GENE ACTION AND COMBINING ABILITY IN GRAIN COWPEA (*Vigna unguiculata* (L.) Walp.) IN RELATION TO APHID BORNE MOSAIC VIRUS RESISTANCE

By

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THESIS

submitted in partial fulfilment of the requirement

for the degree of

MASTER OF SCIENCE IN AGRICULTURE

(PLANT BREEDING AND GENETICS)

FACULTY OF AGRICULTURE

Kerala Agricultural University

DEPARTMENT OF PLANT BREEDING AND GENETICS

COLLEGE OF AGRICULTURE

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THIRUVANANTHAPURAM

1995

DECLARATION

I hereby declare that this thesis entitled "Gene action and combining ability in grain cowpea (*Vigna unguiculata* (L.) Walp) in relation to aphid borne mosaic virus resistance" 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.

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CERTIFICATE

Certified that this thesis entitled "Gene action and combining ability in grain cowpea (*Vigna unguiculata* (L.) Walp) in relation to aphid borne mosaic virus resistance" is a record of research work done independently by **Kum. SMITHA**. 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.

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ACKNOWLEDGMENT

I wish to express my profound gratitude and indebtedness to Smt. N. Kamalam, Associate Professor of Plant Breeding and Genetics, and Chairman of my advisory committee for her valuable guidance and constant encouragement throughout the course of the present investigation.

I am thankful to Dr. R. Gopimony, Professor and Head of Plant Breeding and Genetics for the valuable suggestions and help during this study.

I also express my boundless gratitude to Dr. P. Saraswathy, Professor and Head of Agricultural Statistics for her constant encouragement and valuable suggestions in designing the experiment, conducting the statistical analysis and interpreting the results.

I am extremely grateful to Dr. B. Rajagopalan, Associate Professor of Plant Pathology for his valuable suggestions and help during this study.

I accord my sincere thanks to Mr. C.E. Ajithkumar, Junior Programmer of the Department of Agricultural Statistics for his generous and timely help in the analysis of the data.

I am thankful to Mr. Sulaiman for the great help rendered by him in taking the photographs.

I gratefully acknowledge the sincere help which I have received from K. Chandrakumar and M/s. Athira Computers during the preparation of thesis.

I have pleasure to keep in mind the co-operation and assistance obtained from Deepa, Seeja, Surendran, Animon, Aneesa, Jannet, Rajani and Sanchu for the successful completion of this thesis.

I am deeply indebted to my parents and brother for their encouragement throughout the course of study.

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

Above all, I bow my head before the God Almighty who extended to me every gesture of help in thoughts, words and deeds and blessed me with health, strength and confidence always and this small venture is no exception.

SMITHA. S.

CONTENTS

	PAGE
INTRODUCTION	1
REVIEW OF LITERATURE	3
MATERIALS AND METHODS	40
RESULTS	51
DISCUSSION	70
SUMMARY	81
REFERENCES	
APPENDIX	
ABSTRACT	

LIST OF TABLES

Table	Title	Page No.
1	Details of varieties used for the study	40
2	Parents and hybrids	41
3	ANOVA for line x tester mating design	48
4	Mean performance of lines, testers and hybrids for different characters	52
5	g.c.a effects of parents	56
6	s.c.a effects of hybrids	57
7	Best general combiners and specific combiners for different characters	62
8	Genetic components of variance	64
9	Proportional contribution of lines testers and line x tester to total variance	66
10	Percentage of pods attacked by fruits borer	68

LIST OF FIGURES

	Title
1.	g.c.a. and s.c.a. - Days to flowering
2.	g.c.a. and s.c.a. - Days to maturity
3.	g.c.a. and s.c.a. - Number of branches/plant
4.	g.c.a. and s.c.a. - Length of pod
5.	g.c.a. and s.c.a. - Number of pods/plant
6.	g.c.a. and s.c.a. - Number of seeds/pod
7.	g.c.a. and s.c.a. - 100 - seed weight
8.	g.c.a. and s.c.a. - Seed yield per plant
9.	g.c.a. and s.c.a. - Aphid borne mosaic resistance
10.	Proportional contributions of lines, testers and line x testers to total variance.

LIST OF PLATES

Plate No.	Description
1.	Parents used for crossing
2.	Superior combinations with respect to combining ability.

INTRODUCTION

INTRODUCTION

Pulses occupy a unique position in the world agriculture by virtue of their high protein content and their capacity for directly using the inexhaustible stock of atmospheric nitrogen. They contain 22-24 per cent protein which is much more than that available in cereals. The present production of pulses grown in an area of 22 million hectares 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). A balanced diet should contain three ounces of pulses per day per adult to meet the protein requirement (Aykroyd and Doughty, 1964).

Cowpea (Vigna unguiculata (L.) Walp.) belonging to the subfamily Papilionaceae is an important pulse crop of South India. Virus diseases which cause fifty percent loss in yield have been posing formidable obstacle to step up the production of this crop. It is known to be affected by nineteen types of viruses under natural conditions. Of these viruses cowpea aphid borne mosaic virus (CAMV) is responsible for causing loss in yield to a great extent. Yield lose of 13-87 per cent has been reported from Iran (Kaiser and Mossahebi, 1975). Development of high yielding disease resistant varieties can go a long way in overcoming this problem.

In an earlier study conducted in the department of Plant Breeding, College of Agriculture, Vellayani, Thiruvananthapuram two varieties have been identified as resistant to CAMV. Using these varieties along with five other high yielding varieties the present investigation was under taken to assess combining ability of parents and gene action involved in the inheritance of different yield attributes and CAMV resistance and to isolate high yielding genotypes with CAMV resistance.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Information on combining ability and gene action for yield attributes in relation to aphid borne mosaic virus resistance is essential to chalk out efficient breeding programmes in cowpea. A review of literature on these aspects are presented below.

Days to flowering

Combining ability analysis for days to flowering from the F_1 and F_2 diallel generations involving seven derivatives of soybean revealed that s.c.a. variance was found to be significant in F_2 generation. The estimated g.c.a. variance were higher than those of s.c.a. variances in F_1 and F_2 generations (Srivatsava et al., 1977).

Durong (1980) studied yield and related characters using 8 x 8 diallel cross of soybean and reported the involvement of additive gene effects.

Deshmukh and Manjarae (1980) while analysing the combining ability in mungbean in a diallel cross involving eight varieties found highly significant variance due to g.c.a. and s.c.a. for days to flower. Nonadditive gene action was found important for this character.

Combining ability analysis using a complete set of six parents diallel cross of gardenpea for yield components showed predominance of additive genetic variance for number of days to flower. (Dhillon and Chahal, 1981).

In a study of combining ability analysis of ten diverse cultivars of pigeonpea Venkateswarlu and Singh (1981a) reported predominance of additive gene action for days to first flower opening.

Combining ability studies through 10 x 10 diallel in pea showed significant general and specific combining ability variances for duration upto flowering. In general, additive genetic variance was found higher than dominance variance for this character (Dubey and Lal, 1983).

Salimath and Bahl (1985) from a line x tester analysis in chickpea reported the importance of g.c.a. and s.c.a. variances for days to flower. The variance due to g.c.a. was higher than that due to s.c.a. Based on the g.c.a. effects BG-203, PST-7, and P-10 among lines and NEC-249 among testers were identified as good general combiners for earliness. They also showed importance of additive and nonadditive variances for days to flower with a predominance of additive gene action.

Significant g.c.a. and s.c.a. variance was recorded by Wilson *et al*. (1985) for days to flowering in the analysis of the diallel crosses involving five varieties of greengram and suggested the existence of both additive and nonadditive gene action. The variance due to g.c.a. was much higher than that due to s.c.a. and hence predominance of additive gene action was reported.

Patil and Bhapkar (1986) studied yield and related characters using parents and F_1 of the half diallel cross of cowpea and reported involvement of additive gene effect alone for days to flowering.

Combining ability for yield and its components was studied in the F_2 from a 5 x 5 diallel cross of Lablabbean by Singh et al. (1986). The result showed the significance of both g.c.a. and s.c.a. variance and importance of g.c.a. variance for days to flowering. The importance of both additive and nonadditive gene action with predominance of additive gene effect was suggested for the inheritance of the trait, days to flower.

Eight chickpea varieties and their twenty eight F_1's were studied for combining ability analysis and found that for flowering and maturity good combining parents were chofa JG-62 and BG-121. It was also observed that additive type of gene action was important for days to flowering (Yadavendra and Sudhirkumar, 1987).

Katiyar et al. (1987) in a study with parents, F_1s and F_2s of a fourteen line x three tester cross of pea indicated the predominance of nonadditive gene action for days to flowering. The variety Batribrown was selected as a good general combiner for early flowering.

A line x tester analysis of chickpea varieties showed significant difference in days to flowering. The g.c.a. estimate was reported to be not significant for the trait. This indicated that the trait was under the control of nonadditive gene action, BG-390 and L-550 were suggested as good general combiners for early flowering (Mandal and Bahl, 1987).

Katiyar et al. (1988) in a study with six chickpea genotypes and their F_1 hybrids for combining ability showed significant differences for g.c.a. as well as s.c.a. variances for day to flowering and reported the action of additive and nonadditive gene effects with the predominance of additive gene action.

From a combining ability analysis involving nine diverse parents and their $36F_1$ crosses Mehetre et al. (1988) reported the predominance of additive gene effects for days to flowering.

Moitra et al. (1988) analysed five pea lines for their combining ability and observed that Batri yellow showed negative g.c.a. for days to flowering. R701 x Batri yellow, Kinnauri x T 163 and T10 x T163 showed negative and significant s.c.a. for days to flowering.

F_1 plants derived from a diallel cross among five genotypes of pigeonpea were evaluated for days to flowering (Cheralu et al., 1989) and observed that both parents in the cross ICP 8863 x LRG 30 possessed high g.c.a. for day to flowering.

Half diallel of seven short duration pigeonpea lines was evaluated in the F_1 and F_2 generation by Saxena et al. (1989). The results indicated the predominance of g.c.a. variance.

Combining ability studies were made over environments for yield and nine yield attributing characters utilizing 12-parent diallel F_1 progenies in pea by Singh and Singh (1990) and reported that both additive and nonadditive genetic variances were important for this character.

Combining ability analysis of six cultivars of cowpea indicated significant g.c.a. and s.c.a. variances and importance of additive gene action (Rejatha, 1992).

A line x tester analysis of cowpea varieties showed the presence of additive and nonadditive gene action with predominance of nonadditive gene action for duration upto first flowering Anilkumar (1993) where as Jayarani (1993) reported the predominance of additive gene action for this character.

Days upto maturity

Combining ability analysis in the F_1 and F_2 diallel generations involving seven diverse derivatives of soybean for days to maturity revealed that both g.c.a. and s.c.a. variance were significant. The estimates of g.c.a. variance was reported to be higher than that of s.c.a. variance in F_2 generation and lower in F_1 generation. (Srivatsava et al., 1977).

Deshmukh and Manjare (1980) studied the combining ability analysis of diallel cross involving eight mungbean varieties and found that the variance due to g.c.a. and s.c.a. were highly significant for days to maturity. It was also reported that nonadditive gene action was important for this character.

Durong (1980) studied combining ability using a 8 x 8 diallel cross of soybean and reported additive gene action.

Combining ability analysis in six parental diallel cross in Urdbean by Sandhu et al. (1981) revealed that both additive and nonadditive effects were important for days to maturity and that nonadditive gene effects were preponderant for all the characters studied except days to maturity.

In a diallel cross studied by Chauhan and Joshi (1981) with eight varieties along with parents reported that both general and specific combining ability variances were important for days to maturity but magnitude of g.c.a. variance was reported to be comparatively much higher. They have also suggested that additive gene action was predominent in the inheritance of days to maturity.

Salimath and Bahl (1985) conducted a line x tester analysis in chickpea with five males and nine females and reported that s.c.a. variance was important for days to maturity. They have also reported that nonadditive variance was pronounced for this character.

A significant g.c.a. and s.c.a variance was reported by Wilson et al. (1985) for days to maturity in an analysis of the diallel cross among five varieties of green gram. They have found that the variance due to g.c.a. was much higher than that due to s.c.a. and reported the existance of both additive and nonadditive gene action for days to maturity with predominance of additive gene action.

Singh et al. (1987b) reported highly significant g.c.a. and s.c.a. variances in F_1 and F_2 generations for days to maturity in pea. The variance due to s.c.a. were greater than that due to g.c.a., indicating predominance of nonadditive gene action for the character.

Combining ability analysis of thirty nine hybrids between three lines and thirteen testers in pigeonpea revealed significant role of additive and nonadditive gene action with preponderance of nonadditive gene action for days to maturity. (Patel et al. 1987).

Yadavendra and Sudhirkumar (1987) while analysing the combining ability for days to maturity with eight chick pea lines and their twenty eight F_1's showed the importance of additive gene action for the character.

Singh et al. (1987a) studied ten diverse vigna mungo cultivars for combining ability and reported highly significant g.c.a. and s.c.a. variance in F_1 and F_2 generations. The estimates of variance due to s.c.a. were greater than that due to g.c.a. for days to maturity indicating the predominance of nonadditive gene action.

From a combining ability analysis involving nine diverse parents and their thirty six F_1 crosses in pigeonpea, Mehetre et al. (1988) reported that both additive and nonadditive gene effects were important for days to maturity and that additive gene effects was predominant for this character.

Combining ability analysis by Anilkumar (1993) showed the presence of both g.c.a. and s.c.a. variances with preponderance of nonadditive gene action for the character duration upto maturity in cowpea. The same was reported by Jayarani (1993).

Combining ability studies were carried out by Tiwari et al. (1993) through a 5 x 5 diallel cross and found that nonadditive gene efects were predominant for days to maturity.

Plant height

Diallel analysis for yield components in bengal gram showed that additive genetic variance was higher than dominance variance for this character (Pande et al., 1979).

Deshmukh and Manjare (1980) while analysing the combining ability in mung bean in a diallel analysis involving eight varieties found significant variances due to g.c.a. and s.c.a., reported additive gene action.

Venkateswarlu and Singh (1982a) while analysing the combining ability in peas in a diallel cross involving ten cultivars found importance of both g.c.a. and s.c.a. effects with predominance of additive gene effects.

Significant variance due to g.c.a. and s.c.a. were suggested by Wilson et al. (1985) in an analysis of diallel cross with five green gram cultivars. The g.c.a. variance was found to be higher than s.c.a. variance for plant height.

Twelve parent diallel analysis in peanuts was conducted by Habib et al. (1985) to study combining ability in respect of 6 quantitative traits. Both additive and nonadditive gene effects found to be important for this character.

From a combining ability analysis involving nine diverse parents and their 36 F_1 crosses in pigeonpea it was revealed that both additive as well as nonadditive gene effects were important for this character and that additive gene effects was predominant. (Mehetre et al., 1988).

Sharma and Nishisharma (1988) combining ability analysis of ten soybean lines and their F_1 hybrids for plant height revealed that additive genetic variance was higher than dominance variance for this character.

In a study with six genotypes of chickpea and their hybrids Katiyar et al. (1988) reported significant g.c.a. and s.c.a. for plant height with predominance of additive gene action. Combining ability studies in crosses involving tall and dwarf types in chickpea in a line x tester design showed predominance of nonadditive gene action for plant height (Salimath and Bahl, 1989).

A 7 x 7 diallel cross in greengram by Natarajan et al. (1990) revealed that both additive and non additive gene action was important with a predominance of additive genetic variance for this character.

Combining ability analysis using six parent diallel cross in cowpea conducted by Thiyagarajan et al. (1990) revealed that both additive and nonadditive gene effects were important for this character. They also reported the preponderance of nonadditive gene effects for the character.

The same was reported by Jayarani (1993) in a line x tester analysis in cowpea. Combining ability studies were carried out by Tiwari (1993) through 5 x 5 diallel cross in mung bean and found that nonadditive gene effects were predominant for this trait.

Number of branches per plant

Malhotra (1983) in a 8 x 8 diallel analysis of urdbean showed the importance of both g.c.a. and s.c.a. variance and predominant role of additive gene effects for number of branches/plant.

Combining ability studies with 10 x 10 diallel cross in pea revealed the significance of general and specific combining ability and higher magnitude of additive genetic variance than dominance variance for this character. (Dubey and Lal, 1988).

In a 12 x 12 diallel analysis in peanuts was conducted by Habib et al. (1985) to study combining ability in respect of six quantitative traits and reported that only additive gene effects were important for number of branches/plant.

