where both parents were having maximum gca effect. Eight hybrids had significant positive sca effect. Of these three hybrids were having parents with positive x negative gca effects, two hybrids were having parents with positive x positive gca effects, two hybrids were having parents with negative x negative gca effects and one hybrid was having parents with negative x positive gca effect.

Positive heterosis was recorded in 11 hybrids out of 15. Out of the 11, significant positive heterosis was exhibited in two hybrids over mid parent and two hybrids over better parent and one hybrid over standard parent. Patil and Patil (1988) also reported high heterosis in tomato for pericarp thickness. All the three types of heterosis were significant in Arka Alok x RFH-1 which had shown maximum sca effect, in the combining ability analysis.

Number of leaves/plant

Analysis of variance for number of leaves/plant, showed significant variance for testers and line x tester hybrids. Hence gca and sca effects were significant for this character indicating that both additive and non-additive genetic components were involved in the expression of this trait. But the ratio of additive to dominance variance was less than one, suggesting the predominant role of non-additive gene action. Predominance of non-additive gene action was reported earlier by Konstantinova et al. (1990).

The line Arka Abha alone showed significant positive gca effect. Among the testers, four showed significant gca effects. They were LE 312, LE 370, LE 373 and RFH-1. The maximum positive gca effect was exhibited by the tester LE 312. Out of seven hybrids four exhibited significant positive sca effects and three

(1994). Importance of both additive and non-additive effects were reported by Bagrawat Singh et al. (1980) and Tarrega and Nuez (1983).

Among the lines, Arka Alok recorded significant positive gca effect, while Sakthi recorded significant negative gca effect. None of the testers showed significant positive or negative gca effect. Significant positive sca effect was recorded only in one hybrid ie Arka Abha x RFH-1 which had parents with positive x negative gca effect. As it is indicated, in the combining ability analysis the predominance of non-additive gene action is projected in the expression of heterosis. Out of the 15 hybrids, three hybrids recorded significant positive heterosis over mid parent and one hybrid over better parent. Earlier reports of Ahmed and Petrescu (1983) also indicated positive significant heterosis for locules/fruit in tomato.

Size of fruits

In the analysis of variance for size of fruits significant sum of squares was recorded for lines and line x tester hybrids. This indicated the importance of both gca and sca for this trait. The ratio of additive to dominance variance was less than unity indicating that this character was predominantly under the control of non-additive gene action. Nandpuri and Tyagi (1976), Dudi et al. (1979), Singh and Singh (1980), Govindarasu et al.

(1981) and Dholaria and Qadri (1983) reported predominance of additive gene action for this trait. But significance of both additive as well as non-additive gene action was reported by Nandpuri et al. (1975), Tarrega and Nuez (1983) and Moya et al. (1986).

Combining ability analysis revealed that all the lines showed significant gca effect. Lines Arka Abha and Arka Alok exhibited significant positive gca effect whereas Sakthi exhibited negative gca effect. Maximum gca effect was exhibited by Arka Alok. All the testers, except LE 312, showed significant gca effect. The testers LE 370 and LE 373 exhibited significant negative gca effect whereas RFH-1 and PKM-1 showed positive gca effect. Maximum gca effect was expressed by RFH-1. Three hybrids showed significant positive sca effect and three hybrids showed significant negative sca effect. Maximum positive sca effect was shown by Arka Alok x RFH-1, formed from parents which were having maximum positive gca effects. This was followed by Arka Abha x RFH-1, Arka Alok x LE 312 and Arka Abha x LE 370, where the parents were having positive x negative gca effect.

The heterosis observed in the hybrids also support the above findings. Out of the 15 hybrids, six hybrids recorded significant positive heterosis over mid parent and three hybrids recorded significant positive heterosis over better parent. Two hybrids showed significant positive standard heterosis. Maximum

heterosis was recorded by the hybrid Arka Alok x RFH-1, which had shown maximum sca effect in the combining ability analysis.

Significant heterosis for size of fruits was reported earlier by Alvarez (1985) and Sonone et al. (1981).

In general the specific combination of Arka Abha x LE 370 is showing significantly high sca as well as heterosis for the yield attributes such as fruit yield/plant, individual fruit weight, size of fruit and vegetative characters such as plant height and number of leaves/plant. This combination showed significant heterosis for branches/plant also. Observations on pests and diseases showed that the above hybrid is free from fruit borer attack and diseases like mosaic and leaf curl. It exhibited indeterminate growth habit.

The specific combination Arka Alok x PKM-1 is also showing significantly high sca as well as heterosis for number of fruits/plant, fruit yield/plant, plant height and leaves/plant. This showed determinate growth habit.

