GENETIC EVALUATION OF F_2 GENERATION OF INTERVARIETAL CROSSES IN GREENGRAM (*Vigna radiata* (L.) Wilczek)

By

LEENAMOL M.A.

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DECLARATION

I hereby declare that this thesis entitled **"Genetic evaluation of F_2 generation of intervarietal crosses in greengram (*Vigna radiata* (L.) Wilczek)"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellayani,

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Leenamol M.A.

CERTIFICATE

Certified that this thesis entitled "**Genetic evaluation of F_2 generation of intervarietal crosses in greengram (*Vigna radiata* (L.) Wilczek)**" is a record of research work done independently by Ms. Leenamol M.A. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Vellayani,
25-8-2001

Smt. N. Kamalam
(Chairman, Advisory Committee)
Associate Professor
Department of Plant Breeding and Genetics
College of Agriculture, Vellayani
Thiruvananthapuram-695 522

APPROVED BY:

CHAIRMAN

Smt. N. KAMALAM
Associate Professor,
Department of Plant Breeding and Genetics,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522

24.9.01

MEMBERS

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Professor and Head,
Department of Plant Breeding and Genetics,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522

Dr. S.G. SREEKUMAR
Associate Professor,
Department of Plant Breeding and Genetics,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522

24.9.01

Dr. P. SARASWATHI
Professor and Head,
Department of Agricultural Statistics,
College of Agriculture, Vellayani
Thiruvananthapuram-695522

24/9/01

EXTERNAL EXAMINER

Dr. T. S. RAVEENDRAN
Professor & Head (COTTON)

T. S. Raveendran
24.9.2001
(T.S.RAVEENDRAN)
Prof & Head, Dept of
Cotton, TNAU, CBE-3

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Introduction

1. INTRODUCTION

Pulses occupy a unique position in the world agriculture by virtue of their high protein content and the capacity for directly using the inexhaustible stock of atmospheric nitrogen. They are essential adjuncts to a predominantly cereal based Indian diet as they contain 20-28 per cent protein which is nearly three times more than that in cereals. Pulses account for one-fifth of the cultivated area and one twelfth of the food grain production in India.

Greengram (*Vigna radiata* (L.) Wilczek) belonging to the subfamily Papilionaceae is also known as mungbean, mung, moong, mungo, golden gram, Chickasawpea and Oregon pea. It is a highly priced pulse crop for its high biological value and easy digestibility. Protein content in the seed is around 24 per cent (Poehlman, 1991). It is consumed by all sections of the society in a variety of ways.

In Kerala greengram is cultivated mainly as a pure crop during summer season. The major limitation in extending the area under this crop is the non-availability of open space. In upland condition, the only land available for this crop is the partially shaded interspaces of coconut garden. Under this situation, evolving shade tolerant greengram varieties will be a real boon to the farmers and can go a long way in overcoming this problem.

With the aim of evolving a greengram variety suitable for partial shade conditions, L x T crosses were made among five selected shade tolerant lines and three popular testers as part of a departmental project.

In the present study selfed seeds from these 15 F_1 cross combinations were used to raise F_2 generation. These F_2 progenies were evaluated under the partial shade of coconut garden with the following objectives:

1. To assess the potential of F_2 progenies in terms of variability by estimating genotypic and environment components of variability.

2. To estimate the genotypic and environment correlation with respect to yield, yield attributes and shade tolerance.

3. To estimate the direct and indirect effects of yield on yield attributes and shade tolerance.

The superior types identified will be further utilized for developing hybrid derivatives with high yield and shade tolerance.

Review of Literature

2. REVIEW OF LITERATURE

Genetic improvement of pulses have been attempted by many workers using different breeding methods. However, the related works on genetic evaluation in segregating generations for shade tolerance in pulses are very few. The present study aims at assessing the potential of F_2 progenies of greengram in terms of variability and correlation with respect to yield, yield attributes and shade tolerance. A brief review of literature on these aspects are presented below.

2.1 Variability

Genetic variability in a crop forms the primary pre-requisite for achieving genetic improvement. The most important genetic parameter which provides an efficient estimation of variability is the coefficient of variation. Many workers studied the extent of variability in pulse crops by working out genotypic and phenotypic coefficients of variation.

Greengram

Sagar and Deore (1990) observed that genotypic coefficient of variation was the highest for harvest index followed by grain yield per plant and days to 50 per cent flowering.

The study on F_2 generation revealed that averages and variances were high for yield per plant, seeds per pod and pods per plant in the cross T 44 x PLN 15 and for days to first flower in T 44 x ML 5 (Reddy and Singh, 1990).

Based on genetic variability analysis in 60 diverse genotypes of greengram, Mahalingam (1991) observed high estimates of phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) for plant height, primary branches per plant and number of clusters per plant and low values for harvest index and days to 50 per cent flowering.

Borah and Hazarika (1995) observed high estimates of genotypic variances for plant height and number of pods per plant.

Khorgade (1995) evaluated 30 genotypes of greengram and reported that the characters number of branches per plant, seed yield per plant, number of pods per plant and number of clusters per plant exhibited high genotypic coefficient of variation.

Six parents and their 15 F_2 progenies were evaluated by Tiwari *et al.* (1996) and they reported high variability in the F_2 for days to maturity, clusters per plant, harvest index, pod length and 100 seed weight.

Rajeswari (1998) evaluated 25 genotypes for shade tolerance and observed that genotypic coefficient of variation (GCV) was maximum for leaf area index (41.92 %) followed by number of pod clusters per plant (36.84 %) and number of pods per plant (34.89 %). The difference between phenotypic and genotypic coefficients of variation was least for number of days to blooming followed by number of days to first harvest, grain pod ratio, pod length, number of pods per plant and leaf area index.

Xia and Ying (1998) studied variability in 739 mungbean germplasm lines for six traits. This study revealed high variability for number of pods per plant.

Dodwad *et al.* (1998b) reported that total drymatter at 25 days after sowing and seed yield per plant showed a very high genotypic coefficient of variation, closely followed by total drymatter at 45 days after sowing and harvest index.

Studies on genetic variability in 22 genotypes of greengram revealed that plant height, branches per plant, pods per plant, pod length and yield per plant had high genotypic coefficient of variation (Das and Chakraborty, 1998).

Vikas *et al.* (1998a) evaluated 45 F_1s and their 18 parents and observed moderate to high genetic variation for plant height, number of clusters per plant, number of pods per plant, days to maturity and biological yield.

Based on the evaluation of F_1 and F_2 progenies of six greengram crosses, Manivannan (1999) observed that the crosses Vamban 1 x ME 682 and VGG 11 x PMB recorded high genotypic coefficient of variation for number of pods per plant and seed yield per plant.

Rajan (1999) evaluated seven parents and F_2 progenies of their 21 crosses and observed significant difference among treatments for all the characters studied. High genotypic coefficient of variation was observed for dry weight of plants at maturity, nitrogen content of plants at maturity and grain yield.

Raje and Rao (2000) evaluated greengram lines for seed yield, its components and other morphological characters. High genotypic coefficient of variation was revealed for primary branches per plant, clusters per plant, pods per plant, seeds per plant and seed yield per plant.

Raje and Rao (2001) evaluated 200 germplasm lines and six commercial varieties over four diverse environments for seed yield and its components and identified genetically diverse genotypes with desirable level of particular characters.

Cowpea

Vaidi and Singh (1983) evaluated F_3 and F_4 populations of a cross and reported high estimates of phenotypic and genotypic coefficients of variation for cluster number and yield.

Evaluation of six genotypes by Renganayaki and Sreerengasamy (1992) revealed wide phenotypic and genotypic variation for plant height and number of pods per plant.

Based on variability study in F_2s and parents of cowpea, Mathur (1995) reported that grain yield per plant recorded the highest genotypic coefficient of variation followed by pods per plant.

Backiyarani and Nadarajan (1998) reported high genotypic coefficient of variation for primary leaf area and leaf area index.

High values of phenotypic coefficient of variation and genotypic coefficient of variation were observed for plant height, pod weight, pod length, pod yield per plant and area of primary leaves (Hazra *et al.*, 1999).

Gowri (1999) evaluated 36 full-sib progenies and reported that among yield components, plant height followed by single plant yield showed high values of intra population variability, while days to 50 per cent flowering had low variation.

Study on five F_4 populations revealed maximum variability for seed yield per plant followed by number of pods per plant, 100 seed weight, number of seeds per pod and plant height as reflected by phenotypic coefficient of variation and genotypic coefficient of variation (Kalaiyarasi and Palanisamy, 2000a).

Tyagi *et al.* (2000) reported that evaluation of 24 genotypes of cowpea revealed high estimates of genotypic coefficient of variation for days to 50 per cent flowering (19.95 %), plant height (42.55 %), seed yield per plant (25.71 %) and days to maturity (21.61 %).

Anbuselvam *et al.* (2000) evaluated 50 genotypes and observed that the characters viz., plant height, number of pods per plant and seed yield per plant recorded high genotypic coefficient of variation and phenotypic coefficient of variation.

Blackgram

Kumar and Reddy (1986) studied twenty eight F_3 progenies of blackgram and reported that plant height, branches per plant, clusters per plant and pods per plant showed the greatest diversity.

Philip (1987) reported that leaf area index exhibited high genotypic coefficient of variation (35.87 %) and there was only little difference between phenotypic and genotypic coefficients of variation in the case of days to 50 per cent flowering and leaf area index.

Based on the study conducted on parents, F_1s and F_2s of six intervarietal crosses, Sharma and Rao (1988) reported considerable variation for yield and its components.

Evaluation of blackgram genotypes under the partial shade of coconut plantation revealed that leaf area index and accumulation of drymatter (photosynthetic efficiency) exhibited high genotypic coefficient of variation and phenotypic coefficient of variation (Abraham, 1988).

Renganayaki and Sreerengasamy (1992) evaluated 20 genotypes and reported that phenotypic coefficient of variation and genotypic coefficient of variation were high for dryleaf weight followed by seed yield and leaf area.

High genotypic coefficient of variation and phenotypic coefficient of variation were reported for leaf area index, biological yield, seed yield per plant and plant height in a study conducted by Sajikumar (1995) for evaluation of blackgram genotypes in rice fallows.

Very narrow difference between genotypic coefficient of variation and phenotypic coefficient of variation were observed for days to 50 per cent flowering and days to maturity (Savithramma *et al.*, 1999).

Natarajan and Rathinasamy (2000) evaluated 15 parents and 50 hybrids of blackgram and reported high phenotypic and genotypic coefficients of variation for seed yield and plant height.

Redgram

Singh *et al.* (1981) evaluated genetic variability in 50 F_4 progenies and reported that maximum amount of genetic variability was present for number of pods per plant and minimum for days to maturity.

Natarajan *et al.* (1990) evaluated 37 genotypes and reported that highest genotypic coefficient of variation was recorded for pod number (76.95) followed by cluster number (68.82) and seed yield (53.99) while genotypic coefficient of variation was lowest for seeds per pod (7.60).

Kingshlin *et al.* (2000) evaluated F_3 and full-sib progenies of a cross and estimated the components of genetic variance. Dominance variance was high for days to maturity, clusters per plant, pods per plant, 100 seed weight and seed yield and it was negative for days to 50 per cent flowering, plant height and seeds per pod.

Evaluation of eight pigeonpea lines revealed highly significant differences among genotypes for seed yield, 100 seed weight, pod size and plant height (Sugui *et al.*, 2000).

Other pulses

Rajasree (1988) evaluated different groundnut varieties under the partial shade of coconut garden and the analysis of variance revealed significant difference among varieties for plant height, first date of flowering, pod yield per plant, pod number per plant, 100 kernel weight, harvest index, photosynthetic efficiency and leaf area index.

Manoharan *et al.* (1990) reported highest genotypic coefficient of variation for dry matter production (66.03) followed by pod yield (55.27) and pod number (53.35) in F_2 generation of groundnut.

Abusaleha and Pal (1994) reported significant difference among 13 F_2 populations of garden pea for days to first flowering, plant height, pods per plant, and 100 seed weight.

Vijayalakshmi *et al.* (2000) evaluated parental, F_1 and F_2 generations of two crosses of chickpea and reported significant differences for the characters plant height, number of pods per plant, number of seeds per plant, number of seeds per pod and 100 seed weight.

2.2 Heritability and genetic advance

The extent to which the variability of a quantitative character is transferable to the progeny is referred as heritability for that particular character. Heritability estimates along with genetic advance is usually more useful in predicting the resultant effect through selection of the best individual.