Singh et al. (1987a) studied ten diverse Vigna mungo cultivars for combining ability and reported highly significant g.c.a. and s.c.a. variance in F_1 and F_2 generations. The estimates of variance due to s.c.a. were greater than that due to g.c.a. for this character indicating the predominance of nonadditive gene action.

Eight chickpea lines and their 28 F_1s were studied for combining ability by Yadavendra and Sudhirkumar (1987) found that nonadditive gene action was predominant for this character.

From a combining ability analysis involving nine diverse parents and their 36F_1 crosses in Pigeonpea it was revealed that both additive as well as nonadditive gene effects were important. However the additive gene effects were predominant (Mehetre, 1988).

In a study with six genotypes of chickpea and their hybrids Katiyar et al. (1988) reported that g.c.a. variance was predominant for this character indicating the importance of additive gene effects.

Saxena and Sharma (1989) estimated combining ability in mungbean and reported that both g.c.a. and s.c.a. meansquares were significant for yield per plant in F_1 and F_2. In general mean square due to g.c.a. was reported to be of greater magnitude suggesting the preponderance of additive gene action.

Combining ability studies were made over environments for yield and nine yield contributing characters utilizing 12 parent diallel F_1 progenies in pea. Both additive and non additive genetic variances were important for the number of branches/plant (Singh and Singh, 1990).

In a scaling test with five generation means of five crosses of chickpea, Shinde and Deshmukh (1990) showed the involvement of epistatic geneaction in the expression of fruiting branches/plant.

In a line x tester analysis in cowpea Jayarani (1993) revealed the presence of nonadditive gene action for number of branches/plant.

Combining ability studies were carried out by Tiwari (1993) through a 5 x 5 diallel cross in mungbean and found that additive gene effects were predominant for number of branches/plant.

Length of pod

A half diallel cross of eight cowpea varieties studied by Chauhan and Joshi (1981) revealed that both general and specific combining ability variances were significant for this character, but magnitude of g.c.a. variance was reported to be comparatively much higher suggesting the additive gene action.

In urdbean an 8 x 8 diallel cross was studied by Malhotra (1983) and reported that both additive and nonadditive gene effects were significant for this character with the preponderance of additive gene effects.

Combining ability studies in a 10 x 10 diallel cross in pea showed that general and specific combining ability variances were significant for this character and additive genetic variance was found higher than dominance variance for this trait. (Dubey and Lal, 1983).

Combining ability analysis in a diallel cross of seven french bean cultivars conducted by Singh et al. (1986) revealed significant g.c.a. and s.c.a. effects for length of pod and reported the predominance of g.c.a. effect for this character.

Singh et al. (1987) on analysing the general and specific combining ability of yield and its components from F_1 and F_2 generation of a diallel cross involving ten parents of pea, showed significant additive and nonadditive gene effects for this trait.

Patel et al. (1987) evaluated 39 hybrids between three lines and 13 testers of pigeonpea and revealed that, only additive gene action was found operative for pod length.

In a line x tester analysis in cowpea Jayarani (1993) revealed the presence of additive gene action for the inheritance of this character.

Number of pods per plant

Diallel analysis for yield components in bengal gram showed highly significant variance due to s.c.a. for number of pods per plant. Estimates of variance due to g.c.a. indicate that genes having additive and nonadditive effects were influencing this character and nonadditive effect was more important. (Pande et al., 1979).

Deshmukh and Manjare (1980) while analysing the combining ability in mung bean in a diallel analysis involving eight varieties found highly significant variances due to g.c.a. and s.c.a. for number of pods per plant and reported nonadditive gene action.

General and specific combining ability variances were found important for number of pods per plant in cowpea when a half diallel cross of eight cowpea varieties were studied along with their parents by Chauhan and Joshi (1981). The g.c.a. variance was found to be comparatively much higher for this character suggesting the preponderance of additive gene action in inheritance.

Combining ability analysis using a complete set of six parent diallel crosses of garden pea for yield components showed predominance of nonadditive genetic variance (Dhillon and Chahal, 1981).

Venkateswarlu and Singh (1981b) while analysing the combining ability in peas in a diallel cross involving ten cultivars found importance of both g.c.a. and s.c.a. effects with predominance of additive gene effect.

Combining ability analysis of ten cultivars of pigeonpea indicated the importance of both g.c.a. and s.c.a. variance for number of pods per plant. The g.c.a. variance were more than s.c.a. variance indicating the importance of both additive and nonadditive gene effects and predominance of additive gene effectives additive and nonadditive (Venkateswarlu and Singh, 1982a).

Venkateswarlu and Singh (1982c) while studying the combining ability analysis of ten cultivars of pea crossed in all possible combinations indicated the importance of both g.c.a. and s.c.a. variance for pods per plant. However the variance due to g.c.a. were predominant in both F_1 and F_2 generations.

Combining ability studies through 10 x 10 diallel in pea showed that general and specific combining ability variances were significant and additive genetic variance found higher than dominance variance for the number of pods per plant. (Dubey and Lal; 1983).

Yield and yield related characters were investigated in six cowpea genotypes and their fifteen possible non reciprocal single crosses by Zaveri et al. (1983) and reported significance of both g.c.a. and s.c.a. variance and predominance of nonadditive genetic variance.

A significant variance due to g.c.a. and s.c.a. was suggested by Wilson et al. (1985) in an analysis of diallel cross with five greengram cultivars. The g.c.a. variance was found to be higher than s.c.a. variance for number of pods per plant indicating the existence of both additive and nonadditive gene action with predominance of additive gene action.

Combining ability analysis in mung bean using eight parent half diallel cross showed significant g.c.a. and s.c.a. variance for number of pods per plant (Choudhary, 1986).

Yadavendra and Sudhirkumar, (1987) studied eight chickpea lines and their F_1s for combining ability and revealed that for the character number of pods per plant nonadditive type of gene action was predominant.

The combining ability analysis of thirty nine hybrids between three lines and thirteen testers in pigeonpea revealed a significant role of additive and nonadditive gene action with the predominance of additive gene action for number of pods per plant. (Patel et al. 1987).

Singh et al. (1987c) in the study of combining ability with forty five F_3 progenies generated from 10 x 10 diallel cross in pea revealed that both additive and nonadditive gene effects were significant for the expression of number of pods per plant.

Combining ability analysis with ten soybean lines and their F_1 hybrids for number of pods per plant revealed that both additive and nonadditive genetic variances were important for this character (Sharma and Nishisharma, 1988).

Katiyar et al. (1988) studied the combining ability analysis of six chickpea genotypes and their F_1 hybrids for number of pods per plant and showed significant differences for g.c.a. and s.c.a. variances suggesting additive gene action for the expression of this character.

Saxena and Sharma (1989) estimated combining ability in a diallel cross of mungbean and found that g.c.a. mean squares was significant for number of pods per plant in F_1. In F_2 generation both g.c.a. and s.c.a. mean squares were significant. In general mean square due to g.c.a. was larger in magnitude suggesting the preponderance of additive gene action for the character.

A comparative analysis of combining ability in irradiated and non-irradiated diallel populations of chickpea suggested importance of additive and nonadditive gene action for number of pods per plant. (Onkar Singh and Paroda, 1989).

In a six parent diallel cross in cowpea the combining ability was studied by Thiyagarajan et al. (1990) and reported that both the additive and non-additive gene effects were important for the number of pods per plant. Components of variance analysis revealed that nonadditive effects were predominant.

The combining ability studies by Natarajan et al (1990) in a 7 x 7 diallel in greengram revealed that both additive and nonadditive gene actions were important.

The combining ability studies for seed yield and its components over environments in black gram indicated significant mean sum of squares due to s.c.a. for number of pods per plants (Kaliya et al., 1991).

Yield and yield related characters were investigated in eight mungbean genotypes and their 28F_1s by Saxena and Sharma (1992) and reported the importance of additive as well as nonadditive variances and predominance of additive variance.

Twelve hybrids from three male and four female parents of cowpea were evaluated for combining ability in two seasons for yield and yield components by Thiyagarajan (1992) and reported predominance of additive variance.

A line x tester analysis of cowpea varieties showed the presence of additive and nonadditive gene action with predominance of nonadditive gene action for number of pods per plant (Anil Kumar, 1993) the same was reported by Jayarani (1993).

Kapila et al. (1994) while studying the combining ability analysis involving ten lines and two testers over two locations for nine traits in soybean revealed that both additive and nonadditive genetic variance were important for this character.

A line x tester analysis was carried out involving eleven lines and two testers in groundnut for assessing the combining ability in respect of number of pods/plant. The estimate of g.c.a. / s.c.a. variance showed the predominance of nonadditive gene action for number of pods (Vindhiyavarman and Raveendran; 1994).

Number of seeds per pod

Diallel analysis for yield and yield components in bengal gram showed highly significant variance due to g.c.a. and s.c.a. for number of seeds per pod. Estimates of variance due to s.c.a. were much higher than that due to g.c.a. It was reported that additive and nonadditive gene effects were influencing the characters and the nonadditive effects were more important (Pande et al., 1979).

Deshmukh and Manjare (1980) while analysing the combining ability in mungbean in a diallel cross involving eight varieties found highly significant variance due to g.c.a. and s.c.a. for number of seeds per pod. Nonadditive gene action was found important for this character.

Durong (1980) studied combining ability using a 8 x 8 diallel cross of soybean and reported importance of both additive and nonadditive gene action.

A complete set of six parent diallel crosses in garden pea was evaluated by Dhillon and Chahal (1981) and reported predominance of nonadditive gene action for number of seeds/pod.

Chauhan and Joshi (1981) evaluated eight cowpea varieties crossed in a half diallel fashion along with their parents and reported that both general and specific combining variances were important for number of seeds per pod. The higher magnitude of g.c.a. variances indicated that additive gene action was involved in the inheritance of this character.

The inheritance study of seed yield components in rice bean using a seven parent diallel cross excluding reciprocals were done by Das and Dana (1981) and reported the importance of dominant components for number of seeds per pod. They also found that late maturing parents were good general combiners for number of seeds per pod.

Combining ability analysis of ten diverse cultivars of pigeon pea indicated the importance of both additive and nonadditive gene effects with predominance of additive gene effects for the number of seeds per pod (Venkateswarlu and Singh, 1982a).

Venkateswarlu and Singh (1982b) found from a diallel cross involving ten diverse cultivars of pea that additive gene action was important in determining the seed number. The best general combiners for seed number were identified to be GC 141 and GC 322.

Venkatewswarlu and Singh (1982c) showed the importance of both g.c.a. and s.c.a. variance for number of seeds per pod in the analysis of combining ability in peas. The variance due to g.c.a. predominated in both F_1 and F_2 generations.

The significance of g.c.a. variance for number of seeds per pod in a 8 x 8 diallel analysis in black gram was observed by Malhotra (1983). The varieties L-35-5, G37 and T9 were reported to be good general combiners for number of seeds per pod. Only additive gene effects were important for this character.

Combining ability studies in a 10 x 10 diallel cross in pea showed that general and specific combining ability variance were significant for number of seeds per pod and additive genetic variance was found higher than dominance variance for this trait. (Dubey and Lal 1983).

A significant g.c.a. and s.c.a. variance was observed by Wilson et al. (1985) in an analysis of diallel cross of five greengram varieties for number of seeds per pod. The variance due to g.c.a. was reported to be higher than that of s.c.a. So existence of both additive and nonadditive gene action for number of seeds per pod with a predominance of additive gene action was suggested.

Eight chickpea varieties and their twenty eight F_1s were analysed for combining ability and reported that nonadditive gene action was predominant for number of seeds per pod. (Yadavendra and Sudhirkumar, 1987).

Information on combining ability was derived from data on six chickpea genotypes and their F_1 hybrids. ANOVA for combining ability showed significant differences for g.c.a. and s.c.a. variance for number of seeds/pod indicating additive as well as nonadditive gene effects and predominance of additive gene action (Katiyar et al. 1988).

Saxena and Sharma (1989) estimated combining ability in mungbean in a diallel analysis and reported that both g.c.a. and s.c.a. mean square were significant in F_1 and F_2 for number of seeds per pod. In general mean squares due to g.c.a. were larger in magnitude indicating the preponderance of additive gene action for this trait.

A comparative analysis of combining ability in irradiated and non irradiated diallel population of chickpea suggested that number of seeds per pod was governed mainly by additive genes. (Onkar Singh and Paroda, 1989).

Half diallel of seven short duration pigeon pea lines was evaluated in the F_1 and F_2 generation by Saxena _et al_. (1989). The results indicated the predominance of g.c.a. variance.

A 7 x 7 diallel cross in green gram by Natarajan _et al_. (1990) revealed that both additive and nonadditive gene action were important.

Combining ability studies for seed yield and its components over environments in black gram conducted by Kaliya _et al_. (1991) revealed significant mean sum of squares due to s.c.a. for number of seeds per pod.

Yield and yield characters were estimated in eight mung bean genotypes and their $28F_1$'s by Saxena and Sharma (1992) and reported importance of additive as well as nonadditive variance and predominance of additive variance.

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

Combining ability in six cultivars of cowpea indicated significant g.c.a. and s.c.a. variance and importance of additive gene action (Rajatha, 1992).

In a line x tester analaysis in cowpea Anilkumar (1993) reported the preponderance of additive gene action for number of seeds per pod.

Combining ability analysis by Jayarani (1993) reported the presence of nonadditive gene action for this character.

Combining ability analysis was done by Shanmugasundaram and Sree Rangasamy (1994) using $20F_1$s and $20F_2$ families obtained from a 5 x 5 diallel mating design for yield and its components. Highly significant g.c.a., s.c.a. and reciprocal variances were observed in both F_1 and F_2 generations.

100 - seed weight

Combining ability analysis in a 5 x 5 diallel set in gram for seed yield, hundred seed weight and ascorbic acid revealed that additive type of gene action was predominant for hundred seed weight. (Singh et al. 1975).

Diallel analysis for yield and yield components in bengal gram showed highly significant variance due to g.c.a. and s.c.a. for hundred seed weight. Estimates of variance due to g.c.a. indicated predominance of additive gene effects (Pande et al., 1979).

Chauhan and Joshi (1981) studied a half diallel cross of eight cowpea along with parents and reported that both general and specific combining variances were important for 100 - seed weight. The magnitude of g.c.a. variance was found to be much higher indicating the preponderance of additive gene action in the inheritance of this character.

A diallel cross with six parents in urdbean revealed that both the additive and nonadditive effects were important (Sandhu et al. 1981).

Venkateswarlu and Singh (1982a) while analyzing the combining ability of ten diverse cultivars of pigeonpea indicated the importance of both additive and nonadditive gene effects and predominance of additive gene effects.

The combining ability analysis was done with ten pea cultivars by Venkateswarlu and Singh (1982c) and reported that the variance due to g.c.a. was more than that due to s.c.a. and the performance of parents was highly associated with their g.c.a. effects.

Malhotra (1983) in a 8 x 8 diallel analysis of urdbean showed the importance of both g.c.a. and s.c.a. variance for hundred seed weight and reported that the varieties Mash 1-1 and L35-5 were the good combiners for hundred seed weight. Both additive and nonadditive gene effects were found to be significant and important for this character.

Combining ability studies with 10 x 10 diallel cross in pea revealed the significance of general and specific combining ability and higher magnitude of additive genetic variance than dominance variance for hundred seed weight (Dubey and Lal, 1983).

Singh et al. (1983) estimated combining ability using a 8 x 3 line x tester cross in pigeon pea and reported both additive and nonadditive components with a predominance of additive component for this character.

Wilson et al. (1985) in the analysis of the diallel crosses among five varieties of green gram showed existence of both additive and nonadditive gene action. The variance due to g.c.a. was reported to be much higher than that due to s.c.a., indicating additive gene action in the expression of hundred seed weight.

Patil and Bhapkar (1986) studied yield and related characters from the parents and F_1 of a half diallel cross of cowpea and reported additive gene effects for this trait.

The combining ability analysis using thirty nine hybrids, three lines and thirteen testers in pigeonpea revealed a significant role of additive and nonadditive gene action with the predominance of additive gene action. (Patel et al., 1987).

Yadavendra and Sudhir Kumar (1987) studied eight chickpea lines and F_1's for combining ability and suggested BEG48 as good combiner and reported that 100 - seed weight is controlled by additive gene action.

Singh et al. (1987c) estimated combining ability using forty five F_3 progenies generated from 10 x 10 diallel cross in pea and reported that both additive and nonadditive gene effects were significant.

