Dedicated to my

Parents

COMBINING ABILITY FOR YIELD AND DROUGHT TOLERANCE IN COWPEA [*Vigna unguiculata* (L.) Walp.]

By

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THESIS

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DECLARATION

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

Vellayani,
21/1/'93

ANIL KUMAR S.G.

CERTIFICATE

Certified that this thesis, entitled "Combining ability for yield and drought tolerance in cowpea (*Vigna unguiculata* (L.) Walp.)" is a record of research work done independently by Sri. Anil Kumar S.G. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

Grain legumes contain 22 to 28% protein on dry weight basis which is about three times that of cereals. Hence they are considered as an important and cheap source of vegetable protein necessary for human nutrition. In a balanced diet, pulses at the rate of three ounces per day per adult is necessary to meet the protein requirement (Aykroyd and Doughty, 1964). More over the legumes have capacity of fixing atmospheric nitrogen and thereby improve the soil fertility. The present day production in India is not sufficient to meet the internal requirements. In Kerala from an area of 24285 hectares production is only 18552 tonnes with a productivity of 764 kilograms per hectare. (Anon., 1990).

Cowpea (Vigna unguiculata (L). Walp.) is the most important pulse crop grown in Kerala during the rainy season in uplands and in the rice fallows during summer. Inadequacy of rainfall during the plant growth period poses serious problems for obtaining the full production potential. Development of high yielding drought tolerant varieties can go a long way of overcoming this problem. Different varieties of cowpea respond differently to drought and in an earlier study conducted in the Department of Plant Breeding the varieties DPLC-198, DPLC-216, IC-38956, V-240 and VCM-8 have been identified as drought tolerant. A knowledge on the combining abilities of parents for different traits and the nature of gene action involved is essential for designing efficient breeding programmes. Line x tester analysis is one of the methods used for studying the combining ability and gene action. The present study was undertaken in cowpea with the objective of determining the general and specific combining ability and the type of gene action involved in the inheritance of drought tolerance, grain yield and its components for improving the yield potential under moisture stress condition through recombination breeding.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Duration upto flowering

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

Durong (1980) studied yield and related characters using 8x8 diallel cross of soybean and reported involvement of additive gene action.

Deshmukh and Manjare (1980) while analysing the combining ability in mungbean in a diallel cross involving eight varieties found highly significant variance due to gca and sca for days to flower. Non-additive gene action was found important for this character.

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

Combining ability analysis of ten diverse cultivars of pigeon pea indicated the predominance of additive gene effects for days to first flower opening (Venkateswarlu and Singh, 1981a).

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

Salimath and Bahl (1985) showed from a line x tester analysis in chickpea the importance of gca and sca variance for days to flower. The variance due to gca was higher than the variance due to sca. Based on gca 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 non-additive variance for days to flowering with a predominance of additive gene action.

A significant gca and sca 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 non-additive gene action. The variance due to gca was much higher than that due to sca and hence predominance of additive gene action was reported.

Patil and Bhapkar (1986) studied yield and related characters using parents and F_1 of half diallel cross of cowpea and reported involvement of additive gene effects 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 lablab bean by Singh et al. (1986). Analysis of the result indicated the significance of both gca and sca variance and importance of gca variance for days to flowering. So importance of both additive and non-additive gene action with predominance of additive gene effects were suggested for the inheritance of the trait days to flower.

Eight chick pea lines and their twenty eight F_1s' were studied for combining ability analysis and found that for flowering and maturity good combining parents were Chafa, JG 62 and BG 212. 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 14 line x 3 tester cross of pea indicated the predominance of non-additive gene action for days to flower. 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 gca estimates were reported to be not significant for the trait. This indicate that the trait is under the control of non-additive gene action and suggested BG 390 and L 550 as good general combiners for early flowering (Mandal and Bahl, 1987).

From a combining ability analysis involving nine diverse parents and their 36 F_1 crosses in pigeon pea it was revealed that both additive as well as non-additive gene effects were important for days to flower and suggested predominance of additive gene effects. (Mehetre et al., 1988).

Moitra et al. (1988) analysed five pea lines for their combining ability and observed that Batri yellow showed negative gca for days to flowering. R701 x Batri yellow, Kinnauri x T 163 and T 10 x T 163 showed negative and significant sca for days to flowering.

Katiyar et al. (1988) in a study with six chickpea genotypes and their F_1 hybrids for combining ability showed significant differences for gca as well as sca variances for days to flower and reported the action of additive and non-additive gene effects. Predominance of additive gene action was suggested for this character.

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 gca for days to flowering.

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 gca variance.

Combining ability analysis of 6 cultivars of cow pea indicated significant gca and sca variances and importance of additive gene action (Rejatha, 1992).

Number of pods per plant

Diallel analysis for yield components in bengalgram showed highly significant variances due to gca and sca for number of pods per plant. Estimates of variance due to sca were much higher than the estimates of variance due to gca indicating that genes having additive and non-additive effects were influencing this character and non-additive 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 gca and sca for number of pods per plant and reported non-additive gene action.

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

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

Both 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 magnitude of sca variance seemed to be comparatively much higher for this character suggesting the preponderance of additive gene action in the inheritance.

Combining ability analysis of ten cultivars of pigeonpea indicated the importance of both gca and sca variance for number of pods per plant. The gca variance were more than sca variance indicating the importance of both additive and non-additive gene effects and predominance of additive gene effects. (Venkateswarlu and Singh, 1982 a).

Combining ability analysis of ten cultivars of pea crossed in all possible combinations indicated the importance of both gca and sca variance for pods per plant. However the variance due to gca were predominant in both F_1 and F_2 generations (Venkateswarlu and Singh, 1982 c).

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).

Singh et al. (1983) estimated combining ability using a 8x3 line x tester cross in pigeon pea and reported that both additive and non-additive components were important with a predominant role of additive component for number of pods per plant.

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 gca and sca variance and predominance of non-additive genetic variance.

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

Combining ability analysis in mung bean using eight parent half diallel cross showed significant gca and sca variance for number of pods per plant (Chowdhury, 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 non- additive 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 non-additive 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 non-additive 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 non-additive genetic variances were important for this character (Sharma and Nishisharma, 1988).

Information on combining ability was derived from data on six chickpea genotypes and their F_1 hybrids for number of pods per plant. Anova for combining ability showed significant differences for gca and sca variance suggesting additive and non-additive gene effects and predominant role of additive gene action for the expression of pods per plant (Katiyar _et al_., 1988)

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

A comparative analysis of combining ability in irradiated and non-irradiated diallel populations of chickpea suggested importance of additive and non-additive gene 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 non-additive 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 non-additive 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 sca for number of pods per plant. (Kaliya et al. 1991).

Yield and yield related characters were investigated in 8 mungbean genotypes and their 28 F_1s' by Saxena and Sharma (1992) and reported importance of additive as well as non-additive variances, and predominance of additive variance.

Twelve hybrids f

parents of cowpea were evalu

seasons for yield and yield components by Thiyagarajan (1992) and reported preponderance of additive variance.

Number of seeds per pod

Diallel analysis for yield and yield components in bengalgram showed highly significant variance due to gca and sca for number of seeds per pod. Estimates of variance due to sca were much higher than that due to gca. It was reported that additive and non-additive gene effects were influencing the characters and the non-additive 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 gca and sca for number of seeds per pod. Non-additive 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 non-additive gene action.

A complete set of six parent diallel crosses in garden pea was evaluated by Dhillon and Chahal (1981) and reported predominance of non-additive gene action for number of seeds per 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 gca variances indicated that additive gene action was involved in the inheritance of this character.

The inheritance study of seed yield components in ricebean 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 plant.

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

Venkateswarlu and Singh (1982 b) 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.

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

The significance of gca variance for number of seeds per pod in a 8 x 8 diallel analysis in blackgram was observed by Malhotra (1983). The varieties L-35-5, G 37 and T 9 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 gca and sca 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 gca was reported to be higher than that of sca. So existence of both additive and non-additive 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 non-additive 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 gca and sca variance for number of seeds per pod indicating additive as well as non-additive 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 gca and sca mean squres were significant in F_1 and F_2 for number of seeds per pod. In general mean squres due to gca were larger in magnitude indicating the preponderance of additive gene action for number of seeds per pod.

A comparative analysis of combining ability in irradiated and non irradiated diallel populations 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 gca variance.

A 7 x 7 diallel cross in green gram by Natarajan et al. (1990) revealed that both additive and non-additive gene action were important.

Combining ability studies for seed yield and its components over environments in blackgram conducted by Kaliya et al. (1991) revealed significant mean sum of squares due to sca for number of seeds per pod.

Yield and yield characters were estimated in 8 mung bean genotypes and their 28 F_1s' by Saxena and Sharma (1992) and reported importance of additive as well as non-additive 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 6 cultivars of cowpea indicated significant gca and sca variances and importance of additive gene action (Rejatha, 1992).

Hundred 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 bengalgram showed highly significant variance due to gca and sca for hundred seed weight. Estimates of variance due to gca 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 hundred seed weight. The magnitude of gca 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 non-additive effects were important (Sandhu *et al*., 1981).

Venkateswarlu and Singh (1981b) while analysing the combining ability in peas in a diallel cross involving ten cultivars found importance of both gca and sca and predominant role of additive gene effects for hundred seed weight.

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

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

Malhotra (1983) in a 8 x 8 diallel analysis of urdbean showed the importance of both gca and sca variance for hundred seed weight and reported that the varieties Mash 1-1 and L 35-5 were the good combiners for hundred seed weight. Both additive and non-additive 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 8x3 line x tester cross in Pigeon pea and reported both additive and non-additive components with a predominance of additive component for hundred seed weight. Wilson et al. (1985) in the analysis of the diallel crosses among five varieties of greengram showed existance of both additive and non-additive gene action. The variance due to gca was reported to be much higher than that due to sca, 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 in additive gene effects.

The combining ability analysis usi

hybrids, three lines and thirteen testers in pigeonpea revealed a significant role of additive and non-additive gene action with the predominance of additive gene action. (Patel et al., 1987).

Yadavendra and Sudhirkumar (1987) studied eight chickpea lines and twentyeight F_1s' for combining ability and suggested BEG 48 as good combiner and reported that hundred seed weight is controlled by additive gene action.

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

In a study with six genotypes of chickpea and their hybrids Katiyar et al., (1988) reported significant gca and sca for hundred seed weight and suggested the importance of additive and non-additive gene effects with predominant role of non-additive 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 non-additive gene effects were important for hundred seed weight. They have also reported the preponderance of non-additive 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 Thiyagarajan (1992) and reported preponderance of additive variance.

Duration up to 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 gca and sca variance were significant. The estimates of gca variance was reported to be higher than that of sca variance in F_2 generation and lower in F_1 generation (Srivatsava et al., 1977).

A diallel cross involving eight mungbean varieties was studied for combining ability and found that the variance due to gca and sca were highly significant for days to maturity. It was also reported that non-additive gene action was important for this character (Deshmukh and Manjare, 1980).

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 non-additive effects were important for days to maturity and that non-additive gene effects were preponderant for all the characters studied except days to maturity.

In a half diallel cross studied by Chauhan and Joshi (1981) with eight cowpea varieties along with parents revealed that both general and specific combining ability variances were important for days to maturity but magnitude of gca 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.

Singh et al. (1983) estimated combining ability using a 8x3 line x tester cross in pigeon pea and reported that both additive and non-additive components were important with a predominant role of non-additive component for grain yield.

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 gca and sca variances with a predominance of non-additive genetic variance.

Salimath and Bahl (1985) conducted a line X tester analysis in chickpea with five males and nine females and reported that sca variance was important for days to maturity. They have also reported that non-additive variance was pronounced for days to maturity.

A significant gca and sca variance was reported by Wilson et al. (1985) for days to maturity in an analysis of the diallel cross among five varieties of greengram. They have found that the variance due to gca was much higher than that due to sca and reported the existance of both additive and non-additive gene action for days to maturity with predominance of additive gene action.

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.

Singh _et al_., (1987b) reported highly significant gca and sca variances in F_1 and F_2 generations for days to maturity in peas. The variance due to sca were greater than that due to gca, indicating predominance of non-additive gene action for the character.

Combining ability analysis of thirtynine hybrids between three lines and thirteen testers in pigeonpea revealed significant role of additive and non-additive gene action with preponderance of non-additive 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 chickpea lines and their twentyeight F_1s' 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 gca and sca variance in F_1 and F_2 generations.

The estimates of variance due to sca were greater than that due to gca for days to maturity indicating the predominance of non-additive gene action.

From a combining ability analysis involving nine diverse parents and their thirtysix F_1 crosses in pigeonpea, Mehetre et al. (1988) reported that both additive and non-additive gene effects were important for days to maturity and that additive gene effects was predominant 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 Thiyagarajan (1992) and reported preponderance of additive variance.

Grain yield per plant

Pande et al. (1979) in the diallel analysis for yield and yield components in bengalgram revealed that variances due to general and specific combining ability effects were highly significant for yield per plant indicating that genes having additive and non-additive effects were influencing yield. It was also reported that non-additive 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 gca and sca were highly significant for grain yield per plant. Non-additive gene action was reported to be more important for this character (Deshmukh and Manjare, 1980)

Durong(1980) studied combining ability using a 8x8 diallel cross of Soybean and reported importance of both additive and non-additive gene action.

A Complete set of Six parent diallel crosses in garden pea evaluated by Dhillon and Chahal (1981) and reported predominance of non-additive gene action for yield per plant.

Venkateswarlu and Singh (1981b) while analysing the combining ability in peas in a diallel cross involving ten cultivars found importance of both gca and sca 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 gca variance was reported to be comparatively much higher suggesting the additive gene action.

The combining ability analysis of ten cultivars of pigeonpea conducted by Venkateswarlu and Singh (1982 a) indicated the importance of both additive and non-additive 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 sca and gca variance for seed yield per plant. The variance due to gca was reported to be predominant in F_1 and F_2 generations (Venkateswarlu and Singh, 1982 c).

In urdbean an 8 x 8 diallel was studied by Malhotra (1983) and reported that both the additive and non-additive gene effects were significant for seed yield with the preponderance of additive gene effects. Singh et al., (1983) estimated combining ability in a line x tester cross in pigeon pea and reported that both additive and non-additive components were important with a predominant role of non-additive component.

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 gca and sca variances with predominance of non-additive genetic variance.

An analysis of diallel crosses using five varieties of greengram showed the existance of both additive and non-additive gene action for seed yield per plant. The variance due to gca was reported to be much higher than that due to sca indicating the predominance of additive gene in the expression (Wilson et al., 1985).

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

Combining ability analysis in mung bean using eight parent half diallel cross showed significant gca and sca variance for seed yield per plant (Chowdhury, 1986).

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

Singh et al., (1987a) in the combining ability analysis using a diallel cross of ten blackgram lines reported highly significant gca and sca both in F_1 and F_2 generation for grain yield. The estimates of variance due to sca was reported to be greater than variances due to gca indicating predominance of non-additive gene action.

Eight chickpea lines and their twentyeight F_1s' were studied for combining ability by Yadavendra and Sudhirkumar (1987) and found that non-additive type of gene action was prominent for grain yield.

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

Combining ability analysis in six chickpea genotypes and their F_1 hybrids revealed additive and non-additive 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 gca and sca variance for yield per plant.

Twentyfive 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 the sca variance were greater than that for gca for yield (Bahl and Kumar, 1989).

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

Thiyagarajan *et al*. (1990) analysed in six parent diallel cross in cowpea, and reported that both additive and non-additive gene effects were important for yield per plant. The components of variance analysis revealed preponderance of non-additive effects for the yield per plant.

In a 7 x 7 diallel cross in green gram the combining ability studies by Natarajan et al. (1990) revealed importance of both additive and non additive gene action and predominance of additive gene action.

Kaliya et al.. (1991) estimated the combining ability for seed yield and its components over environments in black gram and reported significant mean sum of squres due to sca for seed yield.

Yield and yield related characters were investigated in a 8 mung bean genotypes and their 28 F_1s' by Saxena and Sharma (1992) and reported importance of additive as well as non-additive 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 the preponderance of additive variance.

Biological yield

Pande et al. (1979) in a diallel analysis for yield and yield components in bengalgram revealed that variances due to general and specific combining ability effects were highly significant indicating the influence of additive and non-additive effects for biological yield. They have reported that non-additive effects were more important for biological yield.

Components of variance for biological yield was analysed in indian mustard (Prakash et al., 1987) with eight varieties and their twentyeight F_1s' and reported the importance of additive and dominance components.

Information on combining ability was derived from data on biological yield between seven male sterile and five restores of soybean and reported that lines 340 A and SPV 603 were the good general combiners for biological yield (Swarnalata and Rana, 1988).

Combining ability studies in crosses involving tall and dwarf types in chickpea in a line x tester design showed predominance of non-additive gene effects for most characters studied, although appreciable additive effects were found for biological yield (Salimath and Bahl, 1989).

Kolb et al. (1990) found additive genetic effects in spring oats for biological yield. But in F_3 it was found that non-additive effects also were significant for the character.

Harvest index

Pande *et al*. (1979) in a 9 x 9 diallel cross studied yield and yield components in bengalgram and reported highly significant gca and sca variance for harvest index. They have also found predominance of additive gene effects over non-additive gene effects for this character.

Combining ability analysis in a diallel cross of ten blackgram lines for yield and its components showed greater estimates of sca variance than the respective gca variance for the harvest index indicating predominance of non-additive gene action (Singh *et al*., 1987a).

Singh *et al*. (1987b) 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 non-additive gene effects for harvest index in both generations. On the basis of *per se* performance of gca effects the good general combiner common in both F_1 and F_2 generation for harvest index was found to be F 9.

Combining ability analysis for phenological and physiological traits in pea using F_1s' of fourteen lines and three testers conducted by Katiyar *et al*. (1987) indicated the predominance of non-additive gene action for harvest index.

The combining ability analysis in soybean conducted by Sharma and Nishisharma (1988) revealed that harvest index was controlled by additive genetic variance.

Combining ability analysis done in mungbean using a 7 x 7 diallel excluding reciprocals revealed significant gca and sca variance for harvest index showing additive and non-additive gene effects. (Patel et al., 1988).

Hazarika et al. (1988) estimated combining ability in a line x testers cross of pigeon pea and reported significance of both gca and sca variance for yield.

