COMBINING ABILITY AND GENE ACTION IN GREENGRAM
(*Vigna radiata* (L.) Wilczek)

BY

SREEKUMAR. S.

THESIS

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT
FOR THE DEGREE

MASTER OF SCIENCE IN AGRICULTURE

[PLANT BREEDING & GENETICS]
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF PLANT BREEDING
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM
1993

Dedicated to

The everlasting memory of
Dr. (Mrs.) SREEKUMARI AMMA, J.

D E C L A R A T I O N

I hereby declare that this thesis entitled **"Combining ability and gene action in greengram (<u>Vigna</u> <u>radiata</u> (L.) Wilczek)** 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,
24.11.1993.

Sreekumar.S

C E R T I F I C A T E

Certified that this thesis entitled "Combining ability and gene action in greengram (Vigna radiata (L.) Wilczek) is a record of research work done independently by Sri.Sreekumar.S., under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Suma Bai D I

Vellayani,
24.11.1993

Dr.(Mrs.) Suma Bai.D.I,
Chairman,
Advisory Committee
Associate Professor
Department of Plant Breeding.

APPROVED BY:

CHAIRMAN:

Dr. (Mrs.) SUMA BAI.D.I. Suma Bai D I

MEMBERS:

1. **Dr. P.D.VIJAYAGOPAL**

2. **Dr. ABDUL KHADER**, K.M

3. **Dr. (Mrs.)P.SARASWATHY** Saraswathy P 29/1/94

EXTERNAL EXAMINER . 29/1/94

(T. RANGASAMY)

ACKNOWLEDGEMENT

The author wishes his deep sense of gratitude and profound feelings to:-

Dr. SUMABAI. D.I., Associate Professor, Department of Plant Breeding and the chairman of his advisory committee for her learned counsel, meticulous and gracious guidance, sustained interest, constant and inspiring encouragement, friendly approach, sympathy and generosity much beyond her formal obligation, affectionate advice, constructive criticism and forbearence all through the research work all of which contributed the most to the completion of the study and for the critical scrutiny of the manuscript;

Dr. VIJAYAGOPAL. P.D., Professor and Head, Department of Plant Breeding for taking much pain in arranging and conducting the final viva-voce;

Dr. ABDUL KHADER. K.M., Assistant Professor, Department of Plant Breeding for his valuable guidance, timely and propitous support extended at all stages of the endeavour;

Dr. (Mrs.) SARASWATHY. P., Professor and Head, Department of Agricultural statistics for her rare brilliance, keen and unstinted interest, active assistance, valuable guidance, ungrudging help rendered during the course of study especially in the interpretation of data and the friendly approach and personnel interest, shown in the progress of this research work;

Dr. SREEKUMAR. S.G., Associate Professor, Department of Plant Breeding from whom the author got first suggestion to take this problem and the help rendered during the preparation of project proposal and Dr. NAIR . V.G., former Head of Department of Plant Breeding for his valuable conselling, useful suggestion during the entire course of study and his invaluable guidance rendered when problems arised;

Late Dr. (Mrs.) SREEKUMARI AMMA. J., Associate Professor, Plant Breeding who was a member of his advisory committee and who had been a source of encouragement. He would like to dedicate this simple piece of work to the enduring memory of her;

Mr. SREEKUMAR. K., Assistant Professor of Plant Breeding, Mr. ANILKUMAR, S.G., and Miss. JAYARANI for their enormous help in finding out solutions for the problems which had arisen during the course of this work;

Mr. SREEKUMAR. P., and also to Mr. AJITHKUMAR. A.E., Junior Programmer, Agricultural Statistics, for their help at various stages of research work and thesis preparation;

Miss. Rekha Francis, Seji, Riji, and Sindhu. J. Chandran, Department of Food Science and Nutrition for their invaluable assistance rendered during the course of work, without which it might had been very difficult for him to complete the work;

His friends, Kum. Seetha Sara Oommen, Sreekala. G.S., Roshini, Mr. Sakeer Hussain, Department of Agricultural Extension and Mr. Moossa. P.P., Mr. Louis Joseph and Mr. Sanjeev. V.,Department of Soil Science for their help at various stages of this thesis work;

and finally to all those who helped him during the course of the work.

Mr. Purushothaman, Department of Plant Pathology for his great help and service rendered throughout the research work.

Miss. Sailakshmi and Diju.D.Pal, Department of Food Science and Nutrition for the personnel interest shown in the progress of his research work.

Sri. Sreekumar.S, his brother-in-law and his sister Smt. Sreedevi for the kind help they extended during the preparation of the manuscript and statistical analysis. The author also place on record their moral support and encouragement even from the start of the research work.

His parents and his brothers and sisters for the financial assistance and encouragement given by them throughout the research work

Sreekumar. S

Vellayani,
23-11-93

SREEKUMAR. S.

C O N T E N T S

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

INTRODUCTION

Greengram (*Vigna radiata* (L.) Wilczek) or the mungbean, also called mung, mong, chickasawpea, oregonpea, goldengram etc. is prized among the pulse species, for its seeds are high in protein and easily digestable producing low flatulence when consumed as food. The protein in the seeds averages to 24 per cent and is rich in lysine, an amino acid defecient in cereals, but defecient in methionine, cystine and cysteine which are found abundant in cereals. It is also rich in vitamin B and is regarded as a remedy for beriberi So pulse grain proteins nutritionally complement the proteins in cereal grains. In a balanced diet, pulses at the rate of 60 g per day per adult is necessary to meet the protein requirement (Swaran Pasricha, 1992).

The present day production of pulse crops is not even sufficient to meet the internal requirements. During 1992-93 pulse grain output was 14.7 million M.T. (Anon., 1993) and the target fixed for 1993-94 by Agricultural Ministery is 20 million M.T. As far as greengram is considered, it is grown as a rainfed crop during kharif and on residual moisture in rabi. Its early maturity enables it to mature on limited soil moisture. Although reported to be a drought tolerent crop, experimental results suggest that mungbean may avoid drought damage through short duration of growth rather than having drought tolerance. By maturing quickly the mungbean makes efficient use of limited soil moisture supply, but may not utilize an abundant supply effectively.

In our state also it is mainly grown as a third season crop in rice fallows by utilising residual moisture. So breeding programmes have to be taken up for evolving better adapted plant types for drought conditions. Thus it is possible to raise the production of greengram by increasing the productivity and area under cultivation.

With the above objective a study was conducted in the Department of Plant Breeding and three lines viz., Pusa-103, PDM-139 and PDM-146 were identified as drought tolerant from a large varietal collection. For improvement of these lines efficient breeding programmes should be executed. Knowledge on combining ability and gene action for different traits which influence yield and drought tolerance are needed so that parents are selected based on these aspects rather than on per se performance. The combining ability can be obtained in different ways and line x tester is one of the efficient methods. The present study was undertaken with the objective of determining the general and specific combining ability and the type of gene action involved in the inheritance of drought tolerance, yield and its components in greengram, for improving the yield potential under moisture stress condition through recombination breeding.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

A couple of decades ago, viable mungbean breeding programmes were found only in India and Philippines, with minor programmes in few other countries. But with the establishment of Asian Vegetable Research and Development Centre (AVRDC) in 1972 research on mungbean expanded rapidly. Since then AVRDC has developed significant research programme on mungbean. A large number of such programmes involve combining ability studies as its part, for the identification of potential parents in the improvement of mungbean varieties It also helps to have a knowledge on the nature of gene action that govern different traits. An overview of the literature on combining ability and gene action in different pulse crops are presented below.

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 s c a variance was found to be significant in F_2 generation. The estimated g c a variance was higher than those of s c a variance in F_1 and F_2 generations (Srivatsava *et al.*, 1977).

Durong (1980) studied yield and related characters using 8 x 8 diallel cross of soybean and reported 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 variances due to g c a for days to flower. Prevalence of non-additive gene action was also reported.

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

Combining ability analysis of ten diverse cultivars of pigeonpea indicated the predominance of additive gene action 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 upto flowering In general, additive genetic variance was found higher than dominance variance for this character (Dubey and Lal, 1983).

Salimath and Bahl (1985) from a line x tester analysis in chickpea showed the importance of g c a and s c a variances for days to flower. The variance due to g c a was higher than that due to s c a. Based on the g c a effect, 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 variances for days to flower with a predominance of additive gene action.

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

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

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

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

Katiyar *et al*. (1987) in a study with parents, F_1s and F_2 s of a fourteen line x three tester cross of pea indicated the predominance of non-additive gene action for days to flowering. The variety Batribrown was selected as a good general combiner for early flowering.

A line x tester analysis of chickpea varieties showed significant difference in days to flowering. The g c a estimate was reported to be not significant for the trait. This indicated that the trait was under the control of non-additive gene action and BG-390 and

L-550 were suggested as good general combiners for early flowering (Mandal and Bahl, 1987).

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

From a combining ability analysis involving nine diverse parents and their thirty six F_1 crosses in pigenonpea, 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 effect (Mehetre *et al*., 1988).

Moitra *et al*. (1988) analysed five pea lines for their combining ability and observed that Batri-yellow showed negative g c a for days to flowering. R 701 x Batri-yellow, Kinnauri x T-163 and T-10 x T-163 showed negative and significant g c a for days to flowering.

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

Half diallel of seven short duration pigeonpea lines were evaluated in the F_1 and F_2 generations by Saxena et al. (1989). The result indicated the predominance of g c a variance for the character.

Githiri et al. (1991) studied the inheritance of time to fifty per cent flowering in pigeonpea and involvement of additive gene action and partial dominance for the character earliness.

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

A line x tester analysis of cowpea varieties showed the presence of additive and non-additive gene action with predominance of non-additive gene action for duration up to first flowering (Anilkumar, 1993).

Leaf area index

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

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

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

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

Anilkumar (1993) reported the presence of additive gene effect for leaf area index in cowpea varieties.

Root length

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

In a study of eight mungbean genotypes and their twenty eight F_1 S in a half diallel cross revealed significant additive and non-additive genetic variances for seedling root length and yield, but additive gene action was more important for root length (Islam _et al_., 1987).

Number of pods per plant

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

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

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

Combining ability analysis using a complete set of six parents diallel cross of gardenpea 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 g c a and s c a effects with predominance of additive gene effect.

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

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

Combining ability analysis of 10 x 10 diallel in pea showed that general and specific combining ability variances were significant and additive genetic variance was found to be higher than dominance variance for number of pods per plant (Dubey and Lal, 1983).

Singh et al. (1983) estimated combining ability using a 8 x 3, line x tester cross in pigeonpea 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). They reported the significance of both g c a and s c a variances and predominance of non-additive genetic variance.

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

Combining ability analysis in mungbean using eight parents half diallel cross showed significant g c a and s c a variances for number of pods per plant (Chowdhury, 1986).

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 for number of pods per plant, with predominance of additive gene action (Patel et al., 1987).

Singh et al. (1987 c) 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.

Yadavendra and Sudhirkumar (1987) studied eight chickpea lines and their F_1 s for combining ability and revealed that for number of pods per plant, non-additive type of gene action was predominant.

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 g c a and s c a variances suggesting additive and non-additive gene effects and predominance of additive gene action for the expression of pods per plant (Katiyar et al., 1988).

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).

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

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

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 in twelve varieties of pea revealed both additive and non-additive genetic components of variation which mainly govern complex characters including pods per plant (Singh and Singh, 1990).

Sood and Garten (1990) reported that number of pods per plant was controlled predominantly by dominance component in their study in urdbean.

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

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

In 9 x 9 diallel cross in blackgram revealed that high per se. performance of parents did not necessarily reflect their good general combining ability and number of pods per plant showed a value less than one for the ratio of g c a to s c a variance (Sood and Garten, 1991).

Yield and yield related characters were investigated in eight mungbean genotypes and their twenty eight F_1 s by Saxena and Sharma (1992) and reported importance of additive gene action as well as non-additive gene action, with 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.

In a line x tester analysis to estimate the combining ability of cowpea varieties, Anilkmumar (1993) reported the preponderance of non-additive gene action for number of pods per plant.

Number of seeds per pod

Diallel analysis for yield and yield components in bengalgram showed highly significant variance due to g c a and s c a for number of seeds per pod. Estimates of variance due to s c a was much higher than that due to g c a. It was reported that additve and non-additive gene effects were influencing the characters and the non-additive effect was 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 variances due to g c a and s c a for number of seeds per pod. Non-additive gene action was reported to be important for the trait.

Durong (1980) studied combining ability using a 8 x 8 diallel cross of soybean and reported the importance of both additive and non-additive gene actions.

A complete set of six parent diallel cross in gardenpea 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 g c a and s c a variances were important for number of seeds per pod. The higher magnitude of g c a variance indicated that additive gene action was involved in the inheritance of this character.

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

Combining ability analysis of ten diverse cultivars of pigeonpea indicated the importance of both additive and non-additive gene effects with predominance of additive gene effect for 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 g c a and s c a variances for number of seeds per pod in the analysis of combining ability in peas. The variance due to g c a predominated in both F_1 and F_2 generations.

Combining ability studies in a 10 x 10 diallel cross in pea showed that general and specific combining ability variances 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).

The significance of g c a 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 effect was important for this character.

Significant g c a and s c a variances were observed by Wilson et al. (1985) in an analysis of diallel cross of five greengram varieties for number of seeds per pod. The variance due to g c a was reported to be much higher than that due to s c a. 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 hybrids were evaluated 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 g c a and s c a variances 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).

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

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

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

A 7 x 7 diallel cross in greengram by Natarajan *et al*. (1990) revealed that both additive and non-additive gene actions 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 square due to s c a for number of seeds per pod.

Yield and yield characters were estimated in eight mungbean genotypes and their twenty eight F_1 s by Saxena and Sharma (1992) and reported importance of additive as well as non-additive variances and predominance of additive variance.

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

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

In a line x tester analysis in cowpea, Anilkumar (1993) revealed the presence of additive gene action for number of seeds per pod.

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 gene action was predominant for hundred seed weight (Singh et al., 1975).

Diallel analysis for yield and yield components in bengalgram showed highly significant variances due to g c a and s c a for hundred seed weight. Estimates of variance due to g c a indicated predominance of additive gene effect (Pande _et al_., 1979).

Chauhan and Joshi (1981) studied a half diallel cross of eight cowpea cultivars and reported that both general and specific combining abilities were important. The magnitude of g c a variance was found to be much higher indicating preponderance of additive gene effect 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 (1981 b) while analysing the combining ability in peas in a diallel cross involving ten cultivars found importance of both g c a and s c a and predominant role of additve gene effect 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 effect.

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

Combining ability analysis with 10 x 10 diallel cross in pea revealed the significance of g c a and s c a and higher magnitude of additive genetic variance than dominance variance for hundred seed weight (Dubey and Lal, 1983).

Malhotra (1983) in a diallel analysis on urdbean showed the importance of both g c a and s c a variances 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.

Singh *et al*. (1983) estimated combining ability using a 8 x 3, line x tester cross in pigeonpea 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 cross among five varieties of greengram showed existence of both additive and non-additive gene

In a study with six genotypes of chickpea and their hybrids Katiyar *et al*. (1988) reported significant g c a and s c a for hundred seed weight and suggested the importance of additive and non-additive gene effects with predominance of non-additive gene action.

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

Combining ability analysis in a 9 x 9 diallel cross in blackgram revealed that the ratio of additive to dominance variance was less than unity for hundred seed weight indicating the preponderance of dominance gene action for the character (Sood and Garten, 1991).

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

In a study to estimate the combining ability of cowpea varieties, Anilkumar (1993) concluded the importance of additive gene action for the character hundred seed weight.

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 g c a and s c a variances were significant. The estimate of g c a variance was reported to be higher than that of s c a variance in the 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 variances due to g c a and s c a 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 for the trait.

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

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 action was preponderant for all characters studied except days to maturity.

Singh et al. (1983) estimated combining ability using a 8 x 3, line x tester cross in pigeonpea and reported that both additive and non-additive components were important.

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

Salimath and Bahl (1985) conducted a line x tester analysis in chickpea with five male and nine female parents and reported that s c a variance was important for days to maturity. They also reported that non-additive variance was pronounced for days to maturity.

Significant g c a and s c a variances were reported by Wilson et al. (1985) for days to maturity in an analysis of a diallel cross among five greengram varieties. They found that the variance due to g c a was much higher than that due to s c a and reported the existence of both additive and non-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 action.