Studies on F_2 generation of greengram revealed high values of genetic advance for number of days to flowering, height, number of pods per plant and number of seeds per plant (Miah and Bhadra, 1989).

High values of heritability and genetic advance were reported for days to 50 per cent flowering and harvest index (Sagar and Deore, 1990).

Mahalingam (1991) observed high heritability with high genetic advance for the traits plant height, number of clusters per plant, number of seeds per pod, 100 seed weight, seed yield and drymatter production. High heritability and low genetic advance was observed for harvest index and days to 50 per cent flowering.

Khorgade (1995) reported that high genetic advance was accompanied by high estimates of heritability for the characters 100 seed weight, number of clusters, number of pods and seed yield.

Days to maturity, clusters per plant, pod length and 100 seed weight exhibited high heritability and low genetic advance in the F_2 generation of greengram (Tiwari *et al.*, 1996).

Byregowda *et al.* (1997) observed high heritability associated with high genetic advance for grain yield and pods per plant.

Genetic evaluation for shade tolerance revealed high heritability for number of pods per plant (91.20 %), leaf area index (90.50 %), pod clusters per plant (85.40 %) and photosynthetic efficiency (80.10 %) (Rajeswari, 1998). High heritability and high genetic advance was observed for leaf area index, pod clusters per plant, pods per plant and grain yield per plant. Grain yield per plot recorded high heritability and low genetic advance.

Dodwad *et al.* (1998 a) reported high heritability along with high genetic advance for 100 seed weight, pod yield, seed yield and pods per plant.

High heritability along with high genetic advance was observed for total drymatter at 25 days after sowing. (Dodwad *et al.*, 1998 b).

Evaluation of 45 F_1 progeny and their parents revealed high heritability and genetic advance for plant height, number of clusters per plant, days to 50 per cent flowering, number of pods per plant and biological yield (Vikas *et al.*, 1998 b).

Based on the studies on seven parents and their 21 F_2 progenies, Rajan (1999) observed high heritability coupled with high genetic advance for dry weight of plants at maturity (84.69 % and 55.86 %)), grain yield (81.87 % and 40.97 %), number of pods (86.41 % and 32.97 %), number of clusters per plant (83.46 % and 27.47 %), harvest index (80.85 % and 27.28 %), 100 grain weight (94.52 % and 23.93 %) and plant height (72.45 % and 20.98 %).

Sharma (1999) evaluated 15 crosses and their six parents in greengram and obtained high values of heritability and genetic advance for days to flowering, pods per plant, seeds per plant, 100 seed weight and seed yield.

In the biparental mated progenies of greengram, Joseph and Santhoshkumar (1999 a) observed very high values of heritability for seeds per pod and test weight, and low values for plant height and number of pods.

Raje and Rao (2000) observed high genetic advance along with high heritability for 100 seed weight. High genetic advance was recorded for clusters per plant, pods per plant, seeds per plant and seed yield per plant.

Cowpea

Vaidi and Singh (1983) reported that heritability and expected genetic advance were high for cluster number and yield in F_3 and F_4 populations of a cross in cowpea.

Thiyagarajan (1989) evaluated seven parents and their F_1 hybrids and reported that heritability and genetic advance were high for plant height, number of seeds per pod and 100 seed weight.

Renganayaki and Sreerengasamy (1992) observed that heritability was highest for 100 seed weight while genetic advance was highest for plant height, pods per plant and primary leaf area.

Studies on 9 yield related traits in F_2 progeny of 2 crosses of cowpea revealed high to moderate heritability and genetic advance for number of clusters per plant, number of pods per plant, number of seeds per plant and pod weight. (Rangaiah *et al.*, 1999).

High heritability coupled with high genetic advance were observed for plant height, plant yield, seed number per pod and cluster number (Gowri, 1999).

Kalaiyarasi and Palanisamy (2000 a) evaluated five F_4 populations and reported that heritability and genetic advance were high for seed yield per plant, number of pods per plant, 100 seed weight and number of seeds per pod.

Tyagi *et al.* (2000) evaluated 24 genotypes of cowpea and observed high estimates of heritability and genetic advance for days to 50 per cent flowering (97.90 % and 40.66 %), plant height (98.80 % and 87.14 %), seed yield per plant (99.80 % and 52.88 %) and days to maturity (99.70 % and 44.44 %).

Anbuselvam *et al.* (2000) reported that heritability and genetic advance for plant height and days to 50 per cent flowering were high.

Blackgram

Kumar and Reddy (1986) evaluated 28 F_3 progenies and reported high heritability coupled with high genetic advance for plant height and branches per plant. Low to moderate heritability and genetic advance were recorded for pods per plant, seeds per pod, 100 seed weight and yield per plant.

Sharma and Rao (1988) analysed data from parents, F_1s and F_2s of six intervarietal crosses and observed high heritability estimates for day to flowering, days to maturity and 100 seed weight.

Abraham (1988) evaluated blackgram genotypes under partially shaded condition in coconut plantation and observed moderate to high heritability and high genetic advance for the characters drymatter accumulation (photosynthetic efficiency), leaf area index and number of days to blooming.

Sajikumar (1995) reported high heritability and high genetic advance for leaf area index, plant height and pods per plant. High heritability was recorded by seeds per pod and 100 seed weight.

Savithramma *et al*. (1999) reported high genetic advance coupled with high heritability for number of primary branches per plant, plant height and dry weight.

According to Natarajan and Rathinasamy (2000) plant height, clusters per plant, pods per plant and seed yield per plant exhibited high heritability and genetic advance.

Redgram

Sidhu *et al*. (1985) reported that heritability estimates were high for all the yield components except seed size and seeds per pod. Genetic advance was maximum for pods per plant.

Natarajan *et al*. (1990) evaluated 37 genotypes and reported high heritability and genetic advance for pod number, cluster number and seed yield.

Kingshlin and Subbaraman (1998) observed that heritability in narrow sense was high for seeds per pod in full-sib progenies of the cross MS Prabhat DT x Vamban- 1.

Other pulses

Rajasree (1988) evaluated different varieties of groundnut under the partial shade of coconut garden and reported that 100 pod weight had high heritability and genetic advance (98.29 % and 46.55 %).

High heritability and genetic advance were reported for drymatter production (58.29 % and 106.01 %), pod number (41.53 % and 66.61 %) and pod weight (31.08 % and 159.06 %) in F_2 generation of groundnut (Manoharan *et al.*, 1990).

Jain *et al.* (2000) observed that 25 diverse genotypes of fababean exhibited high heritability coupled with high genetic advance for the characters 100 seed weight and drymatter production.

Estimation of genetic parameters in chickpea by Shivkumar *et al.* (2001) revealed that additive gene effect was predominant for seed growth rate and seed weight, while non-additive effect was important for pods per plant, seeds per pod and seed yield. Narrow sense heritability was high for seed growth rate and seed weight.

2.3 Correlation

2.3.1 Correlation between yield and other characters

Information on the inter-relationship of yield with other traits is of immense help in any crop improvement programme. This will facilitate selection of suitable high yielding plants through other related characters.

Greengram

Significant positive phenotypic and negative genotypic correlation was obtained for seed weight versus seed yield (Khan, 1985).

Leaf area and leaf area index were associated with high yield at peak vegetative and flowering stages (Thandapani, 1985).

Mahalingam (1991) observed that seed yield was highly and positively influenced by drymatter production, plant height, primary branches per plant, number of clusters per plant and 100 seed weight at both phenotypic and genotypic levels.

Character association study in 400 randomly chosen F_2 plants from four crosses revealed that plant height, clusters per plant and seeds per pod had positive correlation with seed yield (Singh *et al.*, 1995).

Based on the evaluation of 14 cultivars, Bhattacharya (1996) observed that seed yield was correlated with leaf and plant drymatter during vegetative phase and with stem and total plant dry weight during post-flowering phase.

Hegde *et al.* (1996) reported that in the F_2 population of intervarietal crosses, grain yield showed significant positive correlation with clusters per plant (0.73), pods per plant (0.86) and seeds per pod (0.32), but correlation was negative with days to flowering (-0.20) and days to maturity (-0.20).

Grain yield per plant was reported to have positive association with plant height, pod clusters per plant, pods per plant, harvest index, leaf area index and photosynthetic efficiency (Rajeswari, 1998).

Evaluation of segregating F_2 progeny of three cross combinations revealed positive association of seed yield per plant with number of pods per plant in cross ML 131 x K 851 and with harvest index in all the three crosses (Vikas *et al.*, 1998c).

Dodwad *et al.* (1998b) reported significant positive correlation of seed yield per plant with total dry matter at harvest and harvest index.

Based on evaluation of F_2 progenies, Rajan (1999) reported that genotypic correlation with grain yield was significant and positive for number of pods per plant, number of clusters per plant, harvest index, plant height, 100 grain weight and number of seeds per pod.

Joseph and Santhoshkumar (1999 b) reported based on character association study in five F_2 progenies that number of pods per plant was the most important yield contributing character with correlation coefficient values ranging from 0.984 to 0.994.

Pandey and Singh (2000) evaluated 10 diverse genotypes of greengram and the results revealed significant correlation between total plant dry matter and grain yield.

Venkateswarlu (2001) evaluated 13 genotypes of greengram and reported that pods per plant, days to maturity, plant height, 100 seed weight, seeds per pod and pod length showed significant positive association with seed yield.

Cowpea

Renganayaki and Sreerengasamy (1992) observed that seed yield per plant showed significant positive association with total drymatter production and seeds per pod.

Correlation studies in F_2s and parents revealed that yield had positive correlation with plant height, pods per plant and seeds per pod (Mathur, 1995).

Singh *et al.* (1998) evaluated 45 exotic and indigenous collections and reported that genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients. Grain yield per plant was positively and significantly associated with number of clusters per plant, pods per plant and total biomass per plant.

Backiyarani and Nadarajan (1998) reported that harvest index was positively and significantly correlated with seed yield.

Correlation studies on F_3 and F_4 generations indicated that number of branches per plant, number of pods per plant and plant height had positive correlation with seed yield both at genotypic and phenotypic levels (Kalaiyarasi and Palanisamy, 1999).

Gowri (1999) evaluated 36 full-sib progenies obtained by random mating in F_2 segregating population of four single crosses. Plant height, number of clusters, number of pods, number of seeds per pod and drymatter production recorded positive association with plant yield, while days to 50 per cent flowering had negative association.

Seed yield per plant recorded significant positive correlation with days to 50 per cent flowering (0.666 and 0.675), plant height (0.736 and 0.742), number of pods per plant (0.609 and 0.680) and 100 seed weight (0.898 and 0.907) both at phenotypic and genotypic levels (Tyagi *et al.*, 2000).

Kalaiyarasi and Palanisamy (2001) reported positive correlation of seed yield with plant height, number of seeds per pod and 100 seed weight in two F_4 populations.

Blackgram

Luthra and Singh (1978) reported that in the F_3 population of 4 crosses of blackgram, seed yield was positively correlated with branch number, cluster number and pod number.

According to Philip (1987) days to 50 per cent flowering, number of clusters per plant, pods per plant and seeds per pod had high positive genotypic correlation with seed yield per plant.

Abraham (1988) evaluated genotypes under partial shade of coconut plantation and observed that harvest index (1.195), number of pod clusters per plant (1.073), pods per plant (1.113), grains per pod (0.792), leaf area index (0.663) and photosynthetic efficiency (0.836) recorded high positive genotypic correlation with grain yield per plant.

Grain yield recorded significant positive correlation with 100 seed weight, pods per plant, pod length and plant height (Singh and Singh, 1994).

Significant positive correlation was reported for seed yield per plant with pods per plant, clusters per plant, pods per cluster, seeds per pod, pod length and 100 seed weight at both genotypic and phenotypic levels (Kasundra *et al.*, 1995).

Chand (1999 a) evaluated 625 genotypes and character association study revealed that grain yield was positively and significantly associated with days to flowering, days to maturity, plant height, pod number, cluster number, seeds per pod and 100 seed weight at both genotypic and phenotypic levels.

Priya *et al.* (1999) carried out correlation analysis in 70 diverse genotypes and reported significant positive genotypic correlation with seed yield for days to 50 per cent flowering and days to maturity.

Redgram

Awatade *et al.* (1980) reported that in 12 crosses, their F_2s and F_3s, positive and highly significant correlations were noticed between yield and number of pods per plant, number of clusters per plant, plant height and days to maturity at both phenotypic and genotypic levels.

