COMBINING ABILITY IN GRAIN COWPEA
[*Vigna unguiculata* (L.) Walp.]

By

JAYARANI, L. S.

THESIS
submitted in partial fulfilment of the requirement
for the Degree
MASTER OF SCIENCE IN AGRICULTURE
Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF PLANT BREEDING
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM

1993

DECLARATION

I hereby declare that this thesis entitled Combining ability in grain cowpea (*Vigna unguiculata* (L) Walp) is a bonafide record of research work done by me and that the thesis has not previously formed the basis for the award to me of any degree diploma associateship fellowship or other similar title of any other University or Society

Vellayani

07 06 1993

Jayarani L S

CERTIFICATE

Certified that this thesis entitled Combining ability in grain cowpea (*Vigna unguiculata* (L) Walp) is a record of research work done independently by Kum Jayarani L S under my guidance and supervision and that it has not previously formed the basis for the award of any degree fellowship or associateship to her

Dr (Mrs) J Sreekumari Amma
Chairperson
Advisory Committee
Associate Professor
Department of Plant Breeding

Vellayani
07 06-1993

APPROVED BY

CHAIRPERSON

DR (MRS) J SREEKUMARI AMMA

MEMBERS

1 Dr V GOPINATHAN NAIR

2 DR (Mrs) P MANJU

3 DR (Mrs) P SARASWATHY

EXTERNAL EXAMINER

ACKNOWLEDGEMENT

I am greatly indebted to Dr (Mrs) J Sreekumari Amma Chairperson of the advisory Committee for suggesting the research problem and for guiding and inspiring me throughout the research work

I express my sincere and deep sense of gratitude to Dr V Gopinathan Nair Professor and Head Department of Plant Breeding Dr (Smt) P Manju Assistant Professor Department of Plant Breeding Dr (Mrs) P Saraswathy Associate Professor (H G) and Head Department of Agricultural Statistics for their valuable recommendations and help rendered to me all along

I am thankful to Dr N Saifudeen Associate Professor NARP (SR) and Sri K Gopakumar Professor Department of Agricultural Botany Sri C E Ajith Kumar Junior Programmer Department of Agricultural Statistics and Sri K Radhakrishnan Fairtypes for thier help at various stages of research work and thesis preparatioon

Let me record my deep sense of gratitude to M/s K Sreekumar S Sindhu S G Anilkumar T Vanaja B Rani and M R Bindhu for their kind help in the completion of this investigation

I also wish to express my thanks to all staff members of the Department of Plant Breeding for their help and co-operation

I am deeply indebted to my parents and brother for their encouragement and manifold assistance

Vellayani

07-06 1993

Jayarani L S

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

Introduction

The grain legumes commonly known as pulses form an important and ancient component of Indian agricultural system They occupy a unique positon in the world agriculture as well by virtue of their high protein content and their capacity for directly using the inexhaustible stock of atmospheric Nitrogen The pulses serve as a valuable supplement to the cereal based diet especially in areas where animal protein is less available A balanced diet should contain three ounces of pulses per day per adult to meet the protein requirement (Aykroyd and Doughty 1964) Pulses contain 22-24 percent protein which is much more than that available in cereals The present production of pulses grown in an area of 22 million hectare in India is 12 97 million tonnes with a per hectare yield of 537 kg In Kerala pulses occupy an area of 24285 hectares with an annual production of 18552 tonnes with a productivity of 764 kilogram per hectare (Anon 1990)

Cowpea (Vigna unguiculata (L) Walp) is one of the cheapest sources of protein It contains vitamins and minerals like calcium and sodium The crop is so versatile that it always becomes an important plant in intercropping rotation cropping and relay cropping It is an excellent crop for green manure as well and is grown in almost all states of India In Kerala cowpea can be grown in all the three seasons Bulk of the cultivation is in summer rice fallow during the third crop season During the kharif season cowpea is cultivated as a pure crop or as an intercrop in tapioca or as a floor crop in coconut gardens However the availability of open space for extending the area under this crop is very limited Therefore the possibility for extending the cultivation of cowpea in the interspaces of coconut gardens has to be explored The non availability of a variety suited to partially shaded conditions is a limitation in this context Therefore the identification of a new variety with high yield potential and suitability to partial shaded conditions can go a long way in extending the cultivation of this crop as a component of the coconut based farming system

Evaluation of high yielding cultivars suited to shaded conditions requires a good knowledge of the genetic basis of the different components associated with yield Most of the present day cultivars have been developed through selection Comparatively very little effort has been made for generating additional variability through hybridisation This indicates the necessity for undertaking extensive breeding programmes utilising large numbers of genetically divergent stocks of cowpea available in different regions or locally adopted varieties divergent for quantitative characters for evolving varieties with high yield potential

In an earlier study conducted in the Department of Plant Breeding the variety Chharodi 1 has been found as shade tolerant It was in this background that the present investigation was undertaken to assess combining ability with respect to seed yield and other characters nature and magnitude of gene action and to isolate high yielding genotypes with early synchronous maturity and shade tolerance

REVIEW OF LITERATURE

Review of Literature

Combining ability

Combining ability is the ability of a strain to produce superior progeny on hybridisation with other strains Information on the nature of general and specific combining ability with respect to parents and hybrids will facilitate the breeder to plan the breeding programme effectively

Days to flowering

Both general and specific combining ability variances were found significant for this character in mungbean (Deshmukh and Manjare 1980) cowpea (Zaveri et al 1983) greengram (Patel et al 1988) chickpea (Katiyar et al 1988) and in peas (El Muraba et al 1988 and Moitra et al 1988)

A line x tester analysis involving 4 testers and 10 lines of Vigna unguiculata indicated that both general combining ability (g c a) and specific combining ability (s c a) were important for days to 50 percentage flowering with more importantance to g c a (Mishra et al 1987) In another line x tester analysis using chickpea varieties Mandal and Bahl (1987) revealed that g c a estimates were non significant for this character

Saxena *et al* (1989) observed in a diallel crossing system of redgram that the ratio of general to specific combining ability mean squares was high This is in line with the findings of Singh and Dhaliwal (1970) in blackgram Fooland and Bassiri (1983) in *Phaseolus vulgaris* Wilson *et al* (1985) in greengram Csizmadia (1985) and Ranalli *et al* (1989) in pea and Cheralu *et al* (1989) in redgram

But in a diallel crossing system of bengal gram Pande *et al* (1979) observed that the s c a variance was higher than g c a variance

Days to maturity

For days to maturity both general and specific combining ability variances were found significant in mungbean (Deshmukh and Manjare 1980) cowpea (Zaveri *et al* 1983) and in pea (Moitra *et al*, 1988)

Analysis of a half diallel cross of 8 cowpea varieties revealed that both general and specific combining ability variances were important but magnitude of g c a variance seemed to be comparatively much higher (Chauhan and Joshi 1981) Similar results were found in soybean by Srivastava *et al* (1977) in green gram by Wilson *et al* (1985) and in blackgram by Singh *et al* (1987)

In a diallel cross of Arachis hypogaea Habib et al (1985) noticed that variance due to g c a was highly significant and was higher in magnitude than the s c a variance On the contrary only s c a was found to be significant for this trait in chickpea by Katiyar et al (1988)

Plant height

Analysis of variance for combining ability showed significant difference for g c a as well as s c a variances for plant height in mung bean (Deshmukh and Manjare 1980) pea (Venkateswarlu and Singh 1981 Moitra et al 1988 and El-Muraba et al 1988) and in chick pea (Katiyar et al 1988) But general combining ability variance was found predominant for the same character in chick pea (Pande et al 1979) groundnut (Habib et al 1985) greengrem (Wilson et al 1985) and in redgram (Saxena et al 1989)

High g c a variances were reported by Fleck A Von and Ruckenbauer (1989) in faba bean This is in line with the findings of Srivastava et al (1977) in soybean Cheralu et al (1989) in red gram and Tewatia et al (1988) in pea On the contrary s c a was found as dominant component by Kaw and Madhava Menon (1977) in soybean and Rajarathinam and Rathnasamy (1990) in black gram

Number of branches per plant

Highly significant g c a and s c a were found but g c a was more important than s c a for this character (Habib *et al* 1985 in groundnut Nienhuis and Singh 1986 in field bean and Saxena and Sharma 1989 in green gram) whereas s c a was found higher than g c a in blackgram by Singh *et al* (1987) and Rajarathinam and Rathnasamy (1990)

In chickpea g c a alone was found significant in a diallel cross performed by Pande *et al* (1979) and only s c a was found significant in another diallel cross done by Katiyar *et al* (1988) High and positive g c a effect was noticed in red gram for number of branches per plant by Cheralu *et al* (1989)

Number of pods per plant

Mak and Yap (1977) in cowpea Deshmukh and Manjare (1980) in mung bean Zaveri *et al* (1983) in cowpea De-silva and Omran (1986) in winged bean Katiyar *et al* (1988) in chickpea Hazarika *et al* (1988) in redgram and Moitra *et al* (1988) in pea observed that the variances due to g c a and s c a were significant But general combining ability was found to be predominant even though bothwere significant (Chauhan and Joshi 1981 in cowpea Wilson *et al* 1985 in greengram Habib *et al* 1985 in groundnut and Naumkina 1987 in pea) whereas s c a was reported to be higher than g c a by Pande *et al* (1979) in chickpea Fooland and Bassiri (1983) in field bean

Sıngh et al (1987) ın blackgram Kumar and Bahl (1988) and Bahl and Kumar (1989) ın chıckpea and Rajarathınam and Rathnasamy (1990) ın urd bean

Only g c a was found hıghly sıgnıfıcant ın a 12x12 partıal dıallel cross of pea by Tewatıa et al (1988) Sımılar results were obtaıned by Ranallı et al (1989) ın the same crop and Cheralu et al (1989) and Sexena et al (1989) ın redgram On the contrary only s c a mean square was found sıgnıfıcant ın faba bean by Mahmoud and Al Ayobı (1987) ın greengram by Saxena and Sharma (1989) and ın blackgram by Kalıa et al (1991)

Length of pod

Combınıng abılıty analysıs of a dıallel cross of cowpea by Sıngh and Jaın (1972) ındıcated the ımportance of both general and specıfıc combınıng abılıty varıances for length of pod Sımılar results were also obtaıned by Mak and Yap (1977) ın the same crop Patel et al (1988) ın greengram and Kaıla et al (1991) ın blackgram Eventhough both g c a and s c a mean squares were ımportant g c a varıance was found hıgher than s c a varıance ın cowpea by Chauhan and Joshı (1981) and ın greengram by Wılson et al (1985) But ın wınged bean the varıance due to s c a (Erskıne and Kesavan 1981) and ın pea varıance due to g c a (Tewatıa et al 1988) were found hıghly sıgnıfıcant

Number of seeds per pod

Both g c a and s c a variances were important for this trait (Mak and Yap 1977 in longbean Pande et al 1979 in chickpea Chauhan and Joshi 1981 in cowpea De silva and Omran, 1986 in winged bean Katiyar et al 1988 in chickpea and El Muraba et al (1989) in pea and in mungbean by Saxena and Sharma (1989)

Combining ability studies of 25 chickpea hybrids derived from crosses of 5 lines and 5 testers with their F_2 and parents by Bahl and Kumar (1989) revealed that the s c a estimates were greater than those for g c a Mahmoud and Al Ayobi (1987) in faba bean Saxena et al (1989) in redgram and Ranalli et al (1989) in pea observed that variance due to g c a was significant for this character But Singh and Jain (1972) in cowpea and Kalia et al (1991) in blackgram noted that only s c a variance was important

100 - Seed Weight

Singh and Jain (1972) and Mak and Yap (1977) in cowpea Deshmukh and Manjare (1980) in mung bean Singh et al (1985) in field pea Patel et al (1988) in greengram Katiyar et al (1988) in chickpea Jhorar et al (1988) in clusterbean and Moitra et al (1988) in pea reported that variance due to g c a and s c a were important for this trait Combining ability analysis from the F_1 and F_2 diallel generations involving seven diverse derivatives of soybean by Srivastava et al (1977) revealed that even though both g c a and s c a variance vere significant the estimates of g c a variance was higher than s c a variance Similar results were obtained by Pande et al (1979) in chickpea Chauhan and Joshi (1981) in cowpea Fooland and Bassiri (1983) Singh and Saini (1986) and Nilenhuis and Singh (1986) in Phaseolus vulgaris and Bahl and Kumar (1989) in chickpea and Fleck A von and Ruckenbauer (1989) in Vicia faba On tne contrary analysis of combining ability data from crossing chickpea cultivars in a line x tester fashion revealed that g c a estimates were non-significant for 100-seed weight (Mandal and Bahl 1987)

Seed yield per plant

Data from an 8 line x 4 tester analysis of Cajanus cajan indicated that both g c a and s c a variances were significant for seed yield per plant (Hazarika et al 1988) This is in line with the findings of Singh and Jain (1972) and Zaveri et al (1983) in cowpea Deshmukh and Manjare (1980) in mungbean Singh et al (1985) in field pea Singh et al (1987) and Moitra et al (1988) in pea Arora and Pandya (1987) and Katiyar et al (1988) in chickpea and Haque et al (1988) and Moitra et al (1988) in blackgram Saxena and Sharma (1989) has also got the same results in greengram

A half diallel of seven short duration pigeonpea lines was evaluated by Saxena et al (1989) and the results indicated that g c a variance predominated Similar results were obtained in a 5x5 diallel cross of _Dolichos lablab_ by Singh _et al_ (1980) in cowpea by Chauhan and Joshi (1981) in green gram by Wilson _et al_ (1985) in groundnut by Habib _et al_ (1985) in French bean by Singh and Saini (1986) and Nienhuis and Singh (1986) in pea by Naumkina (1987) and Tewatia _et al_ (1988) and in pigeonpea by Cheralu _et al_ (1989) In long bean Mak and Yap (1977) observed that only g c a was significant

The estimates of mean squares due to s c a were greater than their respective mean squares due to g c a as reported by Pande _et al_ (1979) in chickpea Fooland and Bassiri (1983) in common bean De silva and Omran (1986) in winged bean Mishra _et al_ (1987) in cowpea Singh _et al_ (1987) in blackgram Mehtre _et al_ (1988) in pigeonpea Kumar and Bahl (1988) and Bahl and Kumar (1989) in chickpea and Rajarathinam and Rathnasamy (1990) and Kalia _et al_ (1991) in urd bean

Chlorophyll content

Combining ability analysis showed significant difference for g c a as well as s c a for chlorophyll a b and total chlorophyll content in brinjal (Chadha _et al_ 1988)

However g c a was found predominant for flag leaf chlorophyll in bread wheat (Ellison _et al_ 1983) and for chlorophyll a b and a+b in sorghum (Cheng et al 1985) On the contrary Patel and Kukadia (1986) observed in pearl millet that s c a was more important than g c a for chlorophyll content

Reaction to pests

Both general and specific combining ability variances were found significant for resistance to different pests as reported by Hsich and Pi (1988) against aphid and Dabholkar et al (1989) against shoot fly in sorghum However a preponderance of g c a effect over s c a effect was observed for resistance to different crop pests in several plants like European corn borer in maize (Khalifa and Drolsom 1988 and Kim et al 1989) and shoot fly in sorghum (Dixon et al 1990) On the contrary Holley et al (1985) reported that for resistance to the insects Frankliniella fusca and Heliothis zea in groundnut s c a was important

Gene Action

The development of a plant breeding strategy hinges mainly on the support provided by genetic information on the inheritance and behaviour of major quantitative characters

The combining ability is determined by two types of gene action namely additive and non additive The additive effects are mainly due to polygenes which act in additive manner producing fixable effects The non-additive gene action results from dominance epistasis and various other interaction effects which are non-fixable

Days to flowering

Studies by Mehtre _et al_ (1988) in _Cajanus cajan_ Pandey and Tiwari (1989) in chickpea and Singh and Singh (1990) in pea revealed that both additive and non-additive gene effects were important for days to flowering

Combining ability analysis of chickpea varieties showed the existance of both additive and non-additive gene action but additive gene was predominant (Pandey and Tiwari 1989) in _Vicia sativa_ Similar results were obtained by Kanarskaya and Kalinina (1981) and Dubey and Lal (1983) in pea Rao _et al_ (1984) and Wilson _et al_ (1985) in greengram Salimath and Bahl (1985) in chickpea Patil and Bhapkar (1986) in cowpea Singh _et al_ (1986) in _Lalab purpureus_ Katiyar _et al_ (1989) in chickpea Das and Dana (1990) in rice bean and Rejatha (1992) in cowpea

Singh and Dhaliwal (1970) Venkateswarlu and Singh (1981) Gsizmadia (1985) Yadavendra and Sudhirkumar (1987) Gil and Martin (1988) and Tawar _et al_ (1989) opined that only additive gene effects controlled days to flowering in blackgram pigeonpea pea chickpea _Vicia faba_ and soybean respectively

High s c a variances over g c a variances indicated that this character was under the control of non additive gene effects in chickpea (Pande et al 1979) in mungbean (Deshmukh and Manjare 1980) and in cowpea (Zaveri et al 1983 and Anilkumar 1993)

Complementary type of epistasis was observed for the expression of this character in green gram as reported by Rao et al (1984) and Muker et al (1988)

Days to maturity

From a 6 x 6 diallel cross in urdbean the combining ability studies by Sandhu et al (1981) revealed that both the additive and non-additive effects were important for days to maturity Similar results were also obtained by Habib et al (1985) in groundnut Singh et al (1987) in pea Mehtre et al (1988) in pigeonpea Pandey and Tewari (1989) in chickpea and Singh and Singh (1990) in pea

A preponderance of additive gene effects were reported in green gram (Rao et al 1984 and Wilson et al 1985) cowpea (Patil and Bhapkar 1986) chickpea (Katiyar et al 1988) and in pea (Sharma and Nishi Sharma 1988) On the contrary a preponderance of non-additive gene effect was noticed by Deshmukh and Manjare (1980) in mungbean Sandhu et al (1981) in black gram

Zaveri et al (1983) in cowpea Singh et al (1987) in blackgram Patel et al (1987) in redgram Katiyar et al (1987) in pea and Anilkumar (1993) in cowpea

Chauhan and Joshi (1981) and Yadavendra and Sudhirkumar (1987) opined that only additive gene effects were important in cowpea and chickpea respectively and according to Salimath and Bahl (1985) only non additive genetic variance was significant in chickpea

Duplicate type of epistasis was observed for this character in greengram (Rao et al 1984) Gene effects were estimated using parents F_1 F_2 BC_1 and BC_2 generations of a cross involving genetically diverse varieties of chickpea by Sharma et al (1988) and the inheritance appeared to be under the control of dominance variance and epistasis Similar results were obtained by Shinde and Deshmukh (1990) in the same crop and they opined that additive dominance dominance x dominance and additive x additive interactions were important for this trait

Plant height

Plant height was observed to be influenced by the action of both additive and non additive gene effects as observed in blackgram (Sandhu et al 1981) mung bean (Rao et al 1984) groundnut (Habib et al 1985) pea (Singh et al 1987) pigeonpea (Mehtre et al 1988) chickpea (Pandey and Tiwari 1989) and in pea (Singh and Singh 1990)

Pande et al (1979) after studying combining ability in a diallel of chickpea opined that additive genetic variance was higher than dominance variance for this character This was further supported by Deshmukh and Manjare (1980) in green gram Venkateswarlu and Singh (1981) in pea Rao et al (1984) and Wilson et al (1985) in greengram Manoharan et al (1985) in groundnut Yadavendra and Sudhir Kumar (1987) in chickpea Sharma and Nishi Sharma (1988) in pea Katiyar et al (1988) in chickpea Loiselle et al (1990) in soybean Natarajan et al (1990) in greengram and Das and Dana (1990) in rice bean

On the contrary variance due to s c a was found predominant indicating the preponderance of non additive gene action for the expression of plant height in *Vicia sativa* (Kanarskaya and Kalinina 1981) in pigeonpea (Patel et al 1987) in chickpea (Salimath and Bahl 1989) in cowpea (Thiyagarajan et al 1990) and in blackgram (Rajarathinam and Rathnasamy 1990)

According to Rao et al (1984) duplicate type of epistasis was important for plant height in mungbean The inheritance of this character was appeared to be under the dominant and epistatic gene effects as reported by Sharma et al (1988) after studying the parents F_1 F_2 BC_1 and BC_2 generations of the cross involving genetically diverse varieties of chickpea Singh and Singh (1990) also had the same opinion and in pea among epistasis additive x additive interaction contributes more

Over dominance was observed by Tawar et al (1989) in soybean for plant height

Number of branches per plant

10 x 10 diallel analysis of pea by Singh et al (1987) a combining ability analysis of *Cajanus cajan* varieties by Mehtre et al (1988) a combining ability study in chickpea by Pandey and Tiwari (1989) and a 12 x 12 diallel analysis of pea by Singh and Singh (1990) showed that significant additive and non-additive variances occurred for number of branches per plant

Studies conducted by Malhotra (1983) in blackgram Dubey and Lal (1983) and Sharma and Nishi Sharma (1988) in pea Katiyar et al (1988) in chickpea Saxena and Sharma (1989) in greengram and Tawar et al (1989) in soybean revealed that g c a variance wa predominant for this character indicating the importance of additive gene effects

Non additive gene effects were found to control the character number of branches per plant in groundnnut (Habib et al 1985) in blackgram (Singh et al 1987) in chickpea (Yadavendra and Sudhirkumar 1987 and Salimath and Bahl 1989) in cowpea (Thiyagarajan et al 1990) and in urdbean (Rajarathinam and Rathnasamy 1990)

For the inheritance of this character in greengram additive component was significant and dominance component was not significant The preponderance of duplicate type of epistasis was observed (Muker et al 1988) Importance of dominance effect was noted by Das and Dana (1990) in rice bean

In a scaling test with 5 generation means of 5 crosses of chickpea Shinde and Deshmukh (1990) showed the involvement of epistatic gene action in the expression of fruiting branches per plant Additive and dominance gene effects dominance x dominance and additive x additive interactions were important Similar results were also obtained by Vindhiyavarman et al (1990) in groundnut

Number of pods per plant

Results from analysis of a diallel cross involving 10 varieties of pea indicated the importance of additive and non additive genetic effects for number of pods per plant (Singh and

Singh 1990) This is in line with the findings of Rao et al (1984) and Dasgupta and Das (1987) in mungbean Singh et al (1987) in pea Mehtre et al (1988) in redgram Onkar Singh and Paroda (1989) in chickpea and Natarajan et al (1990) in green gram

Combining ability studies revealed that both general and specific combining ability variances were important but magnitude of g c a variance seemed to be comparatively much higher for number of pods per plant which suggested that additive gene action preponderated its influence in the inheritance of this trait in pulses like cowpea (Chauhan and Joshy 1981) blackgram (Dahiya and Waldiya 1982) pea (Dubey and Lal 1983) greengram (Wilson et al 1985) pigeonpea (Patel et al 1987) pea (Sharma and Nishisharma 1988) chickpea (Sharma et al 1988 Katiyar et al 1988 and Salimath and Bahl 1989) urdbean (Sharma and Rao 1990) and cowpea (Thiyagarajan et al 1990)

In chickpea (Pande et al 1979) greengram (Deshmukh and Manjare 1980) chickpea (Singh and Ramanujam 1981) cowpea (Zaveri et al 1983) pigeonpea (Singh et al 1988) chickpea (Yadavendra and Sudhirkumar 1987) greengram (Saxena and Sharma 1989) blackgram (Rajarathinam and Rathnasamy 1990) and in cowpea (Thiyagarajan 1990 and Anilkumar 1993) it was observed that the s c a variance was predominant indicating the preponderance of non additive gene action But according to Sandhu et al (1981) and Habib et al (1985) only non additive gene effects were significantly influencing this character in blackgram and groundnut respectively

Complementary and duplicate types of epistasis were seen to be important for the expression of this character in mungbean as reported by Rao et al (1984) The preponderance of duplicate type of epistasis was observed in green gram by Muker et al (1988) and complementary type of epistasis in chickpea by Pandey and Tiwari (1989) Tawar et al (1989) reported that over dominance was important in soybean for number of pods per plant

Scaling test with 5 generation means showed the involvement of epistatic gene action and dominance gene action for number of pods per plant in pea (Singh and Singh 1990) and chickpea (Shinde and Deshmukh, 1990) But among epistasis additive x additive interaction component contributes more in pea (Singh and Singh 1990) and in chickpea additive and dominance gene effects dominance x dominance and additive x additive interactions were important (Shinde and Deshmukh 1990)

Length of pod

Trials in pea by Singh et al (1987) and Singh and Singh (1990) revealed that both additive and non additive genetic variances were important for length of pod

Eventhough both additive and non additive gene effects were significant a preponderance of additive genetic variance was noticed by Chauhan and Joshi (1981) in cowpea Malhotra (1983) in blackgram Dubey and Lal (1983) in pea Singh _et al_ (1986) in _Lablab purpureus_ and Thiyagarajan _et al_ (1990) and Rejatha (1992) in cowpea

Patel _et al_ (1987) evaluated 39 hybrids between 3 lines and 13 testers and parents of pigeonpea and revealed that only additive gene action was found operative for pod length The same was reported in urdbean by Sharma and Rao (1990) and in greengram by Natarajan _et al_ (1990)

Duplicate type of epistasis was observed for this trait in mungbean (Rao _et al_ 1984) But according to Muker _et al_ (1988) duplicate type of epistasis and complementary type of epistasis were important in different crosses of the same crop Additive and dominance components were also found positive and significant

Number of seeds per pod

In crosses of chickpea by Pande _et al_ (1979) in pea by Singh _et al_ (1987) and Singh and Singh (1990) and in greengram by Natarajan _et al_ (1990) observed that the character number of seeds per pod was conditioned by both additive and non additive genetic variance

The ratio of variance due to g c a to s c a was found high indicating the predominance of additive gene effects as reported by Syr eva *et al* (1981) Venkateswarlu and Singh (1982) and Dubey and Lal (1983) in pea Malhotra (1983) in blackgram Wilson *et al* (1985) in greengram Sharma and Nishi Sharma (1988) in pea Katiyar *et al* (1988) and Onkar Singh and Paroda (1989) in chickpea Saxena *et al* (1989) in pea Saxena and Sharma (1989) in greengram and Rajatha (1992) and Anilkumar (1993) in cowpea

This ratio was found to be low in soybean (Kaw and Madhavamenon 1977) mungbean (Deshmukh and Majare 1980) chickpea (Salimath and Bahl 1989) and cowpea (Thiyagarajan *et al* 1990) showed the preponderated effect of non additive genes Mehtre *et al* (1988) opined that only non-additive gene effect was significant for number of seeds per pod in *Cajanus cajan* Similar results were reported by Das and Dana (1981) in rice bean where dominance component was important