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

Singh et al. (1987 b) reported highly significant g c a and s c a variance in F_1 and F_2 generations for days to maturity in pea. The variance due to s c a was greater than that due to g c a indicating preponderance of non-additive gene action for the character.

Singh *et al.* (1987 a) studied ten diverse blackgram cultivars for combining ability and reported highly sgnificant g c a and s c a variances in F_1 and F_2 generations. The estimates of variance due to s c a was greater than that due to g c a for days to maturity, indicating the predominance of non-additive gene action.

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

In a study conducted by Githiri *et al.* (1991) on pigeonpea revealed the presence of additive gene action with partial dominance for earliness.

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 analysis by Anilkumar (1993) showed the presence of both g c a and s c a variances with preponderance of non-additive gene action for the character duration up to maturity in cowpea.

Grain yield per plant

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 were highly significant for yield per plant, indicating that genes having additive and dominant effects were influencing the character. It was also reported that non-additive effect was more important for seed yield per plant.

A diallel cross involving eight mungbean varieties was studied for combining ability. The variances due to g c a and s c a 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 8 x 8 diallel cross of soybean and reported the importance of both additive and non-additive gene action for the trait.

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. The variance due to g c a was reported to be comparatively much higher in magnitude suggesting the addititive gene action.

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

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

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 s c a and g c a variances for seed yield per plant. The variance due to g c a was reported to be much higher in F_1 and F_2 generations (Venkateswarlu and Singh, 1982 c).

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

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

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

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

Combining ability analysis in mungbean using eight parent half diallel cross showed significant g c a and s c a variances for sed yield per plant. (Chowdhury, 1986).

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

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

Singh <u>et al</u>. (1987 a) in the combining ability analysis using a diallel cross of ten blackgram lines reported highly significant g c a and s c a, both in F_1 and F_2 generations, for grain yield. The estimates of variance due to s c a was reported to be greater than variance due to g c a, indicating predominance of non-additive gene action.

Eight chickpea lines and their twenty eight F_1 s were studied for combining ability by Yadavendra and Sudhirkumar (1987) and found non-additive gene action was predominant for grain yield.

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

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

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

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

A comparative analysis of combining ability in irradiated and non-irradiated diallel population of chickpea suggested importance of additive and non-additive genes for seed yield per plant (Onkar Singh and Paroda, 1989).

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

Thiyagarajan *et al*. (1990) in an analysis with six parents diallel cross in cowpea reported that both additive and non-additive gene effects were important for yield per plant.

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

In a diallel cross from twelve varieties of pea with their F_1 s and F_2 s, Singh and Singh, (1990) concluded the presence of both additive and non-additive genetic variances.

Sood and Garten, (1990) studied the genetic analysis of yield attributes in urdbean from nine diverse pure breeding lines and proposed that the dominance component had greater control over seed yield.

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

In a study to estimate the combining ability in blackgram from nine diverse genotypes Sood and Garten, (1991) revealed the presence of additive gene effect for plant height and grain yield.

Yield and yield related characters were investigated in eight mungbean genotypes and their twenty eight F_1 s by Saxena and Sharma (1992) and reported importance of additive as well as non-additive variances and predominance of additive variance.

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

In a line x tester analysis, Anilkumar (1993) concluded the presence of both additive and non-additive gene action for grain yield in cowpea. The mean square due to s c a was reported to be high indicating the preponderance of non-additive gene action for the character.

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 reported that non-additive effect was important for biological yield.

Components of variances for biological yield analysed in Indian mustard (Prakash et al., 1987) with eight varieties and their twenty eight F_1 s revealed the importance of additive and non-additive components.

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

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

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

Combining ability analysis in cowpea by Anilkumar (1993) revealed the presence of both g c a and s c a effects, but the mean square due to s c a was much higher than the g c a mean square indicating the predominance of non-additive gene action 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 g c a and s c a variances for harvest index. They also reported predominance of additive gene action for the character.

Combining ability analysis for phenological and physiological traits in pea using F_1 s of fourteen lines and three testers conducted by Katiyar *et al*. (1987) indicated the predominance of non-additive gene action for harvest index.

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

Singh *et al*. (1987 b) analysed the general and specific combining abilities for yield and its components from F_1 and F_2 generations of a diallel cross involving ten parents of pea, showed significant additive and non-additive gene actions for harvest index in both generations. On the basis of *per se*.

performance of g c a effect, the good general combiner common in both F_1 and F_2 generations for harvest index was found to be F-9.

Hazarika et al. (1988) estimated combining ability in a line x tester analysis of pigeonpea and reported significance of both g c a and s c a variances for yield.

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

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

Combining ability analysis in a cross involving tall and dwarf types in chickpea showed predominance of non-additive gene action for harvest index (Salimath and Bahl, 1989).

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

In soybean Gadag etal.(1990) noticed significant variation among parents and crosses for harvest index and reported that both g c a and s c a variances were highly significant. They also reported predominance of non-additive gene action for harvest index.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present research programme was carried out at the Department of Plant Breeding, College of Agriculture, Vellayani, Thiruvananthapuram during 1992-93.

Materials

The experimental material consisted of eight greengram varieties as parents and their fifteen hybrids. The parents consisted of three lines and five testers. The fifteen F_1 s were produced by crossing the three lines and five testers. The lines were already identified as drought tolerant. The testers are the recommended high yielding varieties. The lines, testers and their hybrids are detailed in the table 1.

Methods

Experiment I

(A) **Selfing:** The three lines and five testers were first raised in the field during May '92 and allowed for self pollination. To prevent any chance of cross pollination mature flower buds were covered with tissue paper bags. The pods were harvested, dried, seeds extracted, cleaned and kept in separate packets.

Table 1. Details of Parents and their Hybrids

Sl.No.	Treatments	Parents/Hybrids	
A)	LINES : 3		
	L_1	Pusa-103	Drought tolerant
	L_2	PDM-139	Drought tolerant
	L_3	PDM-146	Drought tolerant
B)	TEESTERS : 5		
	T_1	Co-2	High yielding
	T_2	ML-131	High yielding
	T_3	P.S-16	High yielding
	T_4	Pusa baisakhi	High yielding
	T_5	PDM-134	High yielding
C)	HYBRIDS		
	$L_1 T_1$	Pusa-103 x Co-2	
	$L_1 T_2$	Pusa-103 x ML-131	
	$L_1 T_3$	Pusa-103 x P.S-16	
	$L_1 T_4$	Pusa-103 x Pusa baisakhi	
	$L_1 T_5$	Pusa-103 x PDM-134	
	$L_2 T_1$	PDM-139 xCo-2	
	$L_2 T_2$	PDM-139 x ML-131	
	$L_2 T_3$	PDM-139 x P.S-16	
	$L_2 T_4$	PDM-139 x Pusa baisakhi	
	$L_2 T_5$	PDM-139 x PDM-134	
	$L_3 T_1$	PDM-146 x Co-2	
	$L_3 T_2$	PDM-146 x ML-131	
	$L_3 T_3$	PDM-146 x P.S-16	
	$L_3 T_4$	PDM-146 x Pusa baisakhi	
	$L_3 T_5$	PDM-146 x PDM-134	

(B) **Line x Tester hybridization programme**·The parents for crossing were raised during November 1992. The five male parents were sown at three staggered intervals, while the three female parents were sown in five staggered intervals so as to make the crossing programme easier. As sowing was done on different dates the flowering in all the eight parental varieties was fully synchronised.

Boiling et al. (1961) have outlined a techinque for hybridization in greengram, which was followed in the present study. The female lines were first emasculated. For that, yellowish green buds which were likely to open the next morning were selected and emasculated. The emasculated flower buds were protected with tissue paper bags.Evening emasculations (16.00 to 18.30 hours) were followed by the next morning (7.00 to 10.00 hours) pollinations. The artificially pollinated flowers were suitably labelled and again covered with tissue paper bags. The pods of each cross were collected separately, seeds extracted, cleaned, dried and kept for Experiment-II.

Experiment - II

Evaluation of fifteen hybrids and eight parents: The three lines, five testers and their fifteen hybrids were grown adopting a randomised block design with three replications in the uplands at the College of Agriculture, Vellayani, during March 1993. In 2 x 1.5 m plots seeds were dibbled at a spacing of 30 x 20 cm so that fifty plants were accommodated in each plot. The cultural and management practices were followed as per the Package of Practices Recommendations of the Kerala Agricultural University, 1989. Data on various characters were recorded replication wise, from a random sample of ten plants each with respect to treatments, by completely excluding the border rows and the mean values were used for statistical analysis.

Observations were recorded on following characters

a) Duration upto fifty per cent flowering

Number of days taken from the date of sowing of the seeds to approximately fifty per cent flowering of of the crop was recorded.

b) Leaf area index (LAI) at fifty per cent flowering

Leaf area index was measured from each plot when the crop was at fifty per cent flowering using a leaf area meter. All the leaves separated from uprooted plants were fed to the leaf area meter separately and the total leaf area for each plant was calculated. From the leaf area, leaf area index was calculated by the formula suggested by William (1946).

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

c) Root length and spread at harvest time

The length of the roots was measured at harvest time in cm. The sample plants were uprooted carefully and length of the tap root was measured. Root spread was measured at harvest time by placing the root system on a graph paper and measuring the spread of the root system at its broadest part. The root spread was expressed in cm.

d) Root/shoot ratio at harvest time

The ratio of the root dry weight to shoot dry weight was expressed as root/shoot ratio. From each sample plant root and shoot portions were cut away separately, sun dried for two days, oven dried at 60 to 70 degree celcius (^{o} C) for one day, dry weights recorded and the ratio computed.

e) Stomatal distribution

For estimating number of stomates per microscopic fields (40 x 10x) fully opened and matured leaves were selected from the sample plants and leaf impressions were taken by applying a thin coat of nail polish on the lower leaf surface which was subsequently pealed off after drying. From these impressions ten microscopic fields were scored for number of stomata and the mean number per microscopic field was estimated.

f) Leaf proline content

Fully expanded second leaf from top was collected when the crop was at fifty per cent flowering and the proline content was estimated by the method suggested by Bates *et al*. (1973). Leaves collected from each sample plants were dried and powdered and proline content estimated separately. The proline concentration in each sample was determined from the standard curve and calculated on dry weight basis as follows.

$$\frac{(\mu g \text{ proline/ml} \times \text{ml of tolune})(\text{ml of salicylic acid (10 ml)})}{\text{ml of plant extract used (2ml)} \times \text{weight of sample}}$$

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

g) Number of pods per plant

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

h) Number of seeds per pod

The number of seeds from all the pods of observational plants was counted and the mean worked out.

i) Weight of thousand seeds

Random sample of thousand seeds was selected from each plot at harvest and mean weight recorded in g.

j) Duration upto maturity

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

k) Seed yield

Grain yield (economic yield) obtained from the observational plants was recorded and the mean expressed in g.

l) Biological yield

Total dry weight of all plant parts including grain yield were considered as biological yield. The total biological yield of the plants were computed and the mean expressed in g.

m) Harvest index

Harvest index was calculated by using the formula

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

n) 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° C until constant weight was obtained and the loss in weight was expresssed as percentage.

STATISTICAL ANALYSIS

Analysis of variance was done for all the characters and significance of differences among the types including parents and crosses was tested (Singh and Choudhary, 1979).

Combining ability analysis

Comibining ability analysis of the line x tester was done through Anova technique (Dabholkar, 1992).Anova is presented in table 2.

To estimate the additive and dominance genetic components of variance the following relationships are used.

Table - 2. ANOVA FOR LINE X TESTER

Source	df	Mean Square	Expected Mean Square
Replication	r - 1		
Treatments	n - 1		
I) Parents	l+t - 1		
II) Parents Vs. Crosses	1		
III) Crosses	lt - 1		
a) Lines	l - 1	M_L	$\sigma^2 e + r\sigma^2 sca + rt\sigma^2 gca$ (l)
b) Testers	t - 1	M_T	$\sigma^2 e + r\sigma^2 sca + rl\sigma^2 gca$ (t)
c) Line x Tester	(l-1) (t-1)	M_{LT}	$\sigma^2 e + r\sigma^2 sca$
Error	(n-1) (r-1)	M_E	$\sigma^2 e$
Total	nr - 1		

Where n = number of treatment materials = l + t + lt

r = number of replication

l = number of lines

t = number of testers

$$\sigma^2 gca\ (lines) = \frac{(M_L - M_{LT})}{rt} = \text{Cov. H.S. (lines)}$$

$$\sigma^2 gca\ (testers) = \frac{(M_T - M_{LT})}{rl} = \text{Cov. H.S (testers)}$$

$$\sigma^2 sca\ (crosses = \frac{(M_{LT} - M_E)}{r}$$

σ^2 gca = 1/4 σ^2a if inbreeding is absent.

σ^2 sca = 1/4 σ^2d if inbreeding is absent.

So σ^2a = 4 σ^2gca

σ^2d = 4 σ^2sca

The significance of σ^2a is tested from the

$F_{[(l-1), (l-1)(t-1)]} = M_L/M_{LT}$ for lines and

$F_{[(t-1), (l-1)(t-1)]} = M_T/M_{LT}$ for testers

and that of σ^2d from

$F_{[(l-1)(t-1), (n-1)(r-1)]} = M_{LT}/M_E$

A significant 'F' in the above cases is respectively an indication of significant genetic difference among plants chosen as parents and the inconsistant behaviour of the female over male parent or viceversa and thus providing an information on the relative ability of number of male and female parents to produce desirable hybrids.

RESULT

RESULTS

The data are subjected to line x tester analysis and the results are presented below.

Mean performance

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

The shortest duration for fifty per cent flowering was shown by PDM-139 among lines and by Pusa baisakhi among testers both were having an average of 26 days. The maximum days taken for fifty per cent flowering was in Pusa-103 among lines and PDM-134 among testers, 27 and 46 days respectively. The lines and testers differ significantly and maximum range was shown by testers. Among the crosses, the early flowering hybrid was PDM-139 x Co-2 (34 days) and late flowering hybrids were Pusa 103 x Co-2 and PDM-146 x PDM-134 (40 days).

The highest leaf area index was shown by Co-2 (1.93) among testers and Pusa-103 (0.59) among lines. The index was low in PDM-139 (0.28) among lines and in P.S-16 (0.65) among testers. The highest value of 2.11 was recorded by the hybrid Pusa-103 x PDM-134 and the lowest in PDM-139 x P.S-16 (0.55). The lines, testers and hybrids differed significantly.

Table - 3(a). Mean performance of lines, testers and hybrids for various characters

Treatments	Days to flower	L A I	Root length	Root spread	Root / shoot	Stomatal distribution	Proline content
L_1 T_1	40.33	0.90	17.47	21.83	0.28	38.47	168.00
L_1 T_2	36.00	0.72	16.03	17.53	0.41	43.20	47.67
L_1 T_3	40.00	0.67	17.23	17.57	0.47	46.33	86.00
L_1 T_4	37.00	0.72	16.43	15.07	0.48	43.53	43.33
L_1 T_5	39.00	2.11	16.27	17.80	0.38	36.60	81.33
L_2 T_1	33.67	0.85	18.27	18.80	0.36	47.17	179.67
L_2 T_2	36.67	0.83	16.67	17.60	0.28	48.60	80.00
L_2 T_3	36.67	0.55	17.53	18.00	0.37	30.73	45.33
L_2 T_4	39.00	0.58	18.50	19.30	0.32	32.53	80.00
L_2 T_5	40.00	0.92	19.30	21.97	0.30	37.20	44.23
L_3 T_1	36.67	1.22	16.30	21.80	0.28	46.93	188.67
L_3 T_2	38.00	1.12	15.57	20.00	0.30	41.67	47.67
L_3 T_3	38.00	0.75	15.17	13.50	0.26	43.10	54.67
L_3 T_4	37.00	1.07	16.07	15.50	0.33	57.67	83.33
L_3 T_5	40.33	0.86	17.03	20.20	0.25	51.20	117.67
L_1	27.00	0.57	16.03	25.70	0.26	20.57	128.67
L_2	25.67	0.28	16.97	19.53	0.24	47.97	147.33
L_3	26.33	0.40	15.57	23.97	0.32	22.40	167.67
T_1	43.00	1.93	19.13	33.77	0.22	42.26	44.33
T_2	30.00	0.68	16.03	20.93	0.29	36.63	66.00
T_3	30.67	0.65	16.33	26.73	0.23	45.23	104.33
T_4	26.00	0.77	16.43	24.67	0.30	53.67	96.00
T_5	45.67	1.59	15.93	31.30	0.32	32.70	119.00
MSE	0.372	0.02	1.405	3.509	0.003	83.62	10.837
CD	1.004	0.21	1.950	3.080	0.100	--	5.420

Table - 3(b) Mean performance of lines, testers and hybrids Contd.....