Twenty five chick pea hybrids derived from line x tester crosses were analysed for combining ability by Kumar and Bahl (1988) and found that sca variance estimates were higher than gca variance for seed yield.

A comparative analysis of combining ability in irradiated and non-irradiated diallel populations of chickpea suggested importance of additive and non-additive genes for seed yield per plant (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) and reported the predominance of gca variance.

Combining ability studies in crosses involving five tall and nine dwarf types in chickpea showed predominance of non-additive gene action for harvest index (Salimath and Bahl, 1989).

In soybean, Gadag et al. (1990) noticed significant variation among parents and crosses for harvest index and reported that both gca and sca variances were highly significant. They have also reported predominance of non-additive gene effects for harvest index.

Root length

Nanga and Saxena (1986) while analysing the combining ability and heterosis for root and related traits in pearl millet from a line x tester cross involving four lines and two testers revealed the importance of non-additive gene action for root length.

In a study of eight Vigna radiata genotypes and their twentyeight F_1s' in a half diallel cross revealed significant additive and non-additive genetic variances for seedling root length and yield, although additive gene action was more important for root length (Islam et al., 1987).

Leaf area index

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

In a combining ability analysis done for leaf area index in a nine parent half diallel cross in chickpea revealed non-additive gene action (Deshmukh and Bhapkar, 1982b).

Genetic architecture, combining ability and heterosis for certain physiological parameters in sesamum was studied by Reddy and Haripriya (1990) in 9 x 9 diallel set of crosses and reported that both additive and non-additive gene action were evident for leaf area index.

MATERIALS AND METHODS

MATERIALS AND METHODS

The research programme was carried out at the Department of Plant Breeding, College of Agriculture, Vellayani, Thiruvananthapuram during 1991-92.

Materials

The experimental material consisted of five lines, three testers maintained in the germplasm of the Department of Plant Breeding and fifteen F_1s' produced by crossing the lines and testers. The lines consisted of five drought tolerant, high harvest index varieties. Three popular recommended varieties were used as testers. The lines, testers and their hybrids are detailed in table 1.

Methods

Line x Tester hybridization programme

Parents for crossing were raised during October 1991 in three sets at weekly intervals. Emasculation was done on the flower buds, which were due to open on the next day, by splitting open the keel petals and removing stamens one by one holding by the filaments. Emasculation was done on evening between 4 and 6 pm followed by artificial pollination

Table 1. Details of Parents and their hybrids

	Sl. No.	Parents/Hybrids	Salient characters
Lines	1	DPLC -198	Drought tolerant
	2	DPLC -216	Drought tolerant
	3	IC-38956	Drought tolerant
	4	V-240	Drought tolerant
	5	VCM-8	Drought tolerant
Testers	1	C-152	High yield
	2	Chharodi-1	High yield, earliness
	3	Kanakamany (PTB 1)	Good grain quality Dual purpose
Hybrids	1	DPLC -198 x C-152	
	2	DPLC -198 x Chharodi-1	
	3	DPLC -198 x Kanakamany	
	4	DPLC -216 x C-152	
	5	DPLC -216 x Chharodi-1	
	6	DPLC -216 x Kanakamany	
	7	IC -38956 x C-152	
	8	IC -38956 x Chharodi-1	
	9	IC -38956 x Kanakamany	
	10	V-240 x C-152	
	11	V-240 x Chharodi-1	
	12	V-240 x Kanakamany	
	13	VCM-8 x C-152	
	14	VCM-8 x Chharodi-1	
	15	VCM-8 x Kanakamany	

on the next day morning between 7 and 9 am. The protected emasculated flowers were opened the next day and pollination was done by dusting pollen from the tester parents to the stigmatic surface of the emasculated flowers of the lines. Artificially pollinated flowers were tagged and protected with paper covers. The seeds of each cross were collected separately and kept the field experiment.

The five lines, three testers and their fifteen F_1s' were grown adopting a randomised block design with three replications in the uplands at the College of Agriculture, Vellayani during January-April 1992. In each plot of 3x2m area the seeds were dibbled at a spacing of 25x15cm. The cultural and management practices were followed as per the Package of Practices Recommendations of the Kerala Agricultural University 1989. Data on the various characters were recorded from a random sample of ten plants in each treatment per replication.

The observational plants were scored for the following characters and the mean value were used for statistical estimation.

1) Root length

Root length was measured at harvest period. The sample plants were uprooted carefully and length of the tap root was measured in centimeters.

2) Root spread

Root spread was measured at harvest period by placing the dry root specimen on a graph paper and measuring the width of the root at its broadest part. The root spread was expressed in centimeters.

3) Duration upto flowering

Number of days taken from the date of sowing to first flowering in each plot was observed and recorded in days.

4) Root/shoot ratio

Root shoot ratio was studied at vegetative period i.e. just prior to flowering. The ratio of root dry weight to shoot dry weight was expressed as root/shoot ratio. From each sample plant, root and shoot portions were taken separately sun dried for two days and then oven dried at 60-70°c for 24 hours and the dry weights were recorded and ratio found out.

5) Leaf area index

Leaf area index was measured at vegetative period i.e. just prior to flowering using leaf area meter. All the leaves separated from each uprooted sample plants were fed to the leaf area meter separately and the total leaf area of each plant was measured. From the leaf area leaf area index was calculated by the formula suggested by William (1946).

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

6) Stomatal distribution

For estimating number of stomata per microscopic field, fully opened and mature leaves were selected from the sample plants and leaf impressions were taken by giving a thin coat of nail polish on the lower leaf surface and pealing it off after drying. From these impressions ten microscopic fields were scored for number of stomata and the mean number per microscopic field was estimated.

7) Proline content of leaf

Proline content was estimated by the method suggested by Bates et al. (1973). Leaves collected from each sample plants were dried and powdered separately. Approximately 0.25 g of the material was homogenized in 10 ml of three percent aqueous sulfosalicylic acid and the homogenate filtered through Whatman No. 2 filter paper. Two ml of filtrate was reacted with 2ml acid ninhydrin and 2ml of glacial acetic acid in a test tube for one hour at 100°C and the reaction terminated in an ice bath. The reaction mixture was extracted with 4ml toluene, mixed vigorously with a test tube stirrer for 15-20 seconds and warmed to room temperature. The chromophore containing toluene was read in Spectronic 2000 at 520 nm using toluene as a blank.

Purified proline was used to standardise the procedure for quantifying sample values. The proline concentration in the samples were determined from the standard curve and calculated on a dry weight basis as follows.

$$\frac{\mu g \text{ proline/ml} \times \text{ml toluene}}{5/\text{weight of sample (g)}} = \mu g \text{ proline/g of dry weight material}$$

8) Grain filling period

Five random flowers were tagged in each of the observational plants on the day of flower opening and the mean number of days taken for pod maturity were found out.

9) Number of pods per plant

Number of pods in each observational plant was counted and averaged.

10) Number of seeds per pod

Single pod from each observational plant was threshed separately and the number of seeds in each pod was counted and the average was worked out.

11) Hundred seed weight

Random samples of hundred grains were selected from the bulk in each plot, weighed and the mean weight was recorded in gram.

12) Duration upto maturity

Mean number of days taken from sowing to final harvest was recorded.

13) Grain yield per plant

Yield of grains obtained from each observational plants were recorded, averaged and expressed in grams.

14) Biological yield

The total biological yield produced on the observational plants were averaged and expressed in grams.

15) Harvest index

Harvest index for each observational plant was calculated by using the formula

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

Total grain yield from each observational plant was recorded as the economic yield and dry weight of all the other plant parts plus the grain yield were considered as biological yield.

Soil moisture estimation

Soil moisture was determined at weekly intervals by gravimetric method, where a known weight of the fresh soil collected from each plot was oven dried at 105^{o}C until

Table 2. Anova for line x tester

Source	df	ms	expected ms
Replication	r - 1		
Treatment	l + t + lt - 1		
Parents	l + t - 1		
Crosses	lt - 1		
Parents Vs Crosses	1		
Lines	l - 1	M_l	$\sigma^2 e$ + r [Cov. (FS) - 2 Cov. (HS)] + rt Cov. (HS)
Testers	t - 1	M_t	$\sigma^2 e$ + r [Cov. (FS) - 2 Cov. (HS)] + rl Cov. (HS)
Line x tester	(l - 1) (t - 1)	M_{lt}	$\sigma^2 e$ + r [Cov. (FS) - 2 COv. (HS)]
Error	(r - 1) (l + t + lt -1)	M_e	$\sigma^2 e$
Total	ltr - 1		

constant dry weight was obtained and the loss in weight was expressed as percentage.

Statistical analysis

Combining ability analysis in Line x Tester

Analysis of variance

Analysis of ce was done for all the characters and significance of differences among the types including parents and crosses was tested (Table 2).

Estimation of combining ability

For estimating the general and specific combining ability effects, the method described by Kempthorne (1957) was adopted. In this method the covariance of full sibs and half sibs in terms of mean squares due to lines (M_l) tester (M_t), line x tester (M_{lt}) were estimated, from which the variance due to general combining ability (gca) and specific combining ability (sca) were estimated. The significance of lines and testers are tested against mean square due to line x tester, while the significance of line x tester is tested against mean square for error (Singh and Choudhary,1977).

The genetic components were estimated as

$$\text{Cov. H.S. (lines)} = \frac{M_l - M_{lt}}{rt}$$

$$\text{Cov. H.S.(testers)} = \frac{M_t - M_{lt}}{rl}$$

Cov.H.S. (average) =

$$\frac{1}{r\,(2lt - l - t)} \times \frac{(l-1)\,M_l + (t-1)\,M_t}{l + t - 2} - M_{lt}$$

Cov. F.S. =

$$\frac{(M_l - M_e) + (M_t - M_e) + (M_{lt} - M_e)}{3r} + \frac{6r.\text{Cov.H.S.} - (rl+t)\ \text{Cov.H.S.}}{3r}$$

$$\sigma^2 gca = \text{Cov. H.S. (average)} = \left(\frac{1+F}{2}\right)^2 \sigma A^2$$

$$\sigma A^2 = 4\,\sigma^2\,gca \quad \text{when } F = 0$$

$$\sigma^2\,sca = \frac{M_{lt} - M_e}{r}$$

when $F = 0$ $\quad \sigma^2 D = 4\,\sigma^2 sca$

where l = number of lines

t = number of testers

r = number of replications

F = inbreeding coefficient

$\sigma^2 A$ = additive variance

$\sigma^2 D$ = variance due to dominance

Estimation of gca and sca effects

The model used to estimate the gca an observation was as follows

$$X_{ijk} = \mu + g_i + g_j + s_{ij} + e_{ijk}$$

$i = 1, 2, 3, \ldots, l$

$j = 1, 2, 3, \ldots, t$

$k = 1, 2, 3, \ldots, r$

where μ = population mean

g_i = gca effect of i^{th} line

g_j = gca effect of j^{th} tester

s_{ij} = sca effect of ij^{th} combination

e_{ijk} = random error component associated with ijk^{th} observation.

The individuals effects were estimated as follows.

1. mean = $\dfrac{X_{...}}{ltr}$

2. gca effect of lines $g_i = \dfrac{X_{i..}}{tr} - \dfrac{X_{...}}{ltr}$

3. gca effect of testers $g_j = \dfrac{X_{.j.}}{lr} - \dfrac{X_{...}}{ltr}$

4. sca effect in combinations

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

where $X_{...}$ = total of all hybrid combinations

$X_{i..}$ = total of i^{th} line over t testers and r replications

$X_{.j.}$ = total of j^{th} tester over l lines and r replications

$X_{ij.}$ = total of the hybrids i^{th} line and j^{th} tester over r replications.

The standard error pertaining to gca effect of lines and testers and sca effects in different combination were calculated as given below

Lines : $SE(g_i) = (M_l/rt)^{1/2}$

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

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

Proportional contribution of lines, testers and line x tester to total variance is given as

$$\text{Contribution of lines} = \frac{SS(L)x100}{SS(Crosses)}$$

$$\text{Contribution of testers} = \frac{SS(T)x100}{SS(Crosses)}$$

$$\text{Contribution of lines x tester} = \frac{SS(LxT)x100}{SS(Crosses)}$$

where SS(L) = Sum of squares due to lines

SS(T) = Sum of squares due to testers

SS(L x T) = Sum of squares due to line x tester

RESULTS

RESULTS

The data were analysed using appropriate statistical techniques and the results are presented below.

The Average root length at harvest period ranged from 12.6 cm in V-240 to 19.5 cm in DPLC-216 among lines and from 13.6 cm in Kanakamany to 18.9 cm in C-152 among testers. The range among the hybrids were from 15.7 cm in IC-38956 x Kanakamany to 19.3 cm in DPLC-198 x C-152.

The root spread at harvest period had the highest value of 36.8 cm in V-240 and the lowest value of 23.7 cm in IC-38956 among lines

Among testers highest value of 29.0 cm was shown by Chharodi-1 and lowest value of 20.5 cm by Kanakamany. Among hybrids highest r [illegible] .d was recorded by the hybrid DPLC-216 x C-152 [illegible], while the lowest spread by the hybrid VCM-8 x C-152 (26.5 cm).

The mean duration taken for first flowering ranged from 31.7 days in VCM-8 to 43 days in V-240 among lines. The testers had a narrow range of variation from 38 days in Chharodi-1 to 43 days in C-152. Among hybrids the earliest to flower were IC-38956 x C-152 and IC-38956 x Chharodi-1 (34.3 days) The hybrid DPLC-198 x Kanakamany showed the most delayed flowering (41 days).

Root shoot ratio at vegetative period ranged from 0.10 in VCM-8 to 0.40 in V-240 in case of line and from 0.08 in Kanakamany to 0.11 in Chharodi-1 among testers. The range among the hybrids were from 0.07 in the hybrid DPLC-198 x Kanakamany to 0.16 in the hybrid VCM-8 x Chharodi-1.

The mean of lines with respect to leaf area index at vegetative period ranged from 1.15 in IC-38956 to 2.93 in DPLC-198 among lines. In the case of testers the range was from 1.56 in Kanakamany to 2.32 in Chharodi-1. The range in hybrids was between 1.37 in VCM-8 x Chharodi-1 and 5.60 in DPLC-198 x Kanakamany.

Stomatal distribution of lower surface of leaves ranged from 18.17 in VCM-8 to 28.92 in IC-38956 among lines. Among testers the range was from 18.7 in Chharodi-1 to 28.67 in C-152. The range in hybrids was between 21.58 in IC-38956 x C-152 to 28.83 in IC-38956 x Kanakamany.

The Proline content of leaves ranged from 0.21 g/g of leaf sample in VCM-8 to 0.41 in DPLC-198 among lines. The range among the testers were 0.36 in C-152 to 0.41 in Kanakamany. Among hybrids proline content ranged from 0.17 in IC-38956 x C-152 to 0.66 in DPLC-216 x C-152.

In lines the grain filling period ranged from 13.26 days in VCM-8 to 18.0 days in DPLC-198. In the testers this character vary from 15.1 days in Chharodi-1 to 16.1 days in Kanakamany. In the hybrids the range was from 13.8 days in VCM-8 x C-152 to 18.1 days in DPLC-198 x Kanakamany.

Among the lines the mean value of number of pods per plant ranged from 6.76 in V-240 to 13.30 in DPLC-198. Among the testers the range was from 5.83 in Kanakamany to 18.10 in Chharodi-1. In the hybrids the range was from 10.77 in V-240 x Kanakamany to 31.60 in DPLC-198 x C-152.

Number of seeds per pod varied from 9.53 in DPLC-198 to 12.67 in VCM-8 among lines and from 10.90 in Chharodi-1 to 14.93 in C-152 among testers. The range of hybrid was from 9.67 in DPLC-216 x Chharodi-1 to 15.13 in V-240 x C-152.

Hundred seed weight ranged from 8.58 g in VCM-8 to 18.38 g in DPLC-216 among lines. Among testers it ranged from 6.71 g in chharodi-1 to 12.67 g in kanakamany. In the hybrids the range was from 7.84g in VCM-8 x Chharodi-1 to 15.01 g in DPLC-216 x Kanakamany.

Among the lines V-240 had highest maturity (72.0 days) while the lowest was recorded by VCM-8 (60.33 days). Among testers the duration ranged from 67.33 days in Chharodi-1 to 74.7 days in Kanakamany. In the hybrids the highest duration of 88.33 days was recorded by V-240 x Kanakamany and the lowest duration of 61.7 days was recorded by IC-38956 x Chharodi-1. Among the lines the grain Yield per plant varied from 6.42 g in DPLC-216 and V-240 to 9.0 g in DPLC-198. Among the testers it varied from 2.75 g in Kanakamany to 7.83g in C-152.. In the hybrids the lowest grain yield per plant (5.83g) was given by VCM-8 x Chharodi-1 and the highest by DPLC-198 x C-152 (31.17 g).

Biological yield ranged from 10.00 g in DPLC-216 to 17.13g in DPLC-198 among the lines. The testers ranged from 7.25g (Kanakamany) to 17.23g (C-152). Among hybrids the range was from 9.87g in the VCM-8 x Chharodi-1 to 45.26 in DPLC-198 x C-152.

Harvest index had a range from 0.27 in V-240 to 0.43 in IC-38956 in lines and from 0.25 in kanakamany to 0.46 in Chharodi-1 in the testers. Among the hybrids the harvest index ranged from 0.32 in VCM-8 x C-152 and V-240 x Kanakamany to 0.63 in DPLC-198 x C-152.

Mean performance of lines, testers and hybrids for different characters are presented in table 3.

