STUDIES ON IDENTIFICATION OF MORPHOLOGICAL AND PHYSIOLOGICAL TRAITS IN RELATION TO YIELD AND QUALITY OF SEED GUAR (*Cyamopsis tetragonoloba* (L.) Taub.) CULTIVARS UNDER RAINFED CONDITION

By

PRAMODKUMAR NAMPELLI

B.Sc. (Hons.) Hort.

THESIS SUBMITTED TO Dr. Y.S.R. HORTICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF

MASTER OF SCIENCE IN HORTICULTURE

(VEGETABLE SCIENCE)

DEPARTMENT OF VEGETABLE SCIENCE
COLLEGE OF HORTICULTURE, MOJERLA, MAHABUBNAGAR
Dr. Y.S.R. HORTICULTURAL UNIVERSITY

January, 2016

DECLARATION

I, **Mr. PRAMODKUMAR NAMPELLI** hereby declare that the thesis entitled **"Studies on Identification of Morphological and Physiological traits in relation to yield and quality of Seed Guar (*Cyamopsis tetragonoloba* (L.) Taub.) cultivars under Rainfed condition"** submitted to the Dr. Y.S.R. Horticultural University, Venkataramannagudem, for the degree of Master of Science in Horticulture (Vegetable Science) is the result of original research work done by me. I declare that no material contained in the thesis has been published earlier in any manner.

Date: **Name:** PRAMODKUMAR NAMPELLI

Place: Mojerla, Mahabubnagar . **I.D.No:** MHM/13-02

CERTIFICATE

Mr. PRAMODKUMAR NAMPELLI has satisfactorily prosecuted the course of research and that the thesis entitled **"STUDIES ON IDENTIFICATION OF MORPHOLOGICAL AND PHYSIOLOGICAL TRAITS IN RELATION TO YIELD AND QUALITY OF SEED GUAR (*Cyamopsis tetragonoloba* (L.) Taub.) CULTIVARS UNDER RAINFED CONDITION"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination.

I certify that neither the thesis nor its part thereof has been previously submitted by him for a degree of any university.

Date: **(Dr. NATARAJAN SEENIVASAN)**

Place: Mojerla, Mahabubnagar . **Chairman**

CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON IDENTIFICATION OF MORPHOLOGICAL AND PHYSIOLOGICAL TRAITS IN RELATION TO YIELD AND QUALITY OF SEED GUAR (*Cyamopsis tetragonoloba* (L.) Taub.) CULTIVARS UNDER RAINFED CONDITION"** submitted in partial fulfillment of the requirements for the degree of Master of Science in Horticulture (Vegetable Science) of Dr. Y. S. R. Horticultural University, Venkataramannagudem, is a record of the bonafide research work carried out by **Mr. PRAMODKUMAR NAMPELLI** under our guidance and supervision.

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

Thesis approved by the Student's Advisory Committee

Chairman: **Dr. NATARAJAN SEENIVASAN**
Associate Professor (Hort.),
Department of Horticulture,
College of Horticulture, Mojerla,
Mahabubnagar – 509 382. __________________

Member: **Dr. P. PRASHANTH**
Assistant Professor (Hort.),
Department of Horticulture,
College of Horticulture, Mojerla,
Mahabubnagar – 509 382. __________________

Member: **Dr. V.V. PADMAJA**
Assistant Professor,
Department of Plant Physiology,
College of Horticulture, Mojerla,
Mahabubnagar – 509 382. __________________

Date of final viva - voce:

ACKNOWLEDGEMENTS

It is by the unfathomable grace and blessings of the LORD SRIRAMA SWAMY that I have been able to bring out this humble piece of work.

I feel a great pleasure in expressing my whole hearted sense of gratitude to the Chairperson of Advisory Committee, ***Dr. Natarajan Seenivasan,*** *Associate Professor, Dept. of Horticulture, College of Horticulture, Mojerla, Mahabubnagar for his scholastic guidance, unceasing interest, valuable knowledge, technical advice, providing each and every facility and also in bringing out this manuscript, without whom it was impossible to complete the research project. I am fortunate to have been blessed with the privilege of working under his guidance.*

I sincerely extend my profound gratitude and appreciation to my members ***Dr. P. Prashanth****, Assistant Professor, Dept. of Horticulture, College of Horticulture, Mojerla, Mahabubnagar for the valuable suggestions during the course of my study and providing necessary facilities to carry out the research work and* ***Dr. V. V. Padmaja****, Assistant Professor, Dept. of Plant Physiology, College of Horticulture, Mojerla, Mahabubnagar for her guidance and support in my laboratory works which helped me carry out my research effectively.*

It gives me immense pleasure in extending my sincere feelings of gratitude and special thanks to ***Dr. Ravi Chandra Sekhar,*** *Associate Dean, College of Horticulture, Mojerla & COE to Sri Konda Laxman Telangana State Horticultural University, Rajendranagar, Hyderabad for his special care, guidance and assistance in my UG and PG academic career, his support and guidance which went a long way in shaping this humble piece of work.*

I express my sincere gratitude to ***Dr. M. Madhavi,*** *PG academic in-charge, college of horticulture, Mojerla for her valuable counsel, note-worthy guidance and cordial co-operation during the course of investigation.*

I sincerely extend my profound gratitude and appreciation to ***Dr. M. Shiva Prasad, Dr. B. Pedababu, Sri. V. Murali, Sri. D. Laxshmi Narayana, Ms. Shahanaj,*** *academic staff, College of Horticulture, Mojerla, Mahabubnagar.*

I fall in short of words in expressing from the core of my heart mere love, heartfelt regards and affectionate gratitude to my ever beloved mother ***Smt. Nampally Shobha Rani****, father* ***Nampally Rambabu****, brothers* ***Nampally Pradeep Kumar and Nampally Prashanth Kumar,*** *cousin brother* ***Nampally Amardeep****, cousin sister* ***Nampally Vasundhara****, babai* ***Nampally Ram Kishan****, chinnamma* ***Nampally Vijaya****, grand mothers* ***Andalavva and Radha****, grand fathers* ***Ramulu and Venkatadri*** *for the constant inspiration, everlasting and abundant love moulded me to the present situation and whose encouragement brings out my best in every one of my endeavours.*

I owe an encompassing debt to my beloved brother ***N. Prashanth*** *and sister-in-law* ***N. Laxmi Priya*** *for their constant encouragement throughout my career. They have been a fountain of inspiration throughout my life without whose help in every walk of life, this work would not have been possible.*

*I am ever greatful and fortunate to have my dearest friends **P. Manohar Reddy, Yeshoda Vijayanthi Kalyan** as a source of inspiration and strength who has always bestowed me with unfailing support, encouragement and understanding.*

*I express my heartfelt gratitude and thanks to my close friends **Papanka Raju, Prem Sagar, Ramesh, Mosin, Gopi, Jeevan, Bandi Gangadhar, B. Ashok, Nadikuda Sudheer, Nalla Thirupathi, Kasarapu Thirupathi Goud, Chitti Jagadeesh, Shiva Krishna, Mounika, Pradeepthi, Nithya** for their valuable guidance, thought provoking ideas and encouragement throughout my career which elevated me to the world of competition.*

*I feel immense pleasure and joy in expressing my profound affection and gratitude to my seniors **Ashish, Srikanth, Rajesh Vangala, Ramesh** and my friends of **2008 batch, COH, Rajendranagar**, **Rambabu, Bhanumurthy,** juniors **Bobby, Pavani, Dhiradhar Raju, Durgam Sridhar, Shivaraj, Sathya Narayana, Vikarm, Nagesh, Rajendhar, Harsha, Sai Krishna, Bhanu, Srikanth, Ravi, Mahesh, Sainath, Vamshidhar, Maharshi, Praveen Kumar, Rama Krishna, Yella Swamy, Srishailam, Ramesh, Sai Jagadeesh, Boys of 2013 U.G. batch, Boys and girls of 2014 U.G. batch, COH, Mojerla** and others who are not named in this page for the help rendered to me during the course of my research.*

*I sincerely extend my profound gratitude and appreciation to **Thrimurthulu, Raghu, Chinna, Kurmaiah, Ramu, Venkatesh, Madhulety, Narendar, Vijay babu, Kumar, Jhansi, Chandrakala, Janardhan, Prabhakar** and other members in college of Horticulture, Mojerla for providing necessary facilities to carry out the research work.*

*I gratefully acknowledge **Mr. Raghu** and all the field staff and labour, college of Horticulture, Mojerla, who were the heart and soul of this research programme.*

*I humbly thank the authorities of **Dr Y S R Horticultural University** for the financial help in the form of stipend during my study period.*

I convey my whole hearted thanks to my well wishers requesting their forgiveness for not mentioning them here by name.

Mojerla, *Pramodkumar Nampelli*

January, 2016.

CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF ILLUSTRATIONS

LIST OF SYMBOLS AND ABBREVIATIONS

%	:	per cent
&	:	and
@	:	at the rate of
° C	:	degree Celsius
ANOVA	:	Analysis of variance
CCI	:	Chlorophyll Content Index
CD	:	Critical Difference
cm	:	centimetre
CRBD	:	Completely Randomised Block Design
CRIDA	:	Central Research Institute for Dryland Agriculture
CSI	:	Chlorophyll Stability Index
DAS	:	Days After Sowing
df	:	degrees of freedom
Dr.YSRHU	:	Dr Y S Rajasekhar Reddy Horticultural University
dSm^{-1}	:	Decisiemen per metre
E.U./g	:	Enzyme Units per gram fresh weight of leaf
EC	:	Electrical conductivity
et al.	:	and others
etc.	:	et cetera
FDA	:	Food and Drug Administration
Fig.	:	Figure
FYM	:	Farm yard manure
g	:	gram
GA	:	Genetic Advance
GAM	:	Genetic Advance as per cent of Mean
GCV	:	Genotypic Coefficient of Variation
GRAS	:	Generally Recognized As Safe
h^2	:	heritability in broad sense

H_2O_2	:	Hydrogen Peroxide
ha^{-1}	:	per hectare
Hcl	:	Hydrochloric Acid
HI	:	Harvest Index
i.e.,	:	that is
ICAR	:	Indian Council of Agricultural Research
$K_2Cr_2O_7$	:	Potassium dichromate
K_2O	:	Potassium oxide
kg	:	kilogram
kg/ha	:	kilogram per hectare
km/hr	:	kilometre per hour
KVK	:	Krishi Vigyan Kendra
M	:	Molarity
m	:	metre
mg	:	milligram
ml	:	millilitre
mm	:	millimetre
MOP	:	Murate of Potash
MSL	:	mean sea level
MSS	:	mean sum of squares
N	:	Normality
NaOH	:	Sodium Hydroxide
NBPGR	:	National Bureau of Plant Genetic Resources
No.	:	Number
NPK	:	Nitrogen, Phosphorus and Potassium
NS	:	Non Significant
OD	:	Optical Density
P_2O_5	:	Phosphorus pentoxide
PCV	:	Phenotypic Coefficient of Variation
pH	:	puissance de Hydrogen

pp	:	page number
q	:	quintal
q/ha	:	quintal per hectare
r	:	Number of replications
R.H.	:	Relative humidity
rpm	:	revolutions per minute
RWC	:	Relative Water Content
S	:	Significant
S.Em	:	Standard error mean
S.No.	:	Serial Number
SE (d)	:	Standard error difference
SOD	:	Super Oxide Dismutase
SSS	:	Single Super Phosphate
UK	:	United Kingdom
USA	:	United States of America
viz.,	:	namely
WP	:	Wettable Powder

Name of the author	:	**PRAMODKUMAR NAMPELLI**
Title of the thesis	:	**"STUDIES ON IDENTIFICATION OF MORPHOLOGICAL AND PHYSIOLOGICAL TRAITS IN RELATION TO YIELD AND QUALITY OF SEED GUAR (*Cyamopsis tetragonoloba* (L.) Taub.) CULTIVARS UNDER RAINFED CONDITION"**
Degree to which it is Submitted	:	**MASTER OF SCIENCE IN HORTICULTURE**
Faculty	:	**HORTICULTURE**
Major Field	:	**VEGETABLE SCIENCE**
Major Advisor	:	**Dr. NATARAJAN SEENIVASAN**
University	:	**Dr Y.S.R. HORTICULTURAL UNIVERSITY**
Year of submission	:	**2015**

ABSTRACT

A set of fifteen cultivars of seed guar (*Cyamopsis tetragonoloba* (L.) Taub.) was evaluated in a Completely Randomized Block Design with three replications at student research farm, College of Horticulture, Mojerla, Dr.YSRHU during *kharif*, 2014 with an objective to study the mean performance, genetic variability, association among traits, direct and indirect effects of yield components on yield and quality traits.

On the basis of mean performance of the cultivars for all the traits studied, RGC 963, RGC 986, RGC 1033, HG 2-20 were found to be superior in terms of yield and quality characters. With respect to physiological traits contributing for drought tolerance, RGC 1066 recorded low chlorophyll stability index, HG 365 recorded high relative water content, RGC 1002 recorded high peroxidase enzyme activity and JJ-1 recorded high catalase enzyme activity, hence these cultivars may be grouped as drought tolerant based on the above traits and may be used for crop improvement programme for drought tolerance.

The Analysis of Variance revealed significant differences among the genotypes for all the traits studied suggesting existence of considerable amount of variability among the cultivars. The phenotypic coefficient of variation (PCV) was slightly higher in magnitude than genotypic coefficient of variation (GCV) for all the traits indicating that, all traits had influence of environment to some degree. High PCV and GCV were recorded for morphological traits such as number of primary branches per plant, number of clusters per plant, number of

pods per plant, pod yield per plant, pod yield per hectare, seed yield per plant, seed yield per hectare and for physiological traits such as chlorophyll stability index, peroxidase enzyme activity, catalase enzyme activity indicating the existence of wider genetic variability.

High heritability coupled with high genetic advance as per cent of mean indicated operation of additive gene action for morphological traits such as plant height, number of primary branches per plant, number of leaves per plant, number of clusters per plant, number of pods per plant, number of seeds per pod, pod yield per plant, pod yield per hectare, seed yield per plant, seed yield per hectare and similar results were observed for physiological traits such as chlorophyll stability index, peroxidase enzyme activity, catalase enzyme activity, SPAD meter reading. Hence, directional selection for these traits could be effective for desired genetic improvement.

The high heritability accompanied with low genetic advance (GA) as percent of mean was recorded by pod girth, seed to pod ratio, crude gum content, which indicated the presence of non additive gene action in inheritance of these traits. The high heritability is being exhibited due to favourable influence of environment rather than cultivar, hence, selection for these traits may not be rewarding.

The correlation study indicated that the number of primary branches per plant, number of clusters per plant, number of seeds per pod and pod yield per plant had significant positive association with seed yield per plant at both genotypic and phenotypic levels and 100-seed weight had significant positive association with seed yield per plant at genotypic level. So improvement in seed yield per plant is possible by taking above characters as criteria in selection scheme.

Path coefficient analysis study revealed that pod yield per plant and pod length at genotypic level exhibited high positive direct effect on seed yield per plant. However, pod yield per plant recorded significant, positive correlation with seed yield per plant. It clearly indicates that direct selection based on these traits would be effective for an increase in seed yield per plant.

Among the quality parameters studied, the highest crude gum content (31.71%) was recorded with RGC 1033, while the lowest gum content (29.26%) was obtained with RGC 197. Pod colour also indicated considerable variability ranging from light green to green colour among the 15 cultivars studied.

CHAPTER I

INTRODUCTION

Cluster bean (*Cyamopsis tetragonoloba* (L.) Taub. 2n=14), which is popularly known as *guar*, is self pollinated crop belongs to the family Fabaceae. Guar originated in India and Pakisthan and is characterized as a short day erect or bushy annual plant (Purseglove, 1981). It is a drought tolerant, warm season legume crop with deep and well developed root system, cultivated mainly as rainfed crop in arid and semi-arid regions during rainy (*kharif*) season for vegetable, galactomannan gum, forage and green manure. Guar enhances soil productiveness by fixing atmospheric nitrogen for its own necessities and also for the succeeding crop (Bewal *et al.*, 2009).

Guar can be successfully grown in soils where no other crops will survive. The guar crop prefers a well drained sandy loam soil. It can tolerate saline and moderately alkaline soils with pH ranging between 7.5 and 8.0 (Venkataratnam, 1973). Soils with medium to light constituents, without excessive moisture, are suitable for its cultivation. Even soils with poor fertility and depleted plant nutrients are suitable for growing Guar as a green manure crop. Pasture lands receiving little care can also be used for growing guar mixed with grasses.

Guar is a mainly grown for its tender fruits for use as vegetable. It is also used as a nutritious fodder for livestock. Mucilaginous seed flour is used for making guar gum (galactomannan) utilized in textile, paper, cosmetic and oil industries throughout the world and is a useful absorbent for explosives (Smith, 1976).

Guar is predominantly grown in India and Pakistan as a vegetable, fodder and grain crop. Cultivars grown in South India are vegetable types while those in North-West India are grown for seeds.

It has assumed great industrial importance in recent years, mainly due to the presence of gum in its endosperm, which constitutes 35-40 per cent of the whole seed. Guar meal, a byproduct of guar gum industry is also of considerable value as it contains more than 42 per cent protein. Now-a-days, guar has emerged as a new industrial crop and is commercially grown in India, Pakistan and U.S.A and to some extent in Australia, South Africa and Brazil.

This vegetable gum finds a ready international market for its ever increasing demand in various industries. Guar was not known for its industrial application until world war-II, when there was shortage of locust bean crop, the paper and textile industry of the world was searching for a substitute. They found an efficient alternative in the form of guar gum and since then, the derivative of guar ruled out locust bean from this scenario and it was readily accepted for application in many other industries (Kumar, 2002). The refined gum powder has some unique characteristics like grease resistance, thickening agent, capacity to bind water, high viscosity and the capability to function in low temperatures.

