

**GENETIC ANALYSIS OF GREENGRAM
(*Vigna radiata* (L.) Wilczek) SUITABLE FOR
LATE RICE FALLOWS IN PENNAR DELTA,
ANDHRA PRADESH**

**By
DEGAPUDI KODANDA RAMI REDDY**

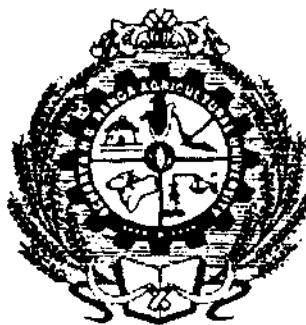
M.Sc. (Ag.)

**ANGRAU Central Library
Hyderabad**

D6844



**THESIS SUBMITTED TO THE
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF
DOCTOR OF PHILOSOPHY
IN THE FACULTY OF AGRICULTURE**



**D6844
01/07/03**

**DEPARTMENT OF GENETICS AND PLANT BREEDING
SRI VENKATESWARA AGRICULTURAL COLLEGE
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY
TIRUPATI - 517 502**

JULY 2002

CERTIFICATE

Mr. DEGAPUDI KODANDARAMI REDDY has satisfactorily prosecuted the course of research and that the thesis entitled "**GENETIC ANALYSIS OF GREENGRAM (*Vigna radiata* (L.) Wilczek) SUITABLE FOR LATE RICE FALLOWS IN PENNAR DELTA, ANDHRA PRADESH**" submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part there of has not been previously submitted by him for a degree of any University.

Date : 11.11.2011

Place : Hyderabad

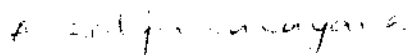
A. Satyanarayana

(**Dr. A. SATYANARAYANA**)
Major Advisor

CERTIFICATE

This is to certify that the thesis entitled "**GENETIC ANALYSIS OF GREENGRAM (*Vigna radiata* (L.) Wilczek) SUITABLE FOR LATE RICE FALLOW IN PENNAR DELTA, ANDHRA PRADESH**" submitted in partial fulfilment of the requirements for the degree of **DOCTOR OF PHILOSOPHY IN AGRICULTURE** of the Acharya N.G.Ranga Agricultural University, Hyderabad is a record of the bonafide research work carried out by **Mr. D. Kodanda Rami Reddy** under our guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

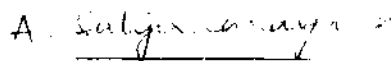
No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All assistance and help received during the course of investigations have been duly acknowledged by the author of the thesis.



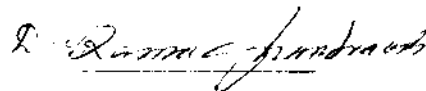
(Dr. A. SATYANARAYANA)
Chairman of the Advisory Committee

Thesis approved by the Student's Advisory Committee

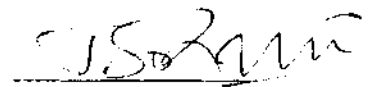
Chairman : **(Dr. A. SATYANARAYANA)**
Director of Extension
A.N.G.R. Agril. University
Rajendra Nagar
Hyderabad - 500 030



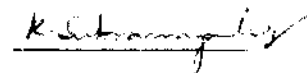
Member : **(Dr. D. RAMCHANDRAIAH)**
Principal Scientist (Millets)
Regional Agricultural Research Station
Palem



Member : **(Dr. J. SURYAPRAKASA RAO)**
Professor & Head
Department of Plant Physiology
S.V. Agricultural College
Tirupati - 517 502



Member : **(Dr. K. SUBRAMANYAM REDDY)**
Associate Professor
Department of Statistics
College of Fisheries Science
Muthukur
Nellore



LIST OF CONTENTS

Chapter	Title	Page No.
I	INTRODUCTION	1-14
II	REVIEW OF LITERATURE	15-24
III	MATERIALS AND METHODS	25-32
IV	RESULTS	33-44
V	DISCUSSION	45-48
VI	SUMMARY	49-50
	LITERATURE CITED	51-55

LIST OF TABLES

Table No.	Title	Page No.
2.1	Literature on variability in Greengram	8
2.2	Literature on Heritability and Genetic advance	12
2.3	Literature on Heterosis in Greengram	17
2.4	Literature on gene action for various characters in greengram	21
2.5	Literature on association of yield component character with seed yield	25
2.6	Literature on association among yield component characters	27
2.7	Literature on direct effects of plant characters on yield	31
2.8	Literature on indirect effects of component characters on yield	33
3.1	Characteristics of the genotypes used in hybridization in a line x tester fashion	37
3.2	Analysis of variance	41
3.3	ANOVA of line x tester making design for combining ability	43
4.1	Mean sum of squares and ANOVA for different characters studied in greengram	47
4.2	Mean values for different traits in parent and crosses	49
4.3	Variability, Heritability and genetic advance for yield and yield component characters in greengram	51
4.4	Estimates of heterosis (%) over mid parent (MP) and better parent	53
4.5	ANOVA for combining ability mean squares for different characters in greengram	55
4.6	General combining ability effects of parents for different characters	57

4.7	Specific combining ability effects of crosses for different characters	85
4.8	Analysis of variance to test for epistasis in four triple test crosses	95
4.9	Analysis of variance to detect additive and dominant components in four triple test crosses viz., 1. LGG 410 x LGG 407 2. LGG 460 x WGG-2 3. Pusa 9672 x LGG 440 and 4. Local x TARM-21	111
4.10	Estimation of genetic components and degree of dominance for seven characters in four triple test crosses viz.,	120
4.11	Genotype (upper half) and Phenotypic (lower half) correlation coefficients in parents and hybrids	125
4.12	Genotypic path coefficient analysis for grain yield in F_1 s and parents	160
4.13	Phenotypic path coefficient analysis for grain yield in F_1 s and parents of greengram	172

LIST OF ILLUSTRATIONS

Title	Page No.
Estimates of variability, heritability and genetic advance for different characters in greengram	
Expression of relative heterosis and heterosis and heterobeltiosis for pods per plant	
Expression of relative heterosis and heterobeltiosis for shoot dry weight per plant	
Expression of relative heterosis and heterobeltiosis for yield plant	
Best parents with high "gca" for yield and yield contributing traits	
Crosses with high "sca" for yield & yield component traits	

ACKNOWLEDGEMENTS

*I am greatly indebted to the chairman of my advisory committee **Dr. A. Satyanarayana** Director of Extension, ANGR Agricultural University, Rajendranagar, Hyderabad, under whose scholarly guidance I carried out my research work. His worthy counsel and indefatigable guidance, keen interest and constructive suggestions and execution of Research work made it possible to bring out this thesis.*

*I express my sincere thanks to the members of my advisory committee, **Dr. D. Ramachandraiah**, Principal Scientist, RARS, Palem, **Dr. J. Surya Prakasa Rao**, Professor and Head, Department of Plant Physiology, N.V. Agricultural College, Tirupati and **Dr. K. Subramanyam Reddy**, Associate Professor, College of Fishery Science, Mutukurru for their valuable suggestions and in the preparation of manuscript.*

*I convey my heartfelt thanks to **Dr. P. Srinivasulu Reddy**, Senior Scientist, Agricultural Research Station, Nellore for his affectionate and valuable guidance and his encouragement which enable me to pursue my research work with zeal.*

*I accord my thanks to **Dr. G. Lakshmikantha Reddy**, Professor & Head, Department of Genetics and Plant Breeding and **Dr. K. Hariprasad Reddy**, Associate Professor, **Dr. M. Reddisekhar**, Assistant Professor, and my Ph.D. colleagues **R. Narasimha Reddy**, Scientist and **Anuradha**, Scientist for their help and guidance during the period of study at this institution.*

*I take this opportunity to express my sincere thanks to **A. Narasi Reddy**, Scientist, RARS, LAM, **Smt. G.L. Sivajyoti**, Scientist, ARS, Podalakuru, **V. Giridhar**, AEO **V. Narahari**, AEO, **Ramachandraiah Chetty** AEO for the help rendered by them during the course of my investigation.*

I am also highly thankful to Head, ARS, Nellore and all the staff members working at ARS, Nellore who helped me directly or indirectly at various stages of investigation.

I am highly indebted to Acharya N.G. Ranga Agricultural University, for allowing me to pursue my higher studies and facilities provided for conducting research work.

Above all I am grateful to my father Late Sri. D. Gopal Reddy, mother Kowsalyamma brother Srinivasulu Reddy, and my Father-in-law Y. Krishna Reddy with whose inspiration and constant encouragement I could complete this programme successfully. I am also highly thankful to my wife Hemalatha children Harish and Rajesh, for their co-operation, encouragement and inspiration during my Ph.D. programme.

Finally I thank Mr. J. Hemanth Reddy for typing to take the final shape of my thesis work.

Place : Tirupati

Date : 8-7-02


(D. KODANDA RAMI REDDY) 

DECLARATION

I, **D. KODANDA RAMI REDDY**, hereby declare that the thesis entitled "**GENETIC ANALYSIS OF GREENGRAM (*Vigna radiata* (L.) Wilczek) SUITABLE FOR LATE RICE FALLOWS IN PENNAR DELTA, ANDHRA PRADESH**" submitted to Acharya N.G. Ranga Agricultural University for the degree of **Doctor of Philosophy** in Agriculture is the result of original work done by me. I also declare that the materials contained in this thesis has not been published earlier.

Date : 8.7.02


(**D. KODANDA RAMI REDDY**)

Abstract

NAME OF THE STUDENT : DEGAPUDI KODANDARAMI REDDY

TITLE OF THESIS : GENETIC ANALYSIS OF GREENGRAM (*Vigna radiata* (L.) Wilczek) SUITABLE FOR LATE RICE FALLOWS IN PENNAR DELTA, ANDHRA PRADESH

**DEGREE TO WHICH IT IS SUBMITTED : DOCTOR OF PHILOSOPHY
IN
AGRICULTURE**

MAJOR FIELD OF STUDY : GENETICS AND PLANT BREEDING

MAJOR ADVISOR

NAME OF THE UNIVERSITY : ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY

YEAR OF SUBMISSION : 2002

ABSTRACT

Studies were conducted on "**Genetic analysis of greengram (*Vigna radiata* (L.) Wilczek) suitable for late rice fallows in Pennar delta, Andhra Pradesh**" at Agricultural Research Station, Podalakur, Nellore district, Andhra Pradesh from 1999 to 2001 during *rabi* season in black soils. Rice yields in South India are stagnating in recent years due to continuous monocropping. This is more particular in Nellore district of Andhra Pradesh. Rice is being cultivated round the year in three continuous monocroppings, overlapping seasons in pennar delta of Andhra Pradesh. More dependency on chemical fertilizers, more depletion of organic matter and other nutrients from the soil has led to the stagnation of rice yields in this region. In addition to meet the growing demand for pulses, legumes have to be introduced in rice fallows in rice monocropping areas to sustain and improve rice production. Keeping this in view an attempt has been made to identify the suitable parameters and their inheritance in greengram to develop varieties for late rice fallows of Pennar delta. A study has been undertaken through combining ability and

triple test cross analysis, and variability studies were carried out by utilizing cross combinations derived from a line x tester programme to understand the genetics of shoot dry weight, along with yield and yield components through combining ability analysis and to estimate the variability, heritability, genetic advance of yield and component traits.

Data were recorded on days to 50% flowering, days to maturity, plant height, pods / plant, seeds / pod, 100 seed weight (g), shoot nitrogen (%), seed protein (%), shoot dry matter and seed yield / plant.

Variability studies indicated existence of wider variability for plant height, pods / plant, shoot dry weight and seed yield / plant. These characters also recorded high heritability coupled with high genetic advance, suggesting the importance of additive gene action for these traits.

High heritability along with low genetic advance was found to be important for days to maturity, seeds per pod, shoot nitrogen and seed protein.

Combining ability analysis revealed that plant height, seeds / pod, seed protein and shoot dry weight are under the influence of additive gene action while, days to flowering, days to maturity, pods / plant, 100 seed weight, shoot nitrogen and seed yield are under the control of both additive and non-additive gene action. Pusa 9672 among lines and LGG 407 among testers were found to be good general combiners for most of the characters studied. Positive and significant heterosis over better parent was noticed for pods/plant, shoot dry weight, seed yield in LGG 410 x LGG 407, MGG 341 x LGG 407, Pusa 9672 x WGG 2, Pusa 9672 x TARM 21 and Pusa 9672 x LGG 440. All these cross combinations also recorded high mean values

coupled with high *scd* effects for seed yield. It is suggested that these cross combinations can be handled through cyclic hybridization followed by selection so as to capitalize both additive and non-additive genes and for isolation of transgenic segregants.

Triple test cross analysis indicated the existence of epistatic gene actions in the inheritance of all the seven characters studied. Both additive and non-additive gene actions were found to be important with predominant role of additive genetic variations in the governance of the characters.

Days to flower, Days to Maturity, 100 seed weight, Plant height, Pods/plant, Seeds / pod and shoot dry weight had showed positive and significance with seed yield both at phenotypic and genotypic level. Associations among these components were also positive and significant. Shoot dry weight had maximum positive direct effect on seed yield followed by pods / plant, 100 seed weight and seeds / pod. Shoot dry weight, pods / plant, 100 seed weight and seeds / pod also had considerable positive indirect effects on seed yield through other yield components.

An overall view of the results obtained from the present study indicate that both additive and non-additive gene actions are involved in the inheritance of major yield contributing characters viz., pods / plant, shoot dry weight, seeds / pod and 100 seed weight. Hence, breeding programs may be modified in such a way so as to accumulate both additive and non-additive genes. Pods / plant, shoot dry weight, seeds / pod and 100 seed weight should be given due consideration in the selection process while constructing selection indices as they have significant associations with seed yield and maximum direct and indirect effects on seed yield. Shoot dry weight has close association and direct positive effect on seed yield / plant. This is the

clear indication for a genotypic suitability under rice fallow condition. A genotype with more biomass has the capacity to grow fast and occupies the gaps in rice fallows. This leads to suppress the weed growth and conserve the soil moisture, which ultimately results with high seed yield. Selection based on this character will definitely result with high yielding genotypes suitable for rice fallow. Parents, Pusa 9672 and LGG 407 may be exploited extensively in breeding programmes aimed at development of high yielding varieties. The most productive cross combinations may be exploited by isolating desirable segregants in the subsequent generations.

Chapter I

Introduction

CHAPTER - I

1. INTRODUCTION

Greengram (*Vigna radiata* (L) Wilczek), also popularly known as mungbean is a diploid ($2n = 22$), self pollinated grain legume grown for its dry beans, which are excellent source of dietary protein in the vegetarian rich diets of Indians. It is consumed as dhal, bean sprouts, boiled beans, mung vada, mung dosa, papad, noodles etc. in different parts of the world.

Greengram contributes to the sustainability of food production system by enriching soil through biological nitrogen fixation and improving the soil physical conditions. Thus, it can be rightly termed as a three in one crop, as food, fodder and soil fertility restorer.

The beneficial effects of legumes in maintaining and improving soil fertility in different cropping systems are well known. Despite this knowledge, legume cultivation has declined in many cropping systems, including rice based cropping systems, because of the monocropping of rice during and post green revolution era supported by the Government policies to achieve self sufficiency in rice production. Most productive areas are being used for multiple cropping of rice such as two to three rice crops per year in Nellore district in Andhra Pradesh, and legumes are not cultivated at all on these

lands. As a consequence soil health has deteriorated and productivity of the agricultural system is plateauing or declining. Crop diversification involving legumes for sustainable production is essential.

World Trade Organisation (WTO) Agreement on Agriculture (AOA) is also expected to play a major influence on the market prices of grain legumes and the countries which can produce at low cost of production will have competitive edge over others.

A more specific breeding work to improve greengram for adaptation to specific situation like rice fallows may play a significant role for increasing its production as well as sustainability of rice based cropping systems. Considering that legumes are low yielding crops, research efforts are needed to improve the yield potential, through ideotype breeding to fit into rice based cropping system.

India produces more than 70 percent of total world mungbean, covering an area of 3.08 m ha, with a very low productivity of 425 kg/ha. Andhra Pradesh is one of the important greengram growing states in different farming situations alround the year with an area of 0.47 m ha, and a productivity of 435 kg/ha. (Directorate of Economics and Statistics, New Delhi, 1996-97). Most of the greengram sown area includes both rice-based as well as other

cropping systems. However, among the pulses grown, blackgram and greengram are the major crops in rice fallows. Cultivation of greengram in rice fallows, sown in the months of January / February is a practice in Nellore district, under pennar delta in Andhra Pradesh. The crop survives and yields only on the receding soil moisture. The constraints to greengram production in rice fallows include soil compaction, excessive moisture at the time of sowing, poor plant stand, terminal moisture stress, weed menace and soil borne diseases.

Understanding of characters associated in adaptation to such conditions and studying of their breeding behaviour to improve mungbean for rice fallow systems is rarely attempted.

Since it is very difficult to manipulate management practices under rice fallows to improve the crop productivity, the best alternative is to develop suitable genotypes for this situation. A mungbean plant type with rapid initial growth under high soil moisture with reasonably high biomass that can mature in 70-75 days is desirable for rice fallows. Genetic improvement in greengram at national level could not gain momentum as much as it is expected to be, due to lack of location specific approach. Hence, an attempt has been made through the present study to understand the variability and inheritance for various traits so as to breed an ideal plant type for a location specific situation like late rice fallows of Nellore district.

A number of methods of genetic analysis have been developed to obtain information on genetics of both morphological and economic traits. Line x tester method (Kempthorne, 1957) is one among them to estimate the combining ability. Triple test cross analysis (Jinks and Perkins, 1970) is an efficient method to estimate the epistatic gene action. Yield is the resultant product of various morphological and yield contributing characters. Phenotypic and genotypic correlations among the characters and their contribution to yield through path analysis provides information on their relative importance in determining yield. The present investigation was thus designed to achieve the following objectives to develop a suitable a mungbean for rice fallows.

1. To estimate genetic variability, heritability and genetic advance for yield and yield component traits of mungbean in rice fallows.
2. To estimate direction and magnitude of heterosis and to identify heterotic crosses for yield and yield components.
3. To identify superior parents and crosses and nature of gene action of yield and yield component characters through L x T analysis.
4. To elucidate nature of epistatic gene action using triple test cross analysis.
5. To identify major yield components and their association among themselves and with yield at both genotypic and phenotypic level.
6. To assess direct and indirect effects of yield component characters on yield through path coefficient analysis.

Chapter II

Review of Literature

CHAPTER - II

2. REVIEW OF LITERATURE

Greengram (*Vigna radiata* (L) Wilczek) an important grain legume of India, originally included in the genus *Phaseolus*, is a diploid with $2n=2x=22$ chromosomes (Marechel, 1970, Sarbhoy, 1977 and 1978) belongs to the family fabaceae (leguminosae), sub family papilionaceae, genus *Vigna*, subgenus *ceratotropis*, species *radiata*. Based on morphological characters such as nature of stipules, curvature of keel petals, nature of pods and biochemical evidence, Verdicourt (1970) revised the *Phaseolus* Linn and *Vigna* savi., The yellow flowered species of *Phaseolus* under subgenera *Ceratotropis* were transferred to genus *Vigna* subgenera *ceratotropis* verd.

The genus *Vigna* is represented with more than 100 species mainly distributed in Africa and Asia (Purseglove, 1968). The greengram (*Vigna radiata* (L) Wilczek) and its close relative blackgram (*Vigna mungo* (L.) Hepper) are two important *Vigna* sps (Jain and Mehre, 1980) grown in India.

The maximum genetic diversity in the wild relatives of *Vigna mungo* and *Vigna radiata* exists in upper Western Ghats and in Bihar. On the basis of a variety of evidences, there is uniformity of opinion that the centre of origin of these two crops lies in the Indian sub-continent.

Vigna sublobata is the ancestor of both *Vigna mungo* and *Vigna radiata*. *Vigna sublobata* is differentiated into two distinct races, one with sub erect, ascending pods and much raised hilums on the seeds and the second with comparatively longer and less hairy pods, borne horizontally reflexed on the peduncle and seeds with a thin and linear hilum which protrudes little above the surface of the seed coat and these races became domesticated as *Vigna mungo* and *Vigna radiata*, respectively (Singh, 1982).

Verdicourt (1970) also considered greengram and blackgram as variants of species but recommended that the two species be kept distinct until monographed. Pachytene analysis of meiotic chromosomes of *Vigna mungo* and *Vigna radiata* and their F₁ hybrids revealed that *Vigna mungo* is of a more recent origin and has been derived from *Vigna radiata* through a deletion in chromosome 10 and a duplication in chromosome 4 (De and Krishnan, 1966).

The work done on greengram in the field of genetics and plant breeding is reviewed briefly under the following heads, taking the examples from other crops wherever necessary.

1. Variability, heritability and genetic advance
2. Heterosis

3. Combining ability and gene action
4. Triple test cross analysis and gene action
5. Association analysis
6. Path coefficient analysis.

2.1 VARIABILITY, HERITABILITY AND GENETIC ADVANCE

2.1.1 Variability :

The nature and extent of variability forms the basis for all plant improvement programmes. Yield is a polygenically controlled quantitative character and is highly influenced by environment (Allard, 1960). Partitioning of observed variability into heritable and non-heritable components is essential to get a true indication of the genetic variation of the trait. Genetic parameters such as genotypic coefficient of variation (GCV), Phenotypic coefficient of variation (PCV), heritability (h^2) and genetic advance (GA) are commonly used in describing variability of a character.

The available literature on the variability in greengram indicated the presence of wider variability for all the characters studied based on the PCV and GCV estimates and is furnished in a tabular form (Table 2.1)

Table 2.1 Literature on variability in Greengram :

S.No.	Character	Wider genetic variability	Narrow genetic variability
(1)	(2)	(3)	(4)
1.	Days to 50% flowering	Singh and Malhotra (1970) Giriraj (1973) Veraswamy <i>et al.</i> (1973) Sandhu <i>et al.</i> (1979) Tickoo <i>et al.</i> (1988) Manivannan <i>et al.</i> (1996) Tiwari <i>et al.</i> (1996) Vikasparoda (1998)	Paramasivam and Rajasekharan (1980) Ramana and Singh (1987) Patil and Deshmukh (1988b) Borah and Hazarika (1995) Patil and Shinde (1995)
2.	Days to maturity	Singh and Malhotra (1970b) Sandhu <i>et al.</i> (1979) Tickoo <i>et al.</i> (1988) Xianghuaihe <i>et al.</i> (1988) Tiwari <i>et al.</i> (1996)	Bhargava <i>et al.</i> (1966) Joshi and Kabaria (1973) Veeraswamy <i>et al.</i> (1973) Medhi <i>et al.</i> (1980) Ramana and Singh (1987) Borah and Hazarika (1995) Patil and Shinde (1995) Reddy (1997)
3.	Plant height	Bhargava <i>et al.</i> (1966) Chowdhury <i>et al.</i> (1971) Yohe and Poehlman (1972) Giriraj (1973) Veeraswamy <i>et al.</i> (1973) Paramasivam and Rajasekharan (1980) Ramana and Singh (1987) Kalpana Pandey <i>et al.</i> (1988) Natarajan <i>et al.</i> (1988) Xianghuaihe <i>et al.</i> (1988) Ilhamuddi <i>et al.</i> (1989) Lakshmaiah <i>et al.</i> (1989) Naidu <i>et al.</i> (1991) Reddy <i>et al.</i> (1991) Pundir <i>et al.</i> (1992) Borah and Hazarika (1995) Patil and Shinde (1995) Veerabhadhiran <i>et al.</i> (1996) Das <i>et al.</i> (1998) Vikas <i>et al.</i> (1998) Vikasparoda <i>et al.</i> (1998)	Rosaiah <i>et al.</i> (1987) Patil and Deshmukh (1988b) Reddy (1997)

S.No.	Character	Wider genetic variability	Narrow genetic variability
(1)	(2)	(3)	(4)
4.	Pods per plant	Bhargava <i>et al.</i> (1966) Gupta and Singh (1969) Singh and Malhotra (1970) Chowdary <i>et al.</i> (1971) Giriraj (1973) Joshi and Kaboaria (1973) Veeraswamy <i>et al.</i> (1973) Rathnaswamy <i>et al.</i> (1978) Sandhu <i>et al.</i> (1979) Paramasivam and Rajasekharan (1980) Liu <i>et al.</i> (1984) Misra and Sahu (1985) Ramana and Singh (1987) Rosaiah <i>et al.</i> (1987) Siddaraju (1987) Kalpana Pandey <i>et al.</i> (1988) Natarajan <i>et al.</i> (1988) Tickoo <i>et al.</i> (1988) Baisakh <i>et al.</i> (1989) Naidu (1989) Ranganayaki and Sreerangaswamy (1993) Vijay Bharathi (1993) Borah and Hazarika (1995) Khorgade (1995) Veerabhadhiran and Jehangir (1995) Hiran Kumar (1996) Tiwari <i>et al.</i> (1996) Byregowda <i>et al.</i> (1997) Reddy (1997) Das <i>et al.</i> (1998) Vikas <i>et al.</i> (1998) Vikasparoda <i>et al.</i> (1998)	Ghulam Hassan <i>et al.</i> (1995) Reddy (1997)

S.No.	Character	Wider genetic variability	Narrow genetic variability
(1)	(2)	(3)	(4)
5.	Seeds per pod	Gupta and Singh (1969) Veeraswamy <i>et al.</i> (1973) Sandhu <i>et al.</i> (1979) Siddaraju (1987) Kalpana Pandey <i>et al.</i> (1988) Tickoo <i>et al.</i> (1988)	Bhargava <i>et al.</i> (1966) Singh and Malhotra (1970) Chowdhury <i>et al.</i> (1971) Giriraj (1973) Joshi and Kavaria (1973) Rathnaswamy <i>et al.</i> (1978) Sandhu <i>et al.</i> (1979) Paramasivam and Rajasekharan (1980) Rosaiah <i>et al.</i> (1987) Natarajan <i>et al.</i> (1988) Patil and Deshmukh (1988b) Pundir <i>et al.</i> (1992) Borah and Hazarika (1995) Gulam-Hassan <i>et al.</i> (1995) Veerabhadhiran and Jehangir (1995)
6.	100 Seed weight	Gupta and Singh (1969) Singh and Malhotra (1970) Rathnaswamy <i>et al.</i> (1978) Sandhu <i>et al.</i> (1979) Medhi <i>et al.</i> (1980) Virmani <i>et al.</i> (1983) Misra and Sahu (1985) Bhadra <i>et al.</i> (1987) Siddaraju (1987) Tickoo <i>et al.</i> (1988) Xianghuaihe <i>et al.</i> (1988) Illhamuddin <i>et al.</i> (1989) Reddy <i>et al.</i> (1992) Gulam-Hassain <i>et al.</i> (1995) Tiwari <i>et al.</i> (1996)	Bhargava <i>et al.</i> (1966) Chowdhury <i>et al.</i> (1982) Ramana and Singh (1987) Veerabhadhiran and Jehangir (1995) Manivannan <i>et al.</i> (1996)
7.	Shoot Nitrogen	Naidu (1989)	Naidu (1989)
8.	Seed protein	Sanhu <i>et al.</i> (1979) Bhadra <i>et al.</i> (1987)	Yohe and Pochlman (1972) Rosaiah <i>et al.</i> (1987) Sandhu <i>et al.</i> (1979)

S.No.	Character	Wider genetic variability	Narrow genetic variability
(1)	(2)	(3)	(4)
9	Shoot dry weight	Naidu (1989)	Naidu (1989)
10.	Seed yield per plant	Bhargava <i>et al.</i> (1966) Singh and Malhotra (1970) Chowdhury <i>et al.</i> (1971) Giriraj (1973) Joshi and Kabaria (1971) Veeraswamy <i>et al.</i> (1973) Sandhu <i>et al.</i> (1979) Medhi <i>et al.</i> (1980) Singh and Sharma (1981) Virmani <i>et al.</i> (1983) Liu <i>et al.</i> (1984) Bhadra <i>et al.</i> (1987) Ramana and Singh (1987) Siddaraju (1987) Kalpana Pandey <i>et al.</i> (1988) Natarajan <i>et al.</i> (1988) Tickoo <i>et al.</i> (1988) Baisakh <i>et al.</i> (1989) Malik and Singh (1983) Naidu <i>et al.</i> (1991) Pundir <i>et al.</i> (1992) Ranganayaki and Sreerangaswamy (1993) Khorgade (1995) Patil and Shinde (1995) Hiran Kumar (1996) Byregowda <i>et al.</i> (1997) Reddy (1997) Shantipriya (1997) Das <i>et al.</i> (1998)	Patil and Deshmukh (1988b) Reddy <i>et al.</i> (1991) Gulam-Hassan <i>et al.</i> (1995)

2.1.2 Heritability and Genetic advance :

Heritability in broad sense can be defined as the ratio of genotypic variance to the total variance in non-segregating populations (Hanson *et al.*, (1956). Heritability (h^2) measures the relative amount of the heritable portion of variability while the genetic advance (GA) helps to measure the amount of progress that could be expected with selection in a character. High heritability coupled with high genetic advance could successfully be improved by direct selection (Paul 1978). The available literature on heritability and genetic advance on greengram is reviewed in a tabular form (Table 2.2).

Table 2.2 : Literature on Heritability and Genetic Advance

S.No.	Character	High h^2 and High G A	High h^2 and Low G A	Low h^2 and High G A	Low h^2 and Low G A
1.	Days to 50% flowering	Giriraj (1973) Paramasivam and Rajasekharan (1980) Borah and Hazarika (1995) Patil and Shinde (1995) Vikasparoda <i>et al.</i> (1998)	Medhi <i>et al.</i> (1980) Singh and Pathak (1986) Ramana and Singh (1987) Patil and Deshmukh (1988b) Naidu <i>et al.</i> (1991) Veerabhadhiran and Jehangir (1995) Manivannan <i>et al.</i> (1996) Appalaswamy (1997) Joshi <i>et al.</i> (1998)	Manivannan <i>et al.</i> (1996)	
2.	Days to maturity	Paramasivam and Rajasekharan (1980) Borah and Hazarika (1975) Patil and Shinde (1995)	Joshi and Kaberia (1973) Medhi <i>et al.</i> (1980) Shah and Patel (1981) Patil and Deshmukh (1988b) Naidu <i>et al.</i> (1991) Liwan <i>et al.</i> (1996) Joshi <i>et al.</i> (1998)		Singh and Pathak (1986) Ramana and Singh (1987) Rosaiah <i>et al.</i> (1987)
3.	Plant height	Giriraj (1973) Medhi <i>et al.</i> (1980) Shah and Patel (1981) Ramana and Singh (1987) Siddaraju (1987) Patil and Deshmukh (1988b) Naidu <i>et al.</i> (1991) Veerabhadhiran and Jehangir (1995) Manivannan <i>et al.</i> (1996) Ganesh Ram <i>et al.</i> (1997) Vikas paroda <i>et al.</i> (1998)	Paramasivam and Rajasekharan (1980) Patil and Shinde (1995) Manivannan <i>et al.</i> (1996) Veerabhadhiran <i>et al.</i> (1996)		Singh and Pathak (1986)

S.No.	Character	High h ² and High GA	High h ² and Low GA	Low h ² and High GA	Low h ² and Low GA
4.	Pods per plant	Bhargava <i>et al.</i> (1966) Giriraj (1973) Reddy and Krishnaiah (1977) Rathanswamy <i>et al.</i> (1978) Paramasivam and Rajasekharan (1980) Parida and Singh (1984) Mishra and Sahu (1985) Rosaiah <i>et al.</i> (1987) Siddaraju (1987) Kalpana Pandey <i>et al.</i> (1988) Naidu <i>et al.</i> (1991) Yadav <i>et al.</i> (1994) Khorgade (1995) Byregowda <i>et al.</i> (1997) Vikasparoda <i>et al.</i> (1998)	Singh and Pathak (1986) Manivannan <i>et al.</i> (1996) Appalaswamy (1997)	Gupta and Singh (1969) Singh and Malhotra (1970b)	Tickoo <i>et al.</i> (1988)
5.	Seeds per pod	Joshi and Kabaria (1973) Medhi <i>et al.</i> (1980) Shah and Patel (1981) Tickoo <i>et al.</i> (1988)	Giriraj (1973) Paramasivam and Rajasekharan (1980) Naidu <i>et al.</i> (1991) Borah and Hazarika (1995) Manivannan <i>et al.</i> (1996) Appalaswamy (1997)	Patil and Shinde (1995) Veerabhadhiran and Jehangir (1995)	Singh and Pathak (1986) Siddaraju (1987) Ramana and Singh (1987) Patil and Deshmukh (1988) Patil and Shinde (1995)
6.	100 Seed weight	Giriraj (1973) Paramasivam and Rajasekharan (1980) Khorgade (1995)	Ramana and Singh (1987) Borah and Hazarika (1995) Patil and Shinde (1995) Veerabhadhiran and Jehangir (1995) Tiware <i>et al.</i> (1996) Appalaswamy (1997)		Patil and Deshmukh (1988) Manivannan <i>et al.</i> (1986)

S.No.	Character	High h ² and High GA	High h ² and Low GA	Low h ² and High GA	Low h ² and Low GA
7.	Shoot nitrogen	Naidu (1989) Anuradha <i>et al.</i> (1991)	---	---	---
8.	Seed protein	Chowdhury <i>et al.</i> (1982) Rosaiah <i>et al.</i> (1987)	---	---	---
9.	Shoot dry weight	Naidu (1989)	---	---	---
10.	Seed yield per plant	Giriraj (1973) Ramana and Singh (1987) Patil and Deshmukh (1988) Naidu <i>et al.</i> (1991) Patil and Shinde (1995) Manivannan <i>et al.</i> (1996) Byregowda <i>et al.</i> (1997) Ganesh Ram <i>et al.</i> (1997) Joshi <i>et al.</i> (1998)	Paramasivam and Rajasekharan (1980) Singh and Pathak (1986) Borah and Hazarika (1995) Veerabadrhan and Jehangir (1995) Manivannan <i>et al.</i> (1996) Veerabadrhan <i>et al.</i> (1996) Tiware <i>et al.</i> (1996) Appalaswamy (1997)	Singh and Mathura (1970b) Parida and Singh (1984)	Tiekoo <i>et al.</i> (1988)

2.2 HETEROSIS :

Heterosis is a complex biological phenomena manifested in the superiority of the hybrid over the parents. Shull (1914) first coined the term heterosis and defined as the increased vigour of F_1 over parental means. Subsequently, Whaley (1952) extended the term for the increased vigour of the F_1 over the better parent, which is termed as heterobeltiosis. Wilson and Gilbert (1960) emphasised that the heterosis over better parent helps the breeder in eliminating the less productive crosses at F_1 itself. While, Singh and Jain (1970) utilised heterosis to identify the crosses which are likely to generate transgressive segregants. Yield is a dependent quantitative character. Therefore, heterosis of all the contributing characters of yield need to be studied together for heterosis in order to assess the worth of the cross (Grafius, 1956). The heterosis effect on intervarietal crosses of grain legumes are generally due to dominance gene effect (Singh and Singh, 1974) but sometimes it is due to epistatic interactions (Sethi, 1975). In self pollinated crops like greengram it is not possible to exploit hybrid vigour. However, if the heterotic effect is due to epistatic interactions such a genetic manifestation could be exploited through repeated cycles of hybridization (Sagar and Chandra, 1977).