The two hybrids Arka Alok x LE 312 and Arka Alok x RFH-1 are showing high sca and heterosis for individual fruit weight, size of fruits and pericarp thickness. For fruit yield/plant the above two combination are showing significant heterosis. These showed indeterminate and semi determinate growth habits respectively.

Sakthi x RFH-1 is a specific combination which showed high sca for fruit yield/plant. This combination is showing significant heterosis for individual fruit weight and number of fruits/plant. This combination exhibited determinate growth habit.

From the general combining ability analysis it is evident that all the three lines viz., Arka Abha, Arka Alok and Sakthi are good general combiners with respect to yield and yield attributes. The testers are good general combiners for the different vegetative characters.

In the specific combining ability analysis of the 15 line x tester hybrids, pronounced specific combining ability and significant heterosis were observed in the five hybrids viz., Arka Abha x LE 370, Arka Alok x PKM-1, Arka Alok x LE 312, Arka Alok x RFH-1 and Sakthi x RFH-1; for the different yield attributes. Among these the hybrid Arka Abha x LE 370 is found to be free from diseases like mosaic and leaf curl and also free from the fruit borer attack.

Fruits of Arka Abha x LE 370, Arka Alok x PKM-1 and Sakthi x RFH-1 are given in plates 1, 2 and 3.

Good general combiners and specific combiners based on their combining ability are presented in table 18 and 19.

Table - 18 Lines and testers with high general combining ability

Characters	Significance for variance	Good lines	Good testers
Plant height	Testers and L x T hybrids	--	LE 373
No. of branches/plant	Lines and Testers	Sakthi	LE 370
Spread of the plant	L x T hybrids	--	--
Period of harvest	Lines, Testers and L x T hybrids	Arka Alok	LE 312, LE 373
Individual fruit weight	Lines and L x T hybrids	Arka Abha, Arka Alok	--
Number of fruits/plant	Lines and L x T hybrids	Sakthi	--
Fruit yield/plant	Lines and L x T hybrids	Sakthi	--
Pericarp thickness	L x T hybrids	--	--
Number of leaves/plant	Testers and L x T hybrids	--	LE 312, LE 370 & LE 373
Locules/fruit	Lines and L x T hybrids	Arka Alok	--
Size of fruit	Lines and L x T hybrids	Arka Abha, Arka Alok	--

Table - 19 Good line x tester combinations for different characters

Lines\Testers	LE 312	LE 370	LE 373	RFH-1	PKM-1
Arka Abha	No. of leaves/plant*	Plant height*	Spread of the plant*	Locules/fruit	No.of fruits/ plant*
		Individual fruit weight*	Individual fruit	Size of fruits	Period of harvest*
		Fruit yield/plant	weight*		
		No.of leaves/plant*	No. of leaves/plant*		
		Size of fruit*			
Arka Alok	Individual fruit weight*	-	-	Individual fruit weight*	Plant height* Spread of the plant*
	Size of fruit			Pericarp thickness*	No. of fruits/plant*
				Size of fruit*	Fruit yield/plant*
					No.of leaves/plant*
Sakthi	Plant height*	Spread of the plant*		Fruit yield/plant	Individual fruit weigh
		No. of fruits/plant*			