Seeds of cluster bean have a large endosperm when compared to other legumes, and contains galactomannan type of gum, which forms a viscous gel and has diversified industrial applications *viz.,* paper, food, cosmetics, mining, petroleum, well drilling, pharmaceuticals (Pathak *et al.,* 2009).

In agriculture, guar gum is used as water retainer, soil aggregating and anticrusting agent (Singh *et al.,* 1985). In varnish industry, it is used as a protective colloid. In paper industry, it is used for improving quality of paper board by enhancing dry and wet strength and for enhancing sizing degree (Yoshyuki, 1985). Guar gum also has greater utility in pollution control. It is used as an adsorbent in waste water treatment and in textile industry as a flocculating and exchanging agent. In waste water purification, guar gum is used as a gelatinizing agent (Mathur *et al.,* 1986).

India is the major guar producer accounting for 80% of the world's production. In India, guar is being grown mainly in arid and semiarid regions of North Western states of Rajasthan, Gujarat, Haryana, Punjab, parts of Uttar Pradesh, Madhya Pradesh and Tamil Nadu covering about 3.34 million hectares with a production of 0.4 million tonnes of guar seed. Rajasthan occupies the largest area under guar cultivation (82.1%), followed by Haryana (8.6%), Gujarat (8.3%) and Punjab (1%) which in turn produced 64, 22, 12 and 2% guar seeds, respectively (Pathak *et al.,* 2010). Rajasthan is the largest producer accounting for 70% of total guar production followed by Gujarat, Haryana and Punjab. The productivity of cluster bean ranges from 474 kg/ha in Rajasthan to 1200 kg/ha in Haryana (Ahlawat *et al.*, 2013).

Clusterbean gum has emerged as the most important agro-chemical, which is non-toxic, eco-friendly and Generally Recognized As Safe (GRAS) by Food and Drug Administration (FDA). Foreign exchange earned from its export has increased from 142 crores in 1994 to 1120 crores during 2007 in India (Henry and Mathur 2008). From India, clusterbean is mainly exported to USA, Germany, Netherlands, Italy, UK, Japan and France value at 200 million rupees annually (Singh *et al.*, 2009).

Although several studies were conducted in *Cyamopsis tetragonoloba* (L.) Taub. for vegetable purpose, studies on cluster bean for Guar Gum purpose is limited in southern parts of India. Production of this crop in India mainly confined to the North-West part of India, however certain areas of Andhra Pradesh and Telangana state are highly suitable for cultivation of this crop as suggested by ICAR-high level expert committee report as an alternate crop for sustainability in scarce rainfall zones (CRIDA, 2012). As majority of the area in Telangana state is occupied with saline alkali soils with poor organic matter, the adoption of this crop in this region may be recommended to bring the poor and marginal lands under cultivation. However, due to limited information, farmers were unaware of the importance of this crop in many areas. Hence to evaluate various cultivars of Guar and identification of suitable cultivars for this region is highly warranted.

Moreover, yield is a complex trait influenced by various agro morphological and reproductive traits and hence, there is a need to study the association and their direct and indirect effects on seed yield (Manivannan and Anandakumar, 2013). This information will help to provide basis for selection and yield improvement in guar, this study will investigate the interrelationship between yield and its components, determine the relative contribution of the different yield components to the final yield and estimate the expected genetic advances and relative efficiencies. As such, before launching any breeding programme, a thorough knowledge of the nature and magnitude of genetic variability and extent of association between yield and other components is very essential.

Heritability of a metric character is a parameter of particular significance to the breeder as it measures the degree of resemblance between the parents and the off-springs and its magnitude indicates the efficacy with which a genotype can be identified by its phenotypic expression, while genetic advance aids in exercising the necessary selection pressure.

The correlation analysis is a biometrical technique to find out the nature and degree of association between various morphological traits indicating yield, while path coefficient analysis splits the correlation coefficient into direct and indirect effects so as to measure the relative contribution of each variable towards the yield.

In view of the above, present study is undertaken with the following objectives:

1. To study the performance of elite cultivars of Guar in Telangana State.
2. To study variability parameters for yield and its component characters.
3. To study the association of physiological parameters (Peroxidase and Catalase activity, Relative water content and Chlorophyll stability index) with drought tolerance.
4. To study the degree and direction of character association among yield and its components.

Chapter – II

REVIEW OF LITERATURE

A critical comprehensive review of literature is inevitable for any scientific investigation. Proper understanding of the problem requires thorough review of the existing knowledge related to the problem. Keeping in view the objectives of the present investigation, the available literature on genetic variability, character association and character contribution in seed guar is presented under the following headings.

2.1 Variability, heritability and genetic advance

2.2 Correlation coefficient analysis

2.3 Path coefficient analysis

2.4 Quality traits

2.1 VARIABILITY, HERITABILITY AND GENETIC ADVANCE

2.1.1 Variability

The nature and extent of variability forms the basis for all crop improvement programmes. According to Allard (1960), yield is polygenically controlled quantitative character and is highly influenced by environment.

Partitioning of observed variability into heritable and non-heritable components is very much essential to get a true indication of the genetic coefficient of variability as a useful measure of the magnitude of genetic variance present in the population.

The genetic variation is of high value to the breeders, as this is the hereditary portion of the total variation and is heritable from generation to generation. Analysis of variation and partitioning the phenotypic variance into genetic and environmental components provide adequate information whether the available genetic variation in the germplasm pool is sufficient for crop improvement by effective selection.

A brief review of studies on genotypic and phenotypic coefficients of variation in seed guar is presented below.

2.1.1.1 Growth parameters

Om Vir and Singh (2015) in cluster bean reported that high estimates of PCV and GCV were observed for number of branches per plant, days to 50% flowering, number of pods per plant. High PCV and moderate GCV were observed for number of clusters per plant, number of pods per cluster.

Vikas kumar and Ram (2015) studied 30 genotypes of cluster bean for genetic variability. The PCV and GCV were low for percentage of germination, days to first flowering, days to 50% flowering whereas, high PCV and GCV for number of clusters per plant, number of pods per cluster. Plant height showed moderate PCV and GCV.

Patil (2014) in cluster bean reported that the low PCV and GCV were observed for percentage of germination, pod girth. High PCV and GCV were recorded for number of clusters/plant. Moderate PCV and GCV were observed for days to 50% flowering, number of pods per cluster. Low GCV and moderate PCV were observed for pod length.

Rahul Kapoor (2014) in cluster bean reported that the PCV estimates were invariably higher than their corresponding GCV values thereby suggesting the environmental influence. High estimates of GCV and PCV were observed for number of leaves per plant.

Bhatkodle *et al.* (2014) in cluster bean reported that the phenotypic variance was higher than genotypic variance for all the characters studied. High PCV and GCV were observed for number of leaves per plant, number of clusters per plant, number of pods per cluster, number of pods per plant, pod length. Moderate PCV and GCV were observed for days to first flowering, days to 50% flowering, pod girth.

Prakash and Ram (2014) in french bean reported that moderate PCV and GCV were observed for number of leaves per plant.

Alemu *et al.* (2013) in french bean reported that low GCV and moderate PCV were observed for number branches per plant.

Manivannan and Anandakumar (2013) assessed 42 genotypes of Clusterbean. High variability was observed for pod length whereas, moderate variability was observed for plant height, days to 50% flowering. High PCV and moderate GCV were observed for number of clusters per plant, number of pods per cluster, number of pods per plant.

Muthuselvi and Shanthi (2013) evaluated 50 genotypes of cluster bean and reported that high estimates of GCV and PCV were recorded for number of branches per plant, number of clusters per plant, number of pods per cluster.

Shabarish Rai *et al*. (2012) evaluated thirty one genotypes of clusterbean and reported that maximum range of variability was observed for number of branches, plant height, clusters per plant, pod length, number of pods per cluster, number of pods per plant. Low PCV and GCV were observed for days to 50% flowering whereas, moderate PCV and GCV were observed for pod girth.

Durga (2012) in horse gram reported that low PCV and GCV were observed for plant height. Moderate PCV and low GCV were observed for number of branches per plant.

Bhat *et al*. (2012) and Pushpa *et al*. (2012) reported that low PCV and GCV were observed for pod length in soya bean and fenugreek, respectively.

Saini *et al.* (2010) in cluster bean reported that high estimates of PCV and GCV were observed for plant height, number of branches per plant, number of clusters per plant, number of pods per cluster, number of pods per plant.

Buttar *et al*. (2008) reported in cluster bean that number of branches per plant and plant height exhibited significant genetic coefficients of variation (>20%). High PCV and moderate GCV were observed for number of pods per plant.