In a study with six genotypes of chickpea and their hybrids, Katiyar et al. (1988) reported significant g.c.a. and s.c.a. for hundred seed weight and suggested the importance of additive and nonadditive gene effects with predominant role of nonadditive gene action for the trait.

Combining ability analysis in a six parent diallel cross in cowpea conducted by Thiyagarajan et al., (1990) revealed that both the additive and nonadditive gene effects were important for hundred seed weight. They also reported the preponderance of nonadditive gene effects for the character.

Twelve hybrids from three male and four female parents of cowpea were evaluated for combining ability in two seasons for yield and yield components by Thiygarajan (1992) and reported preponderance of additive variance.

In a line x tester analaysis in cowpea Anilkumar (1993) revealed the presence of additive gene action for 100 seed wieght.

Combining ability analysis in cowpea by Jayarani (1993) reported the preponderance of nonadditive gene action for this character.

Shanmughasundaram and Sree Rangasamy (1994) reported that in a combining ability analysis using $20F_1$'s and $20F_2$ families obtained from a 5 x 5 diallel mating design for yield and its components.

Seed yield per plant

Pande et al. (1979) in a diallel analysis for yield and yield components in bengal gram revealed that variances due to general and specific combining ability effects were highly significant for yield per plant indicating that genes having additive and nonadditive effects were influencing yield. It was also reported that nonadditive effect were more important for seed yield per plant.

A diallel cross involving eight mungbean varieties were studied for combining ability. The variance due to g.c.a. and s.c.a. were highly significant for grain yield per plant. Nonadditive gene action was reported to be more important for this character (Deshmukh and Manjare, 1980).

Durong (1980) studied combining ability using a 8 x 8 diallel cross of soybean and reported importance of both additive and nonadditive gene action.

A complete set of six parent diallel crosses in garden pea evaluated by Dhillon and Chahal (1981) and reported predominance of nonadditive gene action for yield per plant.

Venkateswarlu and Singh (1981b) while analysing the combing ability in peas in a diallel cross involving ten cultivars found importance of both g.c.a. and s.c.a. and predominant role of additive gene effects.

A half diallel cross of eight cowpea varieties studied by Chauhan and Joshi (1981) revealed that both general and specific combining ability variances were significant for grain yield per plant, but magnitude of g.c.a. variance was reported to be comparatively much higher suggesting the additve gene action.

A complete set of six parents diallel cross in gardenpea was evaluated by Dhillon and Chahal (1981) and reported predominance of nonadditive gene action for yield per plant.

Venkateswarlu and Singh (1981b) while analysing the combining ability in pea in a diallel cross involvin ten cultivars found the importance of both g.c.a. and s.c.a. and predominance of additive gene effect.

The combining ability analysis of ten cultivars of pigeonpea conducted by Venkateswarlu and Singh (1982a) indicated the importance of both additive and nonadditive gene effects for seed yield per plant.

Combining ability analysis using ten cultivars of pea crossed in all possible combinations indicated the importance of both s.c.a. andg.c.a. variances for seed yield per plant. The variance due to g.c.a. was reported to be much higher in F_1 and F_2 generations (Venkateswarlu and Singh, 1982c).

In urdbean an 8 x 8 diallel was studied by Malhotra (1983) and reported that both the additive and nonadditive components were important with a preponderance of additive gene effect for seed yield.

Singh et al. (1983) estimated combining ability in a line x tester cross in pigeonpea and reported that both additive and nonadditive gene actions were important with a predominance of non additive components.

Yield and yield components were evaluated in six cowpea genotypes and their fifteen possible non-reciprocal single crosses by Zaveri et al. (1983) and reported significance of both g.c.a. and s.c.a. variances with predominance of nonadditive gene action.

An analysis of diallel cross using five varieties of green gram showed the existence of both additive and nonadditive gene actions for seed yield per plant. The variance due to g.c.a. was reported to be much higher than that due to s.c.a. indicating the predominance of additive gene action in the expression (Wilson et al. 1985).

Combining ability analysis in mungbean using eight parent half diallel cross showed significant g.c.a. and s.c.a. variances for seed yield perplant (Choudhury, 1986).

Combining ability analysis in a diallel cross of seven frenchbean cultivars conducted by Singh and Saini (1986) revealed significant g.c.a. and s.c.a. effects for yield per plant and they reported the predominance of g.c.a. effect for this character.

A line x tester analysis involving four testers and ten lines of cowpea indicated that both g.c.a. and s.c.a. were important for seed yield (Mishra et al., 1987).

Singh et al. (1987a) in the combining ability analysis using a diallel cross of ten black gram lines reported highly significant g.c.a. and s.c.a. both in F_1 and F_2 generation for grain yield. The estimates of variance due to s.c.a. was reported to be greater than variances due to g.c.a. indicating predominance of nonadditive gene action.

Eight chickpea lines and their twenty eight F_1s were studied for combining ability by Yadavendra and Sudhirkumar (1987) and found that nonadditive gene action was predominant for grain yield.

Haque et al. (1988) in a line x tester analysis with six urdbean lines of diverse origin and four testers reported that higher s.c.a. effect for yield was observed in the cross PLV-652 and T-9.

Combining ability analysis in six chickpea genotypes and their F_1 hybrids revealed additive and nonadditive gene effects for grain yield and the preponderance of additive gene action. (Katiyar et al., 1988).

Patel et al. (1988) conducted diallel analysis in mungbean and reported significant g.c.a. and s.c.a. variance for yield per plant.

Twenty five chickpea hybrids derived from the crosses of five lines and five testers along with their F_2 and parents were studied to estimate heterosis and combining ability and reported that s.c.a. variance were greater than that for g.c.a. for yield. (Bahl and Kumar, 1989).

Saxena and Sharma (1989) estimated combining ability in mung bean and reported that both g.c.a. and s.c.a. mean square were significant for yield per plant in F_1 and F_2. In general mean squares due to g.c.a. was reported to be of greater magnitude suggesting the preponderance of additive gene action.

Thiyagarajan et al. (1990) reported that both additive and nonadditive gene effects were important for yield per plant. The components of variance analysis revealed preponderance of non-additive effects for the yield per plant.

Natarajan et al. (1990) reported the same result in greengram and also the predominance of additive gene action in a 7 x 7 diallel cross.

The combining ability for seed yield and its components over environments was estimated in blackgram by Kaliya et al. (1991) reported significant mean sum of squares due to s.c.a. for seed yield.

In eight mung bean genotype study Saxena and Sharma (1992) reported importance of additive as well as nonadditive variances and predominance of additive variance.

Twelve hybrids from three male and four female parents of cowpea were evaluated for combining ability in the seasons for yield and yield components by Thiyagarajan (1992) and reported preponderance of additive variance.

In a line x tester analysis in cowpea Jayarani (1993) reported the predominance of nonadditive gene action for this character. The same was reported by Sreekumar (1993) in green gram.

CAMV resistance

Govindaswamy et al. (1970) have screened on hundred types of cowpea for resistance to the cowpea mosaic isolates both by sap and aphid transmission.

Cowpea aphid borne mosaic virus (CAMV) was first reported from Tanzania by Bock (1973) Later Bock and Conti (1974) reported that the diseased cultivars showed variable amounts of dark green vein bounding or interveinal chlorosis leaf distortion, blistering and stunting.

KUHN et al. (1981) reported that genetic control of cowpea chlorotic mottle virus movement was controled by a dominant gene in the host.

Preliminary studies by Patel (1982a) on inheritance of CAMV indicated that immune reaction was controlled by a recessive gene in association with minor/modifer genes and the resistant reaction was governed by a partially dominant gene.

Ramiah and Narayanaswamy (1983) have suggested that resistance to CAMV was controlled by a single dominant gene.

Sreelekha (1987) has screened ten lines of cowpea varieties of which the variety C-152 has taken hundred per cent infection on sap inoculation where as the variety CG104 was found to be tolerant to the disease showing only 13.33 per cent infection.

Mali et al. (1988) screened sixty cultivars for the presence of Black eye cowpea mosaic virus and CAMV.

Morales (1991) studied the genetics of resistance to bean golden mosaic virus in Phaseolus Vulgaris and reported that g.c.a. mean squares were highly significant and larger than s.c.a. mean squares.

The screening of fifty nine cowpea varieties through sap inoculations for CAMV resistance under field conditions has shown two varieties namely V-317 and V-276 as highly resistant, other sixteen varieties were found highly tolerant and the remaining thirty four susceptible (Sudhakumari, 1993).

Reactions to major pests

According to Holley et al. (1985) s.c.a. variance were higher than g.c.a. variance for resistance to *Heliothis zea* in groundnut indicating the preponderance of non-additive gene action.

Both general and specific combining ability variances were found to be significant for resistance to different pests as reported by Hsich and Pi (1988) against aphid and Debholkar *et al*. (1989) against shootfly in sorghum. However a preponderance of g.c.a. effect over s.c.a. effect was observed for resistance to European corn borer in maize (Khalifa and Drolosom, 1988 and Kim *et al*., 1989) and shoot fly in sorghum (Dixon *et al*., 1990).

MATERIALS AND METHODS

MATERIALS AND METHODS

The present study was undertaken in the department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 1994-'95 with the objective of estimating the gene action and combining ability for yield and yield attributes along with aphid borne mosaic virus resistance in grain cowpea.

A. MATERIALS

The experimental material consisted of seven varieties of grain cowpea of which two varieties were identified as CAMV resistant lines through a screening study conducted during 1992-'93 in the department of Plant Breeding and Genetics, College of Agriculture, Vellayani and five were the most promising high yielding varieties released and recommended already for cultivation and the details of these varieties are given in Table 1.

Table 1 Details of varieties used for the study

Lines/Testers	Name of variety	Source
Lines	V - 317	College of Agriculture, Vellayani
	V - 276	College of Agriculture, Vellayani
Testers	Pournami	College of Agriculture, Vellayani
	V - 269	Rice Research Station, Kayamkulam
	Covu-85020	Rice Research Station, Kayamkulam
	CO4	Rice Research Station, Kayamkulam
	Charodi	Rice Research Station, Kayamkulam

Plate No. 1

V-317

V-276

The seven parents (Plate 1) and their ten F_1 hybrids as detailed below constituted the experimental material for the present study and are enumerated in Table 2.

Table 2 Parents and hybrids

Sl. No.	Treatment number (Line, Tester, Line x Tester)	Name of variety/ Cross
1.	L_1	V-317
2.	L_2	V-276
3.	T_1	Pournami
4.	T_2	V-269
5.	T_3	Covu-85020
6.	T_4	CO4
7.	T_5	Charodi
8.	L_1 x T_1	V-317 x Pournami
9.	L_1 x T_2	V-317 x V-269
10.	L_1 x T_3	V-317 x Covu-85020
11.	L_1 x T_4	V-317 x CO4
12.	L_1 x T_5	V-317 x Charodi
13.	L_2 x T_1	V-276 x Pournami
14.	L_2 x T_2	V-276 x V-269
15.	L_2 x T_3	V-276 x Covu-85020
16.	L_2 x T_4	V-276 x CO4
17.	L_2 x T_5	V-276 x Charodi

POURNAMI

V-269

Covu-85020

Co4

CHARODI

B. METHODS

(i) Pot culture

The seven cowpea varieties collected were grown in pots for collection of selfed and hybrid seeds. For hybrid seed production ten plants each of the seven varieties were grown in pots following the standard pot culture method. Staggered planting was followed to obtain synchronised flowering for crossing. The techniques followed for the production of selfed and crossed seeds were as follows.

Selfing

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

Crossing

When the flowering commenced crosses were made adopting the following methods. Suitable buds that were to open the next morning were selected. Holding the bud with the thumb and fore finger 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 wing petals was pushed down gently, thereby leaving the keel petal exposed. The keel petal was then split open on the exposed side for about 2 cm and a portion of the keel petel 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. Care should be taken not to rupture the anthers. The disturbed parts of keel petal, wing and standard petals 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 five days. Suitable labels were also attached on the inflorescence. Thus a line x tester crossing was made with two lines and five testers. The pods were harvested when mature, the maturity being judged by the standard ripening colour of the pods.

(ii) Field experiment

The two lines, five testers and their ten hybrids were raised in a randomized block design with 3 replications in a Line x Tester fashion. Each plot has a size of 2 m x 1 m and the seeds were sown with a spacing of 25 x 15 cm. The plants at two leaf stage were screened for their resistance to CAMV through artificial sap inoculation method under field condition.

Sap transmission

Sap transmission was done using virus inoculum prepared in phosphate buffer as described below.

Young leaves of systemically infected cowpea plants showing typical mosaic symptoms were selected and finely crushed using a clean, sterile and previously chilled mortar and pestle, after adding one ml of phosphate buffer (0.05 M; pH 7.0) to every gram of the infected leaf tissue. The resulting pulp was strained through sterilized cotton wool and the filtrate was used as the inoculum.

Virus inoculation was done on young seedlings at two leaf stage after dusting small quantity of carborundum powder of 600 mesh uniformly on the surface of the leaves by gently rubbing the inoculum with the cotton wool. Soon after inoculation the excess sap on the leaves was washed with distilled water using a wash bottle. All the plants in each plot were inoculated.

Observations recorded

The following observations were taken on ten randomly selected plants from each plot except for CAMV where all plants were observed for the development of symptoms.

1. Days to flowering

The number of days taken for the first 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. Number of branches/plant

The mean number of branches from a random sample of ten plants at the final harvest was taken.

4. Plant height at maturity

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.

5. Length of pod

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

6. Number of pods/plant

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

7. Number of seeds/pod

Number of seeds in five randomly selected pods from each of the ten 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/plant

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

10. Aphid borne mosaic scoring

Observations on the incidence of the disease were recorded by counting the number of plants showing the typical symptoms of CAMV disease (Sreelakha 1987). Even the plants showing mild vein clearing on the primary trifoliate leaves were counted as diseased. Observation on the disease incidence was recorded 14 days after the inoculation.

11. Reaction to major pests

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 excreta of the caterpillar. 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 workedout.

No other serious incidence of pests were noticed

STATISTICAL ANALYSIS

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

Line x tester analysis

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

Table 3. ANOVA for line x tester mating design

Source	df	MS	expected mean square
Replication	(r-1)		
Genotypes	(v-1)		
Parents	(l+t)-1		
Hybrids	lt-1		
Parents vs hybrids	1		
Lines	l-1	ML	$\sigma^2_e + r \times \sigma^2_{s.c.a.} + rt \times \sigma^2_{g.c.a.}$
Testers	t-1	MT	$\sigma^2_e + r \times \sigma^2_{s.c.a.} + rl \times \sigma^2_{g.c.a.}$
Line x tester	(l-1) (t-1)	MLT	$\sigma^2_e + r \times \sigma^2_{s.c.a.}$
Error	(r-1)(V-1)	Me	σ^2_e
Total	Vr - 1		

where

r = number of replications

v = number of genotypes

l = number of lines

t = number of testers

$\sigma^2_{s.c.a.}$ = s.c.a. variance

$\sigma^2_{g.c.a.}$ = g.c.a. variance

σ^2_e = Error variance

Estimation of g.c.a. and s.c.a. effects

g.c.a effects of lines

$$g_i = \frac{l_i}{rt} - \text{mean}$$

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

where g_i = g.c.a. effect of i^{th} line

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

G' = total of observations with respect to all hybrids

$$SE\ (g_i - g_j) = \sqrt{\frac{2\ Me}{rt}}$$

g.c.a effects of testers

$$g_j = \frac{t_j}{rl} - \text{Mean}$$

where g_j = g.c.a effect of j^{th} tester

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

$$SE\ (g_i - g_j) = \sqrt{\frac{2\ Me}{rl}}$$

s.c.a effects of line x testers

$$S_{ij} = \frac{(lt)\ i_j}{r} - \frac{l_i}{rt} - \frac{t_j}{rl} + \text{Mean}$$

where

S_{ij} = sca effect of i x j^{th} cross

$(lt)_{ij}$ = value corresponding to i x j^{th} cross

$$SE\ (s_{ij} - s_{il}) = \sqrt{\frac{2\ Me}{r}}$$

$$SE\ (s_{ij} - s_{kl}) = \sqrt{\frac{2\ Me}{r}}$$

Estimation of genetic components of variance

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

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

when $F = 0$

$$\sigma^2_{gca} = 1/4\ \sigma^2_{a}$$

$$\sigma^2_{sca} = 1/4\ \sigma^2_{d}$$

where F = coefficient of inbreeding

σ^2_{a} = additive variance

σ^2_{d} = dominance variance

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

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

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

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

where SSL = Sum of squares due to lines

SSLT = Sum of squares due to line x testers

SST = Sum of squares due to testers

SSC = Sum of squares due to crosses

RESULTS

RESULTS

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

4.a MEAN PERFORMANCE

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

For the character days to flowering the mean values recorded by the lines were 41.01 (V-317) and 38.91 (V-276), the testers ranged from 37.95 (Pournami) days to 45.27 (Covu-85020) days, where as in hybrids the range was from 35.16 days in V-276 x Covu-85020 to 42.35 days in V-317 x charodi.