Pandey and Tiwari (1989) observed that complementary type of epistasis was exhibited for this trait in *Cicer arietinum*

100 - seed weight

According to Sharma *et al* (1988) the inheritance of 100-seed weight appeared to be under the additive dominance and epistatic effects in *Cicer arietinum* A 12 x 12 diallel of *Pisum sativum* indicated that both additive and non-additive gene effects were important for this character (Singh and Singh 1990) This was in agreement to the finding of Kamatar (1985) in chickpea

100-seed weight was observed to be influenced by the action of additive gene effects as reported by Deshmukh and Manjare (1980) in greengram Chauhan and Joshi (1981) in cowpea Venkateswarlu and Singh (1982) and Dubey and Lal (1983) in pea Malhotra (1983) in blackgram Singh *et al* (1983) in pigeonpea Wilson *et al* (1985) in mungbean Patil and Bhapkar (1986) in cowpea Manoharan *et al* (1987) in groundnut Tawar *et al* (1989) in soybean Singh and Singh (1990) in pea Sharma and Rao (1990) in greengram and Anilkumar (1993) in cowpea

Pande *et al* (1979) Katiyar *et al* (1988) and Salimath and Bahl (1989) opined that non-additive gene effect was predominant though both additive and non-additive gene effects present in pea Similar result was obtained by Thiyagarajan *et al* (1990) in a 6x6 diallel of cowpea

Complementary type of epistasis was reported to be influencing this character in mungbean (Rao *et al.* 1984) Muker *et al* (1988) suggested that this character was under the control of duplicate type of epistatic gene action in the same crop while additive x dominant component of epistasis was also found positive and significant

In 5 crosses of chickpea scaling test with five generation means showed the involvement of epistatic gene action In four out of five crosses additive gene effects was involved in the inheritance of 100 seed weight But additive and dominance gene effects dominance x dominance and additive x additive interactions were important (Shinde and Deshmukh 1990)

Seed yield per plant

Combining ability studies using 12 parent diallel F_1 progenies of pea revealed that both additive and non-additive genetic variances were important (Singh and Singh 1990) Similar results were obtained by Rao *et al* (1984) in mungbean Habib *et al* (1985) in groundnut Jhorar *et al* (1985) in clusterbean Dasgupta and Das (1987) in blackgram Mehtre *et al* (1988) in redgram Singh *et al* (1987) in pea and Onkar Singh and Paroda (1989) in chickpea

Eventhough g c a and s c a effects were both significant g c a effects predominated for seed yield per plant showing the preponderance of additive gene action in *Dolichos lablab* (Singh *et al* 1980) rice bean (Das and Dana 1981) cowpea (Chauhan and groundnut (Manoharan *et al.* 1985) *Pisum sativum* (Singh *et al* 1987) soybean (Loiselle *et al* 1990) urdbean (Sharma and Rao 1990) and greengram (Natarajan *et al* 1990)

Importance of non additive genetic variance was noticed by Pande *et al* (1979) in chickpea Deshmukh and Manjare (1980) in mungbean Sandhu *et al* (1981) and Singh *et al.* (1987) in blackgram Zaveri *et al* (1983) in cowpea Singh *et al* (1983) in redgram Chaudhary (1985) in soybean Patil and Bnapkar (1986) in cowpea Patel *et al* (1987) in pigeonpea Yadavendra and Sudhirkumar (1987) Katiyar *et al* (1988) and Salimath and Bahl (1989) in *Cicer arietinum* Rajarathinam and Rathnasamy (1990) in urdbean and Thiyagarajan *et al* (1990) and Anilkumar (1993) in cowpea

According to Singh and Ramanujam (1981) significant additive dominance and epistatic effects were involved in the inheritance of seed yield per plant in bengalgram But in blackgram Dahiya and Waldiya (1982) noted higher magnitude of dominance variance Rao *et al* (1984) stated that duplicate type of epistasis was important for this character in mungbean

Ram *et al* (1986) reported that in pea best crosses involved additive x dominance or dominance x dominance type of epistatic interaction The inheritance was appeared to be under the control of dominance and epistasis in soybean (Gupta *et al* 1982) and chickpea (Sharma *et al* 1988) But over dominance was observed to be important for seed yield per plant in soybean (Tawar 1989) Pandey and Tiwari (1989) reported that this trait was conditioned by complementary type of epistasis in chickpea

The analysis using means of 6 basic populations (P_1 P_2 F_1 F_2 BC_1 and BC_2) of pea by Singh and Singh (1990) reiterated the importance of dominance (h) gene effect for yield per plant However additive (d) effects were pronounced in some crosses whereas additive dominance and epistatic interactions were significantly involved in some other crosses Among digenic epistatic interactions additive x additive appeared to contribute more for this trait

Epistatic gene action involved in the expression of this character in chickpea Additive and dominance gene effects dominance x dominance and additive x additive interactions were important Dominance effects followed by interaction and additive component played a significant role in the inheritance of seed yield per plant Duplicate epistasis was more predominant (Shinde and Deshmukh 1990)

Chlorophyll content

A preponderance of significant g c a variance suggested that additive gene action was of particular importance in the inheritance of flag leaf chlorophyll content in bread wheat (Ellison et al 1983) whereas non-additive gene action was found to be important for chlorophyll content in pearl millet (Patel and Kukadiya 1986)

Chadha et al (1988) observed in brinjal that both additive and non additive gene effects were important for chlorophyll a chlorophyll b and total chlorophyll content

Reaction to pests

In sorghum for resistance to shoot fly (Biradar et al, 1984) aphid (Hsich and Pi 1985) midge (Agrawal et al 1988) and stem borer (Singh and Verma 1988) it was seen that both additive and non-additive gene effects were involved with predominance of additive gene action whereas non-additive gene action prevailed for the resistance to Heliothis zea in groundnut (Holley et al 1985)

MATERIALS AND METHODS

Materials and Methods

The investigation was undertaken with the objective of determining combining ability for yield and related characters in grain cowpea under partial shade in coconut garden The investigation comprised a crossing programme followed by a field experiment

Materials

The experimental material consisted of 8 varieties of cowpea (Vigna unguiculata (L) Walp) collected from the germplasm assembled at the Department of Plant Breeding College of Agriculture Vellayani and at the Regional Agricultural Research Station Pattambi

Two well adapted and early maturing grain cowpea varieties viz Chharodi-1 which is a high yielding short duration shade tolerant variety recommended for upland shade conditions and Culture - 9 (Krishnamani culture with brown seed coat) were used as ovule parents Six distinct cowpea varieties with varying phenotypic expressions were selected based on their general performance and yield and used as testers in the hybridisation programme The details of these varieties are given in Table 1

Table 1   Details of varieties

Sl No	Variety	Source	Salient features
1	Chharodi 1	College of Agriculture Vellayani	High yield earliness shade tolerance
2	Culture-9	R A R S Pattambi	High yield earliness synchronised flowering
3	Kanakamani	College of Agriculture Vellayani	High yield dual purpose
4	V-240	R A R S Pattambi	High yield
5	V 322		High yield
6	GC-82-7		High yield earliness
7	V 26	College of Agriculture Vellayani	High yield shade tolerance
8	S 488	R A R S Pattambi	Earliness high yield

The 8 parents and their 12 F_1 hybrids obtained by crossing them in a line x tester manner were used for the study and are enumerated in Table - 2

Table 2   Materials used in the study

Sl No	Treatment No	Name of variety/cross
1	L_1	Chharodi - 1
2	L_2	Culture - 9
3	T_1	Kanakamani
4	T_2	V 240
5	T_3	V-322
6	T_4	GC-82 7
7	T_5	V-26

8	T_6	S-488	
9	L_1T_1	Chharodı 1	x Kanakamanı
10	L_1T_2		x V 240
11	L_1T_3		x V-322
12	L_1T_4		x GC-82-7
13	L_1T_5		x V 26
14	L_1T_6		x S-488
15	L_2T_1	Culture 9	x Kanakamanı
16	L_2T_2		x V-240
17	L_2T_3		x V-322
18	L_2T_4		x GC-82 7
19	L_2T_5		x V-26
20	L_2T_6		x S 488

Methods

Methods of crossıng

The selfed seeds of eıght varıetıes were sown for a prılımınaary observatıonal trıal to record the flowerıng pattern Inorder to make the crosses the sowıng was done on dıfferent dates so that flowerıng ın all the eıght varıetıes synchronısed

When the flowerıng commenced crosses were made adoptıng the followıng methods Suıtable buds that were to open the next mornıng were selected Holdıng the bud wıth the thumb and forefinger the standard petal was forced to open by running a needle along the ridge where the two edges of the standard met One side of the standard and one of the wing petals were pushed down gently thereby leaving the keel exposed The keel was then split open on the exposed side for about 0 2 cm and a portion of the keel was also pushed down without injuring the other floral parts in any way Then all the stamens were pulled out by holding on the filament with forceps taking care not to rupture the anthers The disturbed parts of keel ving and standard were allowed to assume their original positions The emasculated flower buds were covered with tissue paper bags Pollination was done in the next morning between 7 am and 9 am by gently dusting the pollen collected from the male parents on the stigma The pollinated flowers were again covered with tissue paper bags which were removed after 5 days Suitable labels were also attached on the inflorescence Thus a line x tester crossing was made with 2 lines and 6 testers The pods were harvested when mature the maturity being judged by the standard ripening colour of the pods

Field experiment vas laid out in the interspaces of coconut garden under partially shaded condition during September 1991 adopting a randomised block design with 3 replications Each plot has a size of 2m x 1m and the seeds were sown with a spacing of 25 cm x 15 cm Observations recorded on 10 plant characters and incidence of pests and diseases For recording observations 10 plants were selected at random from each plot

1 Days to first flowering

The number of days taken for the 1st flower to open was recorded as the days to first flowering

2 Days to maturity

The number of days from sowing of the seeds to the harvest of the first pod in the ten observational plants per plot

3 Height of the plant

The height of the plant was measured in centimeters from the ground level to the tip of the main stem at the time of final harvest and the mean height was recorded

4 Number of branches per plant

The mean number of branches from the random sample of 10 plants at the final harvest was taken

5 Number of pods per plant

The total number of pods harvested from the 10 observational plants were noted and mean value was recorded

6 Lenght of pod

Five pods were selected from each observational plant their length measured in centimeters and the mean value was taken

7 Number of seeds per pod

Number of seeds in five randomly selected pods from each of the 10 observational plants was counted and the average number of seeds was taken

8 100-seed weight

From each observational plant the weight of 100 well developed seeds were taken and the mean arrived at

9 Seed yield per plant

The total seed yield from the ten observational plants in each plot was taken and their average value recorded in gram

10 Periodical shade intensity measurements

Periodical light intensity in each plot in the open condition was measured in Kilolux during the flowering (30 days after planting) and the harvest (45 days after planting) stages using a lux meter The light intensity was measured at 2 spots in each plot at three intervals of the day and the averages of the three readings were recorded The percentage of shade available in each plot was calculated as follows

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

where L_1 Light intensity in the open condition

L_2 Light intensity in the shade condition

11 Chlorophyll content

A mature leaf (third from the top of the plant) of each variety was collected from the three replications and chopped One gram leaf sample was taken macerated filtered and made up to 100 ml using 85% Acetone A sample of the made up solution was used as blank in the Bausch and Lomb spectronic 2000 spectrophotometer The absorbance was measured at two different wave lengths viz 645nm and 663nm for estimating chlorophyll a b and total The chlorophyll contents were calculated by the following formulae suggested by Starnes and Hadley (1965)

Chlorophyll a $12\ 7\ A_{663}\quad 2\ 58\ A_{645} \times \frac{V}{1000w}$ mg/litre

Chlorophyll b $22\ 87\ A_{645} - 4\ 67\ A_{663} \times \frac{V}{1000w}$ mg/litre

Total chlrophyll $8\ 05\ A_{663} + 20\ 29\ A_{645} \times \frac{V}{1000w}$ mg/litre where v Volume made up

w Weight of the plant sample taken

A Optical density (absorbance)

12 Reaction to major pests and diseases

a Pod borer (Lampides boeticus) incidence

Pod borer attack was noticed on the pods at harvest stage Caterpillars of this pest bore into the pods and feed on the seeds and other inner portions The attacked pods exhibited holes and excreata of the caterpillar The attack mainly started at the basal part of the pod The number of pods attacked by the pod borer were counted and expressed as percentage of the total number of pods in each plant and the average for each plot was worked out The data were analysed after weighted angular transformation

b) No other serious incidence of other pests and diseases were noted

Statistical analysis

Combining ability analysis in Line x Tester

Analysis of variance

Analysis of variance was done for all the characters and test of significance of differences among the types including parents and crosses was performed (Table 3)

Table 3 ANOVA for line x tester including parents

Source	df	MS	Expected MS
Replication	(r 1)		
Treatments	(l+t+lt 1)		
Parents	(l+t 1)		
Crosses	(lt 1)		
Parents Vs Crosses	1		
Lines	(l 1)	M_1	$\sigma^2 e$+r [Cov (FS) 2Cov (HS)] + rt Cov (HS)
Testers	(t 1)	M_t	$\sigma^2 e$+r[Cov (FS) 2 × Cov (HS)] + rl Cov (HS)
Line x tester	(l 1) (t 1)	M_1t	$\sigma^2 e$+r[Cov (FS) 2Cov (HS)]
Error	(r 1) (l+t+lt 1)	M_e	$\sigma^2 e$
Total	(rlt 1)		

where l number of lines
t number of testers
r number of replications

Estimation of combining ability

For estimating the general and specific combining ability effects the method described by Kempthorne (1957) was adopted In this method the co-variance of full sibs and half sibs in terms of mean squares due to lines (M_l) testers (M_t) line x tester (M_{lt}) were obtained from which the variance due to general combining ability (g c a) and specific combining ability (s c a) were estimated

The significance of lines and testers are tested against mean square due to line x tester while the significance of line x tester is tested against mean square for error (Singh and Chaudhary 1977)

Estimation of g c a and s c a effects

The model used to estimate the g c a and s c a effects of ijkth observation was as follows

$$x_{ijk} \quad \mu + g_i \quad + \quad g_j \quad + s_{ij} \quad + \quad e_{ijk}$$

where	μ	Population mean	
	g_i	g c a effect of ith line	
	g_j	g c a effect of jth tester	
	s_{ij}	s c a effect of ijth combination	
	e_{ijk}	error associated with ijkth observation	
	i	1 2	l number of lines
	j	1 2	t number of testers
	k	1 2	r number of replications

The individual effects were estimated as follows

1 Mean $\frac{x}{ltr}$

2 g c a effect of lines g_i $\frac{x_i}{tr} - \frac{x}{ltr}$

3 g c a effect of tester g_j $\frac{x_j}{lr} - \frac{x}{ltr}$

4 s c a effect in combinations

$$s_{ij} = \frac{x_{ij}}{r} - \frac{x_{i..}}{tr} - \frac{x_{.j.}}{lr} + \frac{x_{...}}{ltr}$$

Where x totality of obervations w r t all hybrid combinations

x_i totality of observations w r t i^{th} line over t testers and r replications

x_j Totality of observations w r t j^{th} tester over l lines and r replications

x_{ij} totality of observations w r t the hybrid between i^{th} line and j^{th} tester over r replications

The standard errors pertaining to g c a effect of lines and testers and s c a effects in different combinations were calculated as given below

S E(g_i) lines $(M_l/rt)^{0.5}$

S E(g_j) testers $(M_t/rl)^{0.5}$

S E(s_{ij}) in combinations $(M_e/r)^{0.5}$

The Genetic Components were estimated as

Cov H S (Line) $M_l - M_{lt} / rt$

Cov H S (testers) $M_t \quad M_{lt} / rl$

Cov H S (Average) $\frac{1}{r(2lt-l\ t)} \times \frac{(l-1)M_l+(t\ 1)M_t}{l+t\ 2} \quad M_{lt}$

Cov F S $\frac{(M_l \quad M_e) + (M_t - M_e) + (M_{lt} \quad M_e)}{3\ r} +$

$\frac{6r \text{ Cov HS} - ((rl+t) \text{ Cov HS}}{3r}$

σ^2(g c a) Cov H S (average) $\left(\frac{1+F}{4}\right)$ σ^2A

σ^2A $4\sigma^2$(g c a) when F 0

σ^2(s c a) $(M_{lt} - M_e)/r$

When F O σ^2D $4\sigma^2$ (s c a)

Where l number of lines

t number of testers

r number of replications

F inbreeding coefficient

σ^2A additive variance

σ^2D variance due to dominance

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

Contribution of lines $\frac{SS(l) \times 100}{SS\ (crosses)}$

Contribution of testers $\frac{SS(t) \times 100}{SS\ (Crosses)}$

Contribution of (l x t) $\frac{SS\ (l \times t) \times 100}{SS\ (crosses)}$

where SS(l) sum of squares due to lines

SS(t) sum of squares due to testers

SS(lxt) sum of squares due to line x tester

RESULTS

Results

The choice of suitable parents in evolving better varieties or hybrids is a matter of constant concern to the plant breeder Some idea on the usefulness of the parents may be obtained from their direct performance particularly for components of yield However the nature of gene action may vary with the genetic structure and divergence between varieties involved in hybridisation Consequently a high yielding line may not necessarily be able to transmit its superiority in cross combinations and vice versa It is therefore necessary to assess the genetic potential of the parents by estimating their combining ability before they are used in a bybridisation programme The line x tester analysis approach is not only useful for practical screening work but it is also more comprehensive than other techniques like diallel which is generally based on fewer parents The present study was undertaken to examine the combining ability and nature and magnitude of gene action in some varieties of grain cowpea under partially shaded conditions

The data evolved from the line x tester experiment were analysed statistically and the results are presented

The mean values for the best line tester and hybrid for 13 characters studied for the 20 treatments are presented in Table 4

Table 4. Phenotypic expression of the best parents and hybrids for the 13 characters

Sl No	Character	Line	Mean	Tester	Mean	Cross Combination	Mean
1	Days to flowering	Culture 9	33 53	S-488	38 93	Culture-9 x V-240	35 10
2	Days to maturity	Culture-9	50 20	GC 82-7	54 30	Chharodi 1 x V 26	50 25
3	Plant height						
	tallness	Chharodi-1	53 81	V-26	64 65	Chharodi 1 x V-322	56 79
	dwarfness	Culture 9	33 27	GC 82-7	48 08	Culture 9 xKanakamani	33 44
4	No of branches/plant	Culture 9	1 57	S-488	3 67	Chharodi-1 x V-26	3 50
5	No of pods/plant	Chharodi-1	18 43	GC 82-7	13 50	Chharodi 1 x V-26	26 17
6	Length of pod	Culture 9	13 43	Kanakamani	16 50	Culture 9 xKanakamani	14 98
7	No of seeds/pod	Culture 9	11 71	Kanakamani	14 14	Culture-9 xKanakamani	11 73
8	100-seed weight	Culture 9	9 27	Kanakamani	11 55	Culture-9 x GC 82-7	12 58
9	Seed yield/plant	Chharodi 1	10 58	V 26	14 08	Chharodi-1 x V 26	18 67
10	Chlorophyll a	Culture 9	1 47	V 240	1 46	Chharodi 1 x V 240	1 94
11	Chlorophyll b	Culture 9	0 53	V 26	0 66	Chharodi 1 x GC-82 7	0 66
12	Total chlorophyll	Culture-9	2 00	V-26	2 05	Chharodi 1 x V-240	2 36
13	Pod borer incidence	Culture-9	14 53	GC-82 7	7 50	Chharodi 1 x V-26	2 27

Table 5 sho vs the analysis of variance for different characters where the treatments are partitioned as parents crosses and parent vs crosses

The variation exhibited by lines testers and hybrids for the thirteen different characters studied are shown in Table 6.

For the character days to flowering the mean values recorded by the lines were 33 53 days (Culture-9) and 38 63 days (Chharodi 1) Among the testers it ranged from 38 93 days to 47 13 days in S-488 and V 322 respectively whereas in hybrids the range was from 35 1 days in Culture 9 x V-240 to 38 36 days in Chharodi 1 x Kanakamani ANOVA showed significant difference among the genotypes Variance due to parents was significant indicating genetic diversity among the parents while variance due to crosses was not significant revealing no difference among the crosses Significant variance due to the parents vs crosses revealed the presence of heterosis for this character

The range of variation for number of days to maturity in the testers was from 54 3 days recorded in GC 82-7 to 61 77 days in V 240 The lines Culture 9 and Chharodi-1 showed mean values 50 2 days and 54 47 days respectively Among the hybrids the range was from 50 25 days recorded by Chharodi-1 x V 26 to 55 43 days recorded by Chharodi 1 x GC-82 7 ANOVA revealed highly

Table 5 ANOVA for 13 characters

Source	df	Mean squares							
		Days to flowering	Days to maturity	Plant height	Number of branches per plant	Number of pods per plants	Pod length	Number of seeds per pod	100 seed weight
Replications	2	11 66**	22 88**	18 80**	0 04	75 90*	2 03	0 59	1 20
Treatments	19	33 13**	26 38**	297 54**	1 50*	89 02	11 61*	13 88**	7 98**
Parents	7	58 96**	46 56 *	315 57**	2 53 *	52 21*	11 59*	10 76*	8 27
Crosses	11	3 19	6 06**	222 70 *	0 84 *	80 66 *	6 90**	7 28	8 18**
Parent Vs cross	1	181 70*	136 77**	994 45**	1 45**	438 69	63 59*	108 12	3 85*
Error	38	1 61	2 05	5 31	0 19	3 60	1 88	0 48	0 42

**Significant at 1% level

Table 5 (Contd)

Source	df	Mean squares: Seed yield per plant	Chlorophyll a content	Chlorophyll b content	Total chlorophyll	Pod borer incidence
Replication	2	41 88**	0 04	0 02	0 11	1 00
Treatments	19	34 00**	0 16	0 03	0 25	51 89
Parents	7	23 53 *	0 03	0 02	0 15	61 19 *
Crosses	11	34 90 *	0 25	0 03*	0 33	22 32
Parent Vs cross	1	97 33	0 004	0 001	0 001	312 27 *
Error	38	5 60	0 13	0 01	0 14	11 62

* Significant at 1% level

Tab e No 6

Mean performance of lines esters and hybrids for hirteen charac ers

Treatments	Days o flo ering	Days o ma uri y	Plan he gh (cm)	Number of branches per plant	Number of pods per plant	Leng h of pod (cm)	Number of seeds per pod
L nes							
Chharodi 1	38 63	54 47	53 81	1 53	18 43	9 93	9 89
Cu ure 9	33 53	50 20	33 27	1 57	6 93	13 43	11 71
Testers							
Kanakamani	39 00	55 10	50 17	3 27	7 47	16 50	14 14
V 240	46 90	61 77	56 11	3 00	7 60	13 53	12 32
V 322	47 3	60 97	62 49	1 10	6 47	14 67	12 64
GC 82 7	39 63	54 30	48 08	2 10	13 50	12 20	8 43
V 26	40 83	56 40	64 65	2 43	11 03	14 42	13 37
S-488	38 93	54 77	60 66	3 67	12 23	14 77	10 59
Hyb ids							
Chharod 1xKanakamani	38 36	54 10	52 51	2 20	18 20	11 78	9 23
Chharodi 1xV 240	37 73	53 30	55 62	3 37	18 90	11 12	10 42
Chharodi 1xV 32	37 60	53 15	56 79	2 20	14 53	11 30	9 34
Chharod 1xGC 82 7	38 25	55 43	45 79	2 04	15 70	11 27	9 18
Chharodi 1xV 26	37 00	50 25	47 05	3 50	26 17	11 48	9 95
Chharodi 1xS-488	37 56	54 23	55 15	2 93	23 17	8 04	9 98
Cu ture 9xKanakamani	36 20	52 27	33 44	2 30	7 37	14 98	11 73
Cul ure 9xV 240	35 10	51 43	40 00	3 37	14 67	11 71	7 29
Culture 9xV 322	37 13	53 70	40 01	2 87	15 67	11 76	7 47
Cu ure 9xGC 82 7	35 63	51 57	39 07	2 50	12 40	11 96	6 53
Cu ure 9xV 26	36 03	52 37	33 46	2 20	11 80	12 29	8 59
Culture 9xS-488	37 07	53 17	52 76	2 33	12 67	11 28	7 06

Table No 6 (Contd)

Treatments	100-seed weight (g)	seed yie d per plant (g)	chlorophyll a con en (mg 1)	chlorophy b conten (mg 1)	total chlorophyll (mg/l)	pod borer incidence (percentage) (transformerd mean)
Lines						
Chharodi 1	6 20	10 58	1 23	0 40	1 36	14 77
Culture 9	9 27	5 67	1 47	0 53	2 00	14 53
Testers						
Kanakamani	11 55	12 30	1 23	0 43	1 66	16 28
V 240	9 37	6 67	1 46	0 43	1 88	10 57
V 322	11 32	8 67	1 43	0 40	1 83	22 19
GC 82 7	10 13	10 95	1 24	0 41	1 65	7 50
V 26	10 22	14 08	1 39	0 66	2 05	14 31
S-488	9 18	10 33	1 42	0 47	1 89	10 01
Hybrids						
Chharodi 1xKanakamani	10 02	15 62	1 45	0 48	1 92	7 22
Chharodi 1xV 240	8 21	14 58	1 94	0 42	2 36	7 20
Chharodi 1xV 322	8 38	9 40	1 28	0 45	1 73	7 55
Chharodi 1xGC 82 7	9 18	11 73	1 05	0 66	1 71	6 33
Chharodi 1xV 26	8 87	18 67	1 46	0 30	1 76	6 27
Chharodi 1xS-488	7 82	16 52	0 84	0 28	1 12	8 01
Culture 9xKanakamani	10 95	8 27	0 96	0 32	1 28	13 55
Culture 9xV 240	11 68	12 80	1 45	0 52	1 97	9 81
Culture 9xV 322	12 18	13 83	1 51	0 58	2 08	8 65
Culture 9xGC 82 7	12 58	8 73	1 34	0 51	1 85	13 17
Cul ure 9xV 26	11 47	11 13	1 39	0 47	1 86	13 30
Culture 9xS-488	10 72	8 80	1 44	0 51	1 94	8 29

significant difference among the different genotypes for this character Significant variance due to parents showed high differences among the parents Variance due to crosses were significant indicating diversity among the crosses Presence of substantial amount of heterosis for this character was indicated by the highly significant variance for parents vs crosses

Significant variation was exhibited by the parents and crosses for plant height Variance due to parents vs crosses was also significant revealing substantial amount of heterosis for height of the plant The mean values recorded by the lines were 33 27cm and 58 81 cm in Culture-9 and Chharodi-1 respectively Testers showed a variation ranging from 48 08cm (GC-82-7) to 64 65cm (V-26) whereas in hybrids the range was between 33 44 cm in Culture-9 x Kanakamani and 56 79cm in Chharodi-1 x V-322 All the cross combinations were intermediate in height with respect to their parents except hybrids of V-26 where the hybrids were shorter than the dwarf parent