Available literature on heterosis over mid parent and superior parent in greengram is reviewed and presented in Table 2.3.

Table 2.3 Literature on Heterosis in Greengram :

S.No.	Character	Mid Parent	Better Parent	Authors
1	Days to 50% flowering	Negative	Negative	Singh and Jain (1970) Tawar and Sudhansu Jain (1988) Singh and Pathak (1992) Sharma and Yadav (1993)
		Negative		Swindell and Poehlman (1978) Ramanujam (1978)
2.	Days to Maturity	Positive significant	Positive significant	Tawar and Sudhansu Jain (1988) Singh and Pathak (1992) Sharma and Yadav (1993)
		Negative significant		Naidu and Satyanarayana (1993) Reddissekhar <i>et al.</i> (1994)
3.	Plant height	Positive significant	Positive significant	Misra <i>et al.</i> (1970) Singh and Jain (1971) Ilyas Ahmad Malik <i>et al.</i> (1988) Reddissekhar <i>et al.</i> (1994) Hegde <i>et al.</i> (1996)
			Positive significant	Thimmappa (1987)
			Negative significant	Tawar and Sudhansu Jain (1988)
4.	Pods per plant	Positively significant	Positive significant	Naidu and Satyanarayana (1993) Patil <i>et al.</i> (1999)
5.	Seeds per pod	Positive significant		Singh and Singh (1974) Swindell and Poehlman (1976) Ramanujam (1978) Ilyas Ahmad Malik <i>et al.</i> (1988) Reddy (1998) Vikasparoda <i>et al.</i> (1998)
			Positive significant	Singh and Jain (1970) Vikas Singh and Tyagi (1988) Tawar and Sadhansu Jain (1988) Singh and Pathak (1992)
		Positive significant	Positive significant	Reddissekhar <i>et al.</i> (1994) Hegde <i>et al.</i> (1996)

S.No.	Character	Mid Parent	Better Parent	Authors
6.	100-Seed weight	Positive significant	Positive significant	Vikas Singh and Tyagi (1988) Reddissekhar <i>et al.</i> (1994) Vikas paroda <i>et al.</i> (1998)
		Negative		Ilyas Ahmad Malik <i>et al.</i> (1988) Singh and Singh (1974)
			Negative	Thimmappa (1987) Tawar and Sudhansu Jain (1988) Singh and Pathak (1992) Sharma and Yadav (1993) Reddissekhar <i>et al.</i> (1994) Hegde <i>et al.</i> (1996)
7.	Shoot nitrogen	Positive significant	Positive significant	Naidu (1989)
8.	Seed protein	Positive and Significant	-	Tiwari and Ramanujam (1976) Quah <i>et al.</i> (1983)
		Negative	-	Singh and Singh (1974)
9.	Shoot dry weight	Positive significant	Positive significant	Naidu (1989)
10.	Seed yield	Positive significant		Gupta <i>et al.</i> (1978) Raghuram Reddy (1980) Raghuram Reddy and Sreeraniulu (1982) Reddy (1998) Vikasparoda and Singh (1998) Reddy (1998) Patil <i>et al.</i> (1999)
			Positive significant	Thimmappa (1987) Singh and Pathak (1992) Patil <i>et al.</i> (1992) Patil <i>et al.</i> (1999)
		Positive significant	Positive significant	Swindel and Poehlman (1978) Imrie <i>et al.</i> (1988) Ilyas Ahmad Malik <i>et al.</i> (1988) Reddissekhar <i>et al.</i> (1994) Hegde <i>et al.</i> (1996)

2.3 COMBINING ABILITY :

The ability of parent to transmit desirable performance to its hybrid progeny is called combining ability. Sprague and Tatum (1942) defined the term general combining ability as the performance of a line or population in several hybrid combinations and specific combining ability to designate those effects in certain combinations, which significantly departed from what would be expected on the basis of the average performance of the lines involved. General combining ability is due to additive effect of genes and specific combining ability is due to dominance deviation and epistatic interactions or non-additive gene actions. The non-additive gene action is usually non-fixable but often brings about phenotypes that are not possible from additive gene action (Griffing, 1956).

Combining ability analysis gives useful information regarding the selection of parents to be used in a hybridization programme and elucidates nature and magnitude of gene action involved in the expression of quantitative traits (Dhillan, 1975), which will help in selecting appropriate breeding method for crop improvement.

Rojas and Spragno (1952) examined the combining ability over years in corn and concluded that specific combining ability not only involved dominance and epistasis but a considerable amounts of genotype x environment interaction. Griffing (1956) expressed that 'gca' involved both additive effects as well as additive x additive interactions.

The review of literature on gene action governing inheritance of different traits based on the combining ability analysis in greengram is summarized in Table 2.4.

Table 2.4 Literature on gene action for various characters in greengram

S. No.	Character	Additive	Non-additive	Additive and Non-additive
1.	Days to 50 percent flowering	Singh and Singh (1974) Tiwari and Ramanujam (1974) Yohe and Poehlman (1975) Ramanujan (1978) Raghuram Reddy (1980) Rao <i>et al.</i> (1984) Wilson <i>et al.</i> (1985) Patel <i>et al.</i> (1988) Tawar and Sudhansu Jain (1988) Reddy <i>et al.</i> (1992)	Murthy <i>et al.</i> (1976) Swindell and Poehlman (1978) Deshmukh and Manjore (1980) Naidu <i>et al.</i> (1991) Poornachandra Rao (1995) Hiran Kumar (1996) Aher and Dahat (1999)	Bhadra and Akhtar (1993) Thimmappa <i>et al.</i> (1989) Saxena and Sharma (1992)
2.	Days to maturity	Murthy <i>et al.</i> (1976) Gupta <i>et al.</i> (1978) Ramanujan (1978) Raghuram Reddy (1980) Patel (1983) Rao <i>et al.</i> (1984) Wilson <i>et al.</i> (1985) Patil <i>et al.</i> (1987) Tawar and Sudhansu Jain (1988) Patel <i>et al.</i> (1988) Naidu <i>et al.</i> (1991) Reddisekhar <i>et al.</i> (1994) Mansuria and Joshi (1994) Shantipriya and Hariprasad Reddy (1999)	Deshmukh and Manjore (1980) Tiware <i>et al.</i> (1993) Vijayabharathi (1993) Aher and Dahat (1999)	Saxena and Sharma (1992)

S. No.	Character	Additive	Non-additive	Additive and Non-additive
3.	Plant height	Yobe and Poehlman (1975) Gupta <i>et al.</i> (1978) Deshmukh and Manjare (1980) Malik and Singh (1983) Singh (1987) Tawar and Sudhansu Jain (1988) Natarajan <i>et al.</i> (1990) Naidu <i>et al.</i> (1991) Reddy <i>et al.</i> (1992)	Ahuja (1980) Lal <i>et al.</i> (1982) Thimmappa (1987) Patel <i>et al.</i> (1988) Natarajan <i>et al.</i> (1990) Reddissekhar <i>et al.</i> (1994) Tiwari <i>et al.</i> (1993) Holkar <i>et al.</i> (1994) Hiran Kumar (1996) Aher and Dahat (1999)	Swindell and Poehlman (1978) Lal <i>et al.</i> (1982) Rao <i>et al.</i> (1984) Malik and Singh (1986) Choudhury (1986) Thimmappa <i>et al.</i> (1989) Natarajan <i>et al.</i> (1990) Bhadra and Akhtar (1993) Saxena and Sharma (1993)
4.	Pods - plant	Singh and Singh (1974) Raghu Ram Reddy (1980) Malik and Singh (1986) Yadav and Rao (1986) Saxena and Sharma (1992)	Gupta <i>et al.</i> (1978) Deshmukh and Manjare (1980) Ahuja (1980) Lal <i>et al.</i> (1982) Nagaraju Rao and Mahaboob Ali (1983) Patel <i>et al.</i> (1988) Poorna Chandra Rao (1995)	Malhotra <i>et al.</i> (1980) Raghuram Reddy and Sreeramulu (1982) Rao <i>et al.</i> (1984) Bhadra and Akhtar (1993)

S. No.	Character	Additive	Non-additive	Additive and Non-additive
5.	Seeds per pod	Singh and Singh (1974) Yohe and Pochlman (1975) Ramanujam (1978) Raghuram Reddy (1980) Wilson <i>et al.</i> (1985) Patel <i>et al.</i> (1988) Natarajan <i>et al.</i> (1989) Naidu <i>et al.</i> (1991) Reddy <i>et al.</i> (1992) Mansuria and Joshi (1994)	Murthy <i>et al.</i> (1976) Gupta <i>et al.</i> (1978) Deshmukh and Manjare (1980) Lal <i>et al.</i> (1982) Patel <i>et al.</i> (1988) Thimmappa <i>et al.</i> (1989) Holkar (1994) Reddissekhar <i>et al.</i> (1994) Poorna Chandra Rao (1995) Aher and Dahat (1999)	Tiwari and Ramanujam (1976) Malhotra (1983) Malik and Singh (1986) Saxena and Sharma (1989) Natarajan <i>et al.</i> (1990) Naidu and Satyanarayana (1991) Bhadra and Akhtar (1993) Vijayabharathi (1993)
6.	100 Seed weight	Singh and Jain (1971) Ramanujam (1978) Deshmukh and Manjare (1980) Raghuram Reddy (1980) Wilson <i>et al.</i> (1985) Malik and Singh (1986) Thimmappa (1987) Tavar and Sudhansu Jain (1988) Patel <i>et al.</i> (1988) Pathak <i>et al.</i> (1990) Naidu <i>et al.</i> (1991) Reddy <i>et al.</i> (1992) Holkar (1994) Rosaiah <i>et al.</i> (1994)	Tiwari and Ramanujam (1974) Murthy <i>et al.</i> (1976) Ahuja (1980) Nagaraja Rao and Mahboob Ali (1983) Naidu <i>et al.</i> (1991) Poornachandra Rao (1995)	Imrie <i>et al.</i> (1988) Malik and Singh (1986) Thimmappa <i>et al.</i> (1989) Reddissekhar <i>et al.</i> (1992) Bhadra and Akhtar (1993) Saxena and Sharma (1993)

S. No.	Character	Additive	Non-additive	Additive and Non-additive
7.	Shoot nitrogen	—	—	Naidu (1989)
8.	Seed protein	Tiwari and Ramanujam (1976) Raghuram Reddy (1980)	Wilson <i>et al.</i> (1985)	Singh and Singh (1974) Singh (1987)
9.	Shoot dry weight	Naidu (1989)	—	—
10.	Seed yield per plant	Singh and Singh (1974) Yohe and Poehlman (1975) Ahuja (1980) Raghuram Reddy (1980) Singh (1984) Wilson <i>et al.</i> (1985) Malik and Singh (1986) Imrie <i>et al.</i> (1988) Naidu <i>et al.</i> (1991) Holkar (1994)	Singh and Singh (1972a) Murthy <i>et al.</i> (1976) Gupta <i>et al.</i> (1978) Krishna Rao and Nagur (1979) Deshmukh and Manjare (1980) Singh (1980) Babeeruddin and Nagur (1981) Patil <i>et al.</i> (1987) Patei <i>et al.</i> (1988) Natarajan <i>et al.</i> (1989) Pathak <i>et al.</i> (1990) Tiwari <i>et al.</i> (1993) Reddisekhar <i>et al.</i> (1994) Poornachandra Rao (1995) Aher and Dahat (1999)	Singh and Jain (1971) Rao <i>et al.</i> (1984) Raghuram Reddy and Sreeramulu (1982) Chowdhury (1986) Patel <i>et al.</i> (1988) Tawar and Sudhansu Jain (1988) Natarajan <i>et al.</i> (1990) Naidu <i>et al.</i> (1991) Saxena and Sharma (1992)

2.4 TRIPLE TEST CROSS ANALYSIS :

Several biometrical procedures are available for detecting the information on most of genetic variation. The North Carolina Design III of Comstock and Robinson (1952) in which homozygous parents are crossed and F_2 parents are back crossed to each of the parents provides reliable estimates of additive and dominance component, but it assumes no epistasis. Kearsey and Jinks (1968) extended this concept and included back crosses to the F_1 generation. This type of experiment was called triple test cross by Jinks *et al.* (1969) and it is modified by many other workers (Jinks and Perkins, 1970. Perkins and Jinks, 1971 ; Jinks and Virk, 1977 ; Chahal and Jinks, 1978). This method is the most efficient for detection and estimation of epistatic variation. If epistasis is present in the material investigated, one can obtain better estimates of additive and dominance components by this method as compared to other methods (Chahal and Singh 1974 ; Pooni *et al.*, 1978). Additionally, this approach is independent of gene correlations ; gene frequency and mating systems. However, if the testers are inadequate, may provide biased estimates of additive and dominance components of genetic variation. Since literature on this type of analysis in greengram is limited available, the results on the other crops are reviewed.

Virk *et al.* (1983) studied a triple test cross involving 10 pure breeding lines of pea to investigate the inheritance of flowering time, harvest at

flowering, final height, number of pods, height of first pod bearing node, number of seeds per five pods and seed yield per plant. Epistasis was found to be an integral component for the genetic variation for all the characters except for the height of first pod bearing node and number of seeds per five pods.

Singh *et al.* (1986) has done triple cross analysis in four F_2 crosses of field pea and estimated the quantitative inheritance of characters viz., days to flowering, plant height, pod number, seed number, test weight and yield per plant. The overall epistasis 'I' type was in general a major contributor in controlling the expression of the characters in all four crosses except for the seeds number in cross 1 and 4. Whereas, the 'j' and 'l' component of epistasis played significant role in determining the expression of this attribute. Through the 'j' and 'l' type component of the epistasis was significant it was relatively less important than the 'I' type epistasis. Both the additive and dominant components of genetic variances were highly significant for all the six traits studied in all the four sets of crosses. The expression of the dominance was directional, only for a few characters in certain crosses. The degree of dominance were high for most of the traits.

A study on triple test cross analysis by Singh *et al.* (1987) in three crosses in F_2 generation in chickpea revealed that epistasis was generally

present for the characters plant height, branches per plant, days to flowering, days to 100 maturity, pods per plant, grains per pod, 100 seed weight and grain yield per plant. The 'j' and 'l' type epistasis was relatively more important than 'i' type in two crosses. The additive component, in general was more predominant in another cross where improvement can be made in the characters through simple selection procedures. This study suggests that all the three components of genetic variation (additive, dominance and epistasis) played significant role in majority of the crosses.

Singh *et al.* (1988) estimated genetic components of variation in field pea following triple test cross and North Carolina Design III in an intervarietal cross (PG-3 x 5046) for days to flowering, plant height, pod number, seed number, 100 seed weight and seed yield. In both the mating designs, additive (D) and dominance (H) components of variance were highly significant for most of the traits. However, the magnitude of additive component was greater than the dominance component for most of the crosses. In general 'l' type epistasis was the major component of epistasis. All the traits showed partial dominance and directional element was found to be non-significant.

Vijaya Kumar *et al.* (1996) carried out triple test cross analysis in rice for nine characters revealed the presence of epistasis for most of the

characters except seed weight per panicle. In the absence of epistasis, additive component (variance for sums) were significant for all the traits. While, the dominance components (Variance for differences) were significant only for six characters namely plant height, panicle length, productive tillers per plant, seeds per panicle, seed weight per plant and 100 seed weight. The estimates of additive (D) and dominance (H) component were highly significant for most of the traits, although the D component was higher than H.

Rambhajan *et al.* (1994) estimated genetic components of yield and yield component characters in mustard through TTC. Partitioning of total epistasis revealed that both (i) and (j and l) types of epistasis were involved in the expression of plant height and yield per plant. Only 'i' type epistasis was detected for primary and secondary branches per plant whereas, j and l components of epistasis were involved in the expression of length of main raceme, test weight and oil content.

2.5 ASSOCIATION ANALYSIS :

Character association studies measure the mutual relationship between various plant characters and determine the component characters on which selection can be based for genetic improvement in yield. Correlation studies indicate the magnitude of association between pairs of characters and are useful for selecting genotypes with desirable combinations of characters

thereby by aiding the plant breeder in crop improvement. Most of the times the association of characters may be due to genetic linkage or pleiotropy. Unfavourable association between desired attributes under selection may result in genetic slippage and limit genetic advance.

Phenotypic correlation is the association between two variables which can be directly observed and is subjected to changes in the environment. It measures the environmental deviations together with non-additive gene action. Genotypic correlation is the correlation of breeding values (additive + additive x additive gene action).

A knowledge of association of yield components with each other and with yield is helpful in improvement of complex character like yield for which direct selection is not effective. A brief review of the studies on the association of characters in mungbean is presented here under.

Review of Literature on association of yield components with seed yield and among yield attributes in mungbean is presented in a concise tabular form (Table 2.5 and 2.6).

Table 2.5 Literature of Association of yield component character with seed yield

S. No.	Character	Positive significant	Negative significant
1.	Days to 50% flowering	Chandel <i>et al.</i> (1973) Joshi and Kabaria (1973) Malhotra <i>et al.</i> (1974) Giriraj and Vijayakumari (1974) Raghuram Reddy (1980) Upadhyaya <i>et al.</i> (1980) Lill <i>et al.</i> (1984) Patil and Deshmukh (1998a) Lakshmaiah <i>et al.</i> (1989) Naidu (1993) Yaqoob <i>et al.</i> (1997)	Gupta and Singh (1969) Xianghuaihe <i>et al.</i> (1988) Holkar and Raut (1992) Pathak and Patel (1993) Veerabadhiran and Jehangir (1995)
2	Days to maturity	Joshi and Kabaria (1973) Gupta <i>et al.</i> (1982) Misra and Sahu (1985) Patil and Deshmukh (1998a) Satyan <i>et al.</i> (1989) Naidu <i>et al.</i> (1991) Reddy <i>et al.</i> (1994) Kumar <i>et al.</i> (1995) Sarma and Talukdar (1996) Hiran Kumar (1996) Shantipriya (1997)	Mungomery <i>et al.</i> (1972) Lawn (1979) Malik <i>et al.</i> (1982) Holkar and Raut (1992) Hegde <i>et al.</i> (1996)
3.	Plant height (cm)	Giriraj and Vijayakumari (1974) Yohe and Poehlman (1975) Raghuram Reddy (1980) Upadhyaya <i>et al.</i> (1980) Boomikumaran and Rathinam (1981) Lill <i>et al.</i> (1985) Misra and Sahu (1985) Rosaiah (1985) Khan (1988) Natarajan <i>et al.</i> (1988) Singh <i>et al.</i> (1988) Lakshmaiah <i>et al.</i> (1989) Reddisekhar (1992) Naidu (1993) Ranganayaki and Sreerangaswamy (1993) Reddy <i>et al.</i> (1994) Borah and Hazarika (1995) Manivanan and Natarajan (1996) Sarma and Talukdar (1996) Shantipriya (1997) Jiji Joseph and Santhosh Kumar (1999)	Bhaumik and Jha (1976) Xianghuai he <i>et al.</i> (1988) Ahuja and Chowdhury (1991) Veerabadhiran and Jehangir (1995)

S. No.	Character	Positive significant	Negative significant
4	Pods per plant	Joshi and Kabaria (1973) Krishnaswamy <i>et al.</i> (1973) Giriraj and Vijayakumari (1974) Bhaumik and Jha (1976) Rathnaswamy <i>et al.</i> (1978) Raghuram Reddy (1980) Nagaraja Rao (1981) Singh and Sharma (1981) Chowdhury <i>et al.</i> (1982) Gupta <i>et al.</i> (1982) Lill <i>et al.</i> (1984) Malhotra <i>et al.</i> (1984) Misra and Sahu (1985) Ramana and Singh (1987) Khan (1988) Natarajan (1988) Patil and Deshmukh (1988a) Xianghuai he <i>et al.</i> (1988) Khan and Ahmed (1989) Lakshmaiah <i>et al.</i> (1989) Satyam <i>et al.</i> (1989) Ahuja and Chowdhury (1991) Naidu <i>et al.</i> (1991) Holkar and Raut (1992) Reddisekhhar (1992) Ranganayaki and Sreerangaswamy (1993) Borah and Hazarika (1995) Gill and Verma (1995) Khorgade <i>et al.</i> (1995) Poornachandra Rao (1995) Prasanna Rajesh (1995) Veerabathiran and Jehangir (1995) Hegde <i>et al.</i> (1996) Byregowda <i>et al.</i> (1997) Shantipriya (1997) Ramaswamy and Jehangir (1998) Sabahpour <i>et al.</i> (1998) Vikas Singh and Tyagi (1998)	

S. No.	Character	Positive significant	Negative significant
5.	Seeds per pod	Joshi and Kabaria (1973) Giriraj and Vijayakumari (1974) Chowdhury <i>et al.</i> (1982) Parida and Singh (1984) Ramana and Singh (1987) Khan (1988) Natarajan <i>et al.</i> (1988) Patil and Deshmukh (1988a) Satyam <i>et al.</i> (1989) Naidu <i>et al.</i> (1991) Pundir <i>et al.</i> (1992) Reddissekhar (1992) Reddy <i>et al.</i> (1994) Borah and Hazarika (1995) Gill <i>et al.</i> (1995) Veerabadhiran and Jehangir (1995) Hegde <i>et al.</i> (1996) Hiran Kumar (1996) Patil <i>et al.</i> (1996) Byragowda <i>et al.</i> (1997) Shantipriya (1997) Vikas Singh and Tyagi (1998)	Pathak and Patel (1993)
6.	100 seed weight	Gupta and Singh (1969) Bhoumik and Jha (1976) Chowdhury <i>et al.</i> (1982) Parida (1982) Kumari and George (1985) Patil and Deshmukh (1988a) Naidu (1989) Ahuja and Choudhury (1991) Holkar and Raut (1992) Pundir <i>et al.</i> (1992) Singh and Pathak (1993) Borah and Hazarika (1995) Gill and Verma (1995) Kumar <i>et al.</i> (1995) Prasanna Rajesh (1995) Veerabadhiran and Jehangir (1995) Sarma and Talukdor (1996) Ramaswamy and Jehangir (1998)	Giriraj and Vijayakumari (1974) Rathnaswamy <i>et al.</i> (1978) Raghuram Reddy (1980) Nagaraja Rao (1981) Reddissekhar (1992) Reddy <i>et al.</i> (1994) Hiran Kumar (1996) Shantipriya (1997)
7.	Shoot nitrogen	Naidu (1989)	
8.	Seed protein	Raghuram Reddy (1980) Thandapani and Rao (1984) Rosaiah (1985) Bhadra <i>et al.</i> (1987) Sajjo <i>et al.</i> (1980)	Naidu (1989)
9.	Shoot dry weight	Babu <i>et al.</i> (1997)	

Table 2.6 Literature on association among yield component characters

S. No.	Character	Positive significant	Negative significant
Days to 50 per cent flowering with			
1	Days to maturity	Singh and Malhotra (1970a) Yohe and Poehlman (1975) Gupta <i>et al.</i> (1982) Malhotra <i>et al.</i> (1984) Patil and Deshmukh (1988a) Naidu <i>et al.</i> (1989) Kumar <i>et al.</i> (1995) Hiran Kumar (1996) Raje and Rao (2000)	
2	Plant height	Singh and Malhotra (1970) Raghuram Reddy (1980) Ramana and Singh (1987) Patil and Deshmukh (1988a) Naidu <i>et al.</i> (1989) Kumar <i>et al.</i> (1995) Veerabhadhiran and Jehangir (1995) Raje and Rao (2000)	
3	Pods per plant	Malhotra <i>et al.</i> (1984) Raghuram Reddy (1980)	
4	Seeds per pod	Singh and Malhotra (1970) Malhotra <i>et al.</i> (1984) Upadhyaya <i>et al.</i> (1980) Ramana and Singh (1987)	Sandhu <i>et al.</i> (1980)
5	100 seed weight		Gupta and Singh (1969) Sandhu <i>et al.</i> (1980) Raghuram Reddy (1980) Nagaraja Rao (1981)
Days to maturity with			
1	Plant height	Malhotra <i>et al.</i> (1984) Lakshmaiah <i>et al.</i> (1989) Patil and Narkhede (1989) Satyan <i>et al.</i> (1989) Khorgade <i>et al.</i> (1990) Naidu <i>et al.</i> (1991) Kumar <i>et al.</i> (1995) Sarma and Talukdar (1996) Raje and Rao (2000)	
2	Pods per plant	Hiran Kumar (1996)	Pathak and Patel (1993)

S. No.	Character	Positive significant	Negative significant
3.	Seeds per pod	Patil and Narkhede (1989) Pathak and Patel (1993)	Sandhu <i>et al.</i> (1979) Sarma and Talukdar (1996)
4.	100 seed weight	Mishra and Sahu (1985) Khorgade <i>et al.</i> (1990) Naidu <i>et al.</i> (1991) Sarma and Talukdar (1996)	Singh and Malhotra (1970a) Malhotra <i>et al.</i> (1984) Reddissekhar (1992) Shantipriya (1997)
Plant height with			
1.	Pods per plant	Naidu <i>et al.</i> (1991) Reddissekhar (1992) Borah and Hazarika (1995) Jiji Joseph and Santhoshkumar (1999) Raje and Rao (2000)	Veerabhadhiran and Jehangir (1995)
2.	Pod length	Sandhu <i>et al.</i> (1980) Sarsawathi <i>et al.</i> (1979) Raghuram Reddy (1980) Singh and Sharma (1981) Manivannan and Natarajan (1986)	
3.	Seeds per pod	Natarajan <i>et al.</i> (1988) Singh <i>et al.</i> (1988) Xianghua; he <i>et al.</i> (1988) Lakshmaiah <i>et al.</i> (1989) Satyan <i>et al.</i> (1989) Naidu <i>et al.</i> (1991) Pathak and Patel (1993) Reddissekhar (1992) Sarma and Talukdar (1996) Raje and Rao (2000)	
4.	100 seeds weight	Naidu <i>et al.</i> (1991) Khattak <i>et al.</i> (1995) Sarma and Talukdar (1996)	Veerabhadhiran and Jehangir (1995) Raghuram Reddy (1980) Nagaraja Rao (1981) Pundir <i>et al.</i> (1992) Reddissekhar (1992) Jiji Joseph and Santhoshkumar (1999)
Pods per plant with			
1.	Seeds per pod	Singh and Singh (1970) Malhotra <i>et al.</i> (1974) Singh <i>et al.</i> (1988) Naidu <i>et al.</i> (1991) Veerabhadhiran and Jehangir (1995)	Singh (1980) Jiji Joseph and Santhosh Kumar (1999)

S. No.	Character	Positive significant	Negative significant
2.	100 seed weight	Singh and Singh (1970) Malhotra <i>et al.</i> (1974) Singh <i>et al.</i> (1988) Naidu <i>et al.</i> (1991)	Malhotra <i>et al.</i> (1974) Raghuram Reddy (1980) Nagaraja Rao (1981) Liu <i>et al.</i> (1984) Siddaraju (1987) Satyan <i>et al.</i> (1989) Reddissekhar (1992) Jiji Joseph and Santhoshkumar (1999) Raje and Rao (2000)
Shoot nitrogen			
1.	Pods / plant	Naidu (1989)	
2.	100-Seed weight	Naidu (1989)	
3.	Shoot dry weight	Naidu (1989)	
Seeds per pod with			
1.	100 seeds weight	Patil and Deshmukh (1988a) Satyan <i>et al.</i> (1989) Kumar <i>et al.</i> (1995)	Singh and Malhotra (1970a) Malhotra <i>et al.</i> (1974) Raghuram Reddy (1980) Misra and Sahu (1985) Natarajan <i>et al.</i> (1988) Lakshmaiah <i>et al.</i> (1989) Reddissekhar (1992) Reddy <i>et al.</i> (1994) Gill and Verma (1995) Raje and Rao (2000)
A. Shoot dry weight			
	Plant height	Naidu (1989)	
	Pods per plant	Naidu (1989)	
	100-Seed weight	Naidu (1989)	
B. Seed protein			
	Seed protein		Sandhu <i>et al.</i> (1978)
	Pods / plant		Sandhu <i>et al.</i> (1978)
	Pod length		Sandhu <i>et al.</i> (1978)
	Seeds / pod		

2.7 PATH COEFFICIENT ANALYSIS :

From mere correlation studies, the direct contribution of each component to the yield and the indirect effect of it through other components cannot be estimated. The path coefficient analysis, a statistical device developed by Wright (1934) is a standardized partial regression coefficient, which helps in partitioning of correlation coefficients into direct and indirect effects of independent variable on dependent variable. Hence, correlation in conjunction with path analysis would give a better understanding of cause and effect relationship between different pairs of characters. Dewey and Lu (1959) and Frakes *et al.* (1961) demonstrated the utility of path coefficient analysis in plant selection.

2.7.1 Direct effects of plant characters on yield

Literature available on direct effects of plant characters on yield is presented in Table 2.7.

