# Combining ability for shade tolerance and yield in greengram ( *Vigna radiata* (L.) Wilczek) grown under coconuts



By

**PREETA LIZ KORAH**

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

**2001**

# DECLARATION

I hereby declare that this thesis entitled **"Combining ability for shade tolerance and yield in greengram (*Vigna radiata* (L.) Wilczek) grown under coconuts"** is a *bonafide* record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Preeta Korah

PREETA LIZ KORAH

Vellayani,

20.10.01

# CERTIFICATE

Certified that this thesis entitled **"Combining ability for shade tolerance and yield in greengram (*Vigna radiata* (L.) Wilczek) grown under coconuts"** is a record of research work done independently by **Mrs. Preeta Liz Korah** 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.

Vellayani,
24-10-2001.

**Smt. N. KAMALAM**
(Chairman, Advisory Committee)
Associate Professor,
Department of Plant Breeding & Genetics,
College of Agriculture, Vellayani

## Approved by

*Chairman :*

**Smt. N. KAMALAM**
Associate Professor
Department of Plant Breeding & Genetics,
College of Agriculture, Vellayani.

*Members :*

1. **Dr. P. MANIKANTAN NAIR**
   Professor and Head,
   Department of Plant Breeding & Genetics,
   College of Agriculture, Vellayani.

2. **Dr. R. V. MANJU**
   Assistant Professor,
   Department of Plant Physiology,
   College of Agriculture, Vellayani

3. **Dr. P. SARASWATHI**
   Professor and Head,
   Department of Agricultural Statistics,
   College of Agriculture, Vellayani

*External Examiner :* Dr. JABARAJ
Professor
Centre for Plant Breeding & Genetics
TNAU. Coimbatore.

S. JEBARAJ
Professor (PB&G)

# ACKNOWLEDGEMENT

*I wish to place on record, my heartfelt gratitude and indebtedness to:*

*God Almighty, for His continuous showers of blessings upon me.*

*Smt. N. Kamalam, Associate Professor Department of Plant Breeding and Genetics and Chairperson of the Advisory Committee for her guidance in the planning and execution of this work and for her advices, sustained interest and constant encouragement throughout this investigation and preparation of the thesis.*

*Dr. P. Manikantan Nair, Professor and Head Department of Plant Breeding and Genetics and member of the Advisory Committee for his valuable suggestions, keen interest and constructive and helpful criticism at all stages of study.*

*Dr. R.V. Manju, Assistant Professor, Department of Plant Physiology and member of the Advisory Committee for her expert advice and timely suggestions and relevant criticism at all stages of study.*

*Dr. P. Saraswathi, Professor and Head, Department of Agricultural Statistics and member of the Advisory Committee for her valuable and scholastic guidance in planning, analysis and interpretation of this thesis work.*

*Dr. Gokulapalan, Associate Professor Department of plant Pathology and Mr. Manoj for the kindness shown in taking the relevant photographs.*

*All teaching and non-teaching staff, Department of Plant Breeding and Genetics for the keen interest evinced in this study.*

*My friends Radhika, Vidhya, Salu, Deepthy and Iswara Prasad for their unstinted and excellent cooperation.*

*Sri. Neshayan, with his coworkers and Smt. Ammini Amma for their assistance in promptly carrying out the field operations related to the experiment.*

*M/s. Athira Computers, Kesavadasapuram, Thiruvananthapuram for the efforts taken in printing the manuscript.*

*On a personal note, I wish to express my feelings of gratitude and indebtedness to Pappa, Mummy, Sony, Nehamol, Chachan and Ammachi for their sincere and constant encouragement in making this endeavour a success.*

PREETA LIZ KORAH

# CONTENTS

*Page No.*

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF PLATES

# INTRODUCTION

# 1. INTRODUCTION

Pulses form one of the main essential adjucts to a predominantly cereal-based diet as they contain about 22-28 per cent protein which is nearly three times more than that in cereals. At the present stage of our economic development, pulses hold the key to solve the protein deficiency in our diet. Production and consumption of more pulses is now widely recognised as the cheapest and most practical way of improving nutrition of the common man. Further, their unique ability to harness the inexhausitble stock of atmospheric nitrogen in symbiosis with bacteria helps in sustaining the fertility of our soils.

Greengram [*Vigna radiata* (L.) Wilczek] also called mungbean or goldengram belonging to the subfamily Papilionaceae is a highly prized pulse crop for its protein content (24%), high biological value and easy digestibility (Poehlman, 1991). India is the leading country in the production of greengram with around 55 per cent of the world hectarage and 45 per cent of the world production.

Greengram is one of the most improtant pulse crops of Kerala and cultivated as a pure crop during summer season. The recommended varieties now grown are suited only to summer rice fallows because they were developed outside Kerala. The. availability of open space in our state for extending the area under the crop is very limited. Therefore, the possibility of cultivating high yielding varieties in interspaces of coconut garden has to be explored. The non-availability of high yielding greengram varieties suited to partially shaded condition is a limitation for the popularisation of the crop.

Five greengram varieties were identified as shade tolerant from the genetic evaluation study done in the Department of Plant Breeding and Genetics. Based on this result the present study envisages a follow up work through a line x tester mating design with lines as shade tolerant and testers as high yielders. Combining ability analysis will be useful in selecting suitable hybrid combinations. The present investigation was undertaken in this context with the following objectives.

i) Estimation of general combining ability of parents.

ii) Estimation of specific combining ability of single crosses.

iii) Identification of gene action governing different characters in the crop.

iv) Estimation of relative heterosis and heterobeltiosis.

# REVIEW OF LITERATURE

# 2. REVIEW OF LITERATURE

Information on combining ability and gene action attributes in relation to shade tolerance is essential to chalk out different breeding programmes in greengram. Crop improvement works done in *Vigna radiata* are limited. The available literature relevant to the studies in greengram and other pulse crops grown in India are reviewed under the following headings.

2.1 Combining ability

2.2 Heterosis

## 2.1 Combining ability

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

### 2.1.1 Greengram

A ten parent half diallel cross was conducted by Candra and Nijhawan (1979) to estimate the combining ability for leaf area index and proposed the presence of non-additive gene effect.

Deshmukh and Manjare (1980) while estimating combining ability in a diallel cross observed the significance of GCA and SCA effects for pods per plant, number of seeds per pod and grain yield per plant. The variance due to SCA was reported to be comparatively much higher in magnitude suggesting non-additive gene action.

An analysis of diallel cross using five varieties of greengram by Wilson *et al.* (1985) indicated the existence of both additive and non-additive gene actions for days to 50 per cent flowering, number of pods per plant, number of seeds per pod and grain yield per plant.

In an eight parental half diallel cross Chowdhury (1986) reported significant GCA and SCA variances for number of pods per plant and grain yield per plant in mungbean.

Patel *et al.* (1988) studied the combining ability in a 7 x 7 diallel cross excluding reciprocals and reported that GCA and SCA variances were significant for yield per plant and harvest index, showing both additive and non-additive gene effects.

Saxena and Sharma (1989) estimated combining ability in 8 x 8 diallel cross and reported that both GCA and SCA variances were significant in $F_1$ and $F_2$ for number of seeds per pod and grain yield per plant. The GCA effect was higher than SCA effect indicating the predominance of additive gene action for these characters.

Information on combining ability is derived from data on ten yield components in seven cultivars and their hybrids from an incomplete diallel cross. The variety Varsha was the best combiner for plant height, early flowering, pod length and yield (Thimmappa *et al.*, 1989).

In a pot experiment conducted to identify mungbean varieties or lines tolerant to shade, Laosuwan *et al.* (1990) reported that seed yield per plant was not much affected by 90 per cent of normal light intensity. But seed yield, plant dry weight and leaf dry weight were decreased and flowering date was delayed at 50 per cent light intensity.

A 7 x 7 diallel cross by Natarajan *et al.* (1990) revealed the importance of both additive and non-additive gene action for number of pods per plant, seeds per pod and grain yield per plant and the predominance of additive gene action for grain yield per plant.

Dasgupta *et al.* (1992) conducted a study on combining ability in a 7 x 7 half-diallel cross and reported that both GCA and SCA effects were highly significant for harvest index. Three good general combiners and three cross combinations showing good SCA were identified.

The study of yield and yield related characters in eight mungbean genotypes and their 28 $F_1$s revealed the importance of additive as well as non-additive variances and predominance of additive variance for seeds per pod, pods per plant and yield per plant (Saxena and Sharma, 1992).

In a line x tester analysis involving four lines and five testers Naidu and Satyanarayana (1993) reported that non-additive gene action was mainly responsible for plant height, seeds per pod and seed yield per plant

In a line x tester analysis in greengram, Sreekumar (1993) reported the influence of both additive and non-additive gene actions for harvest index. Additive to dominance variance ratio was less than unity indicating predominance of non-additive gene action. Presence of non-additive gene action was evident for leaf area index.

Information on combining ability derived from data on seven characters in five genotypes and their ten $F_1$ hybrids revealed that the cross MTM 11/395 x EC213012 showed highly significant SCA for earliness, dwarfness, and seed yield per plant (Tiwari *et al.*, 1993).

Yadav *et al.* (1993) while analysing the combining ability in eight genotypes and their $F_1$ hybrids reported that ML62 was the best general combiner for grain yield.

Twenty hybrids from $F_1$ and $F_2$ of a 4 x 5 line x tester cross were evaluated by Rosaiah *et al.* (1994). Estimates of variance due to SCA were found to be higher than those due to GCA for seed yield in both $F_1$ and $F_2$ indicating non-additive gene action.

Combining ability analysis was undertaken in an 8 x 8 half diallel cross for seed yield and its component characters by Halkude *et al.* (1996). The parent Phule M2 was the best general combiner for seed yield and most of the characters. Phule M2 x Chahardi Local, a combination of the best and the poor general combiners respectively, proved to be the best specific combination for seed yield.

Bhadra (1998) evaluated heterosis and combining ability and reported that both GCA and SCA were significant for plant height, number of pods per plant, number of seeds per pod and grain yield per plant. The GCA effect was not significant for harvest index.

Combining ability analysis of a 6 x 6 half diallel in mungbean by Dasgupta *et al.* (1998) revealed that additive gene effects were predominant for seed yield per plant, number of pods per cluster and harvest index. $B_1$ and $B_{105}$ were good general combiners for seed yield per plant and some of the major yield components.

Aher *et al.* (1999) performed diallel analysis in greengram and observed significant GCA and SCA variances for the 13 traits studied, indicating the importance of both additive and non-additive gene effects. The crosses BM-4 x JLM-5 and Korpagaon x TARM-18 showed significant SCA effects for seed yield per plant and most of the yield attributing characters.

In a genetic study of yield and yield components in greengram under partially shaded coconut garden by Rajeswari and Kamalam (1999), number of pods per plant and pod length were found to be the prime characters for yield improvement.

**2.1.2 Bengalgram**

In a diallel analysis for yield and yield components, Pande *et al.* (1979) reported highly significant variances due to GCA and SCA for number of pods per plant, number of seeds per pod, grain yield per plant and harvest index. Predominance of non-additive gene action was evident for number of pods per plant, number of seeds per pod and grain yield per plant and additive gene action was predominant for harvest index.

Deshmukh and Bhapkar (1982) analysed a half diallel cross involving nine parents in chickpea and reported that leaf area index was predominantly governed by non-additive gene effect.

Salimath and Bahl (1985) reported the importance of GCA and SCA variances for days to flowering from a line x tester analysis. The variance due to GCA was higher than the variance due to SCA indicating the importance of additive gene action for the character.

In a line x tester analysis, Mandal and Bhal (1987) observed significant difference in days to flowering. The GCA effect was not significant for the trait indicating non-additive gene action.

The predominance of non-additive gene action was reported by Yadavendra and Sudhirkumar (1987) for number of pods per plant, number of seeds per pod and grain yield per plant in their studies with eight chickpea varieties and their hybrids.

Six chickpea genotypes and their $F_1$ hybrids were evaluated for their combining ability by Katiyar *et al.* (1988) and reported significant differences for GCA and SCA variances for days to flower, number of pods per plant, number of seeds per pod and grain yield per plant indicating additive as well as non-additive gene effects. Predominance of additive gene action was evident for days to flower, number of seeds per pod and yield per plant. In a line x tester analysis, Kumar and Bahl (1988) revealed that SCA variance estimates were higher than GCA for seed yield and pods per plant.

Bahl and Kumar (1989) in a line x tester analysis reported that SCA variance was much greater than GCA indicating the predominance of non-additive gene action for yield.

In a comparative analysis of combining ability in irradiated and non-irradiated diallel population, Singh and Paroda (1989) suggested that number of seeds per pod was governed mainly by additive genes and that both additive and non-additive genes were important for grain yield per plant.

Combining ability analysis in a cross involving five male and nine female tall and dwarf types by Salimath and Bahl (1989) revealed predominance of non-additive gene action for harvest index.

In a line x tester analysis, involving seven chickpea lines and eight testers and their 56 hybrids, Avrodhi was found to be the best parent for yield per plant while L-550 was the best general combiner for this character (Sandhu *et al.*, 1989).

Singh *et al.* (1992) estimated combining ability from diallel mating design and reported that days to flowering, plant height and seed size were found to be predominantly under additive inheritance and were highly predictable. Both additive and non-additive genetic components were important for seed yield, pods per plant and seeds per pod.

Six chickpea cultivars and their 15 $F_1$ hybrids were studied by Katiyar and Katiyar (1993). No direct association could be established between the GCA of the parents involved in the crosses and SCA and heterotic response. The best combinations for yield per plant generally involved average GCA x low GCA parent crosses, indicating epistatic type of gene action.

In a study of eight varieties of *Cicer arietinum* and their 28 $F_1$s it was revealed that both additive and non-additive gene effects were important for plant height and yield per plant and non-additive effects were predominant for days to 50 per cent flowering and duration upto maturity (Jahagirdhar *et al.*, 1994).

Combining ability was estimated in a cross of 5 line x 3 tester by Mishra and Yadav (1994). They reported the importance of SCA variance for number of pods per plant, earliness and yield per plant indicating the predominance of non-additive gene action. A seven parent diallel analysis excluding reciprocals revealed the predominance of additive variance for pods per plant and seeds per pod and both additive and non-additive variance for seed yield per plant (Annigeri *et al.*, 1996).

Combining ability analysis in chickpea by Kumar *et al.* (1999) indicated that additive and non-additive gene action were involved in the inheritance of days to first flower, days to first pod, days to maturity, total reproductive period, pod establishment period and pod filling period with additive gene effects being predominant in the expression of the first three components and non-additive gene effects for the remaining components of crop duration.

### 2.1.3 Blackgram

In a study of 6 x 6 diallel cross conducted by Sagar and Chandra (1977) it was revealed that the magnitude of SCA variance was very high suggesting the predominance of non-additive gene action for number of pods and that the variance due to GCA was much higher than SCA variance for plant height indicating the predominance of additive gene action.

Pillai (1980) in a combining ability analysis observed that the variance due to GCA was much higher than SCA variance indicating that plant height was governed by additive gene action.

Malhotra (1983) reported the predominance of additive gene effects for number of seeds per pod and grain yield per plant. Combining ability analysis of a diallel cross of ten blackgram lines for yield and its components by Singh *et al.* (1987) revealed greater estimate of SCA variance than GCA variance for yield per plant and harvest index indicating predominance of non-additive gene action.

Haque *et al.* (1988) in a line x tester analysis with six urdbean lines of diverse origin and four testers reported that higher SCA effect for yield was observed in the cross PLV 652 x T9 indicating non-additive gene action.

A line x tester analysis by Rajarathinam and Rathnaswamy (1990) revealed that the variance due to SCA was greater than GCA for plant height and number of pods per plant indicating the preponderance of non-additive gene action. Combining ability analysis for yield and its components over environments revealed significant mean sum of square due to SCA for number of pods per plant, number of seeds per pod and yield per plant (Kaliya *et al.*, 1991)

Sood and Garten (1991) while estimating the combining ability from nine diverse blackgram genotypes proposed the presence of additive gene effects for plant height and grain yield per plant.

Naidu and Satyanarayana (1993) in their combining ability studies of six genotypes reported the predominance of additive gene action for plant height.

In a diallel analysis for yield and yield components, Shanmugasundaram and Rangasamy (1994) reported highly significant differences in GCA and SCA for harvest index in both $F_1$ and $F_2$ generations.

In a field experiment to study response of blackgram to shade by Lakshmamma and Rao (1996) using 0, 33 or 66 per cent shade it was revealed that shading increased plant height and decreased seed yield.

In a line x tester analysis, Thomas (1996) reported that both additive and non-additive gene action were important for the expression of plant height, number of pods per plant, number of seeds per pod and grain yield per plant but non-additive gene action was predominant for all characters except plant height.

Varghese (1997) reported that for plant height, line x tester interaction was significant suggesting the importance of SCA effect for the trait. He observed significant GCA and SCA variances indicating the influence of both additive and non-additive gene action for number of pods per plant, number of seeds per pod and yield per plant. But non-additive gene action seemed to be predominant, since the ratio of additive to dominance variance was less than unity.

Santha and Veluswamy (1999) reported a preponderance of non-additive gene action for all the characters studied in a 10 line x 4 tester blackgram crosses. AB 2135 x Lam BG 20 and Vallanad local x Lam BG

20 showed high SCA effects for seed yield. Good cross combination involved at least one parent with high or moderate GCA effects.

### 2.1.4 Cowpea

A half diallel cross of eight cowpea varieties studied by Chauhan and Joshi (1981) revealed that both GCA and SCA variances were significant for number of pods per plant, number of seeds per pod and grain yield per plant. The variance due to GCA was reported to be higher than SCA indicating the predominance of additive gene action for number of seeds per pod and grain yield per plant.

Zaveri *et al.* (1983) evaluated six cowpea genotypes and their 15 crosses for yield and its components and reported that both GCA and SCA variances were significant with preponderance of non-additive gene action.

Combining ability analysis using parents and $F_1$ of half diallel cross indicated that days to flowering was governed by additive gene action alone. (Patil and Bhapkar, 1986).

A line x tester analysis involving ten lines and four testers indicated that both GCA and SCA were important for seed yield (Mishra *et al.*, 1987)

Thiyagarajan *et al.* (1990) estimated combining ability in a six parent diallel cross and found that both additive and non-additive gene effects were important for number of pods per plant. They also reported the preponderance of non-additive gene effects for the character.

Combining ability in six cultivars of cowpea indicated significant GCA and SCA variances and importance of additive gene action for number of seeds per pod (Rejatha, 1992)

Twelve hybrids from three male and four female parents were evaluated for combining ability in two seasons for yield and yield components by Thiyagarajan (1992) and reported preponderance of additive variance for pods per plant and seeds per pod.

In a line x tester analysis, Anilkumar (1993) revealed the presence of non-additive gene action for number of pods per plant and additive gene action for number of seeds per pod. He observed the presence of both additive and non-additive gene action for grain yield with a preponderance of non-additive gene action for this character.

Kumar (1993) in a combining ability analysis involving five lines and three testers reported the presence of additive gene action for leaf area index and the presence of both additive and non-additive gene action for grain yield. The mean square due to SCA was high indicating the preponderance of non-additive gene action for grain yield per plant.

In a combining ability analysis of a 4 line x 3 tester cross by Thiyagarajan *et al.* (1993), gene action was found to be predominantly non-additive for days to 50 per cent flowering and seed yield per plant.

Combining ability analysis of nine cowpea varieties and 36 $F_1$ hybrids by Patel *et al.* (1994) indicated higher magnitude of GCA variance compared to SCA variance signifying the predominant role of additive type of gene action in the expression of all the yield components.

Line x tester analysis involving nine lines and three testers indicated the importance of both additive and non-additive genetic variance in the inheritance of pod yield and seed yield per plant, with a preponderance of non-additive gene effects. (Madhusudan *et al.*, 1995).

Combining ability analysis of a 10 x 10 diallel cross by Sawant (1995) revealed that both GCA and SCA variances were highly significant and non-additive gene effects predominated for seed yield and yield related traits except for pod length and hundred seed weight.

Hazra *et al.* (1996) conducted diallel analysis with parental genotypes Birsa Sweta, Check Barbati (sub sp.sesquipedalis), Pusa Dofasli (subsp. unguiculata), Assam Local 1 and Dumca Local 1 (subsp. biflora) which revealed that the best general combiner was Birsa Sweta for pod yield.

Jayarani and Manju (1996) reported that plant height was governed by both additive and non-additive gene effects. In a line x tester analysis involving four lines and nine testers, the ratio of GCA to SCA revealed non-additive gene effects for number of pods per plant and seed yield per plant and additive gene action was predominant for days to 50 per cent flowering (Bhushana *et al.*, 1998)

### 2.1.5 Redgram

Combining ability analysis of ten diverse cultivars of pigeonpea indicated the predominance of additive gene action for days to first flowering as reported by Venketeswaralu and Singh (1981).

Combining ability analysis of ten cultivars by Venketeswaralu and Singh (1982) revealed the importance of both additive and non-additive gene effects for number of pods and grain yield per plant with predominance of additive gene effects for number of seeds per pod.

Estimation of combining ability in a 8 x 3, line x tester cross by Singh *et al.* (1983) revealed that both additive and non-additive components were important with the predominance of additive component for number of pods per plant and non-additive gene action for grain yield per plant.

Combining ability analysis of 39 hybrids between three lines and 13 testers revealed significant role of additive and non-additive gene action with predominance of additive gene action for number of pods per plant (Patel *et al.*, 1987).

Hazarika *et al.* (1988) estimated combining ability in a line x tester analysis and reported significance of both GCA and SCA variances for harvest index.

$F_1$ plants derived from diallel cross among five genotypes were grown along with their parents and evaluated for plant height, days to flowering, pods per plant and yield per plant. Each parent in the cross ICP8863 x LRG30 possessed high GCA for yield, along with positive GCA effects for plant height, pods per plant and days to flowering (Cheralu *et al.*, 1989).

A half diallel cross of seven short duration varieties evaluated in $F_1$ and $F_2$ generations indicated the predominance of GCA variance for seeds per pod and harvest index (Saxena *et al.*, 1989).

Estimation of combining ability and heterosis in a 20 line x 3 tester cross by (Sinha *et al.*, 1994) revealed that AS3 and Sel7 were the best general combiners for seed yield.

In a line x tester mating design, Manivel and Rangasamy (1998) observed that both additive and non-additive gene effects were important for all the traits. However, the role of additive gene effects was predominant for seed yield, plant height and pods per plant.

In a line x tester study by Pandey (1999), the total genetic variation was found to be due to over dominance and non-additive type of gene action for days to flowering, plant height, number of pods per plant, seed yield per plant and partial dominance of additive gene action for days to maturity. Most of the cross combinations exhibited high SCA effects for seed yield and yield attributing traits.

A study involving three genetic male sterile lines and eight testers indicated the predominant role of additive gene effects for seed yield per plant and almost all yield attributes except plant height (Khorgade *et al.*, 2000).