Combining ability and gene action

The analysis of variance of 15 characters studied are presented in Table 4. The results showed that all the

Table 3. Mean performance of lines, testers and hybrids for fifteen characters

Treatments	Root length (cm)	Root spread (cm)	Duration upto flowering (days)	Root/ shoot ratio	Leaf area index	Stomatal distri- bution (per field)	Proline content (µg/g)
DPLC-198 x C-152	19.93	30.87	39.33	0.08	5.08	24.17	0.25
DPLC-198 x Chharodi-1	17.33	32.93	35.00	0.09	4.46	26.50	0.48
DPLC-198 x Kanakamany	19.27	29.90	40.00	0.07	5.60	26.92	0.33
DPLC-216 x C-152	17.67	38.80	40.00	0.12	2.89	25.92	0.66
DPLC-216 x Chharodi-1	15.93	32.00	38.00	0.08	2.58	24.08	0.45
DPLC-216 x Kanakamany	16.70	33.10	39.33	0.09	2.37	28.25	0.32
IC-38956 x C-152	16.53	27.27	34.33	0.11	2.83	21.58	0.17
IC-38956 x Chharodi-1	17.80	30.80	34.33	0.09	2.77	26.25	0.48
IC-38956 x Kanakamany	15.73	35.23	36.67	0.07	2.69	28.83	0.35
V-240 x C-152	16.93	23.07	40.67	0.08	3.62	27.75	0.37
V-240 x Chharodi-1	16.23	28.43	39.33	0.10	1.50	21.62	0.25
V-240 x Kanakamany	16.53	37.47	39.00	0.07	3.29	24.17	0.44
VCM-8 x C-152	17.43	26.50	40.00	0.09	3.71	28.00	0.42
VCM-8 x Chharodi-1	17.43	28.07	37.00	0.16	1.37	26.33	0.40
VCM-8 x Kanakamany	14.87	30.63	39.33	0.08	2.92	23.83	0.29
DPLC-198	19.47	32.10	36.00	0.10	2.93	25.42	0.41
DPLC-216	19.50	26.83	38.67	0.15	1.95	26.92	0.26
IC-38956	16.83	23.57	33.67	0.13	1.15	28.92	0.26
V-240	12.57	36.83	43.00	0.40	1.35	23.33	0.28
VCM-8	18.83	33.30	31.67	0.10	1.41	18.17	0.21
C-152	18.90	27.00	43.00	0.10	2.30	28.17	0.36
Chharodi-1	16.40	29.03	38.00	0.11	2.32	18.67	0.38
Kanakamany	13.60	20.47	38.67	0.08	1.56	24.25	0.41

Table 3. (Contd....)

Treatments	Grain filling period (days)	No. of pods /plant	No. of seeds /pod	100 seed weight (g)	Duration upto maturity (days)	Grain yield /plant (g)	Biological yield (g)	Harvest index
DPLC-198 x C-152	16.87	31.60	12.30	12.88	61.67	31.17	45.26	0.63
DPLC-198 x Chharodi-1	17.00	20.50	10.33	10.76	68.00	10.50	17.87	0.42
DPLC-198 x Kanakamany	18.07	19.83	10.13	14.51	77.67	20.11	37.77	0.41
DPLC-216 x C-152	16.40	17.00	13.00	11.77	67.33	12.50	22.79	0.38
DPLC-216 x Chharodi-1	16.20	16.03	9.67	10.48	65.33	7.17	12.78	0.37
DPLC-216 x Kanakamany	16.93	13.37	11.67	15.01	86.67	10.00	18.17	0.38
IC-38956 x C-152	15.07	15.93	12.40	10.24	66.67	12.25	22.54	0.45
IC-38956 x Chharodi-1	15.13	19.93	10.47	8.18	61.67	13.00	21.87	0.37
IC-38956 x Kanakamany	15.87	12.00	11.07	13.20	85.33	13.33	29.66	0.36
V-240 x C-152	15.00	12.33	15.13	10.49	72.33	13.17	21.84	0.45
V-240 x Chharodi-1	14.93	16.10	12.47	8.76	73.00	9.33	15.77	0.36
V-240 x Kanakamany	16.07	10.77	12.93	12.76	88.33	12.33	20.27	0.32
VCM-8 x C-152	13.80	15.30	14.60	11.51	63.67	13.83	24.74	0.32
VCM-8 x Chharodi-1	14.47	13.63	11.73	7.84	63.67	5.83	9.87	0.44
VCM-8 x Kanakamany	15.33	14.30	11.80	12.83	74.87	11.67	25.62	0.33
DPLC-198	18.00	13.30	9.53	18.38	68.33	9.00	17.13	0.28
DPLC-216	17.00	11.77	9.60	14.49	65.33	6.42	10.00	0.37
IC-38956	15.13	10.77	11.13	10.69	60.67	8.00	11.56	0.43
V-240	15.00	6.77	12.67	11.36	72.00	6.42	11.91	0.27
VCM-8	13.20	9.60	11.53	8.58	60.33	7.67	10.35	0.42
C-152	15.27	10.47	14.93	8.94	70.33	7.83	17.23	0.34
Chharodi-1	15.07	18.10	10.90	6.71	67.33	7.67	12.42	0.46
Kanakamany	16.13	5.83	12.47	12.67	74.67	2.75	7.75	0.25

Table 4. Anova of fifteen characters under study

Source	df	Root length	Root spread	Duration upto flowering	Root/ shoot ratio	Leaf area index	Stomatal distri- bution	Proline content
		Mean squares						
Replication	2	0.33	4.88	6.63	0.009	3.55**	86.81	0.33
Treatments	22	9.96	58.69*	25.09**	0.01	4.24**	26.90	9.04**
Parents	7		85.49*	48.67**		1.13		0.02
Crosses	14		41.76	14.83**		4.30**		0.04**
Parent Vs Crosses	1		108.22	3.58		25.08**		0.05*
Lines	4		45.23	25.02**		10.47**		0.03
Testers	2		45.25	28.42**		4.14*		0.02
Line x Tester	8		39.65	6.34**		1.26		0.06**
Error	44	16.93	31.57	2.08	0.01	1.54	45.39	0.01

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

Table 4. (Contd....)

Source	df	Grain filling period	No. of pods /plant	No. of seeds /pod	100 seed weight	Duration upto maturity	Grain yield /plant	Biological yield	Harvest index
		Mean squares							
Replication	2	0.01	139.23**	5.87*	5.27**	10.73	188.91**	526.17**	0.05*
Treatments	22	4.49**	87.19**	7.75**	22.14**	188.65**	97.99**	253.45**	0.02
Parents	7	6.32**	44.12	9.42**	41.28**	78.42**	10.85	35.52	
Crosses	14	3.85**	77.63	7.30**	14.15**	226.72**	106.81**	247.91**	
Parent Vs Crosses	1	0.68**	522.41**	2.31	0.05	427.29**	584.52**	1856.52**	
Lines	4	10.82**	164.53**	10.65**	9.97**	131.81*	170.47*	369.05**	
Testers	2	4.73**	77.74	26.83**	75.31**	1135.40**	208.16*	635.87**	
Line x Tester	8	0.15**	34.16	0.74	0.95	47.01**	49.64**	90.34*	
Error	44	0.03	24.03	1.38	0.68	4.50	16.65	35.61	0.01

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

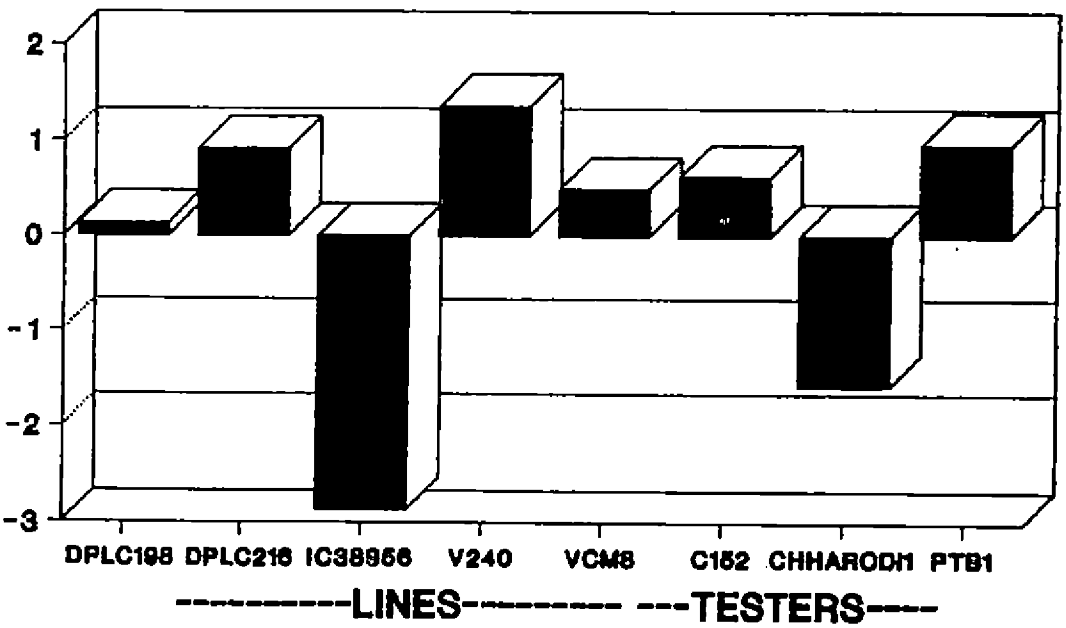
characters except root length and spread at harvest period, root shoot ratio at vegetative period, stomatal distribution of lower leaf surface and harvest index recorded significant treatment effects. Hence the characters which had significant treatment effects were used for line x tester analysis and to study the gene action in terms of gca and sca.

The combining ability analysis for duration upto first flowering showed that both lines and testers differ significantly in their general combining ability. Among lines only IC-38956 showed negative general combining ability (gca) effect (-2.87) which was significantly different from the gca effect of other lines. V-240 showed highly significant positive gca effect (1.36). Among testers Chharodi-1 and Kanakamany differed significantly in their gca effects. Chharodi-1 showed negative gca effect (-1.58) while it was positive for Kanakamany (0.96) and C-152 (0.62). The hybrids IC-38956 x C-152 and DPLC-198 x Chharodi-1 differed significantly from all other hybrids in their specific combining ability (sca) effect with negative values of -1.73 and -1.87 respectively. Apart from the above hybrids the sca effects were negative for four other hybrids vis. VCM-8 x Chharodi-1 (-0.20), DPLC-216 x Kanakamany (-0.84), V-240 x Kanakamany (-1.62) and VCM-8 x Kanakamany (-0.40). The highest positive sca effect was shown by the hybrids DPLC-198 x Kanakamany. The gca and sca effects for duration upto first flowering is shown in the table 5. The gca is represented graphically in fig.1 and sca in fig.2. The ratio of variance due to gca and sca showed a value which is less than unity (0.21) when F=0, F being inbreeding coefficient. So this characters may be predominantly under the control of non-additive gene action.

Leaf area index at vegetative period differed significantly among lines and testers. Variance due to line x tester was found to be non significant. Regarding the gca effects all testers were on par with a negative gca effect (-0.60) in Chharodi-1. Among lines DPLC-198 differed significantly from others in its gca effect. Only DPLC-198 showed positive gca effect (1.91) while all other lines showed negative gca effects. The sca effects were not significantly different. Seven hybrids showed negative sca effects while it was positive in eight hybrids. The gca and sca effects of leaf area index at vegetative period is shown in the table 6. The gca is represented graphically in fig.3 and sca in fig. 4.

Significant gca variance and the ratio of the variance due to gca and sca equa[illegible]5 when F=0, where F is inbreeding coefficient shows that this character is predominantly under the control of additive gene action.

GENERAL COMBINING ABILITY
DAYS TO FLOWER



CD 5% LINE 0.969 TESTER 0.750
SE LINE 0.4806 TESTER 0.3722

Fig 1

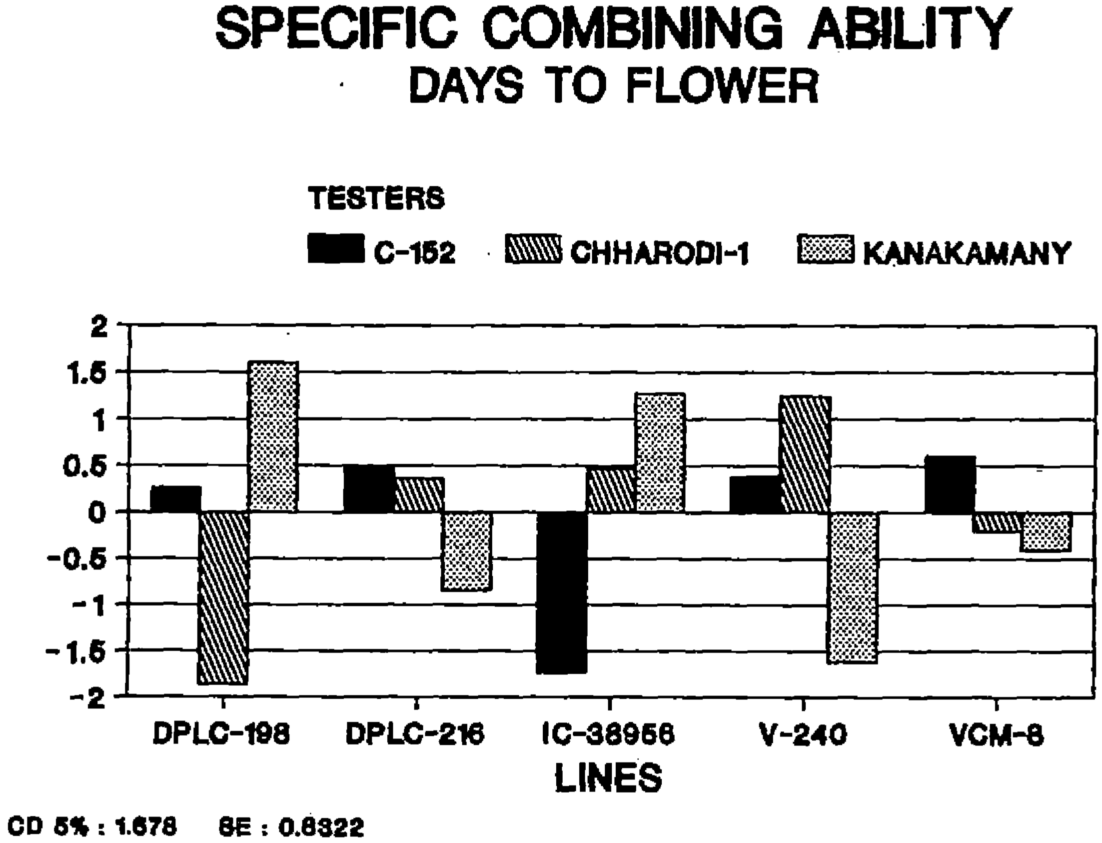

SPECIFIC COMBINING ABILITY
DAYS TO FLOWER
TESTERS
C-152
CHHARODI-1
KANAKAMANY
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
DPLC-198
DPLC-216
IC-36956
V-240
VCM-8
LINES
CD 5% : 1.678 SE : 0.6322

Fig 2

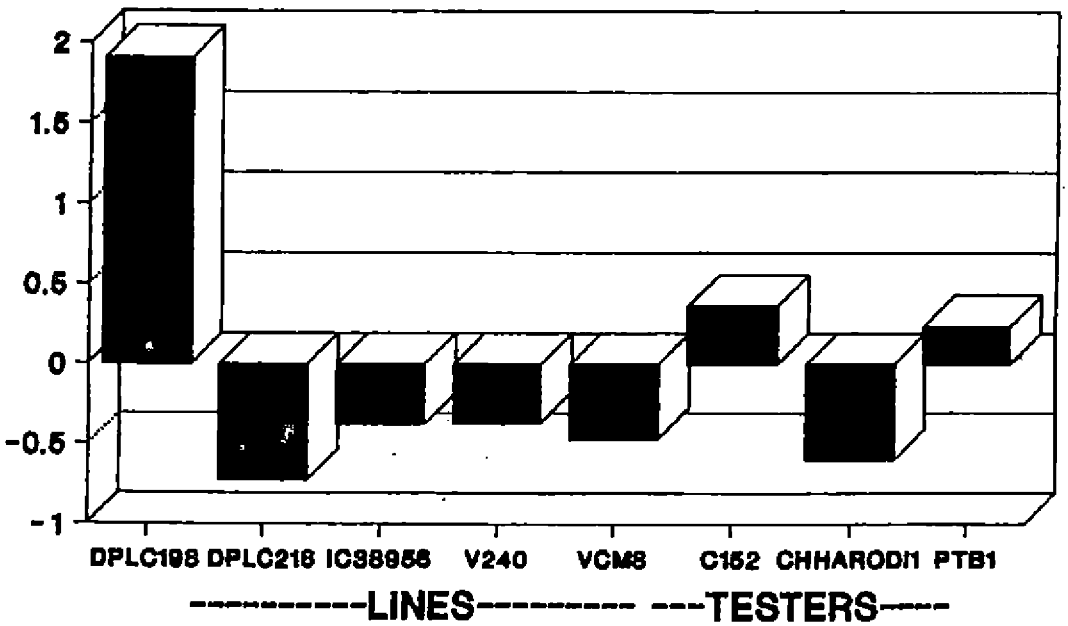
Table 6: General and specific combining abilities for leaf area index at vegetative period

Lines	gca effects	C-152	Chharodi-1	Kanakamany
		0.366	-0.602	0.236
		sca effects		
DPLC-198	1.911**	-0.334	0.014	0.320
DPLC-216	-0.727	-0.489	0.767	-0.278
IC-38956	-0.377	-0.300	0.609	-0.309
V-240	-0.336	0.449	-0.697	0.249
VCM-8	-0.471	0.674	0.692	-0.019

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

	SE	CD 5%
gca Line	0.4136	0.834
gca Tester	0.3204	0.646
sca	0.7164	1.444

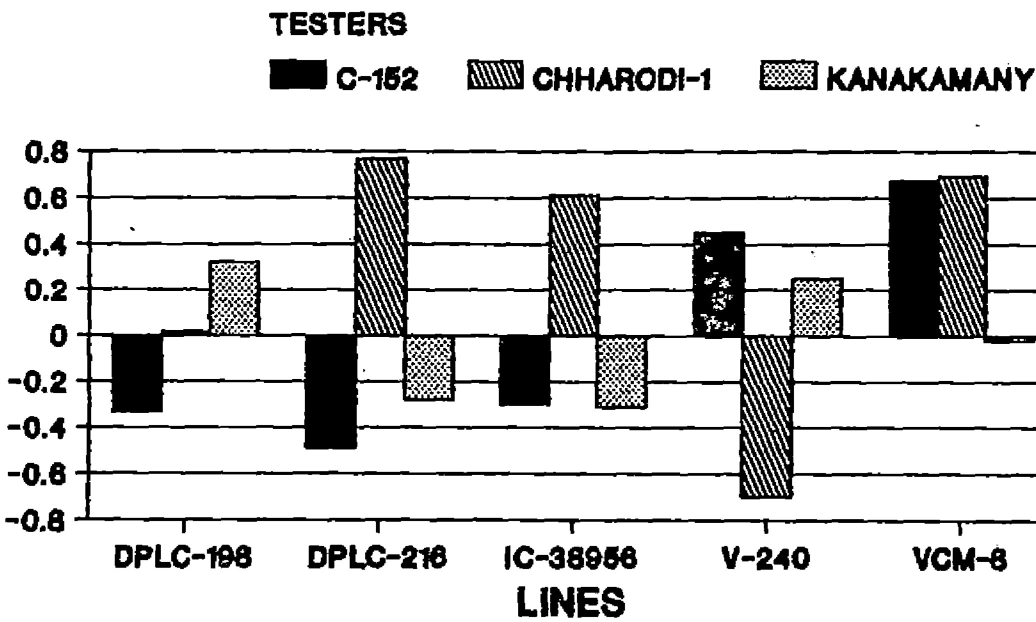
GENERAL COMBINING ABILITY
LEAF AREA INDEX



5% LINE 0.834 TESTER 0.646
LINE 0.4136 TESTER 0.3204

Fig 3

SPECIFIC COMBINING ABILITY
LEAF AREA INDEX



CD 5% : 1.444 SE : 0.7164

Fig 4

Proline content varied significantly among F_1s' while little difference was showed among lines and testers.