* significant heterosis

Plate 1. Fruits of Arka Abha x LE 370

Plate 2. Fruits of Arka Alok x PKM-1

Plate 1. Fruits of Arka Abha x LE 370

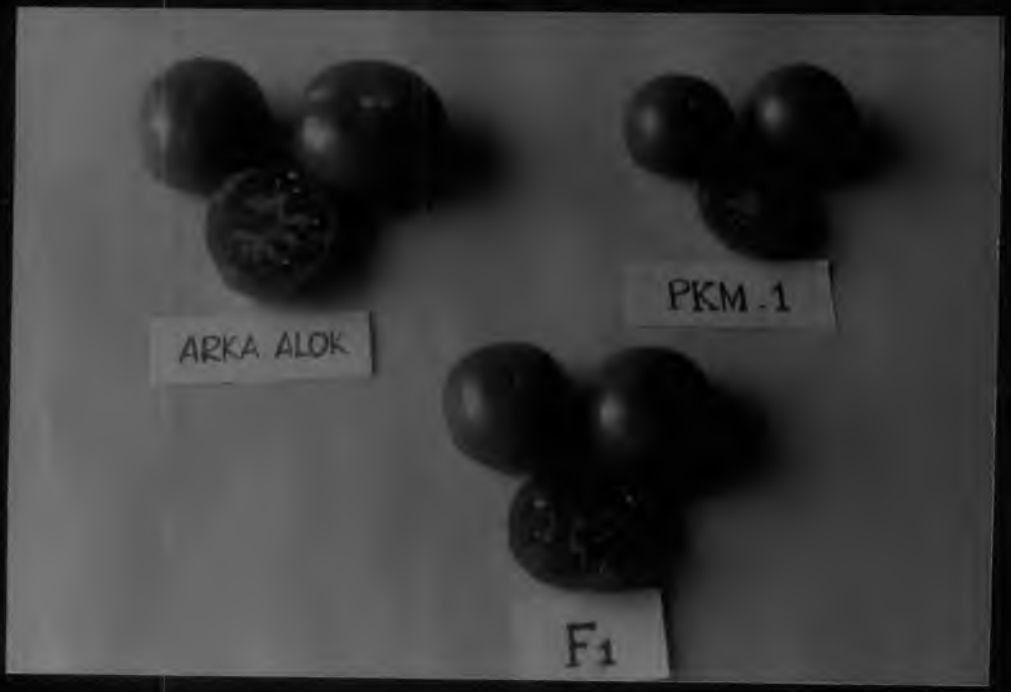


Plate 2. Fruits of Arka Alok x PKM-1

Plate 3. Fruits of Sakthi x RFH-1

significant for spread of the plant and pericarp thickness. Both gca and sca were significant for the remaining characters such as plant height, period of harvest, individual fruit weight, fruits/ plant, fruit yield/ plant, leaves/plant, locules/fruit and size of fruit. The additive to dominance variance ratio indicated a preponderance for non additive gene action in the above characters.

Combining ability analysis showed that all the three lines viz., Arka Abha, Arka Alok and Sakthi were good general combiners with respect to fruit yield and other yield attributes whereas the testers were good general combiners, for the different vegetative characters such as plant height, branches and leaves/ plant. Among the 15 hybrid combinations, significant soa and heterosis were observed in the hybrids such as Arka Abha x LE 370, Arka Alok x PKM-1, Arka Alok x LE 312, Arka Alok x RFH-1 and Sakthi x RHF-1. Among these hybrids, Arka Abha x LE 370 showed significance for fruit yield, individual fruit weight, size of fruit, plant height, leaves/plant, branches/plant and also showed resistance to mosaic, leaf curl and fruit borer. This hybrid exhibited indeterminate growth habit. The hybrid Arka Alok x PKM-1 showed significance for fruits/plant, fruit yield/plant, plant height and leaves/plant. The combinations Arka Alok x LE 312 and Arka Alok x RFH-1 showed high sca and heterosis for

SUMMARY

SUMMARY

Tomato is a nutritious vegetable crop which is facing the serious problem of bacterial wilt in Kerala. Developing high yielding, bacterial wilt resistant varieties adapted to Kerala conditions is of prime importance. Earlier studies show that there is much scope for heterosis breeding since positive heterosis is expressed in tomato hybrids for the different yield attributes. The present study was undertaken with an objective of finding out the genetic basis of the different morphological characters and identifying suitable parents for hybridization programmes, based on the general combining ability of the parents and also specific combining ability and heterosis for the yield attributes of hybrids.

The experiment was carried out in a line x tester model at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 1993-94, using three bacterial wilt resistant varieties viz., Arka Abha, Arka Alok and Sakthi as lines and five popular good varieties viz., LE 312, LE 370, LE 373, RFH-1 and PKM-1 as testers. The experiment was laid out in RBD with three replications.

The observations were recorded on plant height, number of branches/plant, growth habit, spread of the plant, period of harvest, individual fruit weight, number of fruits/plant, fruit

harvest, individual fruit weight, number of fruits/plant, fruit yield/plant, number of leaves/plant, pericarp thickness, locules/fruit, size of fruits and also on pest and diseases. The salient inferences are presented below.

Analysis of variance indicated highly significant differences among the treatments (genotypes) for all the characters - plant height, branches/plant, leaves/plant, spread of the plant, period of harvest, individual fruit weight, number and weight of fruits/plant, size of fruit, pericarp thickness and locules/fruit. Except for branches/plant sca variance was significant for all the characters. Therefore the character branches/plant is mainly governed by additive gene action. The two characters - spread of the plant and pericarp thickness of fruit are mainly governed by non-additive gene action. All the remaining characters are governed by additive as well as non additive gene action showing preponderance to non-additive genes.

The general combining ability analysis showed that all the three lines viz., Arka Abha, Arka Alok and Sakthi were good general combiners with respect to fruit yield and other yield attributes whereas all the five testers were good general combiners for the different vegetative characters, such as plant height, branches/plant and leaves/plant. The lines used in the present study are resistant to bacterial wilt diseases and at the same time they are good general combiners for the yield and yield

attributes such as individual fruit weight, size of fruit, number of fruits/plant and locules/fruit as it is evident in the study. These promising varieties can be used in recombination breeding programmes for better results.