Treatments	Pods per plant	Seeds per pod	1000 seed weight	Duration upto maturity	Seed yield	Biological yield	H.I.
L_1 T_1	22.50	14.31	33.69	56.00	10.97	17.29	0.63
L_1 T_2	50.10	9.73	32.72	57.33	16.47	35.73	0.46
L_1 T_3	18.40	10.09	29.20	58.67	5.85	10.13	0.58
L_1 T_4	14.60	9.11	30.36	58.00	4.14	9.03	0.46
L_1 T_5	34.73	9.48	32.43	57.33	10.86	23.83	0.45
L_2 T_1	21.30	10.13	33.67	55.67	7.38	11.52	0.64
L_2 T_2	37.53	7.61	30.21	58.67	10.79	12.55	0.83
L_2 T_3	17.17	7.77	25.36	51.00	3.11	5.48	0.55
L_2 T_4	39.67	9.70	43.24	57.00	19.36	23.24	0.81
L_2 T_5	37.40	10.34	37.32	58.33	17.35	22.25	0.78
L_3 T_1	22.77	9.24	28.72	56.00	7.53	11.54	0.65
L_3 T_2	44.27	10.17	27.13	56.77	15.34	21.01	0.73
L_3 T_3	11.70	10.08	28.74	54.67	2.89	6.47	0.45
L_3 T_4	15.73	9.55	26.40	52.00	4.48	9.56	0.47
L_3 T_5	37.70	10.44	32.59	57.00	13.98	20.19	0.69
L_1	8.30	10.16	28.68	53.00	2.43	5.65	0.43
L_2	8.57	9.63	29.61	51.67	2.58	7.30	0.35
L_3	8.87	10.28	26.00	49.33	2.48	6.19	0.40
T_1	15.13	10.47	30.63	74.67	5.02	13.02	0.39
T_2	17.53	10.41	29.23	56.67	5.48	13.60	0.40
T_3	12.37	8.45	28.57	56.67	3.11	12.23	0.25
T_4	10.27	9.27	25.87	52.67	2.59	8.18	0.31
T_5	18.40	11.62	31.20	81.00	7.58	13.38	0.56
MSC	0.672	0.306	0.191	0.299	0.089	0.328	0.001
CD	1.350	0.910	0.720	0.900	0.492	0.942	0.055

The average root length at harvest time had a range of 15.17 to 19.30 cm. Among testers, ML-131 had the minimum length (16.03 cm) and Co-2 had the maximum length (19.13 cm). PDM-146 had the shortest root length (15.57 cm) and PDM-139 had the longest roots (16.67 cm) among lines. The hybrid PDM-146 x Pusa baisakhi had the minimum length of 15.17 cm while longest roots was recorded by the hybrid PDM-139 x Pusa baisakhi (18.50 cm). The lines were found to be on par, while testers and hybrids differed significantly.

The average spread of roots at harvest had the highest and lowest values of 33.77 cm and 20.93 cm respectively in Co-2 and ML-131 among testers and among lines Pusa-103 and PDM-139 had the highest and lowest values (25.7 cm and 19.53 cm respectively). The cross PDM-139 x PDM-134 had the maximum root spread of 21.97 cm and minimum spread was recorded by PDM-146 x P.S-16 (13.50 cm). The lines, testers and hybrids were significantly different.

Least root/shoot ratio was recorded by PDM-139 (0.23) among lines and by Co-2 (0.22) among testers. The highest ratio of 0.32 was recorded by both line PDM-146 and tester PDM-134. The range among hybrids was from 0.25 in PDM-146 x PDM-134 to 0.48 in Pusa-103 x Pusa baisakhi. For root/shoot ratio, only hybrids showed significant differences, while the lines and testers were on par.

Stomatal distribution on lower surface of leaves ranged from 20.57 in Pusa-103 to 47.97 in PDM-139 among lines. Among testers, the range was from 32.7 in PDM-134 to 53.67 in Pusa baisakhi. Among hybrids, the values ranged from 30.73 counts per field in PDM-139 x P.S-16 to 57.67 counts per field in PDM-146 x Pusa baisakhi.

Leaves of Pusa-103 among lines and Co-2 among testers had a low level of proline (128.67 and 44.33 µg/g respectively) while PDM-146 and PDM-134 were rich in proline which had values of 167.67 and 119.00 µg/g respectively. Among hybrids it ranged from 43.30 µg/g in Pusa-103 x Pusa baisakhi to 188.67 µg/g in PDM-146 x Co-2. All lines, testers and hybrids differed significantly.

The maximum number of pods per plant was 8.87 in PDM-146 among lines and PDM-134 (18.40) among testers and the minimum number was in Pusa-103 (8.30) and Pusa baisakhi (10.27). The cross PDM-146 x P.S-16 showed the least number of pods (11.70) while Pusa-103 x ML-131 showed the maximum number (50.10). The testers and crosses differed significantly for number of pods per plant while the lines were found to be on par.

The maximum number of seeds per pod was recorded by PDM-134 (12.00) and minimum by P.S-16 (8.45). The lines on an average recorded 10 seeds per pod. The hybrids differed significantly for number of seeds per pod and it ranged from 8 seeds per pod in PDM-139 x ML-131 to 14 seeds in Pusa-103 x Co-2.

The mean weight of thousand seeds ranged from 26.00 g in PDM-146 to 29.61 g in PDM-139 among lines and 25.87 g in Pusa baisakhi to 31.2 g in PDM-134 among testers. The minimum seed weight of 25.63 g was noticed in cross PDM-139 x P.S-16 and maximum in PDM-139 x Pusa baisakhi (43.24 g). The lines, testers and hybrids differed significantly for thousand seed weight.

PDM-146 (46 days) among lines and Pusa baisakhi (53 days) among testers were the early maturing varieties. Among the crosses, PDM-139 x P.S-16 was the early maturing hybrid (51 days). The late maturing varieties were Pusa-103 among lines (53 days) and PDM-134 among testers (81 days). The combinations, Pusa-103 x P.S-16 and PDM-139 x ML-131 recorded the maximum number of days (59 days). The lines, testers and hybrids differed significantly.

The highest grain yield was recorded in PDM-134 (7.58 g) and lowest in Pusa baisakhi (2.59 g). The lines were found to be on par ranging from 2.43 g in PDM-146 to 2.58 g in PDM-139. Among hybrids, PDM-139 x P.S-16 had the lowest value (3.11 g) while PDM-139 x Pusa baisakhi had the highest value (19.36 g). The testers and hybrids differed significantly.

Pusa-103 recorded the lowest biological yield (5.65 g) and PDM-139 (7.30 g) recorded the highest among lines. Among testers, the lowest value was recorded by Pusa baisakhi (8.18 g) and highest by ML-131 (13.60 g). Among hybrids it ranged from 5.48 g in PDM-139 x P.S-16 to 35.73 g in Pusa -103 x ML-131.

The harvest index was minimum (0.35) in PDM-139 among lines and P.S-16 (0.25) among testers. The maximum index was noticed in Pusa-103 (0.43) and in PDM-134 (0.56). Among hybrids, PDM-146 x P.S-16 had the lowest value of 0.45 and PDM-139 x ML-131 had the highest value of 0.83.

Combining ability and gene action

Analysis of variance for fourteen characters presented in the table 4a,b revealed that all the characters exhibited significant genotypic differences.So all the characters were subjected to line x tester analysis to study the gene action in terms of g c a and s c a.

The g c a and s c a effects for duration up to fifty per cent flowering are presented in table 5(a).In the combining ability analysis for fifty per cent flowering, significant differences were observed among lines and testers for their general combining ability. Among lines, Pusa-103 (0.58 days) had significant positive g c a while PDM-139 had significant negative g c a (-0.69 days) both differed significantly from the rest. Among testers, Co-2 and ML-131 had negative g c a of -1.00 day while PDM-134 had a positive g c a of 1.89 days which difered significantly from other two. All hybrids of Pusa-103 had their s c a effect significant and the cross Pusa-103 x Pusa baisakhi (-1.25 days), Pusa-103 x PDM-134 (-1.36days) and Pusa-103 x ML-131 (-1.47 days) were found to be on par.All the hybrids of line PDM-139, except with ML-131 had significant s c a effects.PDM-139 x Co-2 had the maximum negative g c a of -2.53 days. All the s c a

Table - 4(a). ANOVA of fourteen characters under study

Source	df	50% flowering	LAI	Root length	Root Spread	R/S ratio	Stomatal distribn	Proline content
Replication	2	11.15**	0.56**	60.24**	191.47**	0.04	3.26	447.94**
Treatment	22	94.26**	0.60**	3.80**	73.14**	0.02**	253.23**	6651.56**
Parents	7	191.33**	1.02**	3.77**	69.51**	0.05	426.40**	4389.72**
Parents Vs Crosses	1	581.89**	0.06	2.07	855.70**	0.07**	442.18**	7453.69**
Crosses	14	10.89**	0.43**	3.95**	19.063**	0.02**	153.15	7725.18
Lines	2	6.15	0.36	16.21**	5.77	0.05**	318.46	824.83
Testers	4	12.89	0.53	2.98	35.27*	0.09	37.21	22918.10**
L x T	8	11.07**	0.40**	1.36	14.29**	0.09*	169.79	1853.82**
Error	44	0.37	0.02	1.41	3.51	0.04	83.62	10.84

Table - 4(b) ANOVA Contd.......

Number of Pods/plant	Number of Seeds/pod	Weight of 1000 seeds	Duration upto maturity	seed yield	Biological yield	Harvest index
31.13**	4.79**	0.19**	14.09**	4.54**	10.99*	0.02**
485.16**	5.11**	48.58**	148.05**	87.90**	168.72**	0.08**
50.72**	2.53**	11.32*	412.28**	10.95**	35.35**	0.03**
3977.93**	0.70**	116.52**	157.24**	587.32**	571.45**	0.78**
452.89**	6.72**	62.35**	15.28**	90.71**	206.63**	0.06**
66.57	7.79**	103.65**	18.42	30.07	122.15	0.16*
1201.21	6.44	59.81	13.59	164.54*	388.93**	0.03
175.32**	6.59**	53.29**	15.34**	68.95**	136.61**	0.04**
0.67	0.31	0.19	0.30	0.09	0.33	0.001

effects differed significantly.Only two crosses of line PDM-146 had significant s c a effects viz.,PDM-146 x ML-131 (1.00 day) and PDM-146 x Pusa baisakhi (-0.78 day). The highest negative effect was shown by the hybrid PDM-139 x Co-2 (-2.53 days) and positive effect by Pusa-103 x Co-2 (2.87 days).

The g c a and s c a effects for leaf area index are depicted in table 5(a). The variances due to lines and testers were found to be insignificant for leaf area index at fifty per cent flowering and only line x tester was found to be significant. All the lines had significant g c a effects. Pusa-103 (0.10) and PDM-146 (0.80) had positive effects which were on par while PDM-139 had negative g c a effect (-0.18) which differed significantly from the other two. Among testers, P.S-16 (-0.27) and Pusa baisakhi (-0.14) had negative g c a effects and PDM-134 had positive g c a effects (0.37).The three testers differed significantly from each other.

All the hybrids of Pusa-103 and PDM-146 except with P.S-16 had significant s c a effects while only one cross of line PDM-139 with PDM-134 had significant s c a effect (-0.20). Cross Pusa-103 x PDM-134 (0.71) and PDM-146 x PDM-134 (-0.52) differed significantly from all other crosses which were on par. The highest

Table - 5(a). General and Specific Combining abilities for drought related characters

Treatments	Days to flower	L A I	Root length	Root spread	R/S ratio	Proline content	Stomatal distribn.
LINES							
Pusa-103	0.578*	0.100	-0.231	-0.471	0.065	-4.578	-1.380
PDM-139	-0.689*	-0.179*	1.136*	0.702	-0.012	-3.978*	-3.760
PDM-146	0.111	0.080*	-0.904	-0.231	-0.054*	8.556*	5.130
SE	0.158	0.033	0.306	0.484	0.016	0.850	
CD	0.449	0.095	0.873	1.380	0.045	2.423	
TESTERS							
Co-2	-1.000*	0.066	0.427	2.380*	-0.032	88.930**	1.180
ML-131	-1.000*	-0.036	-0.829*	-0.053	-0.005	-31.400**	1.520
P.S.-16	0.333	-0.268	-0.273	-2.075*	0.029	-27.845**	-2.930
P.baisakhi	-0.222	-0.135*	0.060	-1.809*	0.036	-20.956**	1.570
PDM-134	1.889*	0.372*	0.616	1.558*	-0.028	-8.733**	-1.340
SE	0.203	0.043	0.395	0.624	0.020	1.097	
CD	0.580	0.127	1.127	1.780	0.057	3.129	
HYBRIDS							
$L_1 T_1$	2.867*	-0.190*	0.353	1.493	-0.092*	-6.200*	-4.340
$L_1 T_2$	-1.467*	-0.269*	0.176	-0.373	0.014	-6.200*	0.058
$L_1 T_3$	1.200*	-0.087	0.820	1.682	0.040	28.578**	7.640
$L_1 T_4$	-1.245*	-0.167*	-0.313	-1.084	0.037	-20.978**	0.336
$L_1 T_5$	-1.356*	0.713*	-1.036	-1.718	0.001	4.800**	-3.687
$L_2 T_1$	-2.533*	0.038	-0.213	-2.713*	0.062	4.867*	6.738
$L_2 T_2$	0.476	0.119	-0.558	-1.480	-0.036	25.533**	7.838
$L_2 T_3$	-0.867*	0.075	-0.247	0.942	0.014	-12.689**	-5.584
$L_2 T_4$	2.022*	-0.036	0.387	1.976	-0.043	15.089**	-8.284
$L_2 T_5$	0.911*	-0.196*	0.631	1.276	0.004	-32.800**	-0.707
$L_3 T_1$	-0.333	0.153	-0.140	1.220	0.030	1.333	-2.396
$L_3 T_2$	1.000*	0.150*	0.382	1.853	0.023	-19.333**	-7.896
$L_3 T_3$	-0.333	0.013	-0.573	-2.625*	-0.054	-15.889**	-2.051
$L_3 T_4$	-0.778*	0.203*	-0.073	-0.891	0.006	5.889*	7.950
$L_3 T_5$	0.444	-0.158	0.404	0.442	-0.004	28.000**	4.393
SE	0.352	0.074	0.684	1.082	0.035	1.901	
CD	1.004	0.211	1.195	3.084	0.994	5 419	

positive s c a effect was shown by Pusa-103 x PDM-134 (0.71) and negative s c a effect was shown by PDM-146 x PDM-134 (-0.52).

The analysis of variance for root length showed significant values for lines only. The g c a effects differed significantly among lines and testers. PDM-139 had a positive g c a effect (1.4 cm), while PDM-146 had a negative g c a effect (-0.90) both differed significantly. Among testers, ML-131 only had significant g c a effect (-0.83). None of the hybrdis had significant s c a effects. The general and specific combining abilities for root length at harvest time are presented in table 5 a.

The general and specific combining abilities for root spread at harvest time are presented in table 5 a. The g c a effects of all the three lines and the tester ML-131 were found to be insignificant for root spread at harvest time. Testers, Co-2 and PDM-134, had positive g c a effect (2.38 cm and 1.56 cm respectively), while P.S -16 andf Pusabaisakhi had negative g c a effect (-2.08 cm and -1.81 cm respectively) which differed significantly from the other two. Only crosses PDM-139 x Co-2 (-2.71 cm) and PDM-146 x P.S-16 (-2.63 cm) had their s c a effect significant. They were also found to be on par.

Regarding root/shoot ratio at harvest time none of the testers had significant g c a effects. Among lines, Pusa-103 had positive g c a of 0.07 and PDM-146 had negative g c a of -0.05 which differed significantly. Only one cross, Pusa-103 x Co-2 had significant s c a effect of -0.09. The general and specific combining abilities for root/shoot ratio are presented in table 5 a.