2.7.2 Indirect effects

Literature available on indirect effects of plant characters is presented in Table 2.8

Table 2.7 : Literature on Direct effects of plant characters on yield

S. No.	Character	Positive	Negative
1.	Days to 50% flowering	Patil and Deshmukh (1988a) Naidu (1989) Yaqoob <i>et al.</i> (1997)	Malik <i>et al.</i> (1987) Natarajan <i>et al.</i> (1988) Holkar and Raut (1992) Babu Rao (1994) Kumar <i>et al.</i> (1995)
2.	Days to maturity	Upadhaya and Singh (1981) Misra and Sahu (1985) Patel (1991) Pathak and Patel (1993) Babu Rao (1994) Reddy <i>et al.</i> (1994) Yaqoob <i>et al.</i> (1997)	Mallik <i>et al.</i> (1984) Patil and Deshmukh (1988a) Holkar and Raut (1992) Kumar <i>et al.</i> (1995)
3.	Plant height	Giriraj and Vijaya Kumari (1974) Mathotra <i>et al.</i> (1974) Pokle and Patil (1974) Boomikumaran and Rathinam (1981) Malik <i>et al.</i> (1987) Khan (1988) Patil and Narkhade (1989) Khorgade <i>et al.</i> (1990) Pundir <i>et al.</i> (1992) Ranganayaki and Sreerangaswamy (1993) Kumar <i>et al.</i> (1995) Sarma and Talukdar (1996)	Sandhu <i>et al.</i> (1980) Gupta <i>et al.</i> (1982) Malik <i>et al.</i> (1982) Ahuja and Chowdhury (1991) Holkar and Raut (1992) Reddy <i>et al.</i> (1994) Yaqoob <i>et al.</i> (1997)

S. No.	Character	Positive	Negative
4.	Pods per plant	Malhotra <i>et al.</i> (1974) Reddy and Krishnaiah (1977) Rathnaswamy <i>et al.</i> (1978) Misra and Sahu (1985) Natarajan <i>et al.</i> (1988) Patil and Narkhade (1989) Khorgade <i>et al.</i> (1990) Ahuja and Chowdhury (1991) Chhabra <i>et al.</i> (1991) Holkar and Raut (1992) Wani <i>et al.</i> (1992) Naidu <i>et al.</i> (1994) Singh <i>et al.</i> (1995) Veerabhadhiran and Jehangir (1995) Byregowda <i>et al.</i> (1997) Ganeshram <i>et al.</i> (1997) Shantipriya (1997) Ramaswamy and Jehangir (1998)	Pokle and Patil (1974) Gupta <i>et al.</i> (1982) Pun and Villreal (1989) Yaqoob <i>et al.</i> (1997)
5.	Seeds per pod	Malhotra <i>et al.</i> (1974) Reddy and Krishnaiah (1977) Rathnaswamy <i>et al.</i> (1977) Sandhu <i>et al.</i> (1980) Gupta <i>et al.</i> (1982) Kumari and George (1985) Misra and Sahu (1985) Natarajan <i>et al.</i> (1988) Natarajan <i>et al.</i> (1988) Rout <i>et al.</i> (1988) Khan and Ahmed (1989) Pun and Villareal (1989) Holkar and Raut (1992) Geetha <i>et al.</i> (1993) Reddy <i>et al.</i> (1994) Prasanna Rajesh (1995) Byregowda <i>et al.</i> (1997) Shantipriya (1997)	Malik <i>et al.</i> (1984) Khan (1988) Patil and Deshmukh (1988a) Naidu (1989) Pundir <i>et al.</i> (1992) Ranganayaki and Sreerangaswamy (1993) Patil <i>et al.</i> (1996)

S. No.	Character	Positive	Negative
6.	100 seed weight	Chandel <i>et al.</i> (1973) Thulsidas (1984) Patil and Deshmukh (1988a) Rout <i>et al.</i> (1988) Patil and Narkhade (1989) Pun and Villareal (1989) Khorgade <i>et al.</i> (1990) Ahuja and Choudhury (1991) Holkar and Raut (1992) Pundir <i>et al.</i> (1992) Geetha <i>et al.</i> (1993) Kumar <i>et al.</i> (1995) Prasanna Rajesh (1995) Byregowda <i>et al.</i> (1997) Sabaghpur <i>et al.</i> (1998)	
7.	Shoot nitrogen	Naidu (1989)	
8.	Seed protein	Naidu (1989)	
9.	Shoot dry weight	Pokle and Patil (1974)	

Table 2.8 : Literature on Indirect effects of component characters on yield

S. No.	Character	Positive	Negative
1. Days to 50% flowering on yield through			
1.	Plant height	Natarajan <i>et al.</i> (1988) Kumar <i>et al.</i> (1995) Veerabhadhiran and Jehangir (1995)	
2.	Days to maturity		Patil and Deshmukh (1988a)
3.	Pods per plant	Natarajan <i>et al.</i> (1988) Kumar <i>et al.</i> (1995)	Veerabhadhiran and Jehangir (1995)
4.	Seeds per pod	Natarajan <i>et al.</i> (1995)	
5.	100 seed weight	Kumar <i>et al.</i> (1995)	Natarajan <i>et al.</i> (1988)
6.	Shoot nitrogen		Naidu (1989)
7.	Seed protein	Naidu (1989)	
8.	Shoot dry weight	Naidu (1989)	
2. Days to maturity on yield through			
1.	Plant height	Patil and Narkhade (1989) Kumar <i>et al.</i> (1995) Sarma and Talukdar (1996)	Patil and Deshmukh (1988a)
2.	Pods per plant	Patil and Narkhade (1989) Khorgade <i>et al.</i> (1990) Kumar <i>et al.</i> (1995)	
3.	100 seed weight	Kumar <i>et al.</i> (1995)	
4.	Shoot nitrogen	—	Naidu (1989)
5.	Seed protein	Naidu (1989)	—
6.	Shoot dry weight	Naidu (1989)	—

S. No.	Character	Positive	Negative
3. Plant height on yield through			
1.	Days to 50% flowering	Pathak and Patel (1993)	Kumar <i>et al.</i> (1995)
2.	Days to maturity		Kumar <i>et al.</i> (1995) Sarma and Talukdar (1996)
3.	Pods per plant	Malhotra <i>et al.</i> (1974) Malik <i>et al.</i> (1984) Khan (1988) Natarajan <i>et al.</i> (1988) Singh <i>et al.</i> (1989) Khorgade <i>et al.</i> (1990) Holkar and Raut (1992) Jiji Joseph and Santhoshkumar (1999)	Veerabadhiran and Jehangir (1995)
4.	Seeds per pod	Malhotra <i>et al.</i> (1974) Malik <i>et al.</i> (1984) Khan (1988) Natarajan <i>et al.</i> (1988) Khan and Ahmed (1989)	Sarma and Talukdar (1996)
5.	100 seed weight		Sarma and Talukdar (1996)
6.	Shoot nitrogen	Naidu (1989)	—
7.	Seed protein	—	Naidu (1989)
8.	Shot dry weight	Naidu (1989)	
4. Pods per plant on yield through			
1.	Plant height	Pokle and Patil (1974) Patil and Narkhade (1989) Kumar <i>et al.</i> (1995)	Malik <i>et al.</i> (1984)
2.	Pod length	Rathnaswamy <i>et al.</i> (1978) Patil and Narkhade (1989)	

S. No.	Character	Positive	Negative
3	Seeds per pod	Pokle and Patil (1974) Rathnaswamy <i>et al.</i> (1978) Gupta <i>et al.</i> (1982) Thulasidas (1984) Khan and Ahmed (1989) Holkar and Raut (1992) Reddissekhar (1992)	
4	100 seeds weight	Thulasidas (1984)	
5. Seeds per pod on yield through			
1.	Plant height	Pokle and Patil (1974)	
2.	Pods per plant	Chandel <i>et al.</i> (1973) Malhotra <i>et al.</i> (1974) Rathnaswamy <i>et al.</i> (1978) Gupta <i>et al.</i> (1982) Khorgade <i>et al.</i> (1990) Holkar and Raut (1992) Reddissekhar (1992) Veerabhadhiran and Jehangir (1995)	Pokle and Patil (1974) Jiji Joseph and Santhoshkumar (1999)
3.	Pod length	Gupta <i>et al.</i> (1982) Thandapani and Rao (1984) Pathak and Patel (1993)	
4.	100 seed weight		Thandapani and Rao (1984)
5.	Shoot nitrogen	Naidu (1989)	--
6.	Seed protein	Naidu (1989)	--
7.	Shoot dry weight	Naidu (1989)	--
6. 100 seed weight on yield through			
1.	Days to 50% flowering	Veerabhadhiran and Jehangir (1995)	Patil and Deshmukh (1988a)

S. No.	Character	Positive	Negative
2.	Days to maturity	Patil and Narkhade (1989)	
3.	Plant height	Kumar <i>et al.</i> (1995) Sarma and Talukdar (1996)	Misra and Sahu (1985) Patil and Deshmukh (1988a)
4.	Pods per plant	Patil and Narkhade (1989) Singh <i>et al.</i> (1989) Pundir <i>et al.</i> (1992)	Jiji Joseph and Santhoshkumar (1999)
5.	Seeds per pod	Veerabadhiran and Jehangir (1995)	Thandapani and Rao (1984) Misra and Sahu (1985)
6.	Shoot nitrogen		Naidu (1989)
7.	Seed protein	Naidu (1989)	
8.	Shoot dry weight	Naidu (1989)	
7.	Shoot nitrogen on yield through		
	1. Seed protein	Naidu (1989)	
	2. Shoot dry weight	Naidu (1989)	
8.	Seed protein on yield through		
	1. Shoot dry weight	Naidu (1989)	

Chapter III

Materials and Methods

CHAPTER - III

3. MATERIAL AND METHODS

3.1 MATERIAL :

In the present study, five lines, LGG-410, LGG-460, MGG-341, PUSA-9672 and Podalakur local and four testers LGG-407, WGG-2, TARM-21 and LGG-440 were mated in a line x tester design. The salient features of the parents are presented in Table 3.1.

Table 3.1 : Characteristics of the genotypes used in hybridization in a line x tester fashion

Culture	Pedigree	Source	Characters
LGG-410	Mutant from Pant - Mung - 2	RARS, LAM	Dark green, foliage matures in 70-75 days. Seeds are attractive shining green with top bearing habit. Resistant to MYMV and angular black leaf spot disease. Performs better in <i>rabi</i> season and suitable for rice fallows.
LGG-460	LAM M2 x ML-267	RARS, LAM	Erect type with medium high and determinate plant habit with light green foliage. Shining green seed, long pods. Moderately resistant to MYMV. Matures in 65 days synchronously. Suitable for all seasons.
LGG-407	Mutant from Pant Mung-2	RARS, LAM	Erect plant with dark green foliage. Seeds medium bold and shining green in colour. Resistant to MYMV, root rot and angular black leaf spot disease. Duration 75 days, yield potential 14-16 q/ha. Synchronous in maturity.
MGG-341	Selection from Madhira mung	ARS Madira	Medium tall, spreading, long pod with bold and dull green seed, suitable for <i>rabi</i> season
Pusa 9672	M 981 x 11/395	IARI, New Delhi	Medium tall, light green foliage, medium long pods with black shining seed. Drought tolerant.

Local	Podalakuru local greengram	ARS Podalakuru	Tall spreading photosensitive variety. Small seeded with dull green colour. Long duration. Suitable only for <i>rabi</i> season
WGG-2	W75-6 x Pusa 101	ARS Warangal	Darkgreen foliage, stout pod with shining green seed, resistant to ABLS and 65 days duration.
LARM-21	RUM 5 x TPM 5	BARC, Trombay	Medium tall semi spreading, resistant to powdery mildew disease. Seeds medium bold and shining green in colour
LGG-440	ML73 x UPM 79-3-4	RARS, LAM	Erect plant type. Pods confined to top with cereal mimic bearing habit. shining green seed

The lines were crossed to the testers during *Kharif* 1999-2000 to develop 20 F₁ crosses at the Agricultural Research Station, Podalkur.

3.2 METHODS :

3.2.1 Experimental design & layout :

The 20 F₁ hybrids were raised along with their 9 parents in a RBD with 3 replications during late '*rabi*' 1999-2000 under rice fallow at ARS, Nellore. The plot size comprised of two rows of 4 m length, spaced at 30 x 10 cm between plants in the rows. Fifty percent of the crossed seeds were saved for the next season. All the cultural practices for the crop were adopted as per ANGRAU recommended package of practices (Anonymous, 1999).

3.2.2 Sample size :

Observations were recorded on ten randomly selected plants in both parents and hybrids. The mean of each replication were used for statistical analysis.

3.2.3 Sampling of plants and recording data :

1. Days to 50% flowering :

The number of days taken from sowing date to the appearance of first flower on 50% of the plants were recorded as days to flowering.

2. Days to maturity :

The number of days from sowing to maturity (pods turning into black) of 75-80 per cent pods on the plants was expressed as days to maturity.

3. Plant height :

The height was measured in centimetres from the base to base of the terminal raceme at maturity.

4. Pods per plant :

The total number of well filled pods from all clusters in a plant was counted and the mean of each replication was expressed as pods per plant.

5. Seeds per pod :

The seeds of five randomly selected pods from 10 plants were counted and averaged to obtain the number of seeds per pod.

6. 100 seed weight :

A random sample of one hundred well developed seeds were weighed and expressed in grams.

7. Shoot nitrogen :

Nitrogen content of the individual plant was estimated by micro kjeldhal method from the shoot samples collected at anthesis and expressed in percentage.

8. Seed protein :

Nitrogen content of the seed was estimated following (AOAC) Micro-kjeldhal method and the crude protein content was calculated using the factor and expressed in percent.

$$\text{Protein (\%)} = \text{Nitrogen (\%)} \times 6.25$$

9. Shoot dry weight :

The individual plants at maturity were dried in a hot air oven for 24 hours at 80°C, weighed and added the dried hulls weight after removing seeds and expressed in grams.

10. Seed yield per plant :

All the pods collected from a single plant were threshed, cleaned, weighed and the average of 10 plants was expressed in grams.

3.3 ESTIMATION OF VARIANCE, HERITABILITY AND GENETIC ADVANCE :

1. Genotypic and Phenotypic variance

These were estimated according to the formula given by Johnson *et al* (1955)

$$\text{Genotypic variance (} \sigma_g^2 \text{)} = \frac{M_1 - M_2}{r}$$

$$\text{Phenotypic variance (} \sigma_p^2 \text{)} = \sigma_g^2 + \sigma_e^2$$

where,

M_1 = Mean sum of squares due to treatments

M_2 = Mean sum of squares due to error

r = number of replications

σ_e^2 = variance due to error

2. Phenotypic (PCV) and Genotypic (GCV) coefficient of variation :

These were estimated according to the formula given by Burton (1952).

$$PCV\% = \frac{(\text{Phenotypic variance})^{1/2}}{\text{General Mean}} \times 100$$

$$GCV\% = \frac{(\text{Genotypic variance})^{1/2}}{\text{General Mean}} \times 100$$

3. Heritability (h^2) :

Heritability in broad sense was worked out following the method given by Lush (1940) and expressed in percentage.

$$h^2 (\%) = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

where,

σ_g^2 = Genotypic variance

σ_p^2 = Phenotypic variance

4. Genetic advance :

Genetic advance (GA) for a particular character was estimated according to the method suggested by Johnson *et al.* (1955).

$$GA = h^2 \times \sigma_p \times k$$

where,

h^2 = heritability in broadsense

σ_p = phenotypic standard deviation

k = selection differential (at 0.05%) i.e. 2.06

5. Genetic advance as percentage of mean (Falconer, 1967)

$$\frac{\text{GA}}{\text{Population mean}} \times 100$$

3.4 ESTIMATION OF HETEROSIS :

The heterosis effects were estimated for all the characters. The heterosis effects were measured as deviation of F_1 mean from mid parent (relative heterosis) and the better parent (heterobeltiosis) mean.

The percent heterosis was calculated as follows

$$\text{i. Relative heterosis (RH)} = \frac{F_1 - \overline{MP}}{\overline{MP}} \times 100$$

$$\text{ii. Heterobeltiosis (HB)} = \frac{F_1 - \overline{BP}}{\overline{BP}} \times 100$$

Where,

- $\overline{F_1}$ = Mean value of F_1
- $\overline{MP}$ = Mid parent value
- $\overline{BP}$ = Mean value of better parent
- $\overline{P_1}$ = Mean of first parent
- $\overline{P_2}$ = Mean of second parent

ANGRAU Central Library
Hyderabad
D6844
1 2000000 2000 2000 2000 2000 2000

The significance of heterotic effects were tested against standard errors using t test as suggested by Wynne *et al.* (1970).

3.5 COMBINING ABILITY ANALYSIS :

3.5.1 Analysis of variance :

The individual plant data within plot were averaged to obtain replication means. These mean values were used in the statistical and genetical analysis. The analysis of variance (ANOVA) was performed for all the plant characters as suggested by Panse and Sukhatme (1961) to detect the differences among the parents and hybrids. The ANOVA form is presented in Table 3.2.

Table 3.2 : Analysis of variance

Source	DF	MSS	F test
Replications	(r-1)		
Parents	(p-1)	M4	M4/M1
Crosses	(st-1)	M3	M3/M1
Parents vs crosses	(C1)	M2	M2/M1
Error	(r-1) (st + p-1)	M1	

Where,

r	=	replications	p = s + t
s	=	lines	MSS = mean sum of squares
t	=	testers	DF = degrees of freedom

The significance test was carried by referring to the 'F' table.

3.5.2 Combining ability analysis :

The plot mean values of only F_1 hybrids were used for combining ability analysis. Following the methodology described by Kempthorne (1957), the general and specific (gca and sca) combining ability effects and variances were estimated. The analysis of variance for combining ability is given in Table 3.3. This is based on the following linear model :

$$Y_{ijk} = m + g_i + g_j + s_{ij} + r_k + e_{ijk}$$

Where,

Y_{ijk}	=	observation on the ij^{th} cross in the k^{th} replication
m	=	general mean
g_i	=	gca effect of i^{th} line
g_j	=	gca effect of j^{th} tester
s_{ij}	=	sca effect of ij^{th} cross
r_k	=	effect of k^{th} replicate
e_{ijk}	=	error associated with ijk^{th} observation

Table 3.3 : ANOVA of line x tester making design for combining ability

Source	DF	MS	Expected MSS
Replications	(r-1)	-	-
Lines	(s-1)	M4	$\sigma^2 + rs\sigma^2 + rt\sigma_l^2$
Testers	(t-1)	M3	$\sigma^2 + rs\sigma^2 + rs\sigma_m^2$
Lines x Testers	(s-1) (t-1)	M2	$\sigma^2 + r\sigma_l^2$
Error	(r-1) (st-1)	M1	σ^2

i. Estimation of combining ability effects and standard errors

a. GCA effect of line and tester

$$\begin{array}{llll} \text{line} & g_i & = & \frac{X_{i...}}{tr} - \frac{X_{...}}{str} \\ \text{Tester} & g_j & = & \frac{X_{.j}}{sr} - \frac{X_{...}}{str} \end{array}$$

b. SCA effect of cross

$$s_{ij} = \frac{X_{ij}}{tr} - \frac{X_{i...}}{str} - \frac{X_{.j}}{sr} + \frac{X_{...}}{stv}$$

ii. Standard errors of estimates

$$\text{S.E. } (g_i) = \frac{M_t}{rt}$$

$$\text{S.E. } (g_j) = \frac{M_l}{rs}$$

$$\text{S.E. (sij)} = \frac{M_1}{r}$$

where,

$X_{...}$ = Grand total

$X_{i...}$ = Total of i^{th} line over replicates and testers

$X_{.j.}$ = Total j^{th} tester over replicates and lines

X_{ij} = Total of ij^{th} cross over replicates

iii. Estimates of genetic component of variation :

The estimates of variance components were obtained from the algebraic manipulation of mean squares in the ANOVA as follow.

Since $\sigma_p^2 = \sigma_m^2$ in the absence of maternal effects, the line and tester mean squares were pooled as :

Pooled mean squares of line and testers (Mo)

$$\text{a. } M_0 = \frac{(s - 1) M_4 + (t - 1) M_3}{s + t - 2}$$

$$\text{b. } \sigma_g^2 = \sigma_m^2 = \frac{(M_0 - M_1) M_4 + (s + t - 2)}{r (t (s - 1) + s (t - 1))}$$

$$\text{c. } \sigma_s^2 = \frac{(M_3 - M_4)}{r}$$

The genetic components of variation were estimated by relating the variance components to covariance of half sibs (cov. HS) and full sibs (Cov. FS) as

$$\text{i. } \sigma_g^2 = \sigma_m^2 - \text{Cov. HS}$$

$$\text{ii. } \sigma_s^2 = \text{Cov. F.S} - 2 \text{ Cov. HS}$$

$$\text{iii. } \sigma_{gca}^2 = \text{Cov. HS} = \frac{1}{2} \sigma_d^2$$

$$\text{iv. } \sigma_{sca}^2 = \text{Cov. FS} - 2 \text{ Cov. HS} = \sigma_p^2$$

where,

$$\sigma_{gca}^2 = \text{general combining ability variance}$$

$$\sigma_{sca}^2 = \text{specific combining ability variance}$$

3.6 TRIPLE TEST CROSS :

The following four hybrid combinations were chosen based on the parental diversity (Jinks and Perkins, 1970) and F_1 performance in which all the four testers were involved.

1. LGG - 410 x LGG - 407
2. LGG - 460 x WGG - 2
3. PUSA - 9672 x LGG - 440
4. Local x TARM-21

The parents, F_1 s and F_2 s of the above hybrid combinations were raised at ARS, Nellore during *Kharif* 2000-2001 to effect triple test crosses. Twenty plants were randomly chosen from each of the F_2 of the four combinations and were back crossed as males with their respective three testers p_1 , p_2 and F_1 ($P_1 \times P_2$) to obtain L_{1i} , L_{2i} , L_{3i} families respectively.

Sixty families L_1 (20) + L_2 (20) + L_3 (20) obtained from each cross were raised in a completely randomised block design with three replications, during *rabi* 2000-2001 at ARS, Nellore under rice fallow situation. From each family in each replication five random plants were selected for recording the following observations. Data analysis was based on 180 values, each being the mean of five plants.

1. Days to 50% flowering
2. Days to maturity
3. Plant height (cm)
4. Pods per plant
5. Seeds per pod

6. 100 Seed weight (gm)
7. Shoot dry weight (gm)
8. Seed yield per plant (gm)

3.6.1 Statistical analysis :

To detect the epistasis and to test the estimates of additive and dominant components of genetic variance, the method prescribed by Jinks and Perkins (1970) was applied.

3.6.2 Test for epistasis :

For the test of epistasis, 20 values of $L_{1i} + L_{2i} - 2L_{3i}$, for $i = 1$ to 20 were obtained for each of the three replications. After summing over replications, the sum of twenty squared deviations of $L_{1i} + L_{2i} - 2L_{3i}$ from zero for 20 degree of freedom, that is sum of squares due to epistasis, was obtained. Sum of squares due to replicate error, that is the error for testing the significance of epistasis, was obtained for 40 degree of freedom.

The epistasis sum of squares for 20 degree of freedom could be partitioned into an item for one degree of freedom, testing for 'i' type of epistasis (homozygote x homozygote interaction) and an item for 19 degrees of freedom testing 'j' and 'l' type of epistasis (homozygote x heterozygote and heterozygote x heterozygote interactions respectively).

Similarly, the sum of squares due to replicate error for 40 degrees of freedom could be sub divided into two items namely replications and epistasis x replications, for 2 and 38 degree of freedom.

b. Test and estimations of additive and dominance component :

Additive and dominance components were estimated assuming no epistasis. The twenty sums of means of the families yield a variance of sums for 19 degrees of freedom. Similarly, the variance of differences was obtained further for 19 degrees of freedom. Variance of sums x replicates and differences x replicates were obtained each for 38 degrees of freedom.

ANOVA for $L_1 + L_2 + L_3$ totals

Source	df	EMS
Replications	(r-1)	-
Lines (sums)	(n-1)	$\sigma^2 + 3r \sigma_s^2$
Error	(n-1) (r-1)	σ^2

$$^2S = (1 / 8)^D$$

$$\text{Additive component (D)} = 8 (\sigma_s^2)$$

ANOVA for $L_1 - L_2$ totals

Source	df	EMS
Replications	(r-1)	-
Lines (sums)	(n-1)	$\sigma^2 + 2r \sigma_d^2$
Error	(n-1) (r-1)	σ^2

$$\sigma_d^2 = (1 / 8) H$$

$$\text{Dominance component (H)} = 8 (\sigma_d^2)$$

c. **Degree of dominance** = $(H / D)^{1/2}$

d. **Direct of dominance and types of gene exhibiting dominance :**

It can be detected by obtaining correlation coefficients between sums and differences estimated above.

Correlation coefficient 'r'

$$r = (\Sigma xy - (\Sigma x \Sigma y) / n) / \{ (\Sigma x^2 - \frac{(\Sigma x)^2}{n}) \cdot \Sigma y^2 - \frac{(\Sigma y)^2}{n} \}^{1/2}$$

x = Sums

y = Differences

n = Number of observations

3.7 CHARACTER ASSOCIATION :

Phenotypic and genotypic correlation co-efficients were calculated using the method given by Johnson *et al.*, (1955).

3.7.1 Phenotypic correlation co-efficients :

$$r_p(xy) = \frac{Cov_p(xy)}{\sqrt{\sigma_p^2(x) \cdot \sigma_p^2(y)}}$$

where,

$r_p(xy)$ = Phenotypic correlation between X and Y

$Cov_p(xy)$ = Phenotypic Covariance between characters X and Y

$\sigma_p^2(x)$ = Phenotypic variance of x

$\sigma_p^2(y)$ = Phenotypic variance of y

3.7.2 Genotypic correlation co-efficients :

$$r_g(xy) = \frac{Cov_g(xy)}{\sqrt{\sigma_g^2(x) \cdot \sigma_g^2(y)}}$$

where,

$r_g(xy)$ = Genotypic correlation between X and Y

$Cov_g(xy)$ = Genotypic Covariance between characters X and Y

$\sigma_g^2(x)$ = Genotypic variance of x

$\sigma_g^2(y)$ = Genotypic variance of y

3.8 PATH CO-EFFICIENT ANALYSIS :

Path coefficient analysis was carried out by using phenotypic and genotypic correlations co-efficients to know the direct and indirect effects of yield components on yield as suggested by Wright (1921) and as illustrated by Dewey and Lu (1959).

The path co-efficients were obtained by solving the 'p' normal equation following the matrix method given by Singh and Choudhary (1985).

Correlations among all the variables were utilized to get up the simultaneous equations.

$$\begin{aligned} r_{1y} &= P_{1r} + r_{12}P_{2y} + r_{13}P_{3y} + \dots + r_{1k} P_{ky} \\ r_{2y} &= r_{21}P_{1y} + P_{2y} + r_{23}P_{3y} + \dots + r_{2k} P_{ky} \\ &\cdot \\ &\cdot \\ r_{ky} &= r_{k1}P_{1y} + r_{k2} P_{2y} + r_{k3}P_{3y} + \dots + P_{ky} \end{aligned}$$

Where,

$r_{1y}, r_{2y} \dots \dots r_{ky}$ are the correlation of co-efficients of independent variable

$x_1, x_2 \dots \dots x_k$ with the dependent variable Y.

$r_{12}, r_{13} \dots \dots r_{k-1}, k$ are the co-efficients of correlation between the independent variable.

$P_{1y}, P_{2y} \dots \dots p_{ky}$ are the direct effect of the variables $x_1, x_2 \dots \dots x_k$ and y.

The above equations were written in matrix form as under

$$\begin{matrix} \text{A} \\ \left[\begin{array}{c} r_{1y} \\ r_{2y} \\ \cdot \\ \cdot \\ r_{ky} \end{array} \right] \end{matrix} = \begin{matrix} \text{C} \\ \left[\begin{array}{cccccc} 1 & r_{12} & r_{13} & \cdot & \cdot & \cdot & r_{1k} \\ r_{21} & 1 & r_{23} & \cdot & \cdot & \cdot & r_{2k} \\ \cdot & \cdot & \cdot & & & & \cdot \\ \cdot & \cdot & \cdot & & & & \cdot \\ \cdot & \cdot & \cdot & & & & \cdot \\ r_{k1} & r_{k2} & r_{k3} & \cdot & \cdot & \cdot & 1 \end{array} \right] \end{matrix} \begin{matrix} \text{B} \\ \left[\begin{array}{c} P_{1y} \\ P_{2y} \\ \cdot \\ \cdot \\ P_{ky} \end{array} \right] \end{matrix}$$

Then $B = [C]^{-1}A$

Where

$$[C] = \begin{bmatrix} C_{11} & C_{12} & C_{13} & \cdot & \cdot & \cdot & C_{1k} \\ C_{21} & C_{22} & C_{23} & \cdot & \cdot & \cdot & C_{2k} \\ \cdot & & & & & & \\ \cdot & & & & & & \\ C_{k1} & C_{k2} & C_{k3} & \cdot & \cdot & \cdot & C_{kk} \end{bmatrix}$$

Then, direct effects were calculated as follows :

$$P_{1Y} = \sum_{i=1}^k C_{1i} r_{iy}$$

$$P_{2Y} = \sum_{i=1}^k C_{2i} r_{iy}$$

$$P_{iY} = \sum_{i=1}^k C_{ki} r_{iy}$$

Chapter IV

Results

CHAPTER - IV

4. RESULTS

4.1 GENETIC VARIABILITY :

Five lines and four testers along with twenty hybrids were evaluated during late *rabi* 1999-2000 under late rice fallows at the Agricultural Research Station, Nellore, Andhra Pradesh. Biometrical data were recorded on ten characters viz., days to flowering, days to maturity, plant height (cm.), pods per plant, seeds per pod, 100 seed weight (g), shoot nitrogen (%), seed protein (%), shoot dry matter (g) and seed yield per plant (g). Mean values were subjected to statistical analysis in a line x tester model. Statistical analysis revealed existence of significant differences among the genotypes for all the characters studied (Table 4.1). The variance among the genotypes was further partitioned into parents, hybrids, lines, testers and line x testers for evaluation and estimation of interactions.

The mean, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability in broad sense (h^2) and genetic advance expressed as percentage of mean (GAM) are presented in Table 4.2 and 4.3 and are described here under.

Table 4.1 : Mean sum of squares and ANOVA for different characters studied in greengram

Source	DF	Days to 50% flowering	Days to Maturity	Plant height	Pods / plant	100-Seed weight	Shoot N %	Seed protein %	Shoot dry weight	Seed yield / plant (g)
Replications	2	0.14	7.81	62.25*	0.66	0.07	0.01	0.02	93.57*	1.80
Parents	8	29.29**	138.01**	353.08**	43.27**	0.57**	0.35**	7.61**	89.65**	8.03**
Lines	4	52.23**	164.43**	588.13**	53.28**	0.42**	0.15**	17.12**	145.74**	10.22**
Testers	3	6.31	51.00**	134.82**	43.31**	0.69**	0.55**	22.98**	4.34	7.77**
Lines x Testers	1	6.45	293.34**	79.64**	0.08	0.83**	0.56**	3.45**	121.20**	0.06
Grosses	19	103.79**	107.88**	349.08**	165.43**	1.31**	0.20**	20.59**	911.56**	122.99**
Parents vs Crosses	1	0.035	487.86**	489.15**	20.92**	0.62**	0.10**	0.17*	1200.38**	161.25**
Error	56	3.38	7.99	7.93	9.93	0.03	0.05	0.42	24.15	2.37

4.1.1 Days to flowering :

Days to flowering ranged from 32 days (LGG-460) to 43 days (Local) among the parents and in hybrids it ranged from 26 days (Local x WGG-2) to 44 days (MGG-341 x WGG-2). Moderate estimates of PCV (14.41) and GCV (13.53), high heritability (88%) with moderate genetic advance (26.2) were observed for this trait.

4.1.2 Days to maturity :

In parents, days to maturity ranged from 64 days (LGG-460) to 82 days (Local and LGG-440). While in hybrids, days to maturity ranged from 72 days (LGG-460 x LGG-440) to 90 days (LGG-410 x LGG-407). Low GCV (8.18) and PCV (8.94), high heritability (84) and low genetic advance (15.40) as percent over mean were observed for this trait.

4.1.3 Plant height (cm) :

The plant height ranged from 40.17 cm (LGG-460 and MGG-341) to 74.26 cm (Local) among the parents and it ranged from 26.67 cm (Local x WGG-2) to 62.00 cm (LGG-460 x LGG-407) in hybrids. High GCV (23.38) and PCV (24.16) coupled with high heritability (93) and moderate genetic advance as percent over mean (46.58) were observed for this trait.