ANOVA showed that for the character number of branches per plant variance due to parents crosses and parents vs crosses were highly significant denoting the presence of variation among parents and crosses and heterosis for the character The lines Chharodi-1 and Culture-9 recorded mean values 1 53 and 1 57 respectively Among the testers the range was from 1 10 (V 322) to 3 67 (S-488) In hybrids it ranged from 2 04 to 3 50 in Chharodi 1 x GC-82-7 and Chharodi 1 x V 26 respectively

Most of the hybrids produced more number of pods per plant than their parents The mean values recorded by the lines were 6 93 in Culture-9 and 18 43 in Chharodi 1 It ranged from 6 47 in V 322 to 13 50 in GC-82 7 among testers In the hybrids the range was from 7 37 (Culture-9 x Kanakamani) to 26 17 (Chharodi-1 x V 26) ANOVA showed highly significant variance due to parents crosses and parents vs crosses revealing significant differences among parents and crosses and presence of high amounts of heterosis for this character

The mean values for length of pod of lines were 9 93cm in Chharodi 1 and 13 43cm in Culture 9 The range of variation among testers was from 12 20cm in GC 82 7 to 16 50cm in Kanakamani Among the hybrids the range was between 8 04cm and 14 98cm in Chharodi 1 x S-488 and Culture 9 x Kanakamani respectively Hybrids of the line Chharodi 1 were intermediate to their parents except with S-488 A reduction in pod length was noticed among hybrids of the line Culture 9 except with Kanakamani Variance of parents crosses and parents vs crosses were found highly significant indicating the presence of genetic diversity among the parents and hybrids and heterosis for this trait

Treatments showed significant variation for number of seeds per pod Variance due to parents crosses and parents vs crosses were also highly significant showing that parents and crosses vary widely and a substantial amount of heterosis was present for this character The lines Chharodi-1 and Culture-9 recorded mean values of 9 89 and 11 71 respectively Among the testers the range was from 8 43 for GC-82-7 and 14 14 for Kanakamani In the hybrids it ranged from 6 53 (Culture-9 x GC 82 7) to 11 7 (Culture 9 x Kanakamani) Generally hybrids showed a reduction in number of seeds per pod

For the character 100-seed weight much variation was noticed among the genotypes Significant variance due to parents crosses and parents vs crosses revealed high differences among the parents crosses and high amount of heterosis for this character In lines the higher value was recorded by Culture 9 (9 27g) and lower value by Chharodi-1 (6 2g) Among testers Kanakamani produced grains with maximum 100 seed weight (11 55g) and the minimum by S-488 (9 18g) whereas in hybrids it ranged from 7 82g (Chharodi-1 x S-488) to 12 58g (Culture 9 x GC 82-7) Many hybrids produced a higher mean value for this character when compared to their parents

With regard to seed yield per plant treatments showed significant variation Variance due to parents crosses and parents vs crosses were significant indicating genetic diversity among the parents and crosses and a substantial amount of heterosis for this character A grain yield of 10 58g was recorded by the line Chharodi 1 and 5 67g by Culture 9 The range of variation among testers was between 6 67g recorded by V 240 and 14 08g recorded by V 26 Hybrids exhibited a range of 8 27g (Culture 9 x Kanakamani) to 18 67g (Chharodi 1 x GC 82 7)

ANOVA showed no significant difference among genotypes for chlorophyll a content The range was from 1 23 mg/l (Chharodi-1) to 1 47 mg/l (Culture-9) among lines from 1 23 mg/l (Kanakamani) to 1 46 mg/l (V 240) among testers and from 0 84 mg/l (Chharodi-1 x S-488) to 1 51 mg/l (Culture 9 x V-322) among hybrids

For chlorophyll b content significant variation existed among the genotypes Variance due to parents was not significant indicating no genetic diversity among parents Significant variance due to crosses revealed high differences among crosses Variance due to parents vs crosses was not significant Of the two lines a higher mean value was shown by Culture-9 (0 53 mg/l) followed by Chharodi-1 (0 40 mg/l) The mean values recorded by testers ranged from 0 40 mg/l (V-322) to 0 66 mg/l (V 26) whereas the hybrids showed a range of 0 28 mg/l for Chharodi 1 x S-488 to 0 66 mg/l for Chharodi 1 x GC-82 7

Little variation was exhibited by the genotyp/es with respect to total chlorophyll content Among the two lines maximum total chlorophyll content vas recorded by Culture-9 (2 00 mg/l) and minimum by Chharodi 1 (1 36 mg/l) It ranged from 1 65 mg/l recorded in GC-82 7 to 2 05 mg/l recorded in V 26 whereas among hybrids the range was between 1 12 mg/l (Chharodi-1 x S 488) and 2 36 mg/l (Chharodi 1 x V 240)

The mean values recorded by the lines were 14 53 percent by Culture-9 and 14 77 percent by Chharodi-1 with respect to the attribute percentage of pod borer infestation Among the testers the means ranged from 7 50 percent recorded by GC 82-7 to 22 19 percent recorded by V 322 The range of variation of hybrids was between 6 27 percent recorded in Chharodi -1 x V 26 and 13 55 percent recorded in Culture 9 x Kanakamani The genotypes showed significant variation for this attribute Variance due to parents was significant indicating diversity among parents while variance due to crosses was not significant Significant variance due to parent vs crosses indicate the presence of high heterosis for this character

The analysis of variance of shade intensity observed on the plots at three different times of the day at flowering (30 days after sowing) and pod formation (45 days after sowing) periods did not show any significant difference in magnitude The ANOVA for shade intensity is presented in table 7

Table 7 Analaysis of variance for shade intensity

Sl No	Periods	Mean squares Treatment	Error	F Value *
I	30 days after sowing			
	1	29 02	92 56	0 31
	2	5 81	25 67	0 23
	3	13 21	118 80	0 11
II	45 days after sowing			
	1	10 49	150 65	0 07
	2	4 85	19 01	0 26
	3	18 37	353 11	0 05

* Not significant

It was seen that in general the line Chharodi 1 had desirable mean values for tallness number of pods per plant and seed yield per plant while Culture 9 was best for all other characters Among the testers the variety V 26 showed desirable mean values for tallness seed yield per plant chlorophyll b content and total chlorophyll content The other good testers were S-488 (number of branches per plant and early flowering) GC-82-7 (number of pods per plant early maturity dwarfness and low pod borer incidence) Kanakamani (length of pod number of seeds per pod and 100 seed weight) and V 240 (Chlorophyll a content)

Chharodi 1 x V 26 was the best combination for days to maturity number of branches per plant number of pods per plant seed yield per plant and pod borer resistance Culture 9 x Kanakamani had high mean values for length of pod and number of seeds per pod Culture 9 x GC-82 7 for 100 seed weight and Chharodi 1 x V-240 for chlorophyll a and total chlorophyll content

Combining ability

In predominantly self pollinated crops like cowpea the technique of line x tester cross analysis has appeared to be a useful tool for screening the lines with rapidity and a reasonable degree of confidence Results from combining ability analysis from line x tester mating system in cowpea is presented below

The analysis of variance of 13 characters clearly showed significant differences among the genotypes for eleven attributes and non-significant differences for two attributes viz chlorophyll a content and total chlorophyll content Combining ability analysis was carried out only for those characters which established significant differences among treatments The ANOVA for combining ability is presented in Table 8

The mean squares due to lines were significant for six characters viz days to flowering plant height number of pods per plant pod length 100-seed weight and percentage of pod borer infestation whereas variation due to testers showed significant differences only for the character pod length

The interaction between line x tester were significant for most of the characters except days to flowering pod length and pod borer incidence

Table 8 ANOVA for combining ability for 11 characters

		Mean squares					
Source	df	Days to flowering	Days to maturity	Plant height	Number of branches/ plant	Number of of pods/ plant	Pod length
Lines	1	21 82**	8 91	1376 42 *	0 11	453 69 *	21 15**
Testers	5	1 06	5 01	152 44	1 04	35 00	8 45
Line x Tester	5	1 59	6 53*	62 22**	0 79**	51 72**	2 70
Error	38	1 61	2 05	5 31	0 19	3 60	1 88
g c a	7	0 06	0 02	6 13	0 002	1 11	0 16
s c a	11	0 006	1 49	18 97	0 20	16 04	0 27

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

Table 8 (Contd)

Sources	df	Mean Squares				
		No of seeds per pod	100 seed weight	Seed yield per plant	Chlorophyll b content	Pod borer incidence
Lines	1	22 23	73 10**	131 56	0 02	146 35**
Testers	5	4 94	1 78	16 14	0 04	5 77
Line x tester	5	6 65**	1 60**	34 33**	0 04**	14 06
Error	38	0 48	0 42	5 60	0 01	11 62
g c a	7	0 02	0 25	0 02	-0 0001	0 32
s c a	11	2 06	0 39	9 58	0 01	0 81

** Significant at 1% level

The estimates of variance due to g c a was greater than s c a for days to flowering and length of pod indicating the importance of general combining ability for these characters However for all other attributes the s c a variance was greater in magnitude than g c a variance denoting the predominance of specific combining ability for these characters

The estimates of g c a effects of two lines and six testers and s c a effects of twelve F_1s for eleven characters are presented in Table 9

Days to flowering

Variance due to lines showed significant difference for this character indicating that lines differed for their g c a effects MS due to testers and line x testers were not significant for days to flowering suggesting the absence of difference among g c a effect of testers and s c a effect of hybrids Also the g c a variance was greater in magnitude than s c a variance indicating the importance of general combining ability for days to flowering

The estimates of g c a effects of lines and testers and s c a effects of hybrids are presented in Table 9 (i) and Fig 1 The g c a effects were comparatively low for lines and very low for testers Both the lines Chharodi 1 (0 78) and Culture 9 (-0 78)

Table 9 (1) g c a and s c a effects for days to flowering

		Kanakamani (T_1)	V-240 (T_2)	V 322 (T_3)	GC-82 7 (T_4)	V 26 (T_5)	S-488 (T_6)
		Testers					
Lines	g c a effects	0 51	0 56	0 39	-0 03	0 46	0 34
		s c a effects					
Chharodi- 1 (L_1)	0 78*	0 30	0 58	0 55	0 53	0 30	0 53
Culture 9 (L_2)	0 78*	0 30	-0 58	0 55	0 53	0 30	0 53

significant at 5% level

	SE	CD5%
g c a line	0 30	0 61
g c a tester	0 52	1 05
s c a	0 73	1 48

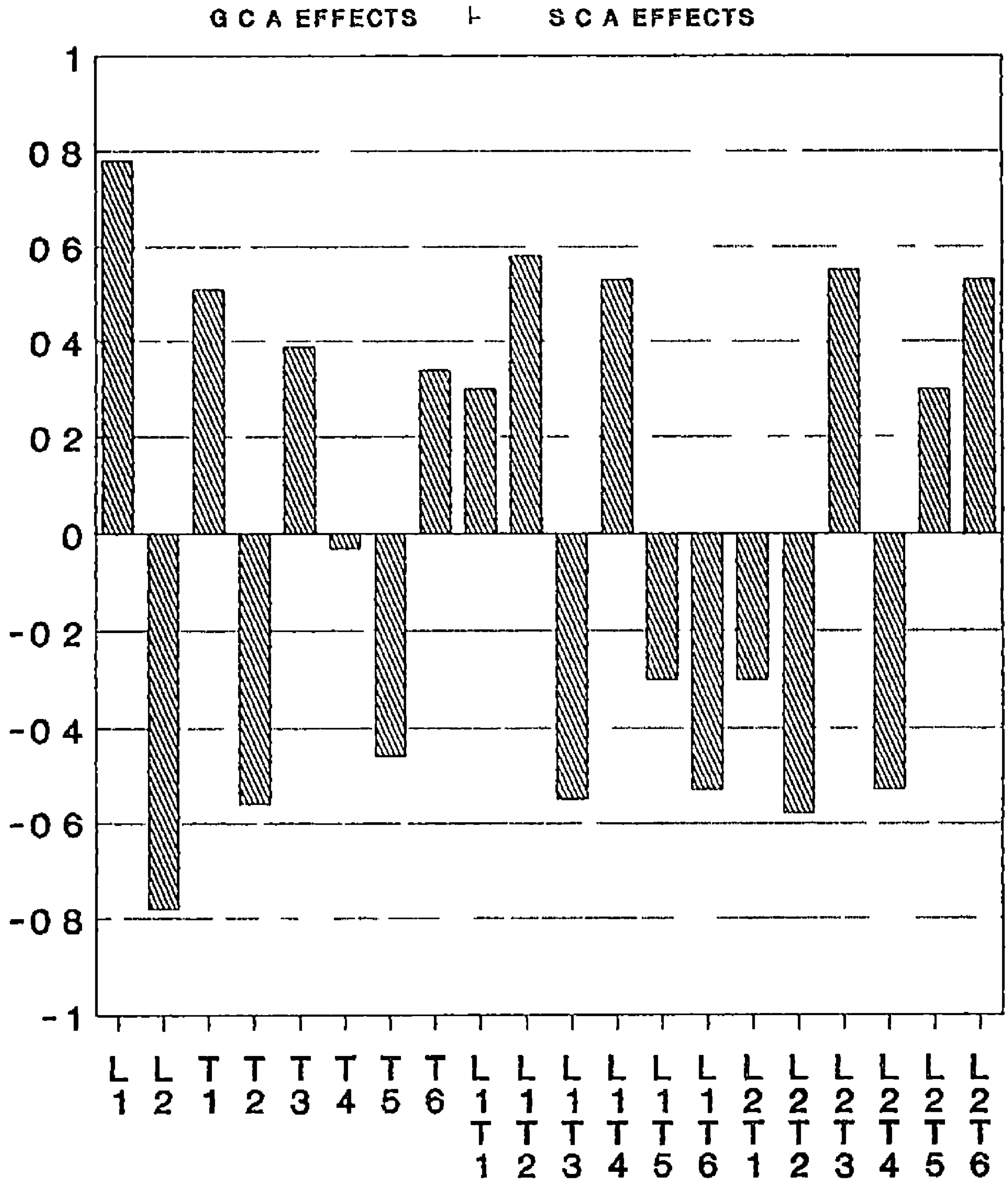
Fig 1 General specific combining ability e fe ts for days to flowering

L_1		Chharodi-1
L_2		Culture-9
T_1		Kanakamani
T_2	-	V 240
T_3	-	V 322
T_4	-	Gu 82-7
T_5	-	V-26
T_6	-	S-488
L_1T_1	-	Chharodi-1 x Kanakamani
L_1T_2	-	Chharodi-1 x V 2
L_1T_3	-	Chharodi-1 x V-
L_1T_4	-	Chharodi 1 x GC 7
L_1T	-	Chharodi-1 x 6
L_1T	-	Chharodi 1 x 488
L	-	Cul ure-9 x Kanakama
L	-	Culture 9 x 40
L_2	-	Culture 9 x V 322
T_4	-	Cultu e 9 x 82-7
L	-	Culture
$L_2\ 6$	-	Culture 9 x S-48

Fig 1 General and specific combining ability effects for days to flowering

L_1	-	Chharodi-1
L_2		Culture-9
T_1		Kanakamani
T_2		V-240
T_3		V 322
T_4		GC 82-7
T_5	-	V 26
T_6	-	S-488
L_1T_1	-	Chharodi-1 x Kanakamani
L_1T_2	-	Chharodi 1 x V-240
L_1T_3		Chharodi-1 x V-322
L_1T_4		Chharodi 1 x GC-82 7
L_1T_5		Chharodi-1 x V-26
L_1T_6		Chharodi-1 x S-488
L_2T_1	-	Culture 9 x Kanakamani
L_2T_2		Culture 9 x V 240
L_2T_3		Culture 9 x V 322
L_2T_4	-	Culture 9 x GC 82-7
L_2T_5		Culture 9 x V 26
L_2T_6		Culture 9 x S-488

General and Specific Combining ability effects



DAYS TO FLOWERING

FIG 1

showed significant g c a effects None of the testers exhibited significant g c a effects The best general combiners for earliness to flowering were Culture 9 (-0 78) among lines and V 240 (0 50) among testers

The s c a effects were also very low for days to flowering and it ranged from -0 58 (Culture 9 x V-240) to 0 58 (Chharodi 1 x V-240) and none of the crosses exhibited significant s c a effects The best specific combination for early flowering was Culture 9 x V-240

Days to maturity

Partitioning of the hybrids indicated that mean squares due to line x testers alone was significant indicating that the crosses alone differed for their s c a effects Variance due to lines and testers were not significant for days to maturity Moreover the variance due to s c a was greater than that of g c a suggesting the importance of specific combining ability for this character

The g c a and s c a effects for this character is presented in Table 9 (ii) and Fig 2 No significant g c a effect was shown by the lines But the line Culture-9 (0 50) showed negative g c a effect which was the desirable one Among the testers g c a effects ranged from 1 61 (V 26) to 0 79 (S-488) of which g c a effect of

Table 9 (ii) g c a and s c a effects for days to maturity

		Testers					
		Kanakamani (T_1)	V 240 (T_2)	V 322 (T_3)	GC 82 7 (T_4)	V 26 (T_5)	S-488 (T_6)
Lines	g c a effects	0 27	-0 55	0 51	0 59	1 61**	0 79
		s c a effects					
Chharodi 1 ((L_1)	0 50	0 42	0 44	0 77	1 44	1 56	0 04
Culture 9 (L_2)	0 50	0 42	0 44	0 77	1 44	1 56	0 04

** significant at 1% level

	SE	CD 5%
g c a line	0 34	0 08
g c a tester	0 58	1 18
s c a	0 83	1 67

Fig 2 General and specific combining ability effects for days to maturity

L_1	-	Chharodi 1
L_2	-	Culture 9
T_1	-	Kanakamani
T_2	-	V 240
T_3	-	V 322
T_4	-	GC-82-7
T_5		V 26
T_6	-	S-488
L_1T_1	-	Chharodi 1 x Kanakamani
L_1T_2	-	Chharodi-1 x V-240
L_1T_3	-	Chharodi-1 x V-322
L_1T_4		Chharodi 1 x GC 82-7
L_1T_5	-	Chharodi-1 x V-26
L_1T_6		Chharodi 1 x S-488
L_2T_1	-	Culture 9 x Kanakamani
L_2T_2	-	Culture 9 x V 240
L_2T_3	-	Culture-9 x V-322
L_2T_4		Culture 9 x GC 82 7
L_2T_5	-	Culture 9 x V 26
L_2T_6	-	Culture 9 x S-488

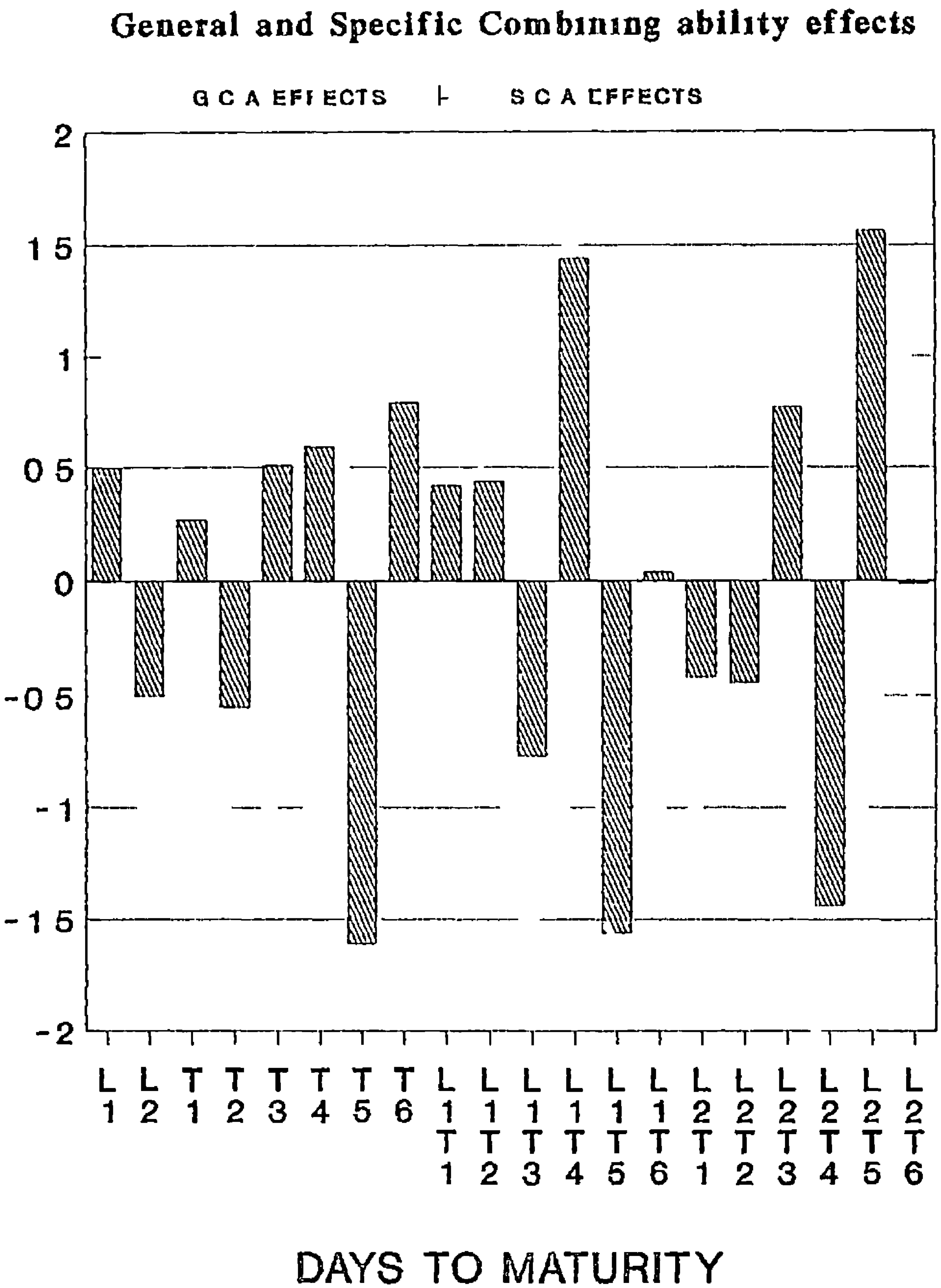

General and Specific Combining ability effects
G C A EFFECTS
S C A EFFECTS
2
1 5
1
0 5
0
-0 5
-1
-1 5
-2
L 1
L 2
T 1
T 2
T 3
T 4
T 5
T 6
L 1 T 1
L 1 T 2
L 1 T 3
L 1 T 4
L 1 T 5
L 1 T 6
L 2 T 1
L 2 T 2
L 2 T 3
L 2 T 4
L 2 T 5
L 2 T 6
DAYS TO MATURITY

FIG 2

V-26 alone was significant statistically and can be considered as a good general combiner for early maturity

None of the cross combinations exhibited significant s c a effects while the range was from -1 56 in Chharodi-1 x V-26 to 1 56 in Culture-9 x V-26 The best specific combination for early maturity was Chharodi 1 x V-26

Plant height

Variance due to lines showed significant difference denoting that lines differed for their g c a effects while variation due to testers was not significant The interaction between line x testers was highly significant indicating significant difference among s c a effects of crosses Mean squares due to s c a was three times higher in magnitude than g c a variance indicating the predominance of specific combining ability for plant height

The effects due to g c a and s c a for plant height is presented in Table 9 (iii) and Fig 3 The lines Chharodi 1 (6 18) and Culture-9 (-6 18) recorded significant g c a effects Kanakamani V-322 GC 82-7 V-26 and S-488 were the testers with significant g c a effects Among these significant positive g c a effects were shown by V-322 (2 43) and S-488 (7 97) while V-26 (-5 71) GC 82-7 (-3 54) and Kanakamani (3 00) showed significant negative g c a

Table 9 (iii) g c a and s c a effects for plant height

		Testers					
		Kanakamani (T_1)	V 240 (T_2)	V 322 (T_3)	GC 82 7 (T_4)	V 26 (T_5)	S-488 (T_6)
Lines	g c a effects	-3 00**	1 84	2 43*	-3 54**	5 71**	7 97**
		s c a effects					
Chharodi 1 (L_1)	6 18**	3 35*	1 63	2 21	2 82*	0 61	4 98*
Culture 9 (T_2)	6 18**	3 35	1 63	2 21	2 82*	0 61	4 98**

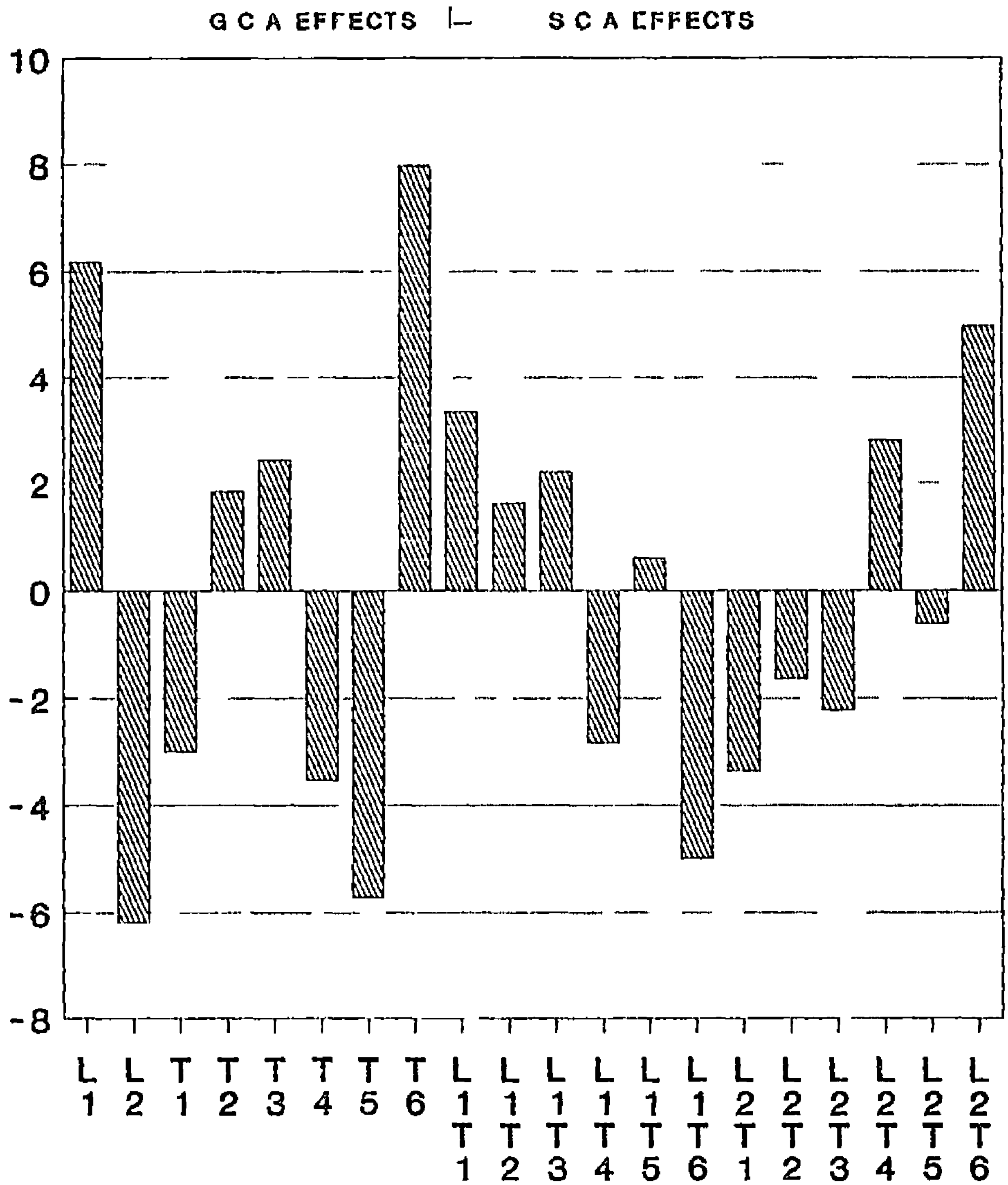
* significant at 5% level
** significant at 1% level