The g c a and s c a effects of parents and hybrids for leaf proline content are presented in table 5 a. Regarding the g c a effect of testers, all of them differed signficantly from each other and only Co-2 (88.93 μg/g) had positive g c a effect. Among lines, Pusa-103 (-4.58 μg/g) and PDM-139 (-3.98 μg/g) showed negative g c a while PDM-146 showed positive effect of 8.56 μg/g. PDM-146 differed significantly from the other two lines.

Among hybrids, all the crosses except PDM-146 x Co-2 showed significant s c a effect for leaf proline content. Seven out of fifteen hybrids showed negative s c a. Hybrid, Pusa-103 x Pusa baisakhi had the highest value of -20.98 μg/g while both Pusa-103 x Co-2 and Pusa-103 x ML-131 had the lowest value of -6.2 μg/g Seven out of fifteen hybrids had sinificant positive s c a effects. The cross Pusa - 103 x P.S. -16 recorded the highest value (28.58) and Pusa-103 x PDM-134 had the lowest value (4.80).

The general and specific combining abilities for pods per plant are presented in table 5 b. The g c a for number of pods per plant had positive values for ML-131 (15.60) and PDM-134 (8.24) and negative values for Co-2 (-6.18), P.S-16 (-12.62) and Pusa baisakhi (-5.04) among testers. Among lines, PDM-139 showed positive g c a of 2.24 and PDM-146 showed negative g c a effect of -1.94. The lines and testers differed significantly from each other. All the s c a effects were found to be significant except for the crosses Pusa-103 x Co-2 and PDM-139 x P.S-16. Seven hybrids showed significant negative s c a effects. The highest value of -8.68 was recorded by PDM-139 x PDM-134. Six F_1 s had positive g c a effects with a maximum value of 14.09 in PDM-139 x Pusa baisakhi and a minium of 2.24 in PDM-146 x ML-131.

The general and specific combining ability for number of seeds per pod are presented in table 5 b. All testers except PDM-134 had significant g c a for number of seeds per pod. Only Co-2 had positive g c a effect (1.38) and significantly different from others.

Treatments	Pods per plant	Seeds per pod	Days to maturity	1000 seed weight	Seed yield	Biological yield	Harvest Index
LINES							
Pusa-103	-0.304	0.696*	1.178*	0.227	-0.375*	3.215*	-0.096*
PDM-139	2.242*	-0.743*	-0.156	2.508*	1.566*	-0.982*	0.110*
PDM-146	-1.938*	0.047	-1.022*	-2.735*	-1.190*	-2.233*	-0.014
SE	0.212	0.143	0.141	0.113	0.077	0.148	0.009
CD	0.603	0.407	0.403	0.321	0.220	0.421	0.025
TESTERS							
Co-2	-6.182*	-1.378*	-0.400*	0.576*	-1.410*	-2.538*	0.027*
ML-131	15.596*	-0.679*	-1.267*	-1.433*	-4.169*	7.109*	0.062*
P.S.-16	-12.616*	-0.537*	-1.511*	-3.685*	-6.084*	-8.629*	-0.086*
P.baisakhi	-5.037*	-0.399*	-0.622*	1.881*	-0.705*	-2.045*	-0.035*
PDM-134	8.240*	0.237	1.267*	2.661*	4.030*	6.103*	0.032*
SE	0.273	0.184	0.182	0.146	0.010	0.191	0.011
CD	0.779	0.525	0.520	0.415	0.284	0.544	0.032
HYBRIDS							
$L_1 T_1$	0.616	2.390*	-1.067*	1.435*	2.719*	0.626	0.091*
$L_1 T_2$	6.438*	-0.135	-1.400*	2.471*	2.643*	9.416*	-0.120*
$L_1 T_3$	2.949*	-0.084	2.711*	1.209*	2.280*	-0.443	0.147*
$L_1 T_4$	-8.429*	-1.035*	1.156*	-3.200*	-4.809*	-8.126*	-0.023
$L_1 T_5$	-1.573*	-1.304*	-1.400*	-1.914*	-2.832*	-1.474*	-0.094*
$L_2 T_1$	-3.131*	-0.359	-0.067	-0.866*	-2.809*	-0.951*	-0.113*
$L_2 T_2$	-8.676*	-0.820*	1.267*	-2.320*	-4.975*	-9.567*	0.050*
$L_2 T_3$	-0.831	-0.804*	-3.622*	-4.912*	-2.408*	0.899*	-0.086*
$L_2 T_4$	14.091*	0.987*	1.488*	7.396*	8.467*	10.277*	0.120*
$L_2 T_5$	-1.453*	0.995*	0.933*	0.702*	1.724*	1.140*	0.030
$L_3 T_1$	2.516*	-2.031*	1.133*	-0.570*	0.090	0.324	-0.022
$L_3 T_2$	2.238*	0.955*	0.133	0.151	2.332*	0.151	0.071*
$L_3 T_3$	-2.118*	0.720*	0.911*	3.704*	0.128	1.342*	-0.061*
$L_3 T_4$	-5.662*	0.048	-2.644*	-4.195*	-3.657*	-2.151*	-0.096*
$L_3 T_5$	3.027*	0.309	0.467	1.212*	1.107*	0.334	0.064*
SE	0.473	0.319	0.316	0.252	0.173	0.330	0.019
CD	1.350	0.909	0.900	0.719	0.492	0.942	0.055

Among lines, Pusa-103 showed positive g c a (0.70) while PDM-139 showed negative g c a (-0.74). Out of the fifteen hybrids, only five showed significant positive s c a. Pusa-103 x Co-2 showed the highest value of 2.39, while PDM-146 x ML-131 had the lowest value of 0.72. Five F_1 s out of fifteen had significant negative s c a effects. PDM-146 x Co-2 had the highest value (-2.03) while PDM-139 x P.S -16 had the lowest value (-0.80).

Table 5 b provides the g c a and s c a effects for duration upto maturity. For duration upto maturity the g c a effects of testers showed significant values. ML-131 and PDM-134 both had positive values (1.27 days) while all others had negative g c a effects. Among the lines, Pusa-103 showed significant positive g c a effect of 1.18 days while PDM-146 showed negative g c a value of -1.02 days which was also found to be significant. All the hybrids except PDM-139 x Co-2, PDM-146 x ML-131 and PDM-146 x PDM-134 showed significant s c a effects. Five out of fifteen hybrids showed significant negative s c a effects while seven F_1 s showed significant positive s c a effects. The highest negatively significant s c a was shown by the cross PDM-139 x P.S-16 (2.71). The lowest values were recorded by Pusa-103 x Co-2 (-1.07) and PDM-146 x P.S-16 (0.91).

The general and specific combining ability analysis for thousand seed weight are presented in table 5 b. For thousand seed weight all the testers were having significant g c a effect. ML-131 and P.S-16 had negative g c a effects (-1.43 g and -3.69 g respectively) and the testers, Co-2 (0.58 g), Pusa baisakhi (1.88 g) and PDM-134 (2.66 g) had positive g c a effects. All the testers differed significantly. Among lines, PDM-146 had negative g c a of -2.74 g and PDM-139 and positive value of 2.51 g both differed significantly from each other. All the s c a effects were found to be significant except for the cross PDM-146 x ML-131. Seven out of fifteen hybrids had negatively significant g c a effects ranging from -4.91 g to -0.57 g in PDM-139 x P.S-16 and PDM-146 x Co-2 respectively. The cross PDM-139 x Pusa baisakhi had the maximum positive g c a of 7.4 g and PDM-139 x PDM-134 had the minimum of 0.70 g.

The g c a and s c a effects for seed yield are presented in table 5 b. Here the g c a effects of both lines and testers were found to be significant. Pusa-103(-0.38 g) and PDM-146 (-1.19 g) had negatively significant g c a while PDM-139 had positively significant g c a (1.57 g). All the lines differed significantly. Co-2 (-1.41 g), P.S-16(-6.08 g) and Pusa baisakhi (-0.70 g) had negative g c a effects which differed significantly from each other. ML-131 (4.17 g) and PDM-134 (4.03 g) were found to be on par.

The s c a effects for all the hybrids except PDM-146 x Co-2 and PDM-146 x P.S-16 were found to be significant. Seven hybrids had positive g c a effects ranging from 1.11 g in PDM-146 x PDM-134 to 8.47 g in PDM-139 x Pusa baisakhi. In the case of negatively significant s c a effects, the values ranged from -4.98 g in PDM-139 x ML-131 to -2.41 g in PDM-139 x PS-16.

Regarding the biological yield, all the lines and testers differed significantly in their g c a effects. Among the lines, Pusa-103 (3.21 g) had positive g c a while PDM-139 and PDM-146 had negative g c a effects (-0.98g and -2.23 g respectively). All the lines differed significantly. Among the testers, Pusa baisakhi (-2.05 g) and Co-2 (-2.53 g) had negative g c a effects which were found to be on par. P.S-16 also had negative g c a of -8.63 g which differed significantly from others. All the hybrids involving the line PDM-139 had significant s c a effects. Three hybrids of Pusa-103 and two hybrids of PDM-146 only had significant s c a effects. Six out of fifteen hybrids had negatively significant s c a effects while four had positively significant s c a. The positive s c a ranged from 1.14 g in PDM-139 x PDM-134 to 10.27 g in PDM-139 x Pusa baisakhi.

The general and specific combining ability for harvest index are presented in table 5 b. All the testers had significant g c a effects for harvest index. P.S-16 (-0.09) and Pusa baisakhi (-0.04) had negative effects while all others showed positive combining ability. Among the lines Pusa-103 had negatively significant g c a (-0.10) and PDM-139 had positive g c a (0.11). Only three F_1 s had insignificant s c a effects. Six hybrids had positive s c a effects which ranged from 0.05 in PDM-139 x ML-131 to 0.15 in Pusa 103 x P.S-16.

The analysis of variance for stomatal distribution showed significant differences for treatments and replication. But the variance of the crosses was found to be not significant.

The general and specific combining abilities for stomatal distribution are presented in table 5 b. It showed that none of the g c a and s c a effects were significant except in the case of the line PDM-146 (5.15). The other two lines had negative g c a. In testers also P.S-16 and PDM-134 had negative g c a and others had positive g c a.

Eight out of fifteen hybrids showed negative s c a effects and the others had positive s c a effects. The highest s c a was shown by PDM-146 x Pusa baisakhi and the minimum by PDM-139 x Pusa baisakhi.

PROPORTIONAL CONTRIBUTION

The proportional contribution of lines, testers and crosses to the total variance of the characters under study had a range of 2.10 for number of pods per plant to 58.69 for root length among lines. Among testers, the values ranged from 6.94 for stomatal distribution to 75.78 for number of pods per plant. In the case of crosses, the values ranged from 19.70 for root length to 63.35 for stomatal distribution.

For the characters root length and root/shoot ratio, lines had contributed the maximum of 58.69 and 50.87 respectively. For all other characters except harvest index and stomatal distribution, the lines had the least contribution to the total variance with respect to testers and crosses.

The testers had contributed the maximum to the total variance for five characters viz., root spread (52.86), proline content (52.86), number of pods per plant (75.78), seed yield (51.83) and biological yield

Table - 6. Proportional contribution of lines. testers and crosses for various characters, towards the total varianc

Characters	Proportional contribution		
	Lines	Testers	Line x testers
1) Duration upto fifty per cent flowering	8.07	33.82	58.11
2) L A I at fifty per cent flowering	11.98	34.90	53.12
3) Root length at harvest	58.69	21.61	19.70
4) Root spread at harvest	4.32	52.86	42.82
5) Root/shoot ratio	50.87	16.56	32.57
6) Stomatal distribution	29.71	6.94	63.35
7) Leaf proline content	4.82	52.86	42.82
8) Number of pods per plant	2.10	75.78	22.12
9) Number of seeds per pod	16.56	27.38	56.06
10) Weight of thousand seeds	23.75	27.41	48.84
11) Duration upto maturity	17.22	25.41	57.37
12) Seed yield	4.74	51.83	43.43
13) Biological yield	8.45	53.78	37.77
14) Harvest index	40.88	16.07	43.05

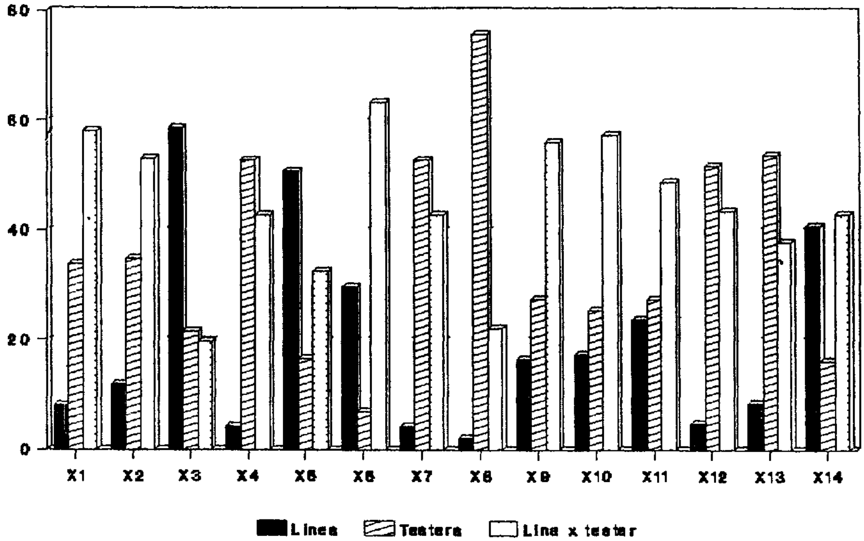

Fig. 1 . Proportional contributions of Lines, testers and line x testers to total variance for various characters

The Characters taken for the study of Proportional Contribution

X_1 Duration upto fifty per cent flowering

X_2 Leaf area index at fifty per cent flowering

X_3 Root length at harvest

X_4 Root spread at harvest

X_5 Root/shoot ratio

X_6 Stomatal distribution

X_7 Leaf proline content

X_8 Number of pods per plant

X_9 Number of seeds per pod

X_{10} Thousand seed weight

X_{11} Duration upto maturity

X_{12} Seed yield

X_{13} Biological yield

X_{14} Harvest index

(53.78). Only for three characters, harvest index (16.07), root/shoot ratio (16.56) and stomatal distribution (6.94) the testers have contributed the least to the total variance.

The crosses had maximum and medium contributions to various characters except for root length for which the cross had contributed the least. For the characters duration upto fifty per cent flowering (58.11), leaf area index (53.12), number of seeds per pod (56.06), weight of thousand seeds (48.05) and stomatal distribution (63.35) crosses had the maximum contribution to the total variance and for the other character it had the medium contribution.

DISCUSSION

D I S C U S S I O N

Hybridzation is the most potent technique for breaking yield barriers and evloving varieties having a built in high yield potential. The selection of suitable parents for hybridization is one of the most important steps in a hybridization programme. Selection of the parents on the basis of phenotypic performance or the mean values alone is not a sound procedure, since phenotypically superior lines may yield poor recombinants in the segregating generation. It is therefore essential that parents should be chosen on the basis of their genetic value or the combining ability. Combining ability analysis is aimed at getting informations about the general combining ability (gca) of parents and specific combining ability (sca) of hybrids. The concept of combining ability was first proposed by Sprague and Tatum (1942) and attributed g c a to additive gene action and s c a to dominance de iation and epistatic effect. According to them, combining ability is the relative ability of a biotype to transmit desirable performance to its crosses and g c a is the average performance of a strain in a series of crosses where as s c a is used to designate those cases in which certain combinations do relatively better or worse than would be expected on the basis of average performance of the lines invloved. The combining ability studies reveal the nature of gene action govering the character which is important in designing a breeeding programme. There are several techniques for he evaluation of varieties or strains in terms of their combining ability. Of these, diallel, partial diallel and line x tester techniques are commonly used.

The line x tester analysis proposed by Kempthorne (1957), which is a modified form of the top-cross, has some advantage over diallel analysis. Line x tester analysis is designed in such a way to avoid the interaction among males and females which is usually unnecessary. It has got another advantage of having 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. This techniques has been extensively used in almost all major field crops to estimate g c a and s c a variances and effects and to understand the nature of gene action involved in the expression of various quantitative traits As mentioned earlier, it measures the g c a and s c a variances and effects and the genetic components of variance ($\sigma^2 a$ and $\sigma^2 d$). It however fails to detect and estimate the epistatic variance.

Analysis of variance had shown that all the treatment mean squares were significant for all the characters suggesting that there was significant differences among the genotypes. The parents differed significantly for all the traits except for root/shoot ratio, since the mean squares due to parents were significant for the traits. All the crosses were found to differ significantly for all the characters except stomatal distribution. So all the characters except stomatal distribution were subjected to line x tester analysis and there by estimating combining ability and gene action.