Average number of days to maturity in the testers was from 54.05 in Pournami to 58.27 in Covu-85020. The lines V-317 and V-276 showed mean values 56.41 and 55.58 days respectively. Among the hybrids the lowest and highest days were recorded by V-276 x Pournami (49.55) and V-317 x Charodi (58.33) respectively.

The range of variation for number of branches/plant in the testers was from 1.86 in charodi to 3.92 in CO4. The lines V-317 and V-276 showed mean values 3.15 and 2.77 respectively.

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

Treatments	Days to flowering (days)	Days to maturity (days)	Branches/ plant (Nos.)	Height of the plant (cm)	Length of the pod (cm)	No.of pods/ plant	No.of seeds/ pod	100 seed weight (g)	Seed yield/ plant (g)	Aphid borne mosaic disease scoring (%)
V-317 (L_1)	41.01	56.41	3.15	111.72	13.89	17.10	12.21	10.37	22.41	0.00
V-276 (L_2)	38.91	55.58	2.77	86.09	12.48	9.73	10.06	8.20	8.03	0.00
Pournomi (T_1)	37.95	54.05	2.93	87.57	15.72	15.07	14.16	10.17	21.68	5.59
V-269 (T_2)	43.06	57.94	3.47	95.79	13.97	8.70	11.74	9.06	9.21	10.31
Covu-85020 (T_3)	45.27	58.27	2.52	101.65	13.82	10.37	12.30	10.2	13.01	12.99
CO4 (T_4)	40.83	57.83	3.92	136.58	14.00	12.67	13.18	10.7	13.01	5.45
Charodi (T_5)	39.72	55.56	1.86	77.14	13.47	9.2	8.54	5.96	6.51	21.08
V-317 x Pournomi (L_1T_1)	37.86	53.86	4.51	92.48	14.56	23.25	13.97	7.3	23.83	16.85
V-317 x V-269 (L_1T_2)	40.50	56.50	3.63	109.37	15.02	15.58	14.00	9.53	20.80	7.57
V-317 x Covu-85020 (L_1T_4)	42.22	55.21	3.62	118.23	13.34	12.76	16.21	9.40	19.25	10.33
V-317 x CO4 (L_1T_4)	39.69	55.69	4.22	91.07	15.46	24.66	15.46	11.12	28.76	14.43
V-317 x Charodi (L_1T_5)	42.35	58.33	3.45	106.29	14.29	17.19	13.87	9.90	23.57	5.36
V-276 x Pournomi (L_2T_1)	36.55	49.55	3.28	105.22	15.32	15.71	12.88	12.00	26.51	7.42
V-276 x V269 (L_2T_2)	35.89	50.89	3.49	114.73	13.55	11.21	12.95	11.33	16.56	5.91
V-276 x Covu-85020 (L_2T_3)	35.16	49.75	2.54	100.04	13.92	14.00	13.91	9.46	18.21	5.27
V-276 x CO4 (L_2T_4)	37.52	53.32	3.77	93.29	13.99	1.24	11.66	6.73	8.78	13.66
V-276 x Cherodi (L_2T_5)	35.27	52.27	2.90	93.38	12.66	9.06	11.27	10.7	15.48	5.37
SEm	1.28	1.28	0.37	10.84	1.32	1.20	0.67	0.56	1.65	0.13
CD	2.63	2.63	0.78		1.31	2.47	1.37	1.16	3.37	0.27

Among the hybrids the minimum and maximum number of branches/ plant were recorded by V-276 x Covu-85020 (2.54) and V-317 x Pournami (4.51) respectively.

Plant height was not significantly different among the genotypes and hence not subjected to line x tester analysis.

Length of pod varied from 13.47 cm in charodi to 15.72 cm in Pournami among the testers. The lines V-317 and V-276 showed mean values 13.89 and 12.48 respectively. In the hybrids the range was from 12.66 in V-276 x Charodi to 15.46 cm in V-317 x CO4.

Average number of pods per plant was minimum in V-269 (8.70) among the testers and in V-276 (9.73) among the lines and was maximum in Pournami (15.07) among the testers and V-317 (17.10) among the lines. Among the hybrids the minimum and maximum values were recorded by V-317 x CO4 (24.66) and V-276 x CO4 (1.24) respectively.

The mean number of seeds per pod among testers was minimum in charodi (8.54) and maximum in Pournami (14.16). The lines V-317 and V-276 showed 12.21 and 10.06 mean number of seeds/pod respectively. In the hybrids the range was from 11.27 in V-276 x Charodi to 16.21 in V-317 x Covu-85020.

Hundred seed weight ranged from 5.96 g in Charodi to 10.7 g in Co4 among the testers. The lines V-317 and V-276 recorded 10.37 g and 8.2 g 100 - seed weight respectively. The range of hybrids was from 6.73 g in V-276 x Co4 to 12 g in V-276 x Pournami.

Among the testers average seed yield per plant ranged from 6.51 g per plant in charodi to 21.68 g per plant in Pournami. The lines V-317 and V-276 showed mean values 22.41 g per plant and 8.03 g per plant respectively. This range was from 8.78 g/plant in V-276 x Co4 to 28.76 g/plant in V-317 x Co4 among the hybrids.

The lines showed zero infection for aphid borne mosaic disease. Among the testers the range of infection was from 5.45 per cent (CO4) to 21.08 per cent (Charodi). The range of variation in infection among of hybrids was between 5.27 per cent (V-276 x Covu-85020) to 16.85 per cent (V-317 x Pournami).

4.b Combining ability and gene action

Analysis of variance of different characters studied are presented in Appendix.

The ANOVA showed that all the characters except height of the plant recorded significant difference among genotypes. Line x tester analysis with the purpose of estimating the gca and sca effects were carried out for those characters and the results are presented below.

The mean squares due to lines were significant for days to flowering, days to maturity, number of branches/plant, number of pods/plant and aphid borne mosaic resistance where as variation due to testers showed significant differences for days to maturity, number of branches/plant and aphid borne mosaic resistance. The interaction between line x tester was significant for seed yield/plant, 100-seed weight, number of pods/plant, number of seeds/pod and aphid borne mosaic resistance.

The general combining ability (g.c.a.) effects of parents and the specific combining ability (s.c.a.) effects of hybrids for different characters are given in tables 5 and 6.

Combining ability analysis of days to flowering revealed that lines differed for their gca effects. Mean squares due to testers and line x testers were not significant for this character suggesting the absence of difference among g.c.a effect of testers and s.c.a effects of hybrids respectively. G.c.a

Table 5 GCA effects of parents

Parents		Days to flowering	Days to maturity	No. of branches/ plant	Length of pod	No.of pods/ plant	No.of seed/ pod	100-seed weight	Seed yield/ plant	Aphid borne mosaic disease resistance
Lines										
	1	2.22**	2.38**	0.32	0.32	3.56**	0.74*	-0.29	3.07**	0.25**
	2	-2.22**	-2.38**	-0.32	-0.32	-3.56**	-0.74*	0.29	-3.07**	-0.25**
	F	13.71**	51.52**	12.98	1.43	14.01**	3.14	0.16	2.48*	2.01*
	SE	0.58	0.58	0.17	0.29	0.54	0.29	0.25	0.74	0.06
	CD	1.66	1.66	0.49	0.83	1.56	0.86	0.73	2.13	0.17
Testers										
	3	-1.09	-1.83	0.27	0.73	3.67**	0.15	-0.09	4.99**	0.43**
	4	-0.10	0.16	0.04	0.07	-2.42**	0.20	0.68	-1.49	-0.36**
	5	0.38	-1.06	-0.44	-0.58	-0.71	-0.26	-0.32	-1.45	-0.20*
	6	0.31	0.97	0.47	0.52	2.14*	0.28	-0.82*	-1.41	0.74**
	7	0.51	1.77	-0.34	-0.74	-2.69**	-0.79	0.55	-0.64	-0.61**
	F	0.24	3.87*	3.81*	1.16	1.74	0.19	0.14	0.42	1.92**
	SE	0.91	0.91	0.27	0.46	0.86	0.47	0.40	1.17	0.09
	CD	2.63	2.63	0.78	1.31	2.47	1.37	1.16	3.37	0.27

* 5% level of significance
** 1% level of significance

Table 6 SCA effects of hybrids

Line x tester hybrids	Days to flowering	Days to maturity	No. of branches/ plant	Length of pod	No.of pods/ plant	No.of seed/ pod	100 seed weight	Seed yield/ plant	Aphid borne mosaic disease resistance
Lines									
L_1T_1	-1.57	-0.22	0.19	-0.71	0.20	-0.19	-2.25**	-4.41*	0.40**
L_1T_2	0.07	0.42	-0.25	0.41	-1.38	-0.21	-0.60	-0.94	-0.11
L_1T_3	1.31	0.35	0.22	-0.61	-2.46*	-1.31	0.27	-2.55	0.17
L_1T_4	-1.14	-1.19	-0.09	0.41	3.14*	1.16	2.49**	6.91**	-0.21
L_1T_5	1.32	0.66	-0.05	0.49	0.49	0.56	-0.10	0.99	-0.26
L_2T_1	1.57	0.23	-0.19	0.71	-0.20	0.19	2.05**	4.41*	-0.40**
L_2T_2	-0.07	-0.42	0.25	-0.41	1.38	0.21	0.60	0.94	0.11
L_2T_3	-1.31	-0.35	-0.22	0.61	2.46*	1.31	-0.27	2.54	0.17
L_2T_4	1.14	1.19	0.09	-0.41	-3.15*	-1.15	-2.49**	-6.91**	0.21
L_2T_5	-1.32	-0.66	0.05	-0.49	-0.49	-0.56	0.10	-0.99	0.26
F	2.17	0.67	0.55	1.75	6.19**	3.87**	16.85**	13.82**	0.47**
SE	1.29	1.28	0.38	0.64	1.21	0.67	0.57	1.65	0.13
CD	3.71	3.71	1.09	1.86	3.49	1.93	1.64	4.77	0.38

* 5% level of significance
** 1% level of significance

Fig. 1 g.c.a. and s.c.a. - Days to flowering

s.c.a. hybrids

1. V-317 x Pournami
2. V-317 x V-269
3. V-317 x Covu-85020
4. V-317 x CO4
5. V-317 x Charodi
6. V-276 x Pournami
7. V-276 x V-269
8. V-276 x Covu-85020
9. V-276 x CO4
10. V-276 x Charodi

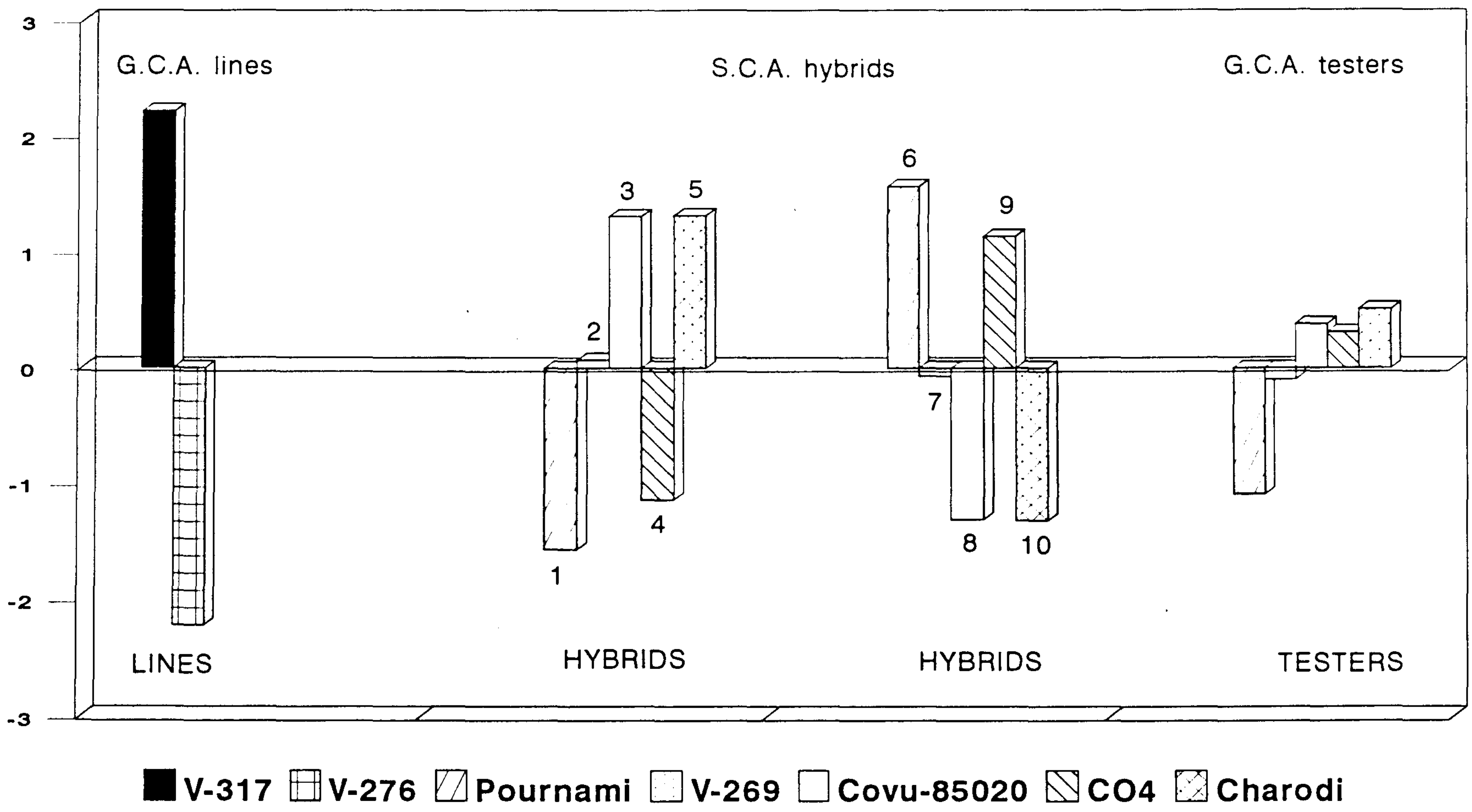

Fig. 1. G.C.A. and S.C.A. - Days to flowering

Fig. 2 g.c.a. and s.c.a. - Days to maturity

s.c.a. hybrids

1. V-317 x Pournami
2. V-317 x V-269
3. V-317 x Covu-85020
4. V-317 x CO4
5. V-317 x Charodi
6. V-276 x Pournami
7. V-276 x V-269
8. V-276 x Covu-85020
9. V-276 x CO4
10. V-276 x Charodi