Correlation studies in 50 F_4 progenies of pigeonpea revealed that seed yield per plant was positively and highly correlated with number of pods per plant, plant height, days to 50 per cent flowering, seeds per pod and days to maturity. Genotypic correlations were higher in magnitude than phenotypic correlations (Singh *et al.*, 1981).

Ganesamurthy and Dorairaj (1990) observed that seed yield in 40 genotypes showed positive and significant correlation with drymatter production, number of pods, number of clusters, plant height, leaf area index, seeds per pod, days to flowering, pods per cluster, days to maturity, 100 seed weight and harvest index.

Salunke *et al.* (1995) reported that grain yield per plant had significant positive association with pods per plant, plant height and 100 seed weight whereas it showed strong negative association with seeds per pod.

Genotypic and phenotypic correlations in parental, F_1 and F_2 populations revealed that plant height, pods per plant, seeds per pod and seed weight were the primary components of yield (Musaana and Nahdy, 1998).

Kingshlin and Subbaraman (1999) evaluated F_3 and full sib progenies of a cross and reported that clusters per plant, pods per plant, seeds per pod and 100 seed weight were strongly associated with seed yield.

Other pulses

Rajasree (1988) reported that in groundnut varieties grown under the partial shade of coconut garden, pod number per plant, harvest index and photosynthetic efficiency during reproductive phase showed high genotypic correlation with dry pod yield per plot.

Chand (1999 b) observed that in soybean, seed yield per plant had highly significant positive association with plant height, pods per plant, days to flowering, seeds per plant, branches per plant and days to maturity.

Evaluation of 60 genotypes of rice bean indicated that grain yield per plant was significantly and positively associated with plant height, pods per cluster, pods per plant and pod length at both genotypic and phenotypic levels (Chaudhari *et al.*, 2000).

Vijayalakshmi *et al.* (2000) reported that seed yield was positively correlated with number of pods and number of seeds in parental, F_1 and F_2 generations of two crosses in chickpea.

2.3.2 Correlation among yield components

Greengram

Laosuwan *et al.* (1991) evaluated 10 cultivars in pots at 100, 90 and 50 per cent of normal light intensity. They observed that pod number and root dry weight decreased and plant height increased at 90 per cent of full sunlight; and seed yield, plant dry weight and leaf dry weight decreased and flowering date delayed at 50 per cent light intensity.

Drymatter accumulation and leaf area development were higher in intercropped stands compared to pure stands (Bhunia *et al.*, 1991).

Mahalingam (1991) reported based on interrelation studies that simultaneous selection for drymatter production, plant height and primary branches per plant will increase seed yield.

Reddy *et al.* (1994) reported that pods per plant, clusters per plant and seeds per pod had strong positive association among themselves.

Hegde *et al.* (1996) reported that clusters per plant exhibited significant positive correlation with pods per plant and seeds per pod.

Rajeswari (1998) observed that among yield components number of pods per plant had high positive correlation with number of pod clusters per plant followed by number of branches per plant, but showed high negative correlation with grains per pod.

Osumi *et al.* (1998) analysed the fruiting behaviour of soybeans, mungbeans, cowpeas and *Phaseolus lunatus* under various light conditions and the results revealed that dry weight of mature seeds remained almost constant irrespective of light conditions. Under shading mungbeans and cowpeas regulated the production of number of mature seeds by reducing the seed set in a pod as well as by reducing the fruit set.

Joseph (1998) reported that in the F_2 generation of greengram intercorrelation of plant height with branch number and pod number were positive while that with seeds per pod and test weight were negative. Pod number exhibited negative association with seeds per pod and test weight.

Cowpea

Significant positive correlation between 100 seed weight and seeds per pod was obtained in the F_2 generation (Virupakshappa *et al.*, 1980).

Renganayaki and Sreerengasamy (1992) reported significant positive intercorrelation among total drymatter production and leaf area index.

Gowri (1999) reported that intercorrelation among yield attributes in 36 full-sib progenies was high and positive for plant height, pod number, seed number per pod and drymatter production.

Positive association was reported for pod length with number of seeds per pod and number of seeds per pod with 100 seed weight in F_4 generation (Kalaiyarasi and Palanisamy, 2000c).

Blackgram

Luthra and Singh (1978) reported significant positive association among branch number, cluster number and pod number in F_3 population of four crosses.

Significant positive association was observed for days to maturity, plant height, branches per plant and leaves per plant with 100 seed weight in 52 diverse genotypes (Singh and Singh, 1994).

Evaluation of the response of blackgram to shade by Lakshmamma and Rao (1996) revealed that shading increased plant height and dry weight but decreased seed yields.

Isaacs (1999) evaluated 32 hybrids of blackgram along with their parents for yield and its components and reported that number of branches per plant, pod length and number of seeds per pod were found to be inter-correlated among themselves.

Negative phenotypic and genotypic correlation for days to maturity was observed with number of clusters per plant (-0.365 and –0.305) and number of pods per plant (-0.437 and -0.371) in blackgram (Rajendrakumar *et al.*, 1999).

Redgram

Salunke *et al.* (1995) evaluated 44 diverse genotypes and observed that days to 50 per cent flowering, days to maturity, plant height and 100 seed weight were positively and significantly associated among themselves. Pods per plant had significant positive association with plant height.

Evaluation of 37 genotypes in pigeonpea revealed significant positive correlation for plant height with number of clusters per plant, number of seeds per pod and 100 seed weight (Natarajan *et al.*, 1990).

Other pulses

Chand (1999 b) reported that in soybean the characters plant height, pods per plant, days to flowering, seeds per plant, branches per plant and days to maturity were positively associated among themselves except days to maturity with seeds per plant.

Verghis *et al.* (1999) conducted an experiment to test the effect of shading on yield and yield components in chickpea and reported that total drymatter production was highly correlated with light interception. Reduced seed yield in shaded plants was accompanied by a large decrease in harvest index.

Evaluation of 40 genotypes of chickpea revealed significant positive correlation between harvest index and 100 seed weight at phenotypic (0.381) and genotypic (0.439) levels (Yadav *et al.*, 1999).

Chaudhari *et al.* (2000) observed that days to 50 per cent flowering was positively correlated with days to maturity in rice bean.

According to Pandey *et al.* (2000) positive correlation was observed for days to flowering with maturity, plant height and 100 seed weight; pods per plant with harvest index, and seeds per pod with harvest index in grasspea.

Evaluation of five chickpea lines revealed positive and significant relationship between number of seeds per pod and number of pods per plant (Guler *et al.*, 2001).

2.4 Path analysis

Path coefficient analysis is applied to partition the genetic association between yield and its component characters into direct and indirect effects on yield. It provides information on the nature of association of several characters contributing to yield by means of untangling the direct and indirect contribution of various factors in building up a complex correlation.

Greengram

Pods per plant was found to have a high positive direct effect on seed yield, followed by seeds per pod (Natarajan *et al.*, 1988).

According to Mahalingam (1991) moderate positive direct effect on seed yield was shown by plant height, primary branches per plant and drymatter production whereas seeds per pod and harvest index showed low positive direct effect. Indirect effect of most of the traits on seed yield was through plant height and primary branches per plant.

Path analysis in F_2 generation revealed that pods per plant and clusters per plant were the major factors contributing to seed yield. Seed size also had positive direct effect on seed yield (Singh *et al.*, 1995).

Manivannan and Nadarajan (1996) reported high direct effect of pods per plant followed by pod length and plant height on seed yield and moderate negative effect of seeds per pod.

Path analysis of yield components in 49 varieties revealed that seeds per plant and 100 seed weight had the largest positive direct effect on mungbean yield (Sabaghpour *et al.*, 1998).

Rajan (1999) reported that path analysis in F_2 generation revealed positive direct effect of number of pods, 100 grain weight and number of seeds per pod on grain yield.

Path analysis revealed that seeds per plant had the highest positive direct effect on grain yield followed by 100 seed weight, plant height and pods per plant (Sharma, 1999).

Vikas *et al.* (1999) observed that seed yield was directly influenced by harvest index, plant height, number of clusters per plant, number of pods per plant and 100 seed weight. Negative direct effect was noticed for days to flowering and days to maturity. Seed yield was indirectly influenced by plant height, number of pods per plant and days to maturity via harvest index.

Cowpea

Analysis of six cowpea genotypes revealed that plant height had maximum positive direct effect on seed yield followed by primary leaf area.

100 seed weight showed negative direct effect. Indirect effect on seed yield through plant height was also high (Renganayaki and Sreerengasamy, 1992).

Based on path analysis in F_2 generation, Golsangi *et al.* (1996) reported that number of pod clusters per plant and length of pod had positive direct effect on yield under normal spacing, whereas pod yield alone had high positive direct effect on yield under wider spacing.

High positive direct effect on seed yield was reported for harvest index, leaf area index and plant height (Backiyarani and Nadarajan, 1998).

Rangaiah and Mahadevu (1999) reported that path coefficient analysis in F_2 generation indicated a greater contribution of pod weight and 100 seed weight to seed yield per plant.

Kalaiyarasi and Palanisamy (1999) conducted path analysis using 12 cross combinations in F_3 and F_4 generations. The results revealed positive direct effect of number of branches per plant, plant height, pod length and 100 seed weight on seed yield in F_3 generation; and in F_4 generation, 100 seed weight and seeds per pod had positive direct effect.

Path coefficient analysis in 24 genotypes indicated that higher seed weight per pod, number of pods per plant and 100 seed weight are important for effective selection (Tyagi *et al.*, 2000).

Kalaiyarasi and Palanisamy (2000b) reported that path analysis in F_4 population of six cross combinations revealed high positive direct effect of number of seeds per pod and number of pods per plant on seed yield. 100 seed weight exhibited negative direct effect on seed yield. Positive indirect effect was recorded for pod length and 100 seed weight through number of pods per plant, number of seeds per pod and crude protein content.

Blackgram

Philip (1987) evaluated blackgram varieties for yield and adaptability under partial shade and reported that number of pods per plant (0.5506), 100 seed weight (0.6019), days to 50 per cent flowering (0.4980) and plant height (0.2739) recorded positive direct effect on seed yield per plant.

Based on evaluation of genotypes under partial shade of coconut plantation, Abraham (1988) reported that leaf area index at 50 per cent flowering had the maximum direct contribution for harvest index followed by number of pods per plant and number of grains per pod. Ideal plant type suggested for partially shaded condition should have a higher leaf area index at 50 per cent flowering, more number of seeds per pod and high drymatter accumulation which results in a higher harvest index.

Significant positive direct effect of harvest index on seed yield was reported by Anuradha and Krishnamurthy (1990).

Shanmugasundaram and Rangaswamy (1995) conducted path analysis on data derived from 20 F_2 families and observed that pod number had the greatest direct effect on seed yield.

Rajendrakumar *et al.* (1999) reported that high to very high direct positive effect was observed for number of pods per plant followed by days to maturity, 1000 grain weight and number of grains per pod.

Path analysis was carried out in 32 hybrids and their parents and the results indicated that breeding for number of branches per plant, pod length, number of seeds per pod, 100 seed weight and harvest index might increase seed yield as they had high direct effect on yield. (Isaacs, 1999).

Natarajan and Rathinasamy (2000) conducted path analysis in 15 parents and 50 hybrids of blackgram and observed that pods per plant exerted positive direct effect on yield.

Red gram

Awatade *et al.* (1980) observed that in parents, F_2s and F_3s number of clusters per plant and 100 seed weight had direct effect on seed yield at both genotypic and phenotypic levels, whereas days to maturity and seeds per pod had low direct effect on yield.

Singh *et al.* (1982) reported that path analysis in 50 F_4 progenies revealed maximum direct and positive effect for number of pods per plant followed by 100 seed weight. Days to 50 per cent flowering exhibited negative direct effect on yield.

Path coefficient analysis in parental, F_1 and F_2 populations revealed that clusters per plant, pods per plant, seeds per pod and seed weight were the yield components with the greatest direct effect on yield (Musaana and Nahdy, 1998).

Kingshlin and Subbaraman (1999) reported that 100 seed weight, days to 50 per cent flowering, day to maturity and seeds per pod were the major characters directly affecting seed yield.

Other pulses

Abusaleha and Pal (1994) carried out path analysis in 13 F_2 generations of gardenpea and reported that pod number is the most important yield contributor followed by pod weight, 100 seed weight, plant height and pod length.