Raghu Prakash *et al*. (2008) in cluster bean reported that high estimates of PCV and GCV were observed for plant height, number of branches per plant, number of clusters per plant, number of pods per cluster, number of pods per plant. Low PCV and GCV were observed for days to 50% flowering.

Anandhi and Oommen (2007) studied 29 varieties of cluster bean. The study revealed that variability was high for number of clusters per plant, number of pods per cluster, number of pods per plant, pod length. Low variability was observed for days to 50% flowering. High PCV and moderate GCV were observed for number of primary branches per plant.

Lal *et al.* (2005) and Raffi and Nath (2004) reported that moderate PCV and GCV were observed for plant height in dolichos bean and dry bean, respectively.

Hanchinamani (2004) in cluster bean reported that that high estimates of PCV and GCV were observed for plant height, number of branches per plant, number of leaves per plant, number of clusters per plant, number of pods per cluster, number of pods per plant, pod length. Moderate PCV and GCV were observed for days to first flowering, days to 50% flowering.

Singh et al. (2004) in cluster bean reported that high estimates of PCV and GCV were observed for number of clusters per plant.

Choudhary *et al.* (2003) in cluster bean reported that high estimates of phenotypic and genotypic coefficients of variation were recorded for plant height, number of branches per plant.

2.1.1.2 Yield parameters

Om Vir and Singh (2015) in cluster bean reported that high estimates of PCV and GCV were observed for number of seeds per pod, seed yield per plant.

Patil (2014) in cluster bean reported that the low PCV and GCV were observed for number of seeds per pod, 100-seed weight. High PCV and GCV were observed for dry pod yield/plant, seed yield per plant.

Bhatkodle *et al.* (2014) in cluster bean reported that the phenotypic variance was higher than genotypic variance for all the characters studied. High PCV and GCV were observed for pod yield per plant.

Verma *et al.* (2014) in dolichos bean reported that high estimates of PCV and GCV were observed for pod yield per hectare.

Rao *et al.* (2014) in soya bean reported that high estimates of PCV and GCV were observed for seed yield per hectare.

Manivannan and Anandakumar (2013) assessed 42 genotypes of Clusterbean. Low PCV and GCV were observed for number of seeds per pod, 100-seed weight. High PCV and moderate GCV were observed for seed yield per plant.

Muthuselvi and Shanthi (2013) evaluated 50 genotypes of cluster bean and reported that high estimates of GCV and PCV were recorded for dry pod yield per plant, 100 seed weight.

Shabarish Rai *et al*. (2012) evaluated thirty one genotypes of clusterbean and reported that maximum range of variability was observed for pod yield per plant, pod yield per hectare. Moderate PCV and GCV were observed for number of seeds per pod.

Saini *et al.* (2010) in cluster bean reported that high estimates of PCV and GCV were observed for pod yield per plant.

Buttar *et al*. (2008) reported in cluster bean that seed yield per plant exhibited significant genetic coefficients of variation (>20%) whereas, low PCV and GCV were observed for number of seeds per pod and moderate PCV and GCV were observed for 100-seed weight.

Raghu Prakash *et al*. (2008) in cluster bean reported that high estimates of PCV and GCV were observed for seed yield per plant. Low PCV and GCV were observed for number of seeds per pod. Moderate PCV and low GCV were observed for 100-seed weight.

Anandhi and Oommen (2007) studied 29 varieties of cluster bean. The study revealed that variability was high for pod yield per plant. Low variability was observed for number of seeds per pod.

Hanchinamani (2004) in cluster bean reported that that high estimates of PCV and GCV were observed for pod yield per plant.

Hanchinamani Nagaraj *et al.* (2004) and Singh et al. (2002) in cluster bean reported that that high estimates of PCV and GCV were observed for seed yield per plant.

2.1.1.3 Physiological parameters

Jitender *et al*. (2014) in cluster bean reported that low estimates of PCV and GCV were observed for relative water content.

Paramesh *et al.* (2014) in mung bean reported that low estimates of PCV and GCV were observed for harvest index, SPAD meter reading whereas, moderate PCV and GCV were observed for chlorophyll stability index.

Kole and Saha (2013) in fenugreek reported that low estimates of PCV and GCV were observed for harvest index.

Swathi (2013) in mung bean reported that moderate PCV and GCV were observed for chlorophyll stability index.

Singh *et al.* (2010) in cabbage reported that high estimates of PCV and GCV were observed for peroxidase enzyme activity and catalase enzyme activity.

Raghu Prakash *et al*. (2008) in cluster bean reported that high estimates of PCV and GCV were observed for harvest index whereas, low estimates of PCV and GCV were observed for SPAD meter reading.

Kole and Mishra (2006) in fenugreek reported that low estimates of PCV and GCV were observed for harvest index.

Dash and Kole (2001) in fenugreek reported that low estimates of PCV and GCV were observed for harvest index.

2.1.1.4 Quality parameters

Jitender *et al*. (2014) in cluster bean reported that low estimates of PCV and GCV were observed for gum content.

Muthuselvi and Shanthi (2013) evaluated 50 genotypes of cluster bean and reported that high estimates of GCV and PCV were recorded for gum content.

Raghu Prakash *et al*. (2008) in cluster bean reported that low estimates of PCV and GCV were observed for crude gum content.

2.1.2 Heritability and genetic advance as per cent of mean

Heritability estimates along with genetic advance serve as a tool to the breeder in determining the direction and magnitude of selection. These are more useful in predicting the resultant effect through selection of the best individual.

Heritability is the measure of transmission of characters from generation to generation. Hanson *et al.* (1956) defined heritability in broad sense as the ratio of genotypic variance to the total phenotypic variance in the non-segregating populations. Heritability (h^2) measures the relative amount of the heritable portion of variability, while genetic advance helps to measure the amount of progress that could be expected with selection in a character.

High heritability coupled with high genetic advance indicates that the improvement could be made for a character by simple selection based on phenotypic performance. High heritability coupled with low genetic advance indicate that heritability alone does not necessarily mean an increase of genetic advance.

Low heritability coupled with low genetic advance indicate that the character is highly influenced by environmental effects and selection would be ineffective.

The available literature on heritability and genetic advance is presented below.

2.1.2.1 Growth parameters

Vikas kumar and Ram (2015) studied 30 genotypes of cluster bean for heritability and genetic advance. The study revealed that high heritability with high genetic advance as per cent of mean were found with plant height (cm), number of branches/plant, days to 50% flowering, number of pods/cluster, number of pods/plant indicating there by that selections based on phenotypic performance could be effective for improvement of these characters. Low heritability coupled with low genetic advance as per cent of mean were observed for percentage of germination, pod girth. Moderate heritability with moderate genetic advance as per cent of mean were observed with pod length. High heritability with moderate genetic advance as per cent of mean were observed with number of pods per cluster.

Patil (2014) in cluster bean reported that the high heritability coupled with high genetic advance as per cent of mean were observed for plant height, number of branches per plant, days to 50% flowering, number of clusters per plant, number of pods per cluster indicated the presence of large number of fixable additive factors and hence these traits could be improved through selection. Moderate heritability with moderate genetic advance as per cent of mean were recorded in pod length. High heritability with moderate genetic advance as per cent of mean were recorded with percentage of germination.

Rahul Kapoor (2014) in cluster bean reported that high heritability along with high genetic advance as per cent of mean were recorded with number of leaves per plant, number of branches indicating that selection would be rewarding for these characters.

Bhatkodle et al. (2014) in cluster bean reported that high heritability coupled with high genetic advance as per cent of mean were observed for the characters like plant height, branches per plant, number of leaves per plant, days to first flowering, days to 50% flowering, number of clusters per plnat, number of pods per cluster, number of pods per plant, pod length, this indicates the influence of additive gene action for these traits.

Manivannan and Anandakumar (2013) assessed 42 genotypes of Clusterbean. High heritability and high genetic advance as per cent of mean were recorded for primary branches per plant, days to 50% flowering, pod length. Moderate heritability and high genetic advance as per cent of mean were recorded for number of clusters per plant, number of pods per cluster.

Muthuselvi and Shanthi (2013) evaluated 50 genotypes of cluster bean and reported that high heritability coupled with high genetic advance as per cent of mean were observed for plant height, number of branches per plant, number of clusters per plant, number of pods per cluster, pod length indicating that these characters had predominance of additive gene action and hence selection is more effective.

Shabarish Rai *et al*. (2012) evaluated thirty one genotypes of clusterbean to estimate broad sense heritability and genetic advance over mean. High heritability coupled with high genetic gain in percentage were observed for number of clusters per plant, number of pods per plant, days to 50% flowering, number of branches and plant height. High heritability with low genetic advance were shown for pod length, pod girth, number of pods per cluster.

Girish *et al*. (2012a) in cluster bean reported that high heritability coupled with high genetic advance as per cent of mean were observed with pod length.

Alemu *et al*. (2013) in french bean reported that high heritability coupled with moderate genetic advance as per cent of mean were observed with pod length.