Analysis of variance for soil moisture taken at weekly intervals didnot show any significant difference indicating that the water content in the field was uniform for all the treatments through out the crop growth period.

Duration up to fifty per cent flowering

Duration upto fifty per cent flowering which is an indication of earliness may not be a true indication for resistance machanism, but it is certainly an important character for drought prone areas. It

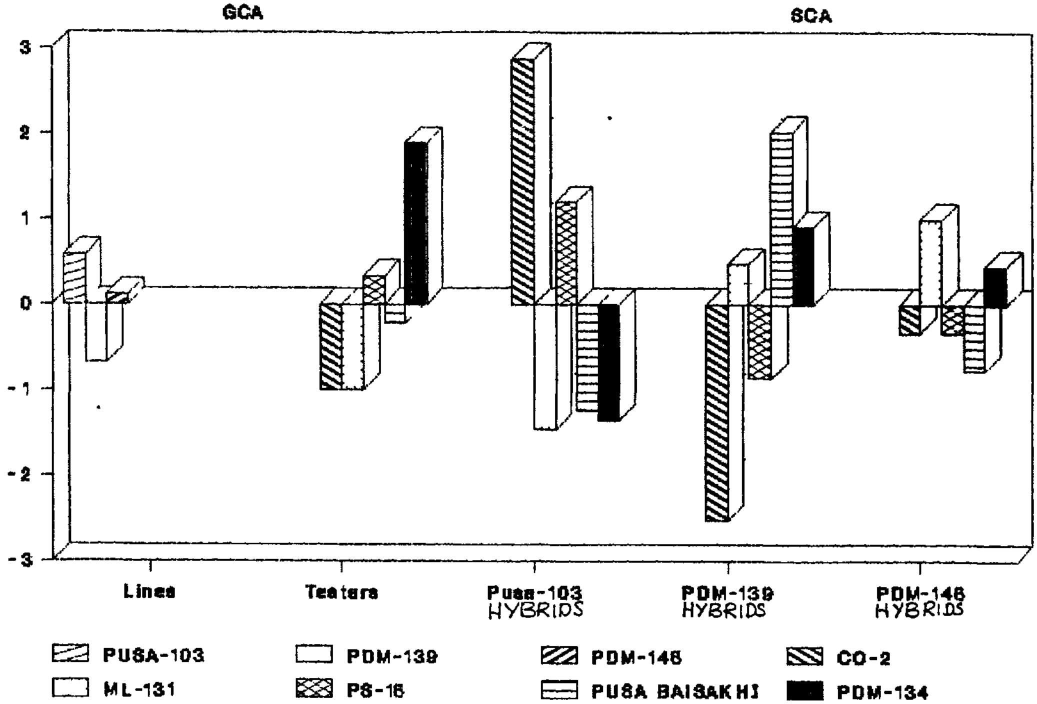

Fig. 2 General and specific combining ability for 50% flowering

results in an escape of the effect of drought by completing the life cycle before the advent of drought. So varieties with short duration for first flowering is recommended under drought conditions. The varieties with 60 to 65 days are recommended as ideal plant type for summer crop.

Variance for duration upto fifty per cent flowering showed that only line x tester was significant. So only s c a variance is found to be significant for this character suggesting non-additive gene action. The importance of non-additive gene action for fifty per cent flowering was reported earlier by Srivatsava *et al*. (1977) in soybean, Mandal and Bahl (1987) in chickpea and Katiyar *et al*. (1987) in peas. On the other hand, the importance of additive gene action was reported by Durong (1980) in soybean and Patil and Bhapker (1986) in cowpea. However, significance of both g c a and s c a effects with a predominance of non-additive gene action was reported by Deshmukh and Manjare (1980) in greengram and predominance of additive gene action was reported by Dubey and Lal (1983) in pea, Wilson *et al*. (1985)in greengram and Githiri *et al* (1991) in pigeon pea for the expression of duration upto flowering.

Among lines, PDM- 139 had negatively significant g c a, while out of three testers which had negative g c a , only Co-2 and ML-131 had significant effect. The maximum significiant s c a effect was shown by PDM-139 x Co-2. Parents with negative g c a effects were involved in this cross. The minimum significant s c a effect was shown by the cross PDM-146 x Pusa baisakhi but its parents had insignificant g c a. The other good hybrids for earliness were Pusa-103 x ML-131, Pusa-103 x Pusa baisakhi, Pusa-103 x PDM-134, PDM-139 x P.S-16 which were found to be on par. The better combination for earliness therefore involved early x early, early x late and late x late combining parents.

Leaf area index at fifty per cent flowering

Reduction in leaf area is an important mechanism for transpiration control under drought tolerance during the entire reproductive and grain filling period. A reduced leaf area decreases the transpirational loss of water as well as avoid mutual shading and there by enhances the photosynthetic activity of the plant. So a medium leaf area index is recommended for greengram varieties under drought conditions.

For leaf area index at fifty per cent flowering, line x tester interaction alone was found to be

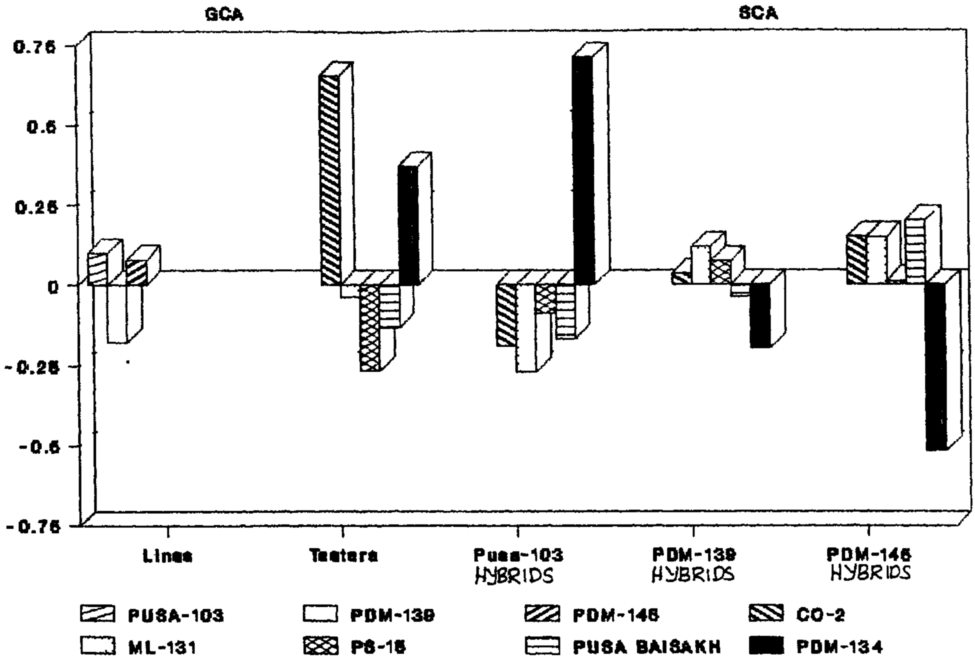

Fig. 3. General and specific combining ability for leaf area index

significant, suggesting the importance of s c a effect for the trait. The ratio of $\sigma^2 a$ to $\sigma^2 d$ was also found to be less than unity indicating the importance of non-additive gene action for its expression. This is in accordance with the findings of Candra and Nijhawan (1979) in mungbean, Deshmukh and Bhapkar (1982 a & b) in chickpea. Contrary to this, Anilkumar (1993) reported the prevalence of additive gene action for the character. In sesamum, Reddy and Haripriya (1990) found the importance of both additive and non-additive gene action.

Lines, Pusa-103 and PDM-146 were found to have insignificant g c a for leaf area index and among testers, Co-2 and ML-131 were found to be insignificant. Two hybrids PDM-146 x P.S-16 and PDM-139 x Pusa baisakhi were found to be better crosses for leaf area index which were evolved from crosses with parents of negative x positive and negative x negative effects.

Root length and spread at harvest time

Root length and spread influence grain yield under stress conditions by influencing the water uptake of plants. A well developed and widespreading root system is characteristic of reduced drought injury and increased yield in crop plants. But in greengram,

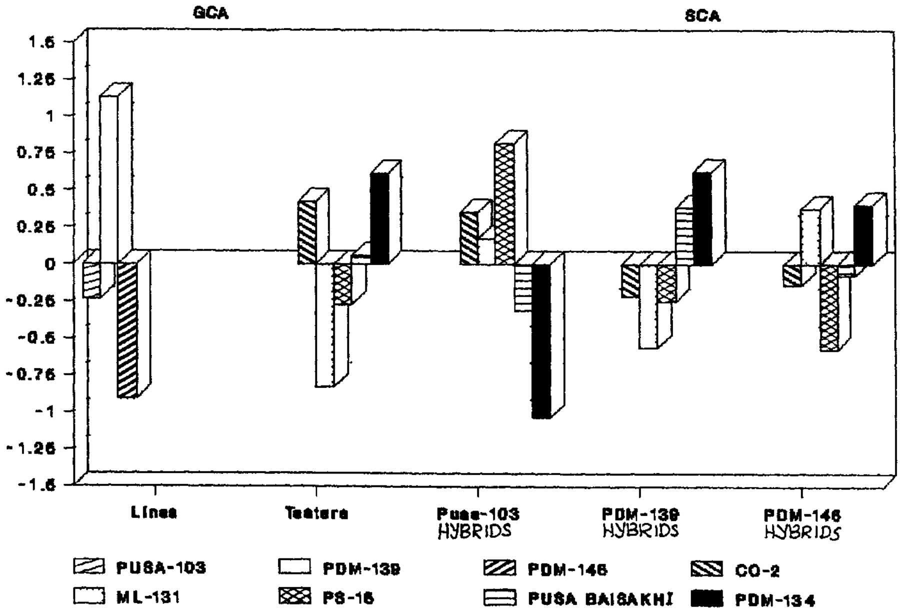

Fig.4. General and specific combining ability for root length at harvest time

varieties with high root length and root spread were found to be low yielding and it may be due to increased vegetative growth at the expence of reproductive growth. So a moderate root length and spread were recommended for drought tolerant high yielding varietis (Anitha 1989).

For root length meansquares were significant for lines and testers while for root spread, testers and line x tester mean squares were found to be significant. So the character root length is controlled mainly by additive gene action since the g c a variance alone is significant while for root spread both g c a and s c a are important indicating the presence of both additive and non-additive gene action for its expression. Contradictory to this a study on pearlmillet by Nanga and Saxena (1986) revealed the importance of non-additive gene action while Islam et al. (1987) reported the presence of both additive and non-additive gene action with a predominance of additive gene action in mungbean for root length. But the ratio of $\sigma^2 a$ to $\sigma^2 d$ was found to be less than one, indicating the predominance of dominant gene action for root spread.

For root length meansquare were significant for lines and testers while for root spread testers and line x tester mean squares were found to be significant. So the character root length is controlled mainly by additive gene action since the g c a variance alone is significant while for root spread both g c a and s c a are important indicating the presence of both additive and non-additive gene action for its expression. Contradictory to this a study on pearlmillet by Nanga and Saxena (1986) revealed the importance of non-additive gene action, while Islam et al. (1987) reported the presence of both additive and non-additive gene action with a predominance of additive gene action in mungbean for root length. But the ratio of $\sigma^2 a$ to $\sigma^2 d$ was found to be less than one indicating the predominance of dominant gene action for root spread.

Among lines, Pusa-103 and among testers, P.S-16 and Pusa baisakhi were found to be the best parents for root length, while PDM-146 and ML-131 were found to be better parents for root spread. The two hybrids, Pusa-103 x ML-131 which had parents with negative x negative effects and PDM-146 x PDM-134 from parents with positive x negative effects can be selected as better hybrids for root spread. The two hybrids of PDM-146, with Co-2 and Pusa baisakhi, were found to have insignificant s c a effect for root length. Both had

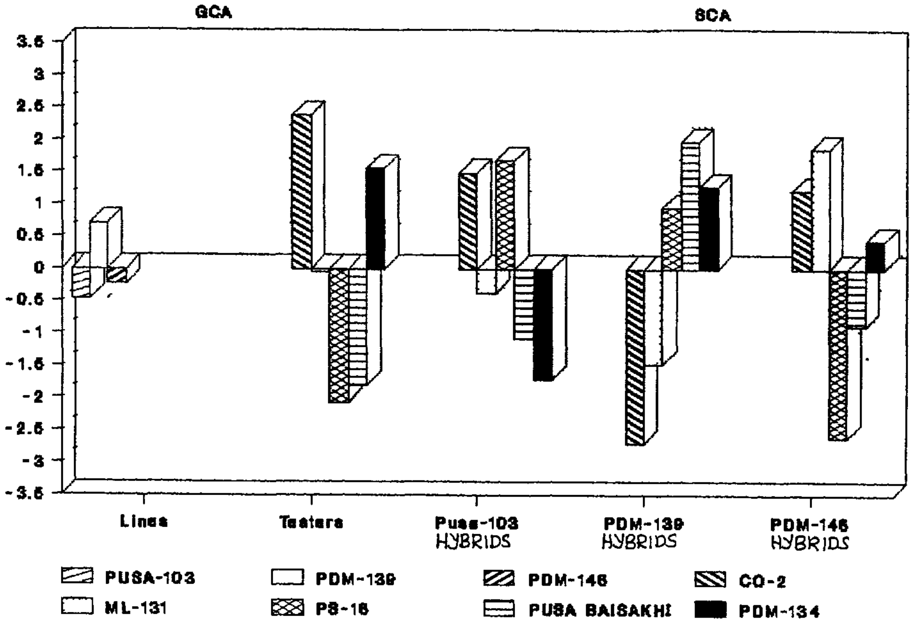

Fig. 5. General and specific combining ability for root spread at harvest time

Among lines, Pusa-103 and among testers, P.S-16 and Pusa baisakhi were found to be the best parents for root length, while PDM-146 and ML-131 were found to be better parents for root spread. The two hybrids, Pusa-103 x ML-131 which had parents with negative x negative effects and PDM-146 x PDM-134 from parents with positive x negative effects can be selected as better hybrids for root spread. The two hybrids of PDM-146, with Co-2 and Pusa baisakhi, were found to have insignificant s c a effect for root length. Both had their parents with positive and negative g c a effects.

Root/shoot ratio at harvest time

Water stress increases the proportion of plant dry matter translocate to the roots compared to the leaves and stems, thus increasing the root/shoot ratio for high yielding greengram varieties at stress.

Both lines and line x tester mean squares were found to be significant for the trait indicating the presence of both g c a and s c a variances for the expression of the trait. But the ratio of σ^2a to σ^2d was found to be less than unity suggesting the predominance of non-additive gene action for the character. No literature was found to support or to contradict this result.

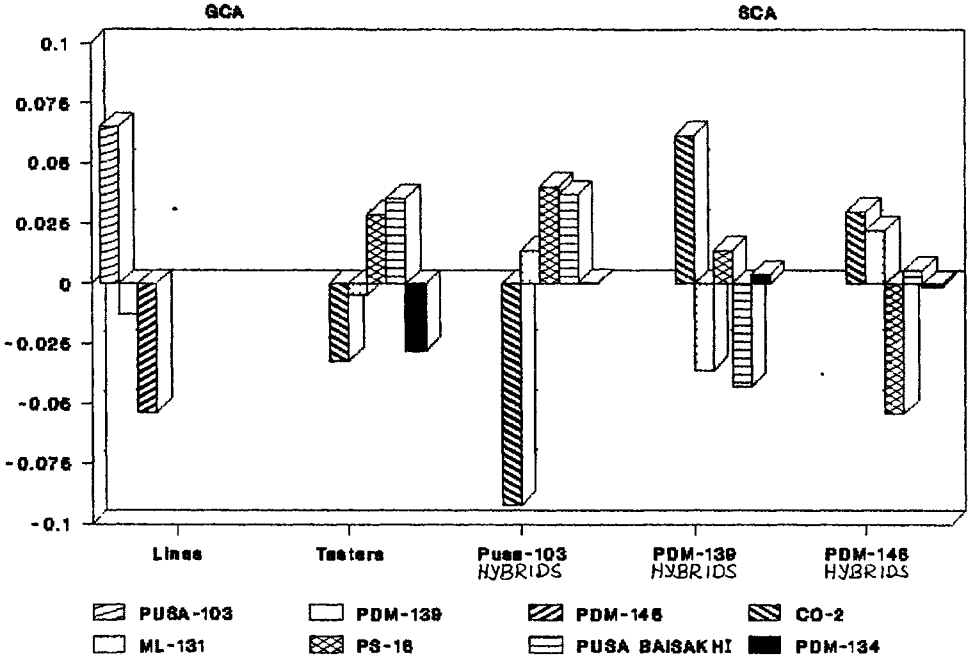

Fig. 6. General and specific combining ability for root / shoot ratio

PDM-139 and ML-131 were found to be better parents for this trait based on the g c a effect. The three hybrids of PDM-134 and the cross PDM-146 x Pusa baisakhi were found to be good combinations for root/shoot ratio. The hybrids were evolved from parents with positive x negative effects and negative x negative effects.