Thaware *et al.* (1999) evaluated 60 genotypes of rice bean and path analysis revealed that days to 50 per cent flowering, days to maturity, pod length and grains per plant had positive direct effects on grain yield while pods per plant and 100 seed weight had negative direct effects as well as positive indirect effects.

Materials and Methods

3. MATERIALS AND METHODS

The present study was undertaken in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani, Thiruvananthapuram during 2000-2001 with the objective to assess the potential of F_2 progenies of greengram in terms of variability and correlation with respect to yield, yield attributes and shade tolerance.

3.1 Materials

The experiment is a continuation of the PG project entitled 'Combining ability for shade tolerance and yield in greengram' in which 15 F_1 cross combinations of greengram derived from L x T crosses involving five shade tolerant lines and three testers were evaluated. In the present study, the experimental material consisted of 15 F_2 progenies obtained by selfing these F_1 cross combinations (Table 1).

3.2 Methods

A field experiment was laid out in the interspaces of coconut garden under partially shaded condition (Plates 1 and 2). The coconut plantation selected was in the age group of 20 –25 years and palms were 9m apart. Randomised block design was adopted with three replications. The F_2 seeds were sown at a spacing of 25 x 15 cm in plots of size 2.5 x 1.5m accommodating 100 plants in each plot. The cultural and management practices followed were as per the Package of Practices Recommendations 'Crops'-1996 (Kerala Agricultural University, 1996).

Table 1. List of cross combinations and F_2 progenies

Sl. No	Treatment (F_2 progenies)	Cross combination
1	T_1	IIPRM 3 x Philippines
2	T_2	Ganga 4 x Philippines
3	T_3	MGG 314 x Philippines
4	T_4	RMG 353 x Philippines
5	T_5	LGG 460 x Philippines
6	T_6	IIPRM 3 x Pusa Baisakhi
7	T_7	Ganga 4 x Pusa Baisakhi
8	T_8	MGG 314 x Pusa Baisakhi
9	T_9	RMG 353 x Pusa Baisakhi
10	T_{10}	LGG 460 x Pusa Baisakhi
11	T_{11}	IIPRM 3 x CO-2
12	T_{12}	Ganga 4 x CO-2
13	T_{13}	MGG 314 x CO-2
14	T_{14}	RMG 353 x CO-2
15	T_{15}	LGG 460 x CO-2

3.2.1 Biometric observations

Five sample plants were selected at random from each plot for recording observations.

3.2.1.1 Days to 50 per cent flowering

Number of days taken from the date of sowing to the date of opening of flowers in 50 per cent of the plants in each plot was recorded.

Height (cm) of the five sample plants was measured from the ground level to the tip of the main stem at the time of final harvest and the mean height was taken as the observation.

3.2.1.3 Leaf area index

Leaf area index was calculated at the flowering stage using the formula suggested by William (1946).

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

Factor method proposed by Sreekumar *et al.* (1978) was used for calculating the total leaf area of the plant. The linear relationship used was

$y = kx$

where y = actual leaf area estimated by graphical method

x = product of leaf length and maximum width

k = 0.61 for terminal leaf

= 0.70 for side leaf 1 and side leaf 2

3.2.1.4 Photosynthetic efficiency (dry matter)

Photosynthetic efficiency was estimated by noting the drymatter accumulation at flowering stage. Random sample of five plants were pulled out from each plot without causing damage to their root system. These plants were kept inside a hot air oven in labelled paper covers with holes at a temperature of 60^0C for 72h. When dried to a constant weight, the mean weight of plant samples were recorded to express the drymatter content in gram.

3.2.1.5 Shade intensity

The light intensity in each plot was measured using a luxmeter at 5 random spots during flowering and pod formation stages and average was worked out. The percentage shade available in each plot was calculated as follows.

$$\text{Percentage shade} = \frac{L_1 - L_2}{L_1} \times 100$$

where L_1 = light intensity in the open condition

L_2 = light intensity in the shaded condition

During flowering and pod formation stages, observations were recorded at 10.00 a.m., 1.30 p.m. and 4.00 p.m.

3.2.1.6 Number of clusters per plant

The number of pod bearing clusters in each of the five observational plants were counted and mean was worked out.

3.2.1.7 Number of pods per plant

The total number of pods harvested from the sample plants were counted and average was recorded.

3.2.1.8 Number of seeds per pod

Five pods were selected at random from each sample plant and average number of seeds per pod was worked out for each plot.

3.2.1.9 100 seed weight

100 seeds were selected at random from each plot and mean weight was recorded in grams.

3.2.1.10 Grain yield

Total grain yield from each of the observational plants was recorded in gram and average was worked out.

3.2.1.11 Days to maturity

Number of days taken from sowing to maturity in the observational plants was recorded when majority of the pods became fully dried up and the mean was worked out.

3.2.1.12 Harvest index

Harvest index was calculated using the following formula.

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

Biological yield- total dry weight of all the plant parts including grain yield.

3.2.1.13 Incidence of pests and diseases

Incidence of pests and diseases during different growth stages of the crop was recorded.

3.2.2 Statistical analysis

The data collected were subjected to the following statistical analyses.

3.2.2.1 Analysis of variance and covariance

Analysis of variance and covariance were done

i) to test varietal effect with respect to various traits

ii) to estimate variance components and other parameters like correlation coefficients, heritability, genetic advance etc.

Table 2 represents the analysis of variance/ covariance. From this table other genetic parameters were estimated.

Variance

	X	Y
Environmental variance (σ^2e)	$= \sigma^2ex = E_{xx}$	$\sigma^2ey = E_{yy}$
Genotypic variance (σ^2g)	$= \sigma^2gx = \frac{G_{xx}-E_{xx}}{r}$	$\sigma^2gy = \frac{G_{yy}-E_{yy}}{r}$
Phenotypic variance (σ^2p)	$= \sigma^2px = \sigma^2gx+\sigma^2ex$	$\sigma^2py = \sigma^2gy + \sigma^2ey$

Table 2. Analysis of variance/ covariance

Source	df	Observed mean square XX	Expected mean square XX	Observed mean sum of products XY	Expected mean sum of products XY	Observed mean square YY	Expected mean square YY
Block	(r-1)	Bxx		Bxy		Byy	
Genotype	(v-1)	Gxx	$\sigma^2ex+r\sigma^2gx$	Gxy	$\sigma exy + r\sigma gxy$	Gyy	$\sigma^2ey + r\sigma^2gy$
Error	(v-1)(r-1)	Exx	σ^2ex	Exy	σexy	Eyy	σ^2ey
Total	(rv-1)	T_{xx}		T_{xy}		T_{yy}	

Hence we have the following estimate

$\sigma^2g(x) = (G_{xx}-E_{xx}) / r$ $\quad$ $\sigma^2ex = E_{xx}$

$\sigma^2g\ (y) = (G_{yy}-E_{yy}) / r$ $\quad$ $\sigma^2ey = E_{yy}$

$\sigma g\ (xy) = (G_{xy}-E_{xy}) / r$ $\quad$ $\sigma e\ (xy) = E_{xy}$

3.2.2.2 Coefficient of variation

Phenotypic and genotypic coefficients of variation (PCV and GCV) were estimated as follows.

$$GCV = \frac{\sigma gx}{\bar{x}} \times 100$$

$$PCV = \frac{\sigma px}{\bar{x}} \times 100$$

where σgx = genotypic standard deviation

σpx = phenotypic standard deviation

3.2.2.3 Heritability (Broad sense)

Heritability was estimated as given in Jain (1982)

$$H^2 = \frac{\sigma^2 gx}{\sigma^2 px} \times 100$$

3.2.2.4 Genetic advance as percentage of mean

$$GA = \frac{kH^2 \sigma px}{\bar{x}} \times 100$$ (Miller *et al.*, 1958)

(where k = selection differential = 2.06 at 5 per cent selection and $\bar{x}$ = mean)

3.2.2.5 Correlation

$$\text{Genotypic correlation } (r_{gxy}) = \frac{\sigma_{gxy}}{\sigma_{gx} \times \sigma_{gy}}$$

$$\text{Phenotypic correlation } (r_{pxy}) = \frac{\sigma_{pxy}}{\sigma_{px} \times \sigma_{py}}$$

$$\text{Environmental correlation } (r_{exy}) = \frac{\sigma_{exy}}{\sigma_{ex} \times \sigma_{ey}}$$

3.2.2.6 Path co-efficient analysis

Path coefficient analysis was carried out according to the method suggested by Dewey and Lu (1959).

Value of path coefficients can be obtained by matrix solution.

i.e., $P = G^{-1}R$

where, P – Vector of path coefficients

G – Correlation matrix of causes

R – Correlation vector of cause and effect

Results

4. RESULTS

The data collected from the experiment were subjected to statistical analysis. The results obtained are presented below.

4.1 Mean performance

The mean values of 15 F_2 genotypes for different characters are given in Table 3. The analysis of variance for 17 characters revealed that there was significant difference among the treatments for all the characters, except shade intensities recorded during both flowering and pod formation stages.

Days to 50 per cent flowering

Among the treatments T_5 (LGG 460 x Philippines) recorded the minimum number of days (36.67) to reach 50 per cent flowering. This was on par with T_7, T_9, T_6, T_{14}, T_3, T_{10}, T_8, T_2 and T_{12}. The maximum period upto 50 per cent flowering (43.33) was recorded by T_1 (IIPRM 3 x Philippines) and T_{15} (LGG 460 x CO-2) and they had no significant difference with the treatments T_4, T_{11} and T_{13}.

Plant height (cm)

The mean values of plant height ranged from 33.02 in T_4 (RMG 353 x Philippines) to 48.54 in T_6 (IIPRM 3 x Pusa Baisakhi). The maximum value recorded by T_6 was on par with T_2 (45.25) and was followed by T_1 (44.57), T_{15} (43.43), T_7 (42.82) and T_{11} (42.25).

Leaf area index

Highest leaf area index (0.98) was recorded by T_6 (IIPRM 3 x Pusa Baisakhi) which was not significantly different from that of T_5, T_1, T_{10}, T_{14}, T_7 and T_2. T_8 recorded the lowest leaf area index (0.48) and was on par with T_4, T_{13}, T_9, T_{11} and T_3.

Photosynthetic efficiency

The maximum photosynthetic efficiency (1.33) was recorded by T_7 (Ganga 4 x Pusa Baisakhi) (Plate 3). It had no significant difference with the values of T_5, T_1, T_2 and T_{14}. T_{12} recorded the lowest value (0.84) which was on par with T_4, T_3, T_{11}, T_{13} and T_9.

Number of clusters per plant

The mean number of clusters per plant ranged from 3.38 in T_{13} (MGG 314 x CO-2) to 4.79 in T_6 (IIPRM 3 x Pusa Baisakhi). T_6 was on par with T_{15} and T_1. The lowest value was recorded by T_{13} which differed significantly from all the other treatments.

Number of pods per plant

The maximum number of pods per plant (13.37) was recorded by T_1 (IIPRM 3 x Philippines) which was significantly higher than that recorded by all the other treatments. This was followed by T_{14}, T_7, T_6 and T_9 which were on par with each other. T_4 recorded the minimum number of pods per plant (6.73).

Number of seeds per pod

T_5 (LGG 460 x Philippines) recorded the maximum number of seeds per pod (11.33) and this was on par with T_2 (Ganga 4 x Philippines), but significantly different from T_{10} (LGG 460 x Pusa Baisakhi). The minimum value was recorded by T_{13} (8.37).

100 seed weight (g)

The mean 100 seed weight ranged from 2.91 in T_{15} (LGG 460 x CO-2) to 4.16 in T_5 (LGG 460 x Philippines). T_{10} (LGG 460 x Pusa Baisakhi) and T_7 (Ganga 4 x Pusa Baisakhi) were on par with T_5 and they differed significantly from all other treatments.

Grain yield (g)

The maximum grain yield (3.52) was recorded by T_5 (LGG 460 x Philippines). T_7 (Ganga 4 x Pusa Baisakhi) and T_{10} (LGG 460 x Pusa Baisakhi) had no significant difference with T_5. These values were followed by T_{14} which had significant difference with all other genotypes. T_4 recorded the minimum value (1.10).