**2.1.6 Soybean**

Durong (1980) studied yield and related characters using a 8 x 8 diallel cross in soybean and reported the involvement of additive gene effects for days to 50 per cent flowering and the importance of both additive and non-additive gene action for grain yield per plant.

From a combining ability analysis involving ten soybean lines and their $F_1$ hybrids, Sharma and Nishisharma (1988) reported that both additive and non-additive genetic variances were important for number of pods per plant and that harvest index was controlled by additive gene action.

In soybean, Gadag *et al.* (1990) noticed significant variation among parents and crosses for harvest index and reported that both GCA and SCA variances were highly significant. They also indicated the predominance of non-additive gene action for harvest index.

Greater shoot height and lower leaf area index were the most significant growth changes noticed in the growth and development of seven soybean cultivars grown under shade in a coconut plantation (Babu and Nagarajan, 1993). They noticed that leaf net photosynthesis and seed yield were also reduced under shade.

Combining ability analysis was carried out for yield and yield related traits in a half diallel set involving seven parents by Gadag *et al.* (1999). The estimates of SCA variances were higher than GCA variances for grain yield and days to maturity indicating that non-additive gene effects were predominant.

In a diallel analysis in soybean by Cho Young Koo and Scott (2000), it was revealed that GCA effects for seed yield were significant and larger than SCA effects. Significant GCA and SCA effects were found for seed weight, indicating that both additive and non-additive genetic effects were involved in conditioning seed weight.

In a diallel cross involving nine parents with large, medium and small leaf area, most progenies from crosses among parents with different leaf areas had larger mean leaf area, longer flowering and late maturity than parents. The GCA and SCA for leaf area were significant. Ratio of GCA to SCA was less than unity (0.96) indicating that SCA effects were more important than GCA effects for leaf area. Soybean cultivars with smaller leaf area have shown better light distribution through their canopy and a higher photosynthetic rate than those with larger leaf area (Suh Sugkee *et al.*, 2000)

## 2.2 Heterosis

The term heterosis was coined by Shull (1914). It has been defined as the superiority of $F_1$ hybrid over the mean of the two parents. A review of literature on heterosis is presented below in a crop wise manner.

### 2.2.1 Greengram

Thimmappa (1987) while studying the inheritance of ten characters in an incomplete diallel cross among seven varieties of greengram observed heterosis over better parent for plant height, pods per plant, seeds per pod and seed yield.

Five genetic stocks, three commercial varieties and fifteen $F_1$ hybrids of *Vigna radiata* were evaluated for seed yield and harvest index. Lowest harvest index was recorded for tester CO.4 and the highest was noted for lines K851 and ML 65. Four hybrids, all with CO.4 as one parent were shown to have highly significant heterosis over better parent for grain yield and pod weight but negative heterosis for harvest index (Natarajan, 1989).

Patil *et al.* (1992) reported that the highest value of heterosis over better parent was shown by pods per plant followed by seed yield/ plant and pod weight/plant.

In a line x tester cross by Naidu and Satyanarayana (1993), twenty $F_1$s derived from four lines and five testers were grown under rice fallows.

Average heterosis over mid and better parents was positive for seed yield per plant, pods per plant and clusters per plant and negative for days to 50 per cent flowering and days to maturity.

Singh and Singh (1994) studied yield traits in greengram from a diallel crossing programme and reported that the highest heterosis over better parent and mid parent for seed yield per plant was seen in the cross T44 x Black Neelalu.

Analysis of a fifteen line x three tester cross by Vikas *et al.* (1998) revealed that in most cases, hybrids showing heterosis for seed yield per plant were also heterotic for number of seeds per pod and number of clusters per plant. EC 206976 x MUM2 and EC 206972 x ML 131 showed the greatest heterosis for seed yield per plant.

The study of heterosis in twenty one different hybrids of mungbean resulting from a 7 x 7 diallel excluding reciprocals indicated pronounced hybrid vigour for yield and most of the yield components. Heterosis to the extent of 63.45 per cent and 61.69 per cent over the mid parent and better parent respectively was recorded for grain yield. Heterosis for yield was generally accompanied by heterosis for yield components (Aher *et al.*, 2000). Joseph and Santhoshkumar (2000) studied five hybrids in $F_1$ and $F_2$ generations for heterosis and inbreeding depression for plant height, number of branches, number of pods, seeds per pod, test weight and seed yield. All the hybrids exhibited significant relative heterosis for seeds per pod. All five hybrids analysed were superior to mid parent, better parent and standard variety.

### 2.2.2 Bengal gram

Twenty five *Cicer arietinum* hybrids derived from a five line x five tester cross showed heterosis for seed yield. Heterosis for seed yield was largely dependent on heterosis for pods per plant for three of the five highest yielding hybrids. Heterosis over better parent was also observed simultaneously for the above two characters. Most of the heterotic hybrids were obtained from combinations of parents with low GCA effects (Kumar and Bahl, 1988).

A five line x five tester analysis by Bahl and Kumar (1989) revealed that two of the five best yielding hybrids showed positive and significant heterosis over the mid parental value for yield and also performed significantly better than their better parent.

Estimation of heterosis in diverse crosses by Rao and Chopra (1989) revealed that the cross BG 256 x ICC 32 gave good yield and had high heterosis and heterobeltiosis for yield per plant, plant height and number of pods per plant. The cross BG 256 x K4 was better for harvest index and number of seeds per pod.

A set of half diallel crosses evaluated in $F_1$ and $F_2$ generations revealed that greater heterosis over the better parent was generally associated with greater inbreeding depression from the $F_1$ to $F_2$, suggesting the importance of non-additive gene actions with over dominance for most yield related traits (Shinde and Deshmukh, 1990).

In a study of 53 $F_1$s and 47 parents, significant heterosis for seed yield over the better parent was given by six crosses. Crosses between parents of genetically divergent origin produced greater hybrid vigour than those between parents of similar origin (Bejiga and Singh, 1991).

Six *Cicer arietinum* cultivars and their 15 $F_1$ hybrids were studied by Katiyar and Katiyar (1993) and it was seen that heterosis was significant in eleven crosses for seed yield. The best combinations for yield per plant generally involved average GCA x low GCA parent crosses. W54-75 x T3 and Radhey x P848 were the best hybrids for yield and these crosses were of the high GCA x low GCA type.

Heterosis over the better parent was determined for six yield characters in 15 hybrids from a half-diallel set of crosses involving six varieties. In general, superior parents tend to produce superior hybrids, but this was not true for all crosses. JG 315 x Selection 436 showed the most marked heterosis for yield/plant (Shinde and Deshmukh, 1993).

Information on heterosis derived from data on seed yield and eight related traits in 66 hybrids and their 17 diverse parents, by Kamatar *et al.* (1996) revealed that maximum positive heterosis was observed for pod number (144.3 %) followed by seed yield per plant (130.5 %).

Patil *et al.* (1998) observed in a study involving crosses among three desi and two kabuli cultivars (desi x desi, desi x kabuli and kabuli x kabuli) that desi x kabuli crosses showed high mid-parent heterosis for seed yield and plant height whereas desi x desi cross exhibited higher better parent heterosis in desirable direction for morphological traits and seed yield.

**2.2.3 Blackgram**

Estimation of heterosis for yield and its components by Pillai (1980) revealed heterosis for pod number and plant height over mid parent and better parent.

Haque *et al.* (1988) noticed maximum heterosis for yield in the cross between the varieties PLU 200B and T9. Heterosis for seed yield was studied by Kalia *et al.* (1988) and they observed significant heterosis for seed yield over the mid parental value in a few crosses, viz., CO.4 x UG170, CO.4 x HPU433 and HPU433 x HPU617.

Information on heterosis derived from data on 11 yield related characters by Shinde and Deshmukh (1989) revealed that the cross between the parental varieties Sindkheda 1-1 and T9 recorded the maximum heterosis for yield.

Sood and Garten (1991) observed heterosis for number of pods per plant and seed yield in a 9 x 9 diallel cross.

Information on heterosis and inbreeding depression derived from data on 5 yield-related traits in the parents, $F_1$s and $F_2$s from 11 crosses of eight blackgram lines by Verma *et al.* (1991) revealed that the highest yielding hybrid (PS1 x RU4) surpassed its better parent by 31 per cent. Crosses showing high hybrid vigour also generally showed high inbreeding depression.

Evaluation of eight varieties and their 10 $F_1$ and 10 $F_2$ progenies revealed high heterosis for seed yield per plant coupled with high heterosis for pods per plant and seeds per pod (Andhale *et al.*, 1996).

Five genotypes and their crosses were studied for heterosis by Neog and Talukdar (1999). The crosses Pant U19 x KU92-1 and KU91 x Pant U30 exhibited high positive heterosis over the better parent for yield per plant. Two crosses KU91 x Pant U30 and KU92-1 x KU-91 exhibited high heterosis for reduced plant height.

According to Santha and Veluswamy (1999), evaluation of 40 hybrids generated by crossing ten lines with four testers along with the parents, revealed that the highest estimates of heterosis were observed for pod number and seed yield. The cross Co.5 x T9 had the highest standard heterosis for seed yield (82.8 %), pod number (53 %) and plant height (32.4 %).

In a six parent diallel analysis, it was observed that the highest average heterosis for seed yield and its components was observed for the hybrid 9025/9020 followed by the hybrid 9012/Mash 3. Parents with high general combining ability and good average performance gave high heterotic effects (Ghafoor *et al.*, 2000).

### 2.2.4 Cowpea

Estimation of heterosis for yield and its components by Hazra *et al.* (1993) revealed that the frequency of level of heterosis was related more to SCA than to genetic divergence of parents.

In a half diallel analysis, heterosis for four characters was evaluated in 15 cowpea genotypes (five parents and their ten $F_1$s) grown under eight different environmental conditions. It was observed that weight of dry pods per plant had high heterosis in the $F_1$, plant height had high to medium heterosis in $F_1$ while pod length, number of dry seeds per pod and early flowering had low heterosis in the $F_1$ (Damarany, 1994).

Sawant *et al.* (1994) observed that the highest positive heterosis over mid parent was for seed yield per plant followed by pods per plant and plant height. A similar trend over better parent was observed except for plant height.

Twenty five crosses among 11 genotypes were evaluated to study heterosis. Nineteen hybrids showed positive heterosis for seed yield over better parent. Heterosis over better parent was observed for number of pods per plant, pod length, seeds per pod and seed weight (Sangwan and Lodhi, 1995).

Significant and positive relative heterosis and heterobeltiosis was observed for seed yield (Sreekumar, 1995).

Evaluation of parents, $F_1$ and $F_2$ plants of 14 crosses by Bhor *et al.* (1997) revealed that heterosis over better parent ranged from 4.33 per cent for plant height to 91.52 per cent for days to maturity. Maximum heterobeltiosis (63.83 %) for seed yield was observed in V240 x VCM8.

Heterosis and inbreeding depression were studied for yield and yield component characters in three intervarietal crosses. Significant heterosis over mid parent and better parent was observed for most characters studied (Viswanatha *et al.*, 1998).

Savithramma and Latha (1999) observed heterosis for number of pods per plant, number of seeds per pod and seed yield.

Heterosis was estimated in 36 hybrids produced through a line x tester mating design. Significant positive heterosis was observed for number of pods per plant, seed yield per plant and pod length. Significant negative heterosis was observed for days to 50 per cent flowering. The lowest positive heterosis over both mid parental and better parental values was recorded for pod length (Bhushana *et al.*, 2000).

### 2.2.5 Redgram

Evaluation of eleven parents and 24 hybrids from a 3 line x 8 tester cross, revealed that crosses involving MSHy9 as the female parent showed marked heterobeltiosis for pods per plant and grain yield per plant (Narladkar and Khapre, 1996).

Heterosis was studied for yield and yield components in four *Cajanus cajan* cultivars and their $F_1$ hybrids. The cross UPAS120 x ICPL84023 gave the maximum heterosis for yield (54.6 %) followed by UPAS120 x Pant A3 (44.2 %) (Verulkar and Singh, 1997).

In a line x tester analysis involving 13 parents, two hybrid combinations, MS Co5 x ICPL 87 and MS Co5 x ICPL 89020 were identified as superior based on three criteria : Significant *per se* performance, standard heterosis and significant SCA effects (Chandirakala and Raveendran, 1998).

Heterosis and combining ability for six traits were studied in 40 heterotic hybrids by Manivel and Rangasamy (1998). Significant heterosis over better parent was observed for seed yield, plant height and pods per plant.

In a study of heterosis in varietal and interspecific crosses by Verulkar and Singh (1998), it was revealed that the varietal cross exhibited a relative heterosis of 32.6 per cent for yield per plant and 17.7 per cent for pods per plant, whereas the interspecific cross showed very high heterosis (99.6 %) for yield per plant.

Hooda *et al.* (1999) estimated heterosis in a 4 line x 11 tester cross. For seed yield a good magnitude of heterosis ranging from 21.1 per cent to 28.9 per cent was observed.

In a line x tester mating design it was observed that the crosses MST 21 x Pant A2 for days to 50 per cent flowering and MS Prabhat NDT x UPAS 120 for good seed yield recorded highest heterobeltiosis. The utilisation of the female parent MS Prabhat NDT for the production of early maturing and high yielding hybrid was suggested (Manivel *et al.*, 1999).

In a line x tester study by Pandey (1999), it was revealed that among the lines, the genotype Bahar was the best general combiner for pods per plant and seed yield per plant. Most of the cross combinations exhibited high SCA effects for seed yield and yield attributing traits. The crosses exhibiting high SCA effects involved one good and other medium and negative combiners.

Heterosis was studied in sixteen interspecific hybrids involving four lines and four testers. Beneficial heterotic response over mid parent was obtained for pods per primary branch (45.53 %) and pods per plant (25.54 %). For pod length, seeds per pod and seed yield per plant, the heterotic response over the mid parental value was in an undesirable direction in almost all the crosses. For almost all the attributes, none of the hybrids exhibited significant heterosis over the better parent in the desirable direction, except for pods per plant (Singh *et al.*, 1999).

### 2.2.6 Soybean

Twenty one hybrids derived from a seven parent half-diallel set along with their parents were evaluated to estimate heterosis. Heterosis was significant and positive in 16 hybrids over the mid parental value and in nine hybrids over better parent. Heterosis for yield was generally accompanied by heterosis for yield components (Gadag and Upadhyaya, 1995).

In a 10 line x 2 tester analysis by Sood *et al.* (1996) it was revealed that the lines Himso 473, Himso 330, Himso 558A and JS 78-53 were good general combiners for yield. On the basis of heterosis and SCA effects, crosses Cocker Stuart x Punjab-1 and Hardee x Lee were good for leaf area and Himso-473 x Punjab-1 was good for seed yield.

In a study of heterosis by Bastawisy (1997) it was observed that highly significant positive heterotic effects and highly significant values of inbreeding depression were found for pods per plant, seeds per plant and seed weight per plant. Heterobeltiosis was detected for pods per plant, seeds per plant and seed weight per plant.

Information on heterosis derived from data on seed yield and its components in six soybean parents and their 15 $F_1$ hybrids revealed that the highest magnitude of heterosis was observed for seed yield per plant (108.2 %) followed by pods per plant (91.3 %). A high degree of heterosis was found between diverse parents. There was close agreement between percentage performance of parents and GCA effects for all characters (Ponnusamy and Harer, 1998).

Estimation of heterosis derived from data on yield and yield components in 13 genotypes and their 22 $F_1$ hybrids revealed significant heterosis for seed yield and all yield related characters (Maheshwari *et al.*, 1999).

# MATERIALS AND METHODS

# 3. MATERIALS AND METHODS

The present study was undertaken at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani, Thiruvananthapuram during 1998-2000 with the objective of estimating combining ability with respect to shade tolerance and yield and the magnitude of heterosis with respect to yield and yield components for further selection.

## 3.1 Materials

The experimental materials consisted of eight greengram varieties as parents and their fifteen hybrids. The parents consisted of five lines which were identified as shade tolerant in a PG project in the Department of Plant Breeding, College of Agriculture, Vellayani by Rajeswari (1998) and three testers which are the recommended high yielding varieties. The lines, testers and their hybrids are presented in Table 1.

## 3.2 Methods

### 3.2.1 Collection of seed materials

Selfed seeds were collected from the selected varieties by covering the mature flower buds with butter paper cover on the previous day of its anthesis. The cover was removed only after the fruit set and

Table 1. Details of parents and hybrids

| Sl. No. | Treatments | Parents/Hybrids | Attribute |
|---|---|---|---|
| I. | Lines : 5 | | Shade tolerant |
| | $L_1$ | IIPRM.3 | |
| | $L_2$ | Ganga 4 | |
| | $L_3$ | MGG.314 | |
| | $L_4$ | RMG.353 | |
| | $L_5$ | LGG.460 | |
| II. | Testers : 3 | | High yielding |
| | $T_1$ | Phillippines | |
| | $T_2$ | *Pusa baisakhi* | |
| | $T_3$ | CO.2 | |
| III. | Hybrids : 15 | | |
| | $L_1T_1$ | IIPRM.3 x Phillippines | |
| | $L_1T_2$ | IIPRM.3 x *Pusa baisakhi* | |
| | $L_1T_3$ | IIPRM.3 x CO.2 | |
| | $L_2T_1$ | Ganga 4 x Phillippines | |
| | $L_2T_2$ | Ganga 4 x *Pusa baisakhi* | |
| | $L_2T_3$ | Ganga 4 x CO.2 | |
| | $L_3T_1$ | MGG.314 x Phillippines | |
| | $L_3T_2$ | MGG.314 x *Pusa baisakhi* | |
| | $L_3T_3$ | MGG.314 x CO.2 | |
| | $L_4T_1$ | RMG.353 x Phillippines | |
| | $L_4T_2$ | RMG.353 x *Pusa baisakhi* | |
| | $L_4T_3$ | RMG.353 x CO.2 | |
| | $L_5T_1$ | LGG.460 x Phillippines | |
| | $L_5T_2$ | LGG.460 x *Pusa baisakhi* | |
| | $L_5T_3$ | LGG.460 x CO.2 | |

the selfed pods were labelled. The pods were harvested, dried, seeds extracted and stored in separate packets.

### 3.2.2 Production of $F_1$ seeds

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

Eight parents (Plates 1 and 2) were crossed in a L x T mating fashion to get hybrid seeds. The technique of hybridisation in greengram outlined by Boiling *et al.* (1961) was followed for the production of hybrid seeds. Yellowish green buds likely to open the next morning were selected in the female lines and emasculated in the evening hours between 4 and 6 p.m. (Plate 3). The emasculated flower buds were covered with butter paper cover. On the following day, hand pollination was done between 6 and 8 a.m. with the pollen from the protected flowers of the male parent and the pollinated flowers were kept covered and labelled (Plate 4). Parents were allowed for self pollination along with production of hybrid seeds. The seeds from each cross were collected separately and this was used as the source material for experiment 1.

### 3.2.3 Experiment 1 : Evaluation of $F_1$ hybrids

Fifteen $F_1$ hybrids obtained by crossing eight parents in a L x T mating fashion along with eight parents were evaluated for estimating combining ability and heterosis.

### 3.2.4 Design and layout

The experiment was laid out in a randomised block design (RBD) with 23 treatments [15 hybrids and 8 parents (5 lines and 3 testers)] in three replications (Plate 5). Seeds were sown at a spacing of 25 x 15 cm in 3 x 2.1 $m^2$ plots.

### 3.2.5 Cultural practices

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

### 3.2.6 Biometric observations

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

#### 3.2.6.1 Number of days to 50 per cent flowering

The number of days from sowing to 50 per cent flowering in the observational plants was observed and mean was recorded.

#### 3.2.6.2 Number of days to final harvest

The average number of days from sowing to final harvest in the observational plants was recorded.

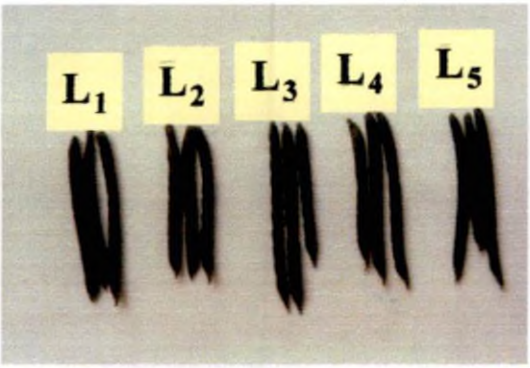


Plate 1. Five lines used as parents in hybrid seed production

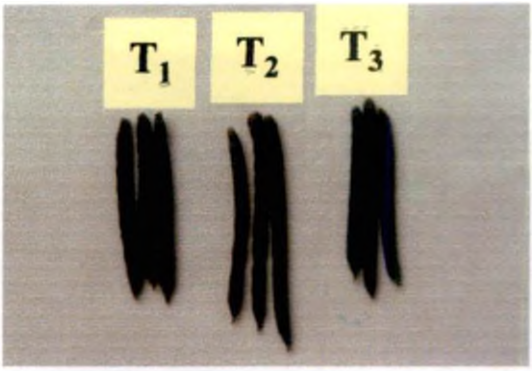


Plate 2. Three testers used as parents in hybrid seed production

Plate 3. Emasculation of selected flower buds

Plate 4. Covering pollinated flowers in crossing

Plate 5. A view of the experimental field

#### 3.2.6.3 Height of plants

Height of the observational plants from ground to the tip of the main stem was measured at maturity and the mean height was recorded in centimeters.

#### 3.2.6.4 Number of pods per plant

Total number of pods from the observational plants were counted and mean was recorded.

#### 3.2.6.5 Length of pod

The length of five pods selected at random from each observational plant was measured, mean worked out and expressed in centimeters.

#### 3.2.6.6 Number of grains per pod

The number of grains per pod from the observational plants in each plot was counted and the mean worked out.

#### 3.2.6.7 Grain yield per plant

The total grain yield from the observational plants was recorded, mean worked out and expressed in grams.

#### 3.2.6.8 Leaf Area Index (LAI)

The leaf area index was calculated at pod formation, using the following formula suggested by William (1946).

$$\text{LAI} = \frac{\text{Total leaf area of the plant}}{\text{Ground area occupied (spacing)}}$$

The total leaf area of the plant was calculated using the leaf area meter.

### 3.2.6.9 Shade intensity

The Photosynthetically Active Radiation (PAR) in each plot was measured at 11.00 a.m., 1.30 p.m. and 4.00 p.m. during flowering and pod formation stages using integrating quantum / radiometer / photometer. The shade intensity was calculated using the formula

$$\frac{L_1 - L_2}{L_1} \times 100$$

where,

$L_1$ = PAR in the open condition

$L_2$ = PAR in the shaded condition

The observations were taken during flowering and pod formation stages.

### 3.2.6.10 Photosynthetic efficiency

Leaf Area Ratio (LAR) was taken as a measure of photosynthetic efficiency.

The LAR is the extent of the proportion of the plant that is engaged in photosynthetic process. The lower the LAR, the higher will be the photosynthetic efficiency.

Five plants selected at random from each plot at pod initiation stage were pulled out without causing any damage to the roots. The total leaf area of each plant was determined using leaf area meter. These plants were kept in hot air oven in labelled paper covers and dried at a temperature of 60°C for 72 hours, weighed to constant weight and expressed in grams per plant.