	SE	CD 5%
g c a line	0 54	1 10
g c a tester	0 94	1 90
s c a	1 33	2 69

Fig 3 General and specific combining ability effects for plant height

L_1	-	Chharodi-1
L_2		Culture-9
T_1	-	Kanakamani
T_2		V 240
T_3		V-322
T_4		GC-82 7
T_5	-	V 26
T_6	-	S-488
L_1T_1	-	Chharodi-1 x Kanakamani
L_1T_2	-	Chharodi-1 x V-240
L_1T_3	-	Chharodi-1 x V-322
L_1T_4	-	Chharodi-1 x GC-82 7
L_1T_5	-	Chharodi 1 x V 26
L_1T_6	-	Chharodi 1 x S-488
L_2T_1	-	Culture-9 x Kanakamani
L_2T_2	-	Culture-9 x V-240
L_2T_3		Culture-9 x V-322
L_2T_4		Culture 9 x GC 82 7
L_2T_5	-	Culture-9 x V-26
L_2T_6	-	Culture 9 x S-488

General and Specific Combining ability effects



PLANT HEIGHT

FIG 3

effects Thus the line Chharodi-1 and the tester S-488 were good general combiners for tallness and Culture-9 among lines and V-26 among testers were the best general combiners for dwarfness

Estimates of s c a effects of crosses ranged from -4 98 to 4 98 Six out of the twelve crosses had significant s c a effects It was positive in three crosses viz Culture 9 x GC-82 7(2 82) Chharodi-1 x Kanakamani (3 35) and Culture 9 x S-488 (4 98) The significant negative s c a effects were recorded by Chharodi-1 x S-488 (-4 98) Culture 9 x Kanakamani (-3 35) and Chharodi-1 x GC 82-7 (-2 82) The best hybrid combination for tallness was Culture-9 x S-488 and Chharodi 1 x S-488 for dwarfness

Number of branches per plant

Mean squares due to lines and testers were not significant Line x testers showed highly significant differences indicating that crosses had significant s c a effects Variance due to s c a was greater in magnitude than g c a effects indicating the importance of specific combining ability for number of branches per plant

G c a and s c a estimates are presented in Table 9 (iv) and Fig 4 G c a effects were very low for lines and none of them were significant whereas g c a effects of three testers viz Kanakamani (0 40) GC 82-7 (0 38) and V 240 (0 72) were significant

Table 9 (iv) g c a and s c a effects for number of branches per plant

		Testers					
		Kanakamani (T_1)	V 240 (T_2)	V 322 (T_3)	GC 82 7 (T_4)	V 26 (T_5)	S-488 (T_6)
Lines	g c a effects	0 40*	0 72**	-0 12	0 38*	0 20	-0 02
		s c a effects					
Chharodi 1 (L_1)	0 06	0 11	-0 06	-0 39	0 29	0 59*	0 24
Culture 9 (L_2)	0 06	0 11	0 06	0 39	0 29	0 59	0 24

significant at 5% level
significant at 1% level

	SE	CD 5%
g c a line	0 10	0 21
g c a tester	0 18	0 36
s c a	0 25	0 51

Fig 4 General and specific combining ability effects for number of branches per plant

L_1		Chharodi-1
L_2	-	Culture 9
T_1	-	Kanakamani
T_2		V 240
T_3		V 322
T_4	-	GC-82 7
T_5		V 26
T_6	-	S-488
L_1T_1		Chharodi 1 x Kanakamani
L_1T_2	-	Chharodi-1 x V-240
L_1T_3	-	Chharodi 1 x V 322
L_1T_4		Chharodi 1 x GC 82 7
L_1T_5	-	Chharodi 1 x V 26
L_1T_6	-	Chharodi-1 x S-488
L_2T_1	-	Culture-9 x Kanakamani
L_2T_2	-	Culture 9 x V 240
L_2T_3		Culture 9 x V 322
L_2T_4	-	Culture 9 x GC 82-7
L_2T_5		Culture 9 x V-26
L_2T_6		Culture-9 x S-488

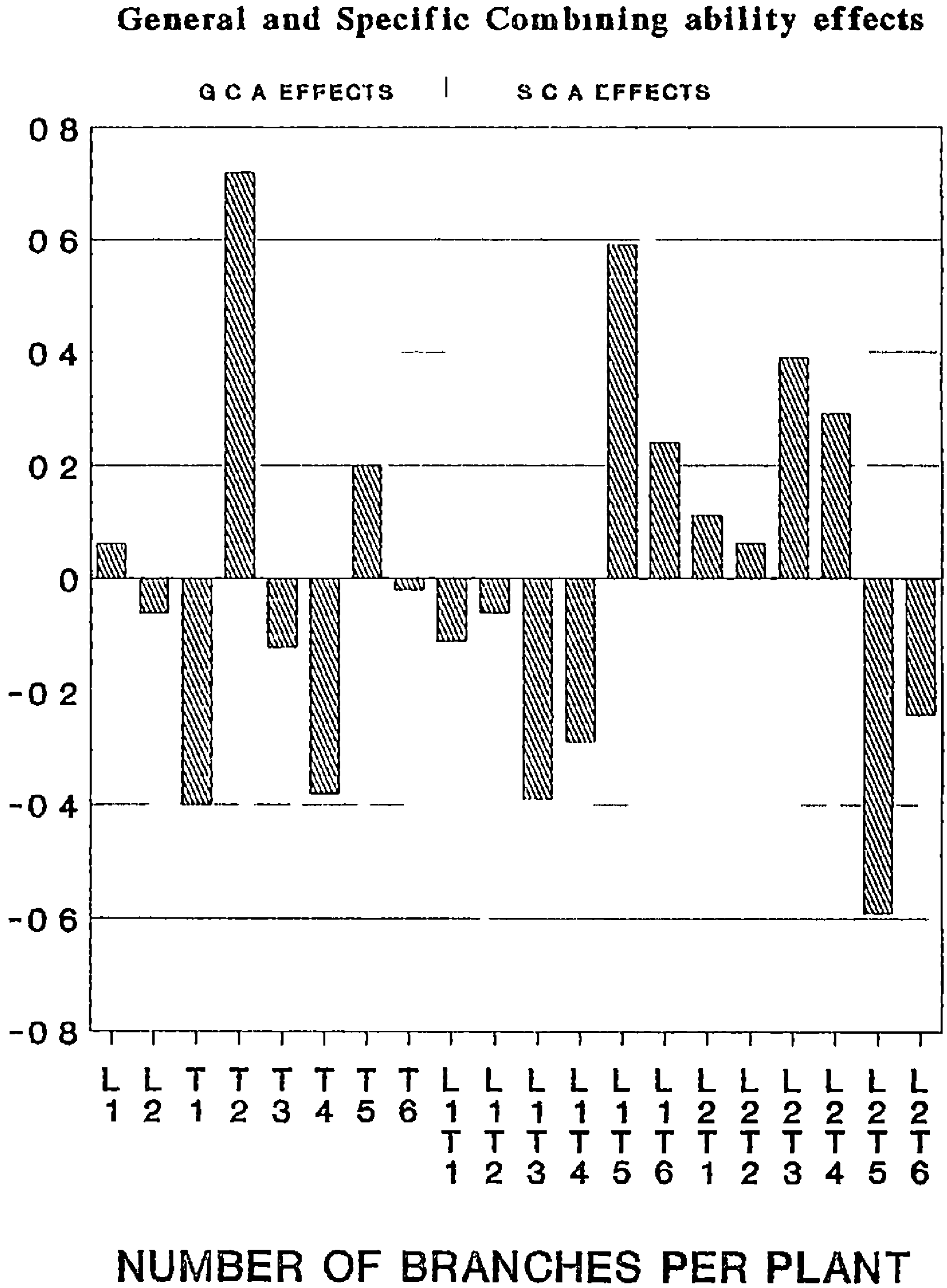

General and Specific Combining ability effects
G C A EFFECTS
S C A EFFECTS
0 8
0 6
0 4
0 2
0
-0 2
-0 4
-0 6
-0 8
L1
L2
T1
T2
T3
T4
T5
T6
L1T1
L1T2
L1T3
L1T4
L1T5
L1T6
L2T1
L2T2
L2T3
L2T4
L2T5
L2T6
NUMBER OF BRANCHES PER PLANT

FIG 4

The s c a effects were comparatively low for this trait and the range was from -0 59 (Culture 9 x V-26) to 0 59 (Chharodi-1 x V 26) Only two out of twelve hybrids produced significant s c a effects viz Culture 9 x V-26 and Chharodi 1 x V-26 For number of branches per plant Chharodi 1 x V-26 can be recommended as the best specific combination

Number of pods per plant

Variance due to lines was significant for no of pods/plant indicating the importance of g c a effect No significant variance was noted for the testers The interaction between line x testers was significant indicating high significant difference among s c a effects of crosses Mean square due to s c a was greater in magnitude than mean square due to g c a Hence it can be infered that though both g c a and s c a were important for the expression of no of pods per plant specific combining ability was predominant

Table 9 (v) and Fig 5 present the g c a effects of lines and testers and s c a effects of hybrids for number of pods per plant G c a effect was significant for both the lines of these Culture-9 (3 55) showed significant negative g c a effect and Chharodi-1 (3 55) showed significant positive g c a effect Among the six testers Kanakamani (3 19) and GC-82 7 (1 93) recorded significant negative g c a effects and V-240 (1 81) S 488 (2 19) and V 26

Table 9 (v) g c a and s c a effects for number of pods per plant

		Testers					
		Kanakamani (T_1)	V 240 (T_2)	V 322 (T_3)	GC 82 7 (T_4)	V 26 (T_5)	S-488 (T_6)
Lines	g c a effects	3 19**	1 81*	0 88	1 93*	3 01**	2 19**
		s c a effects					
Chharodi 1 (L_1)	3 55**	1 87	1 43	4 12**	1 90	3 63**	1 95
Culture 9 (L_2)	3 55**	1 87	1 43	4 12 *	1 90	3 63**	1 95

* significant at 5% level
** significant at 1% level

	SE	CD 5%
g c a line	0 45	0 90
g c a tester	0 77	1 57
s c a	1 10	2 22

Fig 5 General and specific combining ability effects for number of pods per plant

L_1	-	Chharodi-1
L_2		Culture-9
T_1	-	Kanakamani
T_2		V-240
T_3		V 322
T_4	-	GC-82-7
T_5	-	V-26
T_6		S-488
L_1T_1		Chharodi 1 x Kanakamani
L_1T_2	-	Chharodi 1 x V-240
L_1T_3	-	Chharodi 1 x V-322
L_1T_4	-	Chharodi-1 x GC 82-7
L_1T_5		Chharodi-1 x V 26
L_1T_6	-	Chharodi-1 x S-488
L_2T_1		Culture 9 x Kanakamani
L_2T_2	-	Culture-9 x V 240
L_2T_3	-	Culture-9 x V-322
L_2T_4	-	Culture-9 x GC-82-7
L_2T_5	-	Culture 9 x V-26
L_2T_6	-	Culture-9 x S-488

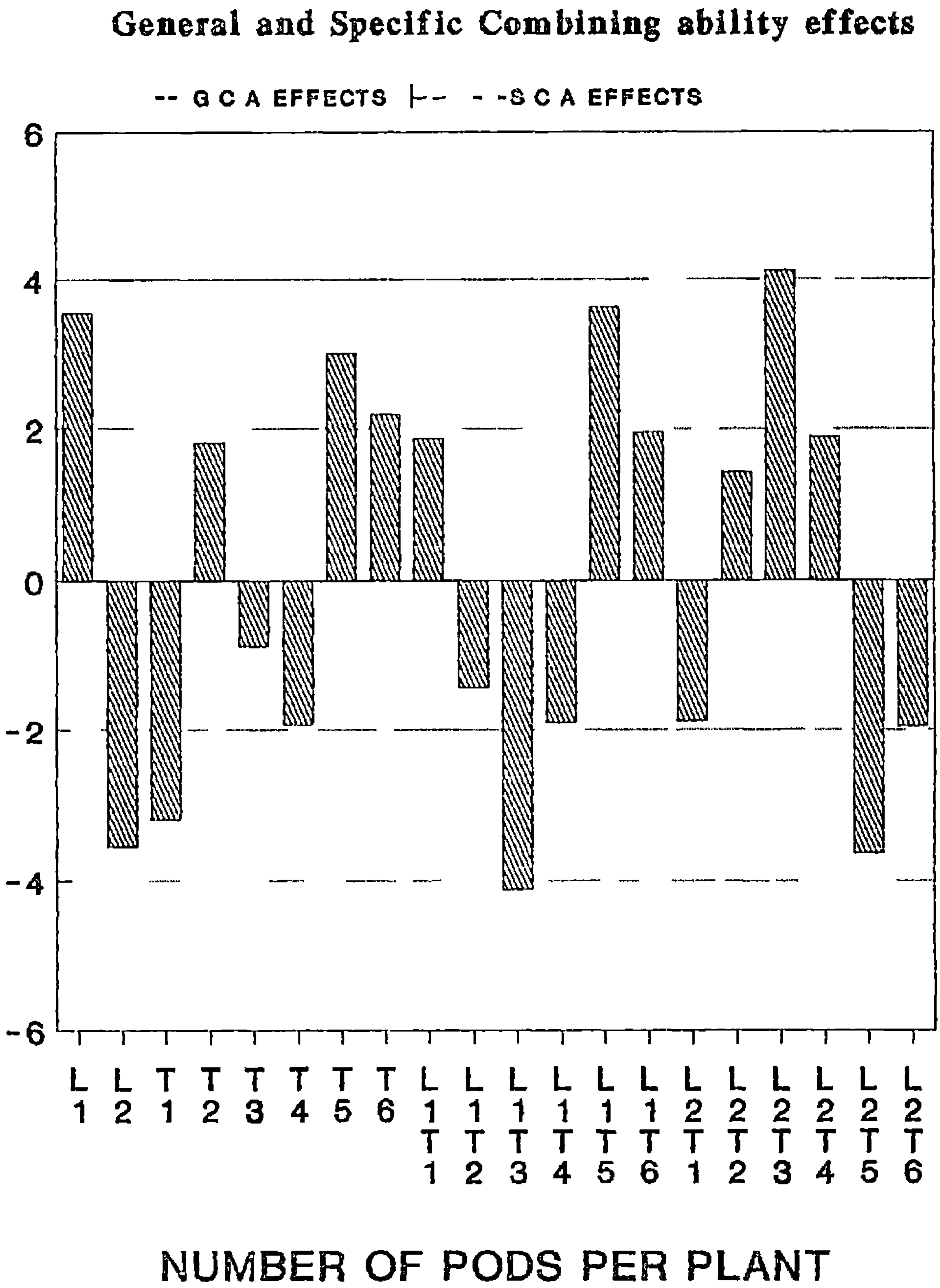

General and Specific Combining ability effects
-- G C A EFFECTS
- - -S C A EFFECTS
6
4
2
0
-2
-4
-6
L1 L2 T1 T2 T3 T4 T5 T6 L1T1 L1T2 L1T3 L1T4 L1T5 L1T6 L2T1 L2T2 L2T3 L2T4 L2T5 L2T6
NUMBER OF PODS PER PLANT

FIG 5

(3 01) recorded significant positive g c a effects Chharodi-I and V-26 can be considered as good general combiners for more number of pods per plant

The s c a effects ranged from 4 12 to 4 12 Out of the twelve hybrid combinations only four crosses exhibited significant s c a effects The crosses Chharodi-1 x V-26 (3 63) and Culture 9 x V 322 (4 12) showed significant positive s c a effects whereas Chharodi 1 x V-322 (4 12) and Culture-9 x V-26 (3 63) produced significant negative s c a effects The best specific combination for number of pods per plant was Culture 9 x V 322 followed by Chharodi-1 x V-26

Length of pod

Combining ability analysis revealed that for length of pod variance due to lines and testers was statistically significant denoting the significant differences among g c a effects of lines and testers But variance due to line x tester interaction did not differ statistically The g c a variance was also higher in magnitude than the corresponding s c a variance These indicated the importance of general combining ability alone for length of pod

The g c a and s c a effects of lines testers and crosses are presented in Table 9 (vi) Fig 6 Among the lines Chharodi-1 showed a significant negative g c a effect of -0 75 and Culture 9 a

Table 9 (vi) g c a and s c a effects for length of pod

		Testers					
		Kanakamani (T_1)	V 240 (T_2)	V 322 (T_3)	GC-82 7 (T_4)	V 26 (T_5)	S-488 (T_6)
Lines	g c a effects	1 80**	0 17	0 05	0 03	0 31	1 92**
		s c a effects					
Chharodi 1 (L_1)	0 75*	0 85	0 46	0 52	0 40	0 35	0 81
Culture 9 (L_2)	0 75*	0 85	0 46	0 52	0 40	0 35	0 81

* significant at 5% level
** significant at 1% level

	SE	CD 5%
g c a line	0 32	0 65
g c a tester	0 56	1 13
s c a	0 79	1 60

Fig 6 General and specific combining ability effects for length of pod

L_1	-	Chharodi-1
L_2		Culture 9
T_1		Kanakamani
T_2	-	V 240
T_3	-	V 322
T_4	-	GC 82-7
T_5	-	V-26
T_6		S-488
L_1T_1	-	Chharodi 1 x Kanakamani
L_1T_2	-	Chharodi 1 x V-240
L_1T_3		Chharodi 1 x V-322
L_1T_4	-	Chharodi 1 x GC-82-7
L_1T_5		Chharodi 1 x V 26
L_1T_6	-	Chharodi 1 x S-488
L_2T_1	-	Culture 9 x Kanakamani
L_2T_2	-	Culture-9 x V 240
L_2T_3		Culture 9 x V-322
L_2T_4	-	Culture 9 x GC-82 7
L_2T_5	-	Culture 9 x V-26
L_2T_6		Culture 9 x S-488

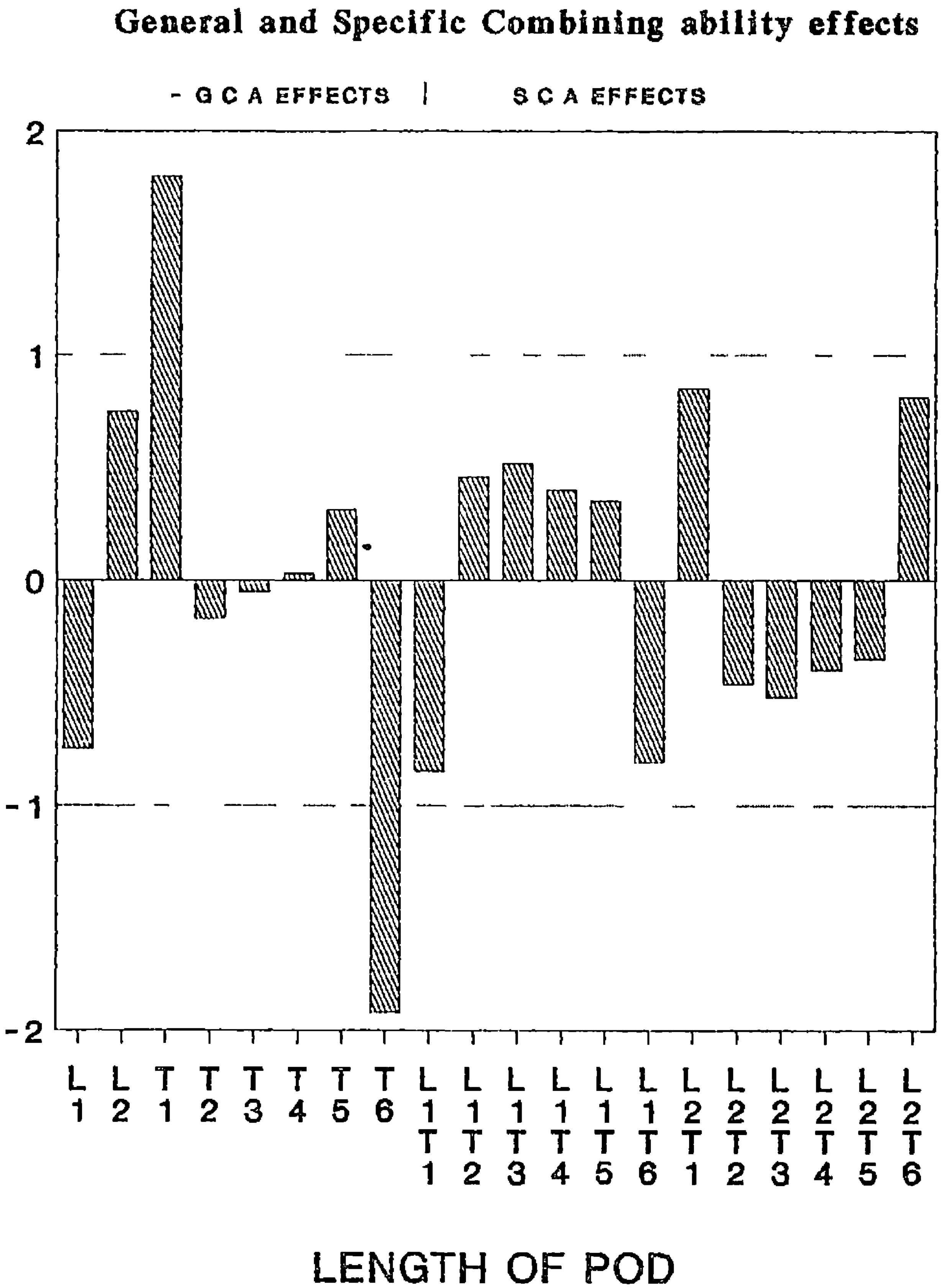

General and Specific Combining ability effects
- G C A EFFECTS | S C A EFFECTS
2
1
0
-1
-2
L1 L2 T1 T2 T3 T4 T5 T6 L1T1 L1T2 L1T3 L1T4 L1T5 L1T6 L2T1 L2T2 L2T3 L2T4 L2T5 L2T6
LENGTH OF POD

FIG 6

significant positive g c a effect of 0 75 Of the six testers only two had significant g c a effect viz Kanakamani (1 80) with significant positive g c a effect and S 488 (1 92) with significant negative g c a effect Culture 9 and Kanakamani were found to be good general combiners for length of pod from lines and testers respectively

None of the combinations showed significant s c a effect However the range was from -0 85 recorded by Chharodi 1 x Kanakamani to 0 85 recorded by Culture 9 x Kanakamani

Number of seeds per pod

Variance due to lines and testers were not significant for number of seeds per pod But the variance due to line x testers was highly significant suggested that crosses differed significantly for their s c a effects Mean squares due to s c a was greater in magnitude than that of g c a indicating the importance of specific combining ability for this character

Estimates of g c a and s c a effects for number of seeds per pod is presented in Table 9 (vii) and Fig 7 Both the lines showed significant g c a effects Of these Chharodi-1 (0 79) had positive effect and Culture-9 (0 79) had negative effect Chharodi-1 can be selected as the best general combiner line

Table 9 (vii) g c a and s c a effects for number of seeds per pod

		Testers					
		Kanakamani (T_1)	V 240 (T_2)	V 322 (T_3)	GC 82-7 (T_4)	V 26 (T_5)	S-488 (T_6)
Lines	g c a effects	1 59**	0 05	-0 49	-1 04**	0 37	0 38
		s c a effects					
Chharodi 1 (L_1)	0 79**	2 04**	0 78	0 15	0 54	0 11	0 68
Culture 9 (L_2)	0 79**	2 04**	-0 78	0 15	0 54	0 11	0 68

** significant at 1% level

	SE	CD 5%
g c a line	0 16	0 33
g c a tester	0 28	0 57
s c a	0 40	0 81

Fig 7 General and specific combining ability effects for number of seeds per pod

L_1	-	Chharodi 1
L_2	-	Culture-9
T_1	-	Kanakamani
T_2	-	V-240
T_3	-	V-322
T_4	-	GC 82 7
T_5	-	V-26
T_6		S-488
L_1T_1	-	Chharodi 1 x Kanakamani
L_1T_2	-	Chharodi-1 x V 240
L_1T_3	-	Chharodi 1 x V-322
L_1T_4	-	Chharodi-1 x GC-82-7
L_1T_5	-	Chharodi-1 x V-26
L_1T_6		Chharodi 1 x S-488
L_2T_1		Culture-9 x Kanakamani
L_2T_2	-	Culture-9 x V 240
L_2T_3	-	Culture-9 x V-322
L_2T_4	-	Culture 9 x GC-82-7
L_2T_5		Culture 9 x V-26
L_2T_6	-	Culture-9 x S-488