Days to maturity

The mean number of days taken for maturity ranged from 55.00 in T_{10} (LGG 460 x Pusa Baisakhi) to 61.67 in T_{15} (LGG 460 x CO-2). The minimum number of days recorded by T_{10} was on par with T_7 and T_9. T_{15} which recorded the maximum value had no significant difference with those recorded by T_4, T_2, T_8, T_{12}, T_{13}, T_{14}, T_{11} and T_1.

Plate 1 & 2 View of the experimental plot

Plate 3 Genotype with maximum photosynthetic efficiency – T_7 (Ganga 4 x Pusa Baisakhi)

Plate 4 Genotype with maximum harvest index - T_{10} (LGG 460 x Pusa Baisakhi)

Plate 1

Plate 2

Plate 3

Plate 4

Table 3 Comparative performance of F_2 genotypes of greengram for different characters

Treatments	Days to 50 per cent flowering	Plant height (cm)	Leaf area index	Photosynthetic efficiency	Number of clusters per plant	Number of pods per plant	Number of seeds per pod	100 seed weight (g)	Grain yield (g)	Days to maturity	Harvest index
T_1	43.33	44.57	0.93	1.30	4.76	13.37	9.97	3.41	1.71	59.33	0.33
T_2	38.67	45.25	0.78	1.26	4.54	9.33	11.30	3.16	2.08	59.67	0.42
T_3	38.33	35.48	0.67	0.86	4.19	8.63	8.53	3.23	2.12	59.00	0.53
T_4	41.33	33.02	.050	0.84	3.88	6.73	8.78	3.55	1.10	60.33	0.36
T_5	36.67	36.53	0.95	1.32	4.07	9.33	11.33	4.16	3.52	57.67	0.52
T_6	37.33	48.54	0.98	1.03	4.79	10.23	9.00	3.28	2.24	58.00	0.44
T_7	37.00	42.82	0.79	1.33	4.36	10.90	10.10	3.96	3.38	56.00	0.52
T_8	38.33	34.07	0.48	1.07	3.98	7.80	9.13	3.19	1.34	59.67	0.41
T_9	37.00	37.33	0.58	0.99	4.58	10.23	10.10	3.45	1.20	57.00	0.35
T_{10}	38.33	41.33	0.86	1.12	4.38	7.87	10.63	4.08	3.33	55.00	0.58
T_{11}	40.67	42.25	0.61	0.89	4.20	7.57	9.37	3.28	1.60	59.33	0.52
T_{12}	39.00	41.73	0.77	0.84	4.39	7.17	9.13	3.15	1.28	59.67	0.38
T_{13}	40.67	39.07	0.57	0.90	3.38	8.10	8.37	3.14	1.35	59.67	0.38
T_{14}	38.33	41.02	0.80	1.24	4.15	10.93	10.37	2.95	2.72	59.67	0.48
T_{15}	43.33	43.43	0.76	1.03	4.78	9.60	9.47	2.91	1.58	61.67	0.38
$F_{14, 28}$	2.99**	14.78**	5.27**	9.82**	188.84**	24.25**	57.34**	13.52**	46.22**	4.48**	82.17**
SE	1.25	1.15	6.93	0.58	0.03	0.36	0.12	0.11	0.12	0.82	0.01
CD	3.63	3.33	0.20	0.17	0.08	1.04	0.36	0.31	0.36	2.38	0.02

** Significant at 1 % level

Table 3 Continued ....

Treatments	Shade intensity					
	Flowering stage			Pod formation stage		
	10.00 a.m.	1.30 p.m.	4.00 p.m.	10.00 a.m.	1.30 p.m.	4.00 p.m.
T_1	11.78	9.58	28.19	19.20	26.00	34.00
T_2	16.00	10.50	38.72	23.70	23.42	35.33
T_3	8.89	8.25	45.83	22.40	30.17	37.33
T_4	18.00	13.83	42.17	30.36	27.67	35.33
T_5	21.56	12.67	44.17	23.62	23.33	32.67
T_6	23.11	20.08	53.89	31.20	36.67	47.33
T_7	17.00	6.00	43.56	23.73	23.83	32.67
T_8	30.67	13.25	35.52	30.69	34.83	40.00
T_9	21.83	19.25	56.78	41.47	36.17	54.67
T_{10}	36.21	12.33	47.94	27.51	34.67	40.67
T_{11}	26.33	19.75	45.78	35.67	31.42	48.00
T_{12}	23.11	23.50	47.89	35.27	41.50	45.33
T_{13}	15.78	22.83	51.11	29.87	41.83	47.33
T_{14}	18.45	6.67	40.44	28.67	23.00	38.00
T_{15}	25.00	15.25	59.55	34.93	42.17	50.00
$F_{14, 28}$	0.83^{NS}	1.00^{NS}	2.02^{NS}	0.72^{NS}	1.44^{NS}	1.15^{NS}
SE	7.74	5.69	5.72	7.13	5.89	6.54
CD	22.43	16.49	16.57	20.66	17.05	18.93

NS – Non-significant

Harvest index

The highest value for harvest index (0.58) was recorded by T_{10} (LGG 460 x Pusa Baisakhi) (Plate 4). This was significantly different from all other treatments. T_1 had the lowest value (0.33).

Shade intensity

There was no significant difference among the treatments for shade intensity at 10.00 a.m., 1.30 p.m. and 4.00 p.m. during flowering as well as pod formation stages.

Incidence of pests and diseases

There was no severe incidence of pests and diseases. During early crop growth stages minor attack by leaf eating caterpillar was noticed and during later stages there was mild incidence of powdery mildew disease.

4.2 Variability components and related genetic parameters

Phenotypic, genotypic and environmental components of variance, phenotypic, genotypic and environmental coefficients of variation, heritability and genetic advance (as percentage of mean) were estimated.

4.2.1 Components of variance

The genotypic variance was higher than environmental variance for most of the characters. Exception was noticed in the case of days to 50 per cent flowering. The estimates of variance components for different characters are presented in Table 4.

4.2.2 Coefficient of variation

The values of phenotypic, genotypic and environmental coefficients of variation are presented in Table 4. Phenotypic coefficient of variation (PCV) was highest for grain yield (41.98 %) followed by leaf area index (25.42 %), number of pods per plant (20.02 %), photosynthetic efficiency (18.98 %) and harvest index (18.33 %). The lowest PCV was recorded for days to maturity (3.56 %).

Grain yield recorded the maximum genotypic coefficient of variation (40.66 %) followed by leaf area index (19.49 %), number of pods per plant (18.84 %), harvest index (17.60 %), photosynthetic efficiency (16.28 %) and 100 seed weight (11.05 %). The least value of GCV was recorded for days to maturity (2.61 %).

Environmental coefficient of variation (ECV) was highest for leaf area index (16.10 %) followed by grain yield (10.40 %), harvest index (10.16 %) and photosynthetic efficiency (9.83 %). Number of clusters per plant had the least ECV (0.01 %).

4.2.3 Heritability and Genetic Advance

The values of heritability coefficient (%) and genetic advance (as percentage of mean) at five per cent selection for different characters are presented in Table 5.

Maximum heritability was observed for the character number of clusters per plant (98.43 %). Apart from this, heritability values were high for the characters harvest index (96.44 %), number of seeds per pod (94.94 %), grain yield (93.78 %), number of pods per plant (88.57 %), plant height

Table 4 Components of variance and coefficient of variation for 11 characters in F_2 generation of greengram

Sl. No.	Characters	σ^2p	σ^2g	σ^2e	PCV	GCV	ECV
1.	Days to 50 per cent flowering	7.85	3.14	4.71	7.14	4.52	5.54
2.	Plant height	22.18	18.22	3.96	11.65	10.56	4.93
3.	Leaf area index	0.03	0.02	0.01	25.42	19.49	16.10
4.	Photosynthetic efficiency	0.04	0.03	0.01	18.98	16.28	9.83
5.	Number of clusters per plant	0.15	0.15	0.00	8.95	8.89	0.01
6.	Number of pods per plant	3.38	2.99	0.39	20.02	18.84	6.77
7.	Number of seeds per pod	0.90	0.86	0.04	9.79	9.54	2.21
8.	100 seed weight	0.17	0.14	0.03	12.29	11.05	5.36
9.	Grain yield	0.73	0.69	0.04	41.98	40.66	10.40
10.	Days to maturity	4.38	2.35	2.03	3.56	2.61	2.42
11.	Harvest index	0.01	0.01	0.00	18.33	17.60	10.16

Table 5 Heritability and genetic advance for 11 characters in F_2 generation of greengram

Sl. No.	Characters	Heritability (%)	Genetic advance as % of mean at 5 % selection
1.	Days to 50 per cent flowering	39.97	5.88
2.	Plant height	82.13	19.71
3.	Leaf area index	58.74	30.75
4.	Photosynthetic efficiency	74.62	28.87
5.	Number of clusters per plant	98.43	18.16
6.	Number of pods per plant	88.57	36.51
7.	Number of seeds per pod	94.94	19.13
8.	100 seed weight	80.67	20.47
9.	Grain yield	93.78	80.98
10.	Days to maturity	53.70	3.94
11.	Harvest index	96.44	36.36

(82.13 %), 100 seed weight (80.67 %) and photosynthetic efficiency (74.62 %). Medium heritability was observed for leaf area index (58.74 %), days to maturity (53.70 %) and days to 50 per cent flowering (39.97 %).

Genetic advance as percentage of mean was high for grain yield (80.98 %), number of pods per plant (36.51 %), harvest index (36.36 %), leaf area index (30.75%), photosynthetic efficiency (28.87 %) and 100 seed weight (20.47 %). The characters plant height (19.71 %), number of seeds per pod (19.13 %), number of clusters per plant (18.16 %), days to 50 per cent flowering (5.88 %) and days to maturity (3.94 %) exhibited low genetic advance.

High values of heritability coupled with high genetic advance was observed for harvest index, grain yield, number of pods per plant, 100 seed weight and photosynthetic efficiency. High heritability and low genetic advance was noticed for number of clusters per plant, number of seeds per pod and plant height.

4.2.4 Correlation

4.2.4.1 Correlation between grain yield and other characters

Phenotypic, genotypic and environmental correlation coefficients for grain yield with 10 other characters are presented in Table 6.

Phenotypic correlation with grain yield was positive and significant for harvest index (0.7902), photosynthetic efficiency (0.6412), number of seeds per pod (0.6123), 100 seed weight (0.6073) and leaf area index (0.5656). Plant height, number of clusters per plant and number of pods per plant exhibited non significant positive correlation with grain yield. Significant

Table 6 Correlation between grain yield and 10 other characters in F_2 generation of greengram

Sl. No.	Characters	Correlation coefficient		
		Phenotypic	Genotypic♣	Environmental
1.	Days to 50 per cent flowering	-0.4406**	-0.6025	-0.3712*
2.	Plant height	0.2320	0.2001	0.5346**
3.	Leaf area index	0.5656**	0.7234	0.1786
4.	Photosynthetic efficiency	0.6412**	0.7200	0.3098
5.	Number of clusters per plant	0.0915	0.1018	-0.2026
6.	Number of pods per plant	0.2865	0.2930	0.2309
7.	Number of seeds per pod	0.6123**	0.6377	0.1881
8.	100 seed weight	0.6073**	0.6919	0.0505
9.	Days to maturity	-0.5445**	-0.7452	-0.0922
10.	Harvest index	0.7902**	0.8025	0.5746**

* Significant at 5 % level

** Significant at 1 % level

♣Significance of genotypic correlation was not tested negative correlation at phenotypic level was observed for days to 50 per cent flowering (-0.4406) and days to maturity (-0.5445).

At genotypic level correlation with grain yield was highest for harvest index (0.8025) followed by leaf area index (0.7234), photosynthetic efficiency (0.7200), 100 seed weight (0.6919) and number of seeds per pod (0.6377). Number of pods per plant (0.2930), plant height (0.2001) and number of clusters per plant (0.1018) recorded comparatively low genotypic correlation with grain yield. Negative genotypic correlation with grain yield was observed for days to maturity (-0.7452) and days to 50 per cent flowering (- 0.6025).

In general, values of genotypic correlation coefficient of the 10 characters with grain yield was higher than the corresponding phenotypic correlation for all the characters except plant height.

Environmental correlation with grain yield was significant and positive for plant height (0.5346) and harvest index (0. 5746). Days to 50 per cent flowering (-0.3712) recorded significant negative environmental correlation with grain yield.

4.2.4.2 Correlation between grain yield and shade intensity

Correlation of shade intensities at different hours of the day during flowering and pod formation stages with grain yield are presented in Table 7.