The instantaneous LAR at pod initiation stage was calculated for all the five plants using the formula

$$\text{LAR} = \frac{\text{Leaf area}}{\text{Total dry weight}}$$

and the average value was recorded in terms of $cm^2\ g^{-1}$.

### 3.2.6.11 Harvest Index

The total grain yield from each observational plant was recorded as economic yield and the total dry weight of all the other plant parts viz., stem, leaves, roots, husk of the pods together with the grain yield was considered as biological yield. Harvest index was calculated as follows

$$\text{Harvest Index} = \frac{\text{Total economic yield}}{\text{Total biological yield}}$$

### 3.2.6.12 Incidence of pests and diseases

Damage caused by pod bug was noticed on the pods at harvest stage. The attacked seeds shrink and shrivel up within the pods and such pods present a rugged appearance. The number of pods attacked by pod bug was counted and expressed as percentage of the total number of pods in each plant. Average for each plot was worked out. No other incidence of pests and diseases was noticed.

## 3.3 Statistical analysis

The data collected were subjected to statistical analysis.

### 3.3.1 Analysis of variance for each character

Analysis of variance (ANOVA) was done for all the characters and significance of differences among the types including parents and crosses was tested (Singh and Chaudhary, 1979). Wherever the genotypic differences were found to be significant for each character, combining ability analysis was performed.

### 3.3.2 Combining ability analysis

Combining ability analysis of the line x tester was done through ANOVA technique outlined by Dabholkar (1992) and presented in Table 2.

### 3.3.3 Estimation of genetic components of variance

The additive and dominance components of genotypic variance ($\sigma^2 a$ and $\sigma^2 d$) are estimated as follows

$$\hat{\sigma}^2 gca\ (lines) = \frac{MSL-MSLT}{rt} = CoV.\ (H.S.)\ (lines)$$

$$\hat{\sigma}^2 gca\ (testers) = \frac{MST-MSLT}{rl} = CoV.\ (H.S.)\ (testers)$$

$$\hat{\sigma}^2 sca\ (crosses) = \frac{MSLT-MSE}{r}$$

$\sigma^2 gca$ - ¼ $\sigma^2 a$ if inbreeding co-efficient is zero

$\sigma^2 sca$ = ¼ $\sigma^2 d$ and hence

$\hat{\sigma}^2 a = 4\ \hat{\sigma}^2 gca$

$\hat{\sigma}^2 d = 4\ \hat{\sigma}^2 sca$

Significant values of 'F' for lines and testers indicate significant genetic difference among plants chosen as parents and the inconsistent behaviour of the female over male parent or vice versa is understood

Table 2. Analysis of variance for combining ability

| Source | df | SS | MS | Expected Mean square | F |
|---|---|---|---|---|---|
| Replication | r-1 | | | | |
| Treatments | n-1 | | | | |
| I. Parents | l+t-1 | | | | |
| II. Parents vs. Crosses | 1 | | | | |
| III. Crosses | lt-1 | SSC | | | |
| a) Lines | l-1 | SSL | MSL | $\sigma^2e + r\sigma^2sca + rt\sigma^2gca$ (l) | MSL/MSLT |
| b) Testers | t-1 | SST | MST | $\sigma^2e + r\sigma^2sca + rl\sigma^2gca$ (t) | MST/MSLT |
| c) Lines x Testers | (l-1) (t-1) | SSLT | MSLT | $\sigma^2e + r\sigma^2sca$ | MSLT/MSE |
| Error | (n-1) (r-1) | | MSE | $\sigma^2e$ | |
| Total | nr-1 | | | | |

where

n = number of treatments (l+t+lt)

r = number of replications

l = number of lines

t = number of testers

Testers : $SE(g_j) = (MSE/rl)^{1/2}$

Crosses : $SE(s_{ij}) = (MSE/r)^{1/2}$

The significance of $g_i$ and $s_{ij}$ values were tested using 't' test. For making pairwise comparisons, critical difference were worked out.

$$CD = t_\alpha \times SE_d$$

where, $t_\alpha$ = 't' w.r.t for error degrees of freedom. Significant gca implied that additive genotypic variance was operating while significant sca effect revealed the importance of non-additive variance for the inheritance of the character.

Proportional contributions of lines, testers and line x tester to total variance are given as

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

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

$$\text{contribution of line x tester} = \frac{SSLT}{SSC} \times 100$$

where, SSL = sum of squares due to lines

SST = sum of squares due to testers

SSLT = sum of squares due to line x tester

SSC = sum of squares due to crosses

### 3.3.5 Heterosis

Heterosis was estimated as the percentage deviation of the mean performance of $F_1$'s from its mid parent (MP) and better parent (BP) for each cross combination

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

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

where $\overline{F_1}$, $\overline{MP}$ and $\overline{BP}$ are respectively the means of $F_1$ hybrids, mid parents and better parents.

The significance of performance of the $F_1$ hybrid with mid parent and better parent was tested by t-test (Singh and Narayanan, 1993) and the critical difference for the comparison of $F_1$ means with mid parental and better parental means are given respectively as

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

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

# RESULTS

# 4. RESULTS

Observations on 11 biometrical characters were subjected to statistical analysis. The results obtained are presented under the following heads:

A - Performance of genotypes

B - Combining ability analysis

C - Heterosis

## 4.1 Performance of genotypes

The average performance of each of the 23 genotypes for the eleven characters subjected to statistical analysis, is furnished in Table 2. Analysis of variance of 11 characters clearly showed significant differences among genotypes for nine attributes viz., days to 50% flowering, number of days to final harvest, number of pods per plant, length of pod, number of grains per pod, grain yield per plant, leaf area index, photosynthetic efficiency (in terms of leaf area ratio) and harvest index. Non significant differences were exhibited by two attributes, viz., height of plants and shade intensity (Table 1). Since incidence of pests and diseases was negligible this character was not subjected to statistical analysis.

Table 1. Anova of different characters

| Source | df | Mean squares | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Days to 50 % flowering | Days to final harvest | Height of plants (cm) | Pods/ plant | Length of pod (cm) | Grains/ pod | Grain yield/ plant (g) | LAI | Shade Intensity (%) | | LAR ($cm^2$ $g^{-1}$) | Harvest index |
| | | | | | | | | | | Flowering | Pod formation | | |
| Replication | 2 | 0.172 | 3.656 | 909.164 | 8.979 | 9.912 | 1.348** | 1.903 | 0.137 | 1.523 | 21.070 | 48.625 | 4.233 |
| Treatment | 22 | 21.689** | 15.906** | 109.512 | 50.084** | 1.587** | 1.419** | 35.357** | 1.230** | 2.214 | 1.906 | 193.386** | 3.391** |
| Parents | 7 | 17.851** | 15.518* | 158.825 | 24.010** | 0.345** | 0.470 | 3.656** | 1.592** | 1.734 | 0.885 | 69.094** | 1.922** |
| Crosses | 14 | 12.756** | 16.882** | 68.823 | 49.651** | 1.247** | 0.594** | 31.454** | 0.952** | 2.593 | 2.221 | 253.143** | 2.385** |
| Parents Vs Crosses | 1 | 173.621** | 4.969 | 333.977 | 238.654** | 15.047** | 19.615** | 311.925** | 2.595** | 0.266 | 4.648 | 226.844** | 0.277** |
| Error | 44 | 1.189 | 5.743 | 88.62 | 4.750 | 3.382 | 0.211 | 1.088 | 0.071 | 4.757 | 8.556 | 20.963 | 0.003 |

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

Table 2. Mean performance of parents and hybrids

| Source | Days to 50 % flowering | Days to final harvest | Height of plants (cm) | Pods/ plant | Length of pod (cm) | Grains/ pod | Grain yield/ plant (g) | LAI | Shade Intensity (%) | | LAR ($cm^2$ $g^{-1}$) | Harvest Index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Flowering | Pod formation | | |
| $L_1$ | 50.33 | 101.33 | 47.27 | 11.85 | 6.48 | 11.33 | 4.43 | 2.51 | 52.51 | 51.92 | 116.82 | 0.42 |
| $L_2$ | 47.33 | 96.67 | 52.63 | 12.95 | 6.29 | 10.67 | 4.32 | 1.17 | 53.33 | 51.30 | 107.29 | 0.49 |
| $L_3$ | 49.33 | 98.33 | 57.17 | 16.88 | 7.21 | 11.00 | 6.35 | 2.30 | 53.33 | 51.72 | 103.62 | 0.39 |
| $L_4$ | 42.67 | 95.00 | 50.13 | 11.97 | 6.37 | 10.00 | 4.07 | 0.94 | 53.21 | 50.51 | 104.18 | 0.52 |
| $L_5$ | 48.00 | 96.67 | 55.33 | 17.57 | 7.03 | 10.67 | 6.32 | 1.17 | 51.80 | 50.45 | 111.90 | 0.62 |
| $T_1$ | 48.00 | 95.00 | 62.27 | 14.86 | 6.46 | 11.00 | 4.85 | 2.27 | 53.95 | 51.29 | 113.88 | 0.43 |
| $T_2$ | 48.33 | 96.67 | 65.80 | 17.22 | 6.47 | 10.67 | 5.54 | 1.96 | 53.00 | 51.31 | 107.39 | 0.45 |
| $T_3$ | 50.33 | 100.00 | 67.10 | 19.29 | 6.38 | 11.00 | 7.00 | 2.93 | 54.20 | 51.71 | 112.80 | 0.58 |
| $L_1 \times T_1$ | 49.00 | 96.67 | 56.17 | 18.54 | 7.33 | 12.00 | 8.22 | 0.86 | 52.09 | 51.10 | 105.83 | 0.61 |
| $L_1 \times T_2$ | 43.33 | 95.00 | 59.20 | 17.93 | 7.47 | 12.00 | 9.39 | 1.43 | 52.30 | 50.47 | 95.47 | 0.62 |
| $L_1 \times T_3$ | 42.67 | 96.33 | 57.40 | 28.29 | 7.07 | 11.00 | 16.32 | 1.23 | 54.05 | 51.61 | 90.20 | 0.67 |
| $L_2 \times T_1$ | 42.00 | 96.33 | 52.80 | 15.35 | 7.04 | 11.00 | 6.90 | 1.06 | 52.95 | 52.28 | 116.70 | 0.68 |
| $L_2 \times T_2$ | 44.67 | 96.67 | 51.13 | 24.59 | 7.45 | 12.33 | 10.17 | 2.82 | 52.97 | 51.15 | 92.51 | 0.43 |
| $L_2 \times T_3$ | 44.33 | 98.33 | 46.13 | 19.67 | 6.97 | 12.00 | 8.64 | 2.24 | 53.31 | 50.23 | 114.43 | 0.58 |
| $L_3 \times T_1$ | 43.33 | 100.33 | 50.80 | 18.00 | 7.30 | 12.33 | 9.85 | 1.18 | 54.61 | 51.83 | 107.02 | 0.66 |
| $L_3 \times T_2$ | 43.00 | 97.00 | 50.40 | 16.41 | 7.68 | 12.00 | 9.30 | 1.29 | 51.72 | 51.96 | 110.32 | 0.67 |

Table 2. (Contd...)

| Source | Days to 50 % flowering | Days to final harvest | Height of plants (cm) | Pods/ plant | Length of pod (cm) | Grains/ pod | Grain yield/ plant | LAI | Shade Intensity (%) | | LAR ($cm^2$ $g^{-1}$) | Harvest Index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Flowering | Pod formation | | |
| $L_3 \times T_3$ | 47.67 | 101.33 | 56.00 | 15.77 | 7.16 | 12.00 | 7.02 | 1.87 | 53.66 | 51.26 | 115.51 | 0.51 |
| $L_4 \times T_1$ | 43.00 | 96.67 | 51.80 | 18.58 | 7.71 | 12.33 | 10.46 | 0.99 | 53.38 | 52.29 | 107.63 | 0.72 |
| $L_4 \times T_2$ | 47.00 | 101.33 | 41.00 | 15.46 | 7.70 | 12.33 | 7.21 | 1.77 | 55.03 | 52.46 | 113.47 | 0.61 |
| $L_4 \times T_3$ | 44.00 | 101.00 | 51.20 | 16.28 | 7.29 | 11.67 | 7.34 | 1.63 | 53.11 | 52.97 | 115.53 | 0.71 |
| $L_5 \times T_1$ | 44.67 | 97.00 | 51.73 | 21.94 | 7.77 | 11.67 | 10.80 | 1.41 | 52.48 | 52.84 | 102.78 | 0.61 |
| $L_5 \times T_2$ | 45.00 | 95.00 | 54.47 | 25.61 | 9.65 | 11.67 | 17.91 | 0.73 | 54.11 | 53.04 | 92.75 | 0.75 |
| $L_5 \times T_3$ | 47.00 | 101.33 | 58.67 | 15.98 | 7.93 | 12.33 | 7.83 | 1.98 | 53.69 | 51.84 | 108.76 | 0.49 |
| F(22,44) | 18.24** | 2.77** | 1.24 | 10.54** | 41.50** | 6.71** | 32.49** | 17.38** | $0.47^{ns}$ | $0.22^{ns}$ | 9.23** | 11.58** |
| SE | 0.89 | 1.96 | 15.45 | 1.78 | 0.16 | 0.38 | 0.85 | 0.22 | 3.58 | 4.80 | 3.74 | 0.04 |
| CD | 1.79 | 3.93 | – | 3.58 | 0.32 | 0.75 | 1.71 | 0.44 | – | – | 7.51 | 0.09 |

** Significant at 1 per cent ns not significant

### 4.1.1 Days to 50% flowering

The shortest duration upto 50 % flowering among lines was observed in $L_4$ (42.67 days) and the longest in $L_1$ (50.33 days). Among testers, minimum days taken for 50 % flowering was by $T_1$ (48.00 days) and maximum by $T_3$ (50.33 days). Among the hybrids, $L_2$ x $T_1$ was the earliest in days to 50 % flowering (42.00 days) whereas $L_1$ x $T_1$ was late (49.00 days). The hybrids $L_1$ x $T_2$ (43.33), $L_3$ x $T_1$ (43.33), $L_3$ x $T_2$ (43.00), $L_4$ x $T_1$ (43.00), $L_1$ x $T_3$ (42.67) were on par with $L_2$ x $T_1$ in earliness for days to 50% flowering.

### 4.1.2 Days to final harvest

The shortest duration of the crop was shown by $L_4$ (95.00) and the longest duration by $L_1$ (101.33) among lines. The testers took 95 days in $T_1$ to 100 days in $T_3$ for final harvest. $L_1$ x $T_2$ and $L_5$ x $T_2$ were the hybrids with the least number of days taken for final harvest (95.00). $L_3$ x $T_3$, $L_4$ x $T_2$ and $L_5$ x $T_3$ took the longest number of days to harvest (101.33). $L_1$ x $T_1$ (96.67), $L_1$ x $T_3$ (96.33), $L_2$ x $T_1$ (96.33), $L_2$ x $T_2$ (96.67), $L_2$ x $T_3$ (98.33), $L_3$ x $T_2$ (97.00), $L_4$ x $T_1$ (96.67) and $L_5$ x $T_1$ (97.00) were on par with $L_1$ x $T_2$ and $L_5$ x $T_2$ as for the days taken for harvest.

### 4.1.3 Number of pods per plant

The average number of pods per plant among lines ranged from 11.85 in $L_1$ to 17.57 in $L_5$ and that in testers ranged from 14.86 in $T_1$ to 19.29 in $T_3$. The average number of pods per plant varied from 15.35 in

$L_2 \times T_1$ to 28.29 in $L_1 \times T_3$. The hybrid $L_5 \times T_2$ (25.61) was on par with $L_1 \times T_3$ which had maximum number of pods per plant.

### 4.1.4 Length of pod

$L_2$ had the shortest pods (6.29 cm.) and $L_3$ had the longest pods (7.21 cm.) among the lines. The average length of pod in testers ranged from 6.38 cm. in $T_3$ to 6.47 cm. in $T_2$. Pod length of hybrids varied between 6.97 cm. ($L_2 \times T_3$) and 9.65 cm. ($L_5 \times T_2$). No other hybrid was on par with $L_5 \times T_2$ which had the longest pods.

### 4.1.5 Number of grains per pod

The average number of grains per pod ranged from 10.00 ($L_4$) to 11.33 ($L_1$) among lines while that of testers ranged from 10.67 in $T_2$ to 11.00 in $T_1$ and $T_3$. Among hybrids, the average number of grains per pod ranged from 11.00 in $L_1 \times T_3$ and $L_2 \times T_1$ to 12.33 in $L_2 \times T_2$, $L_3 \times T_1$, $L_4 \times T_1$, $L_4 \times T_2$ and $L_5 \times T_3$. The hybrids $L_1 \times T_1$ (12.00), $L_1 \times T_2$ (12.00), $L_2 \times T_3$ (12.00), $L_3 \times T_2$ (12.00), $L_3 \times T_3$ (12.00), $L_4 \times T_3$ (11.67), $L_5 \times T_1$ (11.67) and $L_5 \times T_2$ (11.67) were on par with the hybrids with maximum number of grains per pod.

### 4.1.6 Grain yield per plant

The line $L_3$ recorded the highest mean yield of 6.35 g per plant and $L_4$ was the lowest with 4.07 g per plant. The tester $T_3$ had the highest mean yield (7.00 g per plant) and $T_1$ had the lowest mean yield of 4.85 g per plant. The cross $L_5$ x $T_2$ recorded a maximum mean yield of 17.91 g per plant while the cross $L_2$ x $T_1$ produced a minimum mean yield of 6.90 g per plant. The hybrid $L_1$ x $T_3$ (16.32 g per plant) was on par with the highest yielding hybrid $L_5$ x $T_2$.

### 4.1.7 Leaf Area Index (LAI)

The LAI ranged from 0.94 in $L_4$ to 2.51 in $L_1$ among lines and in testers ranged from 1.96 in $T_2$ to 2.93 in $T_3$. Among hybrids, it ranged from 0.73 in $L_5$ x $T_2$ to 2.82 in $L_2$ x $T_2$.

### 4.1.8 **Photosynthetic efficiency** (in terms of leaf area ratio)

Leaf Area Ratio (LAR) was taken as a measure of photosynthetic efficiency. The lower the LAR the higher will be the photosynthetic efficiency. Among lines, the LAR was the lowest in $L_3$ (103.62) and the highest in $L_1$ (116.82). Among the testers, ranged from 107.39 in $T_2$ to 113.88 in $T_1$. The hybrid $L_2$ x $T_1$ showed the maximum LAR (116.70) and $L_1$ x $T_3$ had the minimum LAR (90.20). The hybrids $L_1$ x $T_2$ (95.47), $L_2$ x $T_2$ (92.51) and $L_5$ x $T_2$ (92.75) were on par with $L_1$ x $T_3$ which had the minimum LAR.

### 4.1.9 Harvest Index

The lowest harvest index of 0.39 was recorded by $L_3$ and the highest by $L_5$ (0.62) among lines. The tester $T_1$ recorded the minimum

(0.43) and $T_3$ the maximum (0.58). Harvest index of hybrids varied between 0.43 ($L_2$ x $T_2$) and 0.75 ($L_5$ x $T_2$). The hybrids $L_1$ x $T_3$ (0.67), $L_2$ x $T_1$ (0.68), $L_3$ x $T_1$ (0.66), $L_3$ x $T_2$ (0.67), $L_4$ x $T_1$ (0.72) and $L_4$ x $T_3$ (0.71) were on par with $L_5$ x $T_2$ which had the highest harvest index.

### 4.1.10 Incidence of pod bug

Pod bug was the only pest that was found to be affecting the crop. Hence scoring was done for pod bug only. Generally none of the genotypes showed high incidence of pod bug infestation. The hybrids, $L_5$ x $T_2$, $L_5$ x $T_1$, $L_4$ x $T_2$, $L_1$ x $T_3$ and $L_2$ x $T_3$ showed low pest incidence. Disease incidence was not at all a problem during the crop period.

## 4.2 Combining ability analysis

The gene action was studied through combining ability analysis for the nine characters which exhibited significant genotypic differences. Significant mean squares due to lines, testers and line x tester were detected for the character, length of pod. Mean squares due to line x tester interaction alone were significant for all the characters except days to final harvest (Table 3). The general combining ability effects of parents and the specific combining ability effects of all the crosses are presented in Tables 4 and 5 respectively.