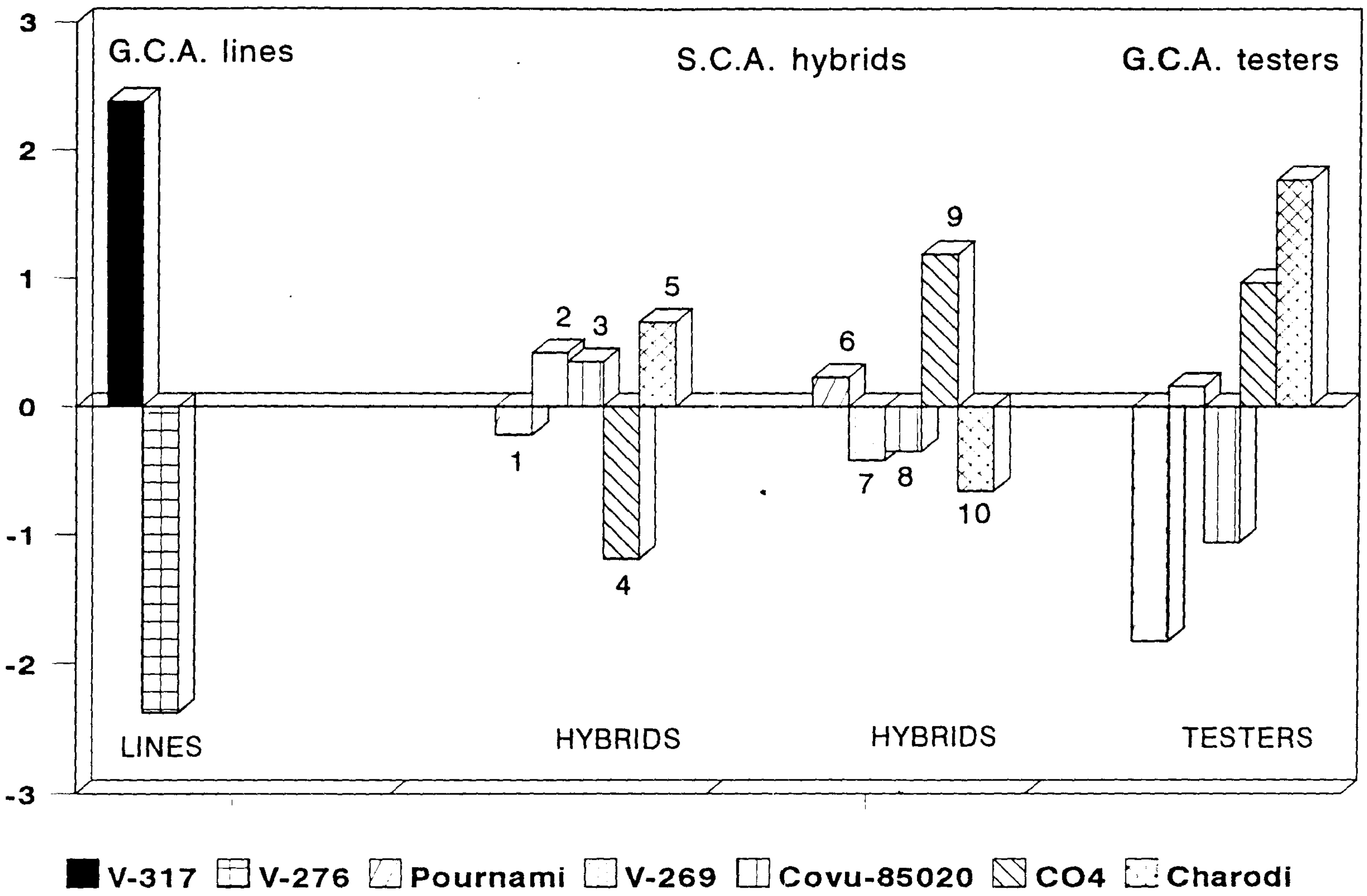

Fig. 2. G.C.A. and S.C.A. - Days to maturity

effect was negative and significant in V-276 (-2.22), positive and significant in V-317 (2.22). The best general combiner for earliness to flowering was V-276 (-2.22) among lines. The testers showed no significant g.c.a effects. The range was from -1.09 to 0.51 days. None of the crosses exhibited significant sca effects while the range was from -1.57. (V-317 x Pournami) to 1.57 (V-276 x Pournami) days. The best specific combination for early flowering was V-317 x Pournami. The g.c.a and s.c.a effects for days to flowering are presented in figure 1.

For the character days to maturity the gca effects differed significantly among the lines. The lines V-317 and V-276 recorded significant g.c.a effect of 2.38 and -2.38 days respectively. None of the testers showed significant g.c.a effects and the range was from -1.83 (Pournami) to 1.77 days (Charodi). None of the combinations exhibited significant s.c.a. effects while the range was from -1.19 days in V-317 x CO4 to 1.19 in V-276 x CO4. The best specific combination for early maturity was V-317 x CO4. The g.c.a. and s.c.a. effects for days to maturity are presented in figure 2.

Mean squares due to lines and testers were significant for number of branches/plant and there was no significant differences among the hybrids. None of the lines and testers

Fig. 3 g.c.a. and s.c.a. - Number of branches/pod

s.c.a. hybrids

1. V-317 x Pournami
2. V-317 x V-269
3. V-317 x Covu-85020
4. V-317 x CO4
5. V-317 x Charodi
6. V-276 x Pournami
7. V-276 x V-269
8. V-276 x Covu-85020
9. V-276 x CO4
10. V-276 x Charodi

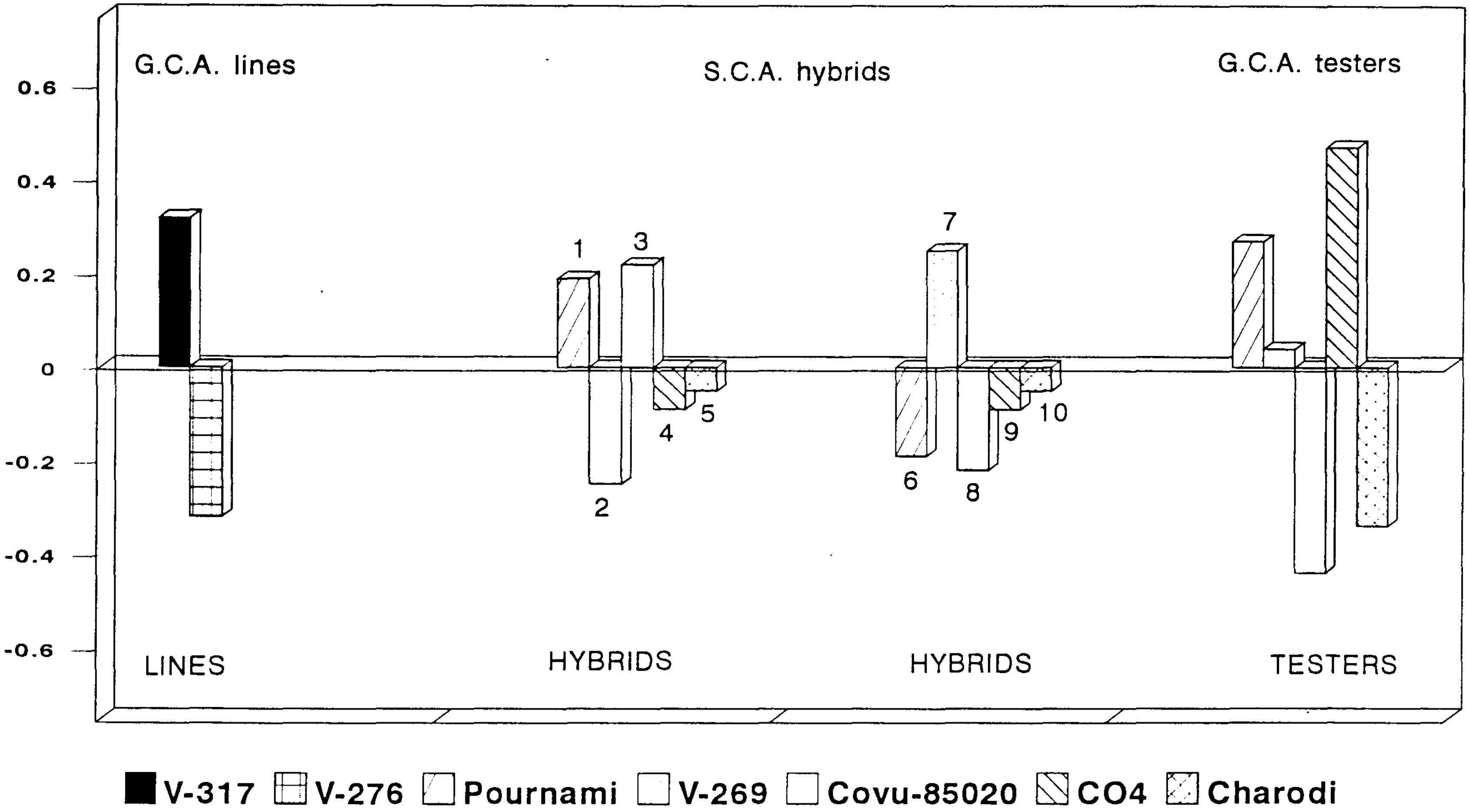

Fig. 3. G.C.A. and S.C.A. - Number of branches per plant

Fig. 4 g.c.a. and s.c.a. - Length of pod

s.c.a. hybrids

1. V-317 x Pournami
2. V-317 x V-269
3. V-317 x Covu-85020
4. V-317 x CO4
5. V-317 x Charodi
6. V-276 x Pournami
7. V-276 x V-269
8. V-276 x Covu-85020
9. V-276 x CO4
10. V-276 x Charodi

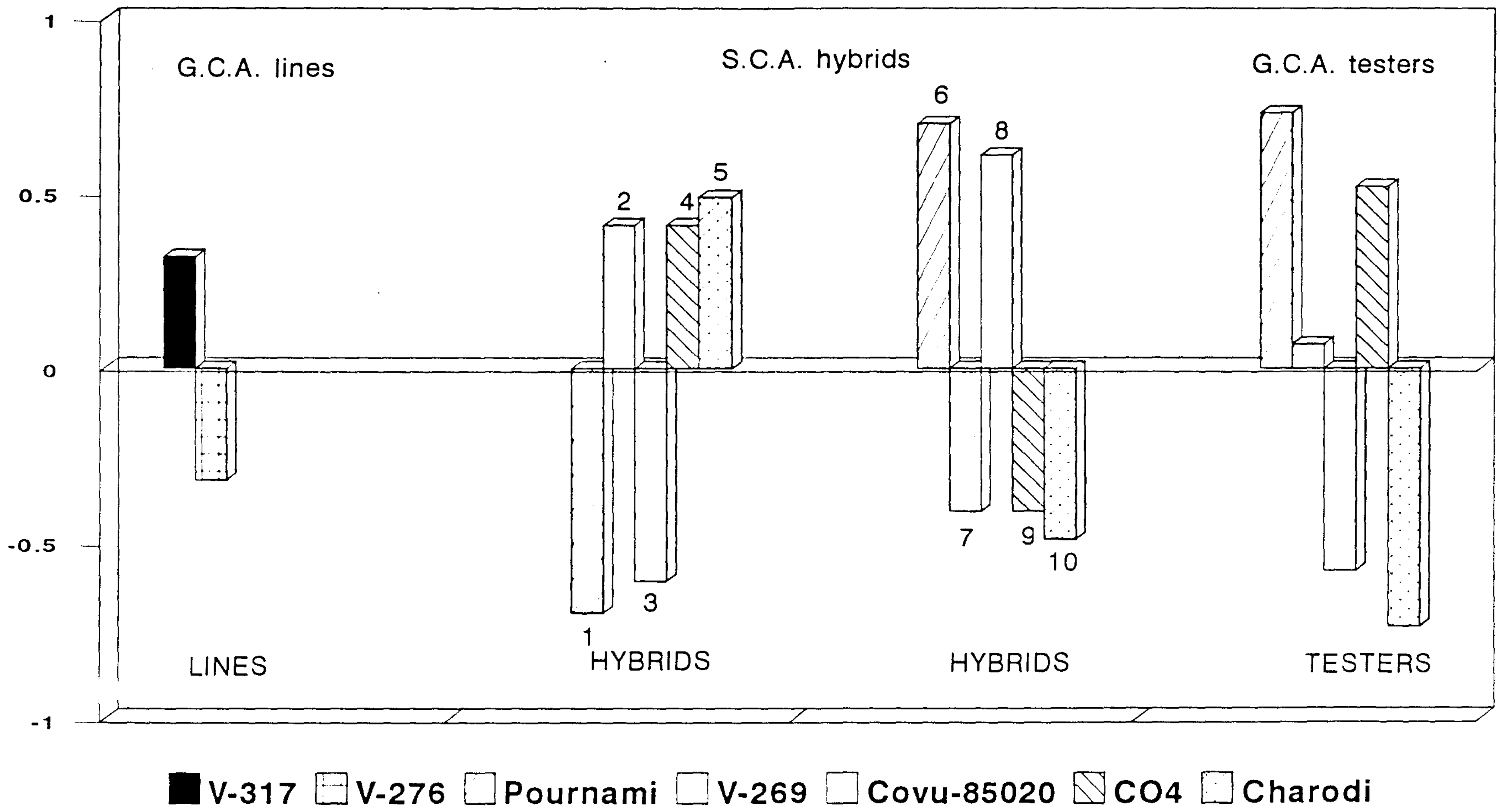

Fig. 4. G.C.A. and S.C.A. - Length of pod

exhibited significant g.c.a effects. The maximum positive and negative g.c.a effects were recorded by the lines V-317 (0.32) and V-276 (-0.32) respectively and among the testers 0.47 (CO4) and -0.44 (Covu-85020) respectively. None of the hybrids exhibited significant s.c.a effects and it ranged from -0.25 (V-317 x V-269) to 0.25 (V-276 x V-269). The best specific combination for this character was V-276 x V-269. The g.c.a and s.c.a effects for this character are presented in figure 3.

The g.c.a and s.c.a effects for length of pod are presented in Figure 4. Combining ability analysis for length of pod showed that none of the lines, testers and hybrids differed significantly. The lines V-317 and V-276 recorded g.c.a effect of 0.32 and -0.32 respectively. Among the testers maximum positive and negative g.c.a effect was shown by Pournami (0.73) and Charodi (-0.74) respectively. Among the hybrids maximum positive and negative s.c.a effects was recorded by V-276 x Pournami (0.70) and V-317 x Pournami (-0.70) respectively. Among the cross combination the best hybrid was V-276 x Pournami (0.70).

The g.c.a. and s.c.a. effects for number of pods per plant are presented in figure 5. The g.c.a. effects differed significantly among the lines and the testers. The lines V-317 (3.56) and V-276 (-3.56) recorded significant g.c.a. effects.

Fig. 5 g.c.a. and s.c.a. - Number of pods/plant

s.c.a. hybrids

1. V-317 x Pournami
2. V-317 x V-269
3. V-317 x Covu-85020
4. V-317 x CO4
5. V-317 x Charodi
6. V-276 x Pournami
7. V-276 x V-269
8. V-276 x Covu-85020
9. V-276 x CO4
10. V-276 x Charodi

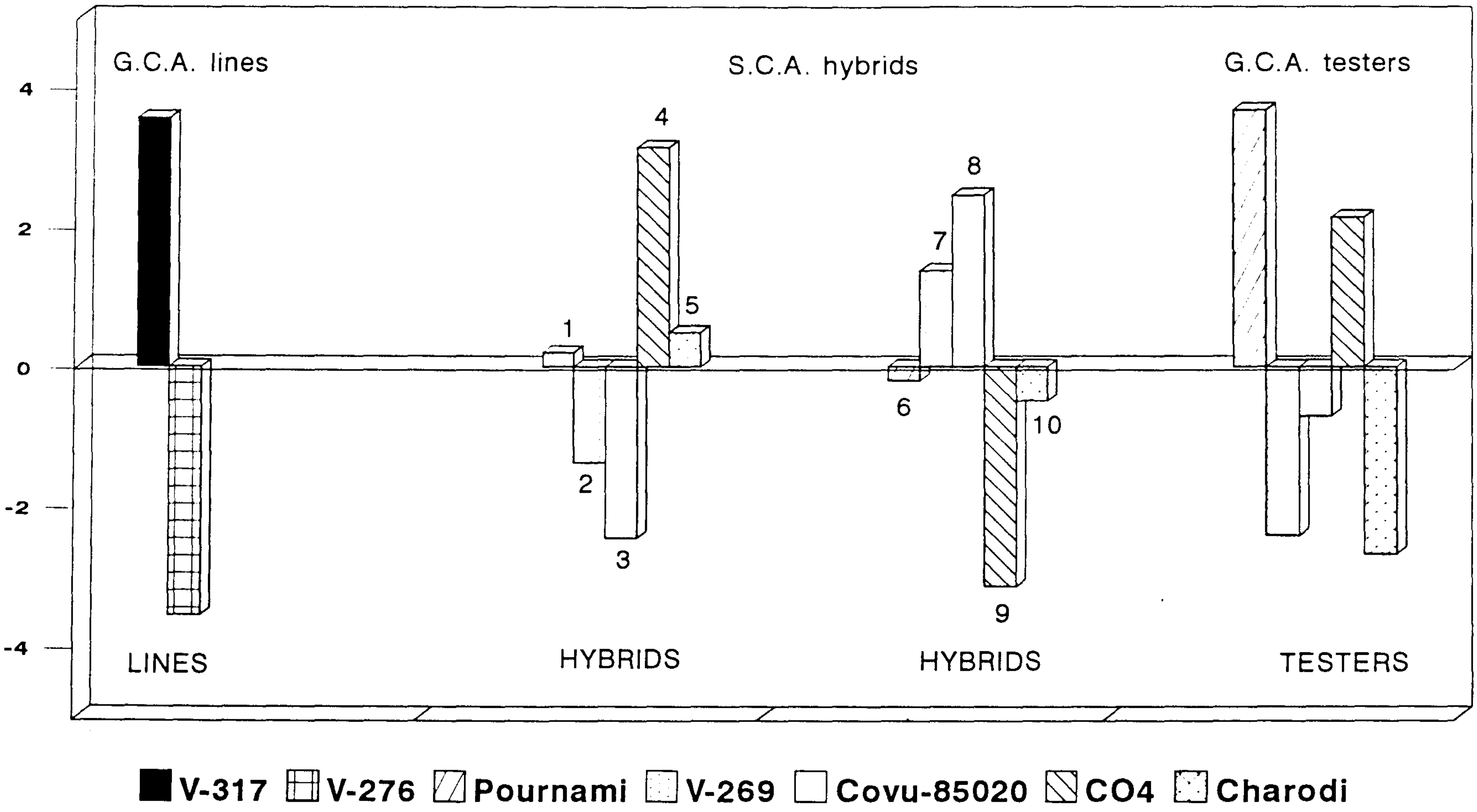

Fig. 5. G.C.A. and S.C.A. - Number of pods/plant

Fig. 6 g.c.a. and s.c.a. - Number of seeds/pod

s.c.a. hybrids

1. V-317 x Pournami
2. V-317 x V-269
3. V-317 x Covu-85020
4. V-317 x CO4
5. V-317 x Charodi
6. V-276 x Pournami
7. V-276 x V-269
8. V-276 x Covu-85020
9. V-276 x CO4
10. V-276 x Charodi