Stomatal Distribution

Analysis of variance showed that the crosses were not significant for the character stomatal distribution and hence further analysis has not been attempted.

Proline Content

Accumulation of proline during stress is considered to be an adaptive mechanism for drought tolerance. Proline increases considerably the amount of strongly bound water in the leaves, there by enhancing the leaf water potential. Maximum proline accumulation was observed in the variety having the highest yield.

Variance for proline content showed significance for testers and line x tester mean squares. So both g c a and s c a variances were significant indicating the importance of both additive and non-additive gene

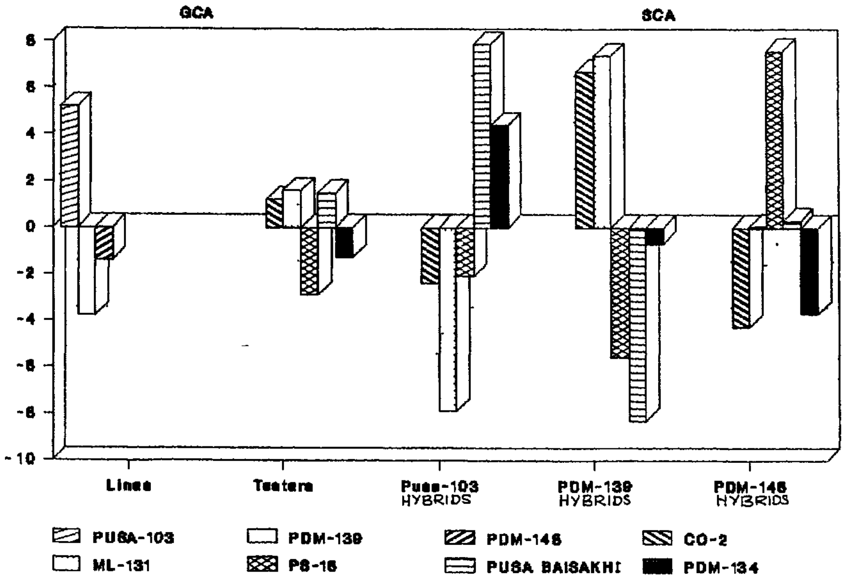

Fig.7. General and specific combining abilities for stomatal distribution

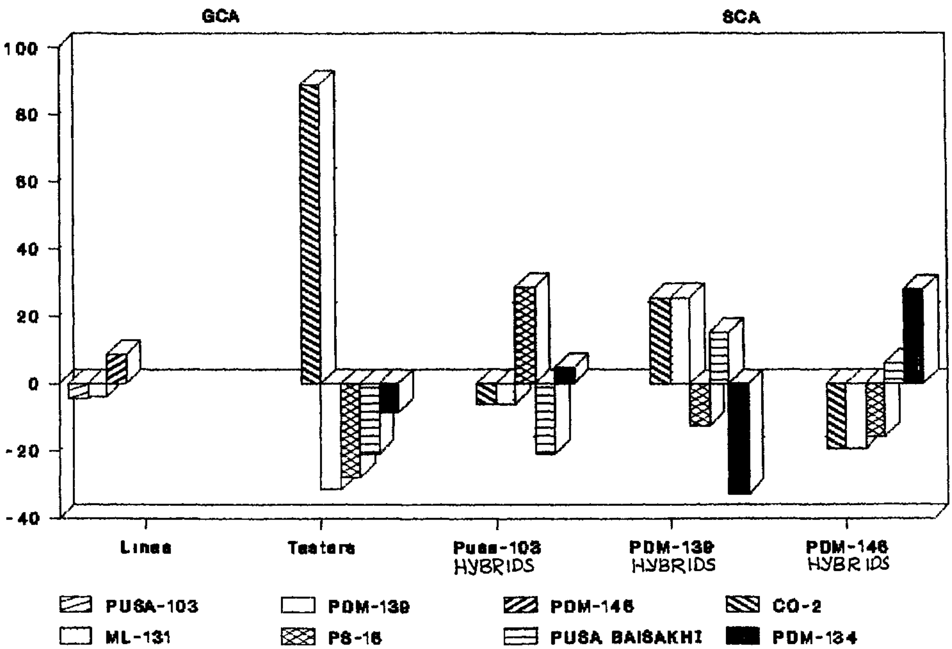

Fig.8. General and specific combining ability for leaf proline content

action for the character. But predominance of non-additive gene action was recorded for its expression since the ratio of additive to dominance variance was less than unity. But Anilkumar (1993) in cowpea had revealed only the presence of dominant component for the trait.

PDM-146 among lines and Co-2 among testers only had significant g c a effect. Seven out of fifteen crosses were found to have significant s c a. Pusa-103 x P.S-16, PDM-146 x PDM-134 and PDM-139 x ML-131 were having very high s c a effect and found to be on par Among the rest, PDM-146 x Pusa baisakhi, PDM-139 x Co-2 and Pusa-103 x PDM-134 were on par and had low s c a. Apart from them PDM-139 x Pusa baisakhi also had significant s c a. Out of these seven hybrids, four had resulted from the parents which were negative x negative combiners and the rest from negative x positive combiners. Since the character is under the control of non-additive gene action, the use of combination breeding can be recommended for its improvement

Number of pods per plant

Plants which produce more pods per plant along with more seeds per pod would be desirable. Pods per plant can be increased either by increasing branches per plant or bunches per plant or pods per bunches. It is found to be desirable to manipulate the bunches per plant or pods per bunches.

Significant g c a and s c a variances were noticed for number of pods per plant because the mean squares for testers and line x tester interaction were found to be significant. So both additive and non-additive gene actions were found to be important with a predominance of non-additive gene action since $\sigma^2 a$ to $\sigma^2 d$ ratio was less than one. This is in agreement with Pande et al (1979) in bengal gram, Deshmukh and Manjare (1980) in mungbean, Zaveri et al. (1983) and Thiyagarajan (1990) in cowpea and many others. But contrary to this Chauhan and Joshi (1981) in cowpea, Venkateswarlu and Singh (1982 a, c) in pigeonpea, Dubey and Lal (1983) also in pigeonpea, Wilson et al. (1985) in mungbean, Katiya et al. (1988) in Chickpea and Saxena and Sharma (1992) in mungbean reported predominance of additive gene action.

Line PDM-139 and testers ML-131 and PDM-134 recorded significant positive g c a effect. Six s c a effects were also significant for the trait. The maximum s c a effect was shown by PDM-139 x Pusa

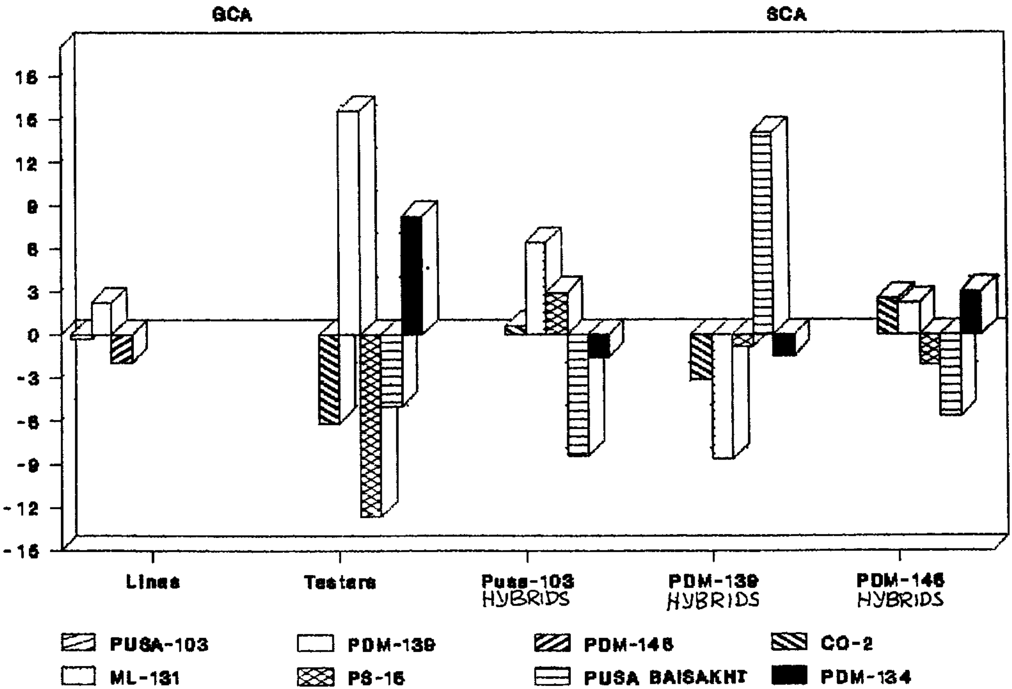

Fig.9. General and specific combining ability for number of pods per plant

baisakhi. Out of the six hybrids, four were combinations of good x poor general combiners and two from poor x poor general combiners.

Number of seeds/pod

Number of pods per plant and number of seeds per pod are having direct influence on yield. So a plant with more clusters, more seeds per pod and high seed weight will form an ideal plant type.

The line x tester interaction alone showed significant variance suggesting the significance of s c a variance for number of seeds per pod. So prevalence of non-additive gene action can be concluded for the expression of the trait. The ratio of $\sigma^2 a$ to $\sigma^2 d$ was also found to be less than unity indicating the importance of non-additive gene action. This is in agreement with Dhillon and Chahal (1981) in garden pea, Das and Dana (1981) in ricebean, Yadavendra and Sudhirkumar (1987) in chickpea, Kaliya et al. (1991) in blackgram. On the other hand additive gene action was reported by Chauhan and Joshi (1989) and Thiyagarajan (1992) in cowpea. Wilson et al. 1985) in mungbean, Katiyar et al. (1988) in chickpea.

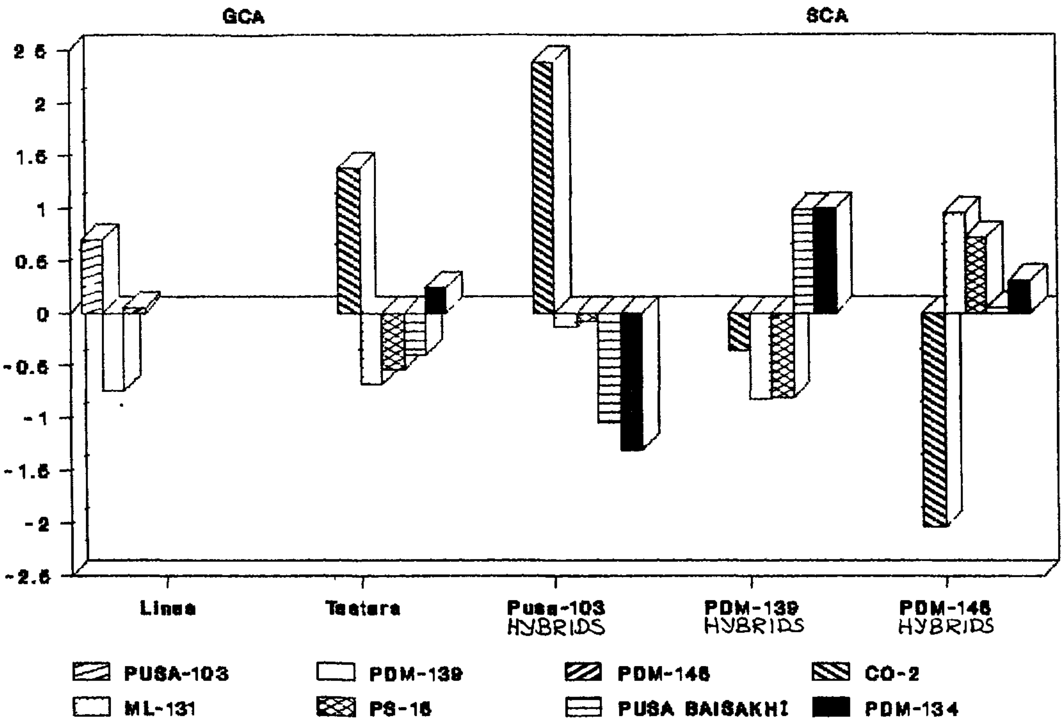

Fig.10. General and specific combining ability for seeds per pod

Among lines Pusa-103 and among testers Co-2 alone had significant positive g c a effect. Out of fifteen hybrids only five s c a effects were found to be positively significant. The maximum s c a effect was shown by the cross Pusa-103 x Co-2 ie., between good and good general combiners. The other four crosses were found to be on par and resulted from good and poor and also between poor and poor combiners.

Duration up to maturity

Only line x tester interaction alone had significant effect suggesting the importance of s c a variance for duration upto maturity. This indicates that the character may be controlled by non-additive gene action. The ratio of σ^2a / σ^2d was also found to be less than unity suggesting the importance of non-additive gene action for the expression of the trait.

Two lines and three testers were found to be negatively significant for the trait. Among lines maximum negative g c a was recorded by PDM-146 followed by PDM-139, both differed significantly. Among testers P.S-16 showed maximum negative effect followed by Pusa baisakhi and Co-2. Only five hybrids showed negatively significant s c a effects. The

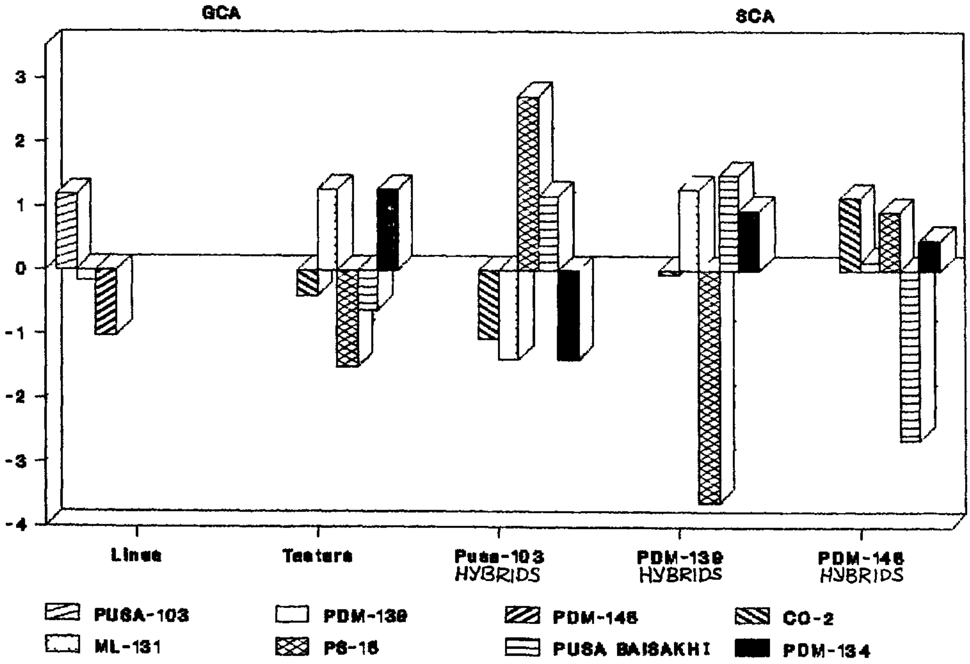

Fig.11. General and specific combining ability for duration upto maturity

maximum s c a effect was shown by the cross PDM-139 x P.S-16 followed by PDM-146 x Pusa baisakhi. The parents involved in these crosses were early maturing. Two cross combinations were resulted from late maturing parents and one from parents of early x late maturity.

Thousand seed weight

Number of pods per plant, number of seeds per pod and seed weight were having direct influence on seed yield. It is seen that varieties with maximum seed weight recorded high yield during stress condition and hence there is scope for the selection of these varieties. Plants having a seed size of 35-40 g per thousand seeds may be preferred for an ideal plant type (Dhanpal Singh, 1991).