Saini *et al.* (2010) in cluster bean reported that high heritability coupled with high genetic advance as per cent of mean were observed with plant height, number of branches per plant, number of clusters per plant, number of pods per plant.

Raghu Prakash *et al*. (2008) in cluster bean reported that high heritability coupled with genetic advance as percent of mean were observed for the characters viz., plant height, number of branches per plant, number of clusters per plant, number of pods per cluster, number of pods per plant indicating that simple selection program would be effective for genetic improvement of guar. High heritability coupled with low genetic advance as per cent of mean were observed with days to 50% flowering. Low heritability coupled with high genetic advance as per cent of mean were observed with number of pods per plant.

Buttar *et al*. (2008) in cluster bean reported that moderate heritability coupled with high genetic advance as per cent of mean were observed with number of pods per plant.

Anandhi and Oommen (2007) studied 29 varieties of cluster bean. The study revealed that high heritability coupled with high genetic advance as per cent of mean were observed for plant height, number of branches per plant, number of pod clusters per plant, number of pods per cluster, pod length and number of pods per plant indicating the presence of additive gene action in the expression of these characters. High heritability coupled with low genetic advance as per cent of mean were observed for days to 50% flowering.

Mahla and Kumar (2006) in cluster bean reported that high heritability coupled with high genetic advance as per cent of mean were observed with number of branches per plant, number of leaves per plant.

Shekhawat and Singhania (2005) in cluster bean reported that high heritability coupled with high genetic advance as per cent of mean were observed with number of branches per plant, number of leaves per plant.

Hanchinamani (2004) in cluster bean reported that high heritability coupled with high genetic advance as per cent of mean were observed with plant height, number of branches per plant, number of leaves per plant.

Saini *et al*. (2004), Singh *et al*. (2004) and Sabarish (2010) in cluster bean reported that high heritability coupled with high genetic advance as per cent of mean were observed with plant height.

Singh *et al*. (2001) in cluster bean reported that high heritability coupled with high genetic advance as per cent of mean were observed with plant height, number of branches per plant, number of clusters per plant, number of pods per plant.

Rai *et al*. (2004) and Singh *et al*. (2000) in french bean reported that high heritability coupled with high genetic advance as per cent of mean were observed with plant height.

2.1.2.2 Yield parameters

Vikas kumar and Ram (2015) studied 30 genotypes of cluster bean for heritability and genetic advance. The study revealed that high heritability with high genetic advance as per cent of mean were found with pod yield per plant, seed yield per plant. High heritability with moderate genetic advance as per cent of mean were shown for number of seeds per pod, 100-seed weight.

Patil (2014) in cluster bean reported that the high heritability coupled with high genetic advance as per cent of mean were observed for pod yield per plant, seed yield per plant indicated the presence of large number of fixable additive factors and hence these traits could be improved through selection. High heritability with moderate genetic advance as per cent of mean were recorded with number of seeds per pod, 100-seed weight.

Bhatkodle et al. (2014) in cluster bean reported that moderate heritability coupled with high genetic advance as per cent of mean were observed for pod yield per plant.

Verma *et al*. (2014) in dolichos bean reported that high heritability coupled with high genetic advance as per cent of mean were observed with pod yield per hectare.

Rao *et al*. (2014) in soya bean reported that high heritability coupled with high genetic advance as per cent of mean were observed with seed yield per hectare.

Manivannan and Anandakumar (2013) assessed 42 genotypes of Clusterbean. Moderate heritability and low genetic advance as per cent of mean were recorded for number of seeds per pod. Moderate heritability and high genetic advance as per cent of mean were recorded for seed yield per plant. High heritability with moderate genetic advance as per cent of mean were shown for 100-seed weight.

Muthuselvi and Shanthi (2013) evaluated 50 genotypes of cluster bean and reported that high heritability coupled with high genetic advance as per cent of mean were observed for dry pod yield per plant, seed yield per plant, 100 seed weight indicating that these characters had predominance of additive gene action and hence selection is more effective.

Shabarish Rai *et al*. (2012) evaluated thirty one genotypes of clusterbean to estimate broad sense heritability and genetic advance over mean. High heritability coupled with high genetic gain in percentage were observed for pod yield per plant. High heritability with low genetic advance as per cent of mean were shown for number of seeds per pod, pod yield per hectare.

Saini *et al*. (2010) in cluster bean reported that high heritability coupled with high genetic advance as per cent of mean were observed with pod yield per plant. High heritability coupled with moderate genetic advance as per cent of mean were observed with 100-seed weight.

Raghu Prakash *et al*. (2008) in cluster bean reported that high heritability coupled with high genetic advance as percent of mean were observed for seed yield per plant indicating that simple selection program would be effective for genetic improvement of guar. Moderate heritability with low genetic advance as per cent of mean were shown for number of seeds per pod. High heritability with moderate genetic advance as per cent of mean were shown for 100-seed weight.

Buttar *et al.* (2008) in cluster bean reported that high heritability coupled with high genetic advance as percent of mean were observed for 100-seed weight. Moderate heritability with low genetic advance as per cent of mean were shown for number of seeds per pod. Moderate heritability with high genetic advance as per cent of mean were shown for seed yield per plant.

Anandhi and Oommen (2007) studied 29 varieties of cluster bean. The study revealed that high heritability coupled with high genetic advance as per cent of mean were observed for pod yield per plant indicating the presence of additive gene action in the expression of these characters. High heritability with moderate genetic advance as per cent of mean were shown for number of seeds per pod.

Rai *et al*. (2004) in french bean reported that high heritability coupled with high genetic advance as per cent of mean were observed with pod yield per plant.

Singh *et al*. (2001) in cluster bean reported that high heritability coupled with high genetic advance as per cent of mean were observed with pod yield per plant.

Singh *et al*. (2000) in french bean reported that high heritability coupled with high genetic advance as per cent of mean were observed with pod yield per plant.

2.1.2.3 Physiological parameters

Jitender *et al*. (2014) in cluster bean reported that high heritability coupled with moderate genetic advance as per cent of mean were observed with harvest index. High heritability coupled with low genetic advance as per cent of mean were observed with relative water content.

Paramesh *et al.* (2014) in mung bean reported that high heritability coupled with high genetic advance as per cent of mean were observed for chlorophyll stability index. Moderate heritability coupled with low genetic advance as per cent of mean were observed for harvest index, SPAD meter reading.

Hefny (2013) in lupin bean reported that high heritability coupled with high genetic advance as per cent of mean were observed for catalase enzyme activity.

Swathi (2013) in mung bean reported that high heritability coupled with high genetic advance as per cent of mean were observed for chlorophyll stability index.

Singh *et al.* (2010) in cabbage reported that high heritability coupled with high genetic advance as per cent of mean were observed for peroxidase enzyme activity and high heritability coupled with low genetic advance as per cent of mean were observed for catalase enzyme activity.

Raghu Prakash *et al*. (2008) in cluster bean reported that high heritability coupled with high genetic advance as per cent of mean were observed for harvest index whereas, high heritability coupled with moderate genetic advance as per cent of mean were observed for SPAD meter reading.

2.1.2.4 Quality parameters

Jitender *et al*. (2014) in cluster bean reported that moderate heritability coupled with low genetic advance as per cent of mean were observed with gum content.

Muthuselvi and Shanthi (2013) evaluated 50 genotypes of cluster bean and reported that high heritability coupled with high genetic advance as per cent of mean were observed for gum content.

Raghu Prakash *et al*. (2008) in cluster bean reported that high heritability coupled with low genetic advance as per cent of mean were observed for gum content.

2.2 ASSOCIATION OF SEED YIELD AND ITS COMPONENTS

Character association analysis reveals the type, nature and magnitude of correlation between seed yield components with yield and among themselves. Yield component characters show association among themselves and with yield. Unfavourable associations between the desired attributes under selection may limit genetic advance. Hence, study of association of component characters with seed yield would aid in planning of an effective selection programme.

Knowledge of inter-relationships existing among yield components is essential when selection for improvement is to be effective. Study of character association has considerable use in plant breeding because selection for one character may bring about simultaneous effect on other depending on the intensity of association between the two traits under consideration.

Correlation studies indicate the magnitude of association between pairs of characters and are useful for selecting genotypes with desirable combinations of characters thereby assisting the plant breeder in crop improvement.

Since, yield of plant is a complex, polygenically inherited trait, direct selection is not effective. But, it could be improved through a number of component characters, which are simple in inheritance and less subjected to environmental influences. Hence, the knowledge of association of yield components with yield and among themselves would be of help to the breeder in obtaining improved yields. For simplicity, these studies presented here in the tabular form.