Phenotypic correlation with grain yield was negative for shade intensities at different hours of the day during both flowering and pod formation stages. Significant correlations were observed for shade intensity

Table 7 Influence of shade intensity at different hours of the day on grain yield

Crop growth stage	Time of the day	Correlation coefficient		
		Phenotypic	Genotypic	Environmental
Flowering	10.00 a.m.	-0.0381	NE	-0.5513**
	1.30 p.m.	-0.4269**	> 1	-0.6382**
	4.00 p.m.	-0.1547	-0.0485	-0.6080**
Pod formation	10.00 a.m.	-0.3946**	NE	-0.7065**
	1.30 p.m.	-0.4355**	-0.8232	-0.6450**
	4.00 p.m.	-0.4119**	> -1	-0.6253**

** Significant at 1 % level

NE – Not estimable

at 1.30 p.m. during flowering stage (-0.4269) and at 10.00 a.m. (-0.3946), 1.30 p.m. (-0.4355) and 4.00 p.m. (-0.4119) during pod formation stage.

Genotypic correlation with grain yield was not estimable for shade intensities at 10.00 a.m. and 1.30 p.m. during flowering stage and at 10.00 a.m. and 4.00 p.m. during pod formation stage. However shade intensity at 4.00 p.m. during flowering stage (-0.0485) and at 1.30 p.m. during pod formation stage (-0.8232) exhibited negative genotypic correlation with grain yield.

Environmental correlation with grain yield was significant and negative for shade intensities at 10.00 a.m., 1.30 p.m. and 4.00 p.m. during flowering stage (-0.5513, -0.6382 and -0.6080) as well as during pod formation stage (-0.7065, -0.6450 and -0.6253).

4.2.4.3 Correlation among yield components

Phenotypic, genotypic and environmental correlations among the yield component characters are presented in Table 8, 9 and 10 respectively.

Days to 50 per cent flowering

This character exhibited significant positive phenotypic correlation with days to maturity (0.5025) and negative correlation with harvest index (-0.4169) and 100 seed weight (-0.3488). Highest positive genotypic correlation was observed for days to maturity (0.8325). Harvest index exhibited the highest negative genotypic correlation (-0.5967) followed by 100 seed weight (-0.4955) and number of seeds per pod (-0.4110).

Environmental correlation was significant only for plant height (-0.4042).

Plant height

Phenotypic correlation with plant height was positive and significant for number of clusters per plant (0.5977), leaf area index (0.5939) and number of pods per plant (0.4770).

Genotypic correlation was highest for leaf area index (0.7425) followed by number of clusters per plant (0.6822), number of pods per plant (0.4959) and photosynthetic efficiency (0.3702). Negative genotypic correlation of low magnitude was observed for 100 seed weight (-0.1988) and days to maturity (-0.0844).

Environmental correlation was significant and positive for harvest index (0.4622) and number of pods per plant (0.3781).

Leaf area index

Phenotypic correlation with leaf area index was significant for plant height (0.5939), number of clusters per plant (0.4899), number of pods per plant (0.4849), photosynthetic efficiency (0.4656) and number of seeds per pod (0.4588).

Highest genotypic correlation with leaf area index was observed for plant height (0. 7425) followed by photosynthetic efficiency (0.7109), number of clusters per plant (0. 6319), number of pods per plant (0.6301) and number of seeds per pod (0.5653). Negative correlation at genotypic level was observed for the characters days to maturity (-0.4083) and days to 50 per cent flowering (-0.1074).

Environmental correlation with leaf area index was insignificant for all the characters.

Photosynthetic efficiency

Positive phenotypic correlation was significant for number of seeds per pod (0.6950), number of pods per plant (0.6232), leaf area index (0.4656) and 100 seed weight (0.3458). Significant negative correlation was observed for days to maturity (-0.3471).

Genotypic correlation with photosynthetic efficiency was comparatively high for the characters number of seeds per pod (0.8643), number of pods per plant (0.7467), leaf area index (0.7109) and 100 seed weight (0.4332). Negative genotypic correlation was exhibited by the characters days to maturity (-0.3486) and days to 50 per cent flowering (-0.2699).

The character days to maturity alone exhibited significant environmental correlation and was negative (-0.3687).

Number of clusters per plant

Phenotypic correlation was significant for plant height (0.5977), leaf area index (0.4899), number of pods per plant (0.5158) and number of seeds per pod (0.3298).

Genotypic correlation with this character was positive and relatively high for plant height (0.6822), leaf area index (0.6319), number of pods per plant (0.5614), number of seeds per pod (0.3378) and photosynthetic efficiency (0.3153). Negative genotypic correlation was highest for days to maturity (-0.1469) followed by harvest index (-0.1101) and 100 seed weight (-0.0586).

The characters days to maturity (0.3844) and harvest index (-0.3820) recorded significant positive and negative environmental correlation respectively with number of clusters per plant.

Number of pods per plant

Significant positive phenotypic correlation with this character was observed for photosynthetic efficiency (0.6232) number of clusters per plant (0.5158), leaf area index (0.4849), plant height (0.4770) and number of seeds per pod (0.3544).

Genotypic correlation was maximum for the character photosynthetic efficiency (0.7467) followed by leaf area index (0.6301), number of clusters per plant (0.5614), plant height (0.4959), number of seeds per pod (0.3825) and days to 50 per cent flowering (0.1070). Harvest index (-0.1565), days to maturity (-0.1303) and 100 seed weight (-0.0159) exhibited negative genotypic correlation with number of pods per plant.

Environmental correlation was significant for the characters 100 seed weight (0.4526), harvest index (0.3950) and plant height (0.3781).

Number of seeds per pod

Phenotypic correlation with number of seeds per pod was significant and positive for photosynthetic efficiency (0.6950), leaf area index (0.4588), 100 seed weight (0.4453), number of pods per plant (0.3544), number of clusters per plant (0.3298) and harvest index (0.3082). Negative phenotypic correlation was significant only for days to maturity (-0.3172).

Photosynthetic efficiency (0.8643), leaf area index (0.5653), 100 seed weight (0.4716), number of pods per plant (0.3825), number of clusters per plant (0.3378) and harvest index (0.3157) exhibited genotypic correlation values of considerable magnitude with number of seeds per pod. Genotypic correlation was negative for days to maturity (-0.4718) and days to 50 per cent flowering (-0.4110).

Environmental correlation of number of seeds per pod was non significant with all the other characters.

100 Seed weight

Harvest index (0.4576), number of seeds per pod (0.4453) and photosynthetic efficiency (0.3458) exhibited significant positive phenotypic correlation with 100 seed weight whereas days to maturity (-0.6626) and days to 50 per cent flowering (-0.3488) recorded significant negative phenotypic correlation.

Comparatively high values of genotypic correlation was observed for 100 seed weight with harvest index (0.5136), number of seeds per pod (0.4716), photosynthetic efficiency (0.4332) and leaf area index (0.3373). This character exhibited negative genotypic correlation with days to maturity (-0.8978) and days to 50 per cent flowering (-0.4955). Plant height (-0.1988), number of clusters per plant (-0.0586) and number of pods per plant (-0.0159) also recorded negative genotypic correlation with 100 seed weight but were of low magnitude.

Significant environmental correlation was observed for the character number of pods per plant (0.4526) alone.

Days to maturity

Positive phenotypic correlation with this character was significant only for days to 50 per cent flowering (0.5025). 100 seed weight (-0.6626), harvest index (-0.4816), photosynthetic efficiency (-0.3471) and number of seeds per pod (-0.3172) exhibited significant negative phenotypic correlation with days to maturity.

At genotypic level also correlation with days to maturity was positive only for days to 50 per cent flowering (0.8325). Negative genotypic correlation was highest for 100 seed weight (-0.8978) followed by harvest index (-0.6319), number of seeds per pod (-0.4718), leaf area index (-0.4083) and photosynthetic efficiency (-0.3486). Genotypic correlations were relatively low for number of clusters per plant (-0.1469), number of pods per plant (-0.1303) and plant height (-0.0844).

Number of clusters per plant (0.3844) and photosynthetic efficiency (-0.3687) exhibited significant environmental correlation.

Harvest index

Harvest index exhibited significant positive phenotypic correlation with 100 seed weight (0.4576) and number of seeds per pod (0.3082). Days to maturity (-0.4816) and days to 50 per cent flowering (-0.4169) had significant negative phenotypic correlations with harvest index.

Genotypic correlation with this character was positive for 100 seed weight (0.5136), leaf area index (0.3342), number of seeds per pod (0.3157), photosynthetic efficiency (0.2452) and plant height (0.0062). Days to maturity (-0.6319), days to 50 per cent flowering (-0.5967), number of pods

Tables 8 Phenotypic correlation among yield components in F_2 generation of greengram

Sl. No	Characters	Days to 50 per cent flowering	Plant height	Leaf area index	Photosynthetic efficiency	Number of clusters per plant	Number of pods per plant	Number of seeds per pod	100 seed weight	Days to maturity	Harvest index
1	Days to 50 per cent flowering										
2	Plant height	0.0003									
3	Leaf area index	-0.1798	0.5939**								
4	Photosynthetic efficiency	-0.1713	0.2746	0.4656**							
5	Number of clusters per plant	0.0519	0.5977**	0.4899**	0.2687						
6	Number of pods per plant	-0.0016	0.4770**	0.4849**	0.6232**	0.5158**					
7	Number of seeds per pod	-0.2567	0.2245	0.4588**	0.6950**	0.3298*	0.3544*				
8	100 seed weight	-0.3488*	-0.1297	0.2521	0.3458*	-0.0551	0.0539	0.4453**			
9	Days to maturity	0.5025**	-0.0632	-0.2231	-0.3471*	-0.0740	-0.1681	-0.3172*	-0.6626**		
10	Harvest index	-0.4169**	0.0424	0.2382	0.2229	-0.1163	-0.1194	0.3082*	0.4576**	-0.4816**	

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

Table 9 Genotypic correlation among yield components in F_2 generation of greengram

Sl. No.	Characters	Days to 50 per cent flowering	Plant height	Leaf area index	Photo-synthetic efficiency	Number of clusters per plant	Number of pods per plant	Number of seeds per pod	100 seed weight	Days to maturity	Harvest index
1	Days to 50 per cent flowering										
2	Plant height	0.2315									
3	Leaf area index	-0.1074	0.7425								
4	Photosynthetic efficiency	-0.2699	0.3702	0.7109							
5	Number of clusters per plant	0.0747	0.6822	0.6319	0.3153						
6	Number of pods per plant	0.1070	0.4959	0.6301	0.7467	0.5614					
7	Number of seeds per pod	-0.4110	0.2435	0.5652	0.8643	0.3378	0.3825				
8	100 seed weight	-0.4955	-0.1988	0.3373	0.4332	-0.0586	-0.0159	0.4716			
9	Days to maturity	0.8325	-0.0844	-0.4083	-0.3486	-0.1469	-0.1303	-0.4718	-0.8978		
10	Harvest index	-0.5967	0.0062	0.3342	0.2452	-0.1101	-0.1565	0.3157	0.5136	-0.6319	

Table 10 Environmental correlation among yield components in F_2 generation of greengram

Sl. No.	Characters	Days to 50 per cent flowering	Plant height	Leaf area index	Photo-synthetic efficiency	Number of clusters per plant	Number of pods per plant	Number of seeds per pod	100 seed weight	Days to maturity	Harvest index
1	Days to 50 per cent flowering										
2	Plant height	-0.4042*									
3	Leaf area index	-0.2568	0.2878								
4	Photosynthetic efficiency	-0.0614	-0.0715	-0.0155							
5	Number of clusters per plant	0.0523	-0.2953	0.1173	-0.0239						
6	Number of pods per plant	-0.2491	0.3781*	0.1400	0.0949	-0.1963					
7	Number of seeds per pod	-0.0202	0.0992	0.2533	-0.2869	0.1176	0.0480				
8	100 seed weight	-0.1979	0.1728	0.0704	0.0440	-0.0532	0.4526*	0.3294			
9	Days to maturity	0.2216	-0.0247	0.0141	-0.3687*	0.3844*	-0.3400	0.1289	-0.2396		
10	Harvest index	-0.3175	0.4622*	-0.1104	0.1566	-0.3820*	0.3950*	0.1431	0.0549	-0.2094	

* Significant at 5% level

per plant (-0.1565) and number of clusters per plant (-0.1101) exhibited negative genotypic correlation with harvest index. .