Table 4.2 : Mean values for different traits in parents and crosses

S. No.	Parent / Crosses	Code No.	Days to flowering	Days to maturity	Plant height (cm)	Pods per plant	Seeds per pod	100 seed weight (g)	Shoot nitrogen (%)	Seed protein (%)	Shoot dry weight (g)	Yield / plant (g)
<u>LINES</u>												
1	LGG-410	L1	34	66	51.92	24.86	9.49	4.48	2.46	23.24	27.84	12.30
2	LGG-460	L2	32	64	40.17	26.89	9.80	4.46	2.58	24.51	23.76	12.40
3	MGG-341	L3	36	70	40.17	22.28	8.74	4.42	2.34	22.64	27.83	9.28
4	PUSA-9672	L4	38	76	49.00	17.58	8.07	4.43	2.08	21.37	26.61	8.23
5	LOCAL	L5	43	82	74.26	28.21	6.20	3.63	2.07	18.23	41.65	10.12
<u>TESTERS</u>												
6	LGG-407	T1	37	80	43.90	27.57	9.38	4.02	3.06	24.71	24.10	12.57
7	WGG-2	T2	36	72	42.00	24.17	8.03	3.95	2.71	21.93	24.38	8.70
8	TARM-21	T3	39	78	57.08	18.57	7.37	4.45	2.03	20.34	26.37	10.13
9	LGG-440	T4	38	82	47.61	25.17	8.76	3.29	2.58	18.14	26.25	10.08
<u>CROSSES</u>												
1	LGG-410 x LGG-407	C1	41	90	50.17	36.45	11.13	4.84	2.55	25.24	57.67	21.38
2	LGG-410 x WGG-2	C2	35	77	43.67	13.19	9.70	4.49	3.24	20.79	21.20	6.53
3	LGG-410 x TARM-21	C3	37	79	39.00	22.44	8.70	4.20	2.75	22.24	28.73	7.48
4	LGG-410 x LGG-440	C4	27	65	35.00	16.85	9.30	3.37	2.56	20.45	29.33	6.98
5	LGG-460 x LGG-407	C5	40	82	62.00	34.47	11.27	4.57	2.73	24.48	65.40	23.18
6	LGG-460 x WGG-2	C6	39	82	52.67	27.91	10.20	4.58	2.51	21.59	49.57	16.39
7	LGG-460 x TARM-21	C7	41	84	30.00	19.13	9.08	4.12	2.66	23.01	20.63	7.46
8	LGG-460 x LGG-440	C8	32	72	35.03	16.16	10.31	3.42	2.38	18.20	18.80	7.45
9	MGG-341 x LGG-407	C9	42	82	54.33	27.44	13.45	4.63	2.40	25.08	54.92	24.50
10	MGG-341 x WGG-2	C10	44	86	46.17	22.17	10.85	4.17	2.57	21.11	23.96	11.11
11	MGG-341 x TARM-21	C11	35	76	43.00	26.42	9.37	4.91	2.49	22.14	20.17	8.90

Table 4.2 Contd...

S. No.	Parent / Crosses	Code No.	Days to flowering	Days to maturity	Plant height (cm)	Pods per plant	Seeds per pod	100 seed weight (g)	Shoot nitrogen (%)	Seed protein (%)	Shoot dry weight (g)	Yield / plant (g)
12.	MGG-341 x LGG-440	C12	29	74	38.33	22.44	9.47	3.72	2.41	19.11	19.48	9.00
13.	PUSA-9672 x LGG-407	C13	43	85	57.00	34.57	11.14	4.77	2.37	24.93	58.04	18.40
14.	PUSA-9672 x WGG-2	C14	43	86	61.33	34.33	9.31	5.10	2.25	21.84	64.55	21.73
15.	PUSA-9672 x TARM-21	C15	42	83	54.00	32.23	9.21	5.68	2.18	21.54	53.08	18.75
16.	PUSA-9672 x LGG-440	C16	42	85	45.67	30.57	7.78	4.62	2.08	18.81	35.45	19.75
17.	LOCAL x LGG-407	C17	40	80	50.67	24.60	9.56	5.12	2.73	24.57	31.67	13.10
18.	LOCAL x WGG-2	C18	26	74	26.67	12.57	9.00	3.20	2.64	22.72	17.59	8.00
19.	LOCAL x TARM-21	C19	36	76	35.33	23.48	9.33	4.15	2.41	17.69	24.54	11.27
20.	Local x LGG-440	C20	27	74	28.33	17.19	7.53	3.38	2.22	16.14	18.67	6.88
	Mean		37	78	46.03	24.55	9.29	4.25	2.48	21.61	33.18	12.45
	SEd		1.06	3.81	1.63	2.57	0.39	0.10	0.04	0.37	4.01	1.26
	CV%		4.96	8.55	6.12	12.84	5.19	4.22	2.69	3.00	14.81	12.35

4.1.4 Pods per plant :

Numbers of pods per plant ranged from 17.58 (Pusa-9672) to 28.21 (Local) in parents and it ranged from 12.57 (Local x WGG-2) to 36.45 (LGG-410 x LGG-407) in hybrids. High GCV (25.23) and PCV (28.31) and high heritability (79) coupled with moderate genetic advance as percent over mean (46.31) were estimated for this trait.

4.1.5 Seeds per pod :

Among the parents, number of seeds per pod ranged from 6.20 (Local) to 9.80 (LGG-460) and among the hybrids it ranged from 7.53 (Local x LGG-440) to 11.27 (LGG-460 x LGG-407). The GCV (13.0) and PCV (14.00) were found to be low with high heritability (86), and low genetic advance as per cent over mean (24.87) for this trait.

4.1.6 100 - seed weight (g) :

This trait ranged from 3.63 (Local) to 4.48 (LGG-410) among the parents while, in hybrids it ranged from 3.20 (Local x WGG-2) to 5.68 (Pusa-9672 x TARM-21). The estimates of GCV and PCV were moderate (13.87 and 14.50) with high heritability (94) and moderate genetic advance as percent over mean (27.29).

4.1.7 Shoot nitrogen content (%) :

The shoot nitrogen content ranged from 2.07 (Local) to 3.06 (LGG-407) in the parents and from 2.08 (Pusa-9672 x LGG-440) to 3.24 (LGG-410 x WGG-2) in hybrids. Low GCV (11.27) and PCV (11.59) with high heritability (94) and low genetic advance (22.58) were estimated for this trait.

4.1.8 Seed protein (%) :

Parents exhibited a range of 18.14 (LGG-440) to 24.51 (LGG-460) for seed protein content, while in hybrids it ranged from 16.14 (Local x LGG-440) to 25.24 (LGG-410 x LGG-407). Low estimates of GCV (11.52) and PCV (11.90) and high heritability (93) with low genetic advance as percent over mean (22.95) were observed for this trait.

4.1.9 Shoot dry weight (g) :

This trait has exhibited a wide range of variation from 23.76 (LGG-460) to 41.65 (Local) in parents and in hybrids from 17.59 (Local x WGG-2) to 65.40 (LGG-460 x LGG -407). High estimates of GCV (44.80) and PCV (42.18) and high heritability (90) coupled with high genetic advance as percent over mean (87.61) were recorded for this trait.

Table 4.3 : Variability, Heritability and genetic advance for yield and yield component characters in greengram

S.No.	Character	Mean	GCV	PCV	h^2	GA	GAM
1.	Days to flowering	37.07	13.53	14.41	88	9.70	26.22
2.	Days to maturity	78.01	8.18	8.94	84	12.01	15.40
3.	Plant height (cm)	46.04	23.38	24.16	93	21.44	46.58
4.	Pods per plant	24.55	25.23	28.31	79	11.37	46.31
5.	Seeds per pod	9.29	13.00	14.00	86	2.31	24.87
6.	100 seed weight (g)	4.25	13.87	14.50	94	1.16	27.29
7.	Shoot nitrogen (%)	2.48	11.27	11.59	94	0.56	22.58
8.	Seed protein (%)	21.61	11.52	11.90	93	4.96	22.95
9.	Shoot dry matter per plant (g)	33.18	44.80	47.18	90	29.07	87.61
10.	Seed yield per plant (g)	12.45	43.77	45.48	93	10.81	86.82

GCV = Genotypic coefficient of variation

PCV = Phenotypic coefficient of variation

h^2 = Heritability in broad sense

GA = Genetic advance

GAM = Genetic advance as percent over mean

4.1.10 Seed yield / plant (g) :

Seed yield per plant ranged from 8.23 (Pusa-9672) to 12.57 (LGG-407) among the parents. While, in hybrids it ranged from 6.98 (LGG-410 x LGG-440) to 24.50 (MGG-341 x LGG-407). The estimates of GCV (43.77) and PCV (45.48) were found to be high with high heritability (93) coupled with high genetic advance (86.82).

4.2 HETEROSIS AND COMBINING ABILITY STUDIES :

Twenty cross combinations were made in a line x tester design utilizing five lines viz., LGG-410, LGG-460, MGG-341, Pusa-9672 and Local and four testers viz., LGG-407, WGG-2, TARM-21 and LGG-440 during *Kharif* 1999. The F_1 generation of 20 crosses along with their parents were studied to understand the nature of gene action for yield and yield component traits of greengram through combining ability analysis during *rabi* 1999-2000 under rice fallow situation.

Data were collected on days to flowering, days to maturity, plant height (cm), pods per plant, seeds per pod, 100 seed weight (gm), shoot nitrogen (%), seed protein (%), dry matter per plant (g) and seed yield per plant (g).

4.2.1 Heterosis :

Analysis of variance revealed significant differences among the parents and crosses for all the characters studied. Significant differences were also observed due to parents versus crosses for all the characters studied. Heterosis was calculated over mid parent and better parent is furnished in Table 4.4 and are described here under.

4.2.1.1 Days to 50% flowering :

The average heterosis was 0.44 percent over mid parent and -2.22 percent over better parent for this trait. It ranged from -33.62 (LOCAL x WGG-2) to 23.72 (MGG-341 x WGG-2) and -39.06 (LOCAL x WGG-2) to 23.15 (MGG-341 x WGG-2) percent over mid and better parent, respectively. Heterosis was found to be negative and significant in desired direction in crosses LGG-410 x TARM-21 (-5.13**), LGG-410 x LGG-440 (-29.57**), LGG-460 x LGG-440 (-15.65**), MGG-341 x TARM-21 (-10.26**), MGG-341 x LGG-440 (-24.34**), LOCAL x LGG-407 (-6.25**), LOCAL x WGG-2 (-39.06**), LOCAL x TARM-21 (-15.63**) and LOCAL x LGG-440 (-35.94**) over better parent and the crosses LGG-410 x LGG-440 (-25.69**), LGG-460 x LGG-440 (-7.62**), MGG-341 x TARM-21 (-6.67**), MGG-341 x LGG-440 (-21.97**), LOCAL x WGG-2 (-33.62**), LOCAL x TARM-21 (-11.84**) and LOCAL x LGG-440 (-32.51**) over mid parent.

Table 4.4 : Estimates of heterosis (%) over mid parent (MP) and better parent (BP)

S. No.	Cross	Character code	Days to 50% flowering		Days to maturity		Plant height	
			MP	BP	MP	BP	MP	BP
1	LGG-410 x LGG-407	C1	15.35**	10.71**	23.74**	12.45**	4.70**	-3.38
2	LGG-410 x WGG-2	C2	0.95	-0.93	12.08**	6.91**	-7.02**	-15.90**
3	LGG-410 x TARM-21	C3	0.91	-5.13**	9.26**	0.43	-28.44**	-31.67**
4	LGG-410 x LGG-440	C4	-25.69**	-29.57**	-11.76**	-20.41**	-29.67**	-32.59**
5	LGG-460 x LGG-407	C5	15.94**	7.14**	13.16**	1.66	48.28**	41.98**
6	LGG-460 x WGG-2	C6	15.84**	9.35**	19.80**	12.90**	28.18**	25.40**
7	LGG-460 x TARM-21	C7	15.09**	4.27**	17.36**	6.81**	-38.30**	-47.44**
8	LGG-460 x LGG-440	C8	-7.62**	-15.65**	-0.69	-11.43**	-20.19**	-26.42**
9	MGG-341 x LGG-407	C9	13.64**	11.61**	9.53**	2.49	29.25**	23.76**
10	MGG-341 x WGG-2	C10	23.72**	23.15**	20.37**	18.43**	12.77**	10.32**
11	MGG-341 x TARM-21	C11	-6.67**	-10.26**	2.92	-2.55**	-11.57**	-24.66**
12	MGG-341 x LGG-440	C12	-21.97**	-24.34**	-2.86	-9.80**	-12.66**	-19.49**
13	PUSA-9672 x LGG-407	C13	14.54**	13.04**	8.51**	5.81*	22.71**	16.53**
14	PUSA-9672 x WGG-2	C14	16.22**	12.17**	15.25**	12.23**	24.50**	25.17**
15	PUSA-9672 x TARM-21	C15	7.76**	6.84**	6.90**	5.53**	1.81	-5.30*
16	PUSA-9672 x LGG-440	C16	8.70**	8.70**	8.02**	4.49**	-5.47**	-6.80**
17	LOCAL x LGG-407	C17	0.00	-6.25**	-0.82*	-1.63	-14.24**	-31.77**
18	LOCAL x WGG-2	C18	-33.62**	-39.06**	-3.90*	-9.39**	-54.12**	-64.09**
19	LOCAL x TARM-21	C19	-11.84**	-15.63**	-5.00**	-6.84**	-46.19**	-52.42**
20	Local x LGG-440	C20	-32.51**	-35.94**	-8.98**	-8.98**	-55.53**	-61.84**
S.E.			1.36	1.50	1.99	2.31	4.99	2.29
Range			-33.62 to 23.77	-39.06 to 9.35	-11.76 to 19.80	-20.41 to 18.43	-54.12 to 48.28	-64.09 to 41.98
Average			9.44	2.22	10.67	6.95	6.17	11.04

Table 4.4 Contd..

S. No.	Cross	Character code	Shoot nitrogen (%)		Seeds protein (%)		Shoot dry weight (g)		Yield / plant (g)	
			MP	BP	MP	BP	MP	BP	MP	BP
1.	LGG-410 x LGG-407	C1	7.49**	-16.47**	5.29**	2.14**	122.05**	139.28**	71.89**	70.04**
2.	LGG-410 x WGG-2	C2	25.18**	19.41**	-7.93**	-10.51**	-18.80**	-13.03**	-37.83**	-46.92**
3.	LGG-410 x TARM-21	C3	28.64**	11.77**	2.10**	-4.27**	6.01	3.21	-33.34**	-39.23**
4.	LGG-410 x LGG-440	C4	1.59**	-0.77	-1.13*	-11.98**	8.45*	5.26	-37.63**	-43.27**
5.	LGG-460 x LGG-407	C5	-2.96**	-10.58**	-0.53	-0.94	173.28**	171.37**	85.64**	84.33**
6.	LGG-460 x WGG-2	C6	-5.23**	-7.62**	-7.03**	-11.93**	105.93**	103.34**	55.36**	32.21**
7.	LGG-460 x TARM-21	C7	15.71**	3.36**	2.60**	-6.13*	-17.68**	-21.74**	-33.74**	-39.80**
8.	LGG-460 x LGG-440	C8	-7.88**	-7.76**	-14.65**	-25.74**	-24.83**	-28.39**	-33.71**	-19.90**
9.	MGG-341 x LGG-407	C9	-10.93**	-21.37**	5.93**	1.48**	111.53**	97.36**	124.19**	94.83**
10.	MGG-341 x WGG-2	C10	1.85**	-5.16**	-5.29**	-3.75**	-8.19**	-1.76**	23.52**	19.68**
11.	MGG-341 x TARM-21	C11	13.89**	6.37**	3.03**	-2.21**	-25.62**	-23.57**	-17.57**	-21.03**
12.	MGG-341 x LGG-440	C12	-2.10**	-0.71**	-0.29**	-15.61**	-27.95**	-15.76**	-7.02**	-10.71**
13.	PUSA-9672 x LGG-407	C13	-7.85**	-22.57**	8.20**	0.89	128.91**	118.10**	76.89**	46.34**
14.	PUSA-9672 x WGG-2	C14	-6.12**	-17.08**	0.85	-0.43	153.17**	142.54**	156.69**	140.71**
15.	PUSA-9672 x TARM-21	C15	6.01**	4.65**	3.30**	0.80*	100.39**	99.46**	104.21**	85.06**
16.	PUSA-9672 x LGG-440	C16	-10.94**	-19.61**	-4.77**	-11.98**	34.10**	33.19**	115.77**	93.97**
17.	LOCAL x LGG-407	C17	6.63**	-10.58**	14.41**	-0.59	-3.66	-23.96**	15.45**	4.19**
18.	LOCAL x WGG-2	C18	10.38**	-3.76**	13.15**	3.62**	-46.73**	-57.77**	-15.00*	-8.08**
19.	LOCAL x TARM-21	C19	17.66**	16.43**	-8.29**	-13.00**	-27.83**	-41.07**	11.34**	11.29**
20.	Local x LGG-440	C20	-4.73**	-14.19**	-11.23**	-11.46**	-45.02**	-55.18**	-31.88**	-31.75**
S.E.			0.047	0.054	0.46	0.53	3.48	4.01	1.09	1.26
Range			-10.94 to 25.18	-22.57 to 19.41	14.65 to 14.41	-25.74 to 3.62	-46.73 to 173.28	-57.77 to 171.37	-37.83 to 156.69	-46.92 to 149.71
Average			7.77	-3.87	-0.43	-6.25	34.88	3.11	29.96	26.77

Table 4.4 Contd.

S. No.	Cross	Character code	Pods / plant		Seeds / pod		100 seed weight (g)	
			MP	BP	MP	BP	MP	BP
1	LGG-410 x LGG-407	C1	39.10**	32.47**	18.02**	17.32**	13.76**	7.96**
2	LGG-410 x WGG-2	C2	47.19**	47.38**	10.73**	2.21**	6.49**	0.15
3	LGG-410 x TARM-21	C3	3.28	-9.83**	3.18**	-8.32**	-6.04**	-6.32**
4	LGG-410 x LGG-440	C4	-32.67**	-32.89**	1.94**	-2.00**	-13.26**	-24.78**
5	LGG-460 x LGG-407	C5	26.71**	25.27**	17.50**	14.97**	7.70**	2.47**
6	LGG-460 x WGG-2	C6	7.42**	3.78	14.41	4.08**	9.08**	2.84**
7	LGG-460 x TARM-21	C7	-15.82**	-28.85**	5.71**	-7.38**	-7.44**	-7.48**
8	LGG-460 x LGG-440	C8	-37.93**	-35.81**	-17.08**	5.17**	-11.62**	-23.10**
9	MGG-341 x LGG-407	C9	8.61**	21.36**	26.38**	22.11**	9.63**	1.67**
10	MGG-341 x WGG-2	C10	0.06	-5.51**	36.57**	24.20**	-9.44**	-5.80**
11	MGG-341 x TARM-21	C11	29.42**	-18.64**	16.24**	7.13**	-9.58**	-9.88**
12	MGG-341 x LGG-440	C12	-5.42**	-10.85**	8.19**	8.11**	-3.40**	-15.83**
13	PUSA-9672 x LGG-407	C13	53.53**	23.64**	27.76**	18.81**	12.89**	7.67**
14	PUSA-9672 x WGG-2	C14	61.01**	36.97**	15.61**	15.32**	21.72**	15.04**
15	PUSA-9672 x TARM-21	C15	78.33**	73.58**	19.23**	14.09**	27.91**	27.64**
16	PUSA-9672 x LGG-440	C16	43.00**	21.44**	7.57**	-3.63**	19.64**	4.27**
17	LOCAL x LGG-407	C17	-11.71**	-12.80**	22.75**	1.96**	33.14**	27.17**
18	LOCAL x WGG-2	C18	-52.82**	-49.87**	-26.49**	12.08**	-15.29**	-18.83**
19	LOCAL x TARM-21	C19	03.7	-16.78**	37.52**	26.58**	2.93**	-6.74**
20	Local x LGG-440	C20	-35.61**	-39.08**	0.74**	-13.97**	-2.32**	-6.54**
S.E.			2.23	2.57	0.34	0.46	0.13	0.13
Range			47.19 to 78.33	-49.87 to -73.58	7.57 to 19.23	12.08 to 26.58	-15.29 to 33.14	-18.83 to -6.54
Average			53.7	1.34	17.7	19.4	13.8	1.27

4.2.1.2 Days to maturity :

The mean heterosis for days to maturity was 6.65 and 0.95 per cent over mid and better parents, respectively. While it ranged from -11.76 (LGG-410 x LGG-440) to 23.74 LGG-410 x LGG-407 percent over mid parent and from -20.41 (LGG-410 x LGG-440) to 12.90 (LGG-460 x WGG-2) percent over better parent. Significant and negative heterosis in the desired direction over mid parent was observed in crosses LGG-410 x LGG-440 (-11.76**), LOCAL x WGG-2 (-3.90**), LOCAL x TARM-21 (-5.00**) and LOCAL x LGG-440 (-8.98**). Whereas, similar trend was observed in crosses LGG-410 x LGG-440 (-20.41**), LGG-460 x LGG-440 (-11.43**), MGG-341 x TARM-21 (-2.55**), MGG-341 x LGG-440 (-9.80**), LOCAL x WGG-2 (-9.39**) LOCAL x TARM-21 (-6.94**) and LOCAL x LGG-440 (-8.98**) over better parent.

4.2.1.3 Plant height (cm)

The average heterosis for plant height was -6.67 and -14.05 over mid and better parents, respectively. Heterosis percent for this trait ranged from -54.12** (LOCAL x WGG-2) to 48.28** (LGG-460 x LGG-407) and from -64.08** (LOCAL x WGG-2) to 41.98** (LGG-460 x LGG-407) over mid and better parents, respectively. Positive and significant heterosis was observed over both mid and better parents, respectively in the crosses LGG-460 x LGG-407 (48.28** and 41.98**), LGG-460 x WGG-2 (28.18** and 25.40**),

MGG-341 x LGG-407 (29.25** and 23.76**), MGG-341 x WGG-2 (12.77** and 10.32**), Pusa-9672 x LGG-407 (22.71** and 16.53*), Pusa-9672 x WGG-2 (24.50** and 25.17**). Whereas, the negative significant heterosis was observed over both mid and better parent, respectively in the cross LGG-410 x WGG-2 (-7.02** and -15.9**), LGG-410 x TARM-21 (-28.44** and -31.67**), LGG-410 x LGG-440 (-29.67** and -32.95**), LGG-460 x TARM-21 (-38.30** and -47.44**), LGG-460 x LGG-440 (-20.19** and -26.42**), MGG-341 x TARM-21 (-11.57** and -24.66**), MGG-341 x LGG-440 (-12.66** and -19.49**), Pusa-9672 x LGG-440 (-5.47** and -6.80*), LOCAL x LGG-407 (-14.24** and -31.77**), LOCAL x WGG-2 (-54.12** and -64.08**), LOCAL x TARM-21 (-4.19** and -52.42**) and LOCAL x LGG-440 (-53.50** and -61.84**).

4.2.1.4 Pods per plant :

The average heterosis for pods per plant was 5.57 and 1.50 per cent over mid and better parent, respectively. Heterosis percentage ranged from -52.82 (LOCAL x WGG-2) to 78.33 (Pusa-9672 x TARM-21) over mid parent and it ranged from -49.87 (LOCAL x WGG-2) to 73.58 (Pusa-9672 x TARM-21) over better parent. The positive and significant heterosis was recorded over both mid and better parents in eight crosses viz., LGG-460 x LGG-407, LGG-460 x LGG-407, MGG-341 x LGG-407, MGG-341 x TARM-21, Pusa-9672 x LGG-407, Pusa-9672 x WGG-2, Pusa-9672 x TARM-21 and Pusa-9672 x LGG-440.

4.2.1.5 Seeds per pod :

The mean percentage of heterosis for seeds per pod was found to be 16.03 over mid parent and 7.94 over better parent. The percentage of heterosis ranged from -7.57 (Pusa-9672 x LGG-440) to 37.52 (LOCAL x TARM-21) over mid parent. While, it ranged from -13.98 (LOCAL x LGG-440) to 26.58 (LOCAL x TARM-21) over better parent. In fifteen crosses viz., LGG-460 x LGG-407, LGG-410 x WGG-2, LGG-460 x LGG-407, LGG-460 x WGG-2, LGG-460 x LGG-440, MGG-341 x LGG-407, MGG-341 x WGG-2, MGG-341 x TARM-21, MGG-341 x LGG-440, Pusa-9672 x LGG-407, Pusa-9672 x TARM-21, LOCAL x LGG-407, LOCAL x WGG-2 and LOCAL x TARM-21 heterosis for this trait over both mid parent and better parent was positive and significant.

4.2.1.6 100 seed weight :

The average heterosis over mid parent was 4.82 percent and -1.25 percent over the better parent. Heterosis ranged from 15.29 (LOCAL x WGG-2) to 33.14 (LOCAL x LGG-407) percent over mid parent and it ranged from -24.78 (LGG-410 x LGG-440) to 27.64 (Pusa-9672 x TARM-21) percent over better parent. Nine crosses viz., LGG-460 x LGG-407, LGG-460 x LGG-407, LGG-460 x WGG-2, MGG-341 x LGG-407, Pusa-9672 x LGG-407, Pusa-9672 x WGG-2, Pusa-9672 x TARM-21, Pusa-9672 x LGG-440 and LOCAL x LGG-407 have recorded significant and positive heterosis over both mid and better parents.

4.2.1.7 Shoot nitrogen (%) :

The average heterosis percent over mid parent was 2.77 for shoot nitrogen. While, the average heterosis percent over the better parent was -3.87. Heterosis percentage ranged from -10.94 (Pusa-9672 x LGG-440) to 25.18 (LGG-410 x WGG-2) over mid parent and it ranged from -22.57 (Pusa-9672 x LGG-407) to 19.41 (LGG-410 x WGG-2) over better parent. Positive and significant heterosis is observed over both mid and better parent in the crosses namely LGG-410 x WGG-2, LGG-410 x TARM-21, LGG-460 x TARM-21, MGG-341 x TARM-21, Pusa-9672 x TARM-21 and LOCAL x TARM-21.

4.2.1.8 Seed protein (%) :

The average heterosis for this trait was -0.41 over mid parent and -62.3 over better parent. Three crosses namely LGG-460 x LGG-407, MGG-341 x LGG-407 and LOCAL x WGG-2 have recorded significant and positive heterosis over both mid and better parents.

4.2.1.9 Shoot dry weight (g) :

The average heterosis percent for shoot dry matter over better parent was 31.1 while, it ranged from -57.77 (LOCAL x WGG-2) to 171.37 (LGG-460 x LGG-407) percent over better parent. The crosses LGG-460 x LGG-407, LGG-460 x LGG-407, LGG-460 x WGG-2, MGG-341 x LGG-407,

Pusa-9672 x LGG-407, Pusa-9672 x WGG-2, Pusa-9672 x TARM-21 and Pusa-9672 x LGG-440 have recorded positive and significant heterosis over better parent.

4.2.1.10 Seed yield per plant (g) :

The average heterosis for seed yield per plant was 20.70 per cent over better parent. The heterosis ranged from -46.92 (LGG-410 x WGG-2) to 149.71 (Pusa-9672 x WGG-2) over better parent. Eleven crosses namely LGG-460 x LGG-407, LGG-460 x LGG-407, LGG-460 x WGG-2, MGG-341 x LGG-407, MGG-341 x WGG-2, Pusa-9672 x LGG-407, Pusa-9672 x WGG-2, Pusa-9672 x TARM-21, Pusa-9672 x LGG-440, LOCAL x LGG-407, LOCAL x WGG-2 and LOCAL x TARM-21 have exhibited positive and significant heterosis over the better parent.

4.2.2 Combining ability analysis :

The analysis of variance revealed significant differences among the parents and crosses for all the characters studied (Table 4.1).

Combining ability analysis for the crosses derived in the L x T design was done as per Kempthorne (1957).

The variance among the genotypes were further partitioned into parents, crosses, parents versus crosses, lines, testers and line x testers. The mean squares due to parents vs crosses were found to be significant for all the traits except days to maturity (Table 4.5). The mean square due to parents and crosses were found to be significant for all the characters studied. Mean square due to parents vs crosses were found significant for all the characters studied indicates the presence of heterosis.

The general combining ability (gca) effects of the parents for different characters are presented in Table 4.6 The specific combining ability (sca) effects of crosses for different characters presented in Table 4.7.

4.2.2.1 Days to 50% flowering :

The lines LGG-410 (-1.92**) and local variety (-4.75**) and the tester LGG-440 (-5.62**) have recorded significant negative 'gca' effects while the line Pusa-9672 (5.33**) and the testers LGG-407 (4.18**) and TARM-21 (0.98**) have recorded positive and significant 'gca' effects. The crosses LGG-410 x LGG-440 (-2.55**), LGG-460 x LGG-407 (-2.18**), MGG-341 x TARM-21 (-3.48**), MGG-341 x LGG-440 (-2.88**), Pusa-9672 x LGG-407 (-3.27**), Pusa-9672 x TARM-21 (-1.73**) and LOCAL x WGG-2 (-6.78**) have shown significant negative 'sca' effects in the desired direction. The component of variance due to 'gca' was found to be more (24.18) compared

Table 4.5: ANOVA for combining ability mean squares for different characters in greengram

Source	df	DF	DM	PH	NDD	SPP	100 seed weight	Shoot Weight	Seed Protein	Shoot dry weight	Yield / plant (g)
Replications	2	0.27	0.15	17.93	1.42	0.06	0.08	0.06	0.008	11.85	1.65
Lines	4	167.08 [*]	121.93	579.79 ^{**}	303.91 [*]	4.31 [*]	2.15 [*]	0.49 ^{**}	6.68	1492.41 ^{**}	180.07 [*]
Testers	3	251.08 [*]	251.42 [*]	965.81 ^{**}	336.24	12.36 ^{**}	3.04 [*]	0.26 [*]	100.25 ^{**}	2433.03 ^{**}	32.04 ^{**}
Lines x Testers	12	45.86 ^{**}	67.31 ^{**}	117.99 ^{**}	76.57	1.17 ^{**}	0.60 ^{**}	0.09 ^{**}	5.32 ^{**}	337.58 ^{**}	53.70 ^{**}
Error	38	3.69	6.22	7.92	13.22	6.20	0.04	0.004	0.55	13.96	3.30
σ^2_{gca}		24.18	17.68	97.01	36.07	1.06	0.30	0.04	7.13	240.76	29.39
σ^2_{sca}		14.06	20.36	36.69	21.12	0.32	0.19	0.03	1.59	107.87	16.88
$2 \sigma^2_{\text{gca}} / 2 \sigma^2_{\text{gca}} + \sigma^2_{\text{sca}}$		0.78	0.64	0.84	0.77	0.87	0.76	0.13	0.90	0.82	0.78

Table 4.6 : General combining ability effects of parents for different characters

S. No.	Parent	Code No.	Days to flowering	Days to maturity	Plant height (cm)	Pods per plant	Seeds per pod	100 seed weight (g)	Shoot nitrogen (%)	Seed protein (%)	Shoot dry weight (g)	Yield / plant (g)
Lines												
1.	LGG-410	L1	-1.92**	-1.77**	-2.49**	-2.55**	0.02	-0.09**	0.27**	0.60**	-1.44**	-2.78**
2.	LGG-460	L2	0.92*	0.23	0.56	-0.37	0.53**	-0.13**	0.06**	0.23	2.93**	0.25
3.	MGG-341	L3	0.42	-0.10	1.06	0.11	0.60**	-0.17**	-0.04**	0.27	-6.04**	-0.22
4.	PUSA-9672	L4	5.33**	5.07**	10.06**	8.14**	-0.33**	0.74**	-0.29**	0.20	17.11**	6.29**
5.	Local	L5	-4.75**	-3.43**	-9.19**	-5.33**	-0.83**	-0.34**	-0.01	-1.30**	-12.56**	-3.55**
6.	SE		0.41	0.53	0.60	0.78	0.10	0.04	0.01	0.16	0.80	0.39
Testers												
7.	LGG-407	T1	4.18**	4.33**	10.46**	6.64**	1.23**	0.48**	0.05**	3.28**	17.87**	6.74**
8.	WGG-2	T2	0.45	1.27**	1.69**	-2.45**	0.13	0.00	0.14**	0.02	-0.30	-0.61
9.	TARM-21	T3	0.98**	-0.13	-4.18**	-0.04	-0.55**	0.13**	-0.01	-0.26	-6.24**	-2.77**
10.	LGG-440	T4	-5.62**	-5.47**	-7.97**	-4.15**	-0.81**	-0.60**	-0.18**	-3.04**	-11.33**	-3.35**
	SE		0.36	0.46	0.52	0.68	0.08	0.04	0.01	0.14	0.69	0.34

BEST PARENTS WITH HIGH "gca" FOR YIELD AND YIELD CONTRIBUTING TRAITS



BEST LINE – PUSA 9672



BEST TESTER – LGG 407

Table 4.7 : Specific combining ability effects of crosses for different characters

S. No.	Parent	Code No.	Days to flowering	Days to maturity	Plant height (cm)	Pods per plant	Seeds per pod	100 seed weight (g)	Shoot nitrogen (%)	Seed protein (%)	Shoot dry weight (g)	Yield / plant (g)
1.	LGG-410 x LGG-407	C1	1.98**	8.17**	-2.25*	7.58**	0.20	0.14*	-0.28**	-0.22	5.5**	4.04**
2.	LGG-410 x WGG-2	C2	-0.28	-1.77	0.02	-6.59**	-0.41	0.26**	0.33**	-1.41**	-12.73**	-3.45**
3.	LGG-410 x TARM-21	C3	0.85**	0.97**	1.22	0.25	-0.46**	-0.15**	-0.02	0.32	0.74	-0.34
4.	LGG-410 x LGG-440	C4	-2.55**	-7.37**	1.01	-1.23	0.40*	-0.25**	-0.04*	1.31**	6.43**	-0.26
5.	LGG-460 x LGG-407	C5	-2.18**	-2.50**	6.87**	3.41*	-0.17	-0.08	0.11**	-0.61*	8.93**	2.81**
6.	LGG-460 x WGG-2	C6	0.55	0.57	5.97**	5.94**	-0.14	0.41**	-0.21**	-0.26	11.27**	3.38**
7.	LGG-460 x TARM-21	C7	1.68*	3.97**	-10.83**	-5.24**	-0.59**	-0.18**	0.10**	1.45**	-11.72**	-3.58**
8.	LGG-460 x LGG-440	C8	-0.05	-2.03**	-2.00	-4.11**	0.40**	-0.15**	-0.02	-0.58**	-8.47**	-2.82**
9.	MGG-341 x LGG-407	C9	-0.02	-1.50	-1.62	-4.50**	-0.60	0.02	-0.12**	-0.05	7.42**	4.60**
10.	MGG-341 x WGG-2	C10	6.38**	4.90**	-0.86	1.24*	0.45**	0.03	-0.03	-0.78**	-5.347**	-1.43**
11.	MGG-341 x TARM-21	C11	-3.48**	-3.03**	1.68	1.58*	-0.37	-0.25**	0.03	0.54	-3.25**	-2.38**
12.	MGG-341 x LGG-440	C12	-2.88**	-0.37	0.80	1.69	-0.61	0.19*	0.12**	0.20	1.18	-0.80
13.	PUSA-9672 x LGG-407	C13	-3.27**	-4.00**	-7.96**	-5.00**	0.56**	-0.75**	-0.10**	-0.12	-12.60**	-8.00**
14.	PUSA-9672 x WGG-2	C14	0.13	-0.27	5.14**	3.86**	-0.18	0.06	-0.10**	0.03	12.07**	2.69**
15.	PUSA-9672 x TARM-21	C15	-1.73*	-1.87*	3.68**	-0.65	0.40*	0.51**	-0.03	0.02	6.55**	1.86**
16.	PUSA-9672 x LGG-440	C16	4.87**	6.13**	-0.86	1.79	-0.7**	0.18**	0.04	0.07	6.01**	3.45**
17.	LOCAL x LGG-407	C17	3.48**	-0.17	4.96**	-1.50	0.52**	0.68**	0.18**	1.01**	-9.31**	-3.46**
18.	LOCAL x WGG-2	C18	-6.78**	-3.43**	-10.27**	-1.44**	0.01	-0.76**	0.00	2.42**	-5.23**	-1.20**
19.	LOCAL x TARM-21	C19	2.68**	-0.03	4.26**	4.06**	1.62**	0.06	-0.08**	-2.33**	7.67**	4.23**
20.	Local x LGG-440	C20	0.62	3.63**	1.05	-0.87	-0.52**	0.02	-0.11**	1.07**	6.88**	0.42
	SE		0.71	0.93	1.05	1.17	0.17	0.07	0.02	0.28	0.00	0.67

BEST CROSSES WITH HIGH " sca" FOR YIELD AND YIELD COMPONENT TRAITS



LGG-460 x LGG-407



PUSA-9672 X WGG-2

to the 'sca' (14.06). The ratio of general combining ability component of variance ($2 \sigma^2_{gca}$) to total variation ($2\sigma^2_{gca} + \sigma^2_{sca}$) was 0.78.