Table 2.1 Review of literature on association of yield component characters with seed yield per plant (g) in seed guar

S. No.	Character	Association	S/ NS	Reference
1.	Plant height (cm)	Positive	S	Ibrahim *et al*. (2013) Rai *et al*. (2012) Shah *et al*. (2000) Arumugarangarajan *et al*. (2000)
		Negative	S	Patil (2014) Maria Sultan *et al*. (2012) Buttar *et al*. (2008)
2.	Number of Primary branches per plant	Positive	S	Manivannan and Anandakumar (2013)
3.	Days to 50 % flowering	Positive	S	Om Vir and Singh (2015) Saini et *al*. (2010) Singh et *al*. (2005) Singh et *al*. (2004) Singh et *al*. (2002) Singh et *al*. (2001) Patel and Chaudhary (2001) Arumugarangarajan *et al*. (2000)
		Negative	S	Patil (2014) Sultan *et al*. (2012) Maria Sultan *et al*. (2012)
4.	Number of clusters per plant	Positive	S	Om Vir and Singh (2015) Patil (2014) Manivannan and Anandakumar (2013) Ibrahim *et al*. (2013) Sultan *et al*. (2012) Maria Sultan *et al*. (2012)

Table 2.1 contd…

S. No.	Character	Association	S/ NS	Reference
				Saini e*t al.* (2010) Singh e*t al.* (2005) Singh e*t al.* (2004) Singh e*t al.* (2002) Singh e*t al.* (2001) Patel and Chaudhary (2001) Arumugarangarajan *et al*. (2000) Shah *et al.* (2000)
5.	Number of pods per cluster	Positive	S	Om Vir and Singh (2015) Patil (2014) Manivannan and Anandakumar (2013) Sultan *et al.* (2012) Rai *et al.* (2012) Maria Sultan *et al.* (2012) Saini e*t al.* (2010) Singh e*t al.* (2005) Singh e*t al.* (2004) Singh e*t al.* (2002) Singh e*t al.* (2001) Patel and Chaudhary (2001) Arumugarangarajan *et al*. (2000)
6.	Pod length (cm)	Positive	NS	Patil (2014)
		Negative	S	Manivannan and Anandakumar (2013) Arumugarangarajan *et al.* (2000)
7.	Pod girth (mm)	Negative	NS	Patil (2014)
		Positive	S	Maria Sultan *et al.* (2012)
8.	Number of seeds per pod	Positive	S	Om Vir and Singh (2015) Patil (2014) Saini e*t al.* (2010)

Table 2.1 contd…

S. No.	Character	Association	S/ NS	Reference
				Singh *et al.* (2005) Singh *et al.* (2004) Singh *et al.* (2002) Singh *et al.* (2001) Patel and Chaudhary (2001) Arumugarangarajan *et al.* (2000)
		Positive	NS	Buttar *et al.* (2008)
9.	Pod yield per plant (g)	Positive	S	Patil (2014) Ibrahim *et al.* (2013) Rai *et al.* (2012) Shah *et al.* (2000) Arumugarangarajan *et al.* (2000)
10.	100-seed weight (g)	Positive	S	Patil (2014) Buttar *et al.* (2008) Singh *et al.* (2004) Brar and Grover (2003)
		Negative	S	Manivannan and Anandakumar (2013)

S- Significant , NS- Non Significant

Table 2.2 Review of literature on association of yield component characters with plant height (cm) in seed guar

S. No.	Character	Association	S/ NS	Reference
1.	Days to 50% flowering	Negative	S	Malaghan *et al.* (2014)
2.	Pod length (cm)	Negative	S	Malaghan *et al.* (2014) Anjani *et al.* (2009) in French bean
		Positive	S	Shabarish Rai and Dharmatti (2014)

Table 2.2 contd…

S. No.	Character	Association	S/ NS	Reference
3.	Number of seeds per pod	Positive	S	Shabarish Rai and Dharmatti (2014)
		Negative	NS	Buttar *et al.* (2008)
4.	Pod yield per plant (g)	Positive	S	Malaghan *et al.* (2014) Vidhya and Sunny (2002) in Yard long bean
5.	100-seed weight	Negative	S	Buttar *et al.* (2008)
6.	Number of pods per cluster	Positive	S	Shabarish Rai and Dharmatti (2014) Manivannan and Anandakumar (2013) Arumugarangarajan *et al.* (2000)

Table 2.3 Review of literature on association of yield component characters with number of primary branches per plant in seed guar

S. No.	Character	Association	S/ NS	Reference
1.	Days 50% flowering	Negative	S	Manivannan and Anandakumar (2013)
2.	No. of clusters per plant	Positive	S	Manivannan and Anandakumar (2013) Anandhi and Oommen (2010) Singh *et al.* (2002)
3.	No. of pods per cluster	Positive	NS	Manivannan and Anandakumar (2013)
4.	Pod length (cm)	Negative	S	Manivannan and Anandakumar (2013) Anandhi and Oommen (2010)

Table 2.3 contd…

S. No.	Character	Association	S/ NS	Reference
5.	No. of seeds per pod	Negative	S	Manivannan and Anandakumar (2013)
7.	Seed yield per plant	Positive	S	Manivannan and Anandakumar (2013)
8.	100-seed weight	Negative	S	Manivannan and Anandakumar (2013)
9.	Number of pods per plant	Positive	S	Anandhi and Oommen (2010) Singh *et al.* (2002)
9.	Plant height	Negative	S	Anandhi and Oommen (2010)

Table 2.4 Review of literature on association of yield component characters with days to 50% flowering in seed guar

S. No.	Character	Association	S/ NS	Reference
1.	Number of clusters per plant	Negative	S	Arumugarangarajan *et al.* (2000)
2.	Pod length (cm)	Positive	S	Manivannan and Anandakumar (2013) Malaghan *et al.* (2014)
		Negative	S	Shabarish Rai and Dharmatti (2014) Arumugarangarajan *et al.* (2000)
3.	Pod girth	Positive	S	Malaghan *et al.* (2014)
		Negative	S	Pan et al. (2004) in Dolichos bean Roy et al. (2006) in French bean
3.	Number of seeds per pod	Negative	S	Shabarish Rai and Dharmatti (2014)

Table 2.4 contd…

S. No.	Character	Association	S/ NS	Reference
4.	100-seed weight	Positive	S	Manivannan and Anandakumar (2013)
5.	Plant height	Negative	S	Malaghan *et al.* (2014)
6.	Pod yield per plant	Negative	S	Malaghan *et al.* (2014)

Table 2.5 Review of literature on association of yield component characters with number of clusters per plant in seed guar

S. No.	Character	Association	S/ NS	Reference
1.	Number of pods per cluster	Positive	S	Girish *et al.* (2012b) Saini *et al.* (2010) Singh *et al.* (2004) Arumugarangarajan *et al.* (2000)
2.	Pod yiled per plant (g)	Positive	S	Shabarish Rai and Dharmatti (2014) Girish *et al.* (2012b) Saini *et al.* (2010) Singh *et al.* (2004)
3.	Number of primary branches per plant	Positive	S	Manivannan and Anandakumar (2013) Anandhi and Oommen (2010)
4.	Plant height	Positive	S	Girish *et al.* (2012b) Saini *et al.* (2010) Singh *et al.* (2004) Arumugarangarajan *et al.* (2000)

Table 2.5 contd…

S. No.	Character	Association	S/ NS	Reference
5.	Seed yield per plant	Positive	S	Manivannan and Anandakumar (2013) Arumugarangarajan *et al.* (2000)
6.	Days to 50 % flowering	Negative	S	Arumugarangarajan *et al.* (2000)
7.	Number of seeds per pod	Negative	S	Arumugarangarajan *et al.* (2000)

Table 2.6 Review of literature on association of yield component characters with number of pods per cluster in seed guar

S. No.	Character	Association	S/ NS	Reference
1.	Pod yiled per plant (g)	Positive	S	Girish *et al.* (2012b) Saini *et al.* (2010) Arumugarangarajan *et al.* (2000)
2.	Number of clusters per plant	Positive	S	Girish *et al.* (2012b) Saini *et al.* (2010) Arumugarangarajan *et al.* (2000)
		Negative	S	Om Vir and Singh (2015)
3.	Plant height	Positive	S	Shabarish Rai and Dharmatti (2014) Manivannan and Anandakumar (2013) Girish *et al.* (2012b) Saini *et al.* (2010) Arumugarangarajan *et al.* (2000)

Table 2.6 contd...