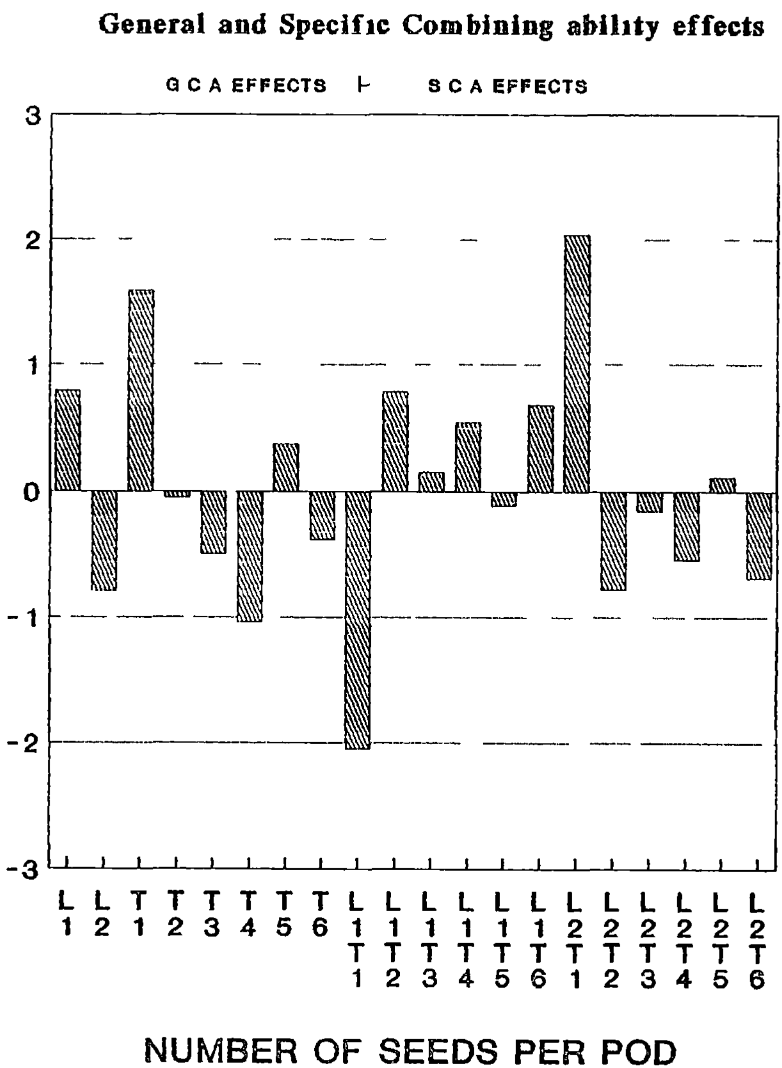

General and Specific Combining ability effects
G C A EFFECTS
S C A EFFECTS
3
2
1
0
-1
-2
-3
L1
L2
T1
T2
T3
T4
T5
T6
L1T1
L1T2
L1T3
L1T4
L1T5
L1T6
L2T1
L2T2
L2T3
L2T4
L2T5
L2T6
NUMBER OF SEEDS PER POD

FIG 7

The range of g c a effect for this character was from -1 04 and 1 59 among the testers Only two testers had significant g c a effects viz Kanakamani (1 59) and GC-82-7 (-1 04) Kanakamani was the best general combiner for more number of seeds per pod

The s c a effects produced by the hybrids for this character ranged from -2 04 to 2 04 It was positive and significant in Culture 9 x Kanakamani (2 04) and negative and significant in Chharodi 1 x Kanakamani (-2 04) The best specific combination for this character was Culture-9 x Kanakamani

100 seed weight

Combining ability analysis revealed significant variance for lines indicating significant g c a effects among lines This was not significant for testers Significant variance due to line x tester showed that the crosses had significantly different s c a effects However s c a variance was greater than g c a variance suggesting the importance of specific combining ability for 100-seed weight

Table 9 (viii) and Fig 8 show the g c a and s c a effects of lines testers and crosses for this trait Both the lines Chharodi-1 (-1 43) and Culture 9 (1 43) exhibited significant g c a effects while Culture-9 was the best general combiner

Table 9 (viii) g c a and s c a effects for 100 seed weight

		Testers					
		Kanakamani (T_1)	V-240 (T_2)	V 322 (T_3)	GC 82-7 (T_4)	V-26 (T_5)	S-488 (T_6)
Lines	g c a effects	0 31	0 22	0 11	0 71**	-0 004	-0 90**
		s c a effects					
Chharodi 1 (L_1)	-1 43**	0 96*	0 31	0 47	0 28	0 13	0 02
Culture 9 (L_2)	1 43**	0 96*	0 31	0 47	0 28	-0 13	0 02

* significant at 5% level
**significant at 1% level

	SE	CD 5%
g c a line	0 15	0 31
g c a tester	0 26	0 53
s c a	0 37	0 76

Fig 8 General and specific combining ability effects for 100 seed weight

L_1		Chharodi-1
L_2	-	Culture 9
T_1	-	Kanakamani
T_2	-	V 240
T_3	-	V-322
T_4		GC-82 7
T_5	-	V 26
T_6	-	S-488
L_1T_1		Chharodi-1 x Kanakamani
L_1T_2	-	Chharodi-1 x V-240
L_1T_3	-	Chharodi 1 x V-322
L_1T_4		Chharodi 1 x GC 82-7
L_1T_5	-	Chharodi 1 x V 26
L_1T_6		Chharodi 1 x S-488
L_2T_1	-	Culture-9 x Kanakamani
L_2T_2	-	Culture 9 x V 240
L_2T_3		Culture 9 x V-322
L_2T_4	-	Culture-9 x GC 82 7
L_2T_5	-	Culture-9 x V-26
L_2T_6	-	Culture 9 x S-488

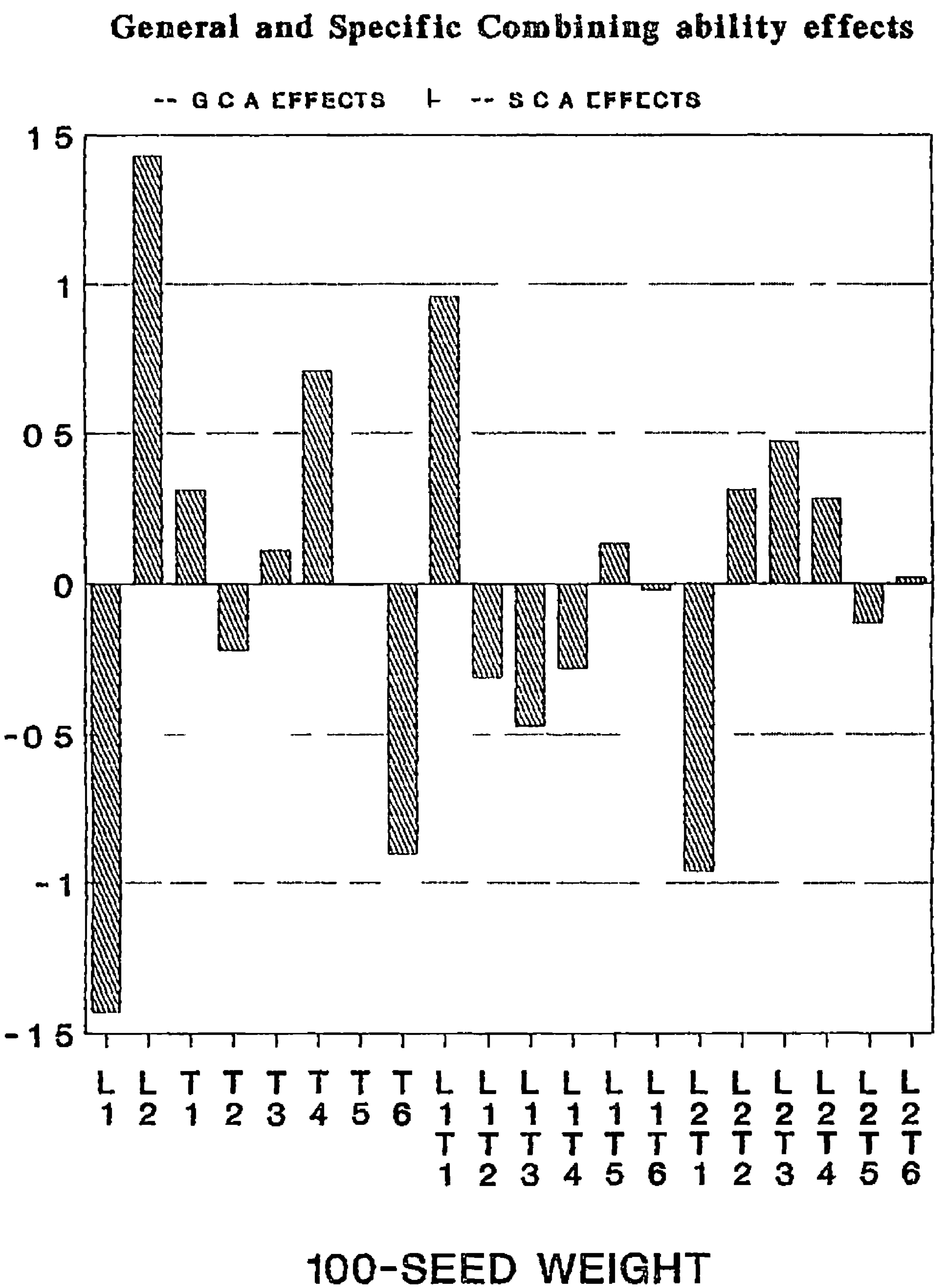

General and Specific Combining ability effects
-- G C A EFFECTS
-- S C A EFFECTS
1 5
1
0 5
0
-0 5
-1
-1 5
L 1
L 2
T 1
T 2
T 3
T 4
T 5
T 6
L 1 T 1
L 1 T 2
L 1 T 3
L 1 T 4
L 1 T 5
L 1 T 6
L 2 T 1
L 2 T 2
L 2 T 3
L 2 T 4
L 2 T 5
L 2 T 6
100-SEED WEIGHT

FIG 8

Only two out of six testers had significant g c a effects viz S-488 (0 90) and GC-82 7 (0 71) The variety GC-82 7 can be recommended as a good general combiner for 100-seed weight V-322 (0 11) and Kanakamani (0 31) exhibited positive but non significant g c a effects

Among the cross combinations s c a effect showed a range of -0 96 to 0 96 Six crosses recorded positive s c a effects But it was significant in the cross Chharodi-1 x Kanakamani (0 96) alone Culture-9 x Kanakamani (-0 96) was the only combination which recorded negative significant s c a effect The best specific combination for 100 seed weight was found to be Chharodi 1 x Kanakamani

Seed yield per plant

Partitioning of the hybrids indicated that mean squares due to lines and testers were not significant and that due to line x tester was significant These showed the significance of s c a effects among crosses Variance due to s c a was higher in magnitude than variance due to g c a indicating the importance of specific combining ability alone for this trait

Table 9 (ix) and Fig 9 show the effects due to g c a and s c a for lines testers and hybrids for this character Significant

Table 9 (ix) g c a and s c a effects for seed yield per plant

		Testers					
		Kanakamani (T_1)	V 240 (T_2)	V 322 (T_3)	GC 82-7 (T_4)	V 26 (T_5)	S-488 (T_6)
Lines	g c a effects	0 56	1 19	0 89	-2 28*	2 39	0 15
		s c a effects					
Chharodi 1 (L_1)	1 91**	1 76	1 02	4 13**	0 42	1 86	1 95
Culture 9 (L_2)	1 91**	-1 76	1 02	4 13**	0 42	1 86	-1 95

* significant at 5% level
** significant at 1% level

	SE	CD 5%
g c a line	0 56	1 13
g c a tester	0 97	1 95
s c a	1 37	2 76

Fig 9 General and specific combining ability effects for seed yield per plant

L_1	-	Chharodi-1
L_2	-	Culture-9
T_1	-	Kanakamani
T_2	-	V-240
T_3	-	V 322
T_4		GC-82 7
T_5		V-26
T_6	-	S-488
L_1T_1	-	Chharodi 1 x Kanakamani
L_1T_2		Chharodi-1 x V-240
L_1T_3	-	Chharodi 1 x V-322
L_1T_4	-	Chharodi 1 x GC 82-7
L_1T_5	-	Chharodi 1 x V-26
L_1T_6	-	Chharodi 1 x S-488
L_2T_1		Culture-9 x Kanakamani
L_2T_2		Culture 9 x V 240
L_2T_3		Culture-9 x V-322
L_2T_4	-	Culture-9 x GC 82-7
L_2T_5	-	Culture-9 x V-26
L_2T_6	-	Culture 9 x S-488

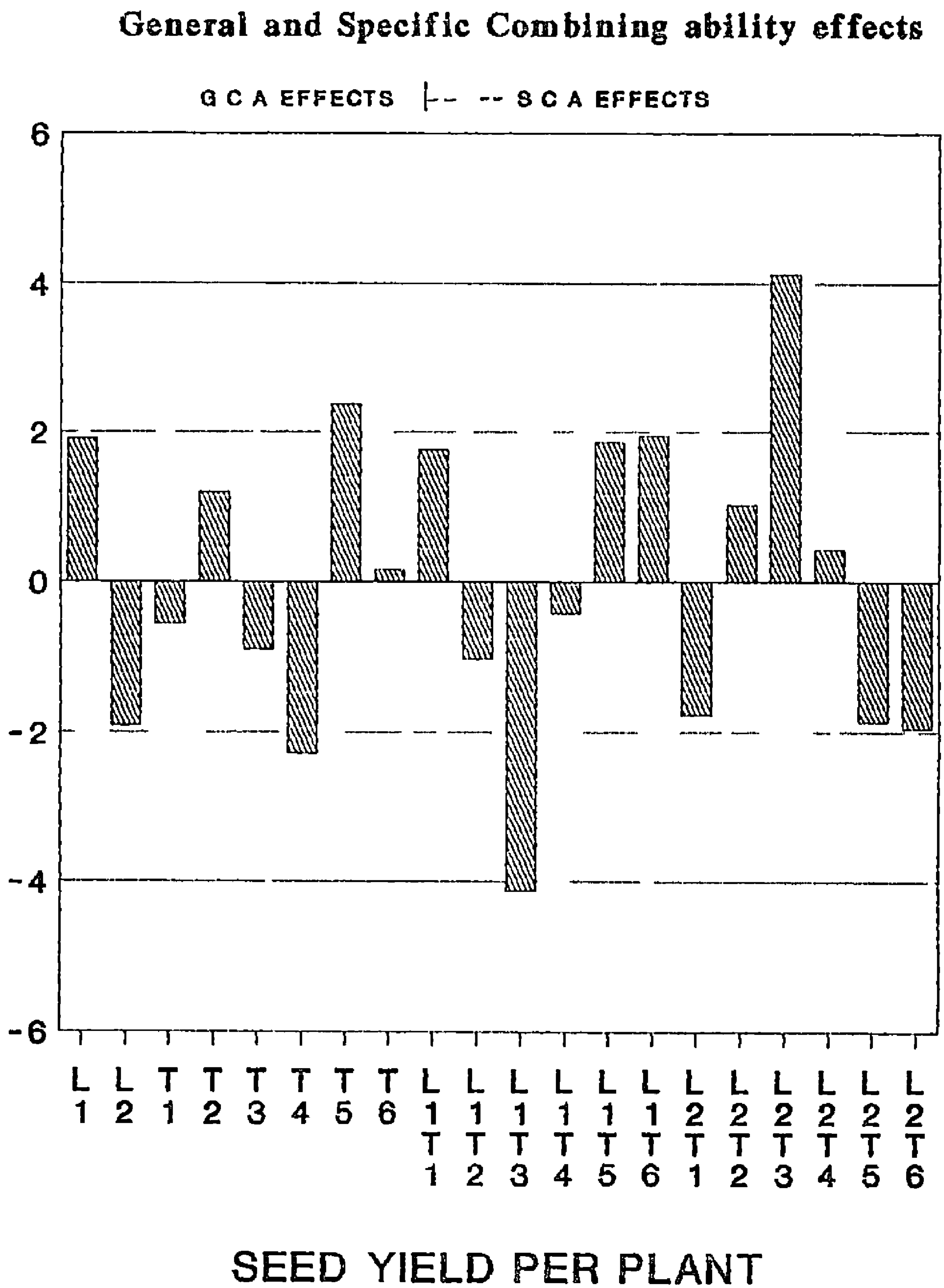

General and Specific Combining ability effects
G C A EFFECTS
S C A EFFECTS
6
4
2
0
-2
-4
-6
L 1
L 2
T 1
T 2
T 3
T 4
T 5
T 6
L 1 T 1
L 1 T 2
L 1 T 3
L 1 T 4
L 1 T 5
L 1 T 6
L 2 T 1
L 2 T 2
L 2 T 3
L 2 T 4
L 2 T 5
L 2 T 6
SEED YIELD PER PLANT

FIG 9

g c a effects were exhibited by the two lines and two testers Of these positive g c a effect was manifested by the line Chharodi-1 (1 91) and the tester V 26 (2 39) These two varieties can be recommended as good general combiners for seed yield per plant However the line Culture 9 (1 91) and the tester GC 82-7 (-2 28) showed negative significant g c a effects

Among the hybrids the s c a effects ranged from -4 13 in Chharodi-1 x V-322 to 4 13 in Culture-9 x V-322 These two cross combinations produced significant s c a effects So the best specific combination for seed yield per plant was Chharodi-1 x V 322

Chlorophyll 'b' content

ANOVA showed non significant variances for lines and testers and highly significant variance for the interaction line x tester suggesting that difference among s c a effects of crosses was significant Mean squares due to s c a was greater in magnitude than variance due to g c a so specific combining ability alone was significant for this attribute

The g c a and s c a estimates of chlorophyll b content is presented in Table 9 (x) and Fig 10 The g c a effects of lines were -0 03 (Chharodi-1) and 0 03 (Culture 9) but none of these was significant statistically The two extremes of g c a effects

Table 9 (x) g c a and s c a effects for chlorophyll b content

		Testers					
		Kanakamani (T_1)	V 240 (T_2)	V-322 (T_3)	GC 82 7 (T_4)	V-26 (T_5)	S-488 (T_6)
Lines	g c a effects	0 06	0 01	0 06	0 13**	0 07	-0 06
		s c a effects					
Chharodi 1 (L_1)	-0 03	0 11	-0 03	0 04	0 10	0 06	0 09
Culture 9 (L_2)	0 03	0 11	0 03	0 04	0 10	0 06	0 09

* significant at 5% level
** significant at 1% level

	SE	CD 5%
g c a line	0 02	0 05
g c a tester	0 04	0 09
s c a	0 06	0 12

Fig 10 General and specific combining ability effects for chlorophyll b content

L_1	-	Chharodi 1
L_2	-	Culture 9
T_1	-	Kanakamani
T_2	-	V-240
T_3		V-322
T_4	-	GC 82 7
T_5	-	V-26
T_6	-	S-488
L_1T_1	-	Chharodi-1 x Kanakamani
L_1T_2	-	Chharodi-1 x V-240
L_1T_3	-	Chharodi 1 x V-322
L_1T_4	-	Chharodi-1 x GC 82-7
L_1T_5	-	Chharodi-1 x V 26
L_1T_6		Chharodi-1 x S-488
L_2T_1	-	Culture-9 x Kanakamani
L_2T_2	-	Culture 9 x V-240
L_2T_3	-	Culture-9 x V 322
L_2T_4		Culture 9 x GC-82-7
L_2T_5	-	Culture 9 x V-26
L_2T_6	-	Culture 9 x S-488

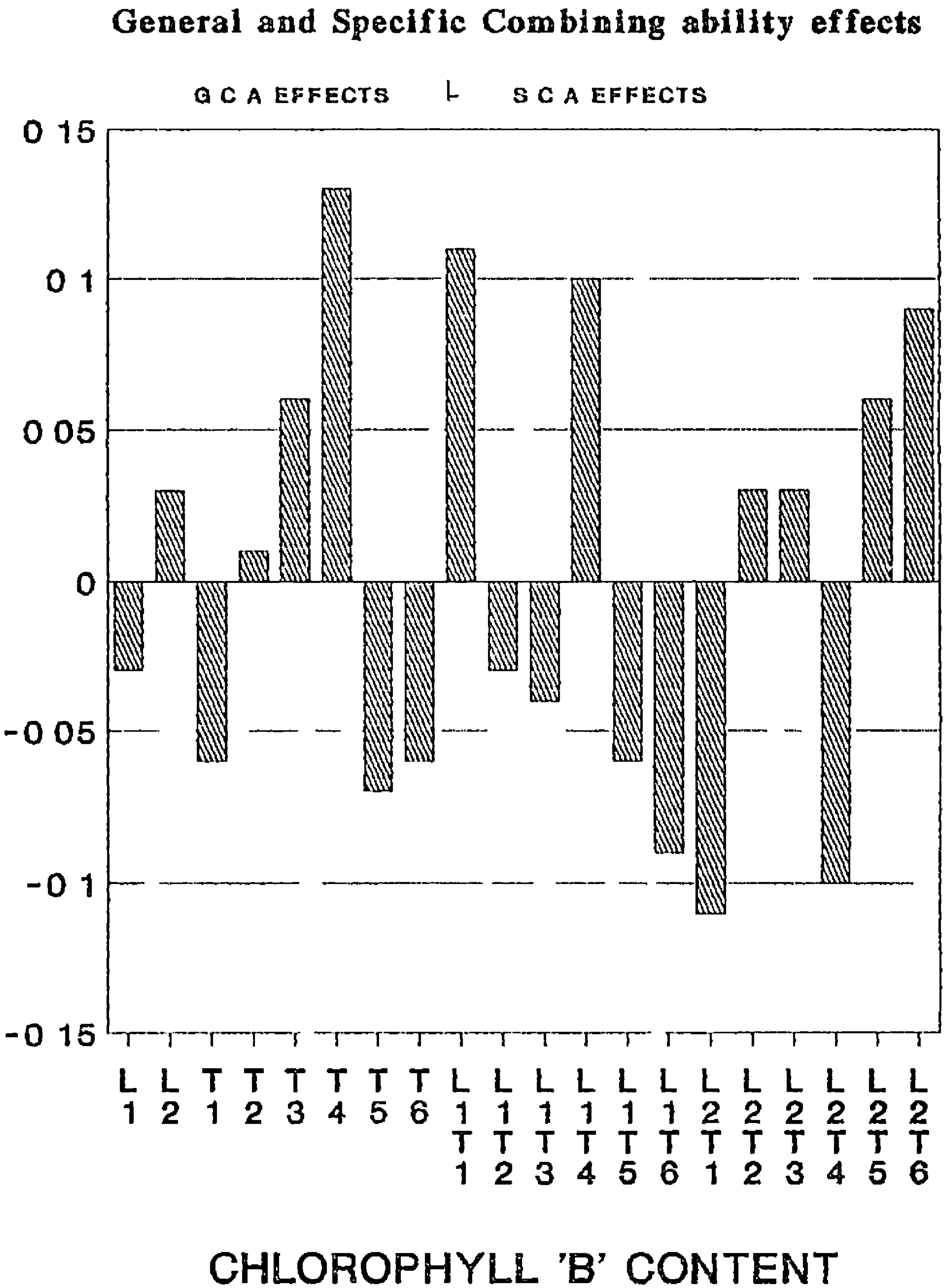

General and Specific Combining ability effects
G C A EFFECTS
S C A EFFECTS
0 15
0 1
0 05
0
-0 05
-0 1
-0 15
L1 L2 T1 T2 T3 T4 T5 T6 L1T1 L1T2 L1T3 L1T4 L1T5 L1T6 L2T1 L2T2 L2T3 L2T4 L2T5 L2T6
CHLOROPHYLL 'B' CONTENT

FIG 10

produced by the testers were -0 06 (S-488) and 0 13 (GC-82 7) GG- 82 7 alone had sıgnıfıcant posıtıve g c a effect Culture-9 and GC-82 7 were the best general combıners for chlorophyll b content from lınes and testers respectıvely

None of the hybrıds showed sıgnıfıcant g c a effects and ıt ranged from -0 11 (Culture 9 x Kanakamanı) to 0 11 (Chharodı-1 Kanakamanı) Chharodı 1 x Kanakamanı was the good specıfıc combınatıon for thıs traıt

Pod borer ıncıdence

Combınıng abılıty analysıs revealed hıghly sıgnıfıcant varıance due to lınes ındıcatıng that lınes dıffered for their g c a efffects whıle varıance due to testers and lıne x tester were not sıgnıfıcant It was also found that s c a varıance was hıgher ın magnıtude than g c a varıance

The estımates of g c a and s c a effects are presented ın Table 9 (xı) and Fıg 11 The g c a effects were comparatıvely low for pod borer ıncıdence It was sıgnıfıcant ın the two lınes Posıtıve g c a effect was exhıbıted by Culture 9 (2 02) and negatıve g c a effect by Chaarodı-1 (2 02) Among the testers Kanakamanı (1 27) showed hıghest g c a effect whıch was not sıgnıfıcant Best general combıner lıne vas chharodı 1 and V 322 (-1 01) was the best general combınıng tester

Table 9 (xi) g c a and s c a effects for pod borer incidence

		Testers					
		Kanakamani (T_1)	V 240 (T_2)	V 322 (T_3)	GC-82 7 (T_4)	V 26 (T_5)	S-488 (T_6)
Lines	g c a effects	1 27	0 61	1 01	0 64	0 67	0 96
		s c a effects					
Chharodi 1 (L_1)	2 02*	1 15	0 71	1 47	-1 40	1 50	1 87
Culture 9 (L_2)	2 02*	1 15	0 71	1 47	1 40	1 50	-1 87

* significant at 5% level
** significant at 1% level

	SE	CD 5%
g c a line	0 80	1 62
g c a tester	1 39	2 82
s c a	1 97	3 98

Fig 11 General and specific combining ability effects for pod borer incidence

L_1	-	Chharodi-1
L_2	-	Culture 9
T_1		Kanakamani
T_2	-	V-240
T_3	-	V 322
T_4	-	GC 82 7
T_5	-	V-26
T_6	-	S-488
L_1T_1	-	Chharodi 1 x Kanakamani
L_1T_2	-	Chharodi 1 x V-240
L_1T_3	-	Chharodi 1 x V-322
L_1T_4	-	Chharodi-1 x GC-82-7
L_1T_5	-	Chharodi 1 x V-26
L_1T_6		Chharodi 1 x S-488
L_2T_1	-	Culture-9 x Kanakamani
L_2T_2	-	Culture-9 x V 240
L_2T_3	-	Culture-9 x V-322
L_2T_4		Culture-9 x GC 82 7
L_2T_5	-	Culture 9 x V 26
L_2T_6		Culture 9 x S-488