4.2.2.2 Days to maturity :

The lines LGG-410 (-1.77**) and Local (-3.43**) and the tester LGG-440 (-5.47**) have recorded negative significant 'gca' effects in the desired direction. While, the line Pusa-9672 (5.07**) and the testers LGG-407 (4.33**) and WGG-2 (1.27**) have recorded positive significant 'gca' effects for this trait. The crosses LGG-410 x LGG-440 (-7.37**), LGG-460 x LGG-407 (-2.50**), LGG-460 x LGG-440 (-2.03**), MGG-341 x TARM-21 (-3.03**), Pusa-9672 x LGG-407 (-4.00**), and LOCAL x WGG-2 (-3.43**) have shown negative significant 'sca' effects in the desired direction. The component of variance due to 'gca' was less (17.68) compared to the variance due to 'sca' (20.36). The ratio general combining ability component of variance ($2 \sigma^2_{gca}$) to total variance ($2 \sigma^2_{gca} + \sigma^2_{sca}$) was found to be 0.64.

4.2.2.3 Plant height :

Pusa-9672 (10.06**) among the lines and LGG-407 (10.46**) and WGG-2 (1.69**) among the testers have recorded significant and positive 'gca' effects for plant height. While, the lines LGG-410 (-2.49**) and local (-9.19**) and the testers TARM-21 (-4.18**) and LGG-440 (-7.97**) recorded negative and significant 'gca' effects for this trait. The crosses LGG-460 x LGG-407

(6.87**), LGG-460 x WGG-2 (5.97**), Pusa-9672 x WGG-2 (5.14**), Pusa-9672 x TARM-21 (3.67**), LOCAL x LGG-407 (4.96**), and LOCAL x TARM-21 (4.26**) have recorded positive and significant 'sca' effect for plant height. While, the crosses LGG-460 x LGG-407 (-2.25*), LGG-460 x TARM-21 (-10.83**), Pusa-9672 x LGG-407 (-7.96**) and LOCAL x WGG-2 (-10.27**) have recorded negative 'sca' effect for this trait.

The estimates of variance due to 'gca' was (97.01) higher than the variance due to 'sca' (36.69). The ratio of general combining ability components of variance to total genetic variance was found to be close unity (0.84).

4.2.2.4 Pods per plant :

The line Pusa-9672 (8.14)** and the testers LGG-407 (6.64)** have recorded significant and positive 'gca' effects for pods per plant. The crosses LGG-460 x LGG-407 (7.58)**, LGG-460 x LGG-407 (3.41)*, LGG-460 x WGG-2 (5.94)**, Pusa-9672 x WGG-2 (3.86)**, LOCAL x TARM-21 (4.06)** have recorded significant positive 'sca' effect for this trait.

The components of variance due to 'gca' (36.07) was found to be more than the components of variance due to 'sca' (21.12). The ratio of general combining ability components of variance to total genetic variance was found to be 0.77.

4.2.2.5 Seeds per pod :

The lines, MGG-341 (0.60^{**}) and LGG-460 (0.53^{**}) and the tester LGG-407 (1.23^{**}) have shown positive and significant 'gca' effects for number of seeds per pod. The crosses LGG-410 x LGG-440 (0.40^{**}), LGG-460 x LGG-440 (0.90^{**}), MGG-341 x WGG-2 (0.45^{*}), Pusa-9672 x LGG-407 (0.56^{**}), Pusa-9672 x TARM-21 (0.40^{*}) and LOCAL x TARM-21 (1.02^{**}) have recorded positive and significant 'sca' effects for this trait. Variance due to 'gca' was greater (1.06) than the variance due to 'sca' (0.32). The ratio of general combining ability component of variance to total genetic variance was found to be 0.87.

4.2.2.6 100 seed weight (g) :

Pusa-9672 (0.74^{**}) among the lines and LGG-407 (0.48^{**}) and TARM-21 (0.13^{**}) among the testers have recorded positive and significant 'gca' effects for this trait. The crosses LGG-460 x LGG-407 (0.14^{*}), LGG-410 x WGG-2 (0.26^{**}), LGG-460 x WGG-2 (0.41^{**}), MGG-341 x LGG-440 (0.19^{**}), Pusa-9672 x TARM-21 (0.51^{**}), Pusa-9672 x LGG-440 (0.18^{*}) and LOCAL x LGG-407 (0.68^{**}) have recorded positive and significant 'sca' effects for 100 seed weight.

The estimates of variance due to 'gca' (0.30) was greater than variance due to 'sca' (0.19). The ratio of general combining ability component of variance to total genetic variance was found to be 0.76.

4.2.2.7 Shoot nitrogen content (%) :

Among the lines LGG-410 (0.27**), LGG-460 (0.06**) and among the testers WGG-2 (0.14**) and LGG-407 (0.05**) have showed positive and significant 'gca' effects for this trait. The crosses LGG-410 x WGG-2 (0.33**), LGG-460 x LGG-407 (0.11**), LGG-460 x TARM-21 (0.10**), MGG-341 x LGG-440 (0.12**), Pusa-9672 x LGG-407 (0.10**), LOCAL x LGG-407 (0.18**) have recorded positive and significant 'sca' effects for shoot nitrogen content. The estimated variance due to 'gca' (0.04) was higher than the 'sca' (0.03) for this trait. The ratio of general combining ability component of variance to total genetic variance was 0.73.

4.2.2.8 Seed protein content (%) :

The line LGG-410 (0.60**) and the tester LGG-407 (3.28**) were found to be good general combiners for seed protein content. While, the crosses LGG-410 x LGG-440 (1.31**), LGG-460 x TARM-21 (1.45**), LOCAL x LGG-407 (1.01**) and LOCAL x WGG-2 (2.42**) showed significant positive 'sca' effects for seed protein content. The estimated variance due to 'gca' (7.13) was greater than the variance due to 'sca' (1.59). The ratio of general combining ability component of variance to total genetic variance was found to be 0.90.

4.2.2.9 Shoot dry weight :

The lines LGG-460 (2.93**) and Pusa-9672 (17.11**) and the testers LGG-407 (17.87**) have recorded positive and significant 'gca' effects for this trait. Crosses LGG-460 x LGG-407 (5.57**), LGG-410 x LGG-440 (6.43**), LGG-460 x LGG-407 (8.93**), LGG-460 x WGG-2 (11.27**), C9(7.42**), Pusa-9672 x WGG-2 (12.07**), Pusa-9672 x TARM-21 (6.55**), LOCAL x TARM-21 (7.67**) and LOCAL x LGG-440 (6.88**) have recorded significant and positive 'sca' effects for shoot dry weight.

The estimated variance due to 'gca' was greater (240.76) than the variance due to 'sca' (107.87). The ratio of general combining ability component of variance to total genetic variance was found to be 0.82.

4.2.2.10 Seed yield per plant :

Among the lines, Pusa-9672 (6.29**) and among the testers LGG-407 (6.74**) recorded positive and significant 'gca' effects for seed yield per plant. Crosses LGG-460 x LGG-407 (4.04**), LGG-460 x LGG-407 (2.81**), LGG-460 x WGG-2 (3.38**), MGG-341 x LGG-407 (4.060**), Pusa-9672 x WGG-2 (2.69**), Pusa-9672 x TARM-21 (1.86**), Pusa-9672 x LGG-440 (3.45**) and LOCAL x TARM-21 (4.23**) have recorded positive and significant 'sca' effects for this trait.

The estimated variance due to 'gca' was greater (29.39) than the variance due to 'sca' (16.80). The ratio of general combining ability component of variance to total genetic variance was found to be 0.78.

4.3 Triple test cross analysis :

Triple test cross analysis was carried out involving four crosses viz., 1. LGG-460 x LGG-407, 2. LGG-460 x WGG-2, 3. Pusa-9672 x LGG-440 and 4. Local x TARM-21 for seven characters. Analysis of variance for seven characters viz., days to 50% flowering, days to maturity, plant height, pods per plant, 100 seed weight, shoot dry weight and seed yield is presented in Table 4.8. The epistatic gene action was further partitioned as over all epistasis 'i' type (additive x additive interaction), 'j' and 'l' (additive x non-additive and non-additive x non-additive). Analysis of variance for sums and differences provide direct tests of significance of additive (significance of sums) and dominant component (significance of difference). The analysis of variance for sums and differences and the estimates of additive (D), dominance (h) and degree of dominance $(H/D)^{1/2}$ are presented in Table 4.9 and 4.10. All the four crosses for seven characters studied showed homogeneity of interactions variance (i x blocks and j 1 x blocks) and hence the epistasis tested against the pooled error (epistasis x block interactions) except for days to 50% flowering, and seed yield in cross 2 (LGG-460 x WGG-2) and days to 50% flowering in cross 3 (Pusa-9672 x LGG-440), where the variances did not attain the level of homogeneity. Therefore, the

Table 4.8 : Analysis of variance to test for epistasis in four triple test crosses

1. LGG-410 x LGG-407, 2. LGG-460 x WGG-2 3. PUSA-9672 x LGG-440 and 4. LOCAL x TARM-21

Source	Cross	df	Days to flowering	Days to maturity	Plant height (cm)	Pods / plant	100 seed weight (g)	Shoot dry weight (g)	Seed yield/ plant (g)
Epistasis $L_{11} + L_{21} = 2L_{31}$	1	20	13.69**	11.49**	43.51**	192.22**	0.72**	209.03**	21.30**
	2	20	29.53**	10.07**	9.32*	96.67**	1.98**	145.04**	30.47**
	3	20	7.49**	7.70**	38.02**	116.23**	1.92**	208.37**	13.99**
	4	20	7.70**	24.10**	32.53**	92.06	0.70**	110.41**	9.84**
(a) i type epistasis	1	1	25.03**	32.05**	22.61	981.25**	0.56*	93.31**	54.55**
	2	1	116.55	23.73**	34.18**	392.34**	12.89**	701.40**	145.88
	3	1	58.31	6.94*	53.14**	252.94**	0.60**	57.03*8	11.66**
	4	1	0.00	233.24*	60.26**	3.55	0.74**	562.92**	15.84**
(b) j and l type epistasis	1	19	13.09**	10.41**	44.62**	150.70**	0.73**	215.12**	19.55**
	2	19	25.10**	9.35**	8.00*	81.11**	1.39**	115.76**	24.40**
	3	19	4.82**	7.74**	37.22**	109.03**	1.99**	216.34**	14.11**
	4	19	8.10**	13.08**	31.07**	96.72**	0.69**	86.59**	9.52**
Replicate error	1	40	2.93	2.81	5.78	18.04	0.09	4.83	0.89
	2	40	2.48	2.11	4.27	18.02	0.17	20.49	5.42
	3	40	1.51	1.35	4.14	12.21	0.11	6.63	0.91
	4	40	1.51	2.67	6.39	21.26	0.06	7.50	0.98
(a) i type epistasis x replicates	1	2	1.17	0.49	3.37	0.35	0.03	10.08	0.76
	2	2	8.13**	1.89	0.26	23.12	0.34	37.07	20.29**
	3	2	6.05**	0.23	3.18	1.08	0.02	9.13	1.22
	4	2	0.68	1.32	2.02	33.18	0.02	0.22	0.56
(b) j and l type x replicates	1	38	3.03	2.93	5.91	18.98	0.09	4.55	0.89
	2	38	2.18	2.12	4.48	17.70	0.16	19.61	4.64
	3	38	1.27	1.41	4.19	12.80	0.13	6.49	0.88
	4	38	1.55	2.75	6.61	20.63	0.06	7.88	0.99

Table 4.9 : Analysis of variance to detect additive and dominant components in four triple test crosses viz.,
1. LGG-410 x LGG-407 2. LGG-460 x WGG-2 3. PUSA-9672 x LGG-440 and 4. LOCAL x TARM-21

Source	Cross	df	Days to flowering	Days to maturity	Plant height (cm)	Pods / plant	100 seed weight	Shoot dry weight	Seed yield / plant
(a) Analysis of sums ($L_{11} + L_{21} + L_{31}$) sums (additive components)	1	19	46.70**	83.25**	131.3**	258.06**	2.13**	264.44**	45.48**
	2	19	27.34**	83.63**	63.99**	186.85**	4.24**	362.80**	37.06**
	3	19	50.97**	76.13**	114.67**	87.79**	1.89**	121.69**	10.60**
	4	19	51.03**	71.70**	99.21**	303.41**	1.78**	148.67**	24.36**
Sums x replicates	1	38	4.23	1.61	6.11	6.58	0.06	4.87	0.84
	2	38	1.08	2.41	5.87	15.24	0.06	14.90	3.40
	3	38	1.25	1.25	5.40	9.35	0.06	8.40	0.50
	4	38	1.86	1.89	4.36	10.45	0.05	10.59	1.05
(b) Analysis of differences ($L_{11} - L_{21}$) Difference (Dominant component)	1	19	24.39**	46.54**	54.93**	142.34**	0.84**	73.77**	6.69**
	2	19	19.86**	28.40**	31.83**	132.50**	1.84**	161.86**	21.93**
	3	19	7.55**	10.23**	39.62**	84.82**	0.36**	83.75**	8.72**
	4	19	10.36**	21.42**	44.12**	60.13**	0.89**	28.83**	6.45**
Difference x replicates	1	38	1.72	0.73	2.86	4.67	0.03	3.87	0.34
	2	38	0.60	1.07	3.09	11.13	0.06	7.52	1.59
	3	38	0.65	0.87	2.35	3.89	0.03	1.73	0.19
	4	38	0.94	0.75	2.06	5.83	0.04	2.54	0.29

** Significant at 1% level

* Significant at 5% level

Table 4.10 : Estimations of genetic components and degree of dominance for seven characters in four triple trest crosses viz., 1. LGG-410 x LGG-407 2. LGG-460 x WGG-2 3. PUSA-9672 x LGG-440 and 4. LOCAL x TARM-2

Component	Cross	Days to flowering	Days to maturity	Plant height (cm)	Pods / plant	100 seed weight	Shoot dry weight	Seed yield per plant
Additive (D)	1	37.74	72.57	111.27	223.53	1.83	230.73	39.68
	2	23.34	72.19	51.67	152.54	3.71	309.24	29.92
	3	44.20	66.55	97.13	69.79	1.62	100.70	8.98
	4	44.30	62.06	84.30	260.40	1.54	122.74	20.72
Dominance (H)	1	30.24	61.09	69.43	183.57	1.08	93.18	8.47
	2	25.58	36.44	38.31	161.82	2.37	205.77	27.12
	3	9.23	12.48	49.70	107.91	0.44	109.36	11.38
	4	12.56	27.56	56.09	72.41	1.13	35.06	8.21
Degree of dominance (H/D) ^{1/2}	1	0.90	0.92	0.79	0.91	0.77	0.64	0.46
	2	1.05	0.71	0.86	1.03	0.80	0.82	0.96
	3	0.46	0.43	0.51	1.24	0.52	1.04	1.13
	4	0.53	0.67	0.82	0.53	0.86	0.53	0.63
Correlation coefficient (r)	1	0.13	0.20	-0.25	0.09	0.28	0.07	-0.19
	2	0.04	-0.11	0.11	0.27	0.10	0.20	0.18
	3	0.18	0.02	-0.28	0.21	-0.13	0.38	0.57**
	4	0.11	-0.09	0.11	0.14	0.07	0.36	0.27

variances of three characters were tested against their respective interaction with blocks. The epistasis estimates of genetic components and degree of dominance are presented below.

4.3.1 Days to 50% flowering :

In general, 'i' type epistasis was found significant to days to flowering in cross 1 (LGG-410 x LGG-407) whereas, the 'j' and 'l' type of interactions were significant in all the crosses. The variances due to sums and differences were found significant in the cross 1 (LGG-410 x LGG-407), 3 (Pusa 9672 x LGG-440) and 4 (Local x TRM-21) indicating the pre-dominant role of additive genetic component for this trait. The cross 2 (LGG-460 x WGG-2) exhibited more than unit degree of dominance indicating the preponderance of dominance gene action.

4.3.2 Days to maturity:

All the three interactions 'i', 'j' and 'l' were found to be significant in all the crosses for this trait. The variance due to sums and difference were also found significant and the degree of dominance was less than one in all the crosses indicating the predominance of additive component.

4.3.3 Plant height :

The 'i' type of interaction was found to be significant in all crosses except in cross No.1 whereas, the 'j' and 'l' type epistasis interactions were found to be significant in all the four crosses. The sums and differences were significant in all the crosses and the degree of dominance was less than one shows the preponderance of additive gene action controlling this trait.

4.3.4 Pods per plant :

The over all 'i' type epistasis and 'j' and 'l' type of epistasis were significant for this trait in all the crosses except for 'i' type of epistasis in cross 4 (Local x TARM-21). The variances of sum and differences were significant indicating the importance of both additive and dominance components for pods per plant. The crosses 2 (LGG-460 x WGG-2) and 3 (Pusa-9672 x LGG-440) recorded more than and the crosses 1 (LGG-410 x LGG-407) and 4 (Local x TARM-21) registered less than one degree of dominance.

4.3.5 100 seed weight (g) :

The trait 100 seed weight recorded significant epistasis for both 'i' and 'j' and type in all the crosses. The genetic components, additive (D) and dominance (H) were also significant and degree of dominance was less than one in all the crosses indicating the presence of additive gene action in controlling this trait.

4.3.6 Shoot dry weight (g) :

All the epistatic interaction 'i', 'j' and 'l' were found significant for shoot dry weight. The genetic components of D and H were also significant in all the four crosses and the degree of dominance was found to be less than one in cross 1 (LGG-410 x LGG-407) 2 (LGG-460 x WGG-2) and 4 (Local x TRM-21) while it was more than one in cross 3 (Pusa-9672 x LGG-440).

4.3.7 Seed yield per plant (g) :

The seed yield per plant recorded significant 'i' and 'j' and 'l' type of epistatic gene interactions in all the 4 crosses studied, except for 'i' type of epistasis in cross 2 (LGG-460 x WGG-2). The variance of sums and differences were significant in all the crosses and the degree of dominance was less than one in all the crosses, except in cross 3 (Pusa-9672 x LGG-440) where it has recorded more than one.

4.4 CHARACTER ASSOCIATION :

Genotypic and phenotypic correlation coefficients between yield and yield components among themselves were worked out for parents and F_1 s and are presented in Table 4.11. In general, genotypic correlations were higher than phenotypic correlations.

Table 4.11 : Genotypic (upper half) and phenotypic (lower half) correlation coefficients in parents and hybrids

S. No.	Character	Days to flowering	Days to maturity	Plant height (cm)	Pods per plants	Seeds / pod	100 seed weight (g)	Shoot nitrogen (%)	Seed protein (%)	Shoot dry weight (g)	Yield / plant (g)
1.	Days to flowering	1.000	0.793**	0.727**	0.695**	0.174	0.667**	-0.170	0.302**	0.634**	0.626**
2.	Days to maturity	0.788**	1.000	0.462**	0.595**	0.210	0.426**	-0.075	0.151	0.590**	0.597**
3.	Plant height (cm)	0.691**	0.437**	1.000	0.684**	0.024	0.524**	-0.296**	0.226	0.740**	0.612**
4.	Pods / plant	0.574**	0.446**	0.586**	1.000**	0.348**	0.635**	-0.167	0.429**	0.856**	0.845**
5.	Seeds / pod	0.160	0.186	0.026	0.292*	1.000	0.318	0.426**	0.598**	0.442**	0.518**
6.	100 seed weight (g)	0.606**	0.393**	0.488**	0.531**	0.307**	1.000	-0.100	0.531**	0.665**	0.691**
7.	Shoot nitrogen (%)	-0.164	-0.062	-0.282*	-0.151	0.370**	-0.104	1.000	0.406**	-0.203	-0.177
8.	Seed protein (%)	0.273*	0.123	0.205	0.359**	0.545**	0.494**	0.386**	1.000	0.421**	0.466**
9.	Shoot dry weight / plant	0.592**	0.533**	0.682**	0.709**	0.351**	0.574**	-0.195	0.392**	1.000	0.919**
10.	Yield / plant (g)	0.556**	0.512**	0.564**	0.787**	0.468**	0.626**	-0.171	0.445**	0.842**	1.000

** Significant at 1% level

* Significant at 5% level

Association analysis revealed that seed yield was significantly and positively associated with days to flowering (0.626**), days to maturity (0.597**), plant height (0.612**), 100 seed weight (0.691**), seed protein (0.466**) and shoot dry weight (0.919**) both at genotypic and phenotypic level.

Significant and positive genotypic association were observed between character pairs viz., days to flowering with days to maturity (0.793**), plant height (0.727**), pods per plant (0.695**), 100 seed weight (0.667**), seed protein (0.302*) and shoot dry weight (0.634**); Days to maturity with plant height (0.462**), pods per plant (0.595**), 100 seed weight (0.426**), shoot dry weight (0.590**); Plant height with pods per plant (0.684**), 100 seed weight (0.524**) and shoot dry weight (0.740**). Pods per plant had positive significant genotypic association with seeds per pod (0.348**), 100 seed weight (0.635**), seed protein (0.429**) and shoot dry weight (0.856**); Seeds per pod with 100 seed weight (0.318*), shoot nitrogen (0.426**). Seed protein (0.598**) and shoot dry weight (0.442**); 100 seed weight with seed protein (0.531**) and shoot dry weight (0.665**) and Seed protein with shoot 'N' (0.406**), and shoot dry weight (0.421*). Similar association trend was observed at phenotypic level also for the above combinations. The character plant height showed negative and significant correlation with shoot N (-0.296*).

4.5 PATH ANALYSIS :

The direct and indirect effect of different component traits on yield were worked out through path analysis of genotypic and phenotypic correlations in parents and F_1 s are presented in Table 4.12 and 4.13. Path analysis revealed that shoot dry weight (0.532 and 0.403) followed by pods per plant (0.215 and 0.344), days to maturity (0.139 and 0.174), 100 seed weight (0.136 and 0.142) and seeds per pod (0.186 and 0.194) had positive direct effect on seed yield both at genotypic and phenotypic level.

Days to flowering had a positive indirect effect through days to maturity, pods per plant and shoot dry weight, at both genotypic and phenotypic level. Plant height had negative direct effect on yield but a positive indirect effect on yield through days to maturity, pods per plant, 100 seed weight and shoot dry weight at genotypic level. At phenotypic level plant height had a positive direct effect on yield. While, it had a negative indirect effect through days to flowering. Pods per plant recorded a maximum positive indirect effect on yield through shoot dry weight followed by 100 seed weight, days to maturity, seeds per pod, plant height, shoot nitrogen and seed proteins at both genotypic and phenotypic level. Seeds per pod had a positive indirect effect through shoot dry weight, 100 seed weight, pods per plant, days to maturity and seed protein, whereas, it had negative indirect effect through plant height and shoot nitrogen. 100 seed weight had a positive

indirect effect through shoot dry weight, pods per plant, days to maturity, seeds per pod, shoot nitrogen and seed protein. While, it had a negative indirect effect on yield through plant height and days to flowering. Shoot nitrogen had a negative direct effects on yield but positive indirect effect on yield through days to flower, plant height, seeds per pod, seed protein and negative indirect effect through days to maturity, pods per plant, 100 seed weight and shoot dry weight. Seed protein had a negative indirect effect on yield through days to flowering, plant height, shoot nitrogen but it had a positive indirect effect through days to maturity, pods per plant, seeds per plant, 100 seed weight, and shoot dry weight. Shoot dry weight had maximum positive direct effect on yield while, it had high indirect effect on yield through pods per plant followed by 100 seed weight, days to maturity, seeds per pod, shoot nitrogen and seed protein. Shoot dry weight had a negative indirect effect through days to flowering and plant height. Same trend was observed in phenotypic path also for the above traits.

Table 4.12 : Genotypic path coefficient analysis for grain yield in F₁s and parents

S. No.	Character	Days to flowering	Days to maturity	Plant height (cm)	Pods / plant	Seeds / pod	100 seed weight (g)	Shoot nitrogen (%)	Seed protein (%)	Shoot dry weight (g)	Correlation with Yield / plant (g)
1.	Days to flowering	-0.094	0.110	-0.035	0.150	0.033	0.091	0.023	0.012	0.337	0.627 ^{**}
2.	Days to maturity	-0.075	0.139	-0.022	0.128	0.039	0.058	0.010	0.006	0.314	0.597 ^{**}
3.	Plant height (cm)	-0.068	0.064	-0.049	0.147	0.004	0.071	0.040	0.009	0.393	0.612 ^{**}
4.	Pods / plant	-0.065	0.083	-0.033	0.215	0.065	0.086	0.022	0.017	0.455	0.845 ^{**}
5.	Seeds / plant	-0.016	0.029	-0.001	0.075	0.186	0.043	-0.058	0.024	0.235	0.518 ^{**}
6.	100 seed weight (g)	-0.065	0.509	-0.025	0.137	0.059	0.136	0.013	0.021	0.354	0.691 ^{**}
7.	Shoot nitrogen (%)	0.016	-0.010	0.014	-0.036	0.079	-0.014	-0.135	0.016	-0.018	-0.177
8.	Seed protein (%)	-0.028	0.021	-0.011	0.092	0.111	0.072	-0.055	0.040	0.224	0.466 ^{**}
9.	Shoot dry weight plant	-0.066	0.082	-0.036	0.184	0.082	0.090	0.027	0.017	0.532	0.919 ^{**}

Residual effect = 0.443181

Table 4.13 : Phenotypic path coefficient analysis for grain yield in F₁s and parents of greengram

S. No.	Character	Days to flowering	Days to maturity	Plant height (cm)	Pods per plants	Seeds per pod	100 seed weight	Shoot nitrogen (%)	Seed protein (%)	Shoot dry weight (g)	Yield / plant (g)
1.	Days to flowering	-0.182	0.137	0.006	0.198	0.031	0.086	0.023	0.019	0.239	0.556
2.	Days to maturity	-0.143	0.174	0.004	0.154	0.036	0.056	0.009	0.008	0.215	0.512
3.	Plant height (cm)	-0.126	0.076	0.009	0.202	0.005	0.069	0.040	0.014	0.275	0.564
4.	Pods / plant	-0.104	0.078	0.005	0.344	0.057	0.075	0.021	0.024	0.286	0.787
5.	Seeds per pod	-0.029	0.032	0.000	0.101	0.194	0.043	-0.052	0.037	0.142	0.468
6.	100 seed weight (g)	-0.110	0.068	0.004	0.183	0.060	0.142	0.015	0.034	0.231	0.626
7.	Shoot nitrogen (%)	0.030	-0.011	-0.003	-0.052	0.072	-0.015	-0.141	0.026	-0.079	-0.171
8.	Seed protein (%)	0.050	0.021	0.002	0.124	0.106	0.070	-0.054	0.068	0.158	0.445
9.	Shoot dry weight	-0.108	0.093	0.006	0.244	0.068	0.081	0.027	0.027	0.403	0.842

Residual effect = 0.40398

Chapter V

Discussion

CHAPTER - V

5. DISCUSSION

5.1 STUDIES ON GENETIC VARIABILITY :

The success of any breeding programme depends mainly on the spectrum of genetic variability available in the population. A wider variability will provide the breeder a greater scope for selecting desired material.

Several workers (Burton 1952, Vishnuswarup and Chagla, 1962) indicated that genetic variability together with heritability estimates would give a better idea on the amount of genetic advance expected from selection. The magnitude of heritable variability is the most important aspect of the genetic constitution of the breeding material, which has a close relationship on its response to selection (Panse, 1957). Most of the quantitative characters are highly influenced by the environment. Phenotypic variability among genotypes does not give a true indication of the heritable and non-heritable components of variances. In order to get true picture of genetic variability in the available genotypes in respect of quantitative characters, it becomes necessary to study them under an array of distinguishable environments.

20 F_1 s and 9 parents of greengram studied in the present investigation differed statistically for all the characters. The results obtained on variability, heritability and genetic advance in percent of mean are discussed here under.