Table 3. Mean squares due to lines, testers, line x tester and environment for individual characters

| Character | Lines | Testers | Line x Tester | Error |
|---|---|---|---|---|
| Days to 50 per cent flowering | 4.26 | 2.15 | 19.66** | 1.189 |
| Days to final harvest | 22.59 | 31.05 | 10.49 | 5.743 |
| Number of pods per plant | 49.64 | 8.67 | 59.90** | 4.750 |
| Length of pod (cm) | 2.38** | 2.07* | 0.48** | 0.382 |
| Number of grains per pod | 0.36 | 0.29 | 0.79** | 0.211 |
| Grain yield per plant (g) | 28.66 | 10.73 | 38.03** | 1.088 |
| Leaf Area Index | 0.95 | 1.91 | 0.71** | 0.071 |
| Leaf Area Ratio ($cm^2 g^{-1}$) | 372.38 | 287.14 | 185.02** | 20.963 |
| Harvest index | 0.16 | 0.14 | 0.31** | 0.003 |

** Significant at 1 per cent level

Table 4. General combining ability of parents for various characters

| G.C.A. | Days to 50 % flowering | Days to final havest | Pods per plant | Length of pod (cm) | Grains per pod | Grain yield per plant (g) | LAI | LAR ($cm^2 g^{-1}$) | Harvest index |
|---|---|---|---|---|---|---|---|---|---|
| **Lines** | | | | | | | | | |
| $L_1$ | 0.29 | -2.02* | 2.36** | -0.28** | -0.24 | 1.48** | -0.33** | -8.76** | 0.01 |
| $L_2$ | -1.04** | -0.91 | 0.64 | -0.42** | -0.13 | -1.25** | 0.54** | 1.95 | -0.06** |
| $L_3$ | -0.04 | 1.53 | -2.50** | -0.19** | 0.20 | -1.10** | -0.05 | 5.02** | -0.01 |
| $L_4$ | -0.04 | 1.64* | -2.45** | 0.00 | 0.20 | -1.48** | -0.04 | 6.28** | 0.06** |
| $L_5$ | 0.84* | -0.24 | 1.95* | 0.88** | -0.02 | 2.35** | -0.13 | -4.50** | -0.00 |
| SE | 0.36 | 0.80 | 0.73 | 0.07 | 0.15 | 0.35 | 0.09 | 1.53 | 0.02 |
| CD | 0.73 | 1.61 | 1.46 | 0.13 | 0.31 | 0.70 | 0.18 | 3.07 | 0.04 |
| **Testers** | | | | | | | | | |
| $T_1$ | -0.31 | -0.62 | -0.75 | -0.14** | -0.04 | -0.58* | -0.40** | 2.06 | 0.03* |
| $T_2$ | -0.11 | -1.02 | 0.77 | 0.42** | 0.16 | 0.97** | 0.11 | -5.03** | -0.01 |
| $T_3$ | 0.42 | 1.64* | -0.03 | -0.28** | -0.11 | -0.39 | 0.29** | 2.96* | -0.03* |
| SE | 0.28 | 0.62 | 0.56 | 0.05 | 0.12 | 0.27 | 0.07 | 1.18 | 0.01 |
| CD | 0.57 | 1.24 | 1.13 | 0.10 | 0.24 | 0.54 | 0.14 | 2.38 | 0.03 |

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

Table 5. Specific combining ability of crosses for various characters

| Cross | Days to 50 % flowering | Days to final harvest | Pods per plant | Length of pod (cm) | Grains per pod | Grain yield per plant (g) | LAI | LAR ($cm^2$ $g^{-1}$) | Harvest index |
|---|---|---|---|---|---|---|---|---|---|
| $L_1 \times T_1$ | 4.31** | 1.29 | -2.30 | 0.18 | 0.38 | -2.51 | 0.09 | 6.60* | -0.06* |
| $L_1 \times T_2$ | -1.56* | 0.02 | -4.43** | -0.24* | 0.18 | -2.90** | 0.15 | 3.33 | -0.01 |
| $L_1 \times T_3$ | -2.76** | -1.31 | 6.73** | 0.07 | -0.56* | 5.40** | -0.24 | -9.93** | 0.07* |
| $L_2 \times T_1$ | -1.36* | -0.16 | -3.78** | 0.03 | -0.73* | -1.09 | -0.58 | 6.76* | 0.08* |
| $L_2 \times T_2$ | 1.11 | 0.58 | 3.95** | -0.12 | 0.40 | 0.63 | 0.67** | -10.35** | -0.13** |
| $L_2 \times T_3$ | 0.24 | -0.42 | -0.17 | 0.10 | 0.33 | 0.46 | -0.09 | 3.59 | 0.04 |
| $L_3 \times T_1$ | -1.02 | 1.40 | 2.02 | 0.06 | 0.27 | 1.70* | 0.13 | -6.00* | 0.01 |
| $L_3 \times T_2$ | -1.56* | -1.53 | -1.09 | -0.12 | -0.27 | -0.40 | -0.27 | 4.39 | 0.06* |
| $L_3 \times T_3$ | 2.58** | 0.13 | -0.92 | 0.06 | 0.00 | -1.31* | 0.13 | 1.60 | -0.07* |
| $L_4 \times T_1$ | -1.36* | -2.38 | 2.55 | 0.28* | 0.27 | 2.70** | -0.07 | -6.65* | 0.01 |
| $L_4 \times T_2$ | 2.44** | 2.69 | -2.08 | -0.29* | 0.07 | -2.10** | 0.20 | 6.28* | -0.07* |
| $L_4 \times T_3$ | -1.09 | -0.31 | -0.47 | 0.01 | -0.33 | -0.60 | -0.12 | 0.36 | 0.06* |
| $L_5 \times T_1$ | -0.58 | -0.61 | 1.51 | -0.54** | -0.18 | -0.80 | 0.43* | -0.71 | -0.04 |
| $L_5 \times T_2$ | -0.44 | -1.76 | 3.66** | 0.78** | -0.38 | 4.76** | -0.75** | -3.66 | 0.14** |
| $L_5 \times T_3$ | 1.02 | 1.91 | -5.17** | -0.24* | -0.56* | -3.96** | 0.32* | 4.37 | -0.10** |
| SE | 0.63 | 1.38 | 1.26 | 0.11 | 0.27 | 0.60 | 0.15 | 2.64 | 0.03 |
| CD | 1.27 | 2.78 | 2.53 | 0.23 | 0.53 | 1.21 | 0.31 | 5.31 | 0.06 |

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

### 4.2.1 Days to 50% flowering

Among the lines $L_2$ had maximum significant negative gca effect (-1.04) while $L_5$ recorded maximum significant positive gca effect (0.84). None of the testers recorded significant gca effect and the three testers did not differ significantly from one another.

The cross $L_1$ x $T_3$ had maximum significant negative sca value of -2.76 (Fig. 1). The maximum significant positive sca was recorded by $L_1$ x $T_1$ (4.31) which was on par with $L_3$ x $T_3$ (2.58). $L_3$ x $T_3$ was followed by $L_4$ x $T_2$ (2.44).

### 4.2.2 Days to final harvest

The line $L_1$ showed maximum significant negative gca effect (-2.02) and $L_4$ exhibited maximum significant positive gca effect (1.64). None of the testers showed significant negative gca effect while $T_3$ recorded the maximum significant positive gca effect (1.64). Both lines and testers did not differ significantly with respect to gca effect.

Hybrids too did not differ significantly in terms of sca effect and significant sca effect was not observed for any of the crosses.

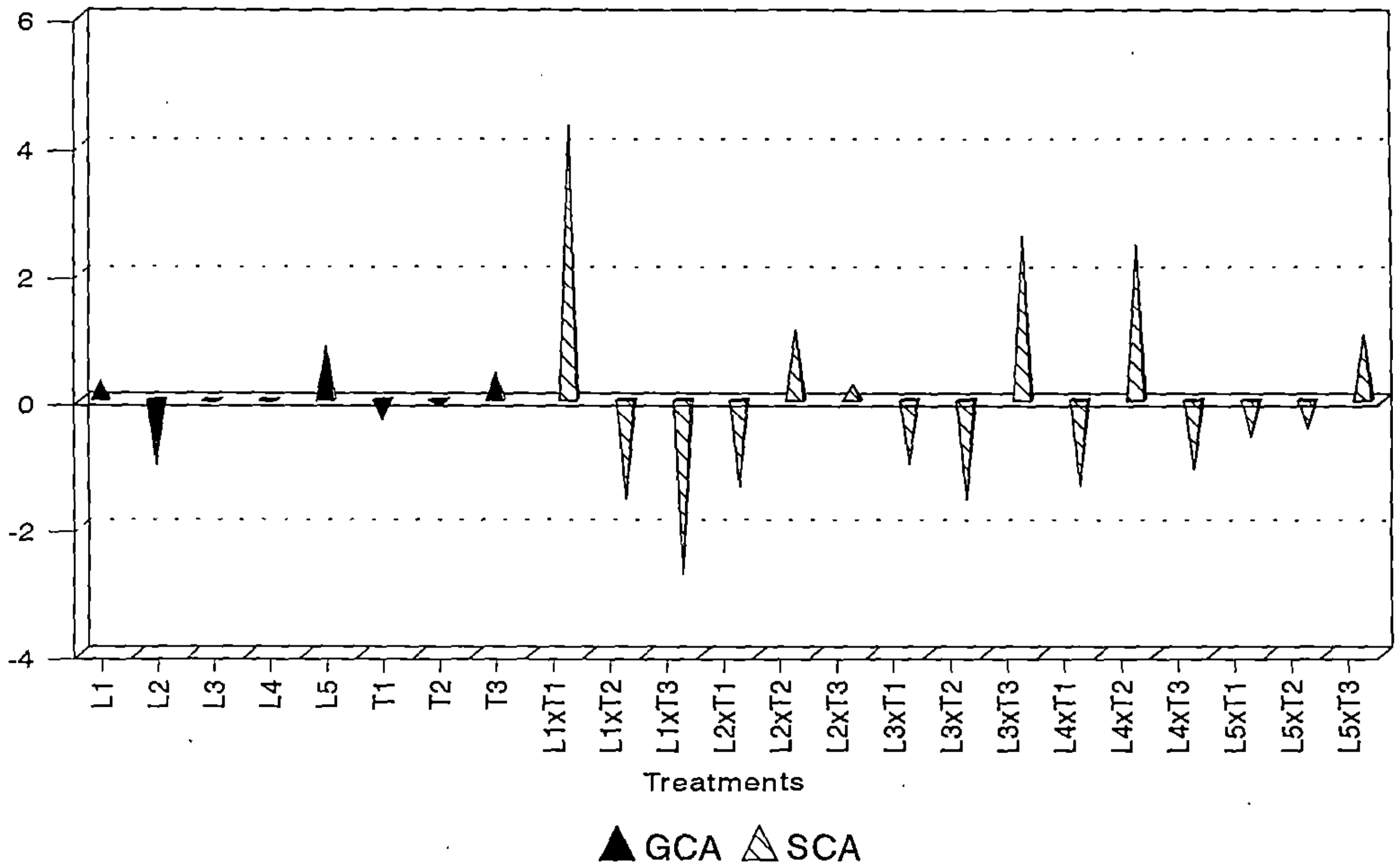


**Fig. 1. GCA and SCA : Days to 50% flowering**

### 4.2.3 Number of pods per plant

Only two lines showed significant positive gca effect, $L_1$ with a maximum value of 2.36 followed by $L_5$ (1.95). $L_1$ and $L_5$ were on par with each other. The line $L_3$ exhibited the highest significant negative gca effect (-2.50) which was on par with $L_4$ (-2.45). None of the testers showed significant gca effects.

Out of the four hybrids exhibiting significant positive sca effects, $L_1 \times T_3$ had the maximum value of 6.73 which was on par with $L_2 \times T_2$ (3.95) and $L_5 \times T_2$ (3.66). Maximum significant negative sca effect was observed for $L_5 \times T_3$ (-5.17). $L_1 \times T_2$ (-4.43) and $L_2 \times T_1$ (-3.78) were on par with $L_5 \times T_3$.

### 4.2.4 Length of pod

Among lines, significant positive gca effect was observed only for $L_5$ (0.88) which differed significantly from other lines. Out of the three lines showing significant negative gca effect, $L_2$ had the maximum value of -0.42 which was on par with $L_1$ (-0.28). The tester $T_2$ had significant positive gca effect (0.42). Maximum significant negative gca effect was observed for $T_3$ (-0.28). $T_1$ (-0.14) was on par with $T_3$.

Two hybrids exhibited significant positive sca effects. Maximum positive sca value of 0.78 was observed for $L_5 \times T_2$ (Fig. 2) which

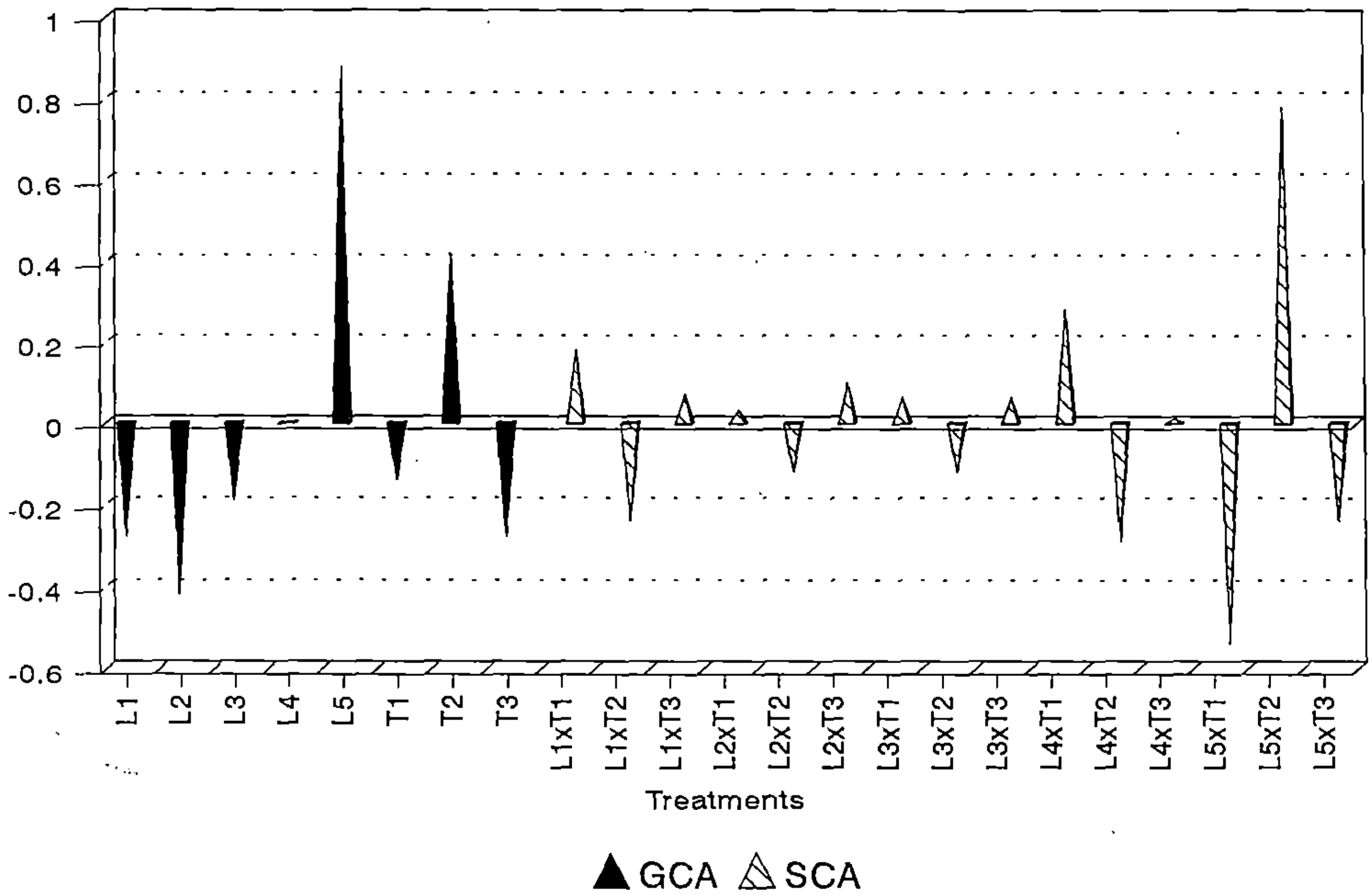


**Fig. 2. GCA and SCA : Length of pod**

differed significantly from $L_4 \times T_1$ (0.28). Among the four crosses with significant negative sca effect, $L_5 \times T_1$ ranked first with a value of -0.54 which was on par with $L_4 \times T_2$ (-0.29), $L_1 \times T_2$ (-0.24) and $L_5 \times T_3$ (-0.24).

### 4.2.5 Number of grains per pod

None of the lines and testers exhibited significant gca effect for this trait.

Significant positive sca effect was not observed in any of the crosses. The hybrid, $L_2 \times T_1$ showed the maximum significant negative sca effect (-0.73) which was on par with $L_1 \times T_3$ (-0.56) and $L_5 \times T_3$ (-0.56).

### 4.2.6 Grain yield per plant

Out of the two lines with significant positive gca effect, $L_5$ had the maximum value of 2.35 and was on par with $L_1$ (1.48). $L_4$ showed the maximum negative gca effect (-1.48) which was on par with $L_2$ (-1.25) and $L_3$ (-1.10). Out of the three testers, $T_2$ alone showed significant positive gca effect of value 0.97 and significant negative gca effect was observed for $T_1$ (-0.58).

Among the four hybrids with significant positive sca effect, maximum value was observed for $L_1 \times T_3$ (5.40) which was on par with

$L_5 \times T_2$ (4.76). This was followed by $L_4 \times T_1$ (2.70) and $L_3 \times T_1$ (1.70). Five hybrids showed significant negative sca effects of which the maximum value of -3.96 was observed for $L_5 \times T_3$. This was followed by $L_1 \times T_2$ (-2.90) and $L_1 \times T_1$ (-2.51) which were on par with $L_5 \times T_3$ (Fig. 3).

### 4.2.7 Leaf Area Index

$L_2$ (0.54) and $L_1$ (-0.33) were the only lines exhibiting respectively significant positive and negative gca effects. Among the testers T3 had significant positive gca effect (0.29) and T1 showed significant negative gca effect (-0.40).

Three hybrids, $L_2 \times T_2$ (0.67), $L_5 \times T_1$ (0.43) and $L_5 \times T_3$ (0.32) showed significant positive sca effects and all these were on par. Maximum significant negative sca effect was observed for $L_5 \times T_2$ (-0.75) which was on par with $L_2 \times T_1$ (-0.58).

### 4.2.8 Photosynthetic efficiency (in terms of leaf area ratio)

Two lines, $L_1$ (-8.76) and $L_5$ (-4.50) showed significant negative gca effect for LAR and were on par. Maximum significant positive gca effect was observed for $L_4$ (6.28) which was on par with L3 (5.02). Among testers, significant negative gca effect was shown by $T_2$ (-5.03) and $T_3$ had significant positive gca effect (2.96).

Four hybrids showed significant negative sca effects, all on par with one another, viz., $L_2 \times T_2$ (-10.35), $L_1 \times T_3$ (-9.93), $L_4 \times T_1$ (-6.65)

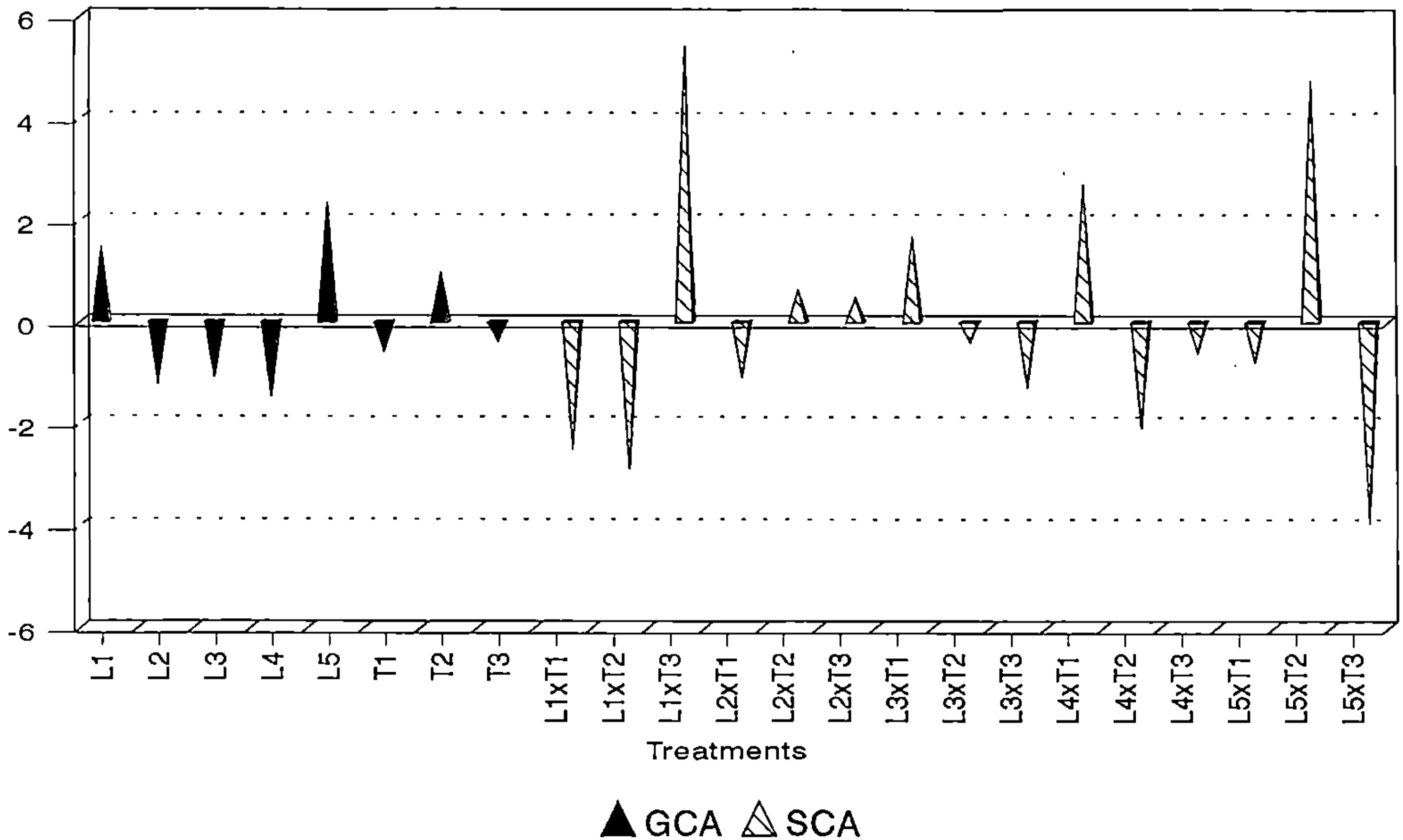


**Fig. 3. GCA and SCA : Grain yield per plant**

and $L_3$ x $T_1$ (-6.00). Significant positive sca effect was observed for $L_2$ x $T_1$ (6.76), $L_1$ x $T_1$ (6.60) and $L_4$ x $T_2$ (6.28) which were on par (Fig. 4).

### 4.2.9 Harvest Index

Among lines, significant positive gca effect was exhibited by $L_4$ (0.06) and significant negative gca effect was shown by $L_2$ (-0.06). Among testers, $T_1$ had significant positive gca effect (0.03) and $T_3$ alone showed significant negative gca effect (-0.03).

Out of the five hybrids with significant positive sca effects, maximum positive sca effect of value 0.14 was observed for $L_5$ x $T_2$ followed by $L_2$ x $T_1$ (0.08), $L_1$ x $T_3$ (0.07), $L_3$ x $T_2$ (0.06) and $L_4$ x $T_3$ (0.06), all on par (Fig. 5). Among the five hybrids which showed significant negative sca effects, $L_2$ x $T_2$ had the maximum negative sca effect (-0.13) followed by $L_5$ x $T_3$ (-0.10), $L_3$ x $T_3$ (-0.07), $L_4$ x $T_2$ (-0.07) and $L_1$ x $T_1$ (-0.06), all on par.