Regarding the gca effects, all testers except Chharodi-1 (0.04) showed negative effect. Among lines DPLC-216 showed significant positive gca effect (0.10) while others showed negative gca effects. In the hybrids significant positive sca effect was shown by DPLC-216 x C-152 (0.18), IC-38956 X Chharodi-1 (0.11) and V-240 x Kanakamany (0.12) while DPLC-216 x Kanakamany (-0.12), IC-38956 x C-152 (-0.16) and V-240 x Chharodi-1 (-0.14) showed significant negative sca effect. Seven out of fifteen hybrids showed negative sca effect. The gca and sca effects of proline content is presented in the table 7. The gca presented graphically in fig. 5 and sca fig. 6. The ratio of variance due to gca to variance due to sca equals 0.03 when F = 0 suggests that this character is predominantly under the control of non-additive gene action.

Grain filling period differed significantly among lines, testers and F_1s'. General combining ability effect of all testers were found to differ significantly. It ranged from -0.38 in C-152 to 0.64 in Kanakamany. All lines were also found to differ significantly in their gca effect. The gca effect in lines ranged from -0.48 in V-240 to 1.50 in DPLC-198. Out of five lines only DPLC-198 and

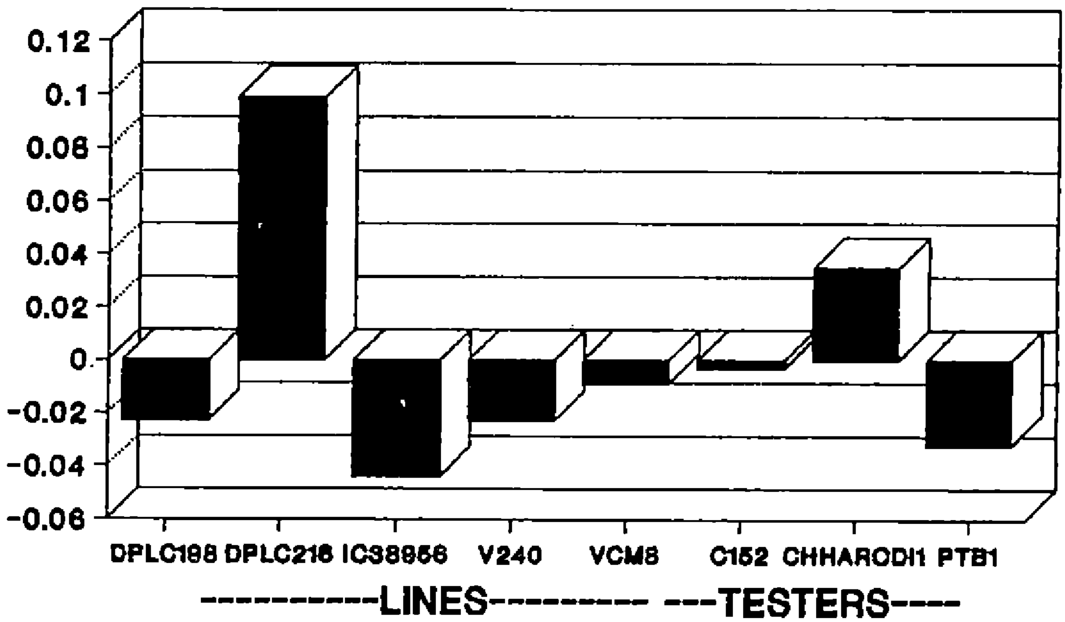
Table 7. General and specific combining ability for proline content

		Testers		
		C-152	Chharodi-1	Kanakamany
Lines	gca effects	-0.003	0.035	-0.032
		sca effects		
DPLC-198	-0.023	-0.099	0.092	0.008
DPLC-216	0.099**	0.184**	-0.060	-0.124*
IC-38956	-0.044	-0.159**	0.113*	0.046
V-240	-0.023	0.020	-0.139*	0.119*
VCM-8	-0.009	0.054	-0.006	-0.049

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

		SE	CD 5%
gca line	=	0.0307	0.062
gca tester	=	0.0238	0.048
sca	=	0.0532	0.107

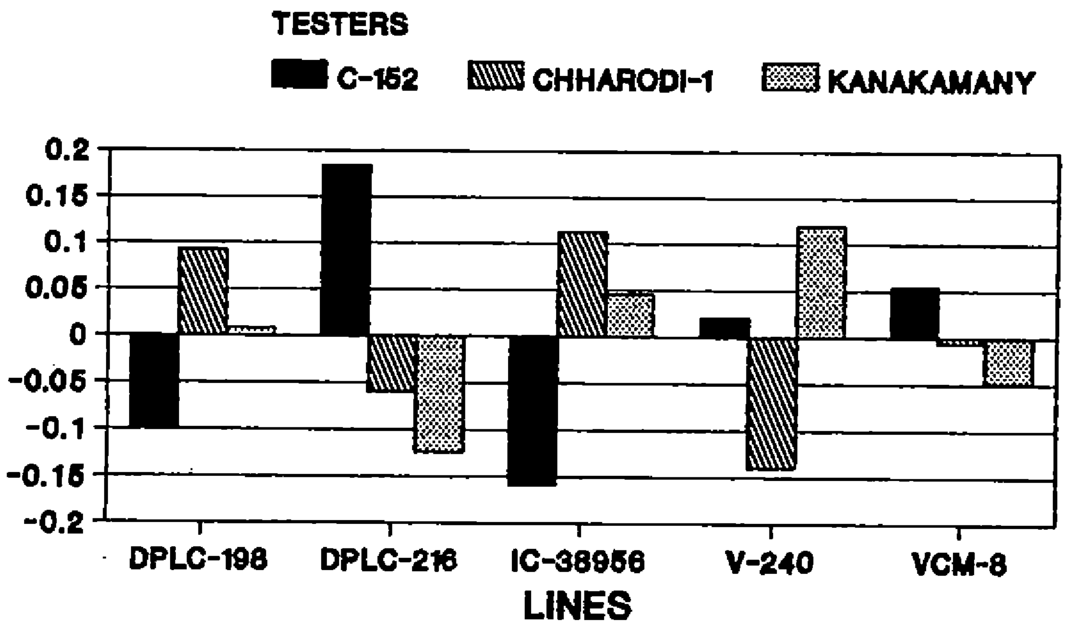
GENERAL COMBINING ABILITY
PROLINE CONTENT



CD 5% LINE 0.062 TESTER 0.048
SE LINE 0.0307 TESTER 0.0238

Fig 5

SPECIFIC COMBINING ABILITY
PROLINE CONTENT



CD 5% : 0.107 SE : 0.0532

Fig 6

DPLC-216 showed positive gca effects. The sca effects were found to differ significantly. The hybrid VCM-8 x C-152 showed significant negative sca effect (-0.35). The hybrids DPLC-216 x C-152, VCM 8 x Chharodi-1 and DPLC-216 x kanakamany showed significant positive sca effects of 0.27, 0.20 and 0.22 respectively. The gca and sca effects of grain filling period are presented in the table 8. The gca is represented graphically in fig. 7 and sca in fig. 8. The ratio of variance due to gca to sca equals 3.35 when F=0 suggests that this characters is predominantly under the control of additive gene action.

Number of pods per plant varied significantly among lines. The gca effects of all the testers were on par but Kanakamany showed a negative sca effect of -2.55. The gca effect among testers varied from 1.83 in C-152 to -2.55 in Kanakamany. Among lines except DPLC-198 all others showed negative gca effect. Highest negative gca effect was shown by the line V-240. Among lines DPLC-198 (7.38) and V-240 (-3.54) were significantly different regarding gca effects. The sca effect was found to be significant only in the hybrid DPLC-198 x C-152 (5.79). Eight out of fifteen hybrids showed negative sca effect. The highest negative sca effect was shown by the hybrid DPLC-198 x Chharodi-1 (-4.20). The gca and sca effects of number of pods per plant is represented in the table 9. The gca is represented graphically in fig. 9 and

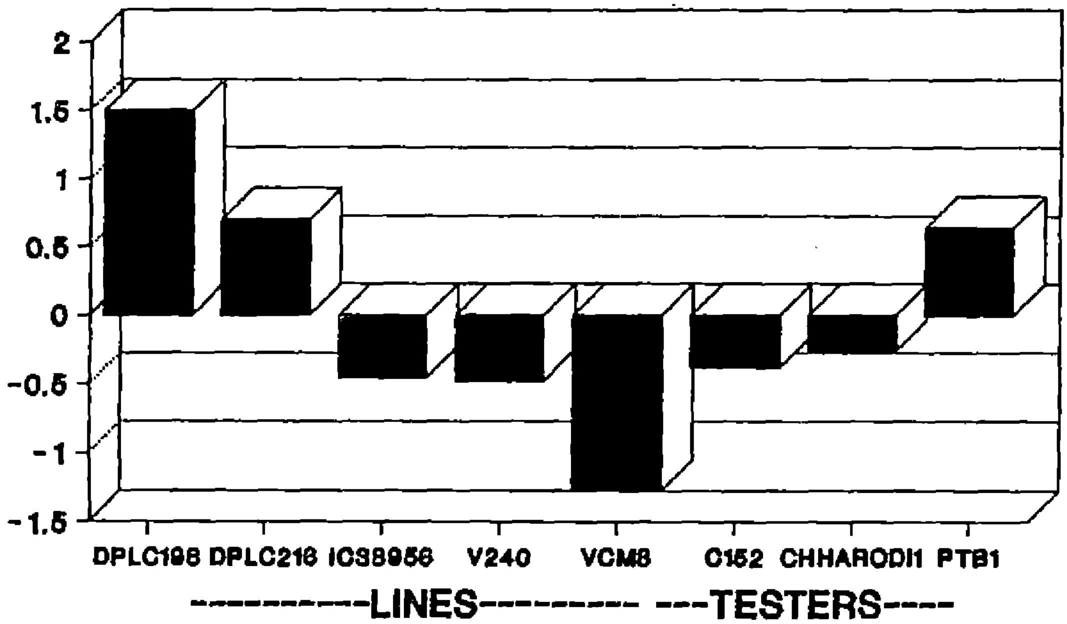
Table 8. General and specific combining ability for grain filling period

		Testers		
		C-152	Chharodi-1	Kanakamany
Lines	gca effects	-0.382**	-0.262**	0.644**
		sca effects		
DPLC-198	1.502**	-0.062	-0.049	0.111
DPLC-216	0.702**	0.271**	-0.049	-0.222*
IC-38956	-0.453**	0.093	0.040	-0.133
V-240	-0.476**	0.049	-0.[illegible]8	0.089
VCM-8	-1.276**	-0.351**	0.196*	0.156

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

	SE	CD 5%
gca line	= 0.0570	0.115
gca tester	= 0.0431	0.087
sca	= 0.0965	0.195

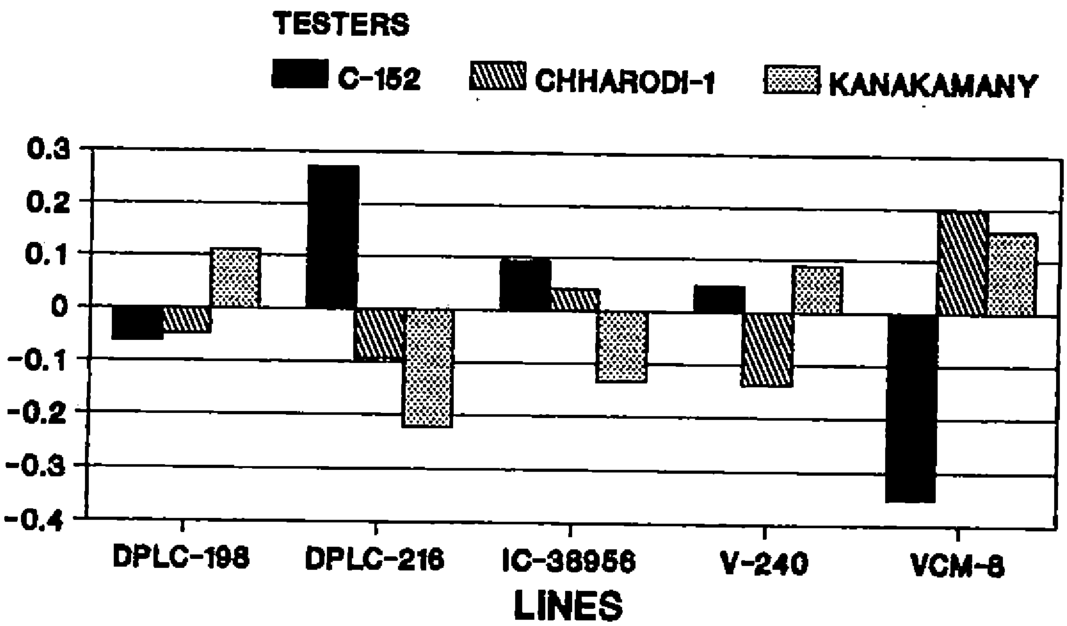
GENERAL COMBINING ABILITY
GRAIN FILLING PERIOD



CD 5% LINE 0.115 TESTER 0.087
SE LINE 0.0570 TESTER 0.0431

Fig 7

SPECIFIC COMBINING ABILITY
GRAIN FILLING PERIOD



CD 5% : 0.195 SE : 0.0965

Fig 8

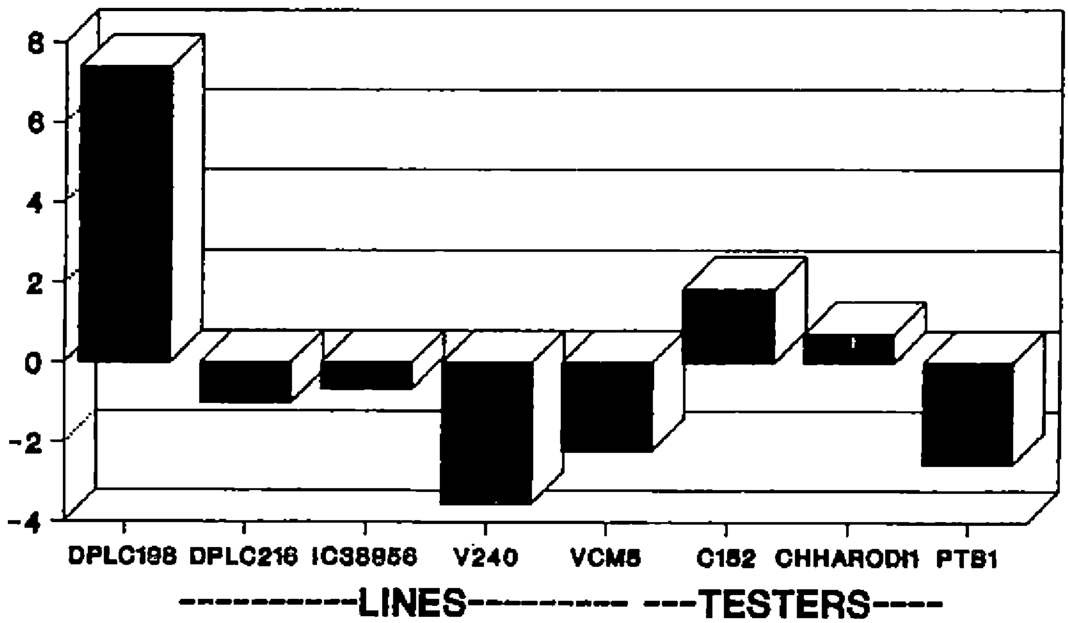
Table 9. General and specific combining ability for number of pods / plants

		Testers		
		C-152	Chharodi-1	Kanakamany
Lines	gca effects	1.831	0.718	-2.549
		sca effects		
DPLC-198	7.376**	5.791*	-4.196	-1.596
DPLC-216	-1.002	-0.431	0.116	0.316
IC-38956	-0.647	-1.853	3.260	-1.407
V-240	-3.536*	-2.564	2.316	0.249
VCM-8	-2.191	-0.942	-1.496	2.438

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

	SE	CD 5%
gca line	= 1.6340	3.294
gca tester	= 1.2657	2.552
sca	= 2.8302	5.706

GENERAL COMBINING ABILITY
NO OF PODS/PLANT



CD 5% LINE 3.284 TESTER 2.552
SE LINE 1.6340 TESTER 1.2657

Fig 9

SPECIFIC COMBINING ABILITY
NO OF PODS/PLANT

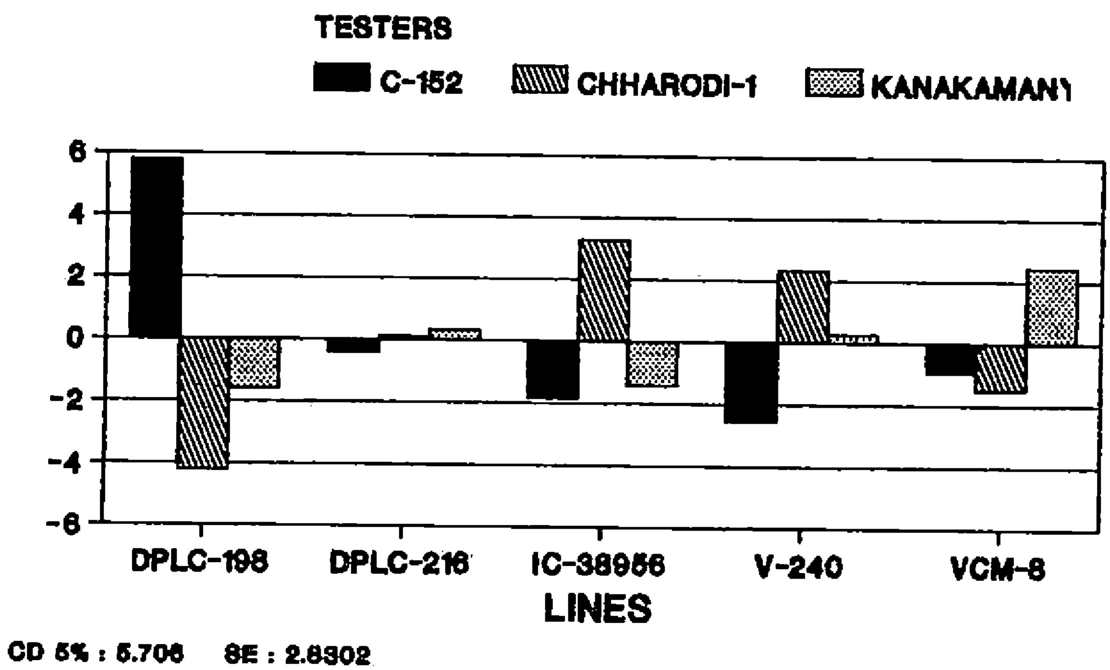


Fig 10

sca in fig. 10. The ratio of variance due to gca to variance due to sca was less than one (0.46 when F=0) suggesting that the character is controlled by non-additive gene action.