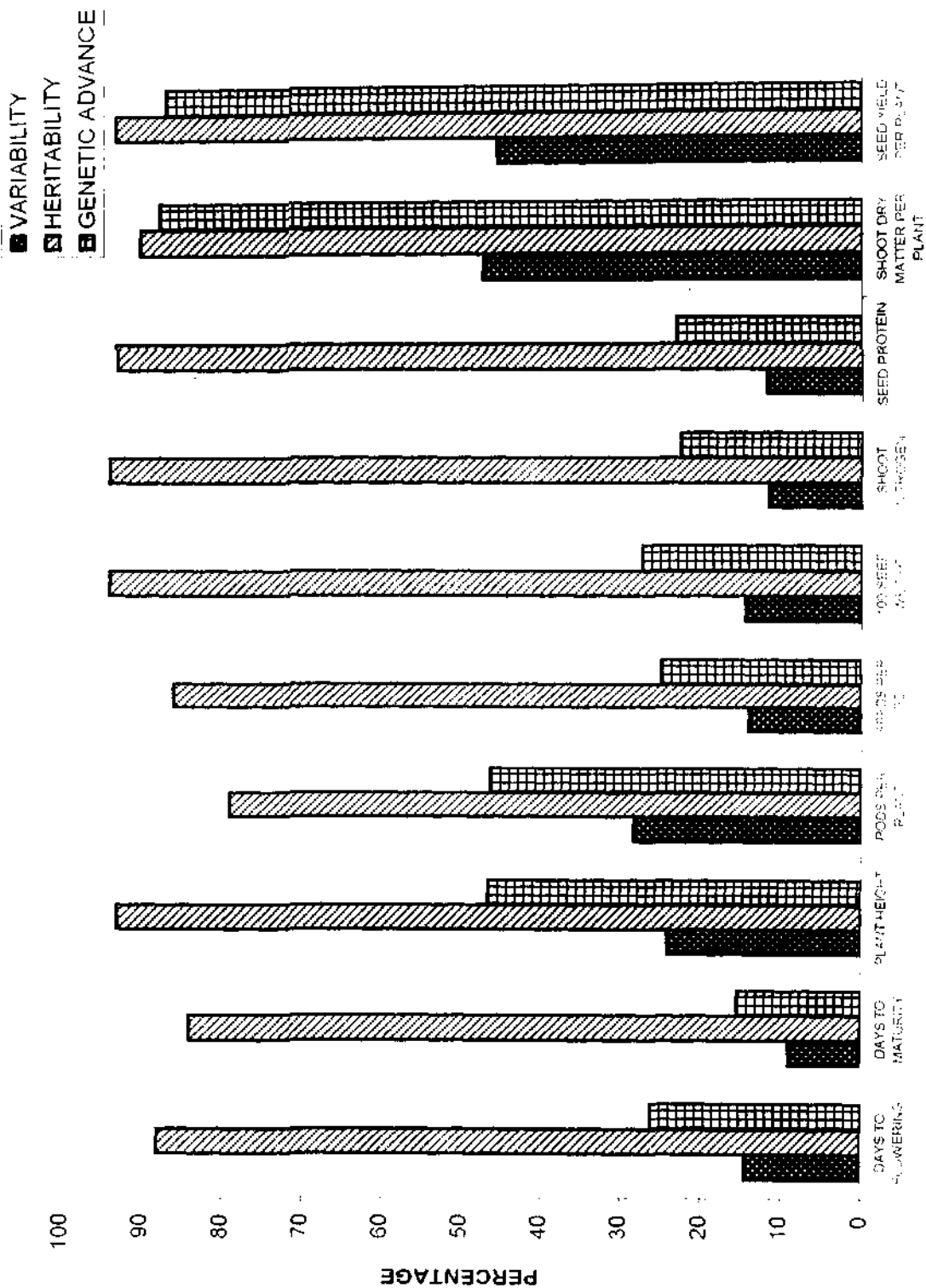
5.1.1 Days to 50% flowering

Number of days taken to 50% flowering were found to be less in parents compared to crosses. PCV and GCV were low for this trait. Similar results were reported by Paramasivam and Rajasekharan (1980), Ramana and Singh (1987), Borah and Hazarika (1995) and Patil and Shinde (1995) for this trait in greengram. High heritability coupled with moderate genetic advance was observed for days to 50% flowering in the present study indicate the possibilities for improvement of the character either by simple selection or by Pedigree method. Giriraj (1973), Paramasivam and Rajasekharam (1980), Borah and Hazarika (1995), Patil and Shinde (1995) and Vikasparoda *et al.* (1998), observed similar results.

5.1.2 Days to maturity :

The number of days taken to maturity were less in parents compared to crosses. The phenotypic coefficient of variability and genotypic coefficient of variability were low for this trait. Low variability for days to maturity in greengram was also reported by Ramana and Singh (1987), Rosaiah *et al.*, (1987), Patil and Deshmukh (1988b) Borah and Hazarika (1995), and Reddy

ESTIMATES OF VARIABILITY, HERITABILITY AND GENETIC ADVANCE FOR DIFFERENT CHARACTERS IN GREEN GRAM



(1997). High heritability coupled with low genetic advance over mean recorded for this trait indicates the operation of non-additive gene action for days to maturity. Similar results were reported by Shah and Patel (1981), Patil and Deshmukh (1988b), Naidu *et al.*, (1991) Tiwari *et al.*, (1996) and Joshi *et al.*, (1998).

5.1.3 Plant height :

Plant height was high in parents compared to the crosses. PCV and GCV were found high for this trait in the present study. Naidu *et al.*, (1991), Reddy *et al.* (1991), Pundir *et al.* (1992), Borah and Hazarika (1995), Patil and Shinde (1995), Veerabadhiran *et al.* (1996), Das *et al.*, (1998) and Vikasparoda *et al.*, (1998) reported wider genetic variability for this trait. High h^2 coupled with high GA over mean obtained for this trait in the present study indicates the influence of additive gene action on plant height and this trait can be improved through simple selection methods. Similar results were reported by Patil and Deshmukh (1988b), Naidu *et al.*, (1991), Veerabadhiran and Jehangir (1995), Manivannan *et al.* (1996), Ganesh Ram *et al.*, (1997) and Vikasparoda *et al.*, (1998).

5.1.4 Pods per plant :

More number of pods per plant were recorded in crosses compared to parents. In the present study high PCV and GCV values recorded for pods

per plant indicates the presence of wider genetic variability. Similar results were reported in greengram by Rosaiah *et al.*, (1987), Siddaraju (1987), Kalpana Pandey *et al.*, (1988), Tickoo *et al.*, (1988), Baisekh *et al.*, (1989), Naidu (1989), Ranganayaki and Sreerangaswamy (1993), Borah and Hazarika (1995), Khorgade (1995), Veerabadhiran and Jehangir (1995), Khorgade (1995), Veerabadhiran and Jehangir (1995), Hiran Kumar (1996), Tiwari *et al.*, (1996), Byregowda *et al.*, (1997), Reddy (1997), Das *et al.*, (1988) and Vikasparoda *et al.*, (1998). High heritability coupled with high genetic advance as percent over mean recorded for this trait in the present study is in confirmation of the results of the earlier workers (Rosaiah *et al.*, (1987), Siddaraju (1987), Kalpana Pandey *et al.*, (1988), Naidu *et al.*, (1991), Khorgade (1995), Byregowda *et al.*, (1997) and Vikasparoda *et al.*, (1998)). High h^2 coupled with high GA over mean indicates less influence of environment in the expression of this trait. Selection will be effective to achieve the genetic gain due to additive gene action.

5.1.5 Seeds per pod :

Number of seeds per pod were higher in crosses than in parents. Phenotypic and genotypic co-efficients of variation were found low for this trait in the present study and is in confirmity with the observations made by Rathnaswamy *et al.*, (1978), Sandhu *et al.*, (1979), Paramasivam and Rajasekharan (1980), Rosaiah *et al.*, (1987), Natarajan *et al.*, (1988), Patil and

Deshmukh (1998b), Pundir *et al.*, (1992), Borah and Hazarika (1995), Ghulam Hassian *et al.*, (1995), Veerabadhiran and Jehangir (1995). High heritability coupled with low genetic advance over mean indicate the operation of non-additive gene action. Selection can be postponed to later generations to improve this trait using recurrent selection procedures. Similar results were observed by Paramasivam and Rajasekharan (1980), Naidu *et al.*, (1991), Borah and Hazarika (1995), Manivannan *et al.*, (1996), and Appala Swamy (1997).

5.1.6 100 Seed weight (g) :

Seed weight was found to be higher in crosses compared to parents. PCV and GCV were found low for this trait indicating the presence of low variability for hundred seed weight. Narrow variability was also reported for this character by Bharghava *et al.*, (1966), Chowdary *et al.*, (1982), Ramana and Singh (1987), Veerabhadhiran and Jehangir (1995), Manivannan (1996). High heritability coupled with moderate genetic advance over mean recorded for this trait indicate the possibility of improving this trait through selection. Giriraj (1973), Paramasivam and Rajasekharan (1980), and Khorgade (1995) reported similar results for this character in greengram.

5.1.7 Shoot nitrogen content (%) :

Shoot nitrogen content was high in crosses compared to parents. Estimates of phenotypic and genotypic coefficients of variability were low for this trait indicating the presence of low range of variability. Similar results were reported by Naidu (1989). High heritability coupled with low genetic advance over mean recorded for this trait indicates that it is difficult to improve this trait through simple selection methods. Selection of a few best plants is effective for improvement of shoot nitrogen in greengram. Contrary to these results, Naidu (1989) and Anuradha *et al.*, (1991) reported additive gene action for shoot nitrogen content in greengram and blackgram respectively.

5.1.8 Seed protein content (%) :

Seed protein content was found to be high in crosses compared to parents. The PCV and GCV were low for this character. Similar results were also reported by Yohe and Poehlman (1972), Rosaiah *et al.*, (1987), Sandhu *et al.*, (1979). High heritability and low genetic advance was recorded for this trait. However earlier worker reported high heritability for seed protein content (Chowdhury *et al.* (1982) and Rosaiah *et al.* (1987)).

High heritability coupled with low genetic advance over mean recorded for this trait indicates non-additive gene action governing the trait

and recurrent selection procedures may improve of seed protein content in greengram. Similar results were observed by Naidu *et al.*, (1991).

5.1.9 Shoot dry weight (g) :

Higher shoot dry weight was recorded in crosses compared to parents. Estimates of PCV and GCV were high for this trait indicating the presence of wider genetic variability. Similar observations were made by Vikas *et al.*, (1998), Naidu (1989). Higher heritability coupled with high genetic advance over mean recorded for this trait indicate the possibility for improvement of this character either through simple selection or by pedigree method.

5.1.10 Seed yield per plant (g)

Higher seed yield was recorded in crosses compared to parents. Estimates of PCV and GCV were high for this trait indicating the presence of wider genetic variability. High variability for seed yield was also reported by Naidu *et al.*, (1991), Pundir *et al.*, (1992), Ranganayaki and Sri Rangaswamy (1993), Khorgade (1995), Patil and Shinde (1995), Hiran Kumar (1996), Byregowda *et al.*, (1997), Reddy (1997), Shanti Priya (1997) and Das *et al.*, (1998) in greengram. High heritability along with high genetic advance over mean recorded for this trait indicate the less influence of environment and simple selection is effective to improve this character. These results were in conformation with the findings of Giriraj (1973), Ramana and Singh

(1987), Patil and Deshmukh (1988), Naidu *et al.*, (1991), Patil and Shinde (1995), Manivannan *et al.*, (1996), Byregowda *et al.*, (1997), Ganeshram *et al.*, (1997), Joshi *et al.*, (1998).

High heritability estimates obtained for all the yield and yield components in the present investigation indicates that not much selection pressure has been applied in this crop. In the present study plant height, pods per plant, shoot dry weight per plant and yield per plant showed high variability, whereas, days to 50% flowering, days to maturity, seeds per pod, 100 seed weight, shoot nitrogen content and seed protein content recorded low variability. Broad sense heritability estimates includes dominance, epistasis as well as additive genetic variance and the estimates so obtained should be considered as maximum heritabilities (Paul 1978). If h^2 is mainly due to additive gene effect then only it is associated with high genetic gain as in case of days to 50% flowering, plant height, pods per plant, 100 seed weight, shoot dry weight and seed yield per plant. If high h^2 is due to non-additive effects then the genetic advance will be low as in case of days to maturity, seeds per pod, shoot nitrogen and seed protein content. The characters with high heritability coupled with high genetic gain can be improved through simple selection procedures; traits with low variability, low GA and high h^2 can be improved through cyclic hybridization followed by selection.

5.2 COMBINING ABILITY STUDIES :

Combining ability analysis is used for testing performance of parents in hybrid combination and also for the identification of nature and magnitude of gene action involved in the expression of quantitative characters to identify the best parents with good general combining ability and best hybrids with specific combining ability.

General combining ability refers to the average performance of a line in a series of hybrid combinations and is attributable to additive gene action (fixable) while the specific combining ability refers to the deviation in the performance of a cross from the average performance of the lines involved and is primarily attributable to dominance, over dominance and epistatic effects of genes (non-additive). The non-additive gene action is mostly non fixable and often brings about the phenotypes that are not attainable under normal additive gene action.

Additive gene action tends to produce normal phenotypic distribution (Griffing, 1956). The total genetic variance among single cross progeny is equal to twice the general combining ability variance ($2\sigma^2_{gca}$) plus, the specific combining ability variance (σ^2_{sca}). Based on this relationship Becker (1975) postulated that relative importance of general and specific combining ability should be assessed by estimating the components of variance and

expressed as $2\sigma^2 \text{ gca} / 2\sigma^2 \text{ gca} + \sigma^2 \text{ sca}$. The closer the ratio to unity, the greater the magnitude of additive gene action.

Lines with high combining ability are good yielders presumably because of the larger proportions of favourable yield genes which they carry. Different methods have been developed to estimate the general and specific combining ability of which, top cross, poly cross, line x tester, diallel, partial diallel and triallel analysis are used commonly. The 'gca' effects are considered as the intrinsic genetic value of the parents and are conceived due to additive gene action, if the interaction effect are also present in the material under study, a variance due to specific combining ability (sca) will also be present, if the 'gca' alone is significant, it indicates that the trait is governed mostly by additive gene action. The 'sca' variances will be significant when the parents possessing high 'sca' effects are combined by hybridization, a large proportion of programmes are expected to have high value for the traits concerned facilitating easy selection. When the 'sca' effects are positive it indicates a high dominance interaction between genes of the two parents involved and the combination is considered as suitable for exploitation of heterosis.

Heterosis is defined as the increased vigour of F_1 over parental mean and is a genetic expression of beneficial effects of hybridization. Heterosis

could be used as indicative of the process which are likely to throw transgressive segregants (Singh and Jain, 1970). The extent of heterosis would also give an idea of the genetic control.

In the present study, line x tester analysis was employed using five lines (LGG 410, LGG 460, MGG 314, Pusa 9672 and Local) and four testers (LGG 407, WGG 2, TARM 21 and LGG 440). The resultant F_1 s and their parents were evaluated with the following objectives.

1. To study the extent of heterosis present in the crosses for various characters.
2. To find out the parents with good 'gca' and crosses with good 'sca' for seed yield and yield components.
3. To understand the gene action involved in the expression of yield and yield component characters.

The mean squares due to parents and crosses were significant for all the characters studied indicating the presence of wider variability among the parents and crosses. Mean squares due to lines were greater than testers for all the characters except 100 seed weight, shoot nitrogen and seed protein indicating wider variability for respective characters among lines and testers. The mean squares due to parents versus hybrids were found significant for

all the characters except days to 50% flowering indicating the presence of heterosis.

Heterosis, ratio of genetic component of variance and estimates of combining ability components for yield and yield components are discussed here under.

5.2.1 Days to 50% flowering :

Heterosis for days to 50% flowering among the crosses was in desired direction both over mid parent and better parent (Table 4.4). Highest heterosis was recorded in desired direction in the cross LOCAL x WGG-2 over both mid parent and better parent, respectively. Significant heterosis over better parent and mid parent was reported by Singh and Jain (1970), Tawar and Sudhansu Jain (1988), Singh and Pathak (1992), Sharma and Yadav (1993) in greengram.

Estimates of 'gca' variance were greater than 'sca' variance. The ratio between 'gca' and 'sca' components of variance is intermediate to unity indicating the importance of both additive and non-additive gene action for this trait. These findings are in agreement with Bhadra and Akhtar (1993), Thimmappa *et al.*, (1989) and Saxena and Sharma (1992).

Among the lines, LGG 410 and Local and tester LGG-440 recorded significant (negative) 'gca' effect in desired direction. The crosses LGG-410 x LGG-440, LGG-460 x LGG-407, MGG-341 x TARM-21, MGG-341 x LGG-440, Pusa-9672 x LGG-407, Pusa-9672 x TARM-21 and LOCAL x WGG-2 recorded significant negative 'sca' effects (in desired direction) involving Low (L) x Low (L), Low (L) x Medium (M), Medium (M) x Medium (M), Medium (M) x High (H) ; and High (H) x High (H) general combiners. The 'sca' effects would be important in self pollinated crops to isolate good transgressive segregants. If additive genetic system is present, good segregants may appear from crosses involving High x Low and Low x High general combiners. Desirable combinations can be isolated and maintained through pedigree method of breeding.

5.2.2 Days to maturity :

Among the 20 crosses studied, crosses LGG-410 x LGG-440, MGG-341 x LGG-440, LOCAL x WGG-2, LOCAL x TARM-21 and LOCAL x LGG-440 recorded negative heterosis over both better and mid parents. Significant negative heterosis for days to maturity over mid and better parent was also reported by Singh and Pathak (1992), Sharma and Yadav (1993), Naidu and Satyanarayana (1993) and Reddisekhar *et al.*, (1994).

The variance due to 'sca' were higher than 'gca' for this trait. The ratio of general combining ability component of variance to total genetic variance was found to be away from unity indicating the importance of both additive and non-additive gene action governing the trait. Similar results were obtained by Saxena and Sharma (1992). Whereas, Deshmukh and Manjore (1990), Tiwari *et al.* (1993), Vijayabharathi (1993) and Aher and Dahat (1999) reported non-additive gene action in controlling this trait.

Among the lines, LGG 410 and local and tester LGG 440 were found good general combiners for maturity. The crosses LGG-410 x LGG-440, LGG-460 x LGG-407, LGG-460 x LGG-440, MGG-341 x TARM-21, Pusa-9672 x LGG-407, Pusa-9672 x TARM-21 and LOCAL x WGG-2 recorded significant 'sca' effects for maturity. Breeding method involving selection, intermating the selects and reselection may help to improve this trait.

5.2.3 Plant height (cm) :

Positive and significant heterosis for plant height over better parent was recorded in crosses LGG-460 x LGG-407, LGG-460 x WGG-2, MGG-341 x LGG-407, MGG-341 x WGG-2, Pusa-9672 x LGG-407 and Pusa-9672 x WGG-2 in the present investigation. These results are in confirmation with results obtained by Misra *et al.*, (1970), Singh and Jain (1971), Ilyas Ahmad Malik *et al.*, (1988), Reddisekhar *et al.*, (1994) and Hegde *et al.*, (1996).

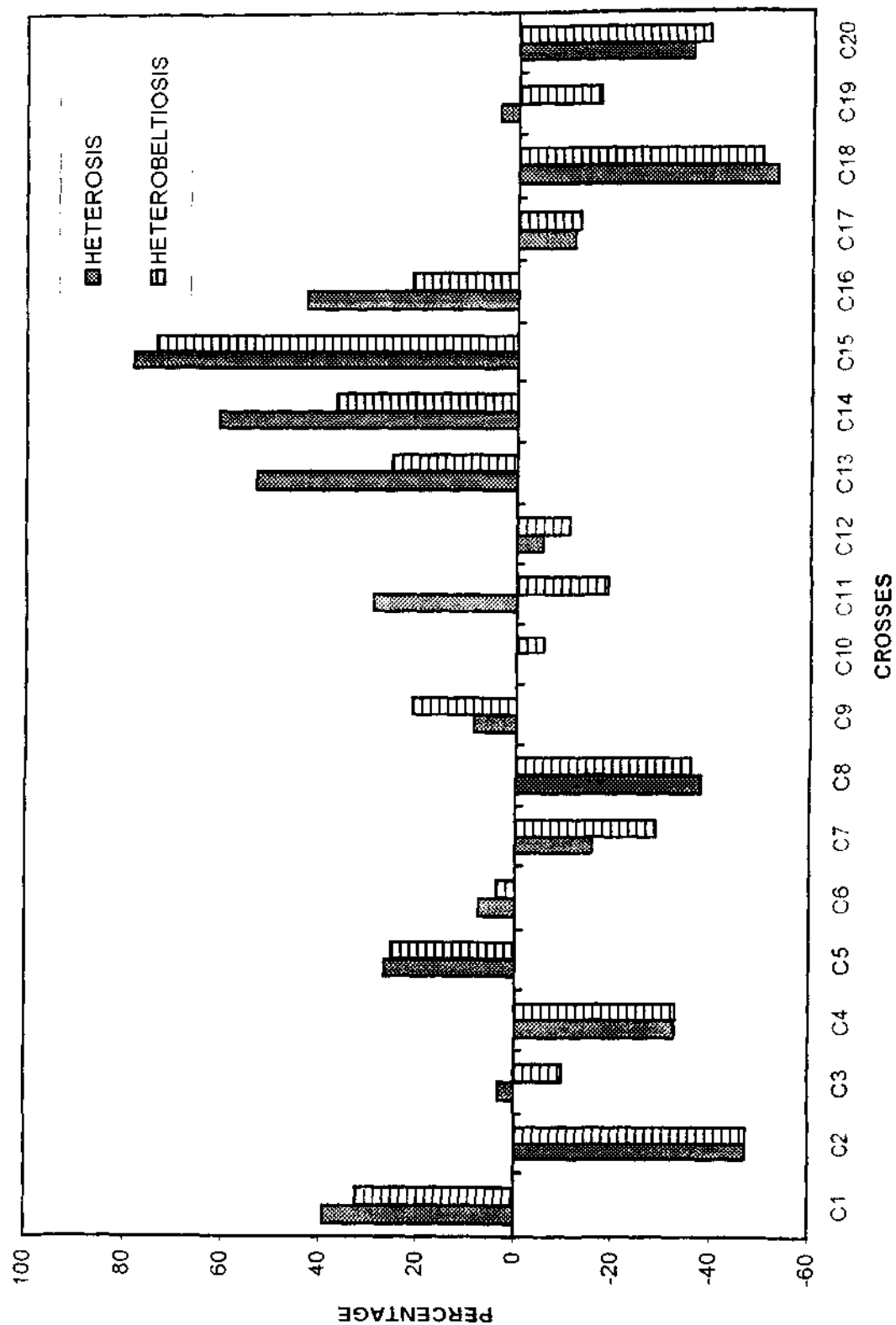
Variance due to 'gca' was greater than 'sca'. The ratio of general combining ability component of variance to total genetic variance was close to unity indicating the predominance of additive gene action for plant height. Similar results were obtained by Malik and Singh (1983), Singh (1987), Tawar and Sudhansu Jain (1988), Natarajan *et al.*, (1990), Naidu *et al.*, (1991) and Reddy *et al.*, (1992).

The line Pusa 9672 and the testers LGG 407 and WGG 2 were found good general combiners for this trait. The crosses LGG-460 x LGG-407 (L x H), LGG-460 x WGG-2 (L x H), Pusa-9672 x WGG-2 (H x H), Pusa-9672 x TARM-21 (H x B), LOCAL x LGG-407 (L x H) and LOCAL x TARM-21 (L x L) recorded significant 'sca' effects. The crosses showing high 'sca' effect with at least one good general combiner could produce desirable transgressive segregants in subsequent generations.

5.2.4 Pods per plant :

The cross combinations LGG-460 x LGG-407, MGG-341 x LGG-407, MGG-341 x TARM-21, Pusa-9672 x LGG-407, Pusa-9672 x WGG-2, Pusa-9672 x TARM-21 and Pusa-9672 x LGG-440 recorded significant and positive heterosis over both mid and better parents. Significant heterosis over both mid and better parents were also reported by Naidu and Satyanarayana (1993) and Patil *et al.*, (1999).

EXPRESSION OF RELATIVE HETEROSIS AND HETEROBELTIOSIS FOR PODS PER PLANT



Estimates of variance due to 'gca' were higher than 'sca'. The ratio of *general combining ability components of variance* to total genetic variance was found to be intermediate indicating the presence of both non-additive and additive gene action in controlling this character. These results are in confirmation with the findings of Malhotra *et al.* (1980), Raghuram Reddy and Sreeramulu (1982), Rao *et al.* (1984) and Bhadra and Akhtar (1993).

Pusa 9672 among lines and LGG 407 among testers were found to be good general combiners for pods per plant with high mean performance. The crosses LGG-410 x LGG-407 (L x H), LGG-460 x LGG-407 (L x H) LGG-460 x WGG-2 (L x L), Pusa-9672 x WGG-2 (H x L) and LOCAL x TARM-21 (L x L) recorded significantly higher 'sca' effects for pods per plant. The crosses LGG-410 x LGG-407, LGG-460 x LGG-407 and Pusa-9672 x WGG-2 involving one parent with desirable and significant 'gca' effect could give desirable segregants in subsequent generations. Since both additive and non-additive gene actions are governing this trait, hybridization followed by selection, inter-mating the selects and reselection may help to improve pods per plant.

5.2.5 Seeds per pod :

Maximum heterosis was recorded by cross LOCAL x TARM-21 for seeds per pod over both mid and better parent. Fourteen crosses LGG-410 x

LGG-407, LGG-410 x WGG-2, LGG-460 x LGG-407, LGG-460 x WGG-2, ~~LGG-460~~ x LGG-440, MGG-341 x LGG-407, MGG-341 x WGG-2, MGG-341 x TARM-21, MGG-341 x LGG-440, Pusa-9672 x LGG-407, Pusa-9672 x WGG-2, Pusa-9672 x TARM-21, LOCAL x LGG-407 and LOCAL x WGG-2 showed positive and significant heterosis for this trait over both mid parent and better parent. Heterosis for seeds per pod over better parent was reported by Singh and Jain (1970) Vikas Singh and Tyagi (1988), Tawar and Sudhansu Jain (1988) and Singh and Pathak (1992). Whereas, Ramanujam (1978), Ilyas Ahmed Malik *et al.*, (1988), Reddy (1998), Vikasparoda *et al.*, (1998) reported significant and positive heterosis over mid parent. While, Reddissekhar *et al.* (1994) and Hegde *et al.* (1996) reported heterosis over both better and mid parent for this trait.

The estimates of variance due to 'gca' were higher than 'sca' variance for number of seeds per pod. The ratio due to component of variance due to 'gca' to total genetic variance was close to unity indicating the presence of additive gene action in governing this trait. The present results obtained on the inheritance of seeds per pod is in agreement with the results of Ramanujam (1978), Raghu Rami Reddy (1980), Wilson *et al.*, (1985), Patel *et al.*, (1988), Natarajan *et al.*, (1989), Naidu *et al.*, (1991) Reddy *et al.*, (1992) and Mansuria and Joshi (1994).

The lines LGG 460 and MGG 341 and tester LGG 407 were found to be good general combiners for seeds per pod. The crosses LGG-410 x LGG-440 (L x L), LGG-460 x LGG-440 (H x L), MGG-341 x WGG-2 (H x L), Pusa-9672 x LGG-407 (L x H) and 19 (L x L) showed positive and significant 'sca' effects. The crosses with good 'sca' effects involving atleast one good general combiners as parent could produce desirable transgressive segregants in the subsequent generations. Progenies with more number of seeds per pod could be isolated in the advanced generations.

5.2.6 100 Seed weight :

The crosses LGG-410 x LGG-407, LGG-460 x LGG-407, LGG-460 x WGG-2, MGG-341 x LGG-407, Pusa-9672 x LGG-407, Pusa-9672 x WGG-2, Pusa-9672 x TARM-21, Pusa-9672 x LGG-440, LOCAL x LGG-407 and LOCAL x TARM-21 recorded positive and significant heterosis over mid parent and better parent for hundred seed weight. Vikas Singh and Tyagi (1988), Reddysekhar *et al.*, (1994) and Vikasparoda *et al.*, (1998) also reported positive heterosis over mid and better parents for hundred seed weight in greengram.

Estimates of variance due to 'gca' were higher than variance due to 'sca'. The ratio of general combining ability component of variance to total genetic variance was found to be intermediate indicating the presence of both

additive and non-additive gene action in governing hundred seed weight in the present study. These results are in agreement with the results obtained by Imrie *et al.* (1988), Malik and Singh (1986), Thimmappa *et al.* (1989), Reddissekhar *et al.* (1997), Bhadra and Akhtar (1993) and Saxena and Sharma (1993).

The line Pusa 9672 and testers LGG 407 and TARM 21 were found good general combiners for 100 seed weight. The crosses LGG-410 x LGG-407 (L x H), LGG-410 x WGG-2 (L x L), Pusa-9672 x TARM-21 (H x H), Pusa-9672 x LGG-440 (H x L), LOCAL x LGG-407 (L x H) showed significant 'sca' effects. The crosses with good 'sca' involving H x L or L x H general combiners as parents indicate the operation of both additive and non-additive gene action for this trait. Seed size can be improved by choosing breeding methods such as Diallel selective mating or bi-parental mating and advancing selected material through pedigree method.

5.2.7 Shoot nitrogen content :

Higher heterosis is recorded in the crosses LGG-410 x WGG-2 and LGG-410 x TARM-21 over both mid parent and better parent. Positive and significant heterosis was recorded in five crosses namely LGG-410 x LGG-440, MGG-341 x TARM-21, Pusa-9672 x TARM-21, LOCAL x LGG-407 and LOCAL x TARM-21.

Variance due to 'gca' was higher than variance due to 'sca'. The ratio of general combining ability component of variance to total genetic variance was found to be intermediate indicating the presence of both additive and non-additive gene action in controlling shoot nitrogen content. Whereas, Naidu (1989) reported additive gene action in controlling this trait. Among the lines LGG 410, LGG 460 and among the testers LGG 407 and WGG 2 were found good general combiners for shoot nitrogen content. The crosses LGG-410 x WGG-2 (H x H), LGG-460 x LGG-407 (H x H), MGG-341 x LGG-440 (L x L), Pusa-9672 x LGG-407 (L x H) and LOCAL x LGG-407 (L x H) recorded significant and positive 'sca' effects. The high 'sca' effects in the crosses involving 'H x H' general combiners indicates the importance of additive gene action whereas, crosses involving 'H x L' or 'L x L' combiners indicates the non-additive gene action. The cross LGG-410 x WGG-2 involving both parents with high 'gca' coupled with high heterosis could give desirable segregants in subsequent generations whereas, other crosses involving 'H x L' or 'L x L' general combiners as parents can be handled through recurrent selection procedures may help to improve this character, since non-additive gene action is involved in controlling shoot nitrogen content.

5.2.8 Seed protein :

High heterosis is recorded over both mid parent and better parent in cross LOCAL x WGG-2 followed by LGG-410 x LGG-407 and MGG-341 x LGG-407 for seed protein content. Tiwari and Ramanujam (1976), Quah *et al.*, (1983) reported positive heterosis for seed protein content in greengram.

Estimates of variance due to 'gca' were higher than 'sca' variance. The ratio of general combining ability component of variance to the total genetic variance was close to unity indicating the preponderance of additive gene action governing this character. These results are in confirmation with the results obtained by Tiwari and Ramanujam (1976) and Raghuram Reddy (1980). Where as Wilson *et al.* (1985) reported non-additive gene action in controlling this trait.

Among lines LGG 410 and among testers LGG 407 were found to be good general combiners for seed protein content. The crosses LGG-410 x LGG-440 (H x L), LGG-460 x TARM-21 (L x L), LOCAL x LGG-407 (L x H), LOCAL x WGG-2 (L x L) have exhibited positive and significant 'sca'. The cross LOCAL x WGG-2 with high 'sca' effect coupled with high mean and high heterosis could give desirable segregants in subsequent generations since non-additive gene action was found predominant in controlling the trait.

Simple pedigree method of breeding may be applied for the improvement of this trait.

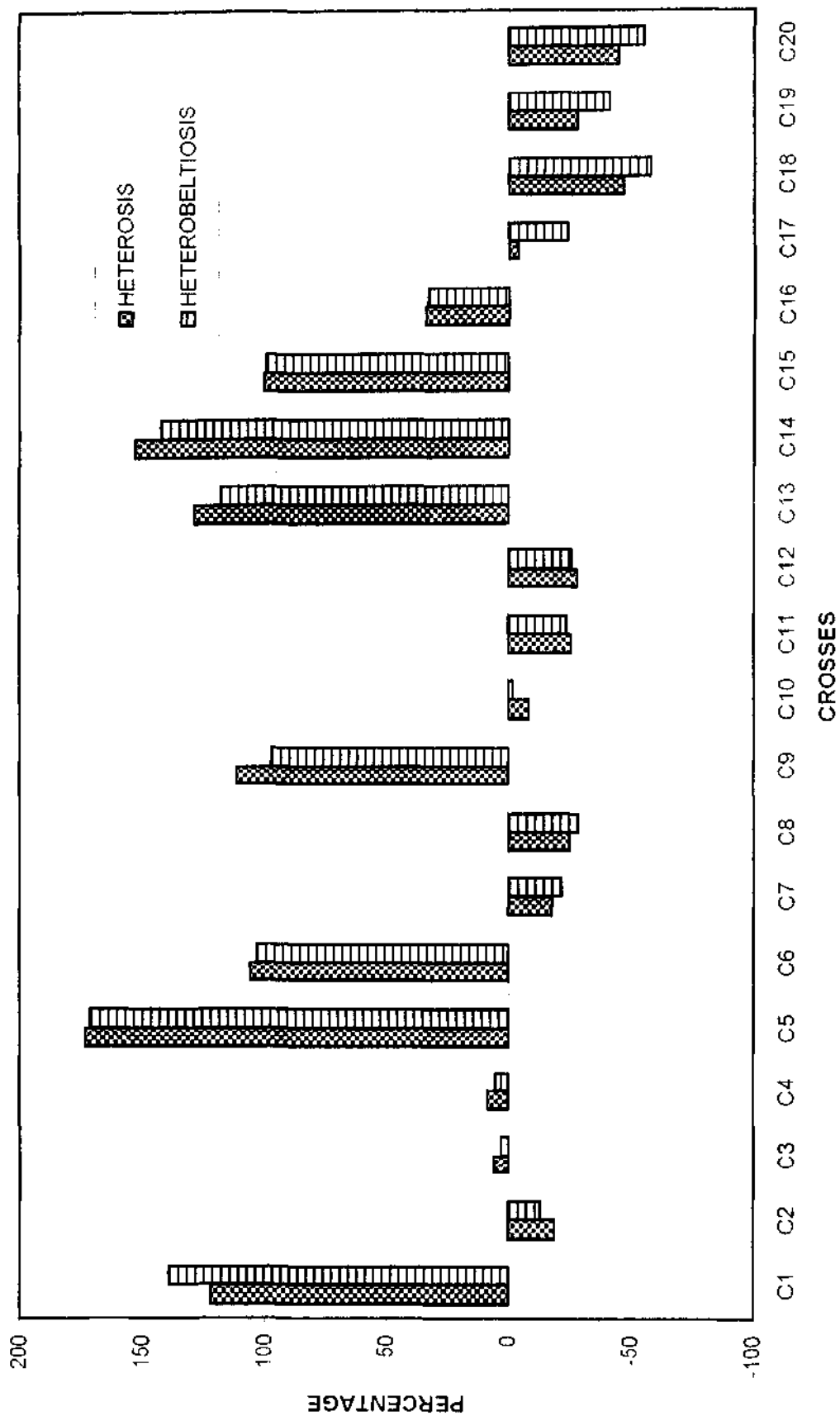
5.2.9 Shoot dry weight :

Maximum heterosis is recorded in LGG-460 x LGG-407 followed by Pusa-9672 x WGG-2 and Pusa-9672 x LGG-407 over mid and better parent. Five crosses have also recorded positive and significant heterosis over both mid and better parent. Similar results were observed by Naidu (1989) in greengram.