Among the 15 line x tester hybrids the performance of five hybrids excel the others. They are Arka Abha x LE 370, Arka Alok x PKM-1, Arka Alok x LE 312, Arka Alok x RFH-1 and Sakthi x RFH-1. The hybrid Arka Abha x LE 370 exhibited highly significant specific combining ability and heterosis for fruit yield, individual fruit weight, size of fruit and for vegetative characters such as plant height and leaves/plant. This combination showed significant heterosis for branches per plant and showed resistance to mosaic, leaf curl and fruit borer. This also showed indeterminate growth habit. The hybrid Arka Alok x PKM-1 exhibited significantly high sca as well as heterosis for fruits/plant, fruit yield/plant, plant height and leaves/plant. This combination exhibited determinate growth habit. The combinations Arka Alok x LE 312 and Arka Alok x RFH-1 showed significantly high sca and heterosis for individual fruit weight, fruit size and pericarp thickness. These combinations also showed high heterosis for fruit yield/plant. Indeterminate and semi determinate growth habits were exhibited by these two combinations respectively.

Sakthi x RFH-1 exhibited significantly high sca for fruit yield/ plant and significant and positive heterosis for number of

fruits/plant and individual fruit weight. This hybrid also showed resistance to the diseases such as leaf curl and mosaic. This showed determinate growth habit.

The above promising hybrids can be directly popularised as hybrid varieties or can be carried forward to evolve high yielding bacterial wilt resistant varities.

REFERENCES

REFERENCES

*Ahmed, S.U. and Petroscu, C.N. (1983). Investigation of variability and heterosis effects in some morphological characters of tomato, with a view to the improvement of selection efficiency. Lucrari Stiintifice, Institutul Agronomic N. Balcescu, B. Horticultura, 26: 21-26.

Ahmed, S.U., Saha, H.K. and Sharfuddin, A.F.M. (1988). Study of heterosis and correlation in tomato. Thai. J. Agric. Sci., 21(2): 117-123.

Ali, M.S. Bhowmik, A. and Khan, S.H. (1989). Combining ability and heterosis in tomato (Lycopersicon esculentum). Bangladesh. J. Agric., 14 (3): 225-231.

Alvarez, M. (1985). Heterosis for morphological characteristics and fruit weight. Cultivos Tropicales, 7 (1): 37-45.

Anbu, S., Muthukrishnan, C.R. and Irulappan, I. (1981). Line x tester analysis in tomato (Lycopersicon esculentum Mill) Part II, Heterosis. South Indian Hort., 29(1): 49-53.

*Araujo, M.L. DE. and Campos, J.P. DE. (1991). Evaluation of prostrate cultivars of tomato and F_1 hybrids in diallel crosses. Pl. Br. Abst., 64: 3061.

*Avdeev, Yu. I. (1974). Heterosis and combining ability in tomato varieties. Pl. Br. Abst., 47: 1773.

AVRDC, (1975). Genetic study of resistance to bacterial wilt. Tomato Reptr. pp. 24-25.

Babu, R.Y. (1978). Studies on heterosis in tomato. Mysore J. Agric. Sci. 12(4): 676-677.

Bagrawat Singh, Kalloo, and Pandita, M.L. (1980). Combining ability for quality characters in tomato (Lycopersicon esculentum). Haryana Agric. Univ. J. Res., 10(2): 179-183.

Bell, A.A. (1981). Biochemical mechanism of disease resistance. Ann. Rev. Plant. Physiol., 32: 21-81.

*Betlach, J. and Novak, F. (1968-69). The combining ability for total and early yield of fruits of some varieties of bush tomatoes with firm stems. Pl. Br. Abst., 41: 6427.

Bhuiyan, S.R., Newaz, M.A. and Faridi, M.N.I. (1986). Heterosis for yield, ascorbic acid and other plant characters in tomato. Bangladesh Hort., 14(1): 34-39.

Bhutani, R.D. (1981). Screening and diallel study for yield and quality characters in tomato (Lycopersicon esculentum Mill). Thesis Abst. Haryana Agric. Univ., 7(2): 170-171.

Bhutani, R. D. and Kalloo. (1991). Inheritance studies of locule number in tomato. Haryana J. Hort. Sci., 20(1-2): 119-124.

Bora, G. C., Hazarika, M.H. and Shadeque, A. (1993). Heterosis for yield and its components in tomato. Crop Improvement Society of India. pp. 10-11.

Borikar, S. T., Chopde, P.R. and Makne, V.G. (1982). Note on line x tester analysis in tomato. Indian J. Agric. Sci., 52(4): 246-247.

Brahma, R. C., Bhowmik, A.K. and Ali, M.S. (1991). Inheritance of four quantitative traits in tomato (Lycopersicon esculentum Mill.). Annals of Bangladesh Agric., 1(1): 41-43.