Significant s c a variance alone was observed for thousand seed weight since the line x tester mean square alone was significant. The ratio of $\sigma^2 a$ to $\sigma^2 d$ also was less than unity suggesting the involvement of dominance gene action for the expression of the character. Prevalence of non-additive gene action was reported earlier also by Katiyar et al. (1988) in chickpea, Thiyagarajan et al. (1990) in cowpea and Sandhu et al (1981) in blackgram. But additive gene

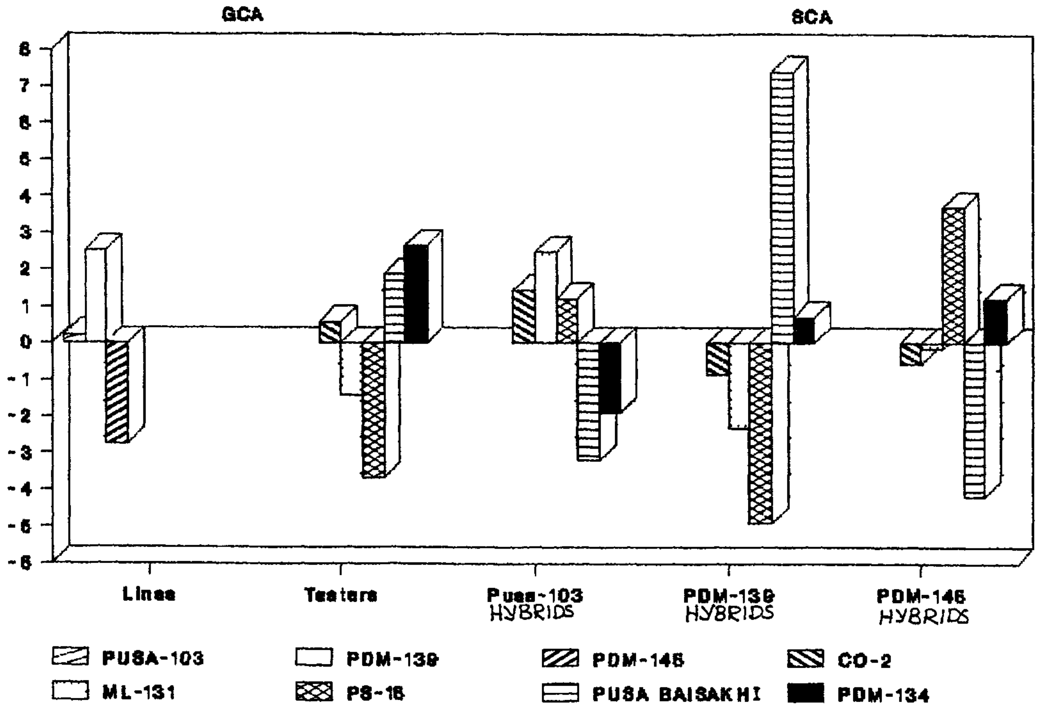

Fig.12. General and specific combining ability for weight of 1000 seeds

effect was reported by Pande *et al*. (1979) and Yadavendra and Sudhirkumar (1987) in chickpea, Wilson *et al*. (1985) and Saxena and Sharma (1992) in mungbean. PDM-139 recorded maximum general combining ability among lines and among testers Co-2, Pusa baisakhi and PDM-134 were good general combiners. Among crosses, PDM-139 x Pusa baisakhi had the maximum s c a effect. Among the significant s c a effects, three were from parents with positive x negative effect, three from positive x positive combination and one from poor x poor combination.

Seed Yield

Importance of both g c a and s c a were revealed from the analysis of variance for seed yield since the testers and line x tester interaction had significant mean squares. The character seed yield is therefore found to be controlled by both additive and dominant gene actions. But the predominance of non-additive component is expected since the ratio of additive to dominance variance is less than unity. This is in accordance with the findings of Pande (1979) in bengalgram, Deshmukh and Manjare (1980) in greengram, Singh *et al*. (1983) in pigeon pea, Zaveri *et al*. (1983) in cowpea, Haque *et al*. (1988) in urdbean, Bahl and

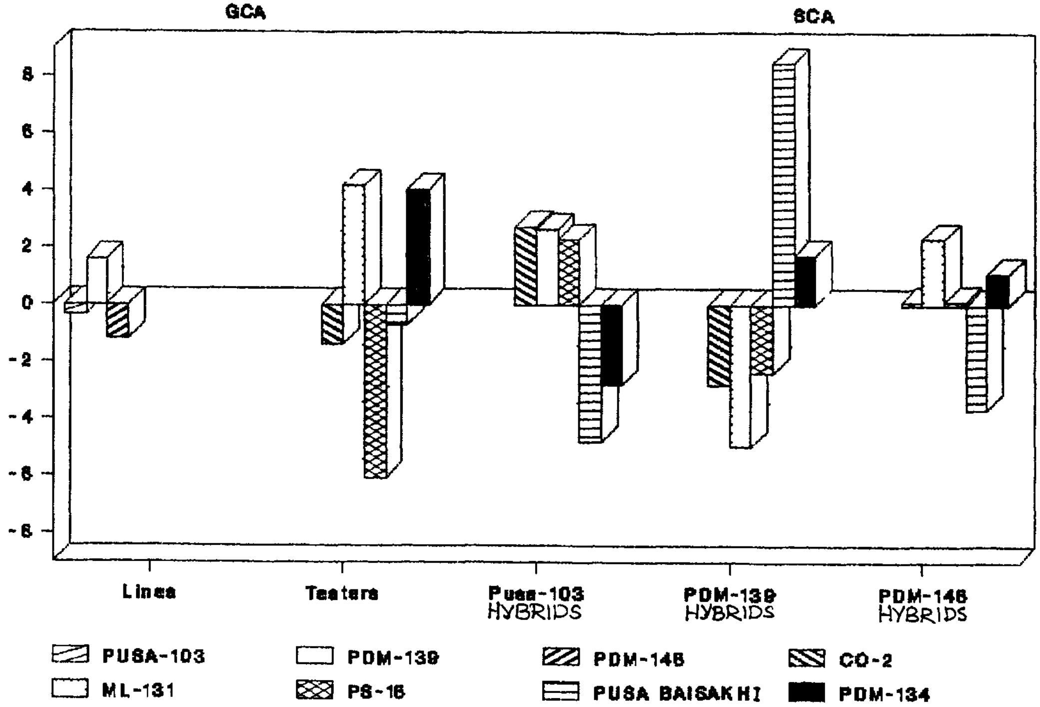

Fig.13. General and specific combining ability for seed yield

Kumar (1989) in chickpea, Sood and Garten (1990) in urdbean, and Anilkumar (1993) in cowpea. Contrary to this, premodinance of additive gene effect was reported by Chauhan and Joshi (1981) in cowpea, Malhotra (1983) in urdbean, Wilson *et al*. (1985) in mungbean, Katiyar *et al*. (1983) in chickpea and Natarajan (1990) in greengram.

The g c a effects were positively significant for one line and two testers and s c a effects for seven hybrids. Among lines, PDM-139 and among testers, ML-131 and PDM-134 were having significant g c a. The maximum positively significant s c a was shown by PDM-139 x Pusa baisakhi. ie., from parents with positive and negative g c a effect. Out of seven cross combinations, two cross combinations were from parents with poor x poor, four from parents with good x poor and one from good x good general combiners.

Biological yield

For biological yield significant mean squares for testers and line x tester interaction were observed indicating the importance of both g c a and s c a variances for the trait. The ratio of additive to dominance variance was found to be less than unity indicating predominance of non-additive gene action for the character. This is in accordance with the findings of

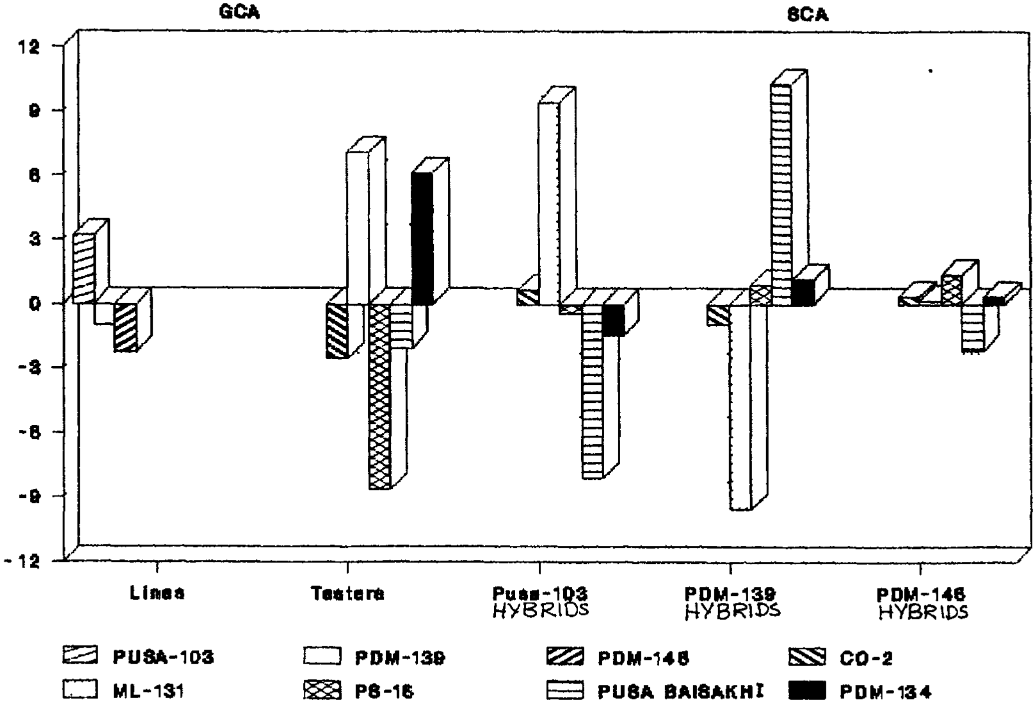

Fig.14. General and specific combining ability for biological yield

Pande *et al*. (1979) in bengalgram, Salimath and Bahl (1989) in chickpea and Anilkumar (1993) in cowpea. But Swarnalatha (1988) in soybean reported the prevalance of additive gene action for the character.

Pusa-103 among lines and ML-131 and PDM-134 among testers were having positively significant g c a effects. Among s c a effects, only four out of fifteen crosses were positively significant. The maximum s c a effect was shown by PDM-139 x Pusa baisakhi, both parents involved were with poor combining ability followed by Pusa-103 x ML-131, both the parents with good combining ability. The other two better combinations were PDM-146 x P.S-16, both parents with poor combining ability and PDM-139 x PDM-134, from good x poor combinations.

Harvest index

Presence of both g c a and s c a effects were observed since the lines and line x tester mean squares were found to be significant for the trait. So the character is under the control of both additive and non-additive gene action. This is in accordance with the results of Singh *et al*. (1987 a) in blackgram, Kumar and Bahl (1988) in chickpea and Gadag *et al*. (1990) in soybean. However preponderance of additive

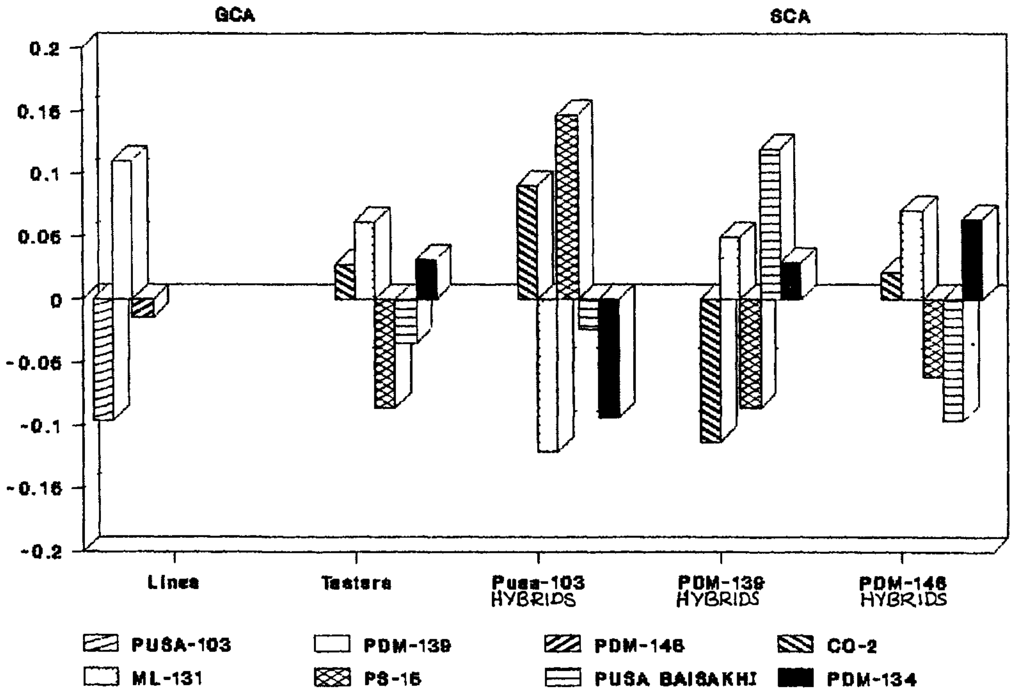

Fig.15. General and specific combining ability for harvest index

gene action was also reported by Pande et al (1979) in bengalgram and Saxena et al. (1989) in pigeonpea.

Analysis of g c a effects showed that only one line PDM-139 and three testers, Co-2, ML-131 and PDM-134 are having positively significant effects. Six out of fifteen crosses had positively significant s c a effect for harvest index. The highest effect was for the cross Pusa-103 x P.S-16, where both parents are having negative g c a effects. Out of six crosses with positively significant s c a effects, four cross combinations were between parents with positive x negative combiners, one combination from parents with positive combiners and the other from negative combiners.

From the combining ability analysis, the line PDM-139 is found to have good general combining ability for duration upto fifty per cent flowering, root/shoot ratio, number of pods per plant, duration upto maturity, grain yield, thousand seed weight, and harvest index. Since the line PDM-139 is found to be a general combiner for most of the traits relating to yield and drought tolerance, the line can be used for further improvement. Among the other two lines Pusa-103 is having good combining ability for leaf area index at fifty per cent flowering, root length at harvest time number of seeds per pod and biological yield, while the line PDM-146 is having good combining ability for leaf area index at fifty per cent flowering, root spread, proline content and duration upto maturity. Pusa-103 is found to have better combining ability for some of the characters which influence yield and drought tolerance, while PDM-146 has combining ability only for certain drought tolerant characters.

Among testers, ML-131 is the best parent which has good combining ability for yield and drought related characters such as duration upto fifty per cent flowering, leaf area index at fifty per cent flowering, root spread, root/shoot ratio, number of pods per plant, total grain yield, biological yield and harvest index. This is followed by Co-2 which have good g c a for duration upto fifty per cent flowering, leaf area index, proline content, number of seeds per pod, days to maturity, weight of thousand seeds and harvest index. These two parents can be used for further breeding programme. Among the other testers, PDM-134 is having significant g c a only for yield and related components such as number of pods per plant, total grain yield, thousand seed weight, biological yield and

Table - 7. **Best lines and testers for various characters based on combining ability**

Character	Best Line	Best Tester
1. Days to flower	PDM-139	Co-2 ML-131
2. Leaf area index	Pusa-103 PDM-146	Co-2 Ml-131
3. Root length	Pusa-103	P.S.-16 Pusa baisakhi
4. Root spread	PDM-146	ML-131
5. Root/shoot ratio	PDM-139	ML-131
6. Stomatal distribution		
7. Proline content	PDM-146	Co-2
8. Number of pods/plant	PDM-139	ML-131 PDM-134
9. Number of seeds/pod	Pusa-103	Co-2
10. Days to maturity	PDM-139 PDM-146	Co-2 P.S.-16
11. Thousand seed weight	PDM-139	PDM-134 Pusa baisakhi
12. Seed yield	PDM-139	ML-131 PDM-134
13. Biological yield	Pusa-103	Ml-131 PDM-134
14. Harvest Index	PDM-139	ML-131 PDM-134

harvest index, while, Pusa baisakhi has significant g c a for root length, days to maturity and thousand seed weight and P.S-16 is significant only for root length and days upto maturity.