Number of seeds per pod differed significantly among lines and testers. gca effect was found to be significant among lines in DPLC-198 (-1.06) and V-240 (1.53). VCM-8 showed positive gca effect (0.73) while others showed negative gca effects. Among the testers all except Kanakamany showed significant gca effects. Significant positive gca effect was shown by the tester C-152 (1.51) while significant negative gca effect was shown by the tester Chharodi-1 (-1.05). The sca effects were found to be non significant. Out fifteen hybrids only six showed negative effects. The gca and sca effects for number of seeds per pod is given in the table 10. The gca is represented graphically in fig. 11 and sca in fig.12. The ratio of variance due to gca to sca showed a value greater than one (1.08 when F=0) suggesting that the character is under the control of additive gene action.

Hundred seed weight varied significantly among lines and testers. Among testers C-152 and Chharodi-1 showed negative gca effects while it was significant and positive for Kanakamany (2.26). Significant negative gca effect was recorded by Chharodi-1 (-2.22). All the lines

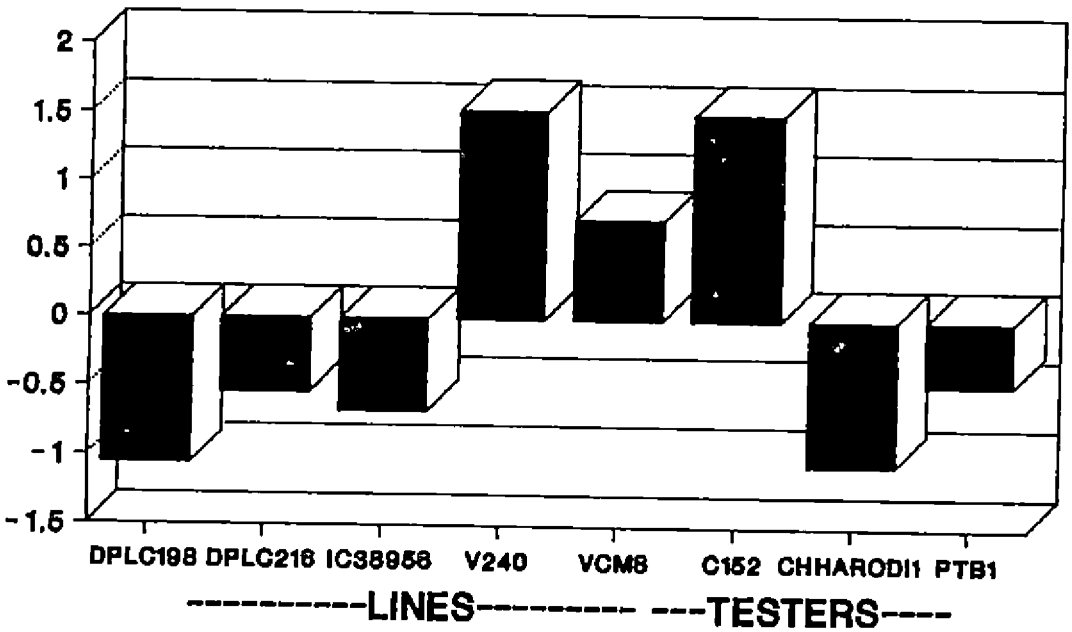
Table 10. General and specific combining ability for number of seeds/pod

		Testers		
		C-152	Chharodi-1	Kanakamany
Lines	gca effects	1.507**	-1.047**	-0.460
		sca effects		
DPLC-198	-1.058**	-0.129	0.458	-0.329
DPLC-216	-0.536	0.049	-0.731	0.682
IC-38956	-0.669	-0.418	0.202	0.216
V-240	1.531**	0.116	0.002	-0.118
VCM-8	0.731	0.382	0.069	-0.451

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

	SE	CD 5%
gca line	= 0.3920	0.790
gca tester	= 0.3036	0.612
sca	= 0.6789	1.369

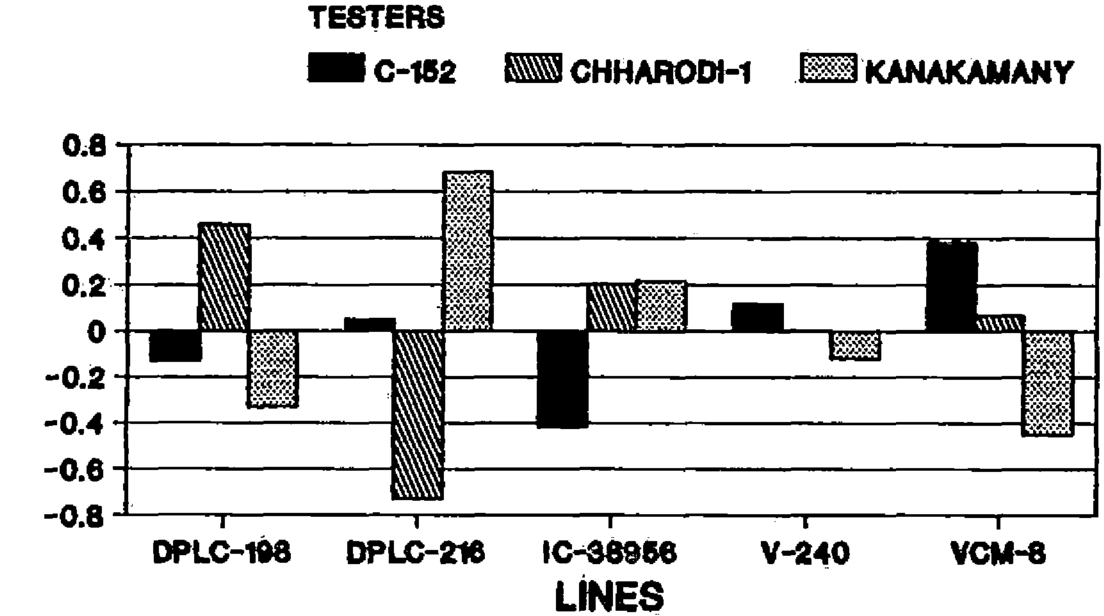
GENERAL COMBINING ABILITY
NO OF SEEDS/POD



CD 5% LINE 0.780 TESTER 0.612
SE LINE 0.3920 TESTER 0.3036

Fig 11

SPECIFIC COMBINING ABILITY
NO OF SEEDS/POD



CD 5% : 1.369 SE : 0.6769

Fig 12

showed significant gca effect DPLC-198 and DPLC-216 showed positive gca effects while others showed negative effects. Highly significant positive gca effect was shown by DPLC-198 (1.29) and highly significant negative gca effect was shown by IC-38956 (-0.84). None of the sca effect were found to be significant. Eight hybrids showed negative sca effects. Highly negative sca effect was shown by the hybrid VCM-8 x Chharodi-1 (-0.67) while highest positive sca effect was shown by the hybrid VCM-8 x C-152 (0.83). The gca and sca effects of hundred seed weight is presented in the table 11. The gca is represented graphically in fig. 13 and sca in fig.14. The ratio of variance due to gca and sca (5.17 when F=0) suggests that hundred seed weight was controlled primarily by the additive gene action.

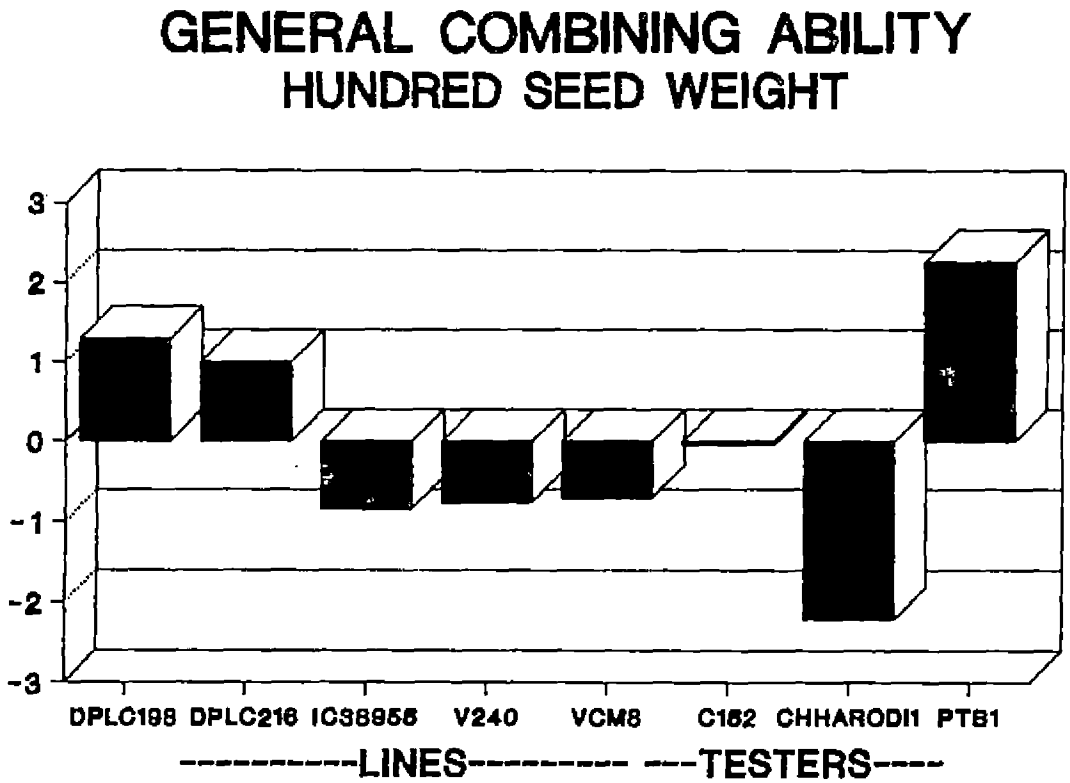
Duration upto maturity differed significantly among lines, testers and F_1s'. All the testers differed significantly in their gca effect. The highest gca effect was shown by Kanakamany (9.93). C-152 and Chharodi-1 showed significant negative gca effects of -3.67 and -6.27 respectively. Among lines IC-38956 (-1.38) and VCM-8 (-5.27) showed negative gca effects. The highest gca effect was shown by the line V-240 (2.29). Of the fifteen hybrids eight were having negative sca effects. The highest sca effect was shown by the hybrid IC-38956 x Kanakamany (4.18). The highest negative sca effect was shown by DPLC-198 x

Table 11. General and specific combining ability for hundred seed weight

Lines	gca effects	Testers		
		C-152	Chharodi-1	Kanakamany
		-0.045	-2.218**	2.263**
		sca effects		
DPLC-198	1.294**	0.209	0.259	-0.468
DPLC-216	0.998**	-0.609	0.281	0.327
IC-38956	-0.841**	-0.296	-0.180	0.476
V-240	-0.755**	-0.135	0.308	-0.173
VCM-8	-0.695*	0.832	-0.668	-0.163

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

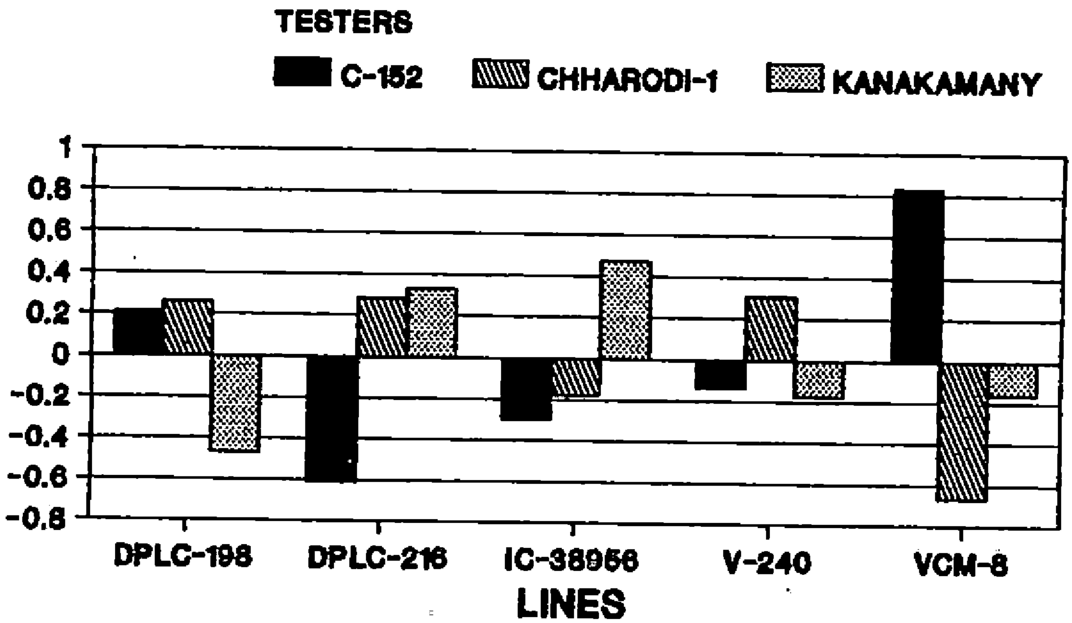
	SE	CD 5%
gca line	= 0.2754	0.555
gca tester	= 0.2133	0.430
sca	= 0.4769	0.961



CD 5% LINE 0.555 TESTER 0.430
SE LINE 0.2754 TESTER 0.2133

Fig 13

SPECIFIC COMBINING ABILITY
HUNDRED SEED WEIGHT



CD 5% : 0.961 SE : 0.4769

Fig 14

Kanakamany (-5.71). The hybrids DPLC-198 x C-152 (4.89), VCM-8 x Chharodi-1 (2.6), DPLC-216 x Kanakamany (3.62) and IC-38956 x Kanakamany (4.18) recorded significant positive sca effects while IC-38956 x Chharodi-1 (-3.29), DPLC-198 x Kanakamany (-5.71) and VCM-8 x Kanakamany (-2.6) showed significant negative sca effects. The ratio of variance due to gca to sca is less than one (0.45 when F=0) indicating non-additive gene action. The gca and sca effects of parents and hybrids for duration upto maturity is presented in the table 12. The gca is represented graphically in fig. 15 and sca in fig.16.

Grain yield per plant varied significantly among lines, testers and line x tester. All lines except DPLC-198 showed negative gca effect DPLC-198 (7.51) and DPLC-216 (-3.19) showed significant gca effect. Among testers gca effects were significant for C-152 (3.5) and Chharodi-1 (-3.91) among hybrids DPLC-198 x C-152 (7.07) and DPLC-198 x Chharodi-1 (-6.18) showed significant sca effects. Among the hybrids eight hybrids showed negative sca. The gca and sca effects for this character is shown in the table 13. The gca is represented graphically in fig. 17 and sca in fig.18. The ratio of variance due to gca to sca showed a value less than one (0.18 when F=0) indicating that this character is under the control of non-additive gene action.