S. No.	**Character**	**Association**	**S/ NS**	**Reference**
4.	Seed yield per plant	Positive	S	Manivannan and Anandakumar (2013) Arumugarangarajan *et al.* (2000)
5.	Pod length	Negative	S	Manivannan and Anandakumar (2013)
6.	100-seed weight	Negative	S	Manivannan and Anandakumar (2013)

Table 2.7 Review of literature on association of yield component characters with pod length (cm) in seed guar

S. No.	**Character**	**Association**	**S/ NS**	**Reference**
1.	Number of seeds per pod	Positive	S	Anandhi and Oommen (2010) Shabarish Rai and Dharmatti (2014)
2.	Plant height	Positive	S	Shabarish Rai and Dharmatti (2014)
		Negative	S	Malaghan *et al.* (2014)
3.	Days to 50% flowering	Positive	S	Malaghan *et al.* (2014) Manivannan and Anandakumar (2013)
4.	Seed yield per plant	Negative	S	Arumugarangarajan *et al.* (2000) Manivannan and Anandakumar (2013)
5.	100-seed weight	Positive	S	Manivannan and Anandakumar (2013)
6.	Number of pods per cluster	Positive	S	Shabarish Rai and Dharmatti (2014)

Table 2.7 contd…

S. No.	Character	Association	S/ NS	Reference
		Negative	S	Manivannan and Anandakumar (2013)
7.	Number of primary branches per plant	Negative	S	Manivannan and Anandakumar (2013) Anandhi and Oommen (2010)
8.	Pod width	Negative	S	Pan *et al*. (2004) in Dolichos bean

Table 2.8 Review of literature on association of yield component characters with pod girth (mm) in seed guar

S. No.	Character	Association	S/ NS	Reference
1.	Pod length (cm)	Positive	S	Shabarish Rai and Dharmatti (2014) Malaghan *et al.* (2014)
		Negative	S	Pan *et al*. (2004) in Dolichos bean
2.	Pod yield per plant	Positive	S	Malaghan *et al.* (2014)
3.	Days to 50% flowering	Positive	S	Malaghan *et al.* (2014)
		Negative	S	Roy *et al*. (2006) in French bean Pan *et al*. (2004) in Dolichos bean
4.	Plant height	Positive	S	Malaghan *et al.* (2014)

Table 2.9 Review of literature on association of yield component characters with number of seeds per pod in seed guar

S. No.	Character	Association	S/ NS	Reference
1.	Pod length (cm)	Positive	S	Shabarish Rai and Dharmatti (2014) Kamleshwar Kumar *et al.* (2013) in Green gram Anandhi and Oommen (2010)
2.	Plant height (cm)	Positive	S	Shabarish Rai and Dharmatti (2014) Kamleshwar Kumar *et al.* (2013) in Green gram
3.	Days to 50 % flowering	Negative	S	Shabarish Rai and Dharmatti (2014)
4.	Pod girth	Positive	S	Shabarish Rai and Dharmatti (2014)
5.	100-seed weight	Positive	S	Shabarish Rai and Dharmatti (2014)
6.	Pod yield per plant	Positive	S	Anandhi and Oommen (2010)
7.	Number of clusters per plant	Negative	S	Arumugarangarajan *et al.* (2000)

Table 2.10 Review of literature on association of yield component characters with pod yield per plant (g) in seed guar

S. No.	Character	Association	S/ NS	Reference
1.	Days to 50 % flowering	Negative	S	Malaghan *et al.* (2014) Anjani *et al.* (2009) in French bean

Table 2.10 contd…

S. No.	**Character**	**Association**	**S/ NS**	**Reference**
2.	Plant height (cm)	Positive	S	Arumugarangarajan *et al.* (2000)
3.	Pod length	Positive	S	Malaghan *et al.* (2014)
4.	Number of pods per plant	Positive	S	Malaghan *et al.* (2014)
5.	Pod length	Positive	S	Malaghan *et al.* (2014)
6.	Pod girth	Positive	S	Malaghan *et al.* (2014)
7.	Seed yield per plant	Positive	S	Arumugarangarajan *et al.* (2000)
8.	Number of clusters per plant	Positive	S	Shabarish Rai and Dharmatti (2014) Arumugarangarajan *et al.* (2000)
9.	Number of pods per cluster	Positive	S	Arumugarangarajan *et al.* (2000)
10.	Number of seeds per pod	Positive	S	Arumugarangarajan *et al.* (2000)

Table 2.11 Review of literature on association of yield component characters with 100-seed weight in seed guar

S. No.	**Character**	**Association**	**S/ NS**	**Reference**
1.	Plant height (cm)	Negative	S	Buttar *et al.* (2008)
2.	Pod length (cm)	Positive	S	Manivannan and Anandakumar (2013)
3.	Primary branches per plant	Negative	S	Manivannan and Anandakumar (2013)

Table 2.11 contd…

S. No.	Character	Association	S/ NS	Reference
4.	Number of clusters per plant	Negative	S	Manivannan and Anandakumar (2013)
5.	Number of pods per cluster	Negative	S	Manivannan and Anandakumar (2013)
6.	Number of seeds per pod	Positive	S	Manivannan and Anandakumar (2013) Buttar *et al*. (2008)
7.	Days to 50 % flowering	Positive	S	Manivannan and Anandakumar (2013)
8.	Seed yield per plant	Positive	S	Buttar *et al*. (2008)

Table 2.12 Review of literature on association of yield component characters with crude gum content (%) in seed guar

S. No.	Character	Association	S/ NS	Reference
1.	Plant height (cm)	Negative	S	Girish *et al.* (2012b) Hanchinamani *et al*. (2004)
2.	Seed yield per plant	Positive	NS	Raghu Prakash *et al.* (2008)
3.	Days to 50% flowering	Negative	NS	Raghu Prakash *et al.* (2008)
4.	100-seed weight	Positive	NS	Raghu Prakash *et al.* (2008)
5.	Pods per cluster	Negative	NS	Raghu Prakash *et al.* (2008)

2.3 PATH COEFFICIENT ANALYSIS

Yield being a complex polygenic character, direct selection for yield may not be a reliable approach on account of being highly influenced by environmental factors. Therefore, it is essential to identify the component characters through which yield improvement could be obtained. Though correlations give information about the components of a complex character like yield, but it could not provide an exact picture of relative importance of the direct and indirect contributions of the component characters on yield. In this context, path coefficient analysis is an important method in partitioning the correlation coefficients into direct and indirect effects of an independent variable on dependence variable. Thus, correlation in conjunction with path analysis would give a better insight into cause and effect relationship between different pairs of characters (Wright, 1921). For simplicity, these studies presented here in the tabular form.

Table 2.13 Direct effects of component characters on seed yield per plant (g) in seed guar

Character	Direct Effect	Through	Reference
Seed yield per plant (g)	Positive	Plant height	Patil (2014) Raghu Prakash *et al.* (2009) Krishnan *et al.* (2002) in urdbean
		Days to 50 % flowering	Patil (2014) Manivannan and Anandakumar (2013) Hingane and Navale (2008) Arumugarangarajan *et al.* (2000)
		Number of clusters per plant	Patil (2014) Manivannan and Anandakumar (2013) Girish *et al.* (2012b) Hingane and Navale (2008) Singh *et al.* (2002) Arumugarangarajan *et al.* (2000)

Table 2.13 contd…

Character	Direct Effect	Through	Reference
		Number of pods per cluster	Patil (2014) Manivannan and Anandakumar (2013) Hingane and Navale (2008) Arumugarangarajan *et al.* (2000)
		Pod length	Hingane and Navale (2008)
		Pod girth	Patil (2014)
		Number of seeds per pod	Patil (2014) Manivannan and Anandakumar (2013) Ibrahim *et al.* (2012) Girish *et al.* (2012b) Hingane and Navale (2008) Buttar *et al.* (2008) Singh *et al.* (2002) Arumugarangarajan *et al.* (2000)
		Pod yield per plant	Patil (2014)
		100-seed weight	Manivannan and Anandakumar (2013) Girish *et al.* (2012b) Hingane and Navale (2008) Singh *et al.* (2002) Arumugarangarajan *et al.* (2000)
		Crude gum content	Raghu Prakash *et al.* (2009)
	Negative	Plant height	Manivannan and Anandakumar (2013) Hingane and Navale (2008) Buttar *et al.* (2008) Arumugarangarajan *et al.* (2000)

Table 2.13 contd…

Character	Direct Effect	Through	Reference
		Days to 50% flowering	Raghu Prakash *et al.* (2009)
		No. of Primary branches per plant	Patil (2014) Manivannan and Anandakumar (2013) Buttar *et al.* (2008) Hingane and Navale (2008) Singh *et al*. (2002) Girish *et al.* (2012b)
		Number of clusters per plant	Raghu Prakash *et al.* (2009) Krishnan *et al.* (2002) in urdbean
		Pods per cluster	Krishnan *et al.* (2002) in urdbean
		Pod length	Patil (2014) Manivannan and Anandakumar (2013) Arumugarangarajan *et al.* (2000)
		Pod girth	Shabarish Rai and Dharmatti (2014) Malaghan *et al.* (2014)
		Number of seeds per pod	Arumugarangarajan *et al.* (2000)
		100-seed weight	Patil (2014) Raghu Prakash *et al.* (2009) Hingane and Navale (2008) Buttar *et al.* (2008) Singh *et al.* (2002) Arumugarangarajan *et al.* (2000)

Table 2.14 Indirect effects of component characters on seed yield per plant (g) in seed guar