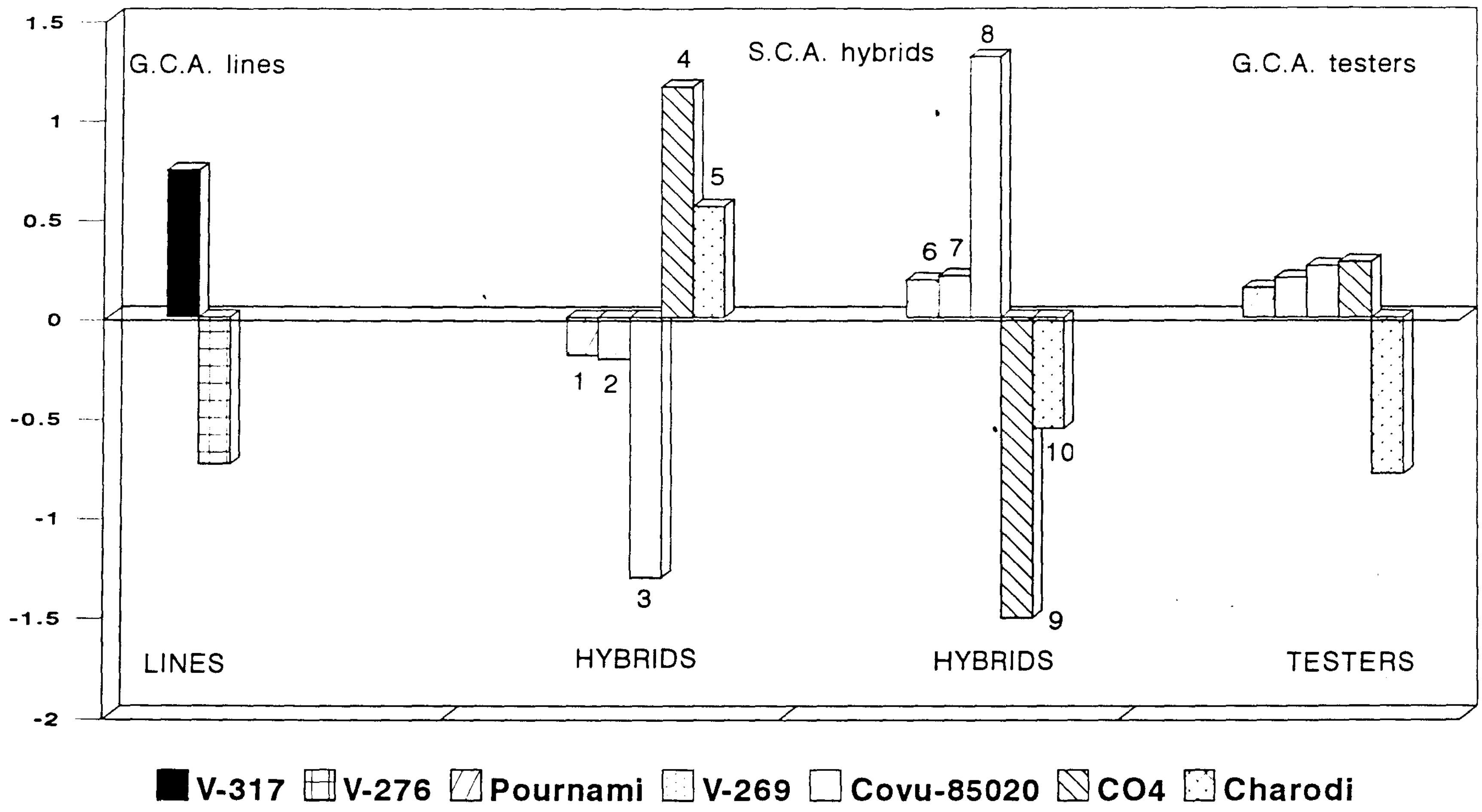

Fig. 6. G.C.A. and S.C.A. - Number of seeds/pod

Among the testers g.c.a. effects of Pournami (3.67) and CO4 (2.14) are significant and positive and are the desirable combiners. Significant and negative g.c.a. effects were shown by V-269 (-2.42) and Charodi (-2.69). In the hybrids V-276 x Covu-85020 (2.46) and V-317 x CO4 (3.14) showed significant positive effects. The best specific combination for number of pods per plant was V-317 x CO4 followed by V-276 x Covu-85020.

Mean squares due to lines and testers were not significant for number of seeds per pod. But variance due to line x testers was significant. The lines V-317 (0.74) and V-276 (-0.74) showed significant g.c.a. effects. V-317 was the best general combiner for more number of seeds per pod. None of the testers showed significant g.c.a effects and the range was from -0.79 to 0.28. None of the hybrids showed significant s.c.a. effects and it ranged from -1.31 (V-317 x Covu-85020) to 1.31 (V-276 x Covu-85020). V-276 x Covu-85020 was the good specific combination for this trait. The g.c.a and s.c.a effects for number of seeds per pod are presented in figure 6.

For the character 100- seed weight, g.c.a effects differed significantly among the testers, only CO4 (-0.82) recorded significant negative g.c.a effect. None of the testers showed significant positive g.c.a effects. The g.c.a effects of lines were -0.29 (V-317) and 0.29 (V-276), but none of these was

Fig. 7 g.c.a. and s.c.a. - 100 - Seeds/pod

s.c.a. hybrids

1. V-317 x Pournami
2. V-317 x V-269
3. V-317 x Covu-85020
4. V-317 x CO4
5. V-317 x Charodi
6. V-276 x Pournami
7. V-276 x V-269
8. V-276 x Covu-85020
9. V-276 x CO4
10. V-276 x Charodi

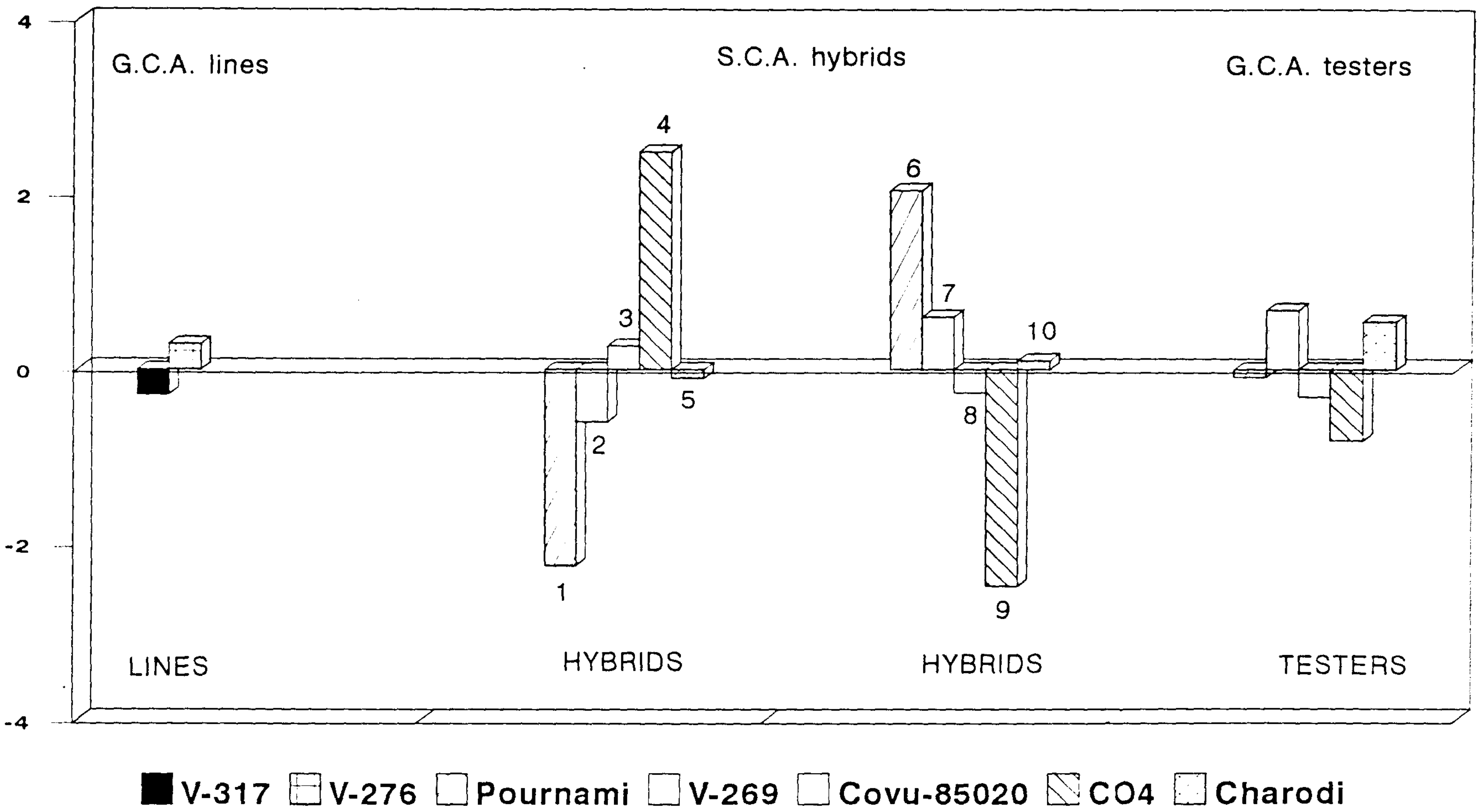

Fig. 7. G.C.A. and S.C.A. - 100 - seed weight

Fig. 8 g.c.a. and s.c.a. - Seed yield per plant

s.c.a. hybrids

1. V-317 x Pournami
2. V-317 x V-269
3. V-317 x Covu-85020
4. V-317 x CO4
5. V-317 x Charodi
6. V-276 x Pournami
7. V-276 x V-269
8. V-276 x Covu-85020
9. V-276 x CO4
10. V-276 x Charodi

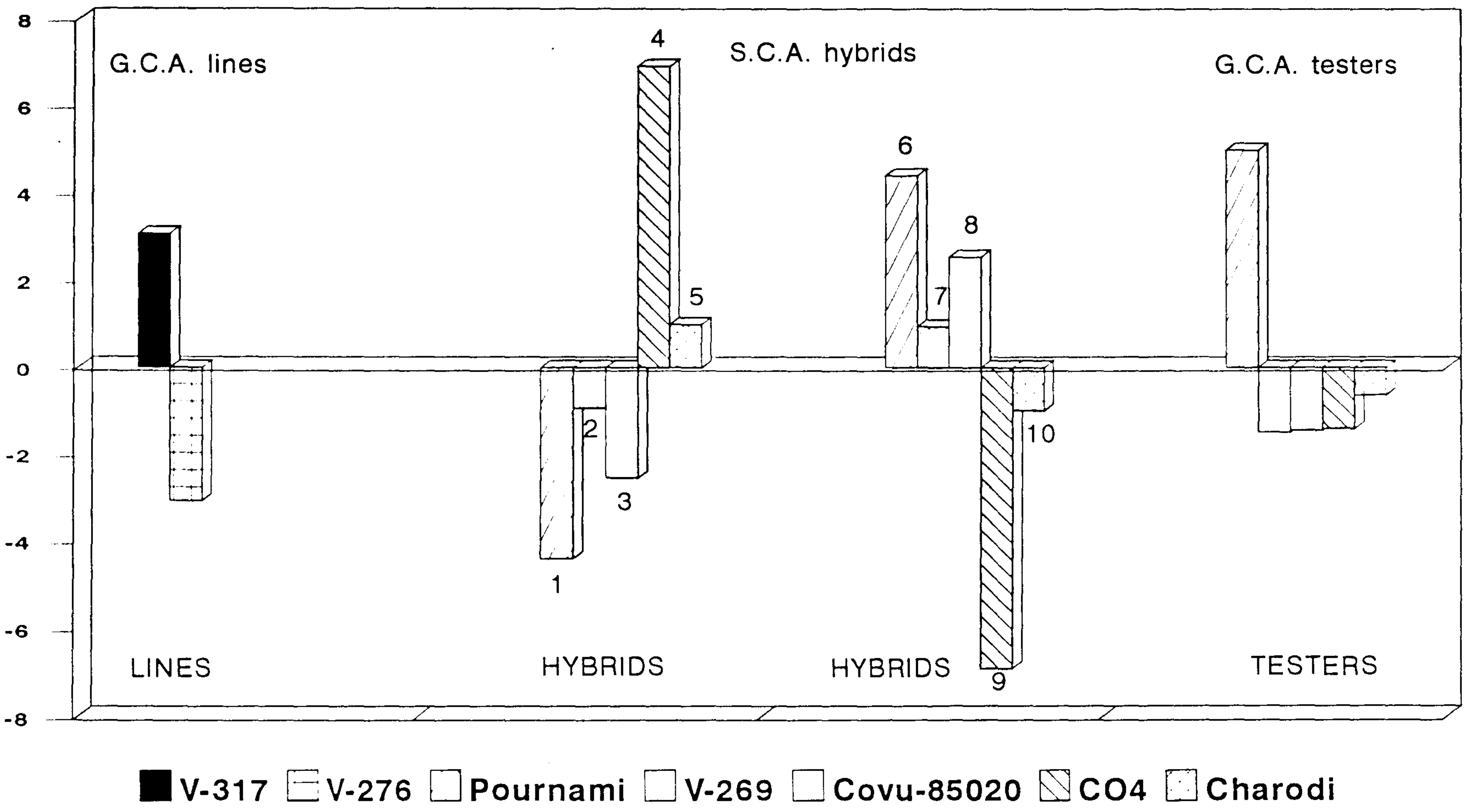

Fig. 8. G.C.A. and S.C.A. - Seed yield / plant

significant statistically. The hybrids V-276 x Pournami (2.05) and V-317 x CO4 (2.49) had positive significant s.c.a effect and V-276 x CO4 (-2.49) and V-317 x Pournami (-2.25) had negative significant s.c.a effect. The best specific combination for 100 seed weight was found to be V-317 x CO4 followed by V-276 x Pournami. The g.c.a and s.c.a effects are presented in figure 7.

The g.c.a and s.c.a effects of seed yield per plant are presented in figure 8. Significant g.c.a effects were exhibited by the lines and testers. The lines V-317 and V-276 recorded significant g.c.a effect of 3.07 and -3.07 respectively. Only Pournami (4.99) recorded significant positive g.c.a effects among the testers. Among the hybrids significant positive s.c.a effect were shown by V-276 x Pournami (4.41) and V-317 x Co_4 (6.91). Hybrids V-317 x Pournami (-4.41) and V-276 x CO4 (-6.91) exhibited significant negative s.c.a effects. The best specific combination for seed yield per plant was V-317 x CO4 followed by V-276 x Pournami.

Analysis of variance for aphid borne mosaic resistance showed significant differences among the lines, testers and line x testers. The lines V-317 (0.25) and V-276 (-0.25) recorded significant positive and negative g.c.a effects respectively. V-276 (-0.25) is the desirable combiner among the lines.