The estimates of variance due to 'gca' was greater than 'sca' variance. The ratio of general combining ability component of variance to total genetic variance was close to unity indicating the predominance of additive gene action in controlling shoot drymatter.

The lines LGG 460 and Pusa 9672 and the tester LGG 407 were found to be good general combiners for this trait. The crosses LGG-410 x LGG-407 (L x H), LGG-410 x LGG-440 (L x L), LGG-460 x LGG-407 (H x H), LGG-460 x WGG-2 (H x L), MGG-341 x LGG-407 (L x H), Pusa-9672 x WGG-2 (H x L), Pusa-9672 x TARM-21 (H x L), LOCAL x TARM-21 (L x L) and LOCAL x LGG-440 (L x L) recorded significant 'sca' effects. Since additive gene effect is predominant in controlling this trait, crosses LGG-460

EXPRESSION OF RELATIVE HETEROSIS AND HETEROBELTIOSIS FOR SHOOT DRY WEIGHT PER PLANT

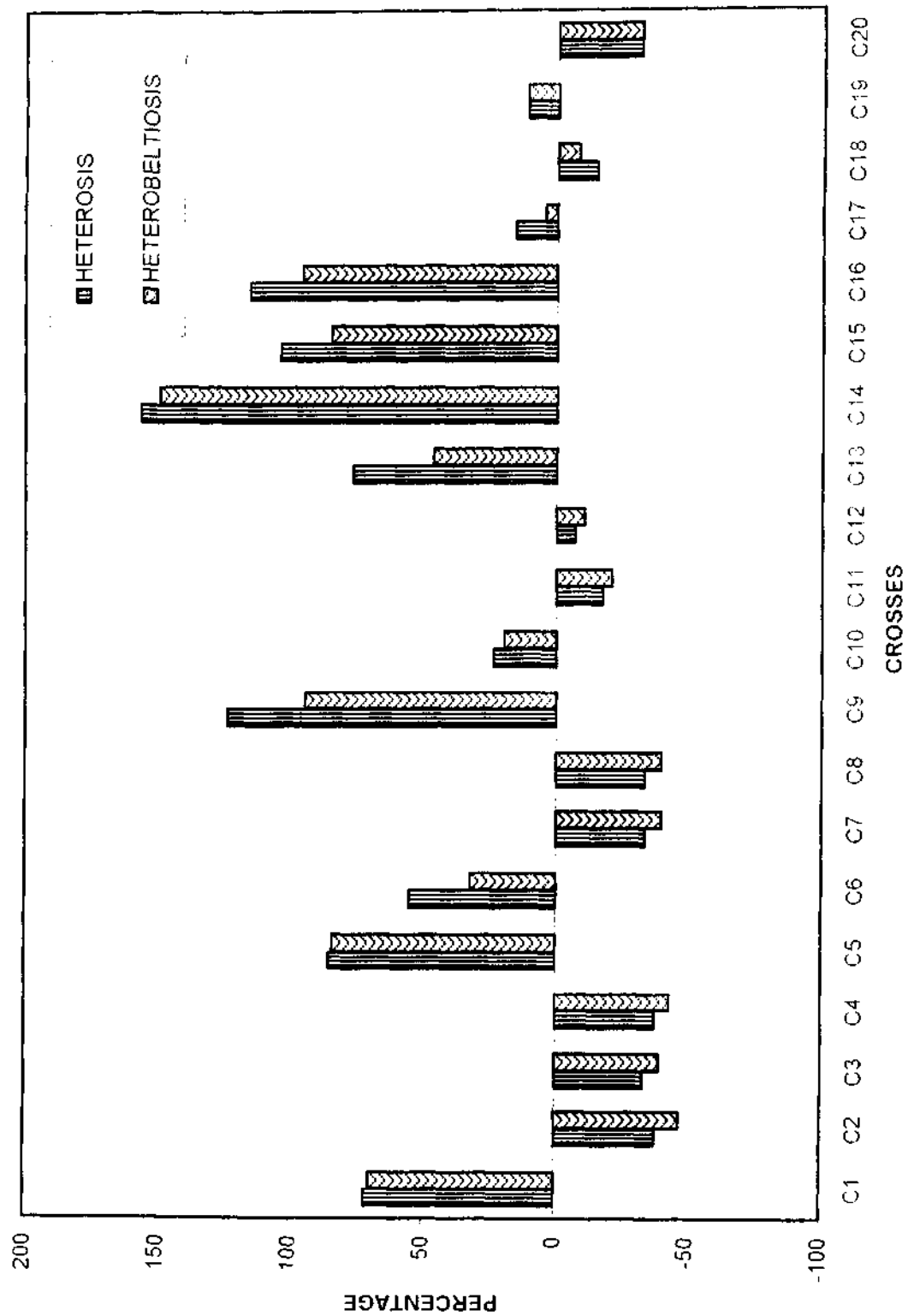


x WGG-2, Pusa-9672 x WGG-2 and Pusa-9672 x TARM-21 may give good transgressive segregants and the LGG-460 x LGG-407 may be handled through pedigree selection for isolation of genotypes with more shoot dry weight.

5.2.10 Seed yield per plant :

Maximum heterosis for seed yield per plant over both mid parent and better parent was recorded in Pusa-9672 x WGG-2 followed by MGG-341 x LGG-407, Pusa-9672 x LGG-440, Pusa-9672 x TARM-21 and LGG-460 x LGG-407. In addition to the above seven crosses, LGG-410 x LGG-407, LGG-460 x LGG-407, LGG-460 x WGG-2, MGG-341 x WGG-2, Pusa-9672 x LGG-407, LOCAL x LGG-407 and LOCAL x TARM-21 have also recorded positive and significant heterosis over both mid parent and better parent. Heterosis for seed yield over mid parent in greengram was also reported by Raghuram Reddy (1980), Raghuram Reddy and Sreeramulu (1982), Vikasparoda and Singh (1998), Reddy (1998), Patil *et al.* (1999), while Thimmappa (1987), Singh and Pathak (1992), Patil *et al.*, (1992) and Patil *et al.*, (1999) reported positive and significant heterosis over better parent for this trait. The crosses LGG-460 x LGG-407, MGG-341 x LGG-407, Pusa-9672 x WGG-2, Pusa-9672 x TARM-21 and Pusa-9672 x LGG-440 recorded significantly higher heterosis for seed yield coupled with high mean values. These crosses also recorded high heterosis for yield component

EXPRESSION OF RELATIVE HETEROSIS AND HETEROBELTIOSIS FOR YIELD PER PLANT



characters like pods per plant, seeds per pod, 100 seed weight and shoot dry weight per plant.

Estimates of 'gca' variance was greater than the variance due to 'sca'. The ratio of general combining ability component of variance to total genetic variance was found to be intermediate indicating the presence of both additive and non-additive components of gene action in governing this trait. This is in agreement with the findings of Singh and Jain (1971), Rao *et al.*, (1984), Raghuram Reddy and Sreeramulu (1982), Chowdhury (1986), Patel *et al.*, (1988), Tawar and Sudhansu Jain (1988), Natarajan *et al.*, (1990), Saxena and Sharma (1993), Naidu *et al.* (1991) and Saxena and Sharma (1992). However, Wilson *et al.*, (1985), Malik and Singh (1986), Imri *et al.*, (1988) and Holkar (1994) reported the preponderance of additive gene action for this trait. Similarly, Patel *et al.*, (1988), Natarajan *et al.*, (1989), Pathak *et al.*, (1990), Tiwari *et al.*, (1993), Reddisekhar *et al.*, (1994), Poornachandra Rao (1995) and Aher and Dahat (1999) reported non-additive gene action for seed yield in greengram.

Among the lines Pusa 9672 and among the testers LGG 407 were found to be good general combiners for seed yield per plant. The tester LGG 407 was found to be good general combiner for all the yield component characters in the present study. The line Pusa 9672 was also found to be

good general combiners for all the characters studied except for seeds per pod, shoot nitrogen content and seed protein content. The lines MGG 341 and LGG 460 are good general combiners for seeds per pod. The crosses LGG-410 x LGG-407 (L x H), LGG-460 x LGG-407 (L x H), LGG-460 x WGG-2 (L x L), MGG-341 x LGG-407 (H x H), Pusa-9672 x WGG-2 (H x L), Pusa-9672 x TARM-21 (H x L), Pusa-9672 x LGG-440 (H x L), LOCAL x TARM-21 (L x L) recorded significant 'sca' effects along with high heterosis and mean. The cross combinations with significant 'sca' involving H x H general combiners may be advanced through pedigree method of breeding for improving yield per plant. While, the crosses with L x H or L x L combinations may be handled through biparental or diallel selective mating or any other form of recurrent selection in the early generations followed by single plant selections to exploit both additive as well as non-additive gene action. Transgressive segregants may be obtained from these crosses, if additive gene system present in the good general combiner and complementary epistatic present in the other act in the same direction.

An over view of the results obtained from combining ability study reveals that different types of gene actions are involved in the expression of different yield components and yield.

S. No.	Character	Nature of gene action	Ratio of genetic components of variance $\frac{2\sigma^2_{gca}}{2\sigma^2_{gca} + \sigma^2_{sca}}$
1.	Days to 50% flowering	Additive and Non-additive	0.78
2.	Days to maturity	Additive and Non-additive	0.64
3.	Plant height	Additive	0.84
4.	Pods per plant	Additive and Non-additive	0.77
5.	<i>Seeds per pod</i>	<i>Additive</i>	0.87
6.	100 seed weight	Additive and Non-additive	0.76
7.	Shoot nitrogen	Additive and Non-additive	0.73
8.	Seed protein	Additive	0.90
9.	Shoot dry weight	Additive	0.82
10.	Seed yield per plant	Additive and Non-additive	0.78

5.3 TRIPLE TEST CROSS ANALYSIS :

The exploitation of genetic variability in any crop depends upon amount of variability present viz., quantity of fixable and non-fixable variation and mating system of a crop species. The triple test cross analysis provides reliable information about the nature and magnitude of gene action present in the material. The triple test cross analysis provides not only an efficient estimates of dominance but also an unambiguous test for epistasis.

Among the existing genetic models used to detect / estimate the different components of continuous variation, the triple test cross method is most efficient (Mather and Jinks, 1982). It has wider application as it can be used to investigate both segregating and non-segregating populations arising from different populations. (Kersey and Jinks, 1968 and Jinks and Virk, 1977). However this type of analysis was done only in few crops like wheat, chickpea, field pea, rice, barley and mustard.

The results of the present study revealed the presence of epistatic gene action for all the characters studied. However, the non-significant 'i' type of epistasis for days to 50% flowering in cross 2 (LGG-460 x WGG-2), 3 (Pusa-9672 x LGG-440) and 4 (Local x TARM-21) ; plant height in cross 1 (LGG-410 x LGG-407) and seed yield per plant in cross 2 (LGG-460 x WGG-2) indicates that overall 'i' type epistasis is relatively a minor component for these characters. However, the 'i' type epistasis is important than the 'j' and 'l' type in majority of the cases.

Since greengram is a self pollinated crop 'i' type epistasis can be utilised in evolving homozygous lines by following standard hybridization and selection procedures. Where as, 'j' (additive x non-additive) and 'l' (non additive x non-additive) type of epistasis can be capitalised by adopting hybridization followed by selection and intermating superior genotypes which

may throw some superior segregants in the further generations. Similar results were reported by Virk *et al.*, (1983) in pea indicating that epistasis was found significant for all the characters except for all plant height, first pod bearing node and seeds per pod. Singh *et al.*, (1986) and Singh *et al.*, (1988) reported that over all epistasis 'i' type was the major component of epistasis in pea. The 'j' and 'l' type of epistasis was reported for seed yield in chick pea by Sirohi and Gupta (1989). Vijayakumar *et al.*, (1995) in rice reported the importance of 'j' and 'l' type of epistasis.

The present study indicate the importance of additive and dominance genetic components in all the crosses for the characters studied (Table 4.12). The degree of dominance further revealed the predominant nature of additive genetic component for almost all the characters except for days to 50% flowering in cross 2 (LGG-460 x WGG-2) for pods per plant ; cross 3 (Pusa-9672 x LGG-440) for shoot dry weight and seed yield per plant in cross 3 (Pusa-9672 x LGG-440) where the degree of dominance was more than unity indicating predominant role of dominant gene action. Similarly significant additive and dominance components with predominant role of additive genetic variations was reported in chick pea by Singh *et al.*, (1987) in field pea and Singh *et al.*, (1988), reported the predominant role of additive genetic component for most of the characters studied.

The correlation coefficient 'r' values were not significant for the characters studied in the present study (Table 4.13) indicating that there is no direction of dominance for other characters except for seed yield in cross 3 (Pusa-9672 x LGG-440). Where it is positive and significant, indicating the decreasing types of genes are dominant. Singh *et al.*, (1988) reported that in field pea the directional element was found to be significant for seed yield, plant height, days to flowering, 100 seed weight segregating directional nature of dominance.

The triple test cross analysis in greengram made in the present study revealed significant 'i' type epistasis suggesting due consideration should be given for epistatic gene action while formulating breeding programme. Further, the analysis reveals that the additive as well as dominance components of variation were significant with predominant role of 'D' component than 'H' indicating the most of the characters in greengram are largely governed by additive and non-additive gene action. Similar results were obtained by Vijayakumar *et al.*, (1996) in rice.

In line x tester analysis, the characters plant height, seeds per pod, seed protein and shoot dry weight exhibited additive gene action while days to 50% flowering, days to maturity, pods per plant, 100 seed weight, shoot nitrogen and seed yield per plant were predominantly governed by both additive and non-additive gene action.

In the triple test cross analysis all the seven characters studied showed epistatic gene action. Further it also indicated that the additive genetic component was more important than dominant component for all the traits except for days to 50% flowering and pods / plant in cross 2 (LGG-460 x WGG-2), pods per plant, shoot dry weight and seed yield in cross 3 (Pusa-9672 x LGG-440) where dominance component was more important than the additive component.

5.4 CHARACTER ASSOCIATIONS :

Yield is a complex and dependent character, which is highly influenced by environment. Hence, selection based on yield alone will limit the improvement whereas, the yield component characters are less complex in inheritance and less influenced by the environment. Thus, effective improvement in yield may be brought through selections in yield components which show close association with yield. Unfavourable associations between the desired attributes under selection may limit the genetic advance. Hence, a knowledge on the association between yield and yield components is essential for efficient selection in any crop improvement.

In the present investigation genotypic and phenotypic correlations between yield and yield component characters were estimated. In general, genotypic correlations were higher than phenotypic correlations. The yield is

positively and significantly correlated at both genotypic and phenotypic level with days to 50% flowering, days to maturity, plant height, pods per plant, seeds per pod, 100 seed weight, seed protein and shoot dry weight. The present findings are in agreement with the results obtained by earlier workers in which yield was positively correlated with days to flowering (Raghuram Reddy (1980), Upadhyaya (1980), Lill *et al.*, (1984), Laxmaiah *et al.*, (1989), Naidu (1993) and Yaqoob *et al.*, (1998)) ; days to maturity (Misra and Sahu (1985), Satyam *et al.*, (1989), Naidu *et al.*, (1991), Reddy *et al.*, (1994), Kumar *et al.*, (1995), Sarma and Talukdar (1996), Hiram Kumar (1996) and Shantipriya (1997)), Plant height, Reddissekhar (1992), Naidu (1993), Ranganayaki and Sreerangaswamy (1993), Reddy *et al.*, (1994), Shantipriya (1997) and Jiji Joseph and Santhosh Kumar (1999)) ; Pods per plant ((Borah and Hazarika (1995), Gil and Verma (1995), Hegde *et al.*, (1996), Byregowda *et al.*, (1997), Shantipriya (1997), Ramaswamy and Jehangir (1998), Sabahgpour *et al.*, (1998) and Vikas Singh and Tyagi (1998)); seeds per plant (Borah and Hazarika (1995), Hegde *et al.* (1996), Shantipriya (1997) and Vikas Singh and Tyagi (1998) ; 100 seed weight (Kumari and George (1985), Naidu (1989), Ahuja and Chowdhury (1991), Holkar and Rant (1992), Pundir *et al.*, (1992), Singh and Petak (1993), Borah and Hazarika (1995), Gill and Verma (1995), Kumar *et al.*, (1995), Sarma and Talukdar (1996) and Ramaswamy and Jehangir (1998)). Seed protein (Raghurami Reddy (1980), Thandapani and Rao (1984), Rosaiah (1985) ; Bhadre *et al.*, (198) and Sajijo

et al. (1980) ; Shoot nitrogen (Naidu (1989) and Shoot dry weight (Babu *et al.* (1997).

Strong genotypic association was observed between yield and days to maturity, plant height, pods per plant, seeds per pod, 100 seed weight and shoot dry weight, plant height is significantly and positively correlated with pods per plant, 100 seed weight and shoot dry weight. Pods per plant had strong positive association with 100 seed weight, seed protein and shoot dry weight. 100 seed weight had positive and significant association with days to flowering, days to maturity, seeds per pod and shoot dry weight. seed protein is significantly correlated with days to flower, pods per plant, seeds per pods and shoot nitrogen. Shoot dry weight had a positive significant correlation with seed protein both at genotypic and phenotypic level.

The present investigation revealed that days to flowering, days to maturity, plant height, pods per plant, seeds per pod, 100 seed weight, seed protein and shoot dry weight exhibited significant positive association with seed yield and also among themselves at both genotypic and phenotypic level indicating simultaneous selection for these traits might bring an improvement in seed yield in greengram.

5.5 PATH COEFFICIENT ANALYSIS :

Correlation simply measures mutual associations without considering the causation while, path coefficient analysis provides an effective means of disclosure of direct and indirect causes of association and permits a critical examination of specific forces acting to produce a given correlation and measures the relative importance of each causal factor.

In the present investigation shoot dry weight was found to have maximum direct positive effect on seed yield followed by pods per plant, seeds per pod, days to maturity and 100 seed weight. Shoot dry weight, pods per plant, seeds per pod, days to maturity and 100 seed weight showed positive significant correlation with seed yield per plant.

The direct positive effect of pods per plant on seed yield was reported by Naidu *et al.*, (1994), Singh *et al.*, (1995), Veerabadhiran and Jehangir (1995), Byregowda *et al.*, (1997), Ganeshram *et al.*, (1997) Shantipriya (1997) and Ramaswamy and Jehangir (1998). The direct positive effect of days to maturity (Patel (1991), Pathak and Patel (1993), Babu Rao (1994), Reddy *et al.*, (1994) and Yaqoob *et al.*, (1997), seeds per pod, Holkar and Raut (1992), Geetha *et al.*, (1993), Reddy *et al.*, (1994), Prasanna Rajesh (1995), Byregowda *et al.*, (1997) and Shantipriya (1997) ; 100 seed weight (Ahuja and Chowdhury (1991), Holkar and Raut (1992), Pundir *et al.*, (1992), Geetha

et al., (1993), Kumar *et al.*, (1995), Byregowda *et al.*, (1997) and Sabaghpour *et al.*, (1998) on seed yield were reported by several workers in greengram. The indirect effects of these characters via.. shoot dry weight, pod per plant and seeds per pod and 100 seed weight were positive.

Hence, selection for shoot dry weight per plant, pods per plant, seeds per pod, days to maturity and 100 seed weight would be fruitful in increasing the yield potential in greengram. Selection based on more shoot dry weight may reflect with high yields of green gram under rice fallows. Because, plants with more biomass cover the gaps quickly and suppress the weeds and conserve moisture.

Chapter VI

Summary

CHAPTER - VI

6. SUMMARY

Greengram (*Vigna radiata* (L) Wilczek), is an important pulse crop of Andhra Pradesh grown all round the year in different farming situations including rice based cropping systems. Rice yields in South India and more in Pennar delta, Andhra Pradesh are stagnating in recent years due to continuous monocropping. Rice is being cultivated round the year in all the three seasons, continuous monocropping of rice and heavy dependency on chemical fertilizers have depleted in soil fertility in this region and the rice yields are declined or stagnated with high cost of cultivation. Introduction of a legume crop like greengram in rice fallows, not only helps in improving the soil fertility but also the productivity of the system as a whole. The constraints of pulses production in rice fallows include soil compactness, excessive moisture at the time of sowing, weeds, poor plant stand, slow initial growth and terminal moisture stress. Hence, the present investigation was taken up to identify suitable mungbean plant type for cultivation under late rice fallows of pennar delta of Andhra Pradesh. To achieve this, it is essential to understand genetic nature of the mungbean plant architecture for rice fallows genetic variability, heritability, genetic advance, heterosis, gene action governing the traits and their influence on yield. Therefore an attempt has been made in the present study to understand the genetic nature of characters

analysis utilizing 20 crosses derived from line x tester (4 x 5) programme and triple test cross analysis. Data on days to 50% flowering, days to maturity, plant height, pods per plant, seeds per plant, 100 seed weight, shoot nitrogen content (%), seed protein content (%), shoot dry weight (g) and seed yield per plant (g) were recorded on nine parents and 20 F_1 's under rice fallows for estimating the combining ability effects, variability, heritability, genetic advance, correlation coefficients and path coefficients. Triple test cross analysis was also carried out with four selected combinations viz., 1. LGG-410 x LGG-407, 2. LGG-460 x WGG-2, 3. Pusa-9672 x LGG-440 and 4. LOCAL x TARM-21 to precisely elucidate the nature of epistatic gene action for seven characters viz., days to 50% flowering, days to maturity, plant height (cm), pods per plant, 100 seed weight, shoot dry weight, seed yield per plant.

Wider genetic variability was recorded for plant height, pods per plant, shoot dry weight and seed yield per plant. High variability, heritability coupled with high genetic advance over mean observed for plant height, pods per plant, shoot dry weight and seed yield indicates that these traits can be improved by adopting simple selection methods like pedigree method of breeding.

Significant heterosis over mid and better parent was observed in the hybrids for all the characters studied. Higher percentage of heterosis over better parent coupled with high mean performance for pods per plant, shoot dry weight, seed yield per plant was observed in crosses, C5 (LGG-460 x LGG-407), C9 (MGG-341 x LGG-407), C14 (Pusa-9672 x WGG-2), C15 (Pusa-9672 x TARM-21) and C16 (Pusa-9672 x LGG-440).

Combining ability analysis revealed that plant height, seeds per pod, seed protein and shoot dry weight registered the ratio of general combining ability component of variance to total genetic variance ($2 \sigma^2_{gca} / 2 \sigma^2_{gca} + \sigma^2_{sca}$) close to unity indicating the predominance of additive gene action governing these traits while, the ratio is intermediate for the days to flowering, days to maturity, pods per plant, 100 seed weight, shoot nitrogen content and seed yield per plant indicating the importance of both additive and non-additive gene action in controlling these traits. The traits governed by additive genes can be improved through breeding methods involving simple selection procedures like pedigree method. Whereas, the traits governed by both additive and non-additive genes can be improved through recurrent selection or biparental mating in early stages followed by selection. The line Pusa-9672 and the tester LGG-407 were found to be good general combiners for shoot dry weight and seed yield per plant. The tester LGG-407 was also found to be good general combiner for all the yield component

characters. The line Pusa-9672 was also found to be good general combiner for all the characters studied except for seeds per pod, shoot nitrogen and seed protein content.

The cross combinations C5 (LGG-460 x LGG-407), C9 (MGG-341 x LGG-407), C14 (Pusa-9672 x WGG-2), C15 (Pusa-9672 x TARM-21) and C16 (Pusa-9672 x LGG-440) and C19 (LOCAL x LGG-440) showed good specific combining ability for shoot dry matter and seed yield combined with high mean values and heterosis. Breeding procedures involving cyclic hybridization which can capitalize both additive and non-additive gene actions and to isolate transgressive segregants can be adopted for the above mentioned crosses.

Triple test cross analysis revealed the presence of epistatic gene action for all the characters studied in all four crosses. Homozygote x homozygote ('i' type) and homozygote x heterozygote and heterozygote x heterozygote ('j' and 'l' types) epistasis are important. However, the 'i' type of epistasis was more predominant than 'j' and 'l' type for majority of the traits. Triple test cross analysis also further revealed the importance of both additive and dominance components for all the characters in all the four crosses. The degree of dominance indicated the predominant role of additive component except for days to 50% flowering and pods per plant in C2 (LGG-460 x

WGG-2), pods per plant, shoot dry weight and seed yield per plant in C3 (Pusa-9672 x LGG-440). The correlation coefficient 'r' value was not significant indicating that there is no direction of dominance for the traits studied except seed yield per plant in the cross C3 (Pusa-9672 x LGG440).

Association analysis between yield and yield component traits and among themselves revealed significant correlations at both genotypic and phenotypic level. Correlations between yield and plant height, pods per plant, 100 seed weight, seeds per pod, and shoot dry matter were stable and positive. These traits also exhibited strong and positive associations among themselves. Thus, simultaneous selection for these traits might bring an automatic improvement in seed yield.

Genotypes with more shoot dry weight may establish quickly and cover the gaps under rice fallows. This may suppress the weeds and conserve moisture as well. Selection based on the shoot dry weight may result with a high yield genotypes suitable for rice fallow.

Path coefficient analysis indicated that shoot dry weight has maximum positive direct effect on seed yield followed by pods per plant, seeds per pod, days to maturity and 100 seed weight. The indirect effects of the characters viz., shoot dry weight, pods per plant seeds per pod and 100 seed weight

were positive. Therefore, it is suggested that emphasis should be give to shoot dry weight, pods per plant 100 seed weight and seeds per pod while making selections to improve the seed yield in greengram.

From the present study, it is evident that mungbean genotypes having higher shoot dry weight i.e., higher biomass are suitable for rice fallows. A genotype with fast initial growth, higher canopy (Tall) may lead to higher shoot dry weight and yields better under rice fallows.

Literature Cited

LITERATURE CITED

- Aher R P and Dahat D V 1999 Genetics of Quantitative Characters in Mungbean J. Mahrastra Agric. Univ. 24(3): 265-267.
- Ahuja S L 1980 Diallel analysis in F_2 generation of greengram (*Vigna radiata* (L.) Wilczek). Thesis Abstracts 6: 110-111.
- Ahuja S L and Choudhury R K 1991 Correlation and path coefficient analysis in greengram. Agricultural Science Digest 11: 223-226.
- Allard R W 1960 Principles of Plant Breeding John Wiley and Sons Inc New York pp. 485.
- Anuradha T Krishna Murthy B Subrmanyam D and Rama Kumar P V 1991 Studies on variability, heritability and Genetic advance of yield and some physical traits in blackgram (*Vigna mungo*) The Andhra Agricultural Journal 38(2&3): 197-200.
- AOAC 1970 Official methods of analysis. The association of official agricultural chemist Washington DC.
- Appalaswamy A 1997 Genetic divergence stability and combining ability studies in mungbean (*Vigna radiata* (L.) Wilczek) Ph.D. Thesis, Acharya N.G. Ranga Agricultural University, Hyderabad.
- Asana R D 1968 In quest of yield. Indian Journal of Plant Physiology 11: 1-10.

- Babu Rao K 1994 Genetic divergence in greengram (*Vigna radiata* L.) Wilczek) M.Sc. (Ag.) Thesis, Andhra Pradesh Agricultural University, Hyderabad, India.
- Babu R C Muralidharan V Rathinaswamy R and Sreerangaswamy S R 1997 Relative importance of drymatter accumulation and harvest index to yield in greengram cultivars. Madras Agricultural Journal 86(6): 317-319.
- Baisakh B Mohapatra B K and Misra R C 1989 Variability correlation and path coefficient analysis of mutant lines of greengram. The Andhra Pradesh Journal 36(4): 282-286.
- Becker W A 1975 Manual of quantitative genetics. Student Book Corp., Pullaman, Washington, U.S.A.
- Bhadra S Akhtar M I Shill M and Osman K T 1987 Variation in seed protein of mungbean and its relation to seed yield and size. TYIS News, Tiawan 2: 2-3.
- Bhadra S K and Akhtar M I 1993 Combining ability analysis of seed yield and its morphological components in mungbean (*Vigna radiata* (L.) Wilczek). Chittagong University Studies - Part-II Science (Bangladesh) 19: 91-96.
- Bhadra S Akhtan M I Shill M and Osman K T 1987 Variability correlation and path coefficient analysis in mutant lines of greengram. The Andhra Pradesh Journal 36(4): 282-286.

- Bhargava P D Johri J N Sharma S K and Bhat B N 1966 Morphological and genetic variability in greengram. Indian Journal of Genetics and Plant Breeding 26: 370-373.
- Bhaumik P K and Jha A R 1976 Estimation of physiological relationship through path coefficient analysis in mungbean (*Phaseolus aureus* Roxb.) Indian Agriculturist 20: 1-10.
- Boomikumaran P and Rathinam M 1981 Correlation and path analysis in greengram. Madras Agricultural Journal 68: 643-647.
- Borah H K and Hazarika M H 1995 Genetic variability and character association in some exotic collection of greengram. Madras Agricultural Journal 82(4): 268-271.
- Burton G W 1952 Quantitative inheritance in grasses. Proceedings of the sixty International Congress 277-283.
- Byregowda M Chandraprakash J Babu C S J and Ruraswamy P 1997 Genetic variability and interrelationships among yield and yield components in greengram (*Vigna radiata* (L.). Crop Research, Hisar 13(2): 361-368.
- Chahal G S and Jinks J L 1978 A general method of detecting additive, dominance and epistatic variation that inbred lines can generate using a single tester. Heredity 40: 117-125.
- Chahal G S and Singh T H 1974 Application of different mating designs to determine gene action in *Gossypium arboreum* L. I Diallel versus simple test cross. Crop Improvement 1: 61-71.

- Chhabra A K Kharb R P S and Singh V P 1991 Simple and multiple correlation analysis between yield and its component traits in mungbean. Indian Journal of Pulses Research 104(1): 94-96.
- Chandel K P S Joshi B S and Pant K C 1973 Yield in mungbean and its components. Indian Journal of Genetics and Plant Breeding 33: 271-276.
- Chowdhury R K, Singh and Kakar S K 1982 Correlation coefficients and selection indices in mungbean (*Vigna radiata* (L.) Wilczek). Pulse Crops New Letter 2: 22-24.
- Chowdary J B and Chowdhury R K and Kakar S N 1971 Studies on the genetic variability in mung (*Phaseolus aureus*). Journal of Research, Punjab Agricultural University 8(2): 169-172.
- Chowdhury R K 1986 Combining ability analysis for seed yield and its components in mungbean. Crop Improvement 13: 95-97.
- Combstock R F and Robinson H F 1952 ESTimation of average dominance of genes. In: J.W. Gowen (Ed.) Heterosis 494-516. IOWA State College Press, Ames, IOWA, USA.
- Das S Y Supriyo Chakraborty Chakraborty S 1998 Genetic variation for seed yield and its components in greengram (*Vigna radiata* (L.) Wilczek) Advances in Plant Sciences 11: 1, 271-273.
- Deshmukh R B and Manjare M R 1980 Combining ability in mungbean (*Vigna radiata* (L.) Wilczek). Legume Research 3: 97-101.

Dewey D R and Lu K H 1959 Correlation and path coefficient analysis in components of crested wheat grass seed production. Agronomy Journal 51: 513-518.

Dhillan B S 1975 The applicability of partial diallel crosses in plant breeding A review crop improvement 1-7.