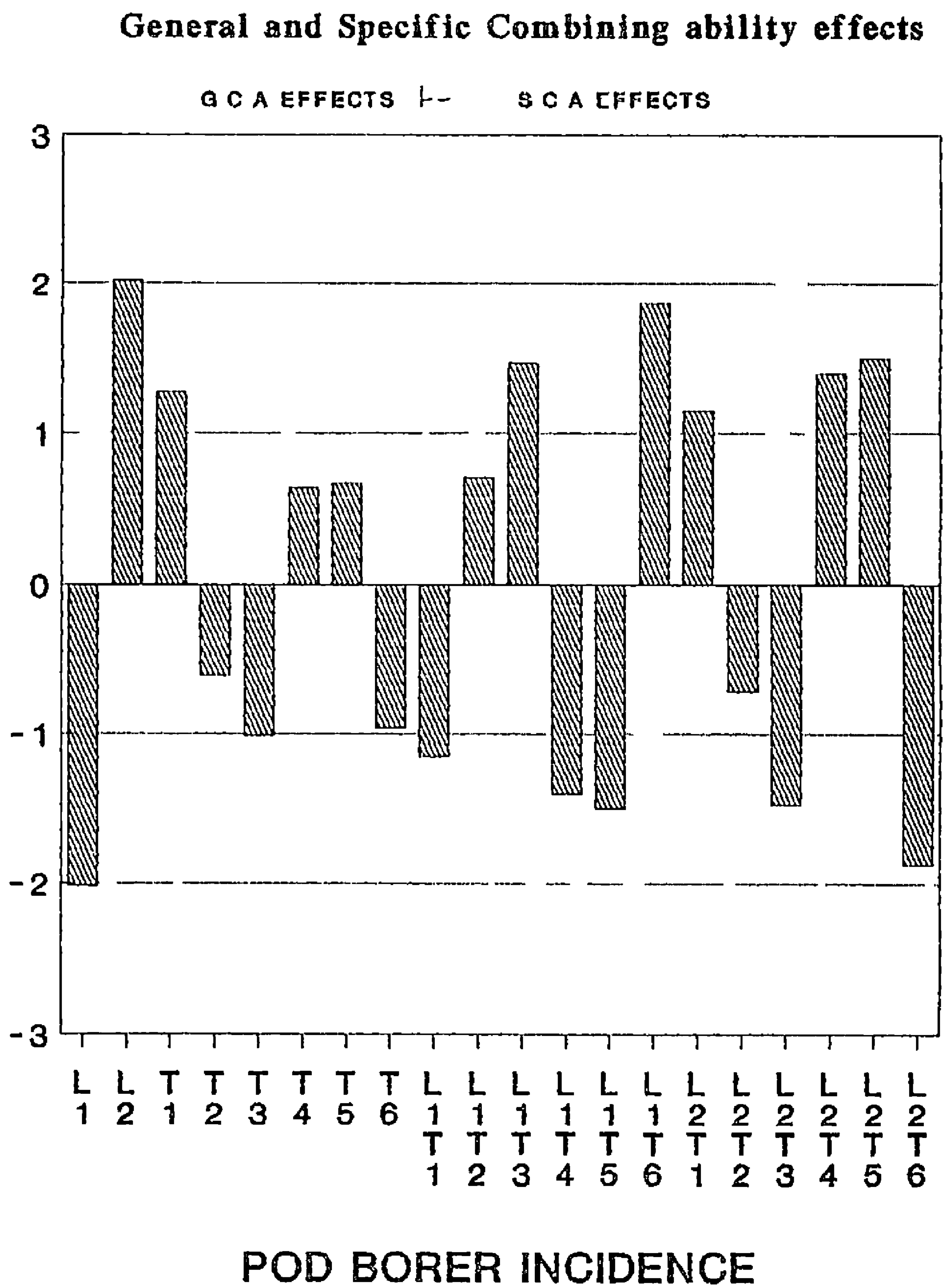

General and Specific Combining ability effects
G C A EFFECTS
S C A EFFECTS
3
2
1
0
-1
-2
-3
L 1
L 2
T 1
T 2
T 3
T 4
T 5
T 6
L 1 T 1
L 1 T 2
L 1 T 3
L 1 T 4
L 1 T 5
L 1 T 6
L 2 T 1
L 2 T 2
L 2 T 3
L 2 T 4
L 2 T 5
L 2 T 6
POD BORER INCIDENCE

FIG 11

The s c a effects were also comparatively low and ranged from -1 87 (Culture 9 x S-488) to 1 87 (Chharodi-1 x S 488) None of the hybrids manifested significant s c a effect The cross combination Culture-9 x S-488 can be taken as the best specific combination with low pod borer attack

The abstract for the best line and tester with high general combining ability and specific combination for each character are given in Table 10 It was found that the line Culture 9 was the best general combiner for early flowering (-0 78) early maturity (-0 50) dwarfness (6 18) length of pod (0 75) 100 seed weight (1 43) and chlorophyll b content (0 03) Chharodi 1 was the best general combining line for tallness (6 18) number of branches per plant (0 06) number of pods per plant (3 55) number of seeds per pod (0 79) seed yield per plant (1 91) and low pod borer incidence (-2 02)

Among the testers it was seen that the variety V 26 was the best general combiner for early maturity (-1 61) dwarfness (5 71) number of pods per plant (3 01) and seed yield per plant (2 39) The variety GC-82-7 was the best general combiner for 100-seed weight (0 71) and chlorophyll b content (0 13) For early flowering (-0 56) and number of branches per plant (0 72) V-240 and for length of pod (1 80) and number of seeds per pod (1 59) Kanakamani were the best general combiners

Table 10 Best General combiners and specific combination for 11 characters

Sl No	Character	Best general combiner				Best specific combination	
		Line	g c a effect	Tester	g c a effect	Hybrid	s c a effect
1	Days to flowering	Culture 9	0 78*	V 240	0 56	Culture 9 x V-240	0 58
2	Days to maturity	Culture 9	-0 50	V 26	1 61**	Chharodi 1 x V-26	1 56
3	Plant height						
	tallness	Chharodi 1	6 18**	S-488	7 97**	Culture 9 x S-488	4 98**
	dwarfness	Culture-9	6 18**	V 26	5 71**	Chharodi 1 x S-488	4 98**
4	Number of branches per plant	Chharodi 1	0 06	V 240	0 72**	Chharodi 1 x V-26	0 59**
5	No of pods per plant	Chharodi-1	3 55**	V-26	3 01**	chharodi 1 x V 26	3 63**
6	Length of pod	Culture 9	0 75**	Kanakamani	1 80**	Culture 9 x Kanakamani	0 85
7	Number of seeds per pod	Chharodi 1	0 79**	Kanakamani	1 59**	Culture 9 x Kanakamani	2 04**
8	100-seed weight	Culture 9	1 43**	GC-82 7	0 71**	Chharodi-1 x Kanakamani	0 96*
9	Seed yield per plant	Chharodi-1	1 91**	V-26	2 39**	Culture-9 x V 322	4 13**
10	Chlorophyll b	Culture 9	0 03	GC-82 7	0 13*	Chharodi 1 x Kanakamani	0 11
11	Pod borer	Chharodi 1	2 02*	V-322	-1 01	Culture 9 x S-488	-1 87

* Significant at 5% level

** Significant at 1% level

Some of the best specific combinations were Chharodi-I x V-26 for early maturity (1 56) number of branches per plant (0 59) and number of pods per plant (3 63) Culture-9 x Kanakamani for length of pod (0 85) and number of seeds per pod (2 04) and Chharodi 1 x Kanakamani for 100-seed weight (0 96) and chlorophyll b content (0 11) which is shown in plate 1

For seven out of eleven characters studied for combining ability the best specific combination involved at least one of the best general combiners

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

Proportional contribution of lines testers and line x tester to the total variance for 11 characters studied for combining ability are presented in Table 11 and represented in Figures 12 to 17

With regard to days to flowering lines contributed 62 17 percent testers 15 13 percent and line x tester interaction 22 70 percent to the total variance The contribution of lines to the total sum of squares due to hybrids was higher than the testers and line x tester interaction indicating high estimates of variances due to g c a

Of the total variance for number of days to maturity the contribution of lines was 13 38 percent of testers 37 61 percent and

Plate No.1. Superior Combinations with respect to combining ability

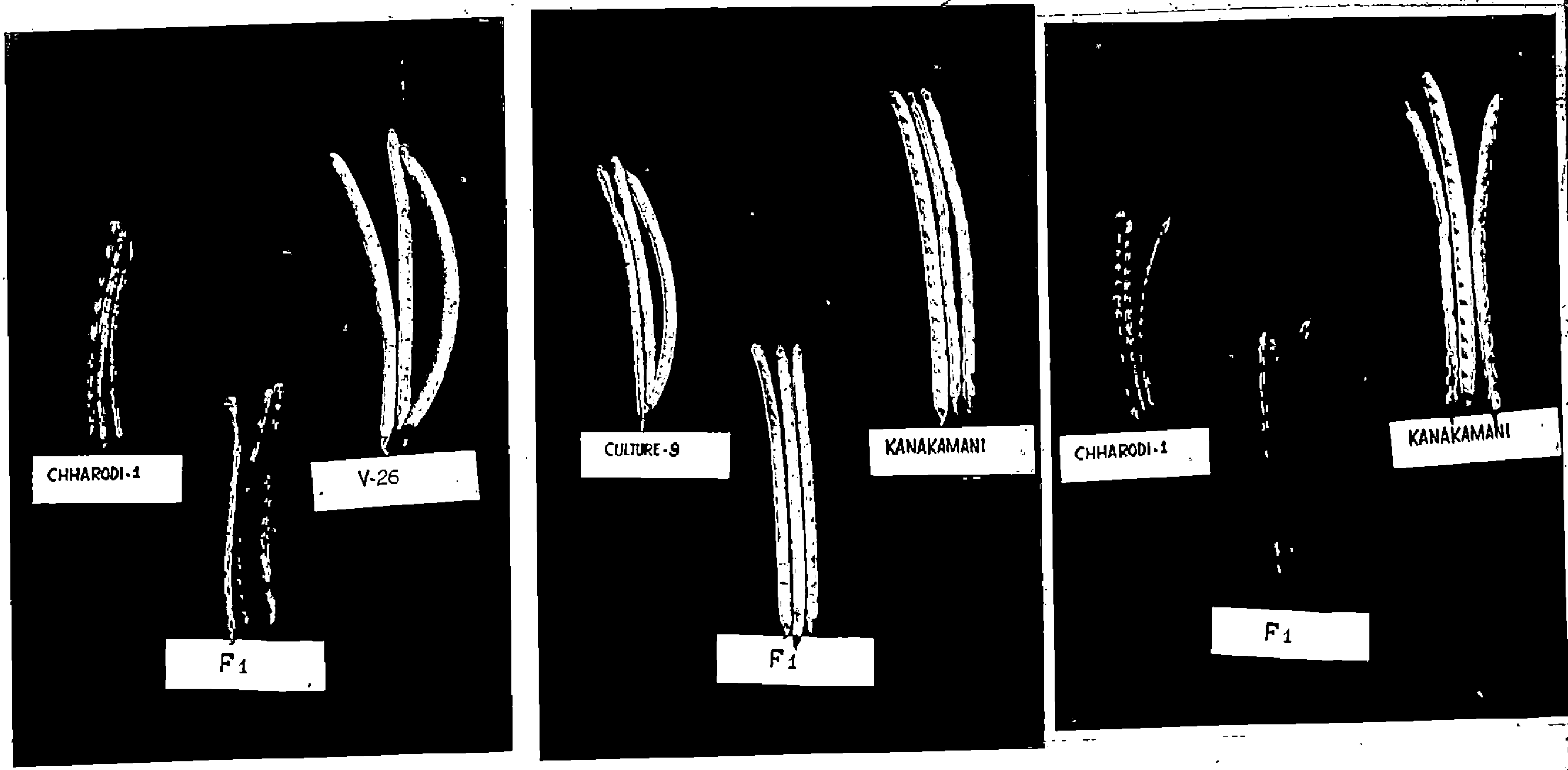


Table 11 Proporitional contribution of lines testers and line x tester interaction to total variance

	Character	Lines (%)	Testers (%)	Line x tester (%)
1	Days to flowering	62 17	15 13	22 70
2	Days to maturity	13 38	37 61	49 01
3	Plant height	56 19	31 12	12 70
4	Number of branches per plant	1 23	56 21	42 56
5	Number of pods per plant	51 13	19 72	29 15
6	Length of pod	26 54	55 68	17 78
7	Number of seeds per pod	27 73	30 82	41 45
8	100-seed weight	81 23	9 90	8 87
9	Seed yield per plant	34 27	21 02	44 71
10	Chlorophyll b content	5 80	46 05	48 15
11	Pod borer incidence	59 62	11 75	28 63

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

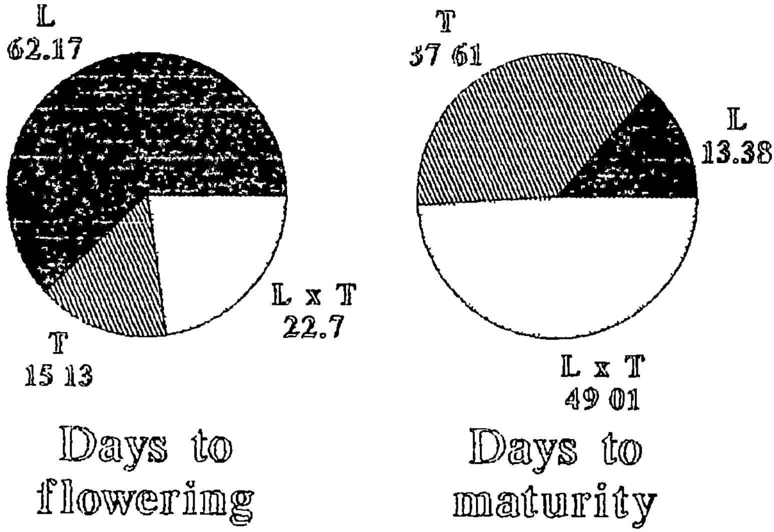


Fig. 12

of line x tester 49 01 perecent The contribution of line x tester interaction was higher than the lines and testers to the total sum of squares due to hybrids revealing the higher estimates of variance due to s c a

In the case of plant height the lines contributed 56 19 percent testers 31 12 percent and line x tester interaction 12 70 percent to the total variance The contribution of lines to the total variance due to hybrids was higher than the testers and line x tester interaction denoting the higher estimates of variances due to g c a

Of the total variance for number of branches per plant the contribution of lines was 1 23 percent of testers 56 21 percent and of line x tester 42 56 percent The contribution of testers to the total mean square due to hybrids was higher than that of the lines and line x tester interaction indicating high estimates of variance due to g c a

With respect to the number of pods per plant lines contributed 51 13 percent testers 19 72 percent and line x tester 29 15 percent Here the contribution of lines to the total sum of squares due to hybrids was higher than that of the testers and line x tester interaction indicated high estimates of variance due to g c a

Propotional contribution of lines testers and line x testers to total variance

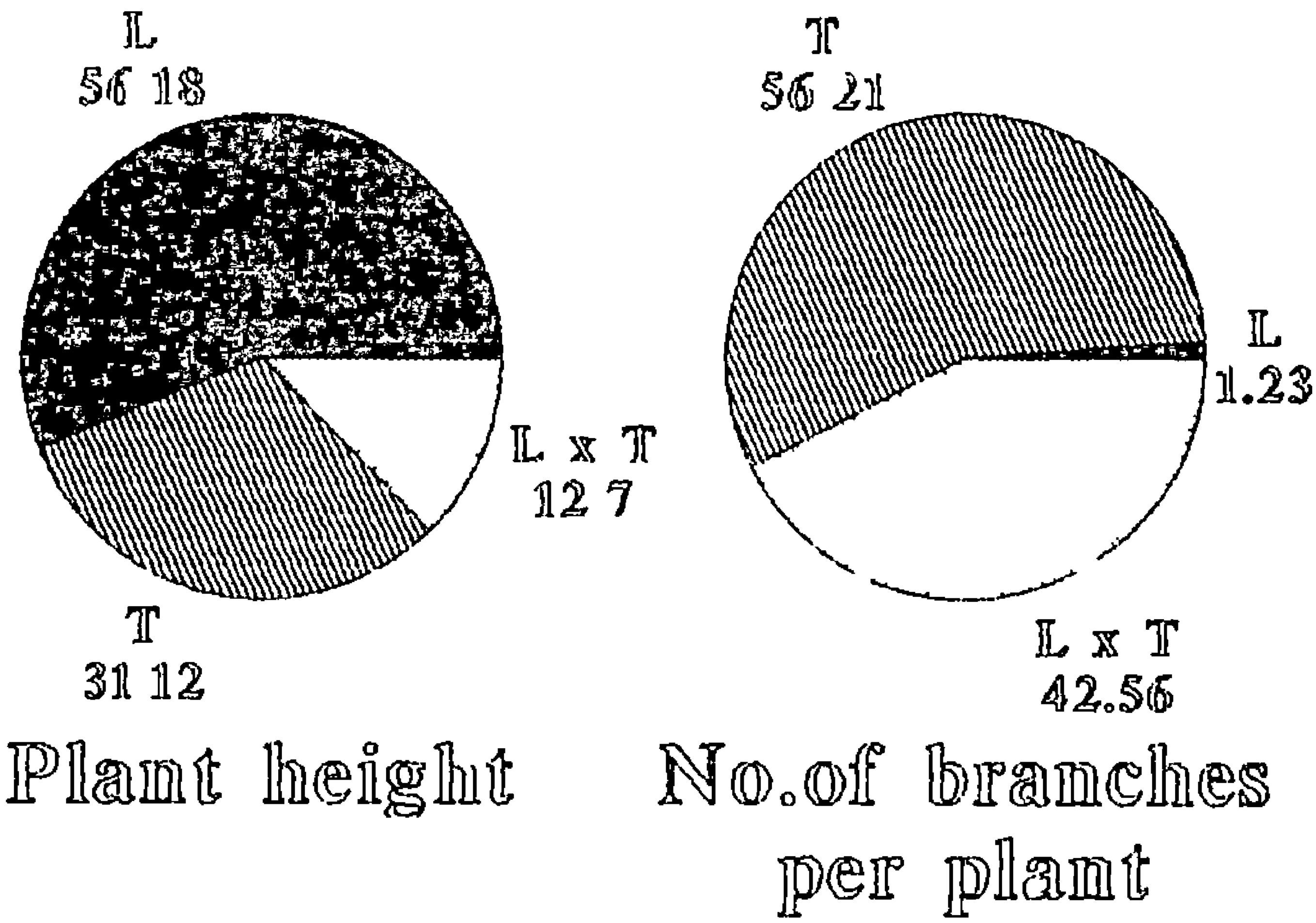
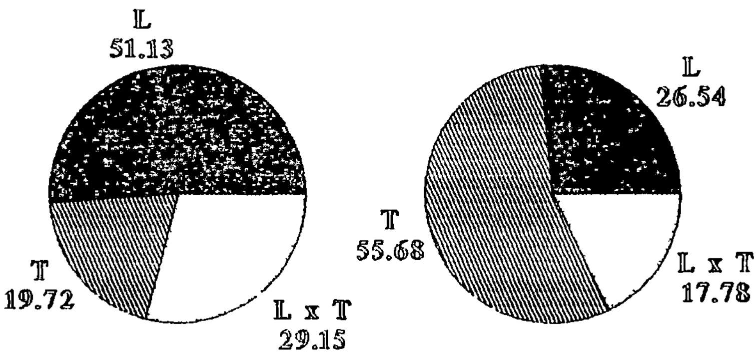


Fig. 13

Propotional contribution of lines testers and line x testers to total variance



No.of pods per plant

Length of pod

Fig. 14

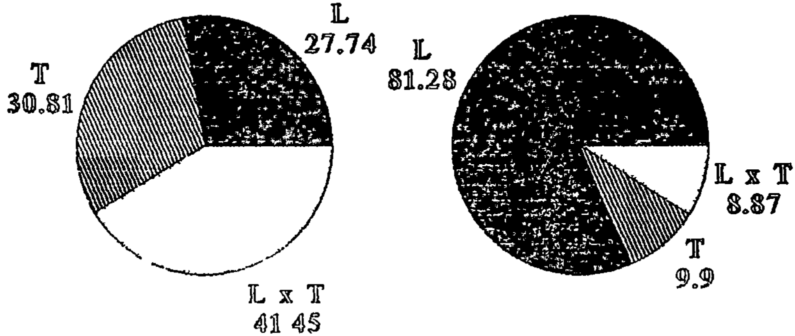
Out of the total variance for length of pod the contribution of lines was 26 54 percent of testers 55 68 percent and of line x tester 17 78 percent The contribution of testers to the total sum of squares due to hybrids was higher than that of the lines and line x tester interaction revealed higher estimates of variance due to g c a

In the case of number of seeds per pod the lines contributed 27 73 percent testers 30 81 percent and line x tester 41 45 percent to the total variance The higher contribution of line x tester interaction to the total sum of squares due to hybrids denoted the higher estimates of variance due to s c a

With regard to 100 seed weight 81 23 percent of total variance was contributed by lines 9 90 percent by testers and 8 87 percent by line x tester The smaller contribution of line x tester interaction than lines and testers to the total sum of squares due to hybrids indicated high estimates of variance due to g c a

Of the total variance for seed yield per plant the contribution of lines was 34 27 percent of testers 21 02 percent and of line x tester 44 71 percent The higher contribution of line x tester interaction over lines and testers to the total sum of squares due to hybrids revealed the higher estimates of variance due to s c a

Propotional contribution of lines testers and line x testers to total variance



No.of seeds per pod   100-seed weight

Fig. 15

Propotional contribution of lines
testers and line x testers to total variance

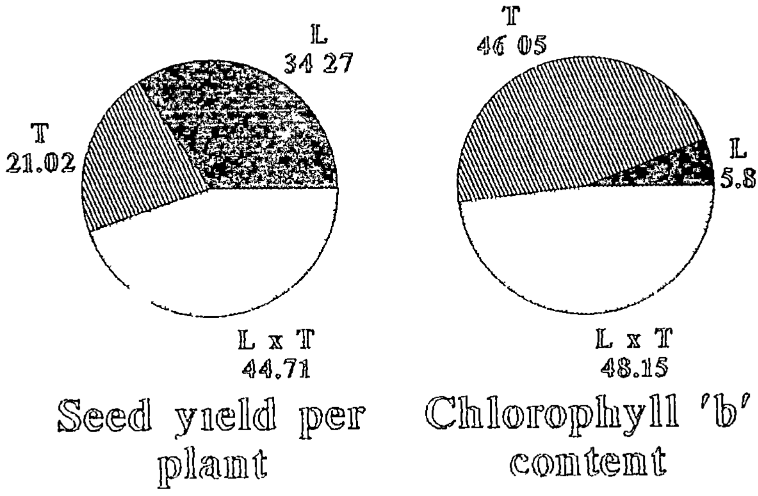
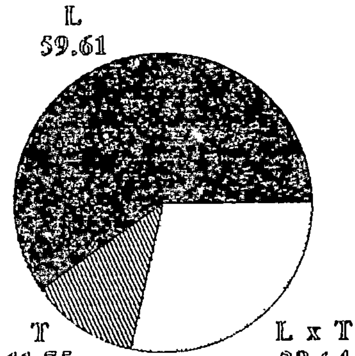


Fig. 16

Propoߙtional contribution of lines testers and line x testers to total variance



Pod borer incidence

Fig. 17

With respect of chlorophyll b content lines contributed 5 80 percent testers 46 05 percent and interaction 48 15 percent to the totral variance The contribution of line x tester interaction to the total sum of squares due to hybrids was higher than that of the lines and testers indicated high estimates of variance due to s c a

In the case of percentage of pod borer incidence the contribution of lines was 59 62 percent testers 11 75 percent and line x tester 28 64 percent to the total variance The smaller contribution of line x tester interaction than lines to the total variance due to hybrids denoted the higher estimates of variance due to g c a

Genetic components of variance

The genetic components of the variance $\sigma^2 A$ and $\sigma^2 D$ (additive and dominance components) and their ratio were estimated and are presented in Table 13

For the character days to flowering additive genetic variance (0 24) was greater than the dominance component (0 024)

Dominance component (5 98) was greater than the additive genetic component (0 07) for days to maturity

Table 12 Genetic components of variance and variance ratio for 11 characters

Sl No	Character	$\sigma^2 A$	$\sigma^2 D$	$\sigma^2 A/\sigma^2 D$
1	Days to flowering	0 24	0 02	10 17
2	Days to maturity	NE	5 98	0 01
3	Plant height	24 52	75 87	0 32
4	No of branches/plant	0 01	0 80	0 01
5	No of pods per plant	4 42	64 16	0 32
6	Lenght of pod	0 64	1 10	0 58
7	No seeds per pod	0 10	8 22	0 01
8	100 seed weight	1 01	1 57	0 67
9	Seed yield per plant	0 09	38 31	0 002
10	Chlorophyll b content	NE	0 04	0 01
11	Pod borer incidence	1 26	3 25	0 39

Where $\sigma^2 A$ additive genetic variance

$\sigma^2 D$ dominance variance

For the trait plant height dominance variance (75 87) was greater than the additive genetic variance (24 52)

Dominance component (0 80) was greater than the additive genetic component (0 01) with regard to number of branches per plant

Dominance variance (64 16) was greater than additive genetic variance (4 42) for number of pods per plant

The dominance genetic variance for length of pod (1 10) was greater than additive genetic variance (0 64)

With respect to the trait number of seeds per pod dominance component of variance (8 22) was greater than additive component of variance (0 10)

For 100-seed weight dominance variance (1 57) was greater than additive variance (1 01)

Seed yield per plant had a dominance component (38 31) which was greater than the additive component

Dominance variance (0 04) was greater than additive variance (-0 0003) for chlorophyll b content

Percentage of pod borer attack had a dominance component (3 25) which was greater than additive component (1 26)

Gene Action

The nature of gene action is known to vary with the genetic make up and the extent of diversity between the parents in the hybridisation programme A knowledge of the inheritance of quantitative traits should therefore increase the effectiveness of selection for these traits The combining ability is determined mainly by two types of gene action viz additive and non-additive The additive effects are mainly due to polygenes which act in additive manner producing fixable effects The non additive gene action results from dominance epistasis and various other interaction effects which are non fixable

In a line x tester analysis if the variance due to lines testers and line x tester interaction were significant it showed that both additive and non-additive gene actions might be involved in the inheritance of the trait (Ramakrishnan and Soundrapandian 1990) A high g c a effect for a particular trait of a parent indicates the additive gene effects for the trait governed by the genes in the parent concerned The estimates of g c a variance if higher than their respective s c a variance indicated predominance of additive gene action and vice versa

For the character days to flowering only variance due to lines was significant and variance due to testers and that due to line x tester interaction were not significant The g c a variance was higher in magnitude than s c a variance and variance ratio was 10 17 1 All these revealed that only additive gene action was important for days to flowering The positive σ^2 g c a estimate and negative σ^2 s c a also indicated the predominant role of additive gene action in the inheritance of this character

Mean square due to lines and testers showed no significant difference for number of days to maturity S c a variance alone was found significant at 5% level of probability Variance due to g c a was lower in magnitude than that of s c a The additive to dominance variance ratio was 0 01 1 So only non additive gene action was involved in the inheritance of this character The negative σ^2 g c a estimate and positive σ^2 s c a estimate also denoted the predominant role of non additive gene action in governing this character