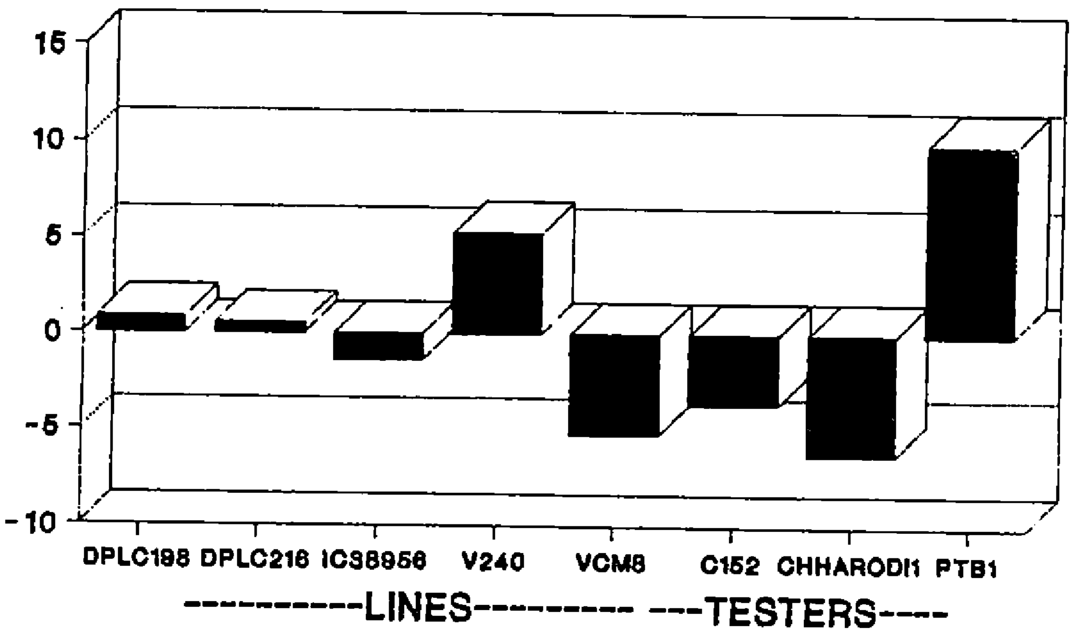
Table 12. General and specific combining ability for duration upto maturity

		Testers		
		C-152	Chharodi-1	Kanakamany
Lines	gca effects	-3.667**	-6.267**	9.933**
		sca effects		
DPLC-198	0.844	4.819**	0.822	-5.711**
DPLC-216	0.511	-2.111	-1.511	3.622**
IC-38956	-1.378	-0.889	-3.289*	4.178**
V-240	5.298**	-1.889	1.378	0.511
VCM-8	-5.267**	-0.000008	2.600*	-2.600*

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

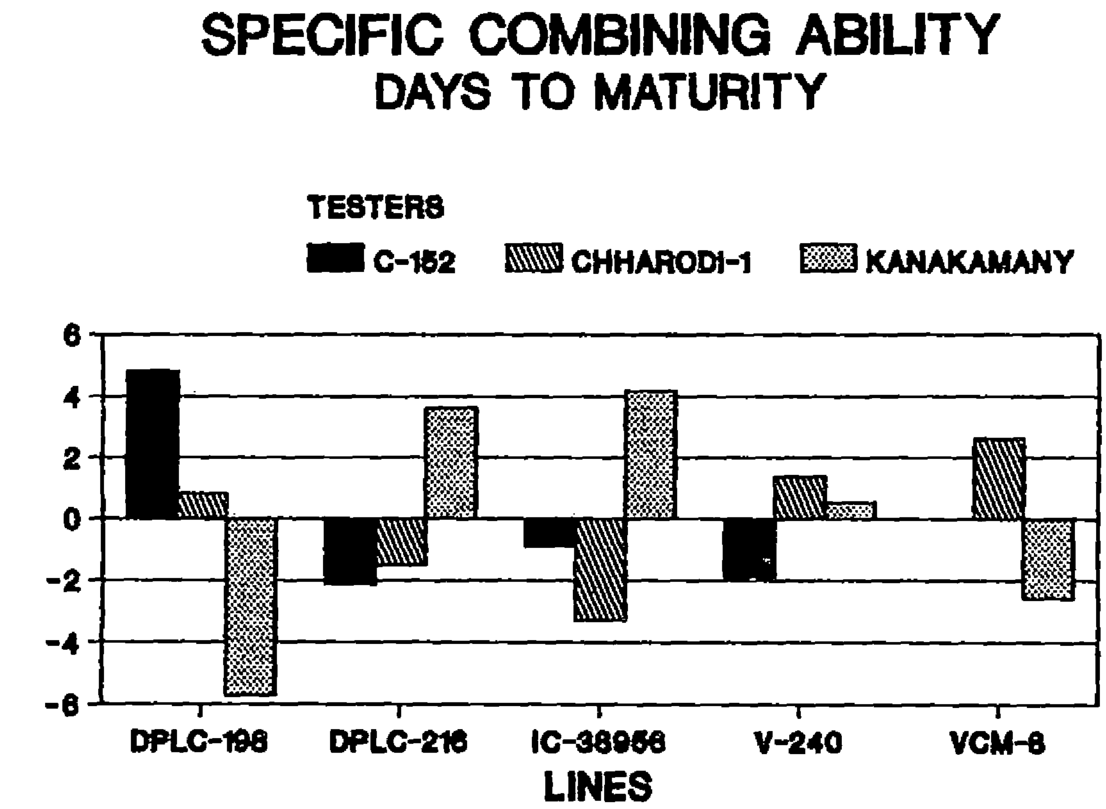
	SE	CD 5%
gca line	= 0.7069	1.425
gca tester	= 0.5475	1.104
sca	= 1.2244	2.468

GENERAL COMBINING ABILITY
DAYS TO MATURITY



CD 5% LINE 1.425 TESTER 1.104
SE LINE 0.7069 TESTER 0.5475

Fig 15



CD 5% : 2.468 SE : 1.2244

Fig 16

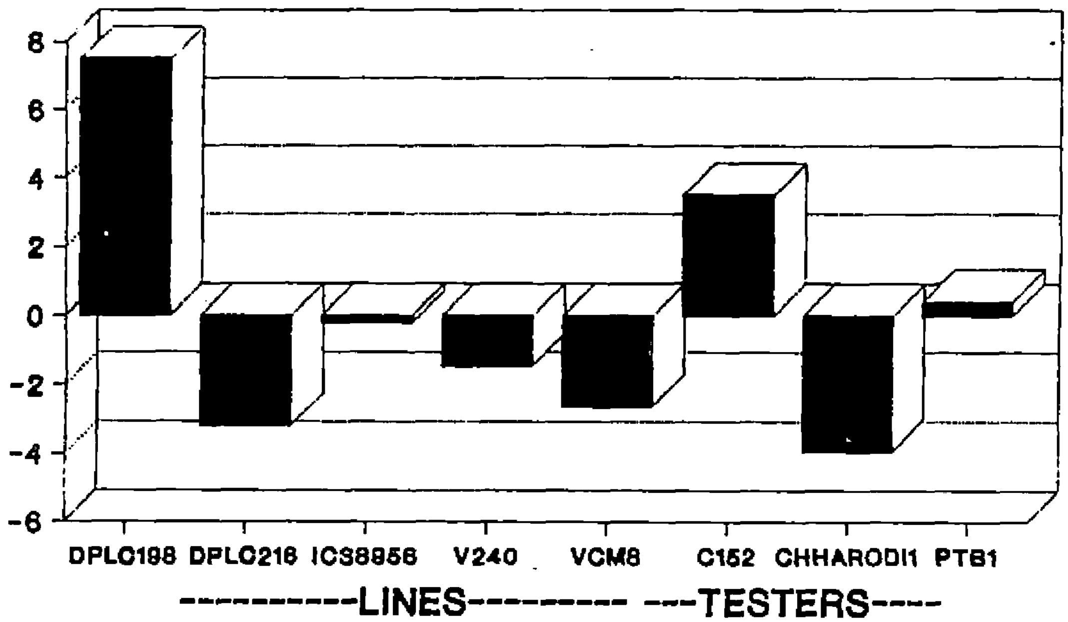
Table 13. General and specific combining ability for Grain yeild per plant

		Testers		
		C-152	Chharodi-1	Kanakamany
Lines	gca effects	3.504**	- 913**	0.410
		sca ffects		
DPLC-198	7.512**	7.071**	- 179*	-0.892
DPLC-216	-3.191*	-0.892	191	-0.298
IC-38956	-0.219	-4.115	4.052	0.063
V-240	-1.469	-1.948	1.635	0.313
VCM-8	-2.634	-0.116	-0.699	0.815

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

	SE	CD 5%
gca line	= 1.3602	2.742
gca tester	= 1.0536	2.124
sca	= 2.3560	4.750

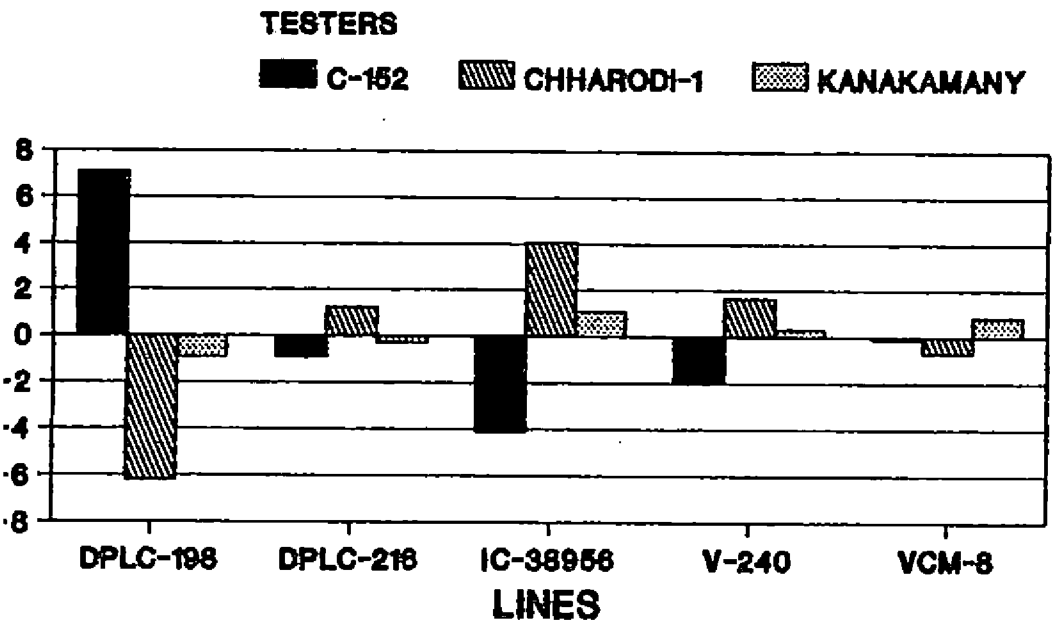
GENERAL COMBINING ABILITY
GRAIN YIELD/PLANT



CD 5% LINE 2.742 TESTER 2.124
SE LINE 1.3602 TESTER 1.0536

Fig 17

SPECIFIC COMBINING ABILITY
GRAIN YIELD/PLANT



CD 5% : 4.750   SE : 2.3560

Fig 18

Biological yield differed significantly among lines, testers and line x tester. The highest gca was shown by C-152 (4.31). The lowest negative gca was shown by Chharodi-1 (-7.49). Among lines all except DPLC-198 and IC-38956 showed negative gca effects. The gca effect was significant for DPLC-198 (10.51) and DPLC-216 (-5.21). Specific combining ability effect of six hybrids were found to be negative. The hybrid DPLC-198 x C-152 (7.31) and DPLC-198 x Chharodi-1 (-8.27) had significantly different sca effects. The gca and sca effects for biological yield is given in the table 14. The gca is represented graphically in fig. 19 and sca in fig. 20. The ratio of variance due to gca to sca was less than one (0.31 when F=0) suggesting importance of non-additive gene action. The best lines, testers and hybrids based on the general and specific combining abilities of ten characters are presented in the table 15.

Proportional contribution

The proportional contributions of lines testers and line x tester for characters under study are presented in the table 16.

The proportional contribution of lines to the duration up to first flowering was the highest (48.20) while the contribution of tester and line x tester were almost equal being 27.38 and 24.42 respectively.

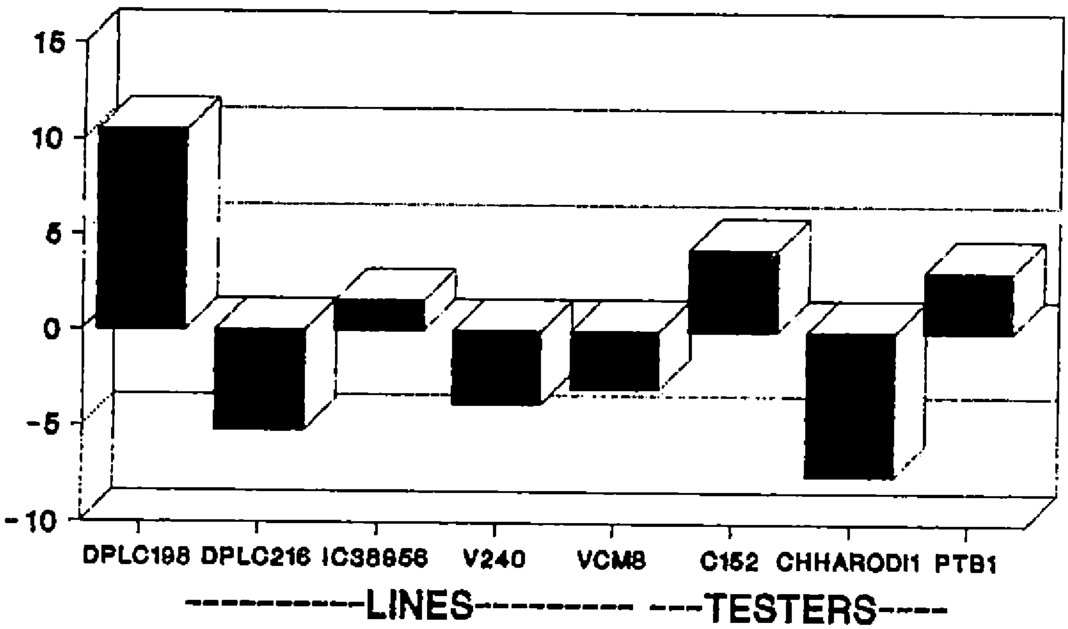
Table 14. General and specific combining ability for Biological yield

		Testers		
		C-152	Chharodi-1	Kanakamany
Lines	gca effects	4.312**	-7.490**	3.177*
		sca effects		
DPLC-198	10.513*	7.315*	-8.275*	0.960
DPLC-216	-5.206*	0.564	2.354	-2.918
IC-38956	1.568	-6.464	4.670	1.793
V-240	-3.829	-1.767	3.969	-2.202
VCM-8	-3.046	0.352	-3.719	2.367

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

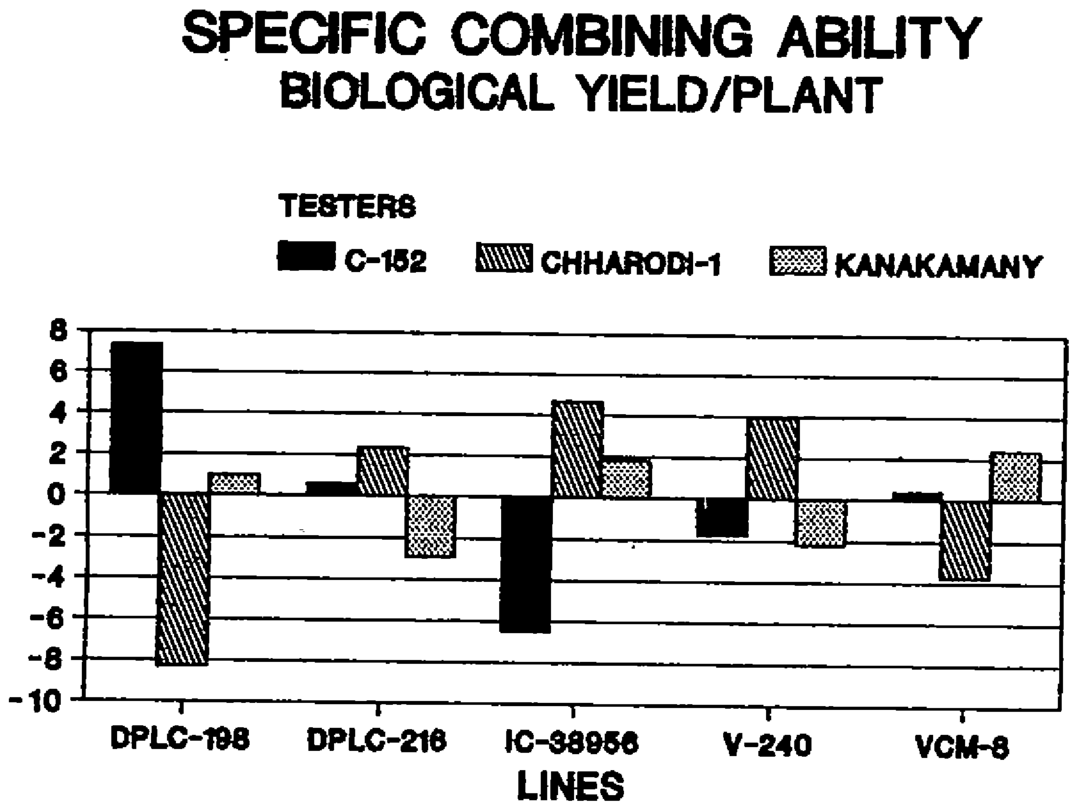
	SE	CD 5%
gca line	= 1.9890	4.010
gca tester	= 1.5407	3.106
sca	= 3.4451	6.945

GENERAL COMBINING ABILITY
BIOLOGICAL YIELD



CD 5% LINE 4.010 TESTER 3.108
SE LINE 1.9890 TESTER 1.5407

Fig 19



CD 5% : 6.945   SE : 3.4461

Fig 20

Table 15. Best lines, testers and hybrids based on combining ability

Characters	Best lines	Best testers	Best hybrids
Duration upto flowering	IC-38956	Chharodi-1	DPLC-198 x Chharodi-1 IC-38956 x C-152
Leaf area index	DPLC-198	C-152	DPLC-216 x Chharodi-1 VCM-8 x Chharodi-1
Proline content	DPLC-216	Chharodi-1	IC-38956 x C-152 V-240 x Chharodi-1
Grain filling period	DPLC-198	Kanakamany	DPLC-216 x C-152 VCM-8 x Chharodi-1
Number of pods/plant	DPLC-198	C-152	DPLC-198 x C-152 IC-38956 x Chharodi-1
Number of seeds/pod	V-240	C-152	DPLC-216 x Kanakamany DPLC-198 x Chharodi-1
Hundred seed weight	DPLC-198	Kanakamany	VCM-8 x C-152 IC-38956 x Kanakamany
Duration upto maturity	VCM-8	Chharodi-1	DPLC-198 x Kanakamany IC-38956 x Chharodi-1
Grain yield	DPLC-198	C-152	DPLC-198 x C-152 IC-38956 x Chharodi-1
Biological yield	DPLC-198	C-152	DPLC-198 x C-152 IC-38956 x Chharodi-1

Table 16. Proportional contributions of lines, testers and line x tester for ten characters towards the total variance.

Characters	Proportional contributions (%)		
	Lines	Testers	line x tester
Duration upto flowering	48.20	27.38	24.42
leaf area index at vegetative period	69.55	13.73	16.72
Proline content	19.35	5.68	74.97
Grain filling period	80.30	17.54	2.16
Number of pods per plant	60.55	14.31	25.14
Number of seeds per pod	41.68	52.51	5.81
Hundred seed weight	20.13	76.02	3.85
Duration upto maturity	16.61	71.54	11.85
Grain yield	45.60	27.84	26.56
Biological yield	42.53	36.64	20.83

Lines were the major components contributing to the total variance in leaf area index at vegetative period (69.55). The lowest contribution was from testers (13.73) while line x tester contributed 16.72.

The proportional contributions of lines, testers and line x tester for duration up to first flowering and leaf area index are pictorially represented in fig. 21.