Celine, V. A. (1981). Genetic cataloguing of tomato germplasm towards isolation of line(s) resistant to bacterial wilt. Masters thesis submitted to Kerala Agricultural University. pp. 69.

Chandrasekhar, P. and Rao, M.R. (1989). Studies on combining ability of certain characters in tomato. South Indian Hort., 37(1): 10-12.

Chhabra, N. (1992). The tomato. Indian Hort., 37(2): 11-13.

Cinar, O. (1978). The susceptibility of various varieties of Lycopersicon esculentum Mill. to Pseudomonas tomato. Hort. Abst., 50(2): 1094.

*Conti, S. (1974). Research on the heterosis and components of phenotypic variance in long fruited tomato hybrids. Pl. Br. Abst., 45: 6863.

Choudhury, B., Pania, R.S. and Sangha, H.S. (1965). Manifestation of hybrid vigour in F_1 and its retention in F_2 generation of tomato (Lycopersicon esculentum Mill.). Indian. J. Hort., 22(1): 52-59.

Dabholkar, A. R. (1992). Elements of biometrical genetics. Concept publishing Co., New Delhi. pp. 431.

*Daskaloff, C., Ognyanova, A. and Konstantinova, M. (1975). Inheritance of growth habit components in selfpruning tomatoes. Pl. Br. Abst., 46: 1932.

Dhaliwal, M. S. and Nandpuri, K.S. (1988). Genetics of yield and its components in tomato. Ann. Bio., 4(1-2): 75-80.

Dhillon, G. S., Nandpuri, K.S. and Gupta, V.P. (1979). Combining ability in tomato. J. Res. Punjab Agric. Univ., 16(1): 34-40.

Dholaria, T. L. and Qadri, M.I. (1983). Combining ability analysis in tomato. South Indian Hort., 31(6): 274-279.

Dixit, J., Kalloo, Bhutani, R.D. and Sidhu, A.S. (1980). Line x tester analysis for the study of heterosis and combining ability in tomato. Haryana J. Hort. Sci., 9(1/2): 56-61.

Dod, V. N., Kale, P.B., Wankhade, R.V. and Jadhao, B.J. (1992). Heterosis in the intervarietal crosses of tomato. Crop Research, 5: 134-139.

Dudi, B. S., Kalloo, and Pandita, M.L. (1979). Line x tester analysis for the study of combining ability in tomato (Lycopersicon esculentum). Haryana J. Hort. Sci., 8(3/4): 117-123.

*Egiyan, M. E. and Luk'yanenko, A.N. (1979). Inheritance of earliness in first generation tomato hybrids. Pl. Br. Abst., 52: 8001.

Ferrer, Z. A. (1976). Resistance to Pseudomonas solanacearum in Lycopersicon esculentum. Dissertation Abst. International, B., 36(1): 517B-518B.

Ghosh, P. K. and Symal, M.M. (1994). Diallel analysis for combining ability in tomato. South Indian Hort., 42(3): 204-205.

Gibrel, G., Boe, A.A., Simpson, W.R. and Everson, D.O. (1982). Evaluation of F_1 hybrid tomato cultivars for earliness, fruit size and yield using diallel analysis. J. Am. Soc. Hort. Sci., 107(2): 243-247.

*Govindarasu, P., Muthukrishnan, C.R. and Irulappan, I. (1981). Combining ability for yield and its components in tomato. Sci. Hortic., 14(2): 125-130.

Govindarasu, P., Muthukrishnan, C.R. and Irulappan, I. (1982). Studies on heterosis in tomato (Lycopersicon esculentum Mill.). South Indian Hort., 30(1): 9-12.

Govindarasu, P., Muthukrishnan, C.R. and Irulappan, I. (1983). Heterosis and combining ability for yield and its components in tomato (Lycopersicon esculentum Mill.). In proceedings of national seminar on the production technology of tomato and chillies. TNAU: 15-17.

Graham, K. M. and Yap, T.C. (1976). Studies on bacterial wilt. I. Inheritance of resistance to Pseudomonas solanacearum in tomato. Malaysian Agric. Res., 5(1): 1-8.

Gurdalbir Singh, and Nandpuri, K.S. (1974). Combining ability studies in tomato (Lycopersicon esculentum Mill.). Cultivars with functional male-sterile lines. J. Res. Punjab Agric. Univ., 11(1): 26-29.

Hanna, H. Y. and Hernandez, T.P. (1979). Heterosis and inheritance of fruit shape in the tomato. Hort. Sci., 14(2): 120.

*Ho, B.L. (1988). Performance of local tomato varieties against bacterial wilt disease. Pl. Br. Abst., 60: 8170.