With respect to plant height mean square due to lines and line x tester interaction vere significant But variance due to testers was not significant This showed the importance of both additive and non-additive gene effects for the control of this character But s c a variance was more than thrice the g c a variance indicating the predominance of non additive gene action The ratio of additive to dominance variance was 0 32 1 which also supported this statement

For the character number of branches per plant variance of lines and testers did not differ significantly whereas variance due to line x tester interaction was significant indicating the importance of non additive gene action Higher magnitude of s c a variance over g c a variance and the variance ratio (0 01 1) evidenced that non additive gene effects was involved in controlling this character

Variance due to lines and due to line x tester interaction were found significant and due to tester was not significant for number of pods per plant This indicated that both additive and interaction effects might govern the inheritance of the character number of pods per plant However this trait appeared to be controlled predominantly by non-additive gene action as evidenced by the high s c a variance compared to g c a variance and the low additive to dominance variance ratio (0 32 1)

With regard to the character length of pod mean square due to lines and testers vere observed as significant while mean square due to line x tester interaction was not significant This showed that only additive gene action might be involved in the inheritance of this trait This was further supported by the high g c a variance over s c a variance The variance ratio was 0 58 1

For the character number of seeds per pod there was no significant variation among lines and testers but significant variance due to line x tester interaction was noticed This revealed the importance of non additive gene effect for this character Variance due to g c a was found to be less than that of s c a and 0 01 1 was the variance ratio This also indicated that only additive gene effect prevailed in the inheritance of this character

Mean square due to lines and line x tester were significant and that due to tester was not significant for 100 seed weight denoting that this character might be governed by both additive and non-additive gene effects The ratio of additive to dominance variance (0 67 1) also supported this inference

With respect to the trait seed yield per plant variance due to line x tester interaction alone was significant which indicated the important role of non additive gene action for the expression of this character However the variances due to line and tester were not significant for 100-seed veight The estimates of variance of g c a and s c a also revealed that the nature of gene action was predominantly non additive as evidenced by the high value of s c a mean square over g c a variance and the low variance ratio (0 002 1)

For the attribute chlorophyll b content the variances due to line and tester were not significant The only significant component was variance due to line x tester interaction which showed that non-additive gene action alone might be involved in the inheritance of chlorphyll b content The negative σ^2 g c a estimate and positive σ^2 s c a estimate and the ratio of additive to dominance variance (0 01 1) also indicated the predominant role of non additive gene action for the expression of this trait

Mean square due to line alone was found to be significant for pod borer incidence Mean square due to testers and line x tester interaction were not significant The s c a variance was greater in magnitude than g c a variance and ratio of additive variance to dominance variance was 0 39 1 These indicated that both additive and non-additive gene effects might govern the inheritance of resistance to pod borer

In general it was seen that for all the eleven characters studied non additive gene action was more predomiant than additive gene action except for days to flowering and length of pod in controlling their inheritance

DISCUSSION

Discussion

The success of crop improvement programme aimed at the production of superior varieties depends solely on the selection of suitable genotypes to be used as parents in the hybridisation programme Breeders have often used high per se performance as a criterian for selection of parents for attempting crosses However apparently good performing parents do not always produce desirable segregants In autogamous crops like cowpea breeders are interested in transgressive segregants that can be obtained in later generations Combining ability analysis provides useful informations on the nature of inheritance of quantitative characters and also helps in identifying superior parents and cross combinations likely to yield better progenies The combining ability approach for line x tester analysis is used for classification of parental genotypes in terms of their hybrid performance and preferred where maternal effect epistasis and non-independent gene action are suspected (Upadhyaya and Sawant 1990) The present experiment was undertaken to study the combining ability and gene action in grain cowpea under partially shaded conditions of coconut garden Two lines six testers and the twelve hybrids obtained by crossing them in line x tester fashion were subjected to statistical analysis The results of the study are discussed here

Combining ability

The general and specific combining ability estimates will be of great value in sorting out good combiners and desirable cross combinations The results obtained from the line x tester analysis are discussed below(Tabes 8 and 9 and Fg 1 11)

The analysis of variance revealed that mean square due to lines and line x tester interaction were significant for the characters plant height number of pods per plant and 100-seed weight This showed the importance of both general and specific combining abilities for these traits Mean square due to lines alone was significant for days to flowering and pod borer incidence and that due to lines and testers were significant for length of pod These indicated the importance of general combining ability for the expression of these traits However the variance due to line x tester interaction alone was found significant for days to maturity number of branches per plant number of seeds per pod seed yield per plant and chlorophyll b content suggesting the importance of specific combining ability for these characters Though g c a and s c a variances were observed a preponderance of s c a variance was observed for plant height number of pods per plant and 100 seed weight

For the character days to flowering the mean square due to lines alone was significant suggesting the importance of general combining ability for this trait This is in accordance with the reports of Mishra *et al* (1987) in cowpea Ranalli *et al* (1989) in pea and Cheralu *et al* (1989) and Saxena *et al* (1989) in pigeon pea However contradictory to this Mandal and Bahl (1987) reported in chickpea that g c a was not significant for days to flowering

A significant negative g c a effect was shown by the line Culture 9 Among testers V-240 had maximum non-significant g c a effect The maximum non-significant s c a effect was exhibited by Culture-9 x V-240 Parents with negative g c a effects were involved in this cross The other good combinations for earliness to flower were Chharodi-I x V-322 Culture-9 x GC 82-7 and Chharodi-1 x S 488 where Chharodi 1 V-322 and S-488 with positive g c a and Culture-9 and GC 82-7 with negative g c a effects The best specific combinations for earliness threfore involved early x early and late x late parents It was seen that the g c a effects of the lines were generally related to their *per se* performance But it was not true for testers and F_1S Out of the six best combinatiosn for earliness two involved parents which were early x early two early x late and two late x late general combiners

The variance due to line x tester interaction alone was significant for the character days to maturity suggesting the importance of s c a for this trait Similar results were also obtained by Katiyar *et al* (1988) in chickpea On the contrary both g c a and s c a were reported to be important with high g c a in cowpea (Chauhan and Joshi 1981) in greengram (Wilson *et al* 1985) and in blackgram (Singh *et al* 1987)

Maximum negative g c a effect for days to maturity was recorded by the line Culture 9 and significant negative g c a effect by the tester V-26 Negative g c a effect was also shown by the tester V 240 but not significant Among the different cross combinations maximum s c a effect was shown by the hybrid Chharodi-1 x V-26 followed by Culture 9 x GC-82 7 and Chharodi-1 x V 322 In the cross Chharodi 1 x V-26 the line being late and the tester being early maturing varieties In other crosses Culture-9 was a general combiner for early maturity and the other three varieties were general combiners for late maturity None of the s c a effects were statistically significant The best combinations involved parents with late x early and late x late general combiners for the character In general the g c a and *per se* performance of lines and s c a and *per se* performance of crosses were related but the g c a and *per se* performance of testers were not related Six crosses with negative s c a effects involved early x late early x early and late x late general combiners The g c a of the parents had relation on the s c a effects of their crosses ie the crosses involving the high negative general combiners were having high negative s c a effects in many of the cases

For the character plant height high variance was observed for lines and line x tester interaction But variance due to testers was not significant These suggested that the character plant height might be governed by both general and specific combining ability effects This is in conformity with the reports of Moitra et al (1988) and El-murabae et al (1988) in pea Katiyar et al (1988) in chickpea and Rajarathinam and Rathnasami (1990) in blackgram However the predominance of s c a effect for this character in the present study is in agreement with the finding of Kaw and Madhava Menon (1977) in soybean whereas Tewatia et al (1988) Cheralu et al (1989) and Saxena et al (1989) observed in pea that s c a was smaller than g c a

The g c a effects were significant in two lines and five testers and s c a effects significant in six hybrids Maximum positive g c a effect (tallness) was expressed by Chharodi-1 among lines and S 488 among testers V-322 was another tester with high positive g c a effect Negative g c a effect (dwarfness) was recorded by the line Culture 9 and by the testers Kanakamani

GC-82-7 and V 26 Among the different cross combinations maximum positive s c a effect was shown by Culture-9 x S-488 which was a combination involving poor and good general combiners for plant height The next best combinations were Chharodi-1 x Kanakamani and Culture-9 x GC 82 7 Of these Chharodi-1 alone was a good combiner All others have negative g c a effects All the best general combiners produced at least one cross with high s c a and vice versa Positive s c a effects were manifested by the six crosses involving good x poor combiners in three crosses good x good combiners in two crosses and poor x poor combiners in one cross The g c a of the parents and s c a of the hybrids in general directly related to their per se performance

Variance due to line x tester interaction alone was significant for the character number of branches per plant indicating higher importance of specific combining ability Similar results were also reported by Katiyar et al (1988) in chickpea Singh et al (1987) and Rajarathinam and Rathnasamy (1990) reported in blackgram that s c a was higher than g c a On the contrary g c a was reported to be high by Nienhuis and Singh (1987) in fieldbean Saxena and Sharma (1989) in greengram and Cheralu et al (1989) in pigeonpea

Maximum positive g c a effect for the character was recorded by the line Chharodi-1 and the tester V 240 Among the different cross combinations maximum s c a effect was shown by the cross Chharodi-1 x V-26 followed by Culture-9 x V-322 and Culture-9 x GC-82-7 In the cross Chharodi-1 x V-26 the line and tester were good general combiners for number of branches per plant whereas in other two crosses the line Culture-9 and the testers V-322 and GC-82 7 were poor general combiners So the best combinations involved parents with good x good and poor x poor general combiners for this character The g c a effects of the parents in general had no bearing on the s c a effects of the crosses ie the crosses having high general combiners need not necessarily have high s c a effects The g c a effects of the parents were generally not related to their per se performance while correspondence between the s c a effect and per se performance of the F_1 S were seen in most of the crosses Out of the six good combinations for high number of branches per plant three involved parents which were poor x poor two poor x good and one good x good general combiners

Significant variances were recorded for lines and line x tester interaction for number of pods per plant but s c a variance was higher in magnitude than the g c a variance Preponderance of s c a variance was also reported by Singh et al (1987) in blackgram Kumar and Bahl (1988) and Bahl and Kumar (1989) in chickpea and Rajarathinum and Rathnasamy (1990) in urd bean But contrary to this Tewatia et al (1988) and Ranalli et al (1989) in pea and Saxena et al (1989) in pigeon pea reported predominant g c a variance for this character

Significant positive g c a effects were shown by one line and three testers and significant positive s c a effects by two crosses The line with good g c a effect was Chharodi-1 and the best tester was V-26 followed by S-488 and V-240 Negative g c a effects were recorded by the line Culture-9 and by the testers Kanakamani V-322 and GC 82 7 Maximum s c a effect for the character was recorded by Culture 9 x V 322 followed by Chharodi 1 x V-26 and Chharodi-1 x S-488 In the cross Culture-9 x V 322 both parents were with negative g c a effects while the other two crosses involved parents with positive g c a effects Out of the six cross combinations with positive s c a effects two were combinations between parents with poor x poor combiners two good x poor and two good x good general combiners The cross with highest s c a effect had the parents with highest g c a effects The g c a effects of the lines were comparable with their per se performance But this was not true for the testers The s c a effect of the crosses were also not generally related to their per se performance

For the character length of pod variance due to lines and testers were significant indicating that g c a might be important for the trait whereas variance due to line x tester interaction was not significant Similar results were also reported by Wilson et al (1985) in greengram and Tewatia et al (1988) in pea However Erskine and Kesavan (1982) suggested the significance of s c a for this character in winged bean

The g c a effect was significant for two lines Culture 9 with positive and Chharodi-1 with negative values Among testers it was significant for Kanakamani (positive) and S 488 (negative) S c a effect was not significant for any of the cross combinations The best positive g c a effect was shown by the tester Kanakamani followed by V-26 and GC 82 7 Among the different cross combinations maximum positive s c a effect was recorded by Culture-9 x Kanakamani followed by Culture 9 x S-488 and Chharodi-1 x V 322 The cross Culture 9 x Kanakamani involved parents with positive g c a effects Culture-9 x S-488 involved one parent with positive g c a effect and the other with negative g c a effect and Chharodi-1 x V-322 involved parents with negative g c a effects Out of the six cross combinations with positive s c a effects three were combinations between parents which were good x poor two between poor x poor and one was a cross between two good general combiners The best general combiners resulted in the highest s c a effect A relation was detected between the per se performance of the lines and their g c a effects But the g c a of the testers and s c a of crosses were not generally related to their *per se* performance

The variance due to line x tester interaction alone was significant for the character number of seeds per pod indicating the importance of s c a for the character Significant s c a was reported for this trait in cowpea by Singh and Jain (1977) and in chickpea by Bahl and Kumar (1989) But g c a was more important for this character as reported in pea (Ranalli *et al* 1989) pigenopea (Saxena *et al.* 1989) and greengram (Saxena and Sharma 1989)

The g c a effects were significant in both the lines and two testers and the s c a effects in two hybrids The maximum positive g c a effect was exhibited by the line Chharodi 1 and the tester Kanakamani V 26 also had positive g c a effect Among the different cross combinations the maximum positive s c a effect was recorded by Culture 9 x Kanakamani followed by Chharodi-1 x V 240 and Chharodi 1 x S-488 All the three combinations involved one parent with positive g c a effect and one with negative g c a effect Here the best specific combination involved the best general combining tester All the six cross combinations with positive s c a effects were between good and poor general combiners This also suggested the importance of s c a for this character The *per se* performance of the lines were not directly related to the g c a effects But the g c a effects of the testers and s c a effects of the crosses were directly related to their per se performance

The character 100 seed weight had significant variance due to lines and line x tester interaction suggested that the g c a and s c a might be important for this character Patel et al (1988) in greengram and Katiyar et al (1988) in chickpea also obtained the similar results In the present study the variance due to s c a was greater than that due to g c a suggesting the predominance of s c a for this character This is in line with the reports of Fleck A Von and Ruckenbauer (1989) in fababean On the contrary Wilson et al (1985) in greengram and Kumar and Bahl (1988) and Bahl and Kumar (1989) in chickpea had reported that the g c a variance was higher for this character

The g c a effects were significant in two lines and two testers and the s c a effects for two cross combinations The maximum positive g c a effect for this character was recorded by the line Culture 9 and by the tester GC 82-7 Maximum negative g c a effect was shown by Chharodi 1 among lines and S-488 among testers Among the different cross combinations maximum positive s c a effect was recorded by Chharodi 1 x Kanakamani which involved parents with negative and positive g c a effects The next best combination was Culture-9 x V-322 which involves two good parents Culture 9 x V-240 was another good cross with one poor and one good general combiners The g c a effects of the lines and testers and s c a effects of the crosses were generally related to their <u>per se</u> performance Of the six cross combinations with positive s c a effects two crosses involved parents which are good general combiners three with good x poor and one cross with poor x poor combiners The best general combiners did not result in highest s c a effect

The combining ability analysis for seed yield showed that mean square due to line x tester alone was significant for seed yield per plant indicating that this character might be controlled by specific combining ability Similar results were reported by De-Silva and Omran (1986) in winged bean Mishra <u>et al</u> (1987) in cowpea Singh <u>et al</u> (1987) in blackgram Kumar and Bahl (1988) and Bahl and Kumar (1989) in chickpea and Rajarathinam and Rathnasamy (1990) and Kalia <u>et al</u> (1991) in blackgram But contrary to this Chauhan and Joshi (1981) cowpea Wilson <u>et al</u> (1985) in greengram Singh and Saini(1986) and Nienhuis and Singh (1986) in fieldbean Naumkina (1986) and Tewatia (1988) in pea and Cheralu <u>et al</u> (1989) in pigeonpea reported higher g c a for this character The g c a effects were significant for two lines and two testers and s c a effects for two hybrids The maximum positive g c a effect was recorded by the line Chharodi 1 and the tester V-26 Negative g c a effects were shown by the line Culture 9 and the tester GC 82-7 Among the different cross combinations the maximum positive s c a effect was recorded by Culture 9 x V-322 both had negative g c a effects The bext best combinations were Chharodi 1 x S 488 and Chharodi-1 x V-26 both involved parents with positive g c a effects Out of the six cross combinations with positive s c a effects two cross combinations with good x good two with good x poor and two with poor x poor general combiners The g c a efffects of the parents had no bearing on the s c a effects of the crosses All these indicated the importance of s c a in controlling this character The g c a effects of the parents and s c a effects of the hybrids were generally not related to their per se performance

The treatments did not differ significantly for the chlorophyll a content and hence the g c a variances were not important Contrary to this Cheng et al (1985) in sorghum and Chadha et al (1988) in brinjal revealed that both g c a and s c a mean squares were high

The variance due to line x tester interaction alone was significant for chlorophyll b content indicating high s c a effect for this trait Similar result was obtained by Patel and Kukadia

(1986) in pearl millet However g c a variance was found predominant for chlorophyll b content in sorghum (Cheng _et al_ 1985) Chadha _et al_ (1988) observed in brinjal that both g c a and s c a were important

The g c a effects of the lines were not significant and that of testers was significant for one variety None of the crosses had significant s c a effect The line Culture 9 recorded positive g c a and Chharodi-1 recorded negative g c a effects The maximum positive g c a effect was recorded by the tester GC-82-7 followed by V-322 and V-240 Negative g c a effects were expressed by the testers Kanakamani V-26 and S-488 Among the twelve hybrid combinations the maximum positive s c a effect was recorded by the cross Chharodi-1 x Kanakamani which involved parents with negative g c a effects The next best combinations were Chharodi-I x GC-82-7 and Culture-9 x S-488 Both involved parents with positive and negative g c a effects Out of the six cross combinations with positive s c a effects three crosses involved parents which were good x poor two good x good and one poor x poor general combiners The g c a effects of the lines and s c a effects of the crosses were related directly to their _per se_ performance The _per se_ performance of the testers did not correspond to their respective g c a effects Also parents with high g c a did not result in crosses with high s c a

Genotypes did not show any variation for total chlorophyll content Hence the g c a and s c a were not important for this trait However significant g c a and s c a effects were reported for total chlorophyll content in brinjal (Chanda et al 1988) Significant g c a for flag leaf chlorophyll was observed in bread wheat (Ellison et al 1983) and in sorghum (Cheng et al 1985) On the contrary the importance of s c a effect for this character was reported by Patel and Kukadia (1986) in pearl millet

For percentage of pod borer incidence mean square due to lines alone was significant denoted that g c a might be important for this trait With regard to different pests similar results were observed in maize against European corn borer (Khalifa and Drolsom 1988 and Kim et al 1989) and in sorghum against shootfly (Dixon et al 1990) On the contrary to this Holley et al (1985) reported in groundnut that resistance to the insects *Frankliniella fusca* and *Heliothis zea* was under the control of s c a

The g c a effects were significant for the two lines whereas g c a effects of testers and s c a effects of crosses were not significant The best general combiner among lines was Chharodi-1 which had a negative g c a effect Culture-9 recorded a positive g c a effect Negative g c a effects were recorded by the testers S-488 V 240 and V-322 and positive g c a effects by

Kanakamani V-26 and GC 82-7 The cross combination which expressed the maximum negative s c a effect was Culture 9 x S-488 where the line had positive g c a effect and the tester had negative g c a effect The other best crosses were Chharodi-1 x V 26 and Culture 9 x V 322 which also involved parents which are poor x good general combiners All the six cross combinations which exhibited negative s c a effects were between good x poor combiners There was no correspondence between the g c a effects of the lines and testers and s c a effects of crosses with their respective <u>per se</u> performance

In general a good relationship between the g c a and <u>per se</u> performance of the lines was observed for seven out of the eleven characters studied which includes days to flowering days to maturity plant height number of pods per plant length of pod 100 seed weight and chlorophyll b content With regard to testers it was true for only three traits viz plant height number of seeds per pod and 100-seed weight It was also obvious that the hybrids with high <u>per se</u> performance recorded high s c a effects for most of the characters studied except for days to flowering length of pod seed yield per plant and pod borer incidence However no such relationship was noticed between g c a and s c a of best crosses except for days to flowering days to maturity number of pods per plant and length of pod

The s c a effects of the crosses revealed that the best cross combinations were between good x good good x poor and poor x poor general combiners for most of the characters studied But a critical examination of the performance of parents and crosses showed that crosses having highest s c a effects for different characters involved parents with high x low and low x low g c a effects of which high x low combinations were more frequent Similar results were also observed in groundnut (Habib et al (1985) chickpea (Mandal and Bahl 1987) blackgram (Singh et al., 1987 and Rajarathinam and Rathnasamy 1990) and in pea (Singh and Singh 1990)

The crosses involving high x high parents could be of immense value for exercising single plant selection in advanced generations Since in such hybrids high s c a effects were due to additive and additive x additive type of gene action which are fixable The crosses which involved at least one good general combiner may be exploited for isolating desirable transgressive segregants in F_2 if the additive genetic system present in the good combiner and the complementary epistatic effects in the F_1 acted in the same direction to maximise the desirable plant attributes (Singh and Singh 1990)

In the crosses involving high x low combinations genetic interactions might be of additive x dominance type and g c a effect played an important role in the expression of positive and significant s c a effects (Singh *et al* 1987) However in hybrids significant s c a effects associated with low x low performers reflected non-additive type of gene effects hence these hybrids could be exploited for heterosis breeding (Singh and Singh 1990) Here the genetic interaction might be of dominance x dominance type (Singh *et al*, 1987)

Intermating amongst the selects in biparental fashion in the early generation is likely to break undesirable linkages and may result in rare desirable combinations

Gene action

Ramakrishnan and Soundrapandian (1990) opined that if the variance due to lines due to testers and due to line x tester interaction were significant both additive and non-additive gene actions might be involved in the inheritance of that chatacter A high g c a effect for a particular trait of a parent indicates the additive gene effect for the trait governed by the genes in the parent concerned In the combining ability analysis if the s c a variance was greater than g c a variance the non-additive gene effect was considered to be predominant for the character The analysis of variance of the present study revealed the preponderance of s c a variance for most of the characters studied The ratio of g c a variance to s c a variance is also used in the interpretation of the significance of additive and non additive gene effects(Tables 8 11 and 12 and Fig 12 17)

For the character days to flowering mean square due to lines alone was significant The contribution of lines to total sum of square due to hybrids was higher than the testers and line x tester interaction Variance due to s c a was negative and lower in magnitude than g c a variance The ratio of $\sigma^2 A / \sigma^2 D$ was more than one All these suggested the predominant role of additive gene effects in the inheritance of this trait This was in conformity with the results of Patel and Bhapkar (1986) in cowpea Yadavendra and Sudhirkumar (1987) in chickpea Gil and Martin (1988) in faba bean Tawar et al 1989) in soybean and Rejatha (1992) in cowpea On the countrary Deshmukh and Manjare (1980) and Zaveri et al (1983) and Anilkumar (1993) reported non-additive gene effects for this character in cowpea The cross combination which have earliest flowering involved parents which were early x early general combiners suggesting the predominance of additive gene action for this character

In the case of the character days to maturity variance due to line x tester alone was found significant Contribution of line x tester interaction to total sum of square due to hybrids was higher than the lines and testers Estimate of σ^2 g c a was negative and smaller than σ^2 s c a The ratio σ^2 A/ ^{2} D was also less than one These revealed the predominant role of non-additive gene action (dominance or epistasis) in the inheritance of this trait Similar results were obtained by Zaveri et al (1983) and Anilkumar (1993) in cowpea Singh et al (1987) in blackgram and Katiyar et al (1989) in pea However in cowpea (Chauhan and Joshi 1981) greengram (Wilson et al 1985) chickpea (Katiyar et al 1988) and pea (Sharma and Nishisharma 1988) observed a preponderance of additive gene action for the expression of this character

As regards to plant height variance due to lines and line x tester interaction were significant but variance due to s c a was higher in magnitude than that due to g c a These facts indicated the predominant role of non-additive gene action even though both additive and non-additive gene effects were involved The low ratio of σ^2 A/ σ^2 D also denoted the same The smaller contribution of line x tester interaction to total variance suggested the importance of additive gene action in governing this trait Plant height was observed to be under the influence of both additive and non adiditive gene effects by Singh et al (1987) in pea Mehtre et al (1988) in pigeonpea Pandey and Tiwari (1989) in chickpea and Singh and Singh (1990) in pea Importance of non-additive gene action over additive gene action was reported in pigeonpea (Patel et al 1987) in chickpea (Salimath and Bahl 1989) and in cowpea

(Thiyagarajan *et al.* 1990) Contrary to this Yadavendra and Sudhirkumar (1987) in chickpea Sharma and Nishisharma (1988) in pea and Loiselle *et al* (1990) in soybean observed preponderance of additive genetic variance for the expression of this character

Variance due to line x tester alone was found significant for number of branches per plant The higher magnitude of variance due to s c a over variance due to g c a and the lower $\sigma^2 A/\sigma^2 D$ ratio indicating the predomiance of non additive gene action for this character Similar results were obtained in chickpea (Yadavendra and Sudhirkumar 1987 and Salimath and Bahl 1989) in cowpea (Thiyagarajan *et al* 1990) and in blackgram (Rajarathinam and Rathnasamy 1990) On the other hand additive genetic variance was found to be predominant in pea (Sharma and Nishi Sharma 1988) in chickpea (Katiyar *et al* 1988) in greengram (Saxena and Sharma 1989) and in soybean (Tawar *et al.*, 1989)

For the character number of of pods per plant mean square due to lines and line x tester were found significant s c a variance was higher in magnitude than g c a variance and the ratio of $\sigma^2 A$ to $\sigma^2 D$ was low All these revealed that the nature of gene action was predominantly non additive though both additive and non additive gene effects were involved in the inheritance of this trait Similar results were reported by Zaveri *et al* (1983) in cowpea Yadavendra and Sudhirkumar (1987) in chickpea Saxena and Sharma (1989) in greengram Thiyagarajan *et al* (1990) and Anilkumar (1993) in cowpea and Rajarathinam and Rathnasamy (1990) in blackgram whereas Chauhan and Joshi (1981) in cowpea Patel *et al* (1987) in pigeonpea Sharma *et al* (1988) Katiyar *et al* (1988) and Salimath and Bahl (1989) in chickpea and Sharma and Rao (1990) in urdbean observed predominance of additive gene effects in governing number of pods per plant

In the case of the character length of pod both variance due to lines and testers were significant Mean square due to g c a had a higher estimate over that due to s c a But ratio of σ^2A to σ^2D was less than one These indicated that the character might be influenced by additive and non additive gene effects This is in conformity with the observations of Chauhan and Joshi (1981) in cowpea Patel *et al* (1987) in pigeonpea and Thiyagarajan *et al* (1990) in cowpea However Rao *et al* (1984) and Muker *et al* (1988) reported non-additive gene action for this character in mungbean