## 4.3 Proportional contribution

The proportional contribution of lines, testers and line x tester to the total variance for different characters are presented in Table 6 and Fig. 6. The proportional contribution of lines ranged from 9.53% for days to 50% flowering to 54.54% for length of pod. Among testers, the values ranged from 2.41% for days to 50% flowering to 28.67% for leaf

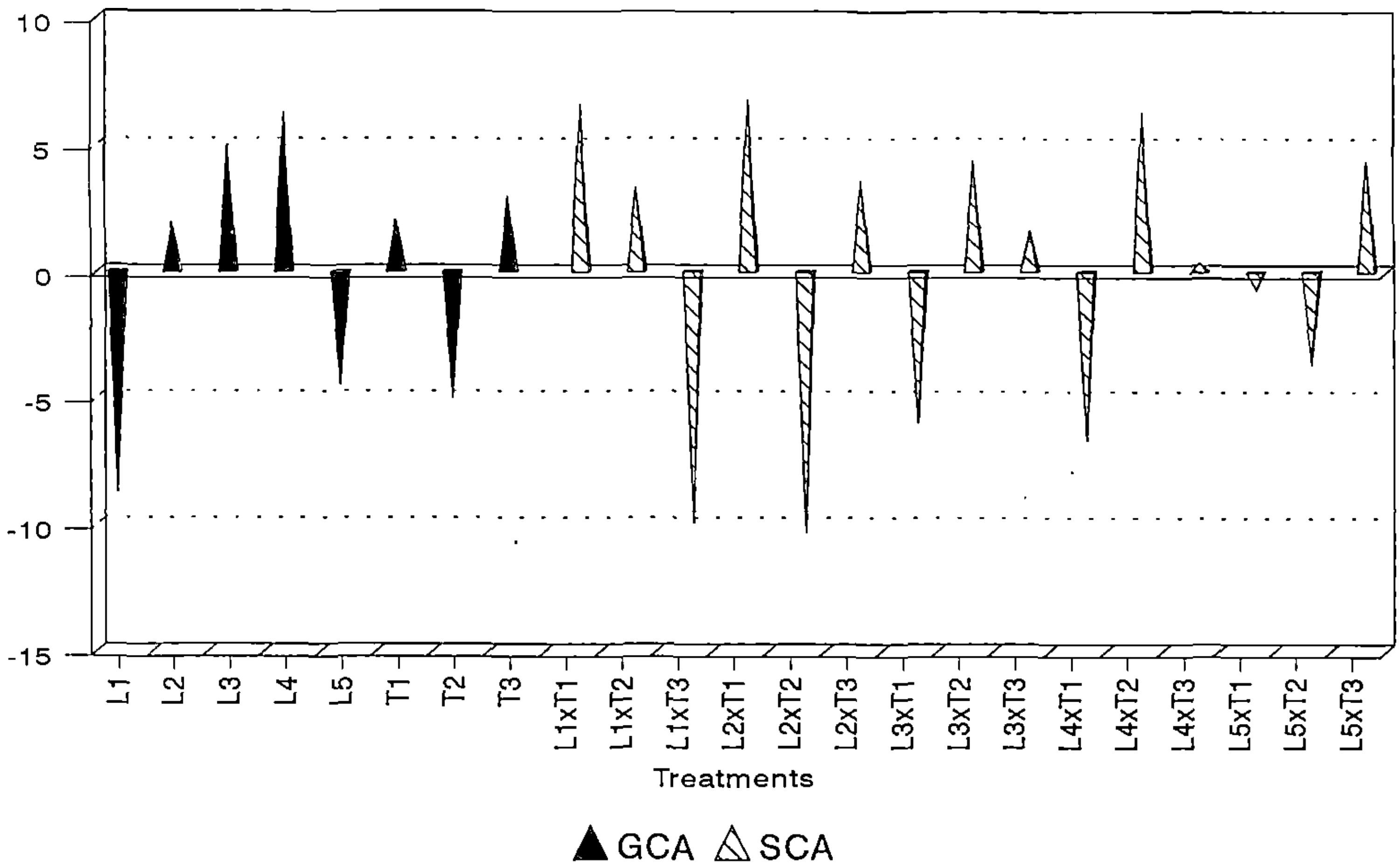


**Fig. 4. GCA and SCA : Photosynthetic efficiency**

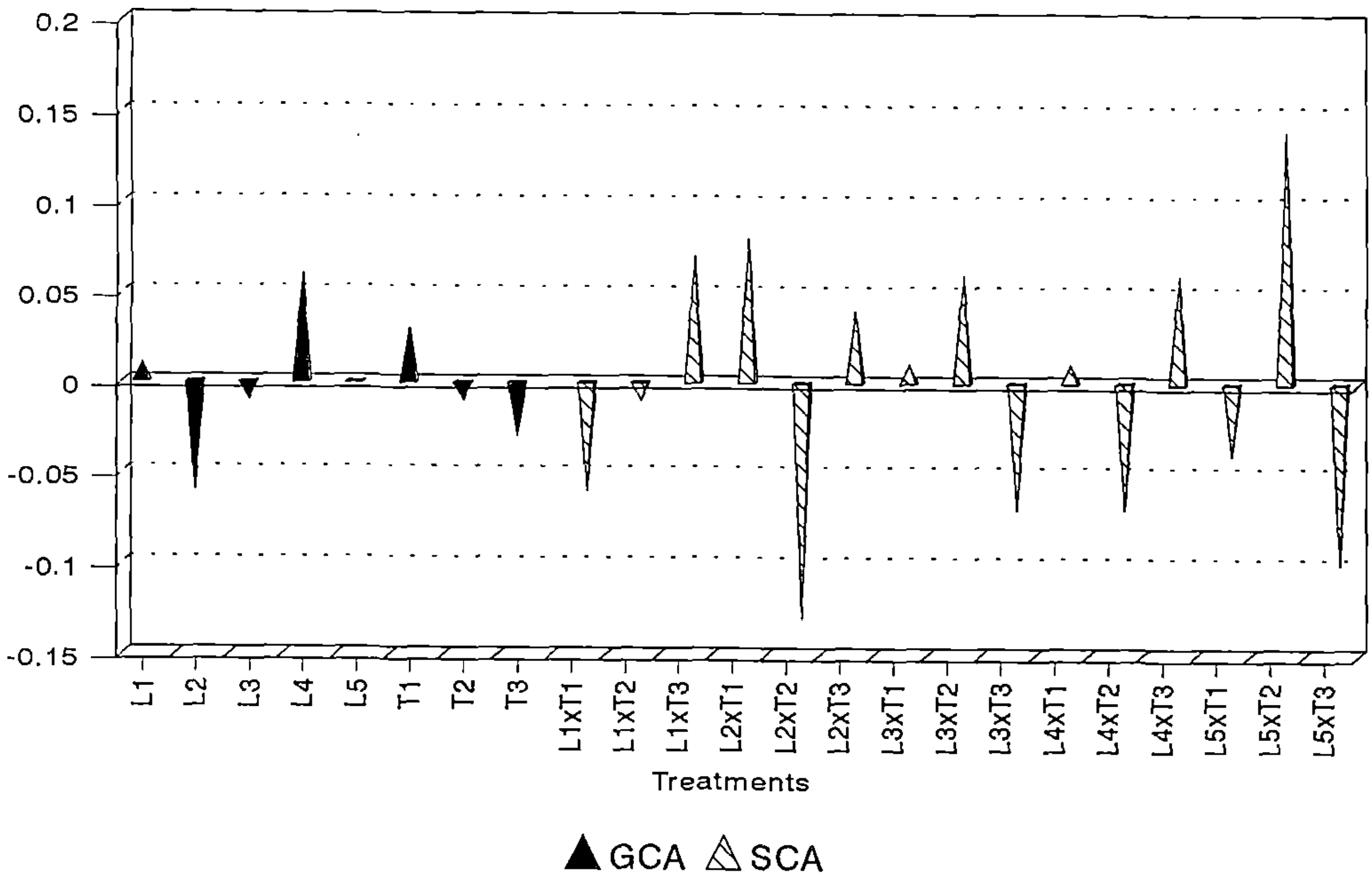


**Fig. 5. GCA and SCA : Harvest Index**

Table 6. Proportional contribution of lines, testers and crosses to total variance

| Character | Proportional contribution (%) | | |
|---|---|---|---|
| | Lines | Testers | Crosses |
| Days to 50 per cent flowering | 9.53 | 2.41 | 88.06 |
| Days to final harvest | 38.23 | 26.27 | 35.50 |
| Pods per plant | 28.56 | 2.50 | 68.94 |
| Length of pod (cm) | 54.54 | 23.71 | 21.75 |
| Grains per pod | 17.11 | 6.96 | 75.93 |
| Grain yield per plant (g) | 26.04 | 4.87 | 69.09 |
| Leaf area index | 28.51 | 28.67 | 42.83 |
| Leaf area ratio ($cm^2$ $g^{-1}$) | 42.03 | 16.20 | 41.77 |
| Harvest index | 18.59 | 8.11 | 73.30 |

area index. In the case of crosses, the range was from 21.75% for length of pod to 88.06% for days to 50% flowering.

Among the lines, the proportional contribution to total variance was high for days to final harvest (38.23 %), length of pod (54.54 %) and leaf area ratio (42.03 %). In general, the contribution of testers was less. The character for which the testers made almost equal contribution as the lines was leaf area index (28.67 %) followed by days to final harvest (26.27 %), length of pod (23.71 %) and leaf area ratio (16.20 %).

Hybrids had comparatively more contribution towards total variance with respect to most of the characters. Contribution of hybrids to total variance was high for the characters days to 50% flowering (88.06 %), grains per pod (75.93 %), harvest index (73.30 %), grain yield per plant (69.09 %) and pods per plant (68.94 %).

### 4.4 Genetic components of variance

Estimates of GCA variance of lines and testers and SCA variance of crosses are presented in Table 7.1. Significant GCA and SCA variances were observed for the character, length of pod alone suggesting the involvement of both additive and non-additive gene action for the expression of this trait. Variance due to SCA alone was significant for the characters, days to 50% flowering, pods per plant, grains per pod, grain yield per plant, leaf area index, leaf area ratio (measure of photosynthetic efficiency)

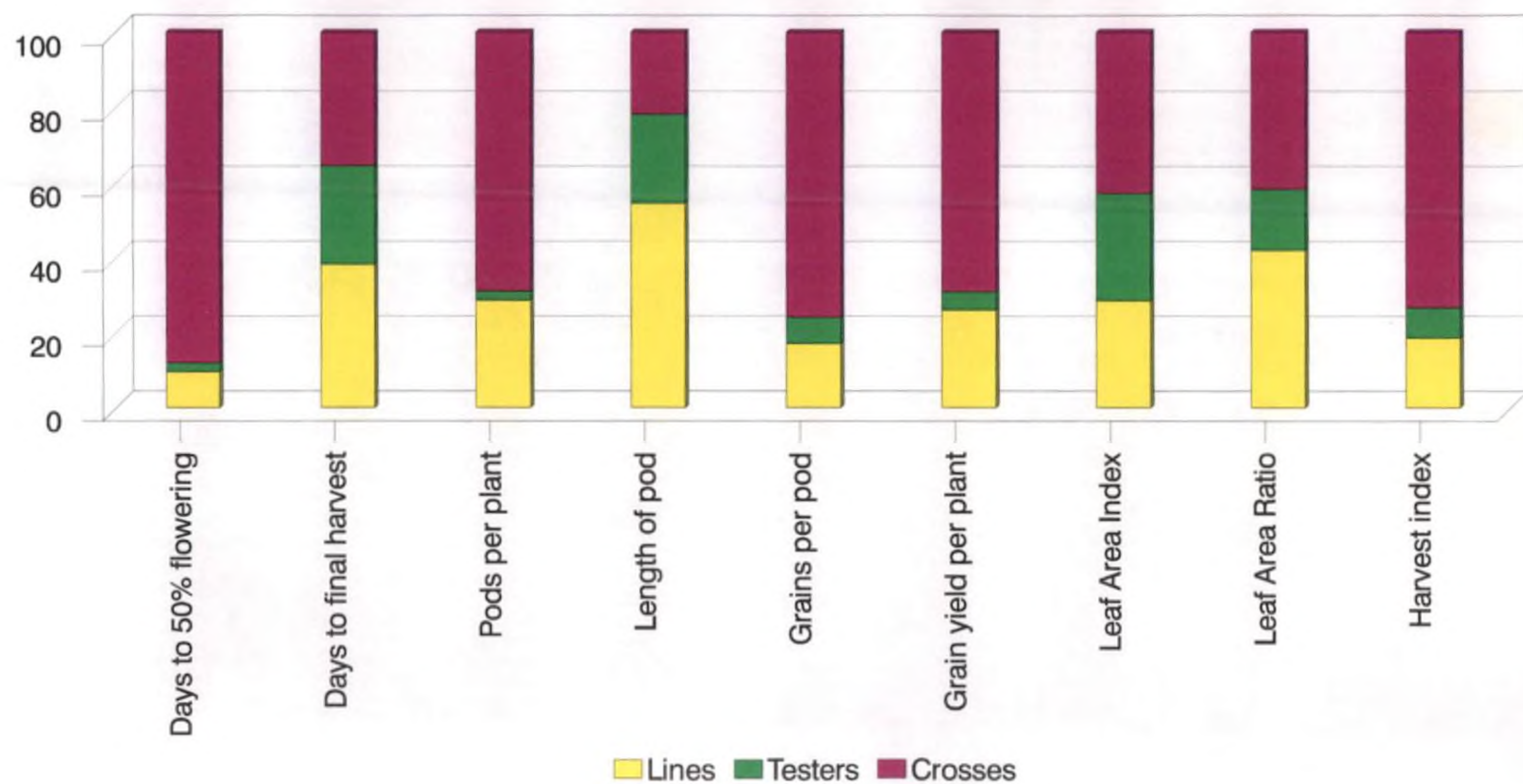


Fig. 6. Proportional contribution of lines, testers and crosses to total variance

Table 7.1 Estimates of GCA variance of lines and testers and SCA variance of crosses

| Character | $\sigma^2$gca (lines) | $\sigma^2$gca (testers) | $\sigma^2$sca | Error |
|---|---|---|---|---|
| Days to 50 per cent flowering | NE | NE | 6.16 | 1.189 |
| Days to final harvest | 1.34 | 1.37 | 1.58 | 5.743 |
| Pods per plant | NE | NE | 18.38 | 4.750 |
| Length of pod (cm) | 0.21 | 0.11 | 0.15 | 0.382 |
| Grains per pod | NE | NE | 0.19 | 0.211 |
| Grain yield per plant (g) | NE | NE | 12.31 | 1.088 |
| Leaf Area Index | 0.02 | 0.08 | 0.21 | 0.071 |
| Leaf Area Ratio ($cm^2$ $g^{-1}$) | 20.82 | 6.81 | 54.69 | 20.963 |
| Harvest index | NE | NE | 0.009 | 0.003 |

NE - Not estimable

and harvest index indicating the importance of non-additive gene action in the inheritance of these traits. For the character, days to final harvest both GCA and SCA variances were not significant.

The genetic components of variance, viz., additive variance and dominance variance were estimated and are presented in Table 7.2. For the characters, days to final harvest, length of pod, leaf area index and leaf area ratio dominance variance was greater than additive variance, and additive variance was not estimable for the other remaining characters. Additive to dominance ratio ranged from 0.04 for both leaf area index and leaf area ratio to 0.19 for length of pod. The ratio was not estimable for days to 50 % flowering, pods per plant, grains per pod, grain yield per plant and harvest index since additive variance was not estimable.

## 4.5 Heterosis

Superior hybrids in relation to mid parent (relative heterosis) and better parent (heterobeltiosis) were estimated for the nine characters and are presented in Table 8.

### 4.5.1 Number of days to 50% flowering

Significant negative heterosis was observed in 13 hybrids over mid parent and nine hybrids over better parent. The cross $L_1 \times T_3$ showed maximum negative relative heterosis (-15.23) and

Table 7.2 Estimate of genetic components of variance when inbreeding coefficient, F=0

| Character | $\sigma^2_A$ | $\sigma^2_D$ | $\sigma^2_A/\sigma^2_D$ |
|---|---|---|---|
| Days to 50 per cent flowering | NE | 24.62 | NE |
| Days to final harvest | 0.90 | 6.33 | 0.14 |
| Pods per plant | NE | 73.54 | NE |
| Length of pod (cm) | 0.11 | 0.58 | 0.19 |
| Grains per pod | NE | 0.77 | NE |
| Grain yield per plant (g) | NE | 49.26 | NE |
| Leaf Area Index | 0.03 | 0.86 | 0.04 |
| Leaf Area Ratio ($cm^2 g^{-1}$) | 9.63 | 218.75 | 0.04 |
| Harvest index | NE | 0.04 | NE |

NE - Not estimable

Table 8. Estimates of percentage heterosis over mid parent and better parent for various characters

| | Days to 50 % flowering | | | Days to final harvest | | | Pods per plant | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | RH | HB | Mean | RH | HB | Mean | RH | HB |
| $L_1$ | 50.33 | — | — | 101.33 | — | — | 11.85 | — | — |
| $L_2$ | 47.33 | — | — | 96.67 | — | — | 12.95 | — | — |
| $L_3$ | 49.33 | — | — | 98.33 | — | — | 16.88 | — | — |
| $L_4$ | 42.67 | — | — | 95.00 | — | — | 11.97 | — | — |
| $L_5$ | 48.00 | — | — | 96.67 | — | — | 17.57 | — | — |
| $T_1$ | 48.00 | — | — | 95.00 | — | — | 14.86 | — | — |
| $T_2$ | 48.33 | — | — | 96.67 | — | — | 17.22 | — | — |
| $T_3$ | 50.33 | — | — | 100.00 | — | — | 19.29 | — | — |
| $L_1 \times T_1$ | 49.00 | -0.34 | 2.08 | 96.67 | -1.53 | -1.76 | 18.54 | 38.86* | 24.79* |
| $L_1 \times T_2$ | 43.33 | -12.16** | -10.35** | 95.00 | -4.04* | -1.73** | 17.93 | 23.37* | 4.12 |
| $L_1 \times T_3$ | 42.67 | -15.23** | -15.22** | 96.33 | -4.30* | -3.67* | 28.29 | 81.70** | 46.63** |
| $L_2 \times T_1$ | 42.00 | -11.89** | -11.26** | 96.33 | 0.52 | 1.40 | 15.35 | 10.39 | 3.30 |
| $L_2 \times T_2$ | 44.67 | -6.62** | -5.62** | 96.67 | 0.00 | 0.00 | 24.59 | 63.03** | 42.80** |
| $L_2 \times T_3$ | 44.33 | -9.22** | -6.34** | 98.33 | 0.00 | 1.72 | 19.67 | 22.04* | 1.97 |
| $L_3 \times T_1$ | 43.33 | -10.96** | -9.73** | 100.33 | 3.79* | 5.61* | 18.00 | 13.42 | 6.64 |
| $L_3 \times T_2$ | 43.00 | -11.95** | -11.03** | 97.00 | -0.52 | 0.34 | 16.41 | -3.76 | -4.72 |
| $L_3 \times T_3$ | 47.67 | -4.35* | -3.37 | 101.33 | 2.18 | 3.05 | 15.77 | -12.78 | -18.24 |
| $L_4 \times T_1$ | 43.00 | -5.15* | 0.77 | 96.67 | 1.75 | 1.76 | 18.58 | 38.54** | 25.06* |
| $L_4 \times T_2$ | 47.00 | 3.30 | 10.95** | 101.33 | 5.74** | 6.66* | 15.46 | 5.96 | -10.20 |
| $L_4 \times T_3$ | 44.00 | -5.38* | 3.12 | 101.00 | 3.59* | 6.32 | 16.28 | 4.14 | -15.64 |
| $L_5 \times T_1$ | 44.67 | -6.94** | -6.93** | 97.00 | 1.22 | 2.11 | 21.94 | 35.33** | 24.90* |
| $L_5 \times T_2$ | 45.00 | -6.57** | -6.25** | 95.00 | -1.72 | -1.73 | 25.61 | 47.26** | 45.81** |
| $L_5 \times T_3$ | 47.00 | -4.41* | -2.08 | 101.33 | 3.05 | 4.82* | 15.98 | -13.31 | -17.19 |
| CD | — | 1.55 | 1.79 | — | 3.41 | 3.93 | — | 3.10 | 3.58 |

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

Table 8. (Contd...)

| | Length of pod | | | Grains per pod | | | Grain yield/plant | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | RH | HB | Mean | RH | HB | Mean | RH | HB |
| $L_1$ | 6.48 | — | — | 11.33 | — | — | 4.43 | — | — |
| $L_2$ | 6.29 | — | — | 10.67 | — | — | 4.32 | — | — |
| $L_3$ | 7.21 | — | — | 11.00 | — | — | 6.35 | — | — |
| $L_4$ | 6.37 | — | — | 10.00 | — | — | 4.07 | — | — |
| $L_5$ | 7.03 | — | — | 10.67 | — | — | 6.32 | — | — |
| $T_1$ | 6.46 | — | — | 11.00 | — | — | 4.85 | — | — |
| $T_2$ | 6.47 | — | — | 10.67 | — | — | 5.54 | — | — |
| $T_3$ | 6.38 | — | — | 11.00 | — | — | 7.00 | — | — |
| $L_1 \times T_1$ | 7.33 | 13.34** | 13.17** | 12.00 | 7.46* | 5.88 | 8.22 | 77.35** | 69.60** |
| $L_1 \times T_2$ | 7.47 | 15.32** | 15.23** | 12.00 | 9.09** | 5.88 | 9.39 | 88.42** | 69.43** |
| $L_1 \times T_3$ | 7.07 | 9.98** | 9.16** | 11.00 | -1.49 | -2.94 | 16.32 | 185.59** | 132.98** |
| $L_2 \times T_1$ | 7.04 | 10.40** | 8.98** | 11.00 | 1.54 | 0.00 | 6.90 | 50.62** | 42.43* |
| $L_2 \times T_2$ | 7.45 | 16.69** | 15.10** | 12.33 | 15.62** | 15.62** | 10.17 | 106.22** | 83.51** |
| $L_2 \times T_3$ | 6.97 | 9.91** | 9.14** | 12.00 | 10.77** | 9.09** | 8.64 | 52.55** | 23.32 |
| $L_3 \times T_1$ | 7.30 | 6.80** | 1.25 | 12.33 | 12.12** | 12.12* | 9.85 | 75.94** | 55.15** |
| $L_3 \times T_2$ | 7.68 | 12.28** | 6.52** | 12.00 | 10.77** | 9.09* | 9.30 | 56.42** | 46.48** |
| $L_3 \times T_3$ | 7.16 | 5.35* | -0.69 | 12.00 | 9.09** | 9.09* | 7.02 | 5.17 | 0.24 |
| $L_4 \times T_1$ | 7.71 | 20.27** | 19.40** | 12.33 | 17.46** | 12.12** | 10.46 | 134.78** | 115.89** |
| $L_4 \times T_2$ | 7.70 | 19.97** | 19.01** | 12.33 | 19.35** | 15.62** | 7.21 | 50.17** | 30.20 |
| $L_4 \times T_3$ | 7.29 | 14.41** | 14.26** | 11.67 | 11.11** | 6.06* | 7.34 | 32.61* | 4.81 |
| $L_5 \times T_1$ | 7.77 | 15.12** | 10.43** | 11.67 | 7.69* | 6.06* | 10.80 | 93.38** | 70.80** |
| $L_5 \times T_2$ | 9.65 | 42.88** | 37.16** | 11.67 | 9.38** | 9.38* | 17.91 | 201.88** | 183.18** |
| $L_5 \times T_3$ | 7.93 | 18.16** | 12.70** | 12.33 | 13.85** | 12.12** | 7.83 | 17.46 | 11.76 |
| CD | — | 0.28 | 0.32 | — | 0.65 | 0.75 | — | 1.48 | 1.71 |

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

Table 8. (Contd...)