The contribution of lines towards the total variance for proline content was 19.35. The highest contribution was made by line x tester (74.97) while the tester contributed the least (5.68).

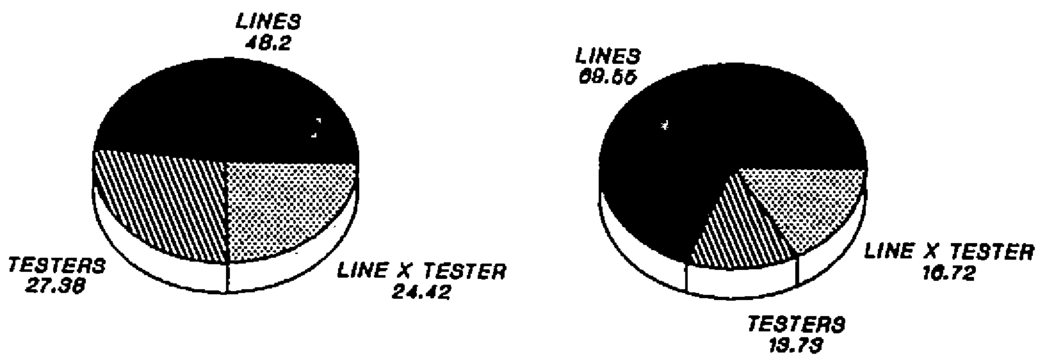
The variance of grain filling period was mainly due to the contribution from lines (80.30). Testers contributed 17.54 whereas the line x tester has the least contribution of 2.16.

The proportional contributions of lines, testers and line x tester for proline content and grain filling period are pictorially represented in fig. 22.

The variance of number of pods per plant was mainly contributed by lines (60.55). The contribution of line x tester was 25.14 and that of the testers was 14.31.

The proportional contributions of lines to number of seeds per pod was less than that of the testers. The

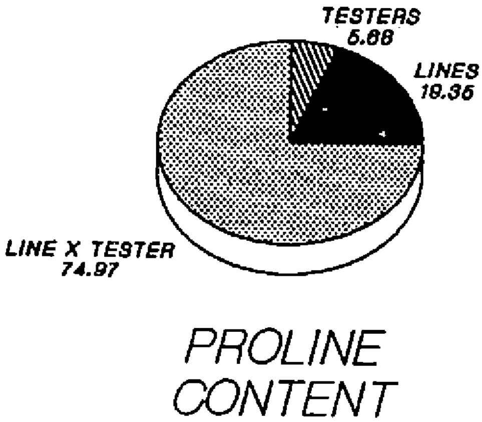
PROPORTIONAL CONTRIBUTIONS OF LINES TESTERS AND LINE X TESTER TO TOTAL VARIANCE (%)



DAYS TO FLOWER LEAF AREA INDEX

Fig 21

PROPORTIONAL CONTRIBUTIONS OF LINES TESTERS AND LINE X TESTER TO TOTAL VARIANCE (%)



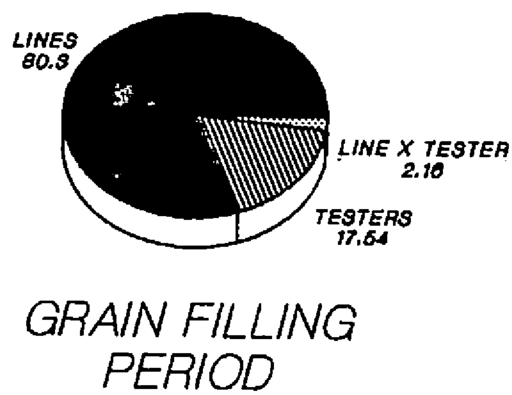


Fig 22

testers contributed 52.51 while lines contributed 41.68 and line x tester 5.81.

The proportional contributions of lines, testers and line x tester for number of pods per plant and number of seed per pod are pictorially represented in fig. 23.

The contribution of testers for the variance of hundred seed weight was 76.02. The lines contributed 20.13 and line x tester 3.85. Variance of duration up to maturity was also maximum for testers (71.54). Lines contributed 16.61 and line x tester 11.85.

The proportional contributions of lines, testers and line x tester for hundred seed weight and duration up to maturity are pictorially represented in fig. 24.

The proportional contribution of lines to grain yield per plant was high (45.60) testers and line x tester contributed almost equally, their contribution being 27.84 and 26.56 respectively.

Lines contributed maximum to biological yield (42.53). The contribution of testers was 36.64 and that of line x testers was 20.83.

The proportional contributions of lines, testers and line x tester for grain yield per plant and biological yield are pictorially represented in fig. 25.

PROPORTIONAL CONTRIBUTIONS OF LINES TESTERS AND LINE X TESTER TO TOTAL VARIANCE (%)

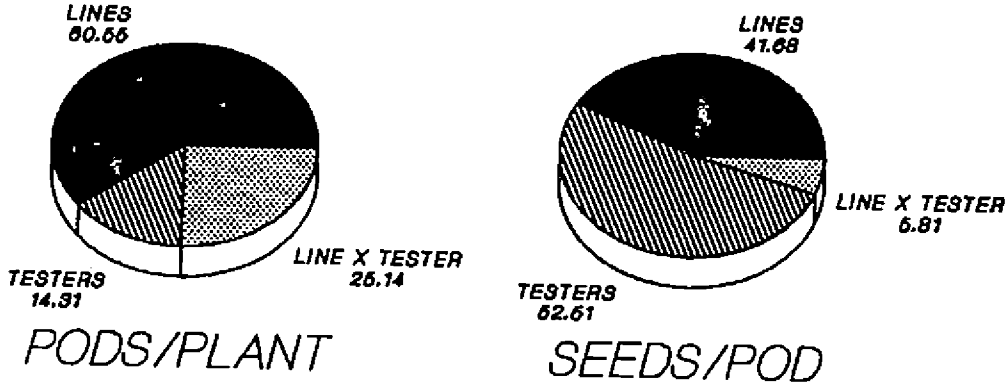


Fig 23

PROPORTIONAL CONTRIBUTIONS OF LINES TESTERS AND LINE X TESTER TO TOTAL VARIANCE (%)

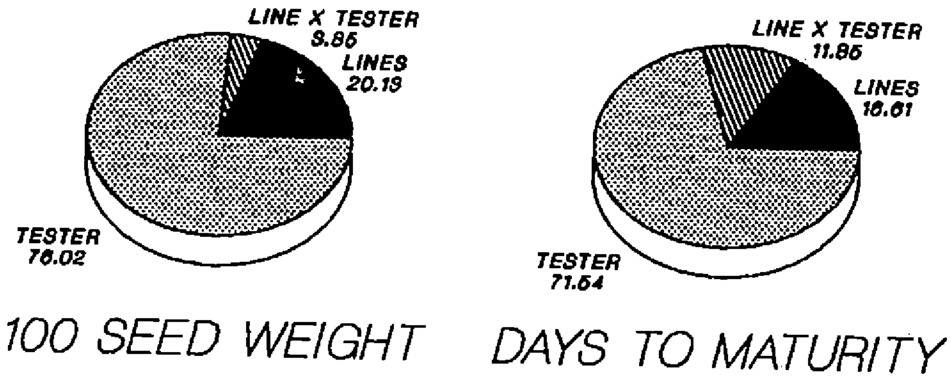


Fig 24

PROPORTIONAL CONTRIBUTIONS OF LINES TESTERS AND LINE X TESTER TO TOTAL VARIANCE (%)

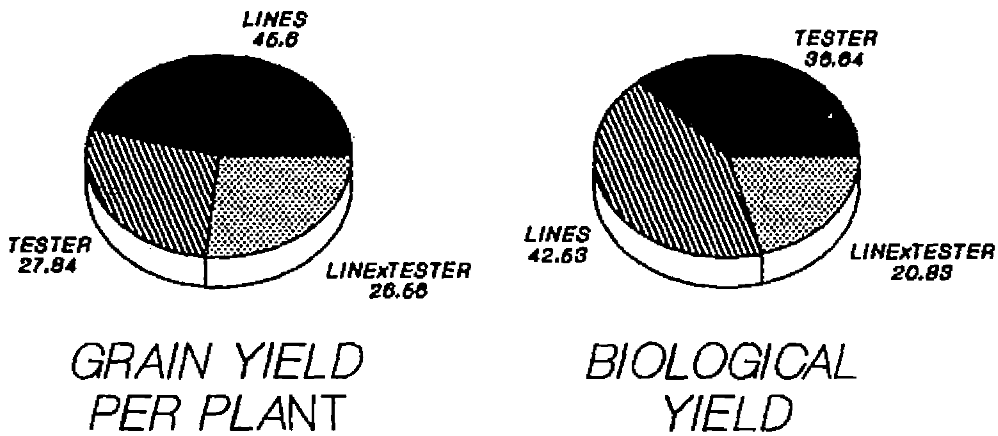


Fig 25

DISCUSSION

DISCUSSION

Combining ability analysis is aimed at getting informations about the general combining ability of parents and the specific combining ability of hybrids. These informations are helpful in selecting materials for the recombination or population breeding programme. The concept of combining ability was first proposed by Sprague and Tatum (1942) and attributed gca to additive gene action and sca to dominance deviation and epistatic interaction. The combining ability studies reveal the nature of gene action governing the character which is important in designing a breeding programme. The commonly used methods to estimate gca, sca and gene action are diallel analysis and line x tester analysis. The line x tester analysis proposed by Kempthorne (1957) has some advantage over diallel analysis. Line x tester analysis is designed in such a way to avoid the interactions among males and females which is usually unnecessary. It has also got another advantage of lower number of cross combinations compared to diallel analysis without affecting the reliability of the information required Reduction in number of crosses is helpful in the case of self pollinated crops like cowpea where artificial hybridization is difficult.

Analysis of variance showed that there was no significant difference between the genotypes for the traits like root length at harvest period, root shoot ratio at vegetative period, stomatal distribution and harvest index. On further analysis there were no significant differences (Appendix i and ii) among the crosses for the root spread at harvest period. Hence the above characters were excluded from the line x tester analysis. The line x tester analysis was done using the characters duration up to first flowering, leaf area index at vegetative period, proline content, grain filling period, number of pods per plant, number of seeds per pod, hundred seed weight, duration up to maturity, grain yield per plant and biological yield.

Analysis of variance for soil moisture taken at weekly intervals did not show any significant differences indicating that the water content in the field was uniform for all the treatments through out the crop growth period.

Duration up to flowering

Duration up to flowering had significant mean sum of squares due to lines, testers and line x tester. Significant gca and sca variance were observed for this character indicating that additive and non-additive genetic components were important for the expression of this trait. But the ratio of $\sigma^2 A$ to $\sigma^2 D$ is less than unity suggesting a predominant role of non-additive gene action. In agreement to this non-additive gene action was reported earlier by Deshmukh and Manjare (1980) in green gram, Singh *et al*. (1986) in lablab bean, Katiyar *et al*. (1987) in pea, and contrary to this a preponderance of additive gene action was reported in pea (Dubey and Lal, 1983), chickpea (Salimath and Bahl, 1985; Yadavendra and Sudhirkumar, 1987 and katiyar *et al*.,1988) and in pigeon pea (Mehetre *et al*., 1988). Wilson *et al*. (1985) reported that in greengram only additive gene action was involved in the expression of duration up to flowering. However in chickpea Mandal and Bahl (1987) observed that sca alone was significant for this trait.

The estimates of combining ability revealed that the line IC-38956 and the tester Chharodi-1 showed significant negative gca effects. Maximum positive gca effects were shown by the line V-240 and the tester Kanakamany. Significant negative sca effects were shown by the hybrids DPLC-198 x Chharodi-1 and IC-38956 x C-152.

Both hybrids involved parents one with positive and one with negative general combining ability. The next best cross combination was V-240 x Kanakamany where both the parents were positive general combiners. Hence the best specific combinations for earliness to flower involved positive x negative and positive x positive general combiners. Out of the six hybrids that showed shorter duration for flowering three involved parents which were positive x negative and three positive x positive general combiners. Since the character is predominantly under the control of non-additive gene action combination breeding will be helpful for the improvement.

Leaf area index

Leaf area index at vegetative period recorded significant mean sum of squres due to lines and testers where as that due to line x tester was not significant. This indicates the importance of gca alone for this character. The ratio of $\sigma^2 A$ to $\sigma^2 D$ was more than unity indicating that this character was under the control of additive gene action. Non-additive gene action reported for leaf area index in chickpea by Deshmukh and Bhapkar (1982 a & b) are contrary to the present findings. In sesamum Reddy and Haripriya (1990) have reported additive gene action in addition to non-additive gene action.

Line DPLC-198 showed significant and positive gca in the estimation of combining ability effects: Among the testers C-152 and Kanakamany showed positive but non significant gca. No hybrids showed significant sca. Highest positive sca was shown by DPLC-216 x Chharodi-1 which involved both parents showing negative general combining ability. This hybrid was followed by VCM-8 x C-152 and IC-38956 x Chharodi-1 of which the former had one positively and one negatively combining parents while the latter had negatively combining parents. Hence the best specific combinations for high leaf area index involved negative x negative and positive x negative general combiners. Out of the eight hybrids which had positive sca five had parents which are negative x negative two had positive x negative and one had positive x positive combiners. Since this character is under the control of additive gene action selection will be helpful for the improvement.

Proline content

A significant mean sum of squres due to line x tester was recorded for proline content while that due to lines and testers were not significant, indicating the significance of sca alone. The ratio of $\sigma^2 A$ to $\sigma^2 D$ was less than unity suggesting a non-additive gene action. No literature was found to support the results.

Analysis of combining ability effects revealed that all the lines except DPLC-216 showed negative non significant gca. DPLC-216 showed positive significant gca. All the testers except chharodi-1 showed negative non-significant gca effects. Three hybrids showed significant negative sca.

They were IC-38956 x C-152, the hybrid of negative x negative general combiners and V 240 x chharodi-1 and DPLC-216 x Kanakamany both being the hybrid of positive x negative general combiners. So the best specific combinations for low proline content involved negative x negative and positive x negative general combiners. Out of the seven hybrids which had negative sca three involved negative x negative, three positive x negative and one positive x positive general combiners. Since proline content is under the control of non-additive gene action combination breeding will help in the improvement.

Grain filling period

A significant mean sum of squres due to lines, testers, and line x tester were recorded for grain filling period indicating significant gca and sca variances and the involvement of additive and non-additive genetic components in the expression of this trait. The ratio of $\sigma^2 A$ to $\sigma^2 D$ was greater than unity indicating the predominant role of additive gene action. No literature was found to support the results.

The estimates of combining ability effects revealed that all lines showed significant gca. The lines DPLC-198 and DPLC-216 had positive and significant gca. All testers except Kanakamany had significant negative gca. Kanakamany showed significant positive gca. Significant positive sca were shown by three hybrids viz. DPLC-216 x C-152, DPLC-216 x Kanakamany and VCM-8 x Chharodi-1. Highest sca effect was shown by DPLC-216 x C-152 the parents of which were one positive and one negative general combiners. The parents of the cross DPLC-216 x Kanakamany were positive combiners, while the parents of VCM-8 x Chharodi-1 were negative combiners. Hence the best specific combinations for high grain filling period involved negative x positive, positive x positive and negative x negative general combiners. Of the ten hybrids which had positive sca four involved parents with positive x negative general combining ability, four negative x negative and two positive x positive general combining ability. Selection will be helpful for improvement since grain filling period is under the control of additive gene action.

Number of pods per plant

Number of pods per plant recorded a significant mean sum of squres due to lines. While that due to testers and line x testers were non-significant. This indicates a significant gca variance. The ratio of σ^2_A to σ^2_D was less than unity indicating the importance of non-additive gene action. Importance of non-additive gene action for number of pods per plant were reported by Thiyagarajan et al. (1990) in cowpea, Deshmukh and manjare (1980) in green gram and Pande *et al*. (1979) and Yadavendra and Sudhirkumar (1987) in chickpea in agreement to the present findings. Contrary to this preponderance of additive gene action was reported by Chauhan and Joshi (1981) in cowpea Venkateswarlu and Singh (1982 a) and Patel *et al*. (1987) in pigeonpea, Dubey and lal (1983) in pea Wilson *et al*. (1985) and Saxena and Sharma (1989 and 1992) in green gram and katiyar *et al*. (1988) in chick pea.

Estimates of combining ability revealed that the line DPLC-198 showed significant positive gca. Hence DPLC-198 is the best general combiner for the number of pods per plant. Non significant positive gca were recorded by testers C-152 and Chharodi-1. significant positive sca effect was recorded by DPLC- 198 x C-152 which involved parents with positive general combining ability. This was followed by IC-38956 x Chharodi-1 and V240 x Chharodi-1 both had positive non-significant sca. Both these hybrids involved positive x negative general combining parents. Hence the best specific combination for more number of pods per plant involved positive x positive and positive x negative general combiners. Out of the seven hybrid which had positive sca, one involved positive x positive, five positive x negative and one negative x negative general combiners.

Number of pods per plant is found to be under the control of non-additive gene action. so for the improvement of this character combination breeding can be adopted.

Number of seeds per pod

A significant mean sum of squres due to lines and testers were found for number of seeds per pod. mean sum of squres due to line x tester was not significant indicating that gca alone was important for this character. The ratio of $\sigma^2 A$ to $\sigma^2 D$ was found to be greater than one suggesting additive gene action.

Additive gene action for number of seeds per pod suggested by Chauhan and Joshi (1981) and Thiyagarajan (1992) in cowpea, Wilson et al. (1985) and Saxena and Sharma (1989 and 1992) in greengram, Malhotra (1983) in black gram, Venkateswarlu and Singh (1982 b) and Dubey and Lal (1983) in peas, Venkateswarlu and Singh (1982 a) in pigeon pea and Katiyar et al. (1988) in chickpea are in conformity to the present results. Contrary to the present findings non-additive gene action was reported by Deshmukh and Manjare (1980) in green gram, Yadavendra and Sudhirkumar (1987) in peas and Pande et al. (1979) in chick pea.

Analysis of combining ability revealed that the line V-240 and the tester C-152 recorded significant positive gca effects. The varieties V-240 and C-152 are the best general combiners for number of seeds per pod. Significant negative gca effects were shown by the line DPLC-198 and the tester Chharodi-1. No hybrids showed significant sca effects. High sca estimates were recorded by DPLC-216 x Kanakamany, DPLC-198 x Chharodi-1 and VCM-8 x C-152.