Jamwal, R. S., Rattan, R.S. and Saini, S.S. (1984). Hybrid vigour and combining ability in tomato. South Indian Hort., 32(2): 69-74.

*Kalf-Allah, A. M. and Kaseem, E. (1985). A diallel analysis of quantitative characters in tomato. Egyptian Journal of Genetics and Cytology, 14(2): 251-257.

Kanthaswamy, V. (1994). Studies on hybrid vigour in tomato (Lycopersicon esculentum Mill.). Madras Agric. J., 81(3): 145-146.

Kanthaswamy, V. and Balakrishnan, R. (1989). Studies on hybrid vigour in F_1 and its retention in F_2 generation of tomato (Lycopersicon esculentum Mill.). South Indian Hort., 37(2): 77-83.

Kapoor, A.S., Sugha, S.K. and Dhanbir Singh (1991). Varietal resistance to bacterial wilt in tomato. Indian Phytopathology, 44(2): 224-225.

KAU, (1993). Package of Practices Recommendation Crops '93. Kerala Agricultural University, Mannuthy. pp. 176-177.

Kempthorne, O. (1957). An Introduction to Genetic Statistics. John Wiley and Sons, Inc., London, Chapman and Hall Ltd., pp. 514.

*Khalil, R.M., El-gazar, T.M. and El-Sayed, M.M. (1983). Genetics and heritability of number of fruits per plant and fruit weight in tomato. Minufiya J. Agric. Res., 7: 301-317.

*Khatyleva, L. V. (1980). Study of the combining ability of tomato lines in top crosses using an intervarietal hybrid. Pl. Br. Abst., 51: 7702.

Konstantinova, M., Bak, D. and Molle, E. (1990). Effect of growing conditions on the genetics of the character "no. of leaves between inflorescences". In proceeding of XIth Eucarpia meeting on tomato genetics and breeding. pp. 205-210.

Kryuchkov, A. V. Monakhos, G.F. and Al-Fakhil, I.Yu. (1992). Genetic control of yield and combining ability in early tomato varieties. Pl. Br. Abst., 64: 5178.

Lobo, A. M. and Marin, V.O. (1975). Heterosis and combining ability in tomato (Lycopersicon esculentum Mill.). I. Heterosis. Tropical Agric. Abst., 3(1): 12503.

Lonkar, S. G. and Borikar, S.T. (1988). Combining ability studies with positional male sterile lines in tomato. J. Maharashtra Agric. Uni., 13(3): 261-262.

*Lopez-Rivares, P. and Cuartero, J. (1985). Genetics of the components of early yield in tomato. Genetica Iberica, 37(1/2): 25-38.

*Maggiore, T., Motto, M., Salamini, F. and Soressi, G.P. (1976). Combining ability for adaptability to indoor cultivation in tomato. Pl. Br. Abst., 47: 6864.

Mandal, A. R., Hazra, P. and Som, M.G. (1989). Studies on heterobeltiosis for fruit yield and quality in tomato. Haryana J. Hort. Sci., 18(3-4): 272-279.

*Milkova, L. (1975). General and specific combining ability for mean fruit weight in a tomato (Lycopersicon esculentum Mill.). diallel cross. Pl. Br. Abst., 46: 1921.

*Moya, C., Auchet Jenckens, F.A., Amores, H. and Lopez, T. (1986). Estimation of general and specific combining ability in nine tomato varieties. Pl. Br. Abst., 58: 4593.

Nandpuri, K. S., Kanwar, J.S. and Singh, S. (1975). General versus specific combining ability in a set of top crosses of male sterile lines x pollinators in tomato (Lycopersicon esculentum Mill.). J. Res. Punjab Agric. Univ. Ludhiana, 12(1): 34-39.

Nandpuri, K. S. and Tyagi, D.D. (1976). Inheritance of some characters in tomato. J. Res. Punjab Agric. Univ., 13(1): 80-84.

Narcisco, J.O. and Rosario, T.L. (1988). Bacterial wilt resistance and processing quality of tomato F_1 hybrids. Philippine Agriculturist. 71(4): 387-396.

Omara, M.K. Younis, S.E.A., Sherif, T.H.I. and Hussein, M. (1988). A genetic analysis of yield and yield components in the tomato. Assiut J. Agric. Sci., 19(1): 227-238.

Palaniappan, E., Muthukrishnan, C.R. and Irulappan, I. (1981). Growth analysis for biological yield, harvest index and fruit yield in tomato (Lycopersicon esculentum Mill.). Madras Agric. J., **68(9)**: 561-567.

Patil, A.A. and Bojappa, K.M. (1968). Combining ability for certain quality traits in tomato. Prog. Hortic., **18(1-2)**: 73-76.