| | Leaf Area Index | | | Leaf Area Ratio | | | Harvest Index | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | RH | HB | Mean | RH | HB | Mean | RH | HB |
| $L_1$ | 2.51 | — | — | 116.82 | — | — | 0.42 | — | — |
| $L_2$ | 1.17 | — | — | 107.29 | — | — | 0.49 | — | — |
| $L_3$ | 2.30 | — | — | 103.62 | — | — | 0.39 | — | — |
| $L_4$ | 0.94 | — | — | 104.18 | — | — | 0.52 | — | — |
| $L_5$ | 1.17 | — | — | 111.90 | — | — | 0.62 | — | — |
| $T_1$ | 2.27 | — | — | 113.88 | — | — | 0.43 | — | — |
| $T_2$ | 1.96 | — | — | 107.39 | — | — | 0.45 | — | — |
| $T_3$ | 2.93 | — | — | 112.80 | — | — | 0.58 | — | — |
| $L_1 \times T_1$ | 0.86 | -63.88** | -65.60** | 105.83 | -8.25** | -7.07* | 0.61 | 42.75* | 41.09 |
| $L_1 \times T_2$ | 1.43 | -36.21** | -43.16** | 95.47 | -14.84* | -11.10** | 0.62 | 41.76** | 37.04** |
| $L_1 \times T_3$ | 1.23 | -54.87** | -58.09** | 90.20 | -21.44** | -20.04** | 0.67 | 34.22** | 15.43* |
| $L_2 \times T_1$ | 1.06 | -38.43** | -53.30** | 116.70 | 5.53* | 8.06* | 0.68 | 47.64** | 39.04** |
| $L_2 \times T_2$ | 2.82 | 80.02** | 43.80** | 92.51 | -13.82** | -0.14 | 0.43 | -8.19 | -11.64 |
| $L_2 \times T_3$ | 2.24 | 9.43 | -23.35 | 114.43 | 3.99 | 6.65 | 0.58 | 8.41 | -0.57 |
| $L_3 \times T_1$ | 1.18 | -48.21** | -48.55** | 107.02 | -1.59 | 3.28 | 0.66 | 59.51** | 52.71** |
| $L_3 \times T_2$ | 1.29 | -39.48** | -43.91** | 110.32 | 4.56 | 6.47 | 0.67 | 58.10** | 48.15** |
| $L_3 \times T_3$ | 1.87 | -28.32** | -35.99** | 115.51 | 6.75* | 11.47** | 0.51 | 5.12 | -12.00 |
| $L_4 \times T_1$ | 0.99 | -38.32** | -56.39** | 107.63 | -1.29 | 3.31 | 0.72 | 51.41** | 38.71** |
| $L_4 \times T_2$ | 1.77 | 21.70 | -10.02 | 113.47 | 7.26* | 8.92* | 0.61 | 25.52** | 17.42* |
| $L_4 \times T_3$ | 1.63 | -15.86 | -44.42** | 115.53 | 6.49* | 10.89** | 0.71 | 29.09** | 21.71** |
| $L_5 \times T_1$ | 1.41 | -18.14 | -38.03** | 102.78 | -8.95** | -8.15* | 0.61 | 15.93* | -1.62 |
| $L_5 \times T_2$ | 0.73 | -53.35** | -62.82** | 92.75 | -15.41** | -13.63** | 0.75 | 41.25** | 22.16** |
| $L_5 \times T_3$ | 1.98 | -3.42 | -32.46** | 108.76 | -3.20 | -2.81 | 0.49 | -18.33** | -20.54** |
| CD | — | 0.38 | 0.44 | – | 6.51 | 7.51 | – | 0.08 | 0.09 |

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

heterobeltiosis (-15.22) for this trait. None of the hybrids were on par with $L_1$ x $T_3$ in terms of negative relative heterosis and heterobeltiosis (Fig. 7). $L_1$ x $T_3$ was followed by $L_2$ x $T_1$ (Plate 6) with respect to both relative heterosis (-11.89) and heterobeltiosis (-11.95). None of the hybrids showed significant positive heterosis over mid parent and better parent.

### 4.5.2 Number of days to final harvest

Out of the five hybrids with significant relative heterosis, $L_1$ x $T_3$ and $L_1$ x $T_2$ exhibited significant negative heterosis over mid parent (-4.30 and -4.04) respectively. $L_4$ x $T_2$ (5.74), $L_3$ x $T_1$ (3.79) and $L_4$ x $T_3$ (3.59) showed significant positive relative heterosis. Out of the two hybrids with significant negative heterobeltiosis, $L_1$ x $T_3$ had maximum value of -3.67 which was on par with $L_1$ x $T_2$ (-1.73). Three hybrids showed significant positive heterobeltiosis of which $L_4$ x $T_2$ had the maximum value (6.66).

### 4.5.3 Number of pods per plant

Eight hybrids showed significant positive heterosis over mid parent. $L_1$ x $T_3$ (Plate 7) showed maximum heterosis (81.70) which differed significantly from other hybrids. This was followed by $L_2$ x $T_2$ (63.03), $L_5$ x $T_2$ (47.26), $L_1$ x $T_1$ (38.86), $L_4$ x $T_1$ (38.54) and $L_5$ x $T_1$ (35.33). Out of the six positively heterobeltiotic hybrids $L_1$ x $T_3$ ranked

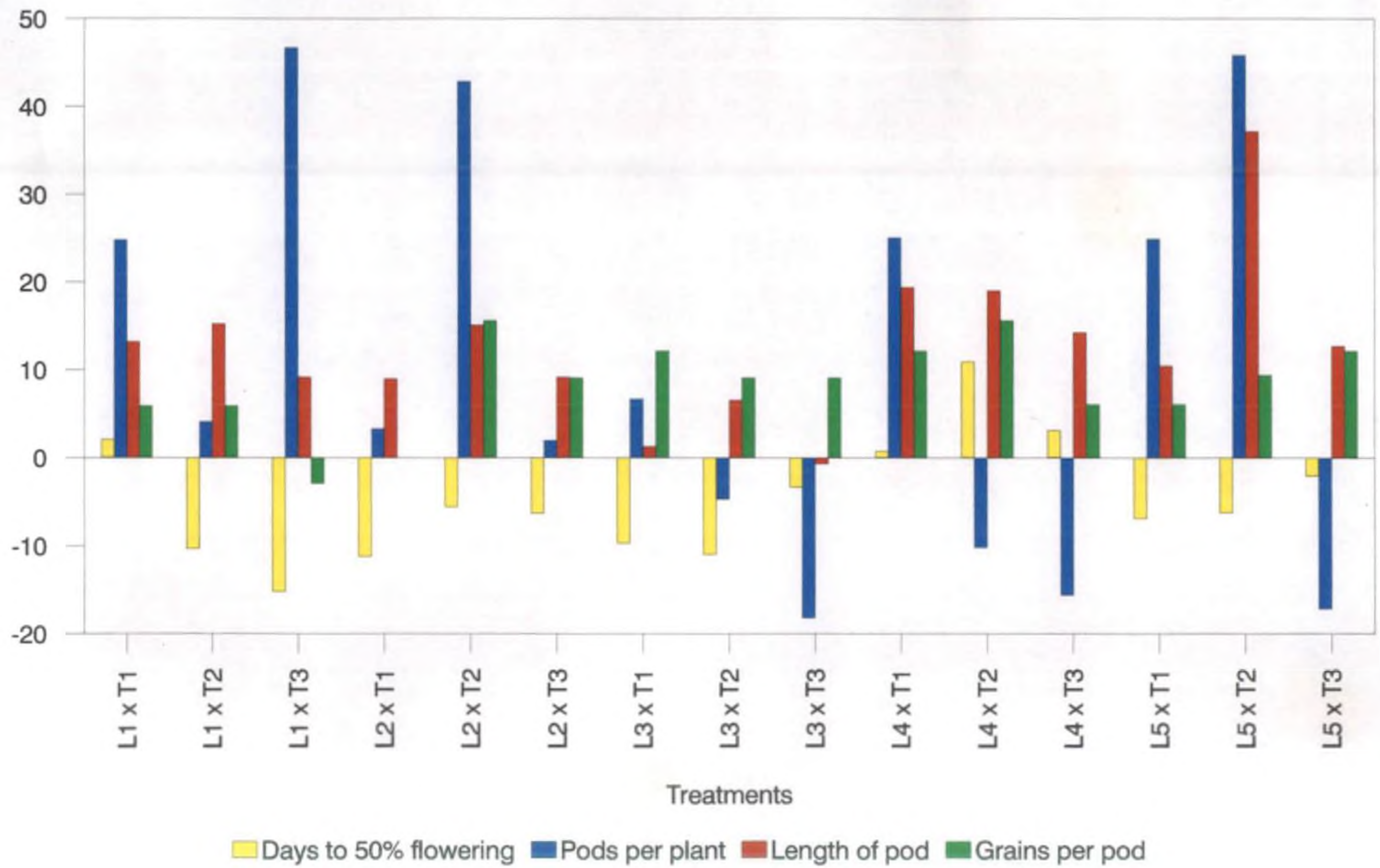


Fig. 7. Heterobeltiosis for various characters

first (46.63), followed by $L_5$ x $T_2$ (45.81) and $L_2$ x $T_2$ (42.80) which were on par with $L_1$ x $T_3$ (Fig. 7). None of the crosses showed significant negative relative heterosis or heterobeltiosis.

### 4.5.4 Length of pod

Significant positive heterosis was shown by all the 15 hybrids over midparent and 13 hybrids over better parent. The cross $L_5$ x $T_2$ (Plates 8 and 9) exhibited maximum significant positive heterosis over mid parent (42.88) and better parent (37.16). None of the hybrids were on par with $L_5$ x $T_2$ in terms of relative heterosis and heterobeltiosis. $L_5$ x $T_2$ was followed by $L_4$ x $T_1$ (20.27) and $L_4$ x $T_2$ (19.97) which were on par with each other with respect to relative heterosis. $L_4$ x $T_1$ (19.40) and $L_4$ x $T_2$ (19.01) were also on par with each other with respect to heterobeltiosis (Fig. 7). No hybrid showed significant negative relative heterosis or heterobeltiosis.

### 4.5.5 Number of grains per pod

The hybrid $L_4$ x $T_2$ exhibited maximum positive relative heterosis (19.35) which significantly differed from all the other hybrids. This was followed by $L_4$ x $T_1$ (17.46) and $L_2$ x $T_2$ (15.62). The crosses $L_4$ x $T_2$ and $L_2$ x $T_2$ (Fig. 7) showed maximum significant positive heterosis over better parent (15.62) followed by $L_3$ x $T_1$ (12.12), $L_4$ x $T_1$ (12.12) and $L_5$ x $T_3$ (12.12). Significant positive values were shown by 13 hybrids over


Plate 6

$L_2xT_1$ : heterotic for days to 50% flowering and harvest index


Plate 7

$L_1xT_3$ : heterotic for days to 50% flowering, number of pods per plant, grain yield per plant and photosynthetic efficiency

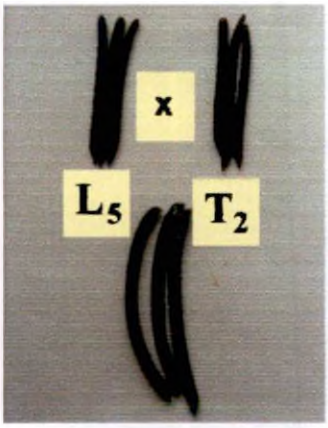


Plate 8


Plate 9

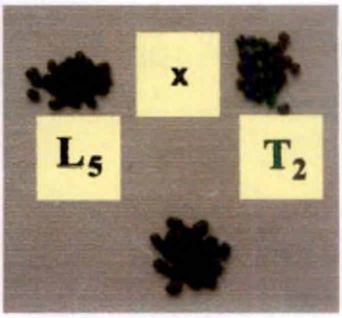


Plate 10

Plates 8, 9 and 10. $L_5xT_2$ : heterotic for number of pods per plant, length of pod and grain yield per plant


Plate 11. $L_3xT_2$ : heterotic for days to 50% flowering and harvest index

mid parent and 11 hybrids over better parent. None of the hybrids showed neither significant negative relative heterosis or heterobeltiosis.

### 4.5.6 Grain yield per plant

Among the 13 hybrids with significant positive relative heterosis, $L_5 \times T_2$ ranked first with a value of 201.88. None of the hybrids were on par with $L_5 \times T_2$ in terms of relative heterosis (Plate 10). $L_5 \times T_2$ was followed by $L_1 \times T_3$ (185.59) and $L_4 \times T_1$ (134.78). Out of the 10 hybrids with positive and significant heterobeltiosis, $L_5 \times T_2$ showed the maximum value of 183.18 which differed significantly from all other hybrids (Fig. 8). $L_1 \times T_3$ (132.98) and $L_4 \times T_1$ (115.89) showed significant positive heterosis over better parent. None of the hybrids exhibited significant negative heterosis over mid parent or better parent. $L_5 \times T_2$, $L_1 \times T_3$ and $L_4 \times T_1$ are three superior crosses with respect to yield which exhibited high values for both the types of heterosis.

### 4.5.7 Leaf Area Index

Significant positive heterosis over mid parent and better parent was shown by only one hybrid, $L_2 \times T_2$ with values 80.02 and 43.80 respectively. Out of the nine hybrids with significant negative relative heterosis, $L_1 \times T_1$ ranked first (-63.88) followed by $L_1 \times T_3$ (-54.87) and $L_5 \times T_2$ (-53.35). Among the 13 crosses with significant negative heterobeltiosis, $L_1 \times T_1$ showed the maximum value of -65.60 (Fig. 8) followed by $L_5 \times T_2$ (-62.82) and $L_1 \times T_3$ (-58.09).

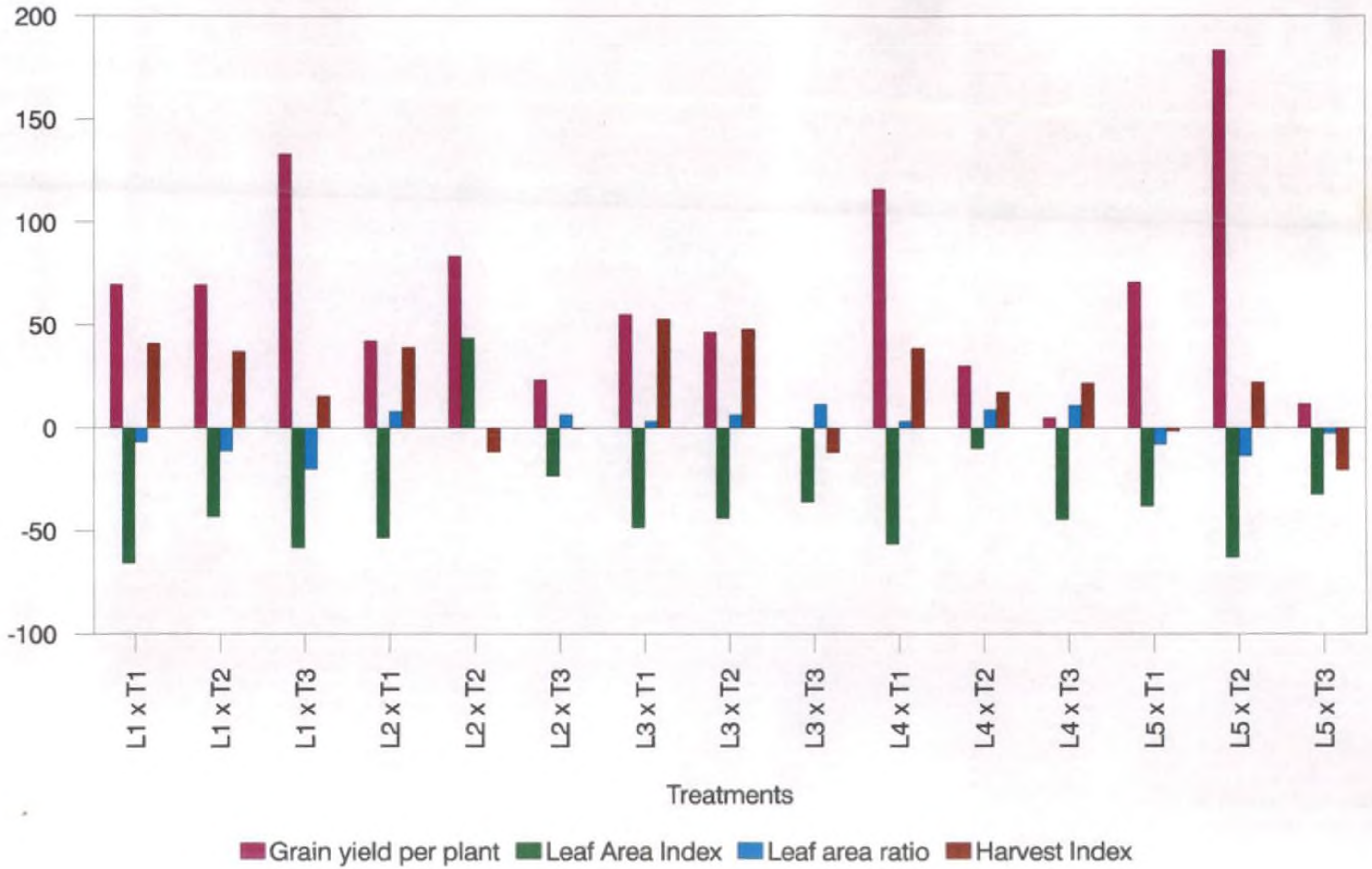


Fig. 8. Heterobeltiosis for various characters

### 4.5.8 Photosynthetic efficiency (in terms of leaf area

Maximum significant negative relative heterosis for was shown by $L_1$ x $T_3$ (-21.44) which was on par with $L_5$ $L_1$ x $T_2$ (-14.84) and $L_2$ x $T_2$ (-13.82). The hybrid, $L_1$ x T exhibited maximum significant negative heterobeltiosis ( was on par with $L_5$ x $T_2$ (-13.63) and $L_1$ x $T_2$ (-11.10). hybrids showed significant negative relative heterosis and 5 l negative heterobeltiosis. Out of the 4 hybrids with signif values, maximum positive relative heterosis was observec (7.26) while $L_3$ x $T_3$ exhibited maximum positive heterobel

### 4.5.9 Harvest Index

Among the 11 hybrids with significant positive h mid parent, $L_3$ x $T_1$ had maximum heterosis (59.51) wl significantly from all other hybrids. $L_3$ x $T_1$ was followe (58.10) (Plate 11) and $L_4$ x $T_1$ (51.41). Out of the 1 heterobeltiotic hybrids (Fig. 8) $L_3$ x $T_1$ ranked first (52.71) $L_3$ x $T_2$ (48.15) and $L_1$ x $T_1$ (41.09). None of the hybrids with $L_3$ x $T_1$ in terms of positive heterobeltiosis. $L_5$ x $T_3$ hybrid which had significant negative heterosis over bot (-18.33) and better parent (-20.54).

# DISCUSSION

# 5. DISCUSSION

The research programme was carried out at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani as an initial step to develop superior greengram varieties for yield and adaptability under partially shaded conditions of coconut gardens in Kerala. The basic steps in heterosis breeding programme include selection of desirable parents, evaluation of parents and hybrid seed production. In the present study the selected five shade tolerant lines and three testers were evaluated in a line x tester cross. The combining ability effects and heterosis of single crosses were studied and superior crosses were identified. A brief discussion regarding the results obtained is furnished below.

## 5.1 Mean performance

In the early days of breeding research, methods like selection was purely based on the mean performance of the concerned genotypes. Hybridisation programmes also require rigorous selection for the identification of suitable parents. In the present study combining ability of parents and *per se* performance of genotypes are given due consideration.

Among the 12 characters studied, the data on the character incidence of pest and disease was not subjected to analysis of variance since the attack was negligible and not serious enough to cause economic damage. Analysis of variance on the mean data of the other 11 characters revealed significant differenceS among the 23 genotypes of greengram for all the characters except plant height and shade intensity.

The periodical shade intensity measured during flowering and pod formation stages in each plot at three intervals of the day did not show any significant differences which indicated the prevalence of uniform shade condition in all the experimental plots. The experimental area was under on an average of 50 to 55 per cent shade.

Among lines $L_4$ (RMG.353) was the earliest in the production of 50 per cent flowers and among testers $T_1$ (Phillippines) took the minimum number of days to 50 per cent flowering. Shortest duration of the crop was also shown by the same parents. Among the hybrids, $L_2 \times T_1$ (Ganga 4 x Phillippines) was the earliest to produce 50 per cent flowers. Seven other hybrids were on par with $L_2 \times T_1$. Shortest duration of the crop was shown by the hybrids $L_1 \times T_2$ (IIPRM.3 x *Pusa baisakhi*) $L_5 \times T_2$ (LGG.460 x *Pusa baisakhi*) which were on par with nine other hybrids.

The line $L_5$ (LGG.460) produced the maximum number of pods per plant and among testers $T_3$ (CO.2) was the best parent for this character. The hybrid $L_1$ x $T_3$ (IIPRM.3 x CO.2) produced the maximum number of pods per plant. The performance of the hybrid $L_1$ x $T_3$ was better than that of the best parent $T_3$.

The longest pods were produced by $L_3$ (MGG.314) among lines and by $T_2$ (*Pusa baisakhi*) among testers. The hybrid $L_5$ x $T_2$ (LGG.460 x *Pusa baisakhi*) was significantly superior than the best parent $L_3$ for the trait. None of the hybrids was on par with $L_5$ x $T_2$ which had the longest pods.

The line $L_1$ (IIPRM.3) produced the maximum number of grains per pod and the testers $T_1$ (Phillippines) and $T_3$ (CO.2) had the maximum number of grains per pod. Among hybrids $L_2$ x $T_2$ (Ganga.4 x *Pusa baisakhi*), $L_3$ x $T_1$ (MGG.314 x Phillippines), $L_4$ x $T_1$ (RMG.353 x Phillippines) $L_4$ x $T_2$ (RMG.353 x *Pusa baisakhi*) and $L_5$ x $T_3$ (LGG.460 x CO.2) had the highest number of grains per pod and were on par with 8 other hybrids for the above trait.

Grain yield per plant was maximum for $L_3$ (MGG.314) and $T_3$ (CO.2) among parents. The hybrid $L_5$ x $T_2$ (LGG.460 x *Pusa baisakhi*) recorded the maximum mean yield which was higher than that of the best parent $T_3$. The hybrid $L_1$ x $T_3$ (Phillippines x CO.2) was on par with the highest yielding hybrid $L_5$ x $T_2$.

Among lines $L_1$ (IIPRM.3) showed the highest LAI whereas among testers $T_3$ (CO.2) exhibited the highest LAI. $L_2$ x $T_2$ (Ganga.4 x *Pusa baisakhi*) was the best hybrid for the trait.

Highest photosynthetic efficiency (in terms of LAR) was exhibited by $L_3$ (MGG.314) among lines and by $T_2$ (*Pusa baisakhi*) among testers. The hybrid $L_1$ x $T_3$ (IIPRM.3 x CO.2) had the maximum photosynthetic efficiency which was higher than the best parent $L_3$. Three other hybrids viz., $L_1$ x $T_2$, $L_2$ x $T_2$ and $L_5$ x $T_2$ were on par with the best hybrid $L_1$ x $T_3$.