Fig. 9 g.c.a. and s.c.a. - Aphid borne mosaic resistance

s.c.a. hybrids

1. V-317 x Pournami
2. V-317 x V-269
3. V-317 x Covu-85020
4. V-317 x CO4
5. V-317 x Charodi
6. V-276 x Pournami
7. V-276 x V-269
8. V-276 x Covu-85020
9. V-276 x CO4
10. V-276 x Charodi

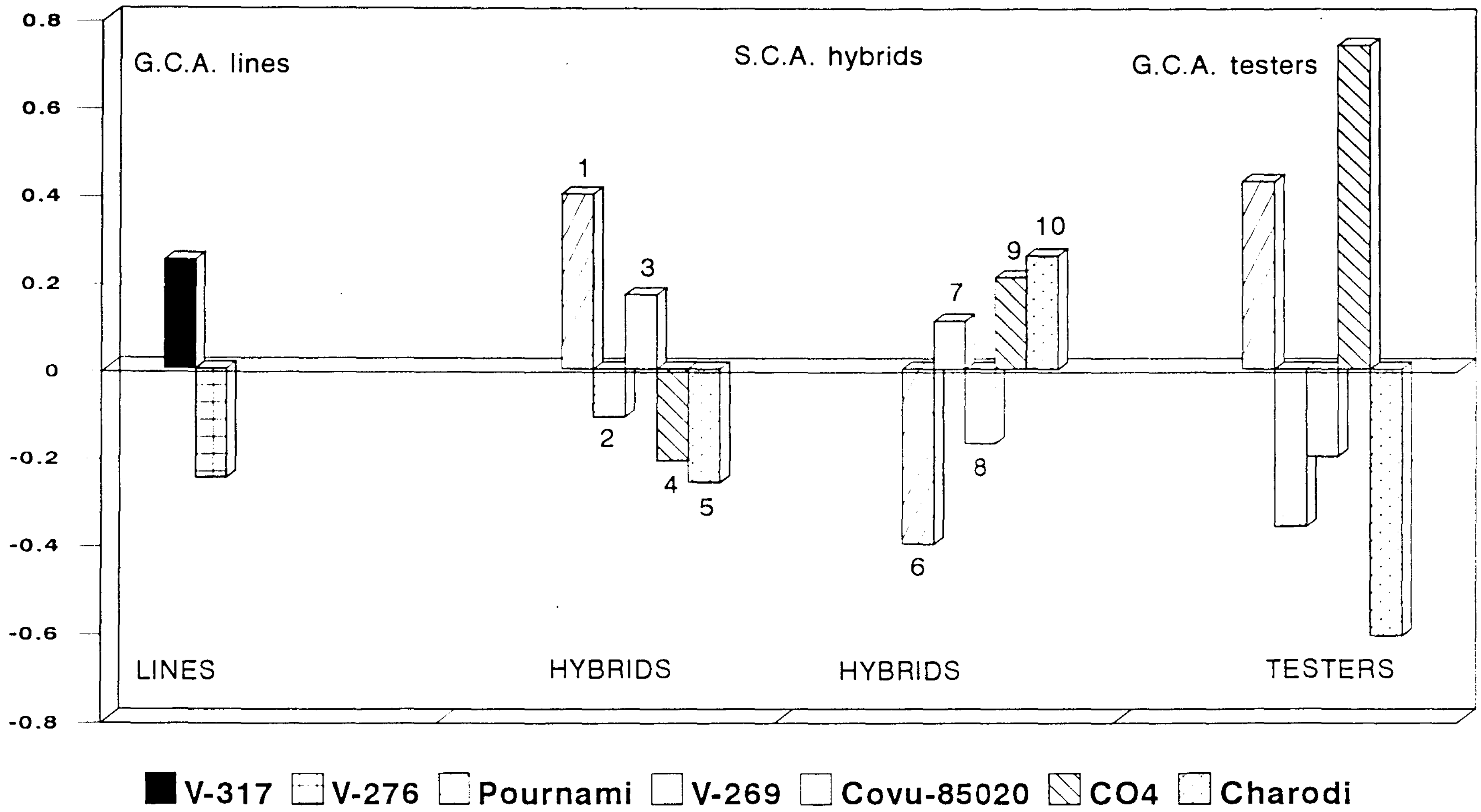

Fig. 9. G.C.A. and S.C.A. - Aphid borne mosaic disease resistance

Table 7 Best general combiners and specific combiners for different characters

Character	Line	Tester	Hybird
Days to flowering	V-276	Pournami	V-317 x Pournami
Days to maturity	V-276	Pournami	V-317 x CO4
Number of branches/plant	V-317	CO4	V-276 x V-269
Number of seeds/pod	V-317	CO4	V-276xCovu-85020
Number of pods/plant	V-317	Pournami	V-317 x CO4
100 - seed weight	V-276	V-269	V-317 x CO4, V-276 x Pournami
Seed yield/plant	V-317	Pournami	V-317 x CO4, V-276 x Pournami
Aphid borne mosaic resistance	V-276	Charodi	V-276 x Pournami

Regarding the g.c.a effects of testers, Pournami (0.43) and CO4 (0.74) recorded significant and positive effects. Testers V-269 (-0.36), Covu-85020 (-0.20) and Charodi (-0.61) with significant and negative g.c.a effects are the desirable combiners. Two out of ten hybrids showed significant s.c.a effects. Significant negative s.c.a effect was shown by the hybrid V-276 x Pournami. (-0.40). The s.c.a effect was significnat and positive in V-317 x Pournami (0.40). The best specific combination was V-276 x Pournami. The g.c.a and s.c.a effects for this character are presented in figure 9. The best lines, testers and hybrids bosed on the general and specific combining abilities of different characters are presented in Table 7.

4c. GENETIC COMPONENTS OF VARIANCE

The genetic components of variance such as additive variance (σ_a^2) dominance variance (σ_d^2) and environmental variance (σ_e^2) were estimated and they are presented in Table 8.

For all the characters except days to maturity and number of branches/plant, dominance component was greater than additive component. For seed yield/plant, 100 seed weight and number of seeds/pod environmental component was greater than additive genetic component.

Table 8. Genetic components of variance

Characters	Additive variance σ^2_a	Dominance variance σ^2_d	Environmental variance σ^2_e
Days to flowering	2.14	7.78	4.98
Days to maturity	4.21	NE	4.98
No. of branches/plant	0.11	NE	0.43
Length of pod	0.05	1.23	0.24
No. of pods/plant	8.93	30.46	4.39
No. of seeds/pod	NE	5.15	1.35
100 seed weight	NE	20.42	0.97
Seed yield/plant	NE	140.39	8.21
Aphid borne mosaic virus disease Resistance	0.06	2.85	0.05

NE - Not estimable

4 d Proportional Contribution

Proportional contributions of lines, testers and line x tester hybrids to total variance were estimated and are presented in table 9 and Figure 10.

Among the different characters, the proportional contributions of lines, ranged very widely from a minimum of 3.46 per cent for hundred seed weight to a maximum of 73.49 per cent for days to flowering. In the testers also the proportional contribution varied very widely from a minimum of 5.07 per cent for days to flowering to a maximum of 66.30 per cent for aphid borne mosaic disease resistance. In the line x tester hybrids this range was from 5.65 per cent for days to maturity to 84.40 per cent for 100-seed weight.

Contribution of lines to the total variance was high for the characters, duration upto first flowering, days to maturity, number of pods/plants having the values 73.49 per cent 72.48 per cent and 56.10 per cent respectively.

The contribution of lines was medium for number of branches/plant (40.3 per cent) seed yield/plant (30.48), number of seeds/pod (39.84 per cent) and aphid borne mosaic disease resistance (17.34 per cent). The contribution of lines was less for 100 seed weight (3.46 per cent) and length of pod (14.19 per cent).

Table 9. Proportional contributions of lines testers and line x tester for different characters towards the total variance

Characters	Proportional contribution (%)		
	Lines	testers	line x tester
Days to flowering	73.49	5.07	21.44
Days to maturity	72.48	21.88	5.65
Number of branches/ plant	40.30	47.28	12.42
Length of pod	14.19	46.12	39.69
Number of pods/plant	56.10	27.88	16.01
No.of seeds/pod	39.84	9.43	50.73
100 - seed weight	3.46	12.14	84.40
Seed yield/plant	30.48	20.51	49.02
Aphid borne mosaic disease resistance	17.34	66.30	16.34

Fig. 10 Proportional contributions of Lines, Testers and Line x Testers to total variance

X_1 - Days to flowering

X_2 - Days to maturity

X_3 - Number of branches/plant

X_4 - Length of pod

X_5 - Number of pods/plant

X_6 - Number of seeds/pod

X_7 - 100 - seed weight

X_8 - Seed yield/plant

X_9 - CAMV resistance

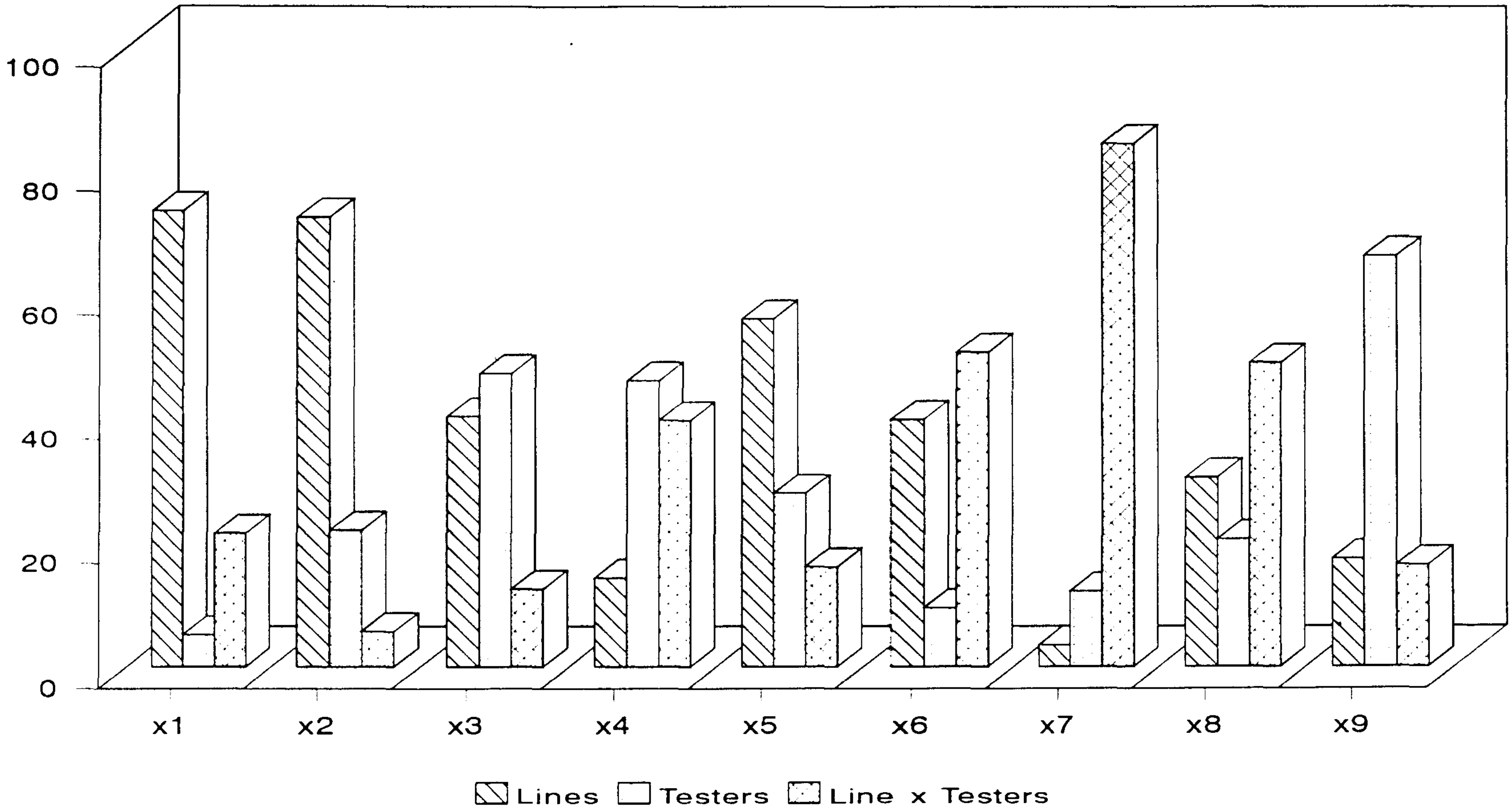

Fig. 10. Proportional contributions of Lines, Testers and Line x Testers to total variance

Contribution of testers was high for number of branches/plant (47.28 per cent), length of pod (46.12 per cent) and aphid borne mosaic disease resistance (66.30 per cent). Contribution of testers was medium for days to maturity (21.88 per cent), 100 seed weight (12.14 per cent) and number of pods/plant (27.88 per cent). Contribution of testers was less for duration upto first flowering (5.07 per cent) seed yield/plant (20.51 per cent) and number of seeds/pod (9.43 per cent).

Contribution of the line x tester hybrids to the total variance was less for the characters days to maturity (5.65 per cent), number of branches/plant (12.42 per cent) number of pods/plant (16.01 per cent) and aphid borne mosaic disease resistance (16.34 per cent). It was high for seed yield/plant (49.02 per cent) 100 seed weight (84.4 per cent) and number of seeds/pod (50.73 per cent). For the remaining characters, days to flowering and length of pod the contribution of the hybrids was medium, the proportion being 21.44 per cent and 39.69 per cent respectively.

4 (e) Reaction to major pests

The major pest noticed was fruit borer. The percentage of pods attacked by fruit borer in the lines, testers and hybrids

Table 10. Percentage of pods attacked by fruits borer

Parents/Hybrids	Pods attacked by borer (%)
V-317	6.38
V-276	9.87
Pournomi	7.67
V-269	12.5
Covu - 85020	13.15
CO4	15.13
Charodi	12.15
V-317 x Pournomi	6.51
V-317 x V-269	7.46
V-317 x Covu 85020	12.15
V-317 x CO4	4.34
V-317 x Charodi	3.46
V-276 x Pournami	3.45
V-276 x V-269	6.51
V-276 x Covu-85020	5.23
V-276 x CO4	5.56
V-276 x Charodi	6.24

were presented in Table 10. The lines V-317 and V-276 showed 6.38 and 9.87 per cent infection respectively. In the testers the range was from 7.67 per cent to 15.13 per cent. In the hybrids the percentage of fruits showing the pest attack ranged from 3.45 to 12.15 per cent.

DISCUSSION

DISCUSSION

Proper identification of the genetically superior parents is done on the basis of the performance of the hybrids which inturn is dependent on the information obtained from the analysis of the combining ability in terms of g.c.a. of the parents and s.c.a. of the hybrids. The concept of combining ability was first proposed by Sprague and Tatum (1942). Line x tester analysis is one of the method for evaluating the performance of varieties or strains in terms of their combining ability. This method has some advantage over diallel analysis, in that interaction among males and females can be avoided and the number of cross combinations can be reduced without affecting the accuracy of the results. The present study was carried out in a line x tester model using seven varieties of cowpea to estimate the general combining ability of the parents and specific combining ability of the hybrids. The results of the study are discussed below:

Combining ability and Gene action

The analysis of variance revealed that mean squares due to lines and line x tester interaction were significant for the characters number of pods/plant and aphid borne mosaic resistance. This showed the importance of both general and specific combining abilities of these traits, which inturn suggest the involvement of both additive and nonadditive gene action in the inheritance of these characters. Mean squares due to lines and testers were significant for days to maturity, number of branches/plant and aphid born mosaic resistance and that due to lines alone was significant for days to flowering. These indicated the importance of g.c.a. for the expression of these traits, which inturn reflects the importance of additive gene action. However the variance due to line x tester interaction alone was found significant for seed yield/plant, 100 seed weight and number of seeds/pod suggesting the involvement of s.c.a. for the inheritance of these characters. Though g.c.a. and s.c.a. effects were observed a preponderance of s.c.a. effects was observed for number of pods/plant and aphid borne mosaic resistance.