Directorate of Economics and Statistics 1993 Andhra Pradesh Statistical Abstract.

Falconer D S 1967 Introduction to quantitative genetics Oliver and Boyd Ltd. London W.I pp. 365.

Frakes R V Davis R L and Patterson F L 1961. The breeding behaviour of yield and related variables in Alfalfa II a - Association between characters. Crop Science: 207-209.

Fisher R A and Yates F 1967 Statistical tables for biological, Agricultural and Medical Research. Oliver and Boyd London pp. 46-63.

Geetha S Kirubakaran A P M Nataraja Moorthy K Palaniswamy S and Abdul Kareem 1993 Path analysis in greengram (*Vigna radiata* (L) Wilczek) genotypes in rice fallow situations. Crop Research 6: 557-559.

Ganesh Ram S Rajkumar R Gomathi Narayanan P and Rathnaswamy R 1997 Variability and association analysis of yield components in greengram. 84(8): 469-470.

- Gill J S Verma M M Gumber R K and Singh B 1995 Character association in mungbean lines derived from three inter varietal crosses in mungbean. *Crop Improvement* 22(2): 255-260.
- Giriraj K and Vijayakumar S 1974 Path coefficient analysis of yield attributes in mungbean. *Indian Journal of Genetics and Plant Breeding* 34: 27-30.
- Giriraj K 1973 Natural variability in greengram (*Phaseolus aureus* Roxb.) *Mysore Journal of Agricultural Sciences* 7: 184-187.
- Grafius J E 1956 Components of yield in oats. A geometric interpretation. *Agronomy Journal* 48: 419-423.
- Griffing 1956 Concept of general and specific combining ability in relation to diallel crossing system. *Australian Journal of Biological Sciences* 9: 963-93.
- Gulam Hassan Raizuddin Saeedual Hassan Hidayat Ur Rahman and Fifi Mohammad 1995 Heritability estimates of post-harvest parameters in mungbean (*Vigna radiata* L.) genotypes. *Sarhad Journal of Agriculture* 11(4): 471-475.
- Gupta S N Lal S and Rai T 1982 Correlations and path analysis in mungbean (*Vigna radiata* (L.) Wilczek). *Haryana Agricultural University Journal of Research* 12: 281-291.
- Gupta S N Arora N D Singh R K and Chowdhury B D 1978 Combining ability and gene action in mungbean. *Indian Journal of Heredity* 10: 59-66.

- Gupta M P and Singh R B 1969 Variability and correlation studies in greengram (*Phaseolus aureus* Roxb.). Indian Journal of Heredity 10: 59-66.
- Gupta S K Bhatia V S Singh D N and Ganguly S B 1989 Genotype variation and relationship of specific leaf weight with photosynthesis in chickpea (*Cicer arietinum* L.) Indian Journal of Plant Physiology 32: 224-227.
- Hanson G H Robinson H F and Comstock R E C 1956 Biometrical studies of yield on segregating population of Koran Lespedz. Agronomy Journal 47: 314-318.
- Hegde V S Parameshwarappa R and Goud T V 1996 Association analysis in F_2 populations of inter-varietal crosses in mungbean. Legume Research 19(2): 107-110.
- Hiran Kumar P 1996 Studies on combining ability and variability in F_2 generation 7 x 7 diallel set of greengram (*Vigna radiata* (L.) Wilczek). M.Sc. (Ag.) Thesis submitted to Andhra Pradesh Agricultural University, Hyderabad.
- Holkar S and Raut N D 1992 Character association and path analysis in greengram. Journal of Maharashtra Agricultural Universities 17: 335-336.
- Ilhamuddin Tajammal M A Inayatullah 1989 Genotypic and phenotypic variability in yield and other quantitative characters in mungbean (*Vigna radiata* L.) Sarhad Journal of Agriculture 5(1): 69-71.

Ilyas Ahamd Malik Yousaf Ali and Mohammed Saleem 1988 In corporation of tolerance to mungbean yellow mosaic virus from local germplasm into exotic large seeded mungbean.

Imrie B C Ratchift D and Eerens J P J 1988 Analysis of gene action in cross behaviour in early and late maturity in mungbeans. Proceedings of Second Symposium on mungbean, Bangkok, Thailand 146-151.

Jain H K and Mehre K L 1980 Evolution adaptation relationship and uses of the species of *Vigna* cultivated in India. In advances in legume science. eds. R J Summer field and A H Bentings Proc. International Legume Conference 1978. Vol. 1 pp. 459-68 Royal Botanic Gardens Kew.

Jiji Joseph and Santosh Kumar A V 1999 Character association and cause effect analysis in some F_2 population in gram (*Vigna radiata* (L.) Wilczek Legume Research, 22(2): 99-103.

Jinks J L, Perkins J M and Breese E L 1969 A general method detecting additive, dominance and epistatic variation for metric traits II Application to inbred lines. Heredity 24: 45-47.

Jinks J L and Perkins J M 1970 A general method for detection of additive, dominance and epistatic components of variation III. F_2 and back cross populations. Heredity 25: 419-429.

Jinks J L and Virk D S 1977 A modified triplet test cross analysis to test and allow for inadequate testers. Heredity 39: 165-170.

- Johnson H W Robinson H F and Comstock R E 1955 Genotypic and Phenotypic correlations in soybeans and their implications in selections. *Agronomy Journal* 47: 477-483.
- Joshi S N and Kabaria M M 1973 Inter relationship between yield and yield components in (*Phaseolus aureus* Roxb.). *Madras Agricultural Journal* 60: 1331-1334.
- Joshi A B Dhameliya H R and Poshiya V K 1998 Genetic variability for yield and some yield attributing traits in green gram Gujarath *Agricultural Journal* 24(1): 95-96.
- Kalpana Pandey Raghuvanshi S S and Singh S P 1988 Selection of parameters for different traits in mungbean (*Vigna radiata* (L.) Wilczek). *Narendra Dev Journal of Agricultural Research* 3: 69-72.
- Kearsey M J and Jinks J L 1968 A general method detecting additive, dominance and epistatic variation for material traits. I Theory. *Heredity* 23: 403-409.
- Kempthorne O 1957 An introduction to genetic statistics. John Wiley and Sons. New York.
- Khan I A 1988 Path coefficient analysis of yield attributes in mungbean. *Legume Research* 11: 41-43.
- Khorgade P W 1995 Genetic parameters and regression analysis in greengram. *Indian Journal of Agricultural Research* 29(4): 232-236.

- Khan I A and Rafiq Ahmed 1989 Relationship of yield and its component characters in mungbean (*Vigna radiata* (L.) Wilczek). Legume Research 12: 173-176.
- Krishnaswamy S Fazullah Khan A K and Sreerangaswamy S R 1973 Association of metric traits in mutants of (*Phaseolus aureus* Roxb.) Madras Agricultural Journal 60: 1323-1326.
- Kumar S S Sudharashanam A Vinod Kumar S and Narasimha Reddy V 1995 Correlation and path coefficient analysis in greengram (*Vigna radiata* (L.) Wilczek). Madras Agricultural Journal 82: 160-162.
- Kumari K T P and George M K 1985 Correlation and path analysis in greengram. Agricultural Research Journal of Kerala 20: 82-85.
- Lakshmaiah K Ramesh Babu P and Lokanatha Reddy D 1989 Genetic parameters and correlations in greengram. Journal of Research, Andhra Pradesh Agricultural University 27: 387-390.
- Lal S Gupta S N and Tomer Y S 1982 Line x tester analysis in mungbean. Haryana Agricultural University Journal of Research 12: 438-443.
- Lill D J Gao H F and Zheny K P 1984 Studies on local cultivars of *Vigna radiata* (L.) Wilczek in Fujian I - Yield correlations and regression analysis. Journal of Fujian Agricultural College 13: 135-140 (CF : PBA 1985-5987).

- Liu D J Zhou Y F Liu C H and Wu B 1984 Heritability, genetic correlations and path analysis of quantitative characters in local cultivars of *Phaseolus aureus* Roxb. Hereditas, China 6: 13-14.
- Lush J L 1940 Intraclass correlation and regression of offspring on dams as a method of estimating heritability of characters. Proceedings of American Society of Animal Production 33: 293-301.
- Malhotra R S 1983 Genetics of pod length, seeds per pod and seed size in mungbean (*Vigna radiata* (L.) Wilczek). Genetic Agraria 37: 345-53.
- Malhotra V V Sukh Dev Singh and Singh K B 1984 Yield components in greengram (*Phaseolus aureus* Roxb.). Indian Journal of Agricultural Sciences 44: 133-146.
- Malhotra R S Gupta P K and Arora N D 1980 Diallel analysis over environment in mungbean. Indian Journal of Genetics and Plant Breeding 40: 64-66.
- Malik B P S and Singh V P 1983 Genetics and some metric traits in greengram. Indian Journal of Agricultural Sciences 53: 1002-1005.
- Malik B A Tahir M Khan I A Zubair M and Chowdhury A H 1984 Genetic variability, character correlation and path analysis of yield components in mungbean. Pakistan Journal of Botany 19: 89-97.
- Malik B P S Singh V P Chowdhury R K 1982 Path coefficients and selection indices in greengram. Indian Journal of Agricultural Sciences 52: 288-291.

- Malik B P S and Singh V P 1986 Detection of epistatic, additive and dominance variation in greengram (*Vigna radiata* (L.) Wilczek). Genetic Iberica 38: 119-212.
- Manivanan N Ramoorthy N and Nadarajan N 1996 Genetic variability in greengram. Madras Agricultural Journal 83: 770-771.
- Marechel R 1970 Donneees cytologiques surles especes dela sons. Tribudes Phaseolinae, Deuxieme, Serie, Bulljord, Dot Nat, Belgique 40: 307-348.
- Mather K and Jinks J L 1982 Biometrical genetics 3rd ed. Chapman and Hill, London.
- Medhi B N Hazarika M H and Choudhury P K 1980 Genetic variability and heritability for seed yield and components in greengram. Tropical grain legume. Bulletin 17/18: 32-34.
- Murthy B K Patel G J and Jaisani B G 1976 Gene action and heritability estimates of some quantitative traits in mungbean. Gujarat Agricultural University Research Journal 2: 1-4.
- Misra R C and Sahu B C 1985 Genetic parameters, correlation and path coefficient analysis in greengram (*Vigna radiata* (L.) Wilczek.). The Andhra Agricultural Journal 32: 87-91.
- Misra R C, Sahu B C and Tripathy D 1970 A note on heterosis in greengram (*Phaseolus aureus* Roxb.). Current Science 39: 190-191.

Nagaraja Rao B 1981 Heterosis and combining ability studies in greengram (*Vigna radiata* (L.) Wilczek). M.Sc. (Ag.) Thesis submitted to Andhra Pradesh Agricultural University, Hyderabad.

Nagaraja Rao and Mahaboob Ali S 1983 Combining ability in greengram (*Vigna radiata* (L.) Wilczek) in Andhra Pradesh Agricultural University, Hyderabad.

Naidu N V 1989 Genetic analysis of yield and yield components of mungbean (*Vigna radiata* (L.) Wilczek) Ph.D. Thesis submitted to Andhra Pradesh Agricultural University, Hyderabad.

Naidu N V, Satyanarayana A and Ramaiah D K 1991 Yield components in greengram. *Annals of Agricultural Research* 12: 238-243.

Naidu N V 1993 Interrelationship between yield and yield components in mungbean (*Vigna radiata* (L.) Wilczek). *Annals of Plant Physiology* 7: 119-122.

Naidu N V and Satyanarayana 1993 Heterosis and combining ability in mungbean (*Vigna radiata* (L.) Wilczek). *Indian Journal of Pulses Research* 6: 38-44.

Natarajan C Thiyagarajan K and Rahinaswamy R 1988 Association and genetic diversity studies in greengram (*Vigna radiata* (L.) Wilczek). *Madras Agricultural Journal* 75: 238-245.

- Natarajan C Thiyagarajan K and Rathnaswamy R 1990 Combining ability in greengram (*Vigna radiata* (L.) Wilczek). Madras Agricultural Journal 79: 382-385.
- Panse V G 1957 Genetics of quantitative characters in relation to plant breeding. Indian Journal of Genetics and Plant Breeding 17: 318-28.
- Paramasivan J and Rajasekharan S 1980 Genetic variability in greengram. Madras Agricultural Journal 67: 421-424.
- Parida S 1982 The evaluation of varietal and wide crosses in greengram. M.Sc. (Ag.) Thesis, G B Pantnagar University of Agriculture and Technology, Pantnagar, India pp. 83.
- Parida D and Singh D P 1984 Association, Heritability and Genetic advance in the F_2 generation of wide and varietal crosses of greengram. Madras Agricultural Journal 71: 351-356.
- Patel H S 1991 Genetic variability, correlation and path coefficient analysis in greengram (*Vigna radiata* (L.) Wilczek). Thesis abstracts XVII: 259-260.
- Patel J A Patel S A Zaveri P P and Pathak A R 1988 Combining ability analysis in mungbean. Indian Journal of Pulses Research 1: 105-110.
- Pathak H C and Patel M S 1993 Selection criteria in summer mungbean (*Vigna radiata* (L.) Wilczek). Gujarat Agricultural University Research Journal 19: 64-69.

- Pathak A R Shah R M Zaveri P P and Patel J A 1990 Genetic analysis of homogenous and heterogenous populations grown over environments in mungbean. *Indian Journal of Genetics and Plant Breeding* 50: 333-337.
- Patil A S Dumbre A D and Bhor T J 1999 Heterosis and inbreeding depression in Mungbean J. *Maharashtra - Agric. Univ.*, 24(2): 202-203.
- Patil H S and Deshmukh R B 1998a Correlation and path coefficient analysis in mungbean. *Journal of Maharashtra Agricultural University* 13: 183-185.
- Patil H S and Deshmukh R B 1998b Genetic variability in mungbean. *Journal of Maharashtra Agricultural University* 13: 338-339.
- Patil H S and Shinde Y M 1995 Genetic variability in greengram. *Madras Agricultural Journal* 82: 490-491.
- Patil S L Hunshal C S Vishwanath D P Kubsad and Chimad V P 1996 Correlation and path coefficient analysis in mungbean (*Vigna radiata* L.) Wilczek). *Haryana Agricultural University Journal of Research* 22: 256-258.
- Patil H S and Narkhede B N 1989 Association and path analysis of yield attributes in mungbean. *Journal of Maharashtra Agricultural University* 14: 240-241.
- Patil A J Wanjari K B Patil A N Raut B R and Ghaw Ghawe P B 1992 Studies on mungbean. *Journal of Soils and Crops* 2: 1-4.

- Paul N K 1978 Genetic architecture yield and components of yield in mustard (*Brassica juncea* (L.) Theoretical and Applied Genetics 53: 233-237.
- Perkins J M and Jinks J L 1971 Analysis of genotype x environment interaction in triple test cross data heredity 26: 203-209.
- Pokle V S and Patil V N 1974 Path coefficient analysis in greengram (*Phaseolus aureus* Roxb.) Science and Culture 41: 265-266.
- Pooni H S Jinks J L and Jayasekhara N E M 1978 An investigation of gene action and genotype x environment interaction in two crosses of *Nicotiana rustica* by triple test cross and inbred analysis. Heredity 41: 83-92.
- Poornachandra Rao K G 1995 Diallel analysis of the inheritance of quantitative characters in mungbean (*Vigna radiata* (L.) Wilczek). M.Sc. (Ag.) Thesis submitted to Andhra Pradesh Agricultural University, Hyderabad.
- Prasanna Rajesh A 1995 Studies on genetic divergence in greengram (*Vigna radiata* (L.) Wilczek). M.Sc., Thesis submitted to Andhra Pradesh Agricultural University.
- Pun L and Villareal R H 1989 Inter-relationships and path coefficient of some quantitative traits in mungbean (*Vigna radiata* (L.) Wilczek) under post-rice growing conditions, Philippine Journal of Crop Science 14: 91-95.

- Pundir S R Gupta K R and Singh V P 1992 Studies on correlation coefficients and path coefficient analysis in mungbean (*Vigna radiata* (L.) Wilczek). Journal of Research, Haryana Agricultural University, 21(2): 109-112.
- Purseglove J W 1968 Tropical crops. Dicotyledons, 3rd reprint 1974 Longman, London.
- Quah S C Sidek M S M and Mat C H C 1983 Variation grain yield, protein content and other agronomic characters in mungbean (*Vigna radiata* (L.) Wilczek). In crop improvement Research (eds) Yap T C, Graham M and J Sukaini, Bangi, Seloungor, Malya pp. 289-294.
- Raghuram Reddy P 1980 Combining ability and genotype - environment interaction in greengram (*Vigna radiata* (L.) Wilczek). Ph.D. Thesis submitted to Andhra Pradesh Agricultural University, Hyderabad.
- Raghuram Reddy P and Sreeramulu C 1982 Heterosis and combining ability for yield and its components in greengram (*Vigna radiata* (L.) Wilczek). Genetica Agraria 36: 297-30.
- Raje R S and Rao S K 2000 Association analysis for yield and its components in mungbean (*Vigna radiata* (L.) Wilczek). Legume Research 23(1): 42-48.
- Rambhajan Y S Chuhan and Kamlesh Kumar 1994 Triple test cross analysis for oil content, seed yield and component traits in Indian mustard. Indian J Genet 54(3); 315-316.

- Ramana M V and Singh D P 1987 Genetic parameters and character associations in greengram. Indian Journal of Agricultural Sciences 57: 661-663.
- Ramaswamy A and Jehngir K S 1998 Character association in mungbean (*Vigna radiata* (L.) Wilczek). Madras Agric. J. 85(7-9): 371-372 July - September.
- Ramanujam S 1978 Biometrical basis for yield improvement in mungbean. In R Cowell (ed.) The First International Mungbean Symposium Proceeding AVRDC Taiwan pp. 210.
- Ranganayaki K and Sreerangaswamy S R 1993 Path coefficient analysis in greengram. Madras Agricultural Journal 80(2): 7-12.
- Rathnaswamy R Krishnaswami S Iyamperumal S and Marappan P V 1978 Estimates of variability, correlations coefficient and path coefficient analysis in early maturing greengram (*Vigna radiata* (L.) Wilczek) Madras Agricultural Journal 65: 188-190.
- Rao S S Singh S P and Rao S K 1984 Estimation of additive, dominance, digenic epistatic interaction effects for yield and its components in mungbean (*Vigna radiata* (L.) Wilczek). Legume Research 7: 6-12.
- Reddi Sekhar M Raja Reddy K and Raja Reddy C 1994 Heterosis and combining ability studies in mungbean (*Vigna radiata* (L.) Wilczek). Indian Journal of Genetics and Plant Breeding 54: 8-13.

- Reddissekhar M 1992 Heterosis and combining ability studies in greengram (*Vigna radiata* (L.) Wilczek. M.Sc. (Ag.) Thesis submitted to Andhra Pradesh Agricultural University, Hyderabad.
- Reddy C R and Sekhar M R and Reddy K R 1994 Character association and path coefficient analysis in greengram (*Vigna radiata* (L.) Wilczek). Annals of Agricultural Research 15: 423-427.
- Reddy S R and Krishnaiah V V 1977 Study of yield components and their interrelationships in greengram. The Andhra Agricultural Journal 24: 69-73.
- Reddy Mishra R K and Yadav R K 1991 Genetic variability and correlation coefficients related to yield and other quantitative characters and use of path coefficients in mungbean (*Vigna radiata* (L.) Wilczek). Indian Journal of Pulses Research 4: 100-104.
- Reddy K H P 1997 Genetic variability in greengram (*Vigna radiata* (L.) Wilczek). Annals of Agricultural Research 13: 554-855.
- Reddy K M Reddy S C and Reddy T V 1992 Dry matter production, distribution and nutrient content of greengram (*Phaseolus radiatus*) varieties as influenced by fertility treatment. Indian Journal of Pulse Research 37: 268-272.
- Reddy K H P 1998 Heterosis in greengram (*Vigna radiata* (L.) Wilczek) Annals of Agricultural Research 19: 1, 26-29.

- Rojas B A Spragno 1952 A comparison on variance components in corn yield trials III. General and specific combining ability and their interactions with location and years. *Agronomy Journal* 44: 462-464.
- Rosaiah G Shantha Kumari D Satyanarayana A and Rao Y K 1987 Estimates of genetic parameters of greengram (*Vigna radiata* (L.) Wilczek). *Indian Journal of Botany* 10: 1-6.
- Sabahgpour H Moghddam M Grami A Sadri B 1998 Path analysis of yield components in mungbean varieties of Iran 3rd European conference on grain legumes opportunities for high quality healthy and added value crops to meet European demands. Valla dolid Spain 14-19 November 1998. 219.
- Sagar P and Chandra S 1977 Heterosis and combining ability in urdbean. *Indian J. Genetics and Plant Breeding* 37: 420-424.
- Sarma R N and Talukdar P 1996 Casual relationships in micromutants of greengram (*Vigna radiata* (L.) Wilczek). *Annals of Agricultural Research* 17(1): 38-41.
- Sandhu T S Bullar B Cheema H S and Gill A S 1979 Variability and interrelationships among grain protein, yield and yield components in mungbean. *Indian Journal of Genetics and Plant Breeding* 39: 480-484.
- Sandhu T S Bhular B S Cheema H S and Brar J S 1980 Path coefficient analysis for grain yield and its attributes in greengram. *Indian Journal of Agricultural Sciences* 50: 541-544.

- Sarbhoy R K 1977 Cytogenetical studies in the genus *Phaseolus* L. III evolution in genus *Phaseolus* - Cytologia 42: 401-413.
- Sarbbhoy R K 1978 Cytogenetical studies in genus *Phaseolus* L. I and II somatic meiotic studies in fifteen species of *Phaseolus* Cytologia 43: 161-70.
- Satyan B A Amaranth K C N and Siddaraju I G 1989 Phenotypic and genotypic correlation coefficients of some quantitative characters of greengram. Current Research, University of Agricultural Sciences 18: 170-172.
- Sethi S C 1975 Gene action governing some quantitative characters in mungbean. Ph.D. Thesis. Haryana Agricultural University, Hissar.
- Shakoor A Ahsaulhag and Sadiq M 1979 Induced variation in mungbean (*Vigna radiata* (L.) Wilczek). Environmental Biology 18: 169-174.
- Shah R M and Patel J D 1981 Heritability in grain yield and its components in greengram (*Vigna radiata* (L.) Wilczek). Pulse Crops News Letter 1: 26.
- Saexna S D and Sharma R K 1992 Analysis of combining ability in mungbean (*Vigna radiata* (L.) Wilczek). Legume Research 15: 7.
- Sharma D J and Yadav R K 1993 Heterosis and inbreeding depression in mungbean. Indian Journal of Pulses Research 6: 191-193.

- Shantipriya M 1997 Genetic analysis of F_3 progenies derived out of 7 x 7 diallel crosses of greengram (*Vigna radiata* (L.) Wilczek). M.Sc. (Ag.) Thesis submitted to Andhra Pradesh Agricultural University, Rajendra Nagar, Hyderabad, India.
- Siddaraju I G 1987 Studies on variability, correlation and genetic advance in greengram (*Vigna radiata* (L.) Wilczek). M.Sc. (Ag.) Thesis submitted to University of Agricultural Sciences, Bangalore.
- Shull G H 1914 Methods of Plant Breeding by Honeys H K, F R Immer and D C Smith 1958 Mc Graw Hill Book Company, New York. 53
- Singh K B and Malhotra R S 1970 Estimates of genetic and environmental variability in mung (*Phaseolus aureus* Roxb.) Madras Agricultural Journal 57: 157-59.
- Singh T P and Singh K B 1974 Heterosis and combining ability in *Phaseolus arueus* Roxb. Theoretical Applied Genetics 44: 12-16.
- Singh I S Hue N T N Gupta A K 1995 Associations can cause and effect analysis in some F_2 populations of greengram. Legume Research 18(4): 137-142.
- Singh R K and Chaudhury B D 1985 Biometrical methods in quantitative genetic analysis. Kalyani Publishers, Ludhiana.
- Singh R P 1987 Diallel analysis in greengram. Journal of Research, Assam Agricultural University 5: 143-146.

- Singh T P and Singh K B 1970 Inheritance of clusters per node in mungbean (*Phaseolus aureus* Roxb.) Current Science 32: 67-72.
- Singh D P 1982 Genetics and Breeding of Blackgram and Greengram. Res. Bulletin No. 109 G B Pant University of Agricultural and Technology, Pant Mager p. 1-68.
- Singh R P and Pathak M M 1986 Variability studies on mungbean. Pulse Crops News Letter 6: 26-27.
- Singh D P and Sharma B L 1981 Evaluation of mungbean germplasm. Madras Agricultural Journal 68: 289-295.
- Singh K B and Jain R P 1971 Analysis of diallel cross in *Phaseolus aureus* Roxb. Theoretical and Applied Genetics 41: 279-81.
- Singh R P and Pathak M M 1992 Heterosis in mungbean (*Vigna radiata* (L.) Wilczek). Agricultural Science Digest 12: 44-46.
- Singh K B and Jain R P 1970 Heterosis in mungbean. Indian Journal of Genetics and Plant Breeding 30: 244-60.
- Singh S D, Dhul R S and Mishra S B 1979 Triple test cross analysis in F_2 populations of four barley crosses. Theor Appl Genet 55: 243-245.
- Singh B B, Singh U P, Rai B and Singh R M 1986 Triple test cross analysis in F_2 populations of four promising crosses of field pea. Z P Pflanzenzucht 97: 357-363

Singh I P Singh S and Pawar I S 1987 Triple test cross analysis in three chick pea crosses. Crop Improvement 14: 28-32.

Singh U P Singh B B Singh R M and Singh R K 1988 Additive, dominance and epistatic components of variation for economic traits in field pea. Indian Journal Pulses Res. 1: 1-5.

Singh U P Singh R K and Singh R M 1989 Estimations of gene action and detection of linked interacting genes for yield traits in the triple test cross progeny of field pea. National Symposium on Recent Advances in Genetics and Plant Breeding Research in India, (No 15-16), BHU, Varanasi.

Sirohi A and Gupta V P 1989 Additive, dominance and epistatic components of variation for seed protein content in peas (*Pisum sativum* L.) National Symposium on recent advances in Genetics and Plant Breeding Research in India (Nov. 15-16), B H U, Varanasi.

Sprague G F and Tatu L A 1942 General and specific combining ability in single crosses of corn. Agronomy Journal 34: 923-32.

Sreedevi G 1998 Genetic analysis and character association studies in F_3 derived progenies of mung bean (*Vigna radiata* (L.) Wilczek). M.Sc. (Ag.) Thesis submitted to Andhra Pradesh Agricultural University, Rajendra Nagar, Hyderabad, India.

Swindell R E and Poehlman J M 1978 Heterosis and combining ability in mungbean (*Vigna radiata* (L.) Wilczek). Tropical Agricultural 53: 25-30.

- Thandapani V and Saktharam Rao J 1984 Yield parameters and their significance in greengram (*Vigna radiata* (L.) Wilczek) genotypic in relation to yield. Madras Agricultural Journal 71: 233-236.
- Tawar M L and Sudhanshu Jain 1988 Combining ability and heterosis analysis for yield and its components in mungbean (*Vigna radiata* (L.) Wilczek). Narendra Deva Journal of Agricultural Research 3: 141-146.
- Thimmappa A S Chandrappa H M Patil S S and Goud J V 1989 Studies on combining ability in greengram. Journal of Maharashtra Agricultural Universities 14: 26-27.
- Thimmappa A S 1987 Genetic analysis of quantitative traits in greengram (*Vigna radiata* (L.) Wilczek). Mysore Journal of Agricultural Sciences 21: 94.
- Thulasidas G 1984 Multiple regression and classificatory analysis in *Vigna radiata* (L.) Wilczek Field Crop Research 9: 183-191.
- Tickoo J L, Ahn C S, Chen H K and Shanmugasundram S 1988 Utilisation of the genetic variability of the second international symposium on mungbean, Bangkok, Thailand p. 103-110.
- Tiwari A S and Ramnujam S 1976 Combining ability heterosis for protein and methionine contents in mungbean. Indian Journal of Genetics and Plant Breeding 36: 353-53.

- Tiwari D S Vijaipal Singh and Shukla P S 1993 Combining ability studies in mungbean (*Vigna radiata* (L.) Wilczek). Indian Journal of Genetics and Plant Breeding 53: 395-398.
- Tiwari V K, Mishra Y, Ramgiry S R and Rawat G S 1996 Genetic variability in parents and segregating generation of mungbean (*Vigna radiata* (L.) Wilczek). Advance in Plant Science 9(2): 43-47.
- Upadhyaya L P Singh R B and Agarwal R K 1980 Character association in greengram populations of different maturity groups. Indian Journal of Agricultural Sciences 50: 473-476.
- Veerabadhiran P and Jehangir K S 1995 Genetic variability, correlation and path analysis in greengram. Madras Agricultural Journal 82(5): 633-635.
- Veeraswamy R Rathnaswamy R and Palaniswamy G A 1973 Genetic variability in some quantitative characters of *Phaseolus aureus* Roxb. Madras Agricultural Journal 60: 1320-1322.
- Verdicourt B 1970 Studies in the leguminosael papilionideae for the flora of tropical East Africa I V. Kew Bult 24: 507-569.
- Vijayabharathi G 1993 Genetic analysis of certain quantitative characters in a 8 x 8 diallel set of greengram (*Vigna radiata* (L.) Wilczek) in F₂ generation. M.Sc. (Ag.) Thesis submitted to Andhra Pradesh Agricultural University, Hyderabad.

- Vijayakumar S B Kulkarni R S and Niranjana Murthy 1996 Triple test cross analysis in rice. *Indian J Genet.* 56(2): 169-172.
- Vikas Singh S P and Tyagi V K 1988 Phenotypic correlation in segregating and non-segregating population of mungbean (*Vigna radiata* (L.) Wilczek) *Annals of Biology Ludhiana* 14: 2, 181-183.
- Vikas Paroda V R S and Singh S P 1998 Genetic variability in mungbean (*Vigna radiata* (L.) Wilczek) over environments in *Kharif* Season *Annals of Agri-Bio-Research* 3: 2, 211-215.
- Virk D S, Virk P S and Varma M M 1983 A triple test cross analysis allowing for inadequacy of testers for some metric traits in pea. *Crop improve.* 10: 19-25.
- Virmani S S Singh K B Singh K and Malhotra R S 1983 Evaluation of mungbean germplasm. *Indian Journal of Genetics and Plant Breeding* 43: 54-58.
- Vishnuswarup and Chagle D S 1962 Studies on the genetic variability in Sorghum. Phenotypic variation and its heritability component in some important quantitative characters contributing towards yield. *Indian Journal of Genetics and Plant Breeding* 23: 31-36.
- Wani S A Zargar G H and Ahanger H W 1992 Path coefficient analysis in mungbean (*Vigna radiata* (L.) Wilczek). *Advances in Plant Sciences* 5(2): 554-558.

- Whaley W G 1952 In Heterosis (ed John W Groben). Iowa State College Press. Ames.
- Wilson S W and Gilbert 1960 Heterosis and inheritance of yield in the Tomato. *Heredity* 15: 133-50.
- Wilson D Mercy S T and Nayar N K 1985 Combining ability in greengram. *Indian Journal of Agricultural Sciences* 55: 654-70.
- Wright S 1921 Correlation and causation. *Journal of Agricultural Sciences* 20: 557-585.
- Wright S 1934 The method of path coefficients. *Annals of Mathematics and Statistics* 5: 161-215.
- Wynne J C, Emery D A and Rice P W 1970 Combining ability estimates in *Achis hypogaea* - II. Field performance of F_1 hybrids. *Crop Science* 10: 713-715.
- Xianghuai He Isoyuanhe Xiang and Chauenhai Jiao 1988 Research and use of mungbean germplasm resources in Hubei, China, In the proceedings of the Second International Symposium on mungbean, Bangkok, Thailand.
- Yadav L Gupta R B and Mishra S P 1994 Selection parameters in mungbean. *International Symposium on Pulses Research* New Delhi, April 2-6, Abstracts pp. 11-149.

Yadava H S and Rao S K 1986 Genetics of yield and its components in mungbean. Egyptian Journal of Genetics and Cytology 15: 119-125.

Yaqoob M Malik A J Malik B A Khan H U Nawab K 1997 Path coefficient analysis in some mungbean (*Vigna radiata* (L.) Wilczek) mutants under rainfed conditions Sarhad Journal of Agriculture 13: 2, 129-133.

Yohe J M and Poehlman J M 1972 Genetic variability in mungbean (*Vigna radiata* (L.) Wilczek). Crop Science 12: 461-464.

Yohe J M and Poehlman J M 1975 Regressions, correlations and combining ability in mungbean (*Vigna radiata* (L.) Wilczek). Tropical Agriculture 34: 343-52.