First two hybrids involved parents with negative general combining ability, while the third involved parents with positive general combining ability. Hence the best specific combinations for more number of seeds per pod involved negative x negative and positive x positive general combiners. Among the nine hybrids which had positive sca effects four hybrids resulted from the crosses between parents which are negative x negative combiners, three hybrids resulted from the parents with positive and negative gca effects and two from parents with positive and positive gca effects. Since the number of seeds per pod is under the control of additive gene action improvement of this character through selection is possible.

Hundred seed weight

Hundred seed weight showed significant mean sum of squres due to lines and testers whereas that due to line x tester was non-significant. This indicated the importance of gca alone for this character. The ratio of $\sigma^2 A$ to $\sigma^2 D$ was more than unity indicating that the character is under the control of additive gene action. Additive gene action was reported for hundred seed weight by Pande et al. (1979) and Yadavendra and Sudhirkumar (1987) in chick pea, Chauhan and Joshi (1981) and Thiyagarajan (1992) in cowpea, Venkateswarlu and Singh (1982 a) and patel et al. (1987) in pigeon pea Dubey and lal (1983) in pea and Wilson et al. (1985) and Saxena and Sharma (1992) in green gram in agreement to the results of this study. Contrary to this non-additive gene action was reported by Katiyar et al. (1988) in chickpea, Thiyagarajan et al. (1990) in cowpea and Sandhu et al. (1981) in black gram. But Malhotra (1983) in black gram reported both additive and non-additive gene action for hundred seed weight.

The estimates of combining ability revealed that the line DPLC-198 and DPLC-216 had significant positive gca effect, while others had significant negative gca effect. Among the testers Kanakamany recorded significant positive gca. The sca effects of hybrids were found to be non-significant. High sca estimates were recorded by VCM-8 x C-152 and IC-38956 x Kanakamany. The former involved negatively combining parents while the latter involved one negatively combining and one positively combining parent. Hence the best specific combinations for high hundred seed weight involved negative x negative and positive x negative general combiners. Out of the seven hybrids which had positive sca five hybrids resulted from the parents which are positive x negative combiners, one hybrid resulted from negative x negative combiners and one from positive x positive combining parents. Since hundred seed weight is under the control of additive gene action the improvement of this character can be done by selection.

Duration up to maturity

Duration up to maturity had significant mean sum of squres due to lines, testers and line x tester. This indicate significant gca and sca variances and involvement of both additive and non-additive gene action for the expression of this trait. The ratio of σ^2_A to σ^2_D is less than unity suggesting the predominant role of non-additive gene action. The results 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 Patel et al. (1987) in pigeon pea were in conformity to the present findings. Contrary to this importance of additive gene action was reported earlier by Chauhan and Joshi (1981) and Thiyagarajan (1992) in cowpea, Wilson et al. (1985) in green gram, Yadavendra and Sudhirkumar (1987) in chickpea and mehetre et al. (1988) in pigeon pea.

Lines VCM-8 and V-240 had significant negative and positive gca effects respectively in the combining ability analysis. Among the testers Chharodi-1 and C-152 showed significant negative sca effects. The varieties V-240 and Kanakamany are the best general combiners for duration up to maturity. Kanakamany showed significant positive gca effect. Significant negative sca effects were recorded by the hybrids DPLC-198 x Kanakamany, IC-38956 x Chharodi-1 and VCM-8 x Kanakamany. Both the parents involved in the cross IC-38956 x Chharodi-1 had negative combining abilities. The cross VCM-8 x Kanakamany had parents with positive x negative general combiners. Hence the combinations for less duration up to maturity involved positive x positive, negative x negative and positive x negative general combiners. Out of eight hybrids which showed negative sca four involved parents which are positive x negative combiners, three involved negative x negative and one involved positive x positive combiners. Since this character is predominantly under the control of non-additive gene action combination breeding would be helpful for the improvement.

Grain Yield per plant

Grain yield per plant had significant mean sum of squres due to lines, testers and line x tester. This indicates the significance of gca and sca variances and the involvement of additive and non-additive gene action for the expression of this trait. The ratio of $\sigma^2 A$ to $\sigma^2 D$ was less than unity indicating the predominant role of non-additive gene action. In agreement to the present findings Pande et al. (1979) and Yadavendra and Sudhirkumar (1987) in chickpea, Deshmukh and Manjare (1980) in green gram, Singh et al. (1987a) in black gram and Thiyagarajan (1990) in cowpea reported non-additive gene action. Contrary to this additive gene action was reported Chauhan and Joshi (1981) and Thiyagarajan (1992) in cowpea, Wilson et al.(1985) and Saxena and Sharma (1992) in green gram, Malhotra (1989) in black gram and katiyar et al. (1988) in chickpea.

Significant positive gca effects were recorded by the line DPLC-198 and tester C-152 in the combining ability analysis indicating that DPLC-198 and C-152 are the best general combiners for gain yield per plant. Significant negative gca effects were shown by the line DPLC-216 and tester Chharodi-1. The hybrid DPLC-198 x C-152 had significant positive sca effects and DPLC-198 x Chharodi-1 had significant negative sca effects. The parents involved in the cross DPLC-198 x C-152 were significant positive general combiners for yield. IC-38956 x Chharodi-1 recorded non-significant positive sca. The parents involved in this cross were negative general combiners. Hence the best combinations for high yield involved positive x positive and negative x negative general combiners. Out of the seven hybrids that had positive sca effects three had parents which are positive x negative combiners, three had negative x negative and one had positive x positive general combiners. Since the character is predominantly under the control of non-additive gene action combination breeding would be useful for the improvement of yield.

Biological yield

Significant mean sum of squres due to lines, testers and line x tester recorded for the biological yield indicates significant gca and sca variances and the involvement of additive and non-additive genetic components in the expression of this trait. The ratio of $\sigma^2 A$ to $\sigma^2 D$ was found to be less than unity indicating the predominant role of non-additive gene action. In agreement to this non-additive gene action was reported earlier by Pande et al. (1979) and Salimath and Bahl (1989) in chick pea and Kolb et al. (1990) in spring oats. The findings of Prakash et al. (1987) in indian mustard indicates the importance of both additive and non-additive gene action in the biological yield. The estimates of combining ability revealed that the line DPLC-198 had significant positive gca and DPLC-216 had significant negative gca effects. The testers C-152 and Kanakamany recorded significant positive gca and Chharodi-1 recorded significant negative gca. Non significant positive gca was shown by the line IC-38956. The hybrid DPLC-198 x C-152 had significant positive sca. IC-38956 x Chharodi-1 had non-significant positive sca. The parents involved in the hybrid DPLC-198 x C-152 had positive general combining ability effects while the parents of hybrid IC-38956 x Chharodi-1 had positive and negative general combining ability effects. Hence the best combinations for high biological yield involved positive x positive and positive x negative general combiners. Out of the nine hybrids which had positive sca, four resulted from the parents with positive x negative effects, three resulted from positive x positive and two resulted from negative x negative general combiners. Biological yield was found to be predominantly under the control of non-additive gene action. So in the breeding programme further improvement can be made through combination breeding.

In general DPLC-198 showed significant general combining abilities for leaf are index, grain filling period, number of pods per plant, hundred seed weight, grain yield and biological yield. IC-38956 showed significant negative gca for duration up to first flowering. It also showed the lowest gca for proline content. So these two lines viz. DPLC-198 and IC-38956 can be selected for further breeding programme based on their general combining abilities. The tester C-152 showed significant gca for number of seeds per pod, duration up to maturity, grain yield and biological yield. It also showed high but non-significant gca for leaf area index and number of pods per plant. Chharodi-1 showed significant gca effects for earliness such as duration up to first flowering and duration up to maturity. So from the testers C-152 and Chharodi-1 can be selected for further breeding programme based on their general combining abilities.

Characters like root length and spread at harvest period, root shoot ratio, stomatal distribution and harvest index were found not significantly different among lines testers and hybrids. This means that lines testers and hybrids were uniform in the expression of above characters. So cross combinations were identified based on the earliness and yield.

Among the hybrids DPLC-198 x C-152 showed significant sca for grain yield, biological yield and number of pods per plant. IC-38956 x Chharodi-1 showed significant sca for duration up to maturity and high and non-significant sca for yield, biological yield and number of pods per plant. DPLC-198 x Chharodi-1 showed significant sca for duration up to first flowering and non-significant high sca for number of seeds per pod. IC-38956 x C-152 showed significant sca for duration up to first flowering and proline content. So for further improvement these hybrids viz. DPLC-198 x C-152, IC-38956 x Chharodi-1, DPLC-198 x Chharodi-1 and IC-38956 x C-152 are promising.

SUMMARY

above characters. From the combining ability estimates made on other characters it was difficult to select general combiner for all the characters considered together. Similarly no cross combination was observed to be good for all the characters.

For duration upto first flowering the best line and tester based on gca were IC-38956 and Chharodi-1 respectively. The best hybrids based on sca were f)e DPLC-198 x Chharodi-1 and IC-38956 x C-152. For leaf area index the best line was DPLC-198. There were no significant difference among gca of the testers. However C-152 recorded highest gca. The hybrids did not differ significantly for sca estimates. The cross DPLC-216 x Chharodi-1 showed the highest sca.

None of lines and testers were found significant for proline content. The lowest sca effect was shown by the line IC-39568 and tester Kanankamany. Three hybrids viz. IC-38596 x C-152, V-240 x Chharodi-1 and DPLC-216 x Kanakamany showed significant and negative sca.

Lines DPLC-198 and DPLC-216 and tester Kanakamany showed significant and positive gca and the hybrids DPLC-216 x C-152 and DPLC-216 x Kanakamany showed significant positive sca for grain filling period. For number of pods per plant, line DPLC-198 showed significant positive gca while testers showed no significance. Highest gca among testers was shown by C-152. DPLC 198 x C-152 showed significant positive sca. The line V-240 and tester C-152 showed significant positive gca while sca showed no significance for number of seeds per pod. Highest sca was shown by DPLC-216 x Kanakamany.

For hundred seed weight significant positive gca was recorded by lines DPLC-198 and DPLC-216. Among testers was Kanakamany recorded significant positive gca. The sca effect was not significant. However VCM-8 x C-152 showed highest sca. Significant and negative gca were shown by lines VCM-8 and IC-38956, testers Chharodi-1 and C-152 and sca by hybrids DPLC-198 x Kanakamany, IC-38956 x Chharodi-1 and VCM-8 x Kanakamany for duration upto maturity.

Significant positive gca was shown by the line DPLC-198 and tester C-152 for grain yield per plant. Significant positive sca was shown by DPLC-198 x C-152. Line DPLC-198 and testers C-152 and Kanakamany showed significant positive gca for biological yield. Significant positive sca for the same was shown by the hybrid DPLC-198 x C-152.

It was seen that duration upto flowering is controlled by both additive and non-additive gene action. But the ratio of σA^2 to σD^2 suggests the importance of non-additive gene action more in the control of the character. Leaf area index was found to be controlled by additive gene action. The proline content was under the control of non-additive gene action.

Grain filling period was influenced by both additive and non-additive genes. But the ratio of σA^2 to σD^2 is indicative of a comparatively stronger influence of additive genes than non-additive genes. Number of pods per plant was controlled by non-additive genes while number of seeds per pod was controlled by additive genes. Additive gene effect was also important in the case of hundred seed weight.

Duration upto maturity was controlled by both additive and non-additive genes with the preponderance of non-additive gene action. Grain yield was seen influenced more by non-additive gene action than the additive gene action since the ratio of σA^2 to σD^2 is less than unity. Biological yield was also influenced by additive and non-additive genes with a preponderance of non-additive gene action.

For the characters where additive gene action was important recurrent selection can be used for improvement. For those characters which are predominantly under the control of non-additive gene action recombination breeding is suggested. In the absence of biological feasibility for artificial pollination exploitation of heterosis is not economic as a plant improvement programme in this crop.

Lines, testers and hybrids showed uniform expression of characters such as root length and spread at harvest period, root shoot ratio, stomatal distribution and harvest index. Since a number of characters related to drought showed non significant variation selection of varieties and hybrids were done based on yield and earliness. Thus line DPLC-198 and IC-38956 and testers C-152 and Chharodi-1 were identified as good parents. The hybrids which showed high sca for yield and earliness such as DPLC-198 x C-152, IC-38956 x Chharodi-1, DPLC-198 x Chharodi-1 and IC-38956 x C-152 were also identified and recommended for further utilization.

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* Original not seen

APPENDICES

Appendix i Mean soil moisture content at weekly intervels

Treatments	14DAS	21DAS	28DAS	35DAS	42DAS	49DAS	56DAS	63DAS
DPLC-198	9.52	7.52	6.84	6.80	6.55	5.55	5.12	6.01
DPLC-216	9.36	7.72	7.61	6.85	6.77	6.00	5.43	6.11
IC-38956	9.37	7.81	7.90	7.00	6.34	5.80	5.41	6.34
V-240	9.43	9.34	6.49	6.31	5.57	5.96	5.37	6.03
VCM-8	9.89	7.50	6.46	7.77	5.93	5.85	5.54	6.09
C-152	8.84	7.15	7.02	7.22	6.62	6.32	5.61	5.88
Chharodi-1	8.94	7.37	7.11	6.89	7.19	6.38	6.13	6.05
Kanakamany	9.42	7.68	7.40	6.33	6.94	5.45	6.14	6.15
DPLC-198xC-152	9.37	7.38	7.59	6.31	6.19	5.39	6.11	5.79
DPLC-198xChharodi-1	10.34	7.48	6.82	7.86	6.92	6.38	5.46	6.00
DPLC-198xKanakamany	10.28	7.53	8.05	5.93	5.52	5.26	5.71	5.90
DPLC-216xC-152	9.81	7.36	7.43	5.76	5.95	5.69	5.93	6.15
DPLC-216xChharodi-1	9.04	7.43	6.71	6.57	6.06	5.60	6.12	5.49
DPLC-216xKanakamany	8.80	7.67	6.56	7.97	5.86	5.80	6.12	6.13
IC-38956xC-152	8.78	7.73	7.76	5.74	6.01	5.77	6.06	5.03
IC-38956xChharodi-1	9.17	7.43	6.74	6.00	5.39	4.96	6.01	6.28
IC-38956xKanakamany	10.15	7.82	7.01	6.81	6.04	5.48	5.86	5.81
V-240xC-152	9.98	7.72	7.18	6.89	6.53	4.52	5.67	5.54
V-240xChharodi-1	8.68	7.73	7.36	6.56	7.27	6.06	5.67	6.05
V-240xKanakamany	9.71	7.26	7.51	6.37	5.36	6.86	5.74	5.96
VCM-8xC-152	9.68	7.85	6.75	7.31	6.62	5.64	6.14	5.67
VCM-8xChharodi-1	9.16	7.81	6.27	6.16	6.34	5.45	5.75	5.71
VCM-8xKanakamany	9.91	7.29	6.91	6.26	5.16	5.51	5.84	6.08

Appendix ii Anova for soil moisture content

Sl. No.	Soil moisture	Mean squares			Treatment F value *
		Replication 2 df	Treatment 22 df	Error 44 df	
1.	14 DAS	0.38	0.73	1.16	0.63
2.	21 DAS	0.26	0.12	1.21	0.10
3.	28 DAS	0.45	0.72	1.82	0.39
4.	35 DAS	0.17	1.16	0.71	1.63
5.	42 DAS	0.38	1.06	0.89	1.19
6.	49 DAS	0.53	0.74	0.67	1.11
7.	56 DAS	0.33	0.27	0.35	0.77
8.	63 DAS	1.55	0.23	0.67	0.35

* Not significant

COMBINING ABILITY FOR YIELD AND DROUGHT TOLERANCE IN COWPEA [*Vigna unguiculata* (L.) Walp.]

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ABSTRACT

A research programme was carried out at the Department of Plant Breeding, College of Agriculture, Vellayani during 1991 to 92 with five lines, three testers and their fifteen F_1s'. The data on sixteen characters were collected and subjected to line x tester analysis for estimating combining ability and gene action in the inheritance of drought tolerance, yield and related characters. Analysis showed that the line DPLC-198 had a positive and significant $\overline{gca}$ for leaf [illegible] index, grain filling period, number of pods per plant, hundred seed weight, grain yield per plant and biological yield. The line IC-38956 showed negative and significant gca for duration upto first flowering and duration upto maturity. The line DPLC-216 had positive and significant gca for grain filling period and hundred seed weight. The line V-240 for number of seeds per pod and VCM-8 for duration upto maturity showed significant gca. The tester C-152 showed significant positive gca for number of seeds per pod, grain yield per plant and biological yield and showed significant gca for duration upto maturity. The tester Chharodi-1 showed significant negative gca for duration upto first flowering and duration upto maturity. The tester Kanakamany showed significant positive gca for grain filling period, hundred seed weight and biological yield.

DPLC-198 x Chharodi-1 and IC-38956 x C-152 showed significant and negative sca for duration upto first flowering while DPLC-198 x Kanakamany, IC-38956 x Chharodi-1 and VCM-8 x Kanakamany showed significant negative sca for duration upto maturity. Significant negative sca for proline content was recorded by IC-38956 x C-152, V-240 x Chharodi-1 and DPLC-216 x Kanakamany. DPLC-216 x C-152 and DPLC-216 x Kanakamany recorded significant positive sca for grain filling period. A significant positive sca for number of pods per plant, grain yield per plant and biological yield was recorded by DPLC-198 x C-152.

Leaf area index, number of seeds per pod and hundred seed weight which had additive gene action can be improved by selection. Number of pods per plant and proline content had non-additive gene action. Presence of additive and non-additive gene action with preponderance of non-additive gene action was noticed for duration upto first flowering, duration upto maturity, grain yield per plant and biological yield while preponderance of additive gene action was noticed for grain filling period.

The characters that are controlled by non-additive genes or predominantly under the control of non-additive genes can be improved by recurrent selection and recombination breeding. Based on the gca estimates the lines DPLC-198 and IC-38956 and the testers C-152 and Chharodi-1 and the hybrids such as DPLC-198 x C-152, DPLC-198 x Chharodi-1, IC-38956 x C-152 and IC-38956 x Chharodi-1 were recommended for further utilization. Exploitation of heterosis normally is not a viable proposition in cowpea in the absence of easy methods of large scale production of hybrid seeds.