In terms of harvest index, $L_5$ (LGG.460) was the best line and $T_3$ (CO.2) the best tester. Among the crosses $L_5$ x $T_2$ (LGG.460 x *Pusa baisakhi*) was the superior hybrid. There were 6 other hybrids which had harvest index higher than the best parent $L_5$. Among the superior hybrids $L_5$ x $T_2$ (LGG.460 x *Pusa baisakhi*), $L_5$ x $T_1$ (LGG.460 x Phillippines) and $L_1$ x $T_3$ (IIPRM.3 x CO.2) showed low incidence of pod bug infestation.

From the above discussion it can easily be comprehended that all hybrids are not equally superior for various characters. Based on the mean performance, a few hybrids can be projected as best in terms of their economic traits. They include $L_5$ x $T_2$ (LGG.460 x *Pusa baisakhi*) - superior in days to final harvest, number of pods per plant, length of pod, number of grains per pod, grain yield per plant, photosynthetic efficiency, harvest index and field tolerance to pod bug, $L_1$ x $T_3$ (IIPRM.3 x CO.2) - superior in days to 50 per cent flowering, days to final harvest, number of pods per plant, grain yield per plant, photosynthetic efficiency and field tolerance to pod bug, $L_1$ x $T_2$ (IIPRM.3 x *Pusa baisakhi*) - superior in days to 50 per cent flowering, days to final harvest, number of grains per pod and photosynthetic efficiency, $L_2$ x $T_2$ (Ganga.4 x *Pusa baisakhi*) - superior in days to final harvest, number of grains per pod, LAI and photosynthetic efficiency), $L_4$ x $T_1$ (RMG.353 x Phillippines) - days to 50 per cent flowering, days to final harvest, number of grains per pod and harvest index and $L_5$ x $T_1$ (LGG.460 x Phillippines) - superior in days to final harvest, number of grains per pod and field tolerance to pod bug. Among parents, $L_3$ (MGG.314) and $L_5$ (LGG.460) were observed to be the superior lines and $T_3$ (CO.2) the superior tester on the basis of mean performance for yield and many yield attributes.

### 5.2 Gene action

Analysis of variance for combining ability gives an estimate of the variance due to lines, testers and line x tester which is an indication of the type of gene action responsible for the variation in each character. Significant mean sum of squares due to lines and testers indicate that additive gene action is operative while significant mean sum of squares due to line x tester shows that non-additive gene action (dominance and epistasis) is controlling the character. The existence of significant amount of dominance variance is a pre-requisite for the exploitation of heterosis (Singh and Narayanan, 1993).

Both GCA and SCA variances were found to be significant for length of pod. This suggests the involvement of both additive and non-additive gene action for the expression of this trait. The ratio of additive variance to dominance variance was found to be less than unity indicating the predominant role of non-additive gene action. Contrary to this, additive gene action was reported for pod length by Sawant (1995) in cowpea. Contribution of lines to total variance was maximum for this trait.

The analysis of variance revealed that variance due to SCA alone was significant for the characters, days to 50 per cent flowering, number of pods per plant, number of grains per pod, grain yield per plant, leaf area index, photosynthetic efficiency and harvest index indicating the importance of non-additive gene action in the inheritance of these traits. This is in agreement with the reports of Kaliya *et al.* (1991) in blackgram, Naidu and Satyanarayana (1993) in greengram, Thiyagarajan *et al.* (1993) in cowpea, Mishra and Yadav (1994) in bengalgram, Rosaiah *et al.* (1994) in greengram and Santha and Veluswamy (1999) in blackgram. Contradictory results were reported by Patel *et al.* (1994) in cowpea, Annigeri *et al.* (1996) in bengalgram, Dasgupta *et al.* (1998) in greengram and Manivel and Rangasamy (1998) in redgram.

Proportional contribution of crosses to total variance was the highest for all the above mentioned traits except for photosynthetic efficiency where both lines and crosses contributed almost equally to total variance.

Variance due to GCA and SCA were found to be non-significant for number of days to final harvest indicating the non-significance of additive and non-additive genetic components in the expression of this trait. This finding is contrary to the observations of Pandey (1999) in redgram indicating partial dominance of additive gene action for the character. Lines and crosses contributed almost equally to the total variance for this trait.

## 5.3 Combining ability and heterosis

In the present study, good crosses under shaded conditions can be identified by taking into consideration the heterosis, sca effect and per se performance of hybrids and gca effect of parents.

For days to 50 per cent flowering, significant values of relative heterosis and heterobeltiosis was shown by $L_1$ x $T_3$ (IIPRM.3 x CO.2). This cross had maximum negative sca effect for the trait and low (favourable) mean value, though both the parents of the hybrid did not have significant gca effects. Mandal and Bhal (1987) reported in a similar manner for the trait in bengalgram. Most of the heterotic hybrids were obtained from combinations of parents with low gca effects in a study by Kumar and Bahl (1988) in bengalgram. Similar results were also reported earlier by Cheralu *et al.* (1989) in redgram and Shinde and Deshmukh (1993) in bengalgram. Other crosses with significant heterosis and sca effect were $L_1$ x $T_2$ (IIPRM.3 x *Pusa baisakhi*), $L_2$ x $T_1$ (Ganga 4 x Phillippines) and $L_3$ x $T_2$ (MGG.314 x *Pusa baisakhi*). All these crosses had high *per se* performance on par with $L_1$ x $T_3$. The superiority of $L_2$ x $T_1$ could be assigned to the significant and high gca effect of the parent $L_2$ and the superiority of the other hybrids may be due to the negative gca effect of both the parents as in the case of $L_3$ x $T_2$ or at least one of the parents as in $L_1$ x $T_2$.

Significant values of relative heterosis and heterobeltiosis were shown by $L_1$ x $T_3$ (IIPRM 3 x CO.2) for days to final harvest. This cross also possessed high *per se* performance. $L_1$ x $T_2$ (IIPRM.3 x *Pusa baisakhi*) was on par with $L_1$ x $T_3$ in terms of relative heterosis and heterobeltiosis and *per se* performance. Here heterosis may be attributed to the presence of $L_1$ which had maximum significant negative gca effect as one of the parents in both the crosses. This is in agreement with the result of Katiyar and Katiyar (1993) in bengalgram.

For number of pods per plant heterosis over mid parent and better parent was significant in $L_1$ x $T_3$ (IIPRM.3 x CO.2) which had maximum sca effect and the highest *per se* performance. The cross $L_5$ x $T_2$ (LGG.460 x *Pusa baisakhi*) was on par with $L_1$ x $T_3$ in terms of heterobeltiosis and *per se* performance. The hybrid $L_2$ x $T_2$ (Ganga 4 x *Pusa baisakhi*) also showed significant heterosis over mid parent and better parent and better *per se* performance. Both these crosses had significant sca effects.

This heterosis may be due to the significant gca effect of one of the parents involved in the cross as in $L_1$ x $T_3$ and $L_5$ x $T_2$ or due to the positive low gca effect of both parents involved in the cross $L_2$ x $T_2$. Results in this line for the trait were presented earlier by Kumar and Bahl (1988) in bengalgram, Pandey (1999) in redgram and Bhushana *et al.* (2000) in cowpea.

The $F_1$ hybrid $L_5$ x $T_2$ (LGG.460 x *Pusa baisakhi*) showed highly significant values for heterosis over mid parent and better parent, sca effect, gca effect of both the parents and *per se* performance for the character length of pod. None of the hybrid was on par with $L_5$ x $T_2$ for any of the above attributes. This high heterosis may be due to the high and significant gca effects of both the parents involved in the cross. This is in agreement with the result of Bhushana *et al.* (2000) in cowpea. But this result is contradictory with the result of Singh *et al.* (1999) in redgram where the heterotic response for pod length over the mid parental value was in an undesirable direction in almost all the crosses.

For number of grains per pod, relative heterosis and heterobeltiosis were significant and high in $L_4$ x $T_2$ (RMG.353 x *Pusa baisakhi*). This cross also possessed the maximum mean value for the trait. The hybrids $L_2$ x $T_2$ (Ganga 4 x *Pusa baisakhi*), $L_3$ x $T_1$ (MGG.314 x Phillippines), $L_4$ x $T_1$ (RMG.353 x Phillippines) and $L_5$ x $T_3$ (LGG.460 x CO.2) had significant heterosis over mid parent and better parent and had the same mean value as in $L_4 \times T_2$. The heterotic hybrids for this trait were obtained from combinations of parents with low gca effects. This is in conformity with the results obtained by Kumar and Bahl (1988) in bengalgram. Heterosis for this character was reported earlier by Savithramma and Latha (1999) in cowpea and by Joseph and Santhoshkumar (2000) in greengram.

Both relative heterosis and heterobeltiosis were maximum in the cross $L_5 \times T_2$ (LGG.460 x *Pusa baisakhi*) for the trait grain yield per plant. This cross had significant and high positive sca effect and the highest *per se* performance for the trait. The superiority of this cross may be attributed to the maximum significant gca effect of both the parents. The same result was reported by Ghafoor *et al.* (2000) in blackgram for yield per plant. Other crosses with significant heterosis over mid parent and better parent were $L_1 \times T_3$ (IIPRM.3 x CO.2), $L_2 \times T_2$ (Ganga 4 x *Pusa baisakhi*) and $L_4 \times T_1$ (RMG.353 x Phillippines). All these crosses possessed significant sca effect except for $L_2 \times T_2$ and had high *per se* performance for the trait. The gca effect was significant for $L_1$ and $T_2$. Similar results for yield per plant were reported by Kumar and Bahl (1988) in bengal gram, Shinde and Deshmukh (1993) in bengalgram, Manivel and Rangasamy (1998) in redgram, Neog and Talukdar (1999) in blackgram, Maheswari *et al.* (1999) in soybean, Aher *et al.* (2000) in greengram and Bhushana *et al.* (2000) in cowpea. For most of the better combinations for yield per plant, no direct association could be established between the gca of parents involved in the crosses and sca and heterotic response of the hybrids. This is in agreement with the result of Katiyar and Katiyar (1993) in bengalgram. Contradictory result, i.e. absence of positive heterosis for the trait was reported by Singh *et al.* (1999) in redgram.

For the character, leaf area index only one hybrid $L_2$ x $T_2$ (Ganga 4 x *Pusa baisakhi*) showed significant positive heterosis over mid parent and better parent. This hybrid also had significant sca effect and the highest *per se* performance. Here heterosis may be due to the significant gca effect of the line $L_2$ involved in the cross.

The hybrid $L_1$ x $T_3$ (IIPRM.3 x CO.2) showed significant values for heterosis over mid parent and better parent for the character leaf area ratio. This cross had significant negative sca effect and the lowest (favourable) mean value. The crosses $L_1$ x $T_2$ (IIPRM.3 x *Pusa baisakhi*) and $L_5$ x $T_2$ (LGG.460 x *Pusa baisakhi*) also showed significant negative heterosis. The hybrid $L_2$ x $T_2$ (Ganga 4 x *Pusa baisakhi*) possessed negative significant relative heterosis and sca effect. All these crosses were on par with $L_1$ x $T_3$ in terms of *per se* performance. This heterosis may be due to the negative gca effect of atleast one of the parents involved in the cross.

In the present study, leaf area ratio (LAR) was taken as a measure of photosynthetic efficiency. Lower the LAR higher is the photosynthetic efficiency. Though the crosses $L_1$ x $T_3$ (IIPRM.3 x CO.2), $L_1$ x $T_2$ (IIPRM.3 x *Pusa baisakhi*) and $L_5$ x $T_2$ (LGG.460 x *Pusa baisakhi*) showed non-significant heterosis and low *per se* performance for leaf area index, these hybrids had significant and high heterosis, sca effect and low *per se* performance for LAR showing that these hybrids are photosynthetically more efficient. This is in line with the result of Suh Sugkee *et al.* (2000) in soybean. They reported that soybean cultivars with smaller leaf area have shown better light distribution through their canopy and a higher photosynthetic rate than those with larger leaf area.

Maximum values of heterosis over both mid parent and better parent was exhibited by the cross $L_3$ x $T_1$ (MGG.314 x Phillippines) for harvest index. This hybrid had positive sca effect and high *per se* performance for the trait. The crosses $L_3$ x $T_2$ (MGG.314 x *Pusa baisakhi*), $L_1$ x $T_1$ (IIPRM.3 x Phillippines), $L_2$ x $T_1$ (Ganga.4 x Phillippines) and $L_4$ x $T_1$ (RMG.353 x Phillippines) also showed significant relative heterosis and heterobeltiosis. $L_3$ x $T_2$ and $L_2$ x $T_1$ had significant sca effect. All hybrids except $L_1$ x $T_1$ had high *per se* performance. The superiority may be attributed to the high gca effect of the common parent $T_1$ in the crosses $L_3$ x $T_1$, $L_1$ x $T_1$, $L_2$ x $T_1$ and $L_4$ x $T_1$. Result in a similar line was presented by Natarajan (1989) in greengram for this character.

In general, four crosses viz. $L_2$ x $T_1$ (Ganga 4 x Phillippines), $L_3$ x $T_2$ (MGG.314 x *Pusa baisakhi*), $L_5$ x $T_2$ (LGG 460 x *Pusa baisakhi*) and $L_1$ x $T_3$ (IIPRM.3 x CO.2) could be identified as superior for economically important traits. They had high heterosis, high sca effect and better *per se* performance under shade. The hybrids $L_2$ x $T_1$ (Ganga 4 x Phillippines) and $L_3$ x $T_2$ (MGG.314 x *Pusa baisakhi*) were identified as superior in terms of days to 50 per cent flowering and harvest index. For yield and yield attributes like number of pods per plant and pod length, the hybrid $L_5$ x $T_2$ (LGG.460 x *Pusa baisakhi*) was observed to be superior. The cross $L_1$ x $T_3$ (IIPRM.3 x CO.2) was superior in terms of days to 50 per cent flowering, number of pods per plant, grain yield per plant and photosynthetic efficiency. The hybrids $L_5$ x $T_2$ and $L_1$ x $T_3$ showed very low incidence of pod bug infestation which may be regarded as an added advantage to the superior crosses.

# SUMMARY

# 6. SUMMARY

The present investigation "Combining ability for shade tolerance and yield in greengram (*Vigna radiata* (L.) Wilczek) grown under coconuts" was conducted at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 1998-2000. The experiment was carried out in a line x tester pattern with five lines, three testers and fifteen hybrids designed in a Randomised Block Design with three replications. Major objectives of the study were identification of gene action, estimation of combining ability effects of parents and hybrids and identification of superior $F_1$ hybrids in greengram.

Observations were recorded on various biometric traits viz., days to 50 per cent flowering, days to final harvest, height of plants, number of pods per plant, length of pod, number of grains per pod, grain yield per plant, leaf area index, shade intensity, photosynthetic efficiency, harvest index and incidence of pests and diseases.

The twenty three genotypes showed significant differences for all the eleven characters subjected to statistical analysis except height of plants and shade intensity. Among lines, $L_3$ (MGG.314) and $L_5$

(LGG.460) were superior in mean performance for days to final harvest, number of pods per plant, length of pod, number of grains per pod and grain yield per plant. The line $L_3$ (MGG.314) was also superior in terms of leaf area index and photosynthetic efficiency whereas $L_5$ (LGG.460) topped in mean performance for harvest index. Among testers $T_3$ (CO.2) was superior in mean performance for grain yield per plant, number of pods per plant, length of pod, number of grains per pod, leaf area index, photosynthetic efficiency and harvest index.

The hybrids $L_5$ x $T_2$ (LGG.460 x *Pusa baisakhi*) and $L_1$ x $T_3$ (IIPRM.3 x CO.2) were superior with respect to yield, pod characters, photosynthetic efficiency and tolerance to pod bug in mean performance. The hybrid $L_2$ x $T_2$ (Ganga 4 x *Pusa baisakhi*) was superior in mean performance for crop duration, number of grains per pod, leaf area index and photosynthetic efficiency while $L_4$ x $T_1$ (RMG. 353 x Phillippines) was superior in traits like days to 50 per cent flowering, crop duration, number of grains per pod and harvest index.

Analysis of variance for combining ability revealed that variance due to SCA alone was significant for all the characters except length of pod and days to final harvest which indicated the importance of non-additive gene action in the inheritance of these traits. For length of pod, GCA variance and SCA variance were significant and the predominant role of non-additive gene action was found for the expression of this trait. Variance due to GCA and SCA were non-significant for number of days to final harvest.

Combining ability analysis indicated that the line $L_5$ (LGG. 460) was the best general combiner for yield and length of pod. $L_1$ (IIPRM. 3) was the best combiner for days to final harvest, pods per plant and photosynthetic efficiency whereas $L_2$ (Ganga 4) was the best combiner for earliness and leaf area index. $L_4$ (RMG.353) was the best combiner for harvest index. Among testers, $T_2$ (*Pusa baisakhi*) was the best general combiner for yield, length of pod and photosynthetic efficiency, $T_1$ (Phillippines) for harvest index and $T_3$ (CO.2) for leaf area index. The hybrid $L_1$ x $T_3$ (IIPRM.3 x CO.2) was the best specific combiner for yield, pods per plant, and days to 50 per cent flowering, $L_5$ x $T_2$ (LGG. 460 x *Pusa baisakhi*) for length of pod and harvest index and $L_2$ x $T_2$ (Ganga 4 x *Pusa baisakhi*) for leaf area index and photosynthetic efficiency.

Significant heterosis was observed for all the nine characters showing significant differences among genotypes. Ten hybrids possessed both relative heterosis and heterobeltiosis for yield. Maximum heterosis over mid parent and better parent for yield was shown by $L_5$ x $T_2$ (LGG.460 x *Pusa baisakhi*). This cross also showed the highest heterosis over mid parent and better parent for length of pod. The hybrid $L_1$ x $T_3$ (IIPRM.3 x CO.2) showed maximum relative heterosis and heterobeltiosis for days to 50 per cent flowering, days to final harvest, number of pods per plant and photosynthetic efficiency, $L_4$ x $T_2$ (RMG.353 x *Pusa baisakhi*) for number of grains per pod, $L_2$ x $T_2$ (Ganga 4 x *Pusa baisakhi*) for leaf area index and $L_3$ x $T_1$ (MGG.314 x Phillippines) for harvest index.

All hybrids with high estimates of heterosis were found to be good specific combiners for that trait with better *per se* performance. Taking into consideration the heterosis, sca effect and *per se* performance of hybrids, $L_5$ x $T_2$ (LGG. 460 x *Pusa baisakhi*) was identified as superior in yield, number of pods per plant and length of pod whereas $L_1$ x $T_3$ (IIPRM. 3 x CO.2) was also superior in yield and number of pods per plant apart from days to 50 per cent flowering and photosynthetic efficiency. These crosses also showed field tolerance to pod bug infestation. The hybrids $L_2$ x $T_1$ (Ganga 4 x Phillippines) and $L_3$ x $T_2$ (MGG. 314 x *Pusa baisakhi*) were identified as superior in terms of days to 50 per cent flowering and harvest index.

The study in general indicated that in view of the preponderance of non-additive gene action for grain yield per plant and all yield attributes, commercial exploitation of hybrid vigour would be the most appropriate method of utilising such gene action for the improvement of these traits. The above mentioned hybrids can be carried forward to evolve high yielding shade tolerant varieties.

# REFERENCES

# REFERENCES

Aher, R.P., Dahat, D.V. and Sonowane, V.P. 1999. Combining ability studies in mungbean (*Vigna radiata* (L.) Wilczek). *Crop Res.* 18: 256-260

Aher, R.P., Sonawane, V.P. and Dahat, D.V. 2000. Heterosis in mungbean (*Vigna radiata* (L.) Wilczek) *Indian J. agric. Res.* 34: 134-137

Andhale, B.M., Patil, J.G. and Dumbre, A.D. 1996. Heterosis and inbreeding depression studies in blackgram. *J. Maharashtra agric. Univ.* 21: 141-142

Anilkumar, S.G. 1993. Combining ability for yield and drought tolerance in cowpea (*Vigna unguiculata* (L.) Walp). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p.99

Annigeri, B.S., Salimath, P.M., Patil, S.J. and Venkataswamy, B.H. 1996. Genetic analysis to identify potential parents and crosses for yield improvement in chickpea. *Indian J. Genet.* 56: 114-116

Babu, R.C. and Nagarajan, M. 1993. Growth and development of soybean (*Glycine max* (L.) Merrill) cultivars under shade in coconut garden. *J. Agron. Crop Sci.* 171: 279-283

Bahl, P.N. and Kumar, J. 1989. Evaluation and utilisation of high yielding hybrids of chickpea. *Indian J. Genet.* 49: 53-58

Bastawisy, M.B., Eissa, M.S., Ali, K.A., Mansour, S.H. and Ali, M.S. 1997. Gene effect and heritability in soybean (*Glycine max* (L.) Merrill). *Ann. agric. Sci.* 35: 15-24

*Bejiga, G. and Singh, K.B. 1991. Estimation of heterosis in kabuli chickpea. *Acta Agronomica Hungaria,* 40: 145-150

Bhadra, K. 1998. Heterosis and combining ability in greengram (*Vigna radiata* (L.) Wilczek) for biological nitrogen fixation and yield. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p.103

Bhor, T.J., Kute, N.S., Dumbre, A.D. and Sarode, N.D. 1997. Heterosis and inbreeding depression in cowpea. *Indian J. agric. Res.* 31: 122-126

Bhushana, H.O., Viswanatha, K.P., Arunachalam, P. and Halesh, G.K. 2000. Heterosis in cowpea (*Vigna unguiculata* (L.) Walp) for seed yield and its attributes. *Crop Res.* 19: 277-280

Bhushana, H.O., Viswanatha, K.P., Manjunatha, A., Kulkarni, R.S. and Khyad, P.R. 1998. Combining ability for seed yield and its components in cowpea (*Vigna unguiculata* (L.) Walp). *Crop Improv.* 25: 116-118

Boiling, M., Sander, D.A. and Matlock, R.S. 1961. Mungbean hybridisation technique. *Agron. J.* 55 : 54-55

Candra, S. and Nijhawan, D.C. 1979. Estimates of components of genetic variance and combining ability for leaf area index in a diallelcross of mungbean. *Legume Res.* 2: 79-84

Chandirakala, R. and Raveendran, T.S. 1998. Combining ability for grain yield and its components in pigeonpea. *Crop Res.* 16: 362-367

Chauhan, C.S. and Joshi, R.K. 1981. A note on combining ability in cowpea. *Legume Res.* 4: 112-114

Cheralu, C., Muralidhar, V., Satyanarayana, A. and Venkateswaralu, S. 1989. Heterosis in relation to combining ability in pigeonpea (*Cajanus cajan*). *Indian J. agric. Sci.* 59: 68-70

*Cho Young, K. and Scott, R.A. 2000. Combining ability of seed vigour and seed yield in soybean. *Euphytica,* 112: 145-150

Chowdhury, R.K. 1986. Combining ability analysis for seed yield and its components in mungbean. *Crop improv.* 13: 95-97

Dabholkar, A.R. 1992. *Elements of biometrical genetics.* Concept Publishing Co., New Delhi, p.431