Patil, A.A. and Patil, S.S. (1988). Preliminary studies on combiners and combinations for quality traits in tomato. Plant Foods for Human Nutrition, **38 (1)**: 43-49.

Patil, A.A. and Patil, S.S. (1988). Heterosis for certain quality attributes in tomato. J. Maharashtra Agric. Univ., 13 (2): 241.

Raijadhav, S.B. and Kale, P.N. (1985). Combining ability of tomato lines resistant to root-knot nematode. J. Maharashtra Agric. Univ., **10(2)**: 172-175.

Rajan, S. (1985). Selection efficiency and genetic and biochemical basis of resistance to bacterial wilt in tomato. Ph.D. Thesis. pp. 129.

Rema Bai, N. (1975). Studies on intervarietal hybrids of tomato. M.Sc. (Ag.) thesis. Fac. Agric., Kerala Agric. Univ., pp. 104.

Rema devi, L. (1978). Bacterial wilt of tomato in Kerala - host range and survival of the pathogen and control. Ph.D. Thesis. Kerala Agric. Univ. Vellanikkara. pp. 168.

Scossiroli, R.E., Silvetti, E. and Grillo, G. (1976). Diallel analysis of morphological and production traits in elongated and round types of Lycopersicon esculentum. Genetica Agraria, **30(3/4)**: 275-292.

Sidhu, A.S., Dixit, J., Kalloo, and Bhutani, R.D. (1981). Heterosis and combining ability in Pear shaped tomato (Lycopersicon esculentum Mill.). Haryana Agric. Univ. J. Res., 11(1): 1-7.

Sidhu, A.S. and Surjan Singh. (1993). Studies on heterosis and divergence in tomato. Crop Improvement Society of India, pp. 64-65.

Singh, H.N. and Mital, R.K. (1978). Combining ability in tomato. Indian J. Genet. Pl. Breed., 38(3): 348-354.

*Singh, K. (1961). Inheritance of North Carolina type of bacterial wilt resistance in tomato (Lycopersicon esculentum L.). M.Sc. thesis. University of Hawaii, Honolulu. pp. 91.

Singh, R.K. and Chaudhary, B.D. (1977). Biometrical Methods in Quantitative Genetic Analysis. Kalyani Publishers, New Delhi. pp. 39-79.

Singh, R.R. and Singh, H.N. (1980). Note on variance components in tomato. Indian J. Agric. Sci., 50(4): 361-363.

Singh, U.P., Tanki, I. and Singh, R.K. (1989). Triallel analysis for yield and total soluble solids in tomato. Haryana J. Hort. Sci., 18(3-4): 257-264.

*Sonoda, R.N., Augustine, J.J. and Volin, R.B. (1980). Bacterial wilt of tomato in Florida, history, status and sources of resistance. Flo. State Hort. Soc. Proc., 92: 100-102.

Sonone, H.N., Deore, B.D. and Patil, S.K. (1981). A preliminary estimation of hybrid vigour in tomato (Lycopersicon esculentum Mill.). J. Maharashtra Agric. Univ., 6(3): 250-252.

Sonone, A.H., Yadav, M.D. and Thombre, M.V. (1986). Combining ability for yield and its components in tomato. J.Maharashtra Agric. Univ., 11(3): 288-290.

Sprague, G.F. and Tatum, C.A. (1942). General Vs. Specific combining ability in single crosses of corn: J. Am. Soc. Agron., 34: 923-932.

*Sunarjono, H. (1980). Increasing tomato production disease resistant varieties show promise. Indonesian Agric. Res. Devepmt. J., 2: 5-7.

Svanosio, A. and Vandoni, G. (1974). Analysis of the combining ability of Lycopersicon esculentum crosses among new lines. Genet. agr., 28(3/4): 256-271.

Swamy, K.R.M. and Mathai, P.J. (1982). Note on combining ability in tomato. Indian J. Agric. Sci., 52(3): 193-196.

*Szwadiak, J. (1974). Some valuable characteristics of various F_1 tomato hybrids. Pl. Br. Abst., 46: 8496.

*Szwadiak, J. and Kordus, R. (1992). Diallel analysis of yield contributing traits in tomato (Lycopersicon esculentum Mill.). Polish. J. Theor. Appl. Genet., 33(3): 219-225.

Tarrega, J. and Nuez, F. (1983). Diallel cross analysis of tomato fruit characters. Genetica Agr., 37 (1/2): 43-51.

Trinklein, D.H. (1975). Estimates of combining ability and reciprocal effects for several tomato characters. Dissertation Abst. International B. 36(1): 1010B-1011B.