Environmental correlation observed was significant and positive for plant height (0.4622) and number of pods per plant (0.3950) but significant and negative for number of clusters per plant (-0.3820).

4.3 Path coefficient analysis

Path analysis was carried out using seven characters viz., days to 50 per cent flowering, leaf area index, photosynthetic efficiency, number of seeds per pod, 100 seed weight, days to maturity and harvest index. Direct and indirect effects of these component characters on grain yield are presented in Table 11.

The character photosynthetic efficiency exhibited the maximum direct effect on grain yield (0.6235) and its genotypic correlation with grain yield was also high (0.7200). It showed negative indirect effect via number of seeds per pod (-0.2546) and relatively high positive indirect effect via leaf area index (0.1274) and harvest index (0.1249).

The second highest positive direct effect on grain yield was recorded by harvest index (0.5095) with a genotypic correlation of 0.8025. Positive indirect effects exhibited especially through photosynthetic efficiency (0.1529) and days to maturity (0.1191) resulted in an increase in its correlation with yield.

Leaf area index showed positive direct effect of low magnitude (0.1793) but its genotypic correlation with grain yield was high (0.7234). This character exhibited considerable positive indirect effect on grain yield

Table 11 Direct and indirect effect of component characters on grain yield in F_2 generation of green gram

Sl. No.	Characters	Days to 50 per cent flowering	Leaf area index	Photosynthetic efficiency	Number of seeds per pod	100 seed weight	Days to maturity	Harvest index	Total correlation
1	Days to 50 per cent flowering	-0.0540	-0.0193	-0.1683	0.1211	-0.0211	-0.1569	-0.3040	-0.6025
2	Leaf area index	0.0058	0.1793	0.4433	-0.1666	0.0144	0.0770	0.1703	0.7234
3	Photosynthetic efficiency	0.0146	0.1274	0.6235	-0.2546	0.0184	0.0657	0.1249	0.7200
4	Number of seeds per pod	0.0222	0.1013	0.5389	-0.2946	0.0201	0.0889	0.1609	0.6377
5	100 seed weight	0.0267	0.0605	0.2701	-0.1389	0.0426	0.1693	0.2617	0.6919
6	Days to maturity	-0.0449	-0.0732	-0.2174	0.1390	-0.0382	-0.1885	-0.3220	-0.7452
7	Harvest index	0.0322	0.0599	0.1529	-0.0930	0.0219	0.1191	0.5095	0.8025

Residual effect = 0

The underlined figures are direct effects.

via photosynthetic efficiency (0.4433) followed by harvest index (0.1703) and negative indirect effect via number of seeds per pod (-0.1666).

The lowest positive direct effect on grain yield was exhibited by 100 seed weight (0.0426) though it had a high genotypic correlation (0.6919). Indirect effect was revealed through photosynthetic efficiency (0.2701), harvest index (0.2617), days to maturity (0.1693) and number of seeds per pod (-0.1389).

Number of seeds per pod had negative direct effect on grain yield (-0.2946) but its genotypic correlation with grain yield was high and positive (0.6377). Considerable indirect effect was observed through the character photosynthetic efficiency (0.5389). Harvest index (0.1609) and leaf area index (0.1013) were the factors which influenced the number of seeds per pod to arrive at a high correlation with yield.

The character days to maturity exhibited negative values for both direct effect (-0.1885) and genotypic correlation (-0.7452) with grain yield. Indirect effect was revealed through harvest index (-0.3220), photosynthetic efficiency (-0.2174) and number of seeds per pod (0.1390).

Days to 50 per cent flowering showed negligible negative direct effect on grain yield (-0.0540) but had high negative genotypic correlation with grain yield (-0.6025). Indirect effect was positive through number of seeds per pod only (0.1211). Negative indirect effect was maximum through harvest index (-0.3040) followed by photosynthetic efficiency (-0.1683) and days to maturity (-0.1569).

Residual effect was absent indicating about 100 per cent contribution to grain yield through the seven selected component characters.

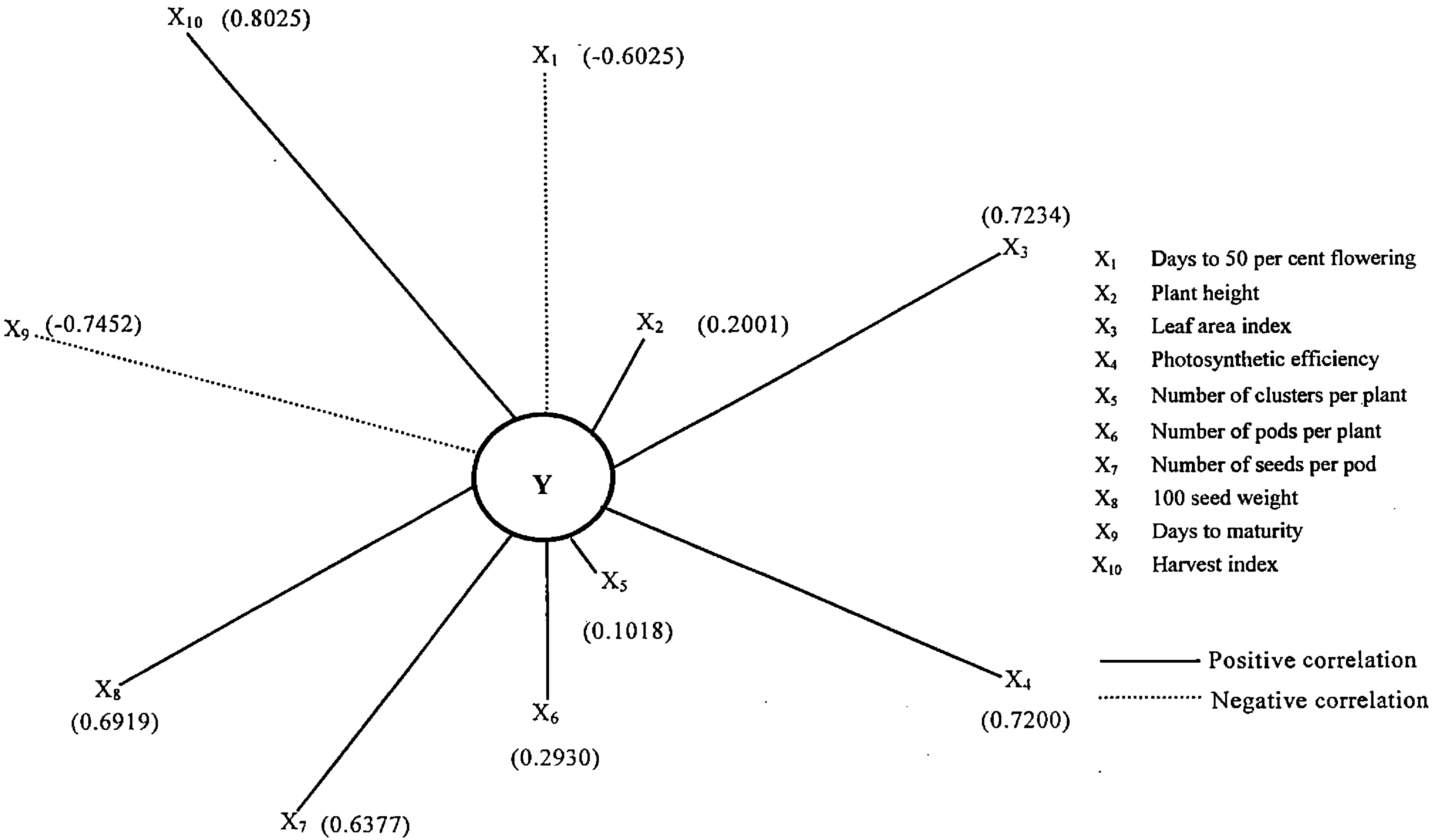
Discussion

Genotypic correlation of component characters with grain yield in the present study is presented in Fig. 3. Grain yield exhibited positive correlation at phenotypic and genotypic levels with all the other characters except days to maturity and days to 50 per cent flowering. Highest positive correlation recorded by harvest index indicates that it is the most reliable yield component. Significant positive association of grain yield with harvest index, leaf area index and photosynthetic efficiency reported by Abraham (1988) in blackgram and Rajeswari (1998) in greengram under partially shaded conditions was in conformity with the present findings. Philip (1987) reported similar result in blackgram for seeds per pod. Rajan (1999) observed high correlation for grain yield with 100 seed weight, harvest index and number of seeds per pod in greengram under open conditions and this also supports the results of present study.

Negative correlation observed for days to maturity and days to 50 per cent flowering helps to conclude that selection against these traits will be desirable when improvement in grain yield is the main objective. Hegde *et al.* (1996) reported similar results in F_2 generation of intervarietal crosses in greengram.

In general genotypic correlation with grain yield was higher than the corresponding phenotypic correlation for most of the characters. This can be attributed to the inherent genetic association between these traits. Selection for these characters might be rewarding.

Fig. 3 Genotypic correlation between grain yield and 10 component characters in F_2 generation of greengram



Correlation between grain yield and shade intensity

Influence of shade intensity on grain yield can be studied based on the results of correlation between the two characters. Significant and negative phenotypic correlation for grain yield was observed with shade intensity at 10.00 a.m., 1.30 p.m. and 4.00 p.m. during pod formation stage and at 1.30 p.m. during flowering stage. High genotypic correlation was recorded only at 1.30 p.m. during pod formation stage. This indicates that grain yield was adversely affected by shade during both flowering and pod formation stages. According to Laosuwan *et al.* (1991) seed yield was decreased at 50 per cent light intensity in greengram and this supports the present observation. Lakshmamma and Rao (1996) in blackgram and Verghis *et al.* (1999) in chickpea also reported decrease in seed yield due to shading.

Correlation among yield components

Besides the knowledge of association between grain yield and its components, inter-relationships among the yield component characters provide reliable information for making selection more effective.

Days to 50 per cent flowering and days to maturity exhibited positive phenotypic as well as genotypic correlation with each other. However these characters had negative correlation with most other characters. Negative association with 100 seed weight and harvest index were highly significant for both the characters. This result suggests that a genotype having longer period for 50 per cent flowering and that matures later will be inferior with respect to most of the other yield component characters. Chaudhari *et al.* (2000) in rice bean, Chand (1999 b) in soybean and Pandey *et al.* (2000) in grasspea reported positive association between days to 50 per cent flowering and days to maturity.

Plant height recorded considerable positive correlation with leaf area index, number of clusters per plant and number of pods per plant at phenotypic and genotypic levels. Positive correlation between plant height and leaf area index reported by Philip (1987) in blackgram under partial shade conforms to the present result. Hegde *et al.* (1996) and Joseph (1998) reported similar results for number of clusters per plant and number of pods per plant respectively in greengram.

Leaf area index exhibited significant positive correlation with photosynthetic efficiency, number of seeds per pod, plant height, number of clusters per plant and number of pods per plant. Rajeswari (1998) observed similar results in greengram under partially shaded condition except for number of seeds per pod.

Phenotypic and genotypic correlation with photosynthetic efficiency was considerably high and positive for number of seeds per pod, number of pods per plant, leaf area index and 100 seed weight while negative correlation was significant for days to maturity. Similar findings were reported in greengram for number of seeds per pod by Rajan (1999). Reports in cowpea by Renganayaki and Sreerengasamy (1992) for leaf area index and Gowri (1999) for pod number and seed number per pod also agrees with the results of present study.

Significant positive correlation for number of clusters per plant with plant height, leaf area index and number of pods per plant observed in the present study is in line with the result reported by Rajeswari (1998) in greengram under partial shade. Hegde *et al.* (1996) observed positive correlation between number of clusters per plant and number of seeds per pod in greengram which also conforms to the present result.

Number of pods per plant recorded significant positive correlation with photosynthetic efficiency, number of clusters per plant, leaf area index, plant height and number of seeds per pod. This is in accordance with the findings of Reddy *et al.* (1994) in greengram for number of clusters per plant and seeds per pod; and Joseph (1998) for dry matter production. Contrary to the present results, Rajeswari (1998) observed negative correlation between number of pods per plant and grains per pod in greengram.

Number of seeds per pod exhibited negative correlation with days to maturity and days to 50 per cent flowering while correlation was positive and significant for all other characters except plant height. This indicates that selection for more number of seeds per pod would result in simultaneous improvement of all other characters and a reduction in the period taken for 50 per cent flowering and maturity. Similar results were observed by Virupakshappa *et al.* (1980), Gowri (1999) and Kalaiyarasi and Palanisamy (2000 c) in cowpea; Reddy *et al.* (1994) in greengram and Pandey *et al.* (2000) in grasspea.