Line x tester interaction alone was significant for number of seeds per pod S c a variance was higher than g c a variance Ratio of σ^2 A to σ^2 D was less than one All these suggested the importance of non additive genetic variance for controlling this chatcter The same was reported by Mehtre *et al* (1988) in pigeonpea Tiwari (1989) and Salimath and Bahl (1989) in chickpea and Thiyagarajan et al (1990) in cowpea On the contrary Wilson et al (1985) in greengram Saxena and Sharma (1989) in greengram Onkar Singh and Paroda (1989) in chickpea and Rejatha (1992) and Anilkumar (1993) in cowpea observed the important role of non-additive gene action in governing this trait

Variance due to lines and line x tester were significant for 100-seed weight Mean square due to s c a was greater in magnitude than mean square due to g c a The ratio of σ^2 A to σ^2 D was low All these pointed out that both additive and non additive genetic variances were involved in the expression of this trait with the later predominant This was also revealed by Katiyar et al (1988) and Salimath and Bahl (1989) in pea and Thiyagarajan et al (1990) in cowpea Contradictory to this Chauhan and Joshi (1981) in cowpea Patel et al (1987) in pigeonpea Singh and Singh (1990) in pea Sharma and Rao (1990) in mungbean and Anilkumar (1993) in cowpea reported that 100 seed weight was observed to be influenced by the action of additive gene effects

For the character seed yield per plant mean square due to line x tester interaction alone was significant S c a variance was many times greater than g c a variance The σ^2 A to σ^2 D ratio also showed a high value of dominance component over additive component of variance Similar results were obtained by Zaveri et al (1983) in cowpea Yadavendra and Sudhirkumar (1987) and Katiyar

SUMMARY

et al (1988) in chickpea Katiyar *et al* (1987) in pea and Thiyagarajan *et al* (1990) and Anilkumar (1993) in cowpea whereas Chauhan and Joshi (1981) in cowpea Singh *et al* (1987) in pea Loiselle *et al* (1990) in soybean and Sharma and Rao (1990) in urdbean reported a predominant effect of additive gene action for seed yield per plant

The variance due to line x tester interaction alone was significant for the character chlorophyll b content σ^2 g c a estimate was negative and the ratio between σ^2 A and σ^2 D was low These indicated the predominant role of non-additive gene action in the inheritance of this trait This is in confirmity with the reports of Patel and Kukadia (1986) in pearl millet However Chadha *et al* (1988) observed in brinjal that both additive and non-additive gene effects were important for chlorophyll b content

The percentage of pod borer incidence was characterised by high s c a variance over g c a variance Mean square due to lines alone was significant for this attribute The ratio of σ^2 A to σ^2 D was low All these suggested that though additive and non-additive genetic variances were involved the later was more important in the inheritance of resistance to pod borer incidence The same result was reported in groundnut against *Heliothis zea* by Holley *et al* (1985) In contradiction to this a predominant role of additive gene action was found in sorghum against shoot fly (Biradar et al. 1984) aphid (Hsich and Pi 1985) and stem borer (Singh and Verma 1988)

In general it was seen that additive gene action was predominated for the inheritance of days to flowering and pod length while a preponderated effect of non additive gene action was observed for the inheritance of days to maturity plant height number of branches per plant number of pods per plant number of seeds per pod 100-seed weight seed yield per plant chlorophyll b content and pod borer resistance

Summary

The investigation on combining ability in grain cowpea was carried out in the Department of Plant Breeding College of Agriculture Vellayani during the year 1991 92 Based on the yield and previous performance eight varieties were chosen as parents Hybridisation was done in the line x tester pattern using two high yielding and short duration varieties as lines and six varieties with high productivity as testers The eight parents and their twelve F_1s were put in a comparative evaluation trial in Randomised Block Design with three replications under partial shaded conditions in coconut garden at the Instructional farm Vellayani Observations were recorded on days to flowering days to maturity plant height number of branches per plant number of pods per plant length of pod number of seeds per pod 100 seed weight seed yield per plant chlorophyll a chlorophyll b and total chlorophyll contents and reaction to major pests and diseases Periodical shade intensity was measured at 30 DAP and 45DAP @ three times per day Combining ability and gene action were estimated The salient inferences from the results are presented below

The analysis of variance revealed significant differences for most of the characters However the twenty treatments did not differ significantly among themsleves for chlorophyll a and total chlorophyll contents The characters having significant differences were then subjected to combining ability analysis

Combining ability analysis revealed that mean square due to lines and line x tester interaction were significant for plant height number of pods per plant and 100 seed weight which showed the importance of both g c a and s c a for these traits However the s c a variance was predominant for all these characters suggesting the importance of specific combining ability Mean square due to lines alone was significant for days to flowering and pod borer incidence and that due to lines and testers were significant for length of pod Variance due to g c a was larger than s c a for days to flowering and length of pod and hence these may be under the influence of general combining ability Since s c a variance was higher than g c a variance for pod borer incidence s c a might be more important for resistance to pod borer incidence Variance due to line x tester interaction alone was found to be significant for days to maturity number of branches per plant number of seeds per pod seed yield per plant and chlorophyll b content Variance due to g c a was smaller than that due to s c a for all these characters indicating the importance of specific combining ability for these traits

Based on g c a effects alone it was difficult to choose good general combiners for all the characters together Similarly no cross combination was observed to be good for all the characters The line Culture 9 was the best general combiner for days to flowering days to maturity length of pod 100 seed weight and chlorophyll b content On the other hand Chharodi 1 was best for plant height number of branches per plant number of pods per plant number of seeds per pod seed yield per plant and pod borer resistance Among the testers V 26 was the best general combiner for days to maturity number of pods per plant and seed yield per plant GC 82 7 for 100 seed weight and chlorophyll b content V 240 for days to flowering and number of branches per plant and Kanakamani for length of pod and 100 seed weight The cross combination Chharodi 1 x V 26 was the best specific combination for days to maturity number of branches per plant and number of pods per plant Culture 9 x Kanakamani for length of pod and number of seeds per pod Chharodi-1 x Kanakamani for 100 seed weight and Chlorophyll b content Culture 9 x S-488 for plant height and resistance to pod borer incidence and Culture 9 x V 322 for seed yield per plant Most of the superior specific combinations for a character involved parents with good and poor general combining ability for the character

The higher magnitude of s c a variance and the ratio of σ^2A to σ^2D being less than unity for days to maturity plant height number of branches per plant number of pods per plant number of seeds per pod 100-seed weight, seed yield per plant chlorophyll b content and pod borer incidence suggested the predominance of non additive gene action in controlling their inheritance Magnitude of variance due to g c a was found to be higher than that due to s c a for days to flowering and length of pod Hence these two characters might be governed by additive genes

The study in general indicated that in view of the preponderance of non-additive gene action for seed yield and some important yield components commercial exploitation of hybrid vigour is the most appropriate method of utilizing such gene action The varieties Chharodi 1 Culture-9 V 26 and GC 82 7 and cross combinations Chharodi-1 x V 26 Culture-9 x Kanakamani and Chharodi-1 x Kanakamani can be given due consideration while formulating future breeding programmes It is suggested that the intermating of randomly selected progenies in early segregating generations obtained by crossing the parents will release the hidden genetic variability through breakage of undesirable linkages involved in different characters and may produce an elite population for selection of high yielding lines in advanced generations Reciprocal recurrent selections may also exploit both types of gene actions

REFERENCE

References

*Agrawal B L Abraham C V and House L R (1988) Inheritance of resistance to midge *Contarinia sorghicola* Coq in sorghum *Sorghum bicolor* (L) Moench *Insect Science and its Application* 9(1) 43 45

Anilkumar S G (1993) Combining ability for yield and drought tolerance in cowpea (*Vigna unguiculata* (L) Walp) MSc (Ag) thesis Fac Agri *Kerala Agric Univ*

Anonymous (1990) *Economic Review* State Planning Board Thiruvananthapuram pp 25 27

Arora P P and Pandya B P (1987) Heterosis in chickpea *International Chickpea Newsletter* 16 3 4

Aykroyd W R and Doughty Joyce (1964) *Legumes in human nutrition* F A O Rome

Bahl P N and Kumar J (1989) Evaluation and utilization of high yielding hybrids of chickpea *Indian J Genet* 49(1) 53-58

*Biradar S G Borikar S T and Chundurwar R D (1984) Genetic analysis of shootfly resistance in sorghum *Sorghum Newsletter* 27 104

Chadha M L Hedge R K and Bajaj K L (1988) Heterosis and combining ability studies of pigmentation in brinjal (*Solanum melongena* L) *Vegetable Sci* 15(1) 64 71

Chauhan G S and Joshi R K (1981) A note on combining ability in cowpea *Legume Research* 4 (2) 112 114

*Cheng B C Liu Q Y Jiang H and Liu L R (1985) Analysis of genetic effects with reference to chlorophyll in sorghum _Hereditas China_ 7 (3) 1 4

Cheralu C Muralidhar V Satyanarayana A and Venkateswarlu S (1989) Heterosis in relation to combining ability in pigeonpea (_Cajanus cajan_) _Indian J agric Sci_ 59(1) 68-70

*Csizmadia L (1985) Combining ability studies in a ten parent diallel cross of pea varieties _Zoldsegtermestisi Kutato Intezet Bulletinje_ 18 5-15

Dabholkar A R Lal G S Mishra R C and Barche N B (1989) Combining ability analysis of resistance of sorghum shoot fly _Indian J Genet_ 49 (3) 325 330

Dahiya B S and Waldia R S (1982) Inheritance of some quantitative characters in blackgram _Indian J Genet_ 43 261-264

Das N D and Dana S (1981) Inheritance of seed yield components in rice bean _Indian J Genet_ 41 264 267

Das N D and Dana S (1990) Gene effects in four metric traits of rice bean _Indian J Genet_ 50 (1) 27 32

Dasgupta T and Das P K (1987) Genetics of yield in blackgram (_Vigna mungo_) _Indian J Genet_ 47(3) 265-270

Deshmukh R B and Manjare M R (1980) Combining ability in mungbean (_Vigna radiata_ (L) Wilczek) _Legume Research_ 3 (2) 97 101

*De-silva H N and Omran D (1986) Diallel analysis of yield and yield components in winged bean (Psophocarpus tetragonolobus (L) D C) Journal of agric Sci U K 106 (3) 485-490

Dixon A G O Bramel Cox P J and Harvey T L (1990) Diallel analysis of resistance in sorghum greenbug biotype E antibiosis and tolerance Crop Sci 30(5) 1055 1059

Dubey R S and Lal S (1983) Combining ability in peas Indian J Genet 43 314-317

Ellison F Darera N F and Pederson S G (1983) Inheritance of physiological characters associated with yield variation in bread wheat Euphytica 31(2) 241 255

*El-Muraba A I Waly E A Abdel Aal S A and Zayed G (1988) Genetic studies in pea (Pisum Sativum L) I Flowering plant height and pod characters Assiut J agric Sci 19(2) 211-221

*Erskine W (1981) Heritability and combining ability of vegetative and phenological characters of winged beans (Psophocarpus tetragonolobus (L) D C) J agric Sci Camb 96 503-508

*Fleck A Von and Ruckenbauer P (1989) The polymers test a step in the breeding method of faba beans experimental results Bodenkultar 44(1) 61-72

*Fooland M R and Bassiri A (1983) Estimate of combining ability reciprocal effects and heterosis for yield and yield components in a common bean diallel cross J agric Sci camb 100 103 108

Gil J and Martin L M (1988) Genetics of days to flowering in _Vicia faba_ L _Legume Research_ 11(2) 59-65

Gupta A K Kuttikrishan K R Sharma S M and Rao S K (1982) Genetic analysis of yield and quality traits in soybean (_Glycine max_ (L) Merril) _Legume Research_ 5(1) 49-53

Habib A F Joshi M S Kullaiswamy B Y and Bhat B N (1985) Combining ability in peanuts (_Arachis hypogaea_ L) _Indian J Genet_ 45(2) 236 239

Haque M F Ganguli D K and Mishra A K (1988) Combining ability and heterosis in urd bean _Indian J pulses Res_ 1(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(2) 111 117

*Holley R H Wynne J C Campbell W V and Isleib T G (1985) Combining ability for insect resistance in peanuts _Oleagineax_ 40(4) 203-209

*Hsich J S and Pi C P (1988) Diallel analysis of resistance to aphid in sorghum _J Agric Assoc China_ 142 67-84

*Jhorar B S Solanki K R and Jatrasa D S (1985) Combining ability analysis of seed yield in cluster bean under different environments _Cuban J agric Sci_ 19(1) 113-119

Jhorar B S Solanki K R and Jatrasa D S (1988) Combining ability analysis of kernel weight in clusterbean under different environments Indian J agric Res 22(4) 188-192

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(1) 42-46

Kamatar M Y (1985) Heterosis and combining ability in chickpea (*Cicer arietinum* L) Mysore J agric Sci 19(3) 216-217

*Kanarskaya L N and Kalinia L U (1981) Study of genetical characteristics and assessment of combining ability in *Vicia sativa* varieties by means of diallel analysis Sb nauch tr NII S kh tsentr r nov Necheronozemn Zony 50 169-175

Katiyar R P Ram R S and Maurya D M (1987) Combining ability for phenological and physicological traits in pea Indian J Genet 47(3) 281-289

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(3) 297-301

Kaw R N and Madhava Menon P (1977) Line x tester analysis of combining ability in soybean Indian J agric Sci 48(2) 110-117

Kemthorne O (1957) An Introduction to Genetic Statistics John Wiley and Sons Inc Newyork pp 458 471

*Khalifa T and Drolsom N (1988) Combining ability for European corn borer resistance and three agronomic traits in maize Maydica 33(4) 247-259

*Kim S K Hallaver A R Guthrie W D Barry D Lamkey K R and Hong C S (1989) Genetic resistance of tropical corn inbreds to second generation European corn borer (Lepidoptera Pyralidae) Journal of Economic Entomology 82(4) 1207-1211

Kumar J and Bahl P N (1988) Hybrid vigour and nicking ability in chickpea Indian J pulses Res 1(2) 96-101

*Loiselle F Voldeng H D Turcotte D and St Pierre C A (1990) Analysis of agronomic characters for an eleven parent diallel of early maturing soybean genotypes in eastern Canada Canadian Journal of Plant Sciences 70 (1) 107 115

*Mahmoud S A and Al-Ayobi D Y (1987) Heterotic performance and combining ability in diallel cross among broad bean Vicia faba L Annals of Agricultural Science Ainshams University 32(2) 1401 1410

*Malhotra (1983) Genetics of pod length seeds per pod and seed size in mungbean (Vigna radiata (L) Wilczek) Genetica Agraria 37(314) 345-353

Malhotra R S (1983) Combining ability in urd bean Indian J Genet 43 324-327

Mandal A K and Bahl P N (1987) Genetic analysis in Desi x Kabuli crosses of chickpea Legume Research 10(1) 37-40

Manoharan V Vindhiyavarman P Sundaran N and Thangavelu S (1985) An analysis of combining ability in groundnut Madras agric J 72(11) 601 605

Mak C and Yap T C (1977) Heterosis and combining ability of seed protein yield and yield components in long bean Crop Sci 17 339 341

Mehtre S S Senone A H Deshmukh R B and Karale M U (1988) Combining ability in pigeonpea Legume Research 11(2) 81-84

Mishra S N Verma J S and Rastoga R (1987) Combining ability for flowering and seed yield in cowpea Annals of Agric Res 8(2) 268 272

Moitra P K Singh S P and Mehta A K (1988) Combining ability in pea (Pisum sativum) Indian J agric Sci 58(6) 479-480

Muker H S Sandhu T S and Bhullar B S (1988) Genetics of quantitative characters in summer mungbean (Vigna radiata (L) Wilczek var radiata) Indian J Genet 48(1) 113 114

Natarajan C Thiyagarajan K and Rathinaswamy R (1990) Combining ability in greengram (Vigna radiata (L) Wilczek) Madras agric J 77 (9 12) 382-385

*Naumkina T S (1987) Evaluating the combining ability of peas in a system of diallel crosses Nauchno - tekhnicheskii Byulleten vsesoyuznogo Nauchno issledovatel skogo Instituta ZernoboboVykh i Krupyanykh Kul tur 35 9 12

Nienhuis, J and Singh S P (1986) Combining ability analysis and relationship among yield yield components and architectural traits in dry bean Crop Sci 29(1) 21-27

Onkar Singh 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) 1 9

Pande K Pandya B P and Jain K C (1979) Diallel analysis for yield and yield components in bengalgram Indian J agric Res 13(3) 187-194

Pandey R L and Tiwari A S (1989) Estimation of gene effects and heterosis in chickpea Indian J agric Res 23(4) 191-199

Patel U G and Kukadia M U (1986) Line x tester analysis of combining ability in pearl millet Gujarat Agric Univ Res J 11(2) 7-16

Patel J A Pathak A R Zaveri P P and Shah R M (1987) Combining ability analysis in pigeonpea Indian J Genet 47(2) 183 188

Patel J A Patel S A Zaveri P P and Pathak A R (1988) Combining ability analysis in mungbean Indian J pulses Res 1(2) 106-110

*Patil R B and Bhapkar D G (1986) Combining ability in cowpea J Maharashtra agric Univ 11(3) 303-306

Rajarathinam S and Rathnasamy R (1990) Combining ability studies in blackgram (Vigna mungo (L) Hepper) Madras agric J 77(9-12) 474-477

Ram R H Chauhan Y S Srivastava R L and Singh I B (1986) Heterosis in peas Farm Science Journal 1(1-2) 42-47

Ramakrishnan M and Soundrapandian G (1990) Line x tester analysis in sesame (*Sesamum indicum* L) Madras agric J 77 (9-12) 486-489

Ranalli P Fantino M G Burchi G and Ruaro G (1989) Selection for yield for seed yield earliness and technological properties in a nine parent diallel cross in peas Indian J Genet 43 (4) 185-190

Rao S S Singh S P and Rao S K (1984) Estimation of additive dominance and digenice epistatic interaction effects for yield and its components in mungbean (*Vigna radiata* (L) Wilczek) Legume Research 7(1) 6-12

Rejatha V (1992) Combining ability in vegetable cowpea (*Vigna unguiculata* var sesquipedalis) M Sc (Ag) thesis Fac Agri Kerala Agric Univ

Salimath P M and Bahl P N (1985) Heterosis and combining ability for earlines in chickpea (*Cicer arietinum* L) Indian J Genet 45 (1) 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(1) 29-34

Sandhu T N Malhotra R S and Sharma A K (1981) Combining ability and inheritance studies in urdbean (*Vigna mungo* L) Legume Research 4(2) 90-94

Saxena K B Byth D E Wallıs L H and De Lacy (1989) Gene action ın short duratıon pıgeonpeas Legume Research 12(3) 103-109

Saxena S D and Sharma R K (1989) Estımatıon of combınıng abılıty ın mungbean (*Vıgna radıata* (L) Wlczek) Legume Research 12(4) 165 169

Sharma S K and Nıshı Sharma (1988) Combınıng abılıty analysıs ın soybean Indıan J Genet 48(3) 355 358

Sharma S M Mehta A K and Tomer G S (1988) Gene actıon for yıeld components ın chıckpea (*Cıcer arıetınum* L) Legume Research 11 (4) 160-162

Sharma R N and Rao S K (1990) Estımatıon of second degree parameters for yıeld and ıts components ın urd Legume Research 13(2) 82-86

Shınde N V and Deshmukh R B (1990) Inherıtance of quantıtatıve characters ın chıckpea Indıan J Genet 50(4) 342-347

Sıngh A K and Saını S S (1986) Combınıng abılıty and hetrosıs ın French bean Indıan J Hortıculture 43 1-2

Sıngh I B Sıngh H G Sıngh H and Sıngh P (1987) Combınıng abılıty for yıeld and ıts components ın blackgram Indıan J Genet 47(1) 99 103

Sıngh K B and Dhalıwal H S (1970) Combınıng abılıty and genetıcs of days to 50% flowerıng ın balckgram (*Phaselous mungo* Rosb) Indıan J agrıc Scı 41(8) 719-723

Singh K B and Jain R P (1972) Heterosis and combining ability in cowpeas Indian J Genet 32(1) 62-66

Singh K N Singh Santhosi U and Singh H G (1987) Genetic analysis of yield components and protein content in pea The analysis of general and specific combining ability Indian J Genet 47(2) 115 118

Singh K N Singh Santhoshi U Singh H G and Singh S P (1985) Diallel analysis in field pea Crop Improvement 12(1) 59-61

Singh M N and Singh R B (1990) Estimation of additive dominance and digenic epistatic interaction effects for certain yield characters in pea Indian J Genet 50(4) 348-353

Singh R K and Choudary B D (1979) Biometrical Methods in Quantitative Genetic Analysis Kalyani Publishers New Delhi pp 39-79

Singh S P Singh H N and Gupta K K (1980) Combining ability and inheritance studies through diallel cross in beans (Dolichos lablab) Indian Journal of Horticulture 37 (4) 388 391

Singh S P Govil J N and Hayat Ram (1983) Combining ability and heterosis in early pigeonpea hybrida Indian J Genet 43 481-486

Singh S P and Ramanujam S (1981) Gene action and hetorosis in Bengal gram Indian J Genet 41(1) 150 153

Singh S P Singh H N and Srivastava J P (1986) Combining ability in lablab bean (Lablab purpureus (L) Sweet) Indian Agriculturist 30(2) 147 152

Singh S P Singh Santhoshi U Singh K N and Singh V S (1987) Combining ability study in segregating generations of pea Legume Research 10(2) 65 68

Singh S P and Varma A N (1988) Combining ability in stem borer Chilo pertellus (Swinhoe) resistance in sorghum Insect science and its application 9(5) 665-668

Srivastava R L Ziauddin Ahamad Singh H G and Saxena J K (1977) Combining ability for yield and related attributes in soybean Indian J agric Res 48(3) 148 155

Starnes W J and Hadley H H (1965) Chlorophyll content of various strains of soybean Crop Sci 5 9 11

*Syr eva T L (1981) Combining ability of pea varieties for number of seeds per pod Nauch - tekhn byul sib, Nll rastenievod i sekktsii No 6/7 99-103

Tawar M L Mishra A K and Rao S K (1989) Gene action in soybean Indian J Heredity 21(1-2) 10-16

Tewatia A S Kalloo G and Dhankar B S (1988) Partial diallel analysis for the study of combining ability in garden pea Vegetable Science 15(2) 163-171

Thiyagarajan K Natarajan G and Rathnasamy R (1990) Gene action in cowpea Madras agric J 77 (9-12) 558 559

Upadhyaya P C and Sawant A R (1990) Combining ability in some quantitative traits in Triticale Madras agric J 77 (9 12) 482 485

Venkateswarlu S and Singh R B (1981) Heterosis and combining ability in peas Indian J Genet 41(2) 255-258

Venkateswarlu S and Singh R B (1982) Combining ability in pigeonpea Indian J Genet 42(1) 11 14

Vindhiyavarman P Manoharan V and Rathinasamy R (1990) Studies on gene action in groundnut Madras agric J 77(9 12) 511-573

Wilson D Mercy S T and Nair N K (1985) Combining ability in greengram Indian J agric Sci 55(11) 665-670

Yadavendra J P and Sudhirkumar (1987) Combining ability in chickpea Indian J Genet 47(1) 67 70

Zaveri P P Patel P K Yadavendra J P and Shah R M (1983) Heterosis and combining ability in cowpea Indian J agric Sci 53(9) 793 796

*Original not seen

APPENDICES

Appendix 1 Mean Shade Intensity

Treatments	30 DAS			45 DAS		
	1	2	3	1	2	3
Chharodi 1	41 59	16 05	34 10	22 03	10 92	38 55
Culture 9	37 56	14 26	35 20	25 55	13 77	37 86
Kanakamani	37 75	12 50	37 19	26 50	13 34	41 28
V 240	34 43	14 04	33 36	23 37	13 26	41 90
V 322	29 64	14 46	30 35	23 49	12 70	39 66
GC 82 7	43 95	12 81	33 20	26 38	11 59	37 00
V 26	37 56	12 92	34 54	24 48	11 51	37 26
S-488	37 90	14 35	34 25	24 39	11 91	39 50
Chharodi 1 x Kanakamani	39 01	16 25	32 46	21 94	13 09	36 49
Chharodi 1 x V 240	41 45	15 83	32 43	26 05	12 78	34 15
Chharodi 1 x V 322	37 75	12 22	38 38	24 20	9 76	37 35
Chharodi 1 x GC 82 7	39 33	14 09	32 02	28 49	11 12	42 73
Chharodi 1 x V 26	34 10	12 46	31 43	26 49	10 17	37 26
Chharodi 1 x S-488	41 45	13 51	32 27	25 67	14 09	31 96
Culture 9 x Kanakamani	37 97	11 54	33 44	28 46	10 68	37 17
Culture 9 x V 240	37 56	15 36	37 28	24 12	11 18	38 54
Culture 9 x V 322	37 89	14 04	33 92	24 35	10 33	37 35
Cul ure 9 x GC 82 7	36 74	14 65	34 19	22 71	12 51	36 23
Culture 9 x V 26	36 18	12 29	32 68	23 49	12 00	36 80
Culture 9 x S-488	40 35	12 61	36 62	26 03	13 18	38 63

COMBINING ABILITY IN GRAIN COWPEA
[*Vigna unguiculata* (L) Walp]

By

JAYARANI, L S

ABSTRACT OF A THESIS
submitted in partial fulfilment of the requirement
for the Degree
MASTER OF SCIENCE IN AGRICULTURE
Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF PLANT BREEDING
COLLEGE OF AGRICULTURE
VELLAYANI THIRUVANANTHAPURAM

1993

Abstract

Two lines six testers and twelve hybrids of cowpea were evaluated in the partially shaded conditions of coconut garden of Vellayani for combining ability and gene action The lines and testers were selected based on their previous performance and crossed in line x tester manner to get twelve hybrids

Observations were made on sixteen characters of which twelve characters showed significant differences among the twenty treatments Combining ability analysis was carried out as suggested by Kempthorn (1957) suggested the importance of specific combining ability for all the characters except for length of pod and days to flowering It was seen that the varieties Chharodi 1 Culture 9 V-26 and GC 82 7 were the best general combiners and the cross combinations Chharodi 1 x V-26 Chharodi-1 x Kanakamani and Culture 9 x V-322 were the best specific combinations for yield and yield attributes under partially shaded upland conditions

The yield and important yield attributes were under the control of non-additive gene actions except days to flowering and length of pod

The varieties Culture 9 GC 82-7 Chharodi 1 and V-26 and the cross combinations Chharodi 1 x V-26 Chharodi 1 x Kanakamani and Culture 9 x Kanakamani can be further exploited through selection