Among the fifteen hybrids, four combinations are found to be better for yield and drought tolerance. They are Pusa-103 x Co-2, Pusa-103 x ML-131, PDM-139 x Pusa baisakhi and PDM-146 x PDM-134. Pusa-103 x Co-2 is found to be significant for duration upto maturity, number of seeds per pod, thousand seed weight, seed yield and harvest index while Pusa-103 x ML-131 is found to be significant for duration upto fifty per cent flowering, duration upto maturity, root spread, number of pods per plant, thousand seed weight, seed yield and bilogical yield. PDM-139 x Pusa baisakhi is found to be significant for leaf area index, proline content, number of pods per plant, number of seeds per pod, thousand seed weight, seed yield, bilogical yield, and harvest index. PDM-146 x PDM-134 is found to be significant for number of pods per plant, thousand seed weight seed yield, harvest index, root spread and root/shoot ratio.

Three more combinations were also found to have significant s c a effects for some of the traits that influence drought tolerance and yield. They were Pus-

Table: 8 - Combinations of parents for various yield and drought characters

	Co-2	ML-131	P.S-16	Pusa Baisakhi	PDM-134
Pusa-103	Days of maturity Seeds per pod Seed weight Seed yield Harvest index --	Days of flower Days to maturity Root spread Pods/plant Seed weight Biological yield	Proline content Pods/plant Seed weight Seed yield Harvest index --	Days to flower -- -- -- -- -- --	Days to flower Days to maturity Root/shoot ratio Proline content -- --
PDM-139	Days to flower Proline content -- --	Proline content Harvest index -- -- -- -- -- --	Days to flower Days to maturity -- -- -- -- -- --	L A I Proline content Pods/plant Seeds/pod Seed weight Seed yield Biological yield Harvest index	Root/shoot ratio Seed Weight Seed yield Biological yield Seeds/pod -- -- --
PDM-146	Root length Pods/plant -- -- -- --	Pods/plant Seeds/pod Seed yield Harvest Index -- --	L A I Seeds/pod Seed weight Biological yeild -- --	Days to flower Days to maturity Root length Root/shoot ratio Proline content	Root spread Root/shoot ratio Proline content Pods/plant Seed weight Seed yield Harvest Index

103 x P.S-16, significant for the traits proline content, number of pods per plant, thousand seed weight, seed yield and harvest index, PDM-139 x PDM-134, significant for root/shoot ratio, number of seeds per pod, weight of thousand seeds, seed yield and biological yield. PDM-146 x P.S-16, for number of seeds per pod, weight of thousand seeds, biological yield and leaf area index. Pusa-103 x PDM-134 and PDM-146 x Pusa baisakhi are significant only for drought tolerant characters and PDM-146 x ML-131 is significant for yield characters.

Future line of work

The four superior combinations viz., Pusa-103 x Co-2, Pusa-103 x ML-131, PDM-139 x Pusa baisakhi and PDM-146 x PDM-134 are recommended for further improvement and generation advancement. For characters which are mainly governed by dominance gene action, such as duration upto flowering, leaf area index, number of seeds per pod, weight of thousand seeds and duration upto maturity can be improved by heterosis breeding. However, since it is not biologically feasible in self pollinated crops like greengram, selection can be done for pure breeding,elite plant types which appear at early generations. Recombination breeding can be practised for root spread, root/shoot ratio, leaf proline content, number of pods per plant, seed yield, biological yield and harvest index where both additive and non-additive components of gene action prevail. For the character root length, selection will help in fixing the additive gene action. Intermating of randomly selected progenies in early segregating generations obtained by crossing the parents will release the hidden genetic variability, through breakage of undesirable linkages involved in different characters and may produce an elite population for selection of high yielding lines in advanced generations. Recurrent selection may also exploit both type of gene actions.

SUMMARY

SUMMARY

Greengram is usually grown under conditions where soil moisture is a limiting factor for the successful production of crops. It utilizes the limited moisture available and completes its growth before the commencement of drought. So breeding for better plant types which can perform better under limited soil moisture is necessary. The present study was taken up with the objective of combining yield characters in to drought tolerant lines.

The experiment was conducted in the Department of Plant Breeding, College of Agriculture, Vellayani, during 1992-'93 Based on yield and previous performance, eight varieties were selected as parents. The hybridization was done between the three drought tolerant lines and five high yielding testers. The fifteen F_1 hybrids along with eight parents were evaluated in R B D with three replications. The observations were recorded on days to fifty per cent flowering, leaf area index at fifty per cent flowering, root length and spread at harvest time, root/shoot ratio, leaf proline content, stomatal distribution, duration upto maturity, number of pods per plant, number of seeds per pod, thousand seed weight, seed

yield, biological yield and harvest index. The salient inferences are presented below.

Analysis of variance indicated significant differences among treatments for all characters. Differences among parents were observed for all the traits except root/shoot ratio indicating that the parents were genetically divergent for all the characters. Significant differences were observed among crosses for all the characters except stomatal distribution and hence the gene action and combining ability were estimated for all the traits.

Among the characters, root length, root/shoot ratio and harvest index showed significant differences among lines. For root spread, leaf proline content, number of pods per plant, seed yield, biological yield and harvest index the testers were found to be significant. Therefore, for all these characters the g c a variance was significant.

Line x tester interaction had significant effect for all the characters except root length at harvest, indicating the importance of s c a variance.

Combining ability analysis had shown that both g c a and s c a variances were important for root/shoot ratio, harvest index, root spread, leaf proline content number of pods per plant, seeds yield and biological yield indicating the influence of both additive and non-additive gene action. In all these cases the ratio of $\sigma^2 a$ to $\sigma^2 d$ was found to be less than unity, indicating the predominance of non-additive gene action, for these traits.

For characters such as duration upto flowering, number of seeds per pod, thousand seed weight and duration upto maturity, line x tester interaction alone was significant indicating that these characters were mainly governed by non-additive gene action. The ratio of additive to dominance variance was also found to be less than unity. For root length at harvest lines alone had significant effect, indicating the importance of g c a variance. Here the ratio also was greater than unity indicating the influence of additive gene action alone for the expression of the trait.

Based on the g c a effect alone it was difficult to choose good general combiners for all the characters together. Similarly no cross combination was observed to be good for all the characters. Certain parents were found to be good for certain traits. Among lines PDM-139 was the best for various yield and drought tolerance characters such as, duration upto flowering, root/shoot ratio, number of pods per plant, duration upto maturity, grain yield, thousand seed weight and harvest index. Among testers ML-131 and Co-2 were good parents which had better g c a for most of the yield and drought tolerance factor. They can be used in future breeding programmes.

Among crosses,Pusa-103 x Co-2, Pusa-103 x ML-131, PDM-139 x Pusa baisakhi, and PDM-146 x PDM-134 were found to be good specific combiners for yield and drought tolerance. Since the study in general indiicated the preponderance of non-additive gene action, commercial exploitation of hybrid vigour is the most appropriate method. But exploitation of heterosis normally is not a viable proposition in greengram in the absence of easy methods of large scale production of hybrid seeds.

REFERENCES

REFERENCES

Anilkumar, S.G. (1993) Combining ability for yield and drought tolerence in cowpea [Vigna unguiculata (L.) Walp.] M.Sc. (Ag.) thesis. Fac. Agri., Kerala Agric. Univ.

Anitha, A.R. (1989) Potential for drought tolerance in greengram [Vigna radiata (L.) Wilczek.] M.Sc. (Ag.) thesis. Fac.Agri., Kerala Agric Univ.

Anonymous, (1993). The Economic Times, New Delhi, April 17.

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

Bates, L.S., Waldrer, R.P. and Teare, I.D. (1973). Rapid determination of free proline for water stress studies. Plant Soil, 39: 205-207.

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

Candra, S. and Nijhawan, D.C. (1979) Estimates of components of genetic variance and combining ability for leaf area duration in a diallel cross of mungbean Legume Res. 2: 79-84.

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

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

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

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

Das, N.D. and Dana, S. (1981). Inheritance of seed yield components in rice bean. Indian J. Genet., 41: 264-267.

Dhanpal Singh. (1991). Genetics and Breeding of Pulse Crops. Kalyani Publishers, New Delhi. pp. 239-306.

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

Deshmukh, R.B. and Bhapkar, D.G. (1982 b). Physiological genetics of chickpea II. Combining ability analysis. Legume Res., 5: 66-68.

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

Dhillon, G.S., and Chahal, G.S. (1981). An analysis of combining ability and reciprocal effects in garden pea. (Pisum sativum L.). Journal of Research, 18: 359-364.

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

Durong, J.K. (1980). Genetic divergence, combining ability and heterosis in soybean (Glycine max (L) Merrill). Ph.D. thesis. Fac. Agri., Kerala Agric. Univ.

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

Githiri, S.M., Saxena, K.B. and Laxman Singh. (1991) Inheritance of time to fifty per cent flowering in pigeon pea at ICRISAT Centre, ICRISAT News letter 13: 6-7.

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

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

*Islam, M.O., Sen, S. and Dasgupta, T. (1987). Seedling root length and seedling root number in mungbean. TVIS News Taiwan, 2: 17-18.

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

Katiyar, R.P., Ram, R.S. and Maurya, D.M. (1987). Combining ability for phenological and physiological traits in pea. Indian J Genet., **47**: 281-289.

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

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

Kolb, F.L., Marshall, H.G. and Hill Jr, R.R. (1990). Inheritance of traits associated with grain yield in a spring oat diallel. Crop Sci., **30**: 1023-1029.

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

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

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

Mehetre, S.S., Sonone, A.H., Deshmukh, R.B. and Karale, M.U. (1988). Combining ability in pigeonpea. Legume Res., **11**: 81-84.

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

Moitra, P.K. Singh, S.,P. and Mehta, A.K. (1988). Combining ability in pea (Pisum sativum). Indian J. Agric. Sci., **58**: 479-480.

Nanga, V.K. and Saxena, M.B.L. (1986). Combining ability and heterosis for root and related traits in pearl millet. Indian J. Agric. Sci., 56: 164-167.

Natarajan, K., Thiyagarajan, K. and Rathnasamy, R. (1990). Combining ability in green gram (Vigna radiata (L.) Wilczek). Madras Agric. J., 77: 382-385.

Onkar Singh, and Paroda, R.S. (1989). A comparative analysis of combining ability in irradiated and non irradiated diallel populations of chick pea. Indian J. pulses Res., 2: 1-9.

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

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

Patel, J.A., Patel, S.A., Zaveri, P.P. and Patjak, A.R. (1988). Combining ability analysis in mungbean. Indian J. pulses Res., 1: 106-110.

*Patil, R.B. and Bhapkar, D.G. (1986). Combining ability in cowpea. Journal of Maharashtra Agricultural Universities 11: 303-306.

Poehlman, J.M. (1991). The Mungbean Oxf. and IBH Publishing Co. Pvt. Ltd., New Delhi.

*Prakash, N., Chauhan, Y.S. and Kumar, K (1987). Genetics of harvest index seed and biological yield in Indian mustard. Narendra Deva Journal of Agricultural Research, 2: 198-201.

Reddy, C.D.R. and Haripriya, S. (1990). Genetic architecture, Combining ability and heterosis in certain physiological parameters in Sesamum (Sesamum indicum L). Indian J. Pl. physiol., 33: 94-96.

Rejatha, V. (1992). Combining ability in Vegetable cowpea (Vigna unguiculata var - sesquipedalis). M.Sc. (Ag.) thesis. Fac. Agri., Kerala Agric. Univ).

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

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

Sandhu, T.S., Malhotra, R.S. and Sharma, A.K. (1981). Combining ability and inheritance studies in urdbean (Vigna mungo L.). Legume Res., 4:90-94.

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

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

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

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

Sharma, S.K. and Nishi Sharma. (1988). Combining ability analysis in soybean. Indian J. Genet., 48: 35-358.

Singh, A.K. and Saini, S.S. (1986). Combining ability and heterosis in frenchbean. Indian J. Hort., 43: 121-126.

Singh, I.B., Singh, H.G., Singh, U., and Singh, P. (1987 a) Comibing ability for yield and its components in blackgram Indian J. Genet., 47: 99-103.

Singh, K.N., Singh Santhoshi, U. and Singh, H.G. (1987 b). Genetic analysis of yield components and protein content in pea. The analysis of general and specific combining ability. Indian J. Genet., 47: 115-118.

Singh, L., Sharma, D., Deodhar, A.D., Bandy, A.H., and Rastogi, K.B. (1975). Combining ability and heterosis for seed yield and ascorbic acid in gram. Indian J. Pulses Res., 3: 127-131.

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

Singh, S.P., Govil, J.N., annd Hayat Ram. (1983). Combining ability and heterosis in early pea hybrids. ,Indian J. Genet., **43**: 121-126.

Singh, S.P., Singh, H.N., and Srivatsava, J.P. (1986). Combining ability in ,lablab bean. Indian Agriculturist, **30**: 147-152.

Singh, S.P., Singh Santhoshi, U., Singh, K.N., and Singh, V.S. (1987 c). Combining ability studies in segregating generation of pea. Legume Res, **10**: 65-68.

Sood, B.C. and Garten, S.L. (1990) Genetic analysis of yield attributes in urdbean Indian J. Pulses Res. 3 : 178-180.

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

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

Srivatsava, R.L., Ziauddin Ahamad, Singh, H.G. and Saxena, J.K. (1977). Combining ability for yield and related attributes in soybean. Indian J. Agric. Sci., **48**: 148-155.

Swarnalatha and Rana, B.S. (1988). Combining ability for biological yield and harvest index in sorghum. Indian J. Genet., **48**: 149-153.

Swaran Pasricha. (1992). Some therapeutic diets. National Institute of Nutrition, ICMR. New Delhi. pp.4-13.

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

Venkateswarlu, S. and Singh, R.B (1981 a). Combining ability for earliness in pigeonpea. Indian J. Genet., 41: 252-254.

Venkateswarlu, S. and Singh, R.B (1981 b). Hetorosis and combining ability in peas. Indian J. Genet., 41: 255-258.

Venkateswarlu, S. and Singh, R.B (1982 a). Combining ability in pigeon pea. Indian J. Genet., 42: 11-14.

Venkateswarlu, S. and Singh, R.B. (1982 b). Inheritance of Seed number and seed weight in pea. Indian J. Genet., 42: 20-22.

Venkateswarlu, S. and Singh, R.B (1982 c). Combining ability analysis for some quantitative characters in pea. Indian J. Genet., 42: 322-323.

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

*Wilczek, R. (1954). Vigna IN Flore du Congo Belge. 6: 343-393.

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

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

Zaveri, P.P., Patel, P.K., Yadavendra, J.P. and Shah, R.N. (1983). Heterosis and combining ability in Cowpea. Indian J. Agric. Sci., 53: 793-796.

* Original not seen

COMBINING ABILITY AND GENE ACTION IN GREENGRAM
(*Vigna radiata* (L.) Wilczek)

BY

SREEKUMAR. S.

ABSTRACT OF THE THESIS

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT
FOR THE DEGREE

MASTER OF SCIENCE IN AGRICULTURE

[PLANT BREEDING & GENETICS]

FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF PLANT BREEDING
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM

1993

ABSTRACT

A research programme, consisting of three lines, five testers and fifteen hybrids, was carried out at the department of Plant Breeding , College of Agriculture, Vellayani, during 1992-'93, to evaluate the combining ability and gene action for yield and drought tolerance under drought condition. The lines and testers were selected based on previous performance and crossed in line x tester manner. Observations were made on both yield and drought related characters. Significant differences among the treatments were observed for all characters. Differences among parents were observed for all characters except root/shoot ratio while crosses were found to be significantly not different for stomatal distribution. Combining ability analysis was carried out for all traits except stomatal distribution, as suggested by Kempthorne (1957). Specific combining ability effects were significant for all traits indicating non-additive gene action except for root length where only g c a was significant indicating additive gene action. Both additive and non-additive gene action were significant for root/shoot ratio, root spread, proline content, number of pods per plant, seed yield, biological yield and harvest index.

Among lines, the best general combiner for various characters was PDM-139 followed by Pusa-103. Among testers, ML-131, can be selected as the best male parent followed by Co-2 and PDM-134. No specific cross combination was found to be significantly different for all traits. The varieties PDM-139, Pusa-103, ML-131, Co-2 and PDM-134, and the cross combinations Pusa-103 x Co-2, Pusa-103 x ML-131, PDM-139 x Pusa baisakhi, and PDM-146 x PDM-134 were recommended for further utilization.