Hundred seed weight and harvest index recorded high positive correlation with each other and with number of seeds per pod while high negative correlation was observed for both these characters with days to maturity and days to 50 per cent flowering. Hundred seed weight recorded significant positive correlation with photosynthetic efficiency also.

Significant positive correlation between 100 seed weight and number of seeds per pod was reported in cowpea by Virupakshappa *et al.* (1980) in F_2 generation and by Kalaiyarasi and Palanisamy (2000 c) in F_4 generation. Pandey *et al.* (2000) reported positive correlation between harvest index and number of seeds per pod in grasspea, while positive association of 100 seed weight and harvest index was reported in chickpea by Yadav *et al.* (1999). However positive correlation for 100 seed weight with days to 50 per cent flowering and days to maturity reported by Salunke *et al.* (1995) in redgram was in contrast to the present findings.

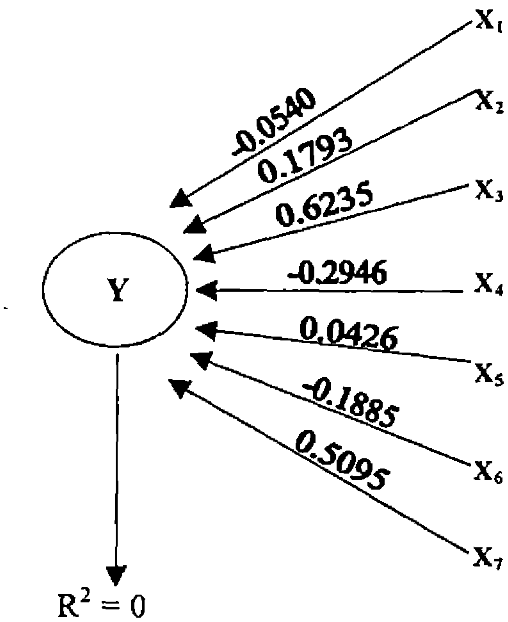
Path coefficient analysis

Association based on correlation between the characters cannot always be considered as the basis of relationship between them, as often such relationships does not seem to exist when it is partitioned into direct and indirect effects by path coefficient analysis. Path analysis reveal whether the component characters under study were responsible for the variation in yield.

In the present study, among seven characters which had high genotypic correlation with grain yield photosynthetic efficiency, harvest index, leaf area index and 100 seed weight recorded positive direct effect while number of seeds per pod, days to maturity and days to 50 per cent flowering exhibited negative direct effect on grain yield. Direct effects and inter-relationships between characters are shown in Fig. 4.

Photosynthetic efficiency exhibited the highest positive direct effect on grain yield. Indirect effect via photosynthetic efficiency was also high for most of the other characters. This indicates that it is the most reliable yield

Fig. 4 Path diagram showing direct effects and inter-relationships in F_2 generation of greengram



-0.1074					
-0.2699	0.7109				
-0.4110	0.5653	0.8643			
-0.4955	0.3373	0.4332	0.4716		
0.8325	-0.4083	-0.3486	-0.4718	-0.8978	
-0.5967	0.3342	0.2452	0.3157	0.5136	-0.6319

Y - Grain yield
R^2 - Residual

X_1 – Days to 50 per cent flowering
X_2 – Leaf area index
X_3 – Photosynthetic efficiency
X_4 – Number of seeds per pod

X_5 – 100 seed weight
X_6 – Days to maturity
X_7 – Harvest index

component. Direct selection for this character will lead to yield improvement. Similar result was reported by Mahalingam (1991) in greengram.

Harvest index recorded positive direct effect on grain yield and indirect effect via photosynthetic efficiency and days to maturity. Indirect effect via this character was considerable for 100 seed weight, leaf area index, number of seeds per pod and photosynthetic efficiency. Vikas *et al.* (1999) in greengram, Backiyarani and Nadarajan (1998) in cowpea and Anuradha and Krishnamurthy (1990) in blackgram observed high positive direct effect of harvest index on grain yield.

Direct effect was low for leaf area index and 100 seed weight though their genotypic correlation with grain yield was high. This may be due to the indirect effect of these characters on grain yield via photosynthetic efficiency and harvest index. Backiyarani and Nadarajan (1998) reported similar result for leaf area index in cowpea. On the contrary, Rajeswari (1998) reported negative direct effect of leaf area index in greengram under partial shade. Positive direct effect for 100 seed weight was reported by Sabaghpour *et al.* (1998), Rajan (1999) and Vikas *et al.* (1999) in greengram; Tyagi *et al.* (2000) in cowpea and Philip (1987) in blackgram under partial shade. Negative direct effect for 100 seed weight reported by Thaware *et al.* (1999) in rice bean was not in agreement with the present result.

It was noticed that number of seeds per pod which exhibited positive and high genotypic correlation with grain yield had negative direct effect. This may be due to the positive indirect effect via photosynthetic efficiency and harvest index. Hence direct selection for this character is not advisable. However indirect selection based on photosynthetic efficiency and harvest index may improve yield. Similar result was reported by Manivannan and Nadarajan (1996) in greengram and Philip (1987) in blackgram under partial shade.

Days to maturity and days to 50 per cent flowering exerted negative direct effect of low magnitude on grain yield. Considerable negative indirect effect was observed via harvest index and photosynthetic efficiency. This indicates that both these characters adversely affect grain yield directly as well as through other characters. Hence they might not form the basis of selection when yield improvement is targeted. These results conform to the earlier reports by Vikas *et al.* (1999) in greengram and Singh *et al.* (1982) in redgram.

Residual effect was approximately nil indicating that all the important yield contributing characters were included for path analysis. The present study revealed that the characters photosynthetic efficiency and harvest index had high direct effect and the indirect effect via these two characters were also high for most other characters. Hence it may be concluded that under partially shaded conditions, the most important and reliable characters contributing to grain yield in greengram are photosynthetic efficiency and harvest index. Based on the mean values of photosynthetic efficiency, the genotypes T_7 (Ganga 4 x Pusa Baisakhi), T_5 (LGG 460 x Philippines), T_1 (IIPRM 3 x Philippines), T_2 (Ganga 4 x Philippines) and T_{14} (RMG 353 x CO-2) may be selected. T_{10} (LGG 460 x Pusa Baisakhi) may be selected based on the value of harvest index. These selected genotypes can be used as the basic material for further work.

Summary

6. SUMMARY

The present study, "Genetic evaluation of F_2 generation of intervarietal crosses in greengram (*Vigna radiata* (L.) Wilczek)" was carried out at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 2000-2001. The objective of the research programme was to assess the potential of F_2 progenies of greengram in terms of variability and correlation with respect to yield, yield attributes and shade tolerance.

Fifteen F_2 progenies derived from intervarietal crosses were evaluated in a randomised block design with three replications under the partial shade of coconut garden. Observations were recorded on a random sample of five plants from each plot for the characters viz., days to 50 per cent flowering, plant height, leaf area index, photosynthetic efficiency, number of clusters per plant, number of pods per plant, number of seeds per pod, 100 seed weight, grain yield, days to maturity and harvest index. Shade intensity was recorded at 10.00 a.m., 1.30 p.m. and 4.00 p.m. during flowering and pod formation stages in each plot. Incidence of pests and diseases in the crop was also recorded.

The data were subjected to analysis of variance. Genetic parameters such as phenotypic and genotypic coefficients of variation, heritability, genetic advance, correlation and path coefficients were estimated.

The salient results of the study are presented below :

The analysis of variance revealed significant difference among the 15 F_2 progenies for almost all the characters.

Shade intensity recorded at different hours of the day during flowering and pod formation stages did not show any significant difference indicating the prevalence of uniform shade in the experimental plots.

Phenotypic and genotypic coefficients of variation (PCV and GCV) were highest for grain yield and was followed by leaf area index, number of pods per plant, photosynthetic efficiency, harvest index and 100 seed weight. ECV values indicated that the influence of environment on the expression of characters was high for leaf area index, grain yield, harvest index and photosynthetic efficiency whereas environmental effect was minimum for number of clusters per plant.

High heritability was exhibited by the characters viz., number of clusters per plant, harvest index, number of seeds per pod, grain yield, number of pods per plant, plant height, 100 seed weight and photosynthetic efficiency. The characters harvest index, grain yield, number of pods per plant, 100 seed weight and photosynthetic efficiency recorded high heritability coupled with high genetic advance indicating that they are controlled by additive gene action and hence amenable for genetic improvement through selection. High heritability along with low genetic advance observed for numbers of clusters per plant, number of seeds per pod and plant height implied the role of non-additive gene action on these characters.

Correlation with grain yield at phenotypic and genotypic levels was positive for all the characters except days to 50 per cent flowering and days to maturity. In general, genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients indicating inherent association between the characters.

Among yield components, photosynthetic efficiency exhibited significant positive correlation with leaf area index, number of pods per plant, number of seeds per pod and 100 seed weight while harvest index recorded significant positive correlation with number of seeds per pod and 100 seed weight. However both these characters recorded negative correlation with days to 50 per cent flowering and days to maturity.

Path analysis revealed that direct effect on grain yield was maximum for photosynthetic efficiency followed by harvest index. Leaf area index and 100 seed weight also exerted positive direct effect of low magnitude. Negative direct effect on grain yield was recorded for number of seeds per pod, days to maturity and days to 50 per cent flowering.

It may be concluded that photosynthetic efficiency and harvest index are the most important yield components which can serve as selection criteria for better yield in greengram under partially shaded conditions. Based on the mean values of photosynthetic efficiency, the genotypes T_7 (Ganga 4 x Pusa Baisakhi), T_5 (LGG 460 x Philippines), T_1 (IIPRM 3 x Philippines), T_2 (Ganga 4 x Philippines) and T_{14} (RMG 353 x CO-2) may be selected. T_{10} (LGG 460 x Pusa Baisakhi) may be selected based on the value of harvest index. These selected genotypes can be used as the basic material for further work.

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GENETIC EVALUATION OF F_2 GENERATION OF INTERVARIETAL CROSSES IN GREENGRAM (*Vigna radiata* (L.) Wilczek)

By

LEENAMOL M.A.

ABSTRACT OF THE THESIS
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DEPARTMENT OF PLANT BREEDING AND GENETICS
COLLEGE OF AGRICULTURE
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ABSTRACT

A research programme was carried out at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 2000-2001 with the objective of assessing the potential of F_2 progenies of greengram in terms of variability and correlation with respect to yield, yield attributes and shade tolerance. Fifteen F_2 progenies derived from intervarietal crosses were evaluated under the partial shade of coconut garden adopting a randomised block design with three replications. Data collected for seventeen characters were subjected to statistical analysis. Coefficient of variation, heritability, genetic advance, correlation and path coefficients were estimated.

The 15 F_2 progenies revealed significant difference for all the characters. However, measurement of periodical shade intensity did not show significant difference among the plots indicating the prevalence of uniform shade. Phenotypic and genotypic coefficient of variation were high for grain yield, leaf area index, number of pods per plant, photosynthetic efficiency, harvest index and 100 seed weight. High heritability coupled with high genetic advance was observed for harvest index, grain yield, number of pods per plant, 100 seed weight and photosynthetic efficiency.

Correlation studies indicated that the characters leaf area index, photosynthetic efficiency, number of seeds per pod, 100 seed weight and harvest index exhibited significant positive correlation with grain yield whereas days to 50 per cent flowering and days to maturity recorded significant negative correlation. Among yield components, photosynthetic

efficiency and harvest index exhibited significant positive correlation with number of seeds per pod and 100 seed weight.

Photosynthetic efficiency exhibited the highest positive direct effect on grain yield followed by harvest index. Negative direct effect on grain yield was recorded for number of seeds per pod, days to maturity and days to 50 per cent flowering.

It can be concluded from the present study that under partially shaded condition, photosynthetic efficiency and harvest index are the most important yield components which can serve as selection criteria for better yield in greengram. Accordingly the genotypes T_7 (Ganga 4 x Pusa Baisakhi), T_5 (LGG 460 x Philippines), T_1 (IIPRM 3 x Philippines), T_2 (Ganga 4 x Philippines) and T_{14} (RMG 353 x CO-2) and T_{10} (LGG 460 x Pusa Baisakhi) may be selected for further work.