For days to flowering significant variance was recorded by the lines only, suggesting the involvement of additive gene action. Moreover contribution of lines was maximum. For line x tester interaction the variance was not significant which implied that the s.c.a. effect was not significant. The predominance of additive gene action for this trait was reported by Dubey and Lal (1983) in pea, Salimath and Bahl (1985), Yadavendra and Sudhirkumar (1987) and Katiyar et al. (1988) in chick pea, Mehetre et al. (1988) in pegionpea and Jayarani (1993) in cowpea. Contrary to this a preponderance of nonadditive gene action was reported by Deshmukh and Manjare (1980) in green gram, Singh *et al*. (1986) in lablab bean, Katiyar *et al*. (1987) in pea and Anilkumar (1993) in cowpea.

Estimates of combining ability revealed that the line V-276 showed significant negative g.c.a. effects. Hence V-276 is the best general combiner for days to flowering. Non-significant negative g.c.a. were recorded by the testers Pournami and V-269. None of the hybrids showed significant s.c.a. effects. Non significant negative g.c.a. effects were shown by the hybrids V-317 x Pournami, V-276 x Charodi, V-276 x Covu-85020, V-317 x CO4 and V-276 x V-269. Out of the five hybrids which had negative s.c.a. effects V-276 x V-269 alone involved negative x negative general combiners; V-276 x Charodi, V-317 x Pournami and V-276 x Covu-85020 involved positive x negative general combiners and V-317 x CO4 alone involved positive x Positive general combiners. Hence the best specific combination for days to flowering involved positive x negative general combiners.

Analysis of variance for days to maturity showed significant variance for lines and testers. This indicate significant g.c.a. variances and involvement of additive gene action for this trait. The same was reported by Chauhan and Joshi (1981) in cowpea, Wilson *et al*. (1985) in greengram, Yadavendra and Sudhir Kumar (1987) in chickpea, Mehetre *et* al. (1988) in pigeonpea. Contrary to this, the importance of non-additive gene action was reported by Deshmukh and Manjare (1980) in green gram, Sandhu et al. (1981) and Singh et al. (1987a) in black gram, Salimath and Bahl (1985) in chick pea, Singh et al. (1987b) in pea and Tiwari et al. (1993) in mung bean.

Lines V-317 and V-276 had significant positive and negative g.c.a. effects respectively in the combining ability analysis. None of the testers and hybrids showed significant g.c.a. and s.c.a. effects respectively. Among the testers nonsignificant negative g.c.a. effects were shown by Pournami and Covu-85020. Among the different cross combinations maximum negative s.c.a. effect was exhibited by the hybrid V-317 x CO4. Both the parents involved in this cross had positive x positive general combiners. Out of the 5 hybrids which showed negative s.c.a., three had parents which are positive x negative general combiners, and the remaining two, one had positive x positive combiners and the other had negative x negative combiners.

For the character number of branches/plant variance due to lines and testers were significant indicating the major involvement of additive gene action. Moreover the contribution of testers was maximum. For line x tester interaction the variance was not significant which implied that s.c.a. effect was not significant. In agreement to this, additive gene action was reported by Habib et al. (1985), Katiyar et al (1988) in chick pea, Saxena and Sharma (1989) and Tiwari (1993) in mungbean. On the other hand nonadditive gene action was reported in chickpea by Yadavendra and Sudhirkumar (1987), Singh (1987) in mung bean and Jayarani (1993) in cowpea.

None of the tester and lines showed significant g.c.a. effects. Maximum positive non significant g.c.a. effect was recorded by the line V-317 and the tester CO4. None of the hybrids showed significant s.c.a. effects. Among the different cross combinations maximum non significant s.c.a. effect was shown by the cross V-276 x V-269. Hence the best combination for number of branches/plant involved positive x negative general combiners. Out of the five hybrids which had positive s.c.a., three involved positive x negative general combiners. Of the remaining two, one had positive x positive combiners and the other with negative x negative general combiners.

Number of pods/plant recorded a significant mean sum of squares due to lines and line x testers. This indicated significant g.c.a. and s.c.a. effects and the involvement of additive and nonadditive genetic components in the expression of this trait. But their ratio of additive to dominance variance was less than unity, indicating the predominant role of non additive gene action. The same was reported by Thiyagarajan et al. (1990) in cowpea, Deshmukh and Manjare (1980) in green gram

Yadevendra and Sudhirkumar (1987) in chickpea and Vindhiyavarman and Raveendran (1994) in groundnut. Contrary to this predominance of additive gene action was reported by Chauhan and Joshi (1981) in cowpea, Venkateswarlu and Singh (1982a) and Patel et al. (1987) in pigeon pea, Dubey and Lal (1983) in pea, Wilson et al. (1985) and Saxena and Sharma (1989) in green gram and Thiyagarajan (1992) in cowpea.

Estimate of combining ability revealed that the line V-317 showed significant positive g.c.a. Hence V-317 is the best general combiner. Significant positive g.c.a. were recorded by the testers Pournami and CO4. Among the hybrids significant positive s.c.a. effects were recorded by V-276 x Covu-85020 and V-317 x CO4 which involved parents with negative x negative g.c.a. effects and positive x positive g.c.a. effects respectively. Hence the best specific combination for more number of pods/plant involved negative x negative and positive x positive general combiners. Out of the five hybrids which had positive s.c.a., two involved positive x positive, two with negative x negative and one with negative x positive general combiners.

Number of seeds per pod recorded a significant mean sum of squares due to line x tester only indicating the importance of nonadditive gene action for the expression of this trait. More over dominance variance was greater than additive variance. So only nonadditive gene action is involved in the inheritance of this trait. The same was reported by Mehtre et al. (1985) in pigeonpea, Salimath and Bahl (1989) in chickpea, Thiyagarajan et al. (1990) and Jayarani (1993) in cowpea. On the contrary, Wilson et al. (1985) in green gram, Katiyar et al. (1988), Rejatha (1992) and Anilkumar (1993) in cowpea observed the important role of additive gene action in governing this trait.

Analysis of combining ability revealed that the line V-317 recorded positive g.c.a. effect. Significant negative g.c.a. effects was shown by the line V-276. None of the testers showed significant g.c.a. effects. The tester CO4 showed maximum nonsignificant g.c.a. effect and none of the hybrids showed significant s.c.a. effects. Out of the five hybrids which had positive s.c.a. effects, three resulted from the crosses between parents which are positive x negative combiners, one hybrid resulted from the parents with positive x positive and remaining one had negative x negative general combiners.

Hundred seed weight had significant mean sum of squares for line x testers only. This indicated the importance of s.c.a. alone for this trait. The ratio of additive to dominance variance was less than unity indicating that the characters is under the control of nonadditive gene action. This was reported by Katiyar et al. (1988) in chickpea, Thiyagarajan et al. (1990) and Jayarani (1993) in cowpea. Contrary to this additive gene action was reported by Pande et al. (1979) Yadavendra and

Sudhirkumar (1987) in chickpea, Chauhan and Joshi (1981), Thiyagarajan (1992) and Anilkumar (1993) in cowpea.

The estimates of combining ability revealed that none of the lines showed significant g.c.a. effects. The line V-276 showed nonsignificant positive g.c.a. effect. Among the testers CO4 showed significant negative g.c.a. effect and none of the testers showed significnat positive g.c.a. effect. Maximum positive nonsignificant g.c.a. effect was shown by the tester V-269. Significant positive s.c.a. effects were shown by the hybrids V-276 x Pournami and V-317 x CO4. The parents involved in the cross V-276 x Pournami had negative x positive general combining ability effects whereas in the cross V-317 x CO4 had negative x negative general combining ability effects. Hence the best combinations for 100 - seed weight involved negative x positive and negative x negative general combiners. Out of the five hybrids which had positive s.c.a., two resulted from parents with negative x negative effects, two involved positive x positive effects and one resulted from negative x positive general combiners.

Seed yield/plant had significant mean sum of squares due to line x testers only. This indicates the significance of s.c.a. variances and the involvement of nonadditive gene action. Moreover the ratio of additive to dominance variance was less than one so only nonadditive gene action is involved in the inheritance of this trait. Similar results were reported by Zaveri et al. (1983) and Jayarani (1993) in cowpea, Sreekumar (1993) in greengram, Yadavendra and Sudhirkumar (1987) and Katiyar et al. (1987) in pea where as Chauhan and Joshi (1981) in cowpea, Singh et al. (1987) in pea, Saxena and Sharma (1992) in urdbean reported a predominant role of additive gene action for seed yield per plant.

In the combining ability analysis significant positive g.c.a. effects were recorded by the line V-317 indicating that V-317 is the best general combiner for seed yield/plant. Significant negative g.c.a. effects were shown by the line V-276. Among the testers Pournami showed significant positive g.c.a. effect. The hybrids V-276 x Pournami and V-317 x CO4 showed significant positive s.c.a. effects and the parents involved in these crosses were positive x negative general combiners. Hence the best combinations for high yield involved the negative x positive general combiners. Out of the five hybrids that had positive s.c.a. effects, three had positive x negative and two had negative x negative general combiners.

Significant mean sum of squares due to lines, testers and line x testers were found for aphid borne mosaic resistance. This indicated significant g.c.a. and s.c.a. effects and the involvement of additive and nonadditive genetic component in the expression of this trait. But the dominant component was greater than additive component. This indicated the importance of nonadditive gene action for the inheritance of this trait. Contrary to this, importance of g.c.a variance was reported by Morales et al. (1991) in phaseolus vulgaris for the inheritance of golden mosaic virus.

Estimate of combining ability revealed that the line V-276 showed significant negative g.c.a. Hence V-276 is the best general combiner. Significant negative g.c.a. were recorded by the testers V-269, Covu-85020 and charodi. Among the hybrids significant s.c.a. effect was recorded by V-276 x Pournami and V-317 x Pournami. The best specific combination, V-276 x Pournami which involved negative x positive general combiners for this trait. Out of the five hybrids that had negative s.c.a. effects three had positive x negative general combiners, one had positive x positive and the other had negative x negative general combiners.

In general V-317 showed significant general combining abilities for seed yield/plant, number of seeds/pod, number of pods/plant. V-276 showed significant negative g.c.a. for days to flowering, days to maturity and aphid borne mosaic resistance. So these two lines can be selected for further breeding programme based on their general combining abilities. The tester pournami

Plate No. 2

V-317 x Co4

V-276 x POURNAMI

showed significant g.c.a. effect for seed yield/plant and number of pods/plant Charodi showed significant negative g.c.a. effect for aphid borne mosaic disease. So from the testers Pournami and Charodi can be selected for further breeding programme based on their general combining abilities.

Among the hybrids V-317 x CO4 showed significant s.c.a. for seed yield/plant, 100 seed weight and number of pods/plant. V-276 x Pournami showed significant s.c.a. for seed yield/plant, 100 seed weight and aphid borne mosaic resistance. Therefore the above hybrids are the good specific combinations for yield and CAMV reistance based on the combining ability analysis (Plate 2).

In general it was seen that additive gene action was predominant for the inheritance of days to maturity and number of branches/plant. Nonadditive gene action was predominant for number of pods/plant, number of seeds/pod, 100 seed weight, seed yield/plant and aphid borne mosaic resistance.

SUMMARY

SUMMARY

The investigation on combining ability and gene action in grain cowpea was carried out in the Department of Plant Breeding, College of Agriculture, Vellayani during the year 1994-95. Hybridisation was done in the line x tester pattern using two aphid borne mosaic resistant varieties as lines and five varieties with high productivity as testers. Seven parents and their ten F_1s were grown in Randomised Block Design with three replications. Observations were recorded on days to flowering, days to maturity, plant height, number of branches per plant, number of pods/plant, length of pod, number of seeds/pod, 100 seed weight, seed yield per plant, aphid borne mosaic disease and on reaction to the major pests. The salient inferences are presented below.

Combining ability analysis revealed that mean square due to linesand line x tester interaction were significant for the characters number of pods/plant and aphid borne mosaic resistance. This showed the importance of both general and specific combining abilities of these traits which inturn suggest the involvement of both additive and nonadditive gene action in the inheritance of these characters. Mean squares due to lines and testers were significant for days to maturity, number of

branches/plant and aphid borne mosaic resistance and that due to lines alone was significant for days to flowering. These indicated the importance of general combining ability for the expression of these traits, which inturn reflects the importance of additive gene action. However the variance due to line x tester interaction alone was found significant for seed yield per plant, 100 seed weight and number of seeds per pod suggesting the involvement of s.c.a. alone for the inheritance of these characters. Though g.c.a. and s.c.a. effects were observed, a preponderance of s.c.a. effects was observed for number of pods/plant and aphid borne mosaic resistance.

The general combining ability analysis showed that the line V-276 was the best general combiner for days to flowering, days to maturity, 100 -seed weight and Aphid borne mosaic resistance. On the other hand V-317 was best for number of branches/plant, number of seeds/pod, number of pods/plant and seed yield/plant. Among the testers, Pournami was the best general combiner for days to flowering, days to maturity, number of pods/plant and seed yield/plant, CO4 for number of brnahces/plant and number of seeds/pod, V-269 for 100 seed weight and charodi for Aphid borne mosaic resistance. The cross combination V-317 x CO4 was the best specific combination for days to maturity, 100 seed weight, number of pods/plant and seed yield/plant, V-276 x Pournami for aphid borne mosaic resistance, V-317 x Pournami for days to flowering V-276 x Covu-85020 for number of seeds/pod and V-276 x V-269 for number of branches/plant.

The study in general indicated that in view of the preponderance of nonadditive gene action for seed yield/plant, number of pods/plant, number of seeds/pod and 100 - seed weight. Commercial exploitation of hybrid vigour is the most appropriate method of utilizing such gene action. The above hybrids can be carried forward to evolve high yielding aphid borne mosaic resistant varieties.

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* Originals not seen.

APPENDIX

APPENDIX

ANOVA for different characters under study

Source	df	Mean square									
		Days to flowering	Days to maturity	No. of branches/ plant	Height of the plant (cm)	Length of pod (cm)	No.of pods/ plant	No.of seeds/ pod	Hundred seed weight (g)	Seed yield/ plant (g)	Aphid borne mosaic resistance (%)
Replication	2	4.94	4.95	2.66**	60.20	1.43	6.77	2.00	2.62	27.85*	0.01
Treatments	16	26.96**	24.30**	1.24**	618.99	2.48*	66.40**	8.41**	8.21**	139.01**	2.99**
Parents	6	20.34**	7.34	1.33*	1196.19*	2.77	31.1**	10.75**	8.50**	121.98**	5.67**
Crosses	9	22.42**	26.13**	0.86	290.21	2.43	75.61**	4.56**	8.57**	102.92**	1.29**
Parent vs cross	1	107.58**	109.68*	4.15*	114.89	1.15	195.37**	29.08**	3.22	565.91**	2.33**
Lines	1	148.31**	170.41**	3.11**	34.84	3.10	381.79**	16.35	2.67	282.32	2.01*
Testers	4	2.56	12.86*	0.91*	392.89	2.52	47.44	0.97	2.34	47.49	1.92**
Liner x testers	4	10.82	3.32	0.24	251.36	2.18	27.24**	5.21*	16.28**	113.51**	0.47**
Error	32	4.98	4.98	0.43	352.50	1.24	4.39	1.35	0.97	8.21	0.05

* 5% level of significance
** 1% level of significance

GENE ACTION AND COMBINING ABILITY IN GRAIN COWPEA (*Vigna unguiculata* (L.) Walp) IN RELATION TO APHID BORNE MOSAIC VIRUS RESISTANCE

By

SMITHA. S.

ABSTRACT OF A THESIS

submitted in partial fulfilment of the requirement

for the degree of

MASTER OF SCIENCE IN AGRICULTURE

(PLANT BREEDING AND GENETICS)

FACULTY OF AGRICULTURE

Kerala Agricultural University

DEPARTMENT OF PLANT BREEDING AND GENETICS

COLLEGE OF AGRICULTURE

VELLAYANI

THIRUVANANTHAPURAM

1995

ABSTRACT

Two lines, five testers and ten hybrids of cowpea were evaluated in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 94-95, with the objective of estimating the combining ability of parents and gene action involved in the inheritance of different yield attributes and CAMV resistance. The lines and testers were selected based on their previous performances and crossed in line x tester manner to get ten hybrids.

Observations were made on ten characters, of which nine characters showed significant difference among the 17 treatments. It was seen that nonadditive gene action was predominated for the inheritance of number of pods/plant, number of seeds/pod, 100 - seed wieght and seed yield/plant and aphid borne mosaic resistance and additive gene action for days to flowering, days to maturity and number of branches/plant.

The varieties Pournami, V-317, V-276 and Charodi were the best general combiners and the cross combinations V-317 x CO4 and V-276 x Pournami were the best specific combinations for yield and CAMV resistance. Hence they can be utilized for further crop improvement programme.