Trinklein, D.H. and Lambeth, V.N. (1975). Reciprocal cross differences and combining ability for six diverse tomato lines. J. Am. Soc. Hort. Sci., 100(6): 650-652.

Younis, S.E.A., Omara, M.K. and Hussein, M.Y. (1988). A genetic analysis of fruit characteristics and their interrelationships in the tomato. Assiut. J. Agric. Sci., 19(3): 312-324.

Younis, S.E.A., Omara, M.K., Sherif, T.H.I. and Elaref, H.M. (1987). A diallel analysis of earliness and some other vegetative characters in tomato. Assiut. J. Agric. Sci., 18(4): 279-290.

*Zubeldia, A. and Nuez, F. (1974). Earliness and yield in tomato hybrids and their parents. Pl. Br. Abst., 45: 3179.

DDDDDDDDDDDDDDDDDDD
* Original not seen

COMBINING ABILITY STUDIES IN TOMATO [Lycopersicon esculentum Mill.]

By

SEEJA G.

ABSTRACT OF A THESIS
Submitted in partial fulfilment of the requirement
for the degree of

MASTER OF SCIENCE IN AGRICULTURE
(PLANT BREEDING AND GENETICS)
FACULTY OF AGRICULTURE
Kerala Agricultural University

DEPARTMENT OF PLANT BREEDING AND GENETICS
COLLEGE OF AGRICULTURE
VELLAYANI
THIRUVANANTHAPURAM
1995

COMBINING ABILITY STUDIES IN TOMATO
[Lycopersicon esculentum Mill.]

By

SEEJA G.

ABSTRACT OF A THESIS
Submitted in partial fulfilment of the requirement
for the degree of

MASTER OF SCIENCE IN AGRICULTURE
(PLANT BREEDING AND GENETICS)
FACULTY OF AGRICULTURE
Kerala Agricultural University

DEPARTMENT OF PLANT BREEDING AND GENETICS
COLLEGE OF AGRICULTURE
VELLAYANI
THIRUVANANTHAPURAM
1996

ABSTRACT

An experiment in tomato (Lycopersicon esculentum Mill.) was carried out at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 1993-94, with the objective of estimating the combining ability of parents and gene action, involved in the inheritance of different yield attributes. The study was conducted in a line x tester model, using three bacterial wilt resistant varieties as lines and five popular varieties as testers.

The three bacterial wilt resistant varieties (lines) were Arka Abha, Arka Alok and Sakthi. The five popular varieties (testers) were LE 312, LE 370, LE 373, RFH-1 and PKM-1. These eight parental varieties and 15 hybrids were planted in the field in RBD, with three replications. Observations recorded were plant height, number of branches/plant, growth habit, spread of the plant, period of harvest, individual fruit weight, number of fruits/plant, fruit yield/plant, number of leaves/plant, pericarp thickness, locules/fruit, size of fruit and pest and disease incidence.

Analysis of variance revealed highly significant differences among the genotypes for all the characters. Gca alone was significant for number of branches/plant while sca alone was

significant for spread of the plant and pericarp thickness. Both gca and sca were significant for the remaining characters such as plant height, period of harvest, individual fruit weight, fruits/ plant, fruit yield/ plant, leaves/plant, locules/fruit and size of fruit. The additive to dominance variance ratio indicated a preponderance for non additive gene action in the above characters.

Combining ability analysis showed that all the three lines viz., Arka Abha, Arka Alok and Sakthi were good general combiners with respect to fruit yield and other yield attributes whereas the testers were good general combiners, for the different vegetative characters such as plant height, branches and leaves/ plant. Among the 15 hybrid combinations, significant sca and heterosis were observed in the hybrids such as Arka Abha x LE 370, Arka Alok x PKM-1, Arka Alok x LE 312, Arka Alok x RFH-1 and Sakthi x RHF-1. Among these hybrids, Arka Abha x LE 370 showed significance for fruit yield, individual fruit weight, size of fruit, plant height, leaves/plant, branches/plant and also showed resistance to mosaic, leaf curl and fruit borer. This hydrid exhibited indeterminate growth habit. The hybrid Arka Alok x PKM-1 showed significance for fruits/plant, fruit yield/plant, plant height and leaves/plant. The combinations Arka Alok x LE 312 and Arka Alok x RFH-1 showed high sca and heterosis for

individual fruit weight, fruit size and pericarp thickness, and also high heterosis for fruit yield/plant. Among these, Arka Aloka 312 showed indeterminated growth and Arka Alok x RFH-1 showed semi determinate growth habit. Sakthi x RFH-1 exhibited high sca for fruit yield/plant and heterosis for fruit number and individual fruit weight. This hybrid also showed resistance to leaf curl and mosaic. This hybrid showed determinate growth habit. Therefore these hybrids can be utilized for further crop improvement programme.