*Damarany, A.M. 1994. Estimates of heterosis and drought tolerance of cowpea under gradient irrigation systems I, II and III. *Assiut J. agric. Sci.* 25: 27-56

Dasgupta, T., Banik, A. and Das, S. 1998. Combining ability in mungbean. *Iranian J. agric. Sci.* 11: 28-32

Dasgupta, T., Dey, G., Gayen, P., Mandal, S.K. and Dutta, S. 1992. Combining ability for harvest index in mungbean. *Exp. Genet.* 8: 1-4

Deshmukh, R.B. and Bhapkar, D.G. 1982. Physiological genetics of yield in chickpea I. Estimates of components of genetic variances. *Legume Res.* 5: 63-65

Deshmukh, R.B. and Manjare, M.R. 1980. Combining ability in mungbean (*Vigna radiata* (L.) Wilczek). *Legume Res.* 3: 97-101

Durong, J.K. 1980. Genetic divergence, combining ability and heterosis in soybean (*Glycine max* (L.) Merrill). Ph.D. thesis, Kerala Agricultural University, Thrissur, p.196

Gadag, R.N. and Upadhyaya, H.D. 1995. Heterosis in soybean (*Glycine max* (L.) Merrill), *Indian J. Genet.* 55: 308-314

Gadag, R.N., Upadhyaya, H.D. and Goud, J.V. 1990. Studies on harvest index in soybean. *Legume Res.* 13: 193-196

Gadag, R.N., Upadhyaya, H.D. and Goud, J.V. 1999. Genetic analysis of yield, protein, oil and other related traits in soybean. *Indian J. Genet.* 59: 487-492

Ghafoor, A., Ahmad, Z., Afzal, M. and Qureshi, A.S. 2000. Influence of genetic diversity and combining ability in determining hybrid vigour in blackgram (*Vigna mungo* L. Hepper). *Indian J. Genet.* 60: 125-131

Halkude, I.S. Aher, R.P., Deshmukh, R.B. and Kute, N.S. 1996. Combining ability analysis in greengram. *J. Maharashtra agric. Univ.* 21: 235-238

Haque M.F., Ganguli, D.K. and Mishra, A.K. 1988. Combining ability and heterosis in urdbean. *Indian J. Pulses Res.* 1: 6-11

Hazarika, G.N., Singh, V.P. and Kharb, R.P.S. 1988. Combining ability for grain yield and its components in pigeonpea. *Indian J. Pulses Res.* 1: 111-117

Hazra, P., Das, P.K. and Som, M.G. 1993. Analysis of heterosis for pod yield and its components in relation to genetic divergence of the parents and specific combining ability of the cross in cowpea (*Vigna unguiculata* (L.) Walp). *Indian J. Genet.* 53: 418-423

Hazra, P., Das, P.K. and Som, M.G. 1996. Combining ability for pod yield and seed protein in cowpea (*Vigna unguiculata* (L.) Walp). *Indian J. Genet.* 56: 553-555

Hooda, J.S., Tomer, Y.S., Singh, V.P. and Singh, S. 1999. Heterosis and inbreeding depression in pigeonpea (*Cajanus cajan* L. Mill. sp.). *Legume Res.* 22: 62-64

Jahagirdhar, J.E., Patil, R.A., Ghodke, M.K. and Kardile, K.R. 1994. Combining ability studies in chickpea. *Indian J. Pulses Res.* 7: 21-24

Jayarani, L.S. and Manju, P. 1996. Combining ability in grain cowpea. *J. trop. Agric.* 34: 93-95

Joseph, J. and Santhoshkumar, A.V. 2000. Heterosis and inbreeding depression in greengram (*Vigna radiata* (L.) Wilczek) *Legume Res.* 23: 118-121

Kalia, R.K., Gupta, V.P. and Kalia, N.R. 1988. Estimates of heterosis and inbreeding for seed yield over locations in urdbean. *Indian J. Pulses Res.* 1: 43-49

Kalia, R.K., Gupta, V.P. and Kalia, N.R. 1991. Combining ability studies for seed yield and its components over environments in blackgram. *Indian J. Genet.* 51: 42-46

Kamatar, M.Y., Biradar, B.D. and Hiremath, S.M. 1996. Heterosis studies in chickpea (*Cicer arietinum* L.) *Crop Res.* 11: 174-178

Katiyar, R.P. and Katiyar, P.K. 1993. Heterosis and combining ability effects in chickpea. *Indian J. Pulses Res.* 69: 127-131

Katiyar, R.P., Solanki, R.K., Singh, H.G., Singh, I.B. and Singh, K.P. 1988. Choice of parents and hybrids for improving productivity from a six parent diallel cross in chickpea. *Indian J. Genet.* 48: 297-301

KAU, 1998. Package of Practices Recommendations Crops 1996. Kerala Agricultural University, Directorate of Extension, Mannuthy, Thrissur, p.267

Khorgade, P.W., Wankhade, R.R. and Wanjari, K.B. 2000. Combining ability analysis in pigeonpea using male sterile lines. *Indian J. agric. Res.* 34: 112-116

Kumar, J. and Bahl, P.N. 1988. Hybrid vigour and nicking ability in chickpea. *Indian J. Pulses Res.* 1: 96-101

Kumar, S., Rheenen, H.A. and Singh, O. 1999. Genetic analysis of different components of crop duration in chickpea. *Indian J. Genet.* 59: 189-200

Kumar, S.G.A. 1993. Combining ability for yield and drought tolerance in cowpea (*Vigna unguiculata* (L.) Walp). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p.99

Lakshmamma, P. and Rao, I.V.S. 1996. Response of blackgram (*Vigna mungo* L.) to shade and napthalene acetic acid. *Indian J. Pl. Physiol.* 1: 63-64

*Laosuwan, P., Saenpratoon, S., Kalawong, S. and Thongsomri, A. 1990. Breeding mungbean for shade tolerance. *Proc. of the mungbean meeting*: Chiang Mai, Thailand, Feb. 23-24, pp. 95-100

Madhusudan, K., Ramesh, S., Rao, A.M., Kulkarni, R.S. and Savithramma, D.L. 1995. Combining ability in cowpea. *Crop Improv.* 22: 241-243

Maheshwari, J.J., Ghorpade, P.B., Sakhare, R.S., Chauvan, A.S. and Dhole, V.J. 1999. Studies on heterosis in soybean (*Glycine max* L. Merrill). *J. Soils Crops.* 9: 61-64

Malhotra, R.S. 1983. Combining ability in urdbean. *Indian J. Genet.* 43: 324-327

Mandal, A.K. and Bhal, P.N. 1987. Genetic analysis in Desi x Kabuli crosses of chickpea. *Legume Res.* 10: 37-40

Manivel, P. and Rangasamy, P. 1998. Influence of environment on heterosis and combining ability in pigeonpea (*Cajanus cajan* L. Millsp.). *Ann. agric. Res.* 19: 133-138

Manivel, P., Rangasamy, P. and Samdur, M.Y. 1999. Heterosis studies involving genetic male sterile lines of pigeonpea. *Crop Res.* 18: 240-242

Mishra, A.K. and Yadav, L.N. 1994. Combining ability analysis in chickpea. *Indian J. Pulses Res.* 7: 185-186

Mishra, S.N., Verma, J.S. and Rastogi, R. 1987. Combining ability for flowering and seed yield in cowpea. *Ann. agric. Res.* 8: 268-272

Naidu, N.V. and Satyanarayana, A. 1993. Heterosis and combining ability in mungbean (*Vigna radiata* (L.) Wilczek). *Indian J. Pulses Res.* 6: 38-44

Naidu, N.V. and Satyanarayana, A. 1993. Heterosis and combining ability in urdbean (*Vigna mungo* (L.) Hepper). *Indian J. Pulses Res.* 6: 10-14

Naidu, N.V. and Satyanarayana, A. 1993. Heterosis and inbreeding depression for yield and yield components of mungbean (*Vigna radiata* (L.) Wilczek). *Ann. agric. Res.* 14: 30-34

Narladkar, V.W. and Khapre, P.R. 1996. Heterosis for yield and yield components in pigeonpea. *Ann. agric. Res.* 17: 100-103

Natarajan, K., Thiyagarjan, K. and Rathnaswamy, R. 1990. Combining ability in greengram (*Vigna radiata* (L.) Wilczek). *Madras agric. J.* 77: 382-385

Natarajan, M. 1989. Heterosis for dry matter components in mungbean. *Crop Improv.* 16: 168-171

Neog, S.B. and Talukdar, P. 1999. Combining ability and heterosis in blackgram. *J. agric. Sci. Soc. N.E. India,* 12: 210-216

Pande, K., Pandya, B.P. and Jain, K.C. 1979. Diallel analysis for yield components in bengalgram. *Indian J. agric. Res.* 13: 187-194

Pandey, N. 1999. Heterosis and combining ability in pigeonpea. *Legume Res.* 22: 147-151

Patel, J.A., Patel, S.A., Zaveri, P.P. and Pathak, A.R. 1988. Combining ability analysis in mungbean. *Indian J. Pulses Res.* 1: 106-110

Patel, J.A., Pathak, A.R., Zaveri, P.P. and Shah, R.M. 1987. Combining ability analysis in pigeonpea. *Indian J. Genet.* 47: 183-188

Patel, R.N., Godhani, P.R. and Fougat, R.S. 1994. Combining ability in cowpea (*Vigna unguiculata* (L.) Walp.) *Gujarat agric. Univ. Res. J.* 20: 70-74

Patil, A.B., Salimath, P.M., Patil, S.A., Patil, S.S. and Kulkarni, J.H. 1998. Heterosis for characters related to plant type in chickpea (*Cicer arietinum* L.) *Legume Res.* 21: 101-104

Patil, A.J., Wanjari, K.B., Patil, A.N., Raut, B.R. and Ghawghawe, P.B. 1992. Studies on heterosis in mungbean (*Vigna radiata* (L.) Wilczek). *J. Soils Crops,* 2: 1-4

Patil, R.B. and Bhapkar, D.G. 1986. Combining ability in cowpea. *J. Maharashtra agric. Univ.* 11: 303-306

Pillai, K.S. 1980. Quantitative genetic study of yield and its components in blackgram (*Phaseolus mungo* (Linn.)) Ph.D. thesis, Kerala Agricultural University, Thrissur, p.195

Poehlman, J.M. 1991. *The Mungbean.* Oxford and IBH Publishing Co., New Delhi, p.375

Ponnusamy, K. and Harer, P.N. 1998. Heterosis and combining ability in soybean. *J. Maharashtra agric. Univ.* 23: 115-117

Rajarathinam, S. and Rathnaswamy, R. 1990. Combining ability in blackgram (*Vigna mungo* (L.) Hepper). *Madras agric. J.* 77: 474-477

Rajeswari, A. 1998. Genetic analysis of greengram (*Vigna radiata* (L.) Wilczek) genotypes for shade tolerance. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p.77

Rajeswari, A. and Kamalam, N. 1999. Genetic study of yield and yield components in greengram (*Vigna radiata* (L.) Wilczek) under partially shaded coconut orchard. *Legume Res.* 22: 237-240

Rao, B.G. and Chopra, V.L. 1989. Heterosis and heterobeltiosis in diverse crosses of chickpea. *Legume Res.* 12: 136-138

Rejatha, V. 1992. Combining ability in vegetable cowpea (*Vigna unguiculata* var. sesquipedalis). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p.113

Rosaiah, G., Kumari, D.S., Satyanarayana, A. and Naidu, N.V. 1994. Combining ability studies on sprout quality traits in mungbean (*Vigna radiata* (L.) Wilczek). *Indian J. Pulses Res.* 1: 1-6

Sagar, P. and Chandra, S. 1977. Heterosis and combining ability in urdbean. *Indian J. Genet.* 37: 420-424

Salimath, P.M. and Bahl, P.N. 1985. Heterosis and combining ability for earliness in chickpea (*Cicer arietinum* L.) *Indian J. Genet.* 45: 97-100

Salimath, P.M. and Bahl, P.N. 1989. Combining ability studies in crosses involving tall and dwarf types in chickpea (*Cicer arietinum* L.). *Indian J. Genet.* 49: 29-34

Sandhu, T.S., Gubmer, R.K. and Bhatia, R.S. 1989. Combining ability analysis for grain yield and its components in chickpea. *Indian J. Pulses Res.* 2: 163-165

Sangwan, R.S. and Lodhi, G.P. 1995. Heterosis for grain characters in cowpea (*Vigna unguiculata* L. Walp). *Legume Res.* 18: 75-80

Santha, S. and Veluswamy, P. 1999. Combining ability studies for biometrical traits in urdbean (*Vigna mungo* L.) *J. Ecobiol.* 11: 29-34

Santha, S. and Veluswamy, P. 1999. Heterosis for yield and yield attributes in blackgram. *J. Ecobiol.* 11: 65-70

*Savithramma, D.L. and Latha, J. 1999. Heterosis for yield traits in cowpea (*Vigna unguiculata* (L.) Walp). *ACIAR Fd. Legume Newsl.* 29: 7-10

Sawant, D.S. 1995. Combining ability studies in cowpea. *Ann. agric. Res.* 16: 206-211

Sawant, D.S., Birari, S.P. and Jadhav, B.B. 1994. Heterosis in cowpea. *J. Maharashtra agric. Univ.* 19: 89-91

Saxena, K.B., Byth, D.E., Wallis, E.S. and De Lacy, L.H. 1989. Gene action in short duration pigeonpea. *Legume Res.* 12: 103-109

Saxena, S.D. and Sharma, R.K. 1989. Estimation of combining ability in mungbean (*Vigna radiata* (L.) Wilczek). *Legume Res.* 12: 165-169

Saxena, S.D. and Sharma, R.K. 1992. Analysis of combining ability in mungbean (*Vigna radiata* (L.) Wilczek). *Legume Res.* 15: 7-10

Shanmugasundaram, P. and Rangasamy, S.R. 1994. Combining ability for yield and its components in blackgram (*Vigna mungo* (L.) Hepper). *Indian J. Genet.* 54: 6-9

Sharma, S.K. and Nishisharma. 1988. Combining ability analysis in soybean. *Indian J. Genet.* 48: 355-358

Shinde, N.V. and Deshmukh, R.B. 1989. Heterosis in urdbean. *Indian J. Pulses Res.* 2: 119-124

Shinde, N.V. and Deshmukh, R.B. 1990. Heterosis and inbreeding depression for yield and its components in chickpea. *Indian J. Pulses Res.* 3: 121-126

*Shinde, N.V. and Deshmukh, R.B. 1993. Heterosis in chickpea. Int. symp. on Heterosis breeding in crop plants - Punjab Agricultural University, Ludhiana. Abstract: 32

*Shull, G.H. 1914. The genotype of maize. *Am. Nat.* 45: 234

Singh, I.B., Singh, H.G., Singh, V. and Singh, P. 1987. Combining ability for yield and its components in blackgram. *Indian J. Genet.* 47: 99-103

Singh, I.P., Dixit, G.P. and Srivastava, D.P. 1999. Heterosis in interspecific hybrids of pigeonpea. *Indian J. Pulses Res.* 12: 176-179

Singh, O. and Paroda, R.S. 1989. A comparative analysis of combining ability in irradiated and non-irradiated diallel populations of chickpea. *Indian J. Pulses Res.* 2: 1-9

Singh, O., Gowda, C.L.L., Sethi, S.C., Dasgupta, T. and Smithson, J.B. 1992. Genetic analysis of agronomic characters in chickpea I. Estimates of genetic variances from diallel mating designs. *Theor. Appl. Genet.* 83: 956-962

Singh, P. and Narayanan, S.S. 1993. *Biometical Techniques in Plant Breeding,* Kalyani Publishers, Ludhiana, p.187

Singh, R.K. and Chaudhary, B.D. 1979. *Biometrical Methods in Quantitative Genetic Analysis*. Kalyani Publishers, New Delhi, p.304

Singh, S.P., Govil, J.N. and Hayat, R. 1983. Combining ability and heterosis in early pea hybrids. *Indian J. Genet*. 43: 481-486

Singh, V.P. and Singh, V.N. 1994. Heterosis for nodulation and yield traits in mungbean. *Indian J. Genet.* 54: 280-287

Sinha, S.C., Singh, K.N. and Ram Lakhan. 1994. Combining ability and heterosis in pigeonpea. *Indian J. Pulses Res*. 7: 63-65

Sood, B.C. and Garten, S.L. 1991. Heterosis in relation to combining ability in blackgram. *Indian J. Genet.* 51: 395-399

Sood, V.K., Rana, N.D., Gupta, V.P. and Sood, O.P. 1996. Combining ability and heterosis studies in soybean. *J. Hill Res.* 9: 139-142

Spraque, G.F. and Tatum, L.A. 1942. General vs. specific combining ability in single crosses of corn. *J. Am. Soc. Agron.* 34: 923-932

Sreekumar, K. 1995. Genetic analysis of biological yield components in cowpea (*Vigna unguiculata* (L.) Walp). Ph.D. thesis, Kerala Agricultural University, Thrissur, p.175

Sreekumar, S. 1993. Combining ability and gene action in greengram (*Vigna radiata* (L.) Wilczek). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p.118

*Suh Sugkee, Cho Young Koo, Park Hoki and Scott, R.A. 2000. Gene action and heritability of leaf and reproductive characteristics in soybean. *Theor. Pop. Biol.* 50: 45-51

Thimmappa, A.S. 1987. Genetic analysis of quantitative traits in greengram (*Vigna radiata* (L.) Wilczek) *Mysore J. agric. Sci.* 21: 94

Thimmappa, A.S., Chandrappa, H.M., Patil, S.S. and Goud, J.V. 1989. Studies on combining ability in greengram. *J. Maharashtra agric. Univ.* 14: 26-27

Thiyagarajan, K., Natarajan, C. and Rathnaswamy, R. 1990. Combining ability and inheritance studies in cowpea (*Vigna unguiculata* (L.) Walp). *Madras agric. J.* 77: 305-309

Thiyagarajan, K., Natarajan, C., Rathnasamy, R. and Rajasekaran, S. 1993. Combining ability for yield and its components in cowpea. *Madras agric. J.* 80: 124-129

Thiyagarajan. 1992. Seasonal effects in combining ability in cowpea. *Indian J. agric. Res.* 26: 155-159

Thomas, B. 1996. Combining ability for biological nitrogen fixation traits and yield components in blackgram (*Vigna mungo* (L.) Hepper). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p.89

Tiwari, D.S., Singh, V. and Shukla, P.S. 1993. Combining ability studies in mungbean (*Vigna radiata* (L.) Wilczek). *Indian J. Genet.* 53: 395-398

Varghese, R.I. 1997. Combining ability for drought tolerance and yield in blackgram (*Vigna mungo* (L.) Hepper). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p.77

Venketeswaralu, S. and Singh, R.B. 1981. Combining ability for earliness in pigeonpea. *Indian J. Genet.* 41: 252-254

Venketeswaralu, S. and Singh, R.B. 1982. Combining ability in pigeonpea. *Indian J. Genet.* 42: 11-14

Verma, S.N.P., Perraju, P. and Mishra, D.K. 1991. Heterosis and inbreeding in blackgram. *Curr. Res.* 20: 180-182

Verulkar, S.B. and Singh, D.P. 1997. Heterosis in pigeonpea. *Int. Chickpea Pigeonpea Newsl.* 4: 33-34

Verulkar, S.B. and Singh, D.P. 1998. Heterosis in varietal and interspecific crosses of pigeonpea. *Int. Chickpea Pigeonpea Newsl.* 5: 34-36

Vikas, Paroda, R.S. and Singh, S.P. 1998. Heterosis in linextester crosses for yield and yield contributing characters over environments in mungbean (*Vigna radiata* (L.) Wilczek) *Ann. Agri Bio Res.* 3: 217-222

Viswanatha, K.P., Balaraju, Chakravarthy, K.K. 1998. Heterosis and inbreeding depression in cowpea. (*Vigna unguiculata* (L.) Walp). *Mysore J. agric. Sci.* 32: 181-185

William, R.F. 1946. The physiology of plant growth with special reference to the concept of net assimilation rate. *Ann. Bot. N.S.* 10: 41-72

Wilson, D., Mercy, S.T. and Nair, N.K. 1985. Combining ability in greengram. *Indian J. agric. Sci.* 55: 665-670

Yadav, H.S., Sunil Holkar and Bilaiya, S.K. 1993. Genetic divergence in greengram. *Ann. agric. Res.* 14: 306-310

Yadavendra, J.P. and Sudhirkumar. 1987. Combining ability in chickpea. *Indian J. Genet.* 47: 67-70

Zaveri, P.P., Patel, P.K., Yadavendra, J.P. and Shah, R.N. 1983. Heterosis and combining ability in cowpea. *Indian J. agric. Sci.* 53 : 793-796

* Original not seen

# Combining ability for shade tolerance and yield in greengram ( *Vigna radiata* (L.) Wilczek) grown under coconuts

By

PREETA LIZ KORAH

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

2001

# ABSTRACT

The current research programme on "Combining ability for shade tolerance and yield in greengram (*Vigna radiata* (L.) Wilczek) grown under coconuts" was carried out at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 1998-2000. The objectives were estimation of gene action, combining ability effects of parents and hybrids and heterosis. The experimental material consisted of five lines, three testers and their fifteen hybrids.

Analysis of variance revealed significant differences among the genotypes for all the eleven characters subjected to statistical analysis except height of plants and shade intensity. The genotypes $L_3$ (MGG. 314), $L_5$ (LGG. 460) and $T_3$ (CO.2)) were superior in mean performance for yield and most of the yield attributes. The hybrids $L_5$ x $T_2$ (LGG. 460 x *Pusa baisakhi*) and $L_1$ x $T_3$ (IIPRM.3 x CO.2) were superior in mean performance for yield, pod characters, photosynthetic efficiency and tolerance to pod bug infestation.

Non-additive gene action predominated for all the nine characters showing significant differences among the treatments. $L_5$ (LGG. 460) and $T_2$ (*Pusa baisakhi*) were the best general combiners for yield and

length of pod while $L_1$ (IIPRM.3) was the best combiner for crop duration, pods per plant and photosynthetic efficiency. The hybrid $L_1$ x $T_3$ (IIPRM. 3 x CO.2) was the best specific combiner for yield.

Significant heterosis was observed for all the characters studied. $L_5$ x $T_2$ (LGG. 460 x *Pusa baisakhi*) showed maximum relative heterosis and heterobeltiosis for yield and pod length whereas $L_1$ x $T_3$ (IIPRM.3 x CO.2) showed maximum heterosis over mid parent and better parent for days to 50 per cent flowering, days to final harvest, pods per plant and photosynthetic efficiency.

Combining the mean performance, sca effects and heterosis, $L_5$ x $T_2$ (LGG. 460 x *Pusa baisakhi*) and $L_1$ x $T_3$ (IIPRM.3 x CO.2) were identified as superior crosses in terms of yield and yield attributes. The hybrid $L_1$ x $T_3$ (IIPRM.3 x CO.2) was also superior for days to 50 per cent flowering, days to final harvest and photosynthetic efficiency.