Character	Indirect Effect	Through	Reference
1.Plant height (cm)	Positive	No. of Primary branches per plant	Manivannan and Anandakumar (2013)
		Number of clusters per plant	Arumugarangarajan *et al.* (2000)
		Number of pods per cluster	Hingane and Navale (2008) Manivannan and Anandakumar (2013) Arumugarangarajan *et al.* (2000)
		Pod length	Manivannan and Anandakumar (2013) Arumugarangarajan *et al.* (2000)
		Number of seeds per pod	Manivannan and Anandakumar (2013) Hingane and Navale (2008)
		Pod yield per plant	Arumugarangarajan *et al.* (2000)
		Crude gum content	Raghu Prakash *et al.* (2009)
		100-seed weight	Manivannan and Anandakumar (2013) Buttar *et al.* (2008) Hingane and Navale (2008) Arumugarangarajan *et al.* (2000)
	Negative	100-seed weight	Raghu Prakash *et al.* (2009)
		Primary branches per plant	Buttar *et al.* (2008) Raghu Prakash *et al.* (2009)

Table 2.14 contd…

Character	Indirect Effect	Through	Reference
		Days to 50 % flowering	Arumugarangarajan *et al.* (2000) Raghu Prakash *et al.* (2009)
		Pods per cluster	Raghu Prakash *et al.* (2009)
		Clusters per plant	Manivannan and Anandakumar (2013) Raghu Prakash *et al.* (2009)
		Number of seeds per pod	Raghu Prakash *et al.* (2009) Buttar *et al.* (2008) Arumugarangarajan *et al.* (2000)
2. Number of primary branches per plant	Positive	Plant height	Manivannan and Anandakumar (2013)
		Clusters per plant	Manivannan and Anandakumar (2013)
		Pods per cluster	Manivannan and Anandakumar (2013)
		Pod length	Manivannan and Anandakumar (2013)
		100-seed weight	Buttar *et al.* (2008)
	Negative	Plant height	Raghu Prakash *et al.* (2009) Buttar *et al.* (2008)
		Number of clusters per plant	Raghu Prakash *et al.* (2009)
		Number of seeds per pod	Manivannan and Anandakumar (2013) Buttar *et al.* (2008)
		100-seed weight	Manivannan and Anandakumar (2013)

Table 2.14 contd…

Character	Indirect Effect	Through	Reference
3. Days to 50 % flowering	Positive	Plant height	Manivannan and Anandakumar (2013) Hingane and Navale (2008) Arumugarangarajan *et al.* (2000)
		Primary branches per plant	Manivannan and Anandakumar (2013)
		Pods per cluster	Hingane and Navale (2008)
		Pod length	Arumugarangarajan *et al.* (2000)
		Number of seeds per pod	Manivannan and Anandakumar (2013) Arumugarangarajan *et al.* (2000)
		Pod yield per plant	Arumugarangarajan *et al.* (2000)
		100-seed weight	Manivannan and Anandakumar (2013) Hingane and Navale (2008)
	Negative	Clusters per plant	Manivannan and Anandakumar (2013) Hingane and Navale (2008) Arumugarangarajan *et al.* (2000)
		Pods per cluster	Manivannan and Anandakumar (2013) Arumugarangarajan *et al.* (2000)
		Seeds per pod	Hingane and Navale (2008)
		Pod length	Manivannan and Anandakumar (2013) Hingane and Navale (2008)
		Crude gum content	Raghu Prakash *et al.* (2009)
		100-seed weight	Arumugarangarajan *et al.* (2000)

Table 2.14 contd…

Character	Indirect Effect	Through	Reference
4. Number of clusters per plant	Positive	Plant height	Manivannan and Anandakumar (2013) Hingane and Navale (2008)
		Pod length	Manivannan and Anandakumar (2013) Arumugarangarajan *et al.* (2000)
		Pods per cluster	Arumugarangarajan *et al.* (2000)
		Days to 50 % flowering	Raghu Prakash *et al.* (2009)
		Pods per cluster	Raghu Prakash *et al.* (2009)
		Number of seeds per pod	Hingane and Navale (2008)
		Pod yield per plant	Arumugarangarajan *et al.* (2000)
		100-seed weight	Hingane and Navale (2008) Arumugarangarajan *et al.* (2000)
	Negative	Pods per cluster	Manivannan and Anandakumar (2013) Hingane and Navale (2008)
		Plant height	Arumugarangarajan *et al.* (2000)
		Pod length	Hingane and Navale (2008)
		100-seed weight	Hingane and Navale (2008)
		Primary branches per plant	Manivannan and Anandakumar (2013)
		Number of seeds per pod	Manivannan and Anandakumar (2013) Arumugarangarajan *et al.* (2000)

Table 2.14 contd…

Character	Indirect Effect	Through	Reference
		Days to 50% flowering	Manivannan and Anandakumar (2013) Hingane and Navale (2008) Arumugarangarajan *et al.* (2000)
		100-seed weight	Manivannan and Anandakumar (2013)
5. Number of pods per cluster	Positive	Days to 50% flowering	Hingane and Navale (2008)
		Clusters per plant	Arumugarangarajan *et al.* (2000)
		Pod length	Manivannan and Anandakumar (2013) Arumugarangarajan *et al.* (2000)
		Number of seeds per pod	Hingane and Navale (2008)
		Pod yield per plant	Arumugarangarajan *et al.* (2000)
		100-seed weight	Hingane and Navale (2008) Arumugarangarajan *et al.* (2000)
	Negative	Plant height	Manivannan and Anandakumar (2013) Hingane and Navale (2008) Arumugarangarajan *et al.* (2000)
		Primary branches per plant	Manivannan and Anandakumar (2013)
		Pod length	Hingane and Navale (2008)
		Number of clusters per plant	Manivannan and Anandakumar (2013) Hingane and Navale (2008)

Table 2.14 contd…

Character	Indirect Effect	Through	Reference
		Days to 50 % flowering	Manivannan and Anandakumar (2013) Arumugarangarajan *et al.* (2000)
		Number of seeds per pod	Manivannan and Anandakumar (2013) Arumugarangarajan *et al.* (2000)
		100-seed weight	Manivannan and Anandakumar (2013)
6. Pod length (cm)	Positive	Plant height	Hingane and Navale (2008) Arumugarangarajan *et al.* (2000)
		Number of seeds per pod	Arumugarangarajan *et al.* (2000)
		Pod yield per plant	Arumugarangarajan *et al.* (2000)
	Negative	Days to 50% flowering	Hingane and Navale (2008) Arumugarangarajan *et al.* (2000)
		Seeds per pod	Hingane and Navale (2008)
		Clusters per plant	Hingane and Navale (2008) Arumugarangarajan *et al.* (2000)
		Pods per cluster	Hingane and Navale (2008) Arumugarangarajan *et al.* (2000)
		100-seed weight	Hingane and Navale (2008) Arumugarangarajan *et al.* (2000)
7. Pod girth (mm)	Positive	Pod length	Shabarish Rai and Dharmatti (2014)
		Clusters per plant	Shabarish Rai and Dharmatti (2014)
	Negative	Plant height	Malaghan *et al.* (2014)
		Days to 50% flowering	Shabarish Rai and Dharmatti (2014)

Table 2.14 contd…

Character	Indirect Effect	Through	Reference
8. Number of seeds per pod	Positive	Days to 50% flowering	Manivannan and Anandakumar (2013) Arumugarangarajan *et al.* (2000)
		Plant height	Buttar *et al.* (2008) Arumugarangarajan *et al.* (2000)
		Primary branches per plant	Manivannan and Anandakumar (2013) Buttar *et al.* (2008)
		Pods per cluster	Hingane and Navale (2008) Arumugarangarajan *et al.* (2000)
		Clusters per plant	Hingane and Navale (2008)
		Pod yield per plant	Arumugarangarajan *et al.* (2000)
		100-seed weight	Manivannan and Anandakumar (2013) Hingane and Navale (2008)
	Negative	Clusters per plant	Manivannan and Anandakumar (2013) Arumugarangarajan *et al.* (2000)
		Plant height	Manivannan and Anandakumar (2013) Hingane and Navale (2008)
		Number of pods per plant	Manivannan and Anandakumar (2013)
		Days to 50 % flowering	Hingane and Navale (2008)
		100-seed weight	Buttar *et al.* (2008) Arumugarangarajan *et al.* (2000)
		Pod length	Manivannan and Anandakumar (2013) Hingane and Navale (2008) Arumugarangarajan *et al.* (2000)

Table 2.14 contd…

Character	Indirect Effect	Through	Reference
9.Pod yield per plant	Positive	Plant height	Arumugarangarajan *et al.* (2000)
		Days to 50 % flowering	Arumugarangarajan *et al.* (2000)
		Clusters per plant	Arumugarangarajan *et al.* (2000)
		Pods per cluster	Arumugarangarajan *et al.* (2000)
		Pod length	Arumugarangarajan *et al.* (2000)
		100-seed weight	Arumugarangarajan *et al.* (2000)
	Negative	Number of seeds per pod	Arumugarangarajan *et al.* (2000)
10. 100-seed weight	Positive	Plant height	Buttar *et al.* (2008) Hingane and Navale (2008)
		Primary branches per plant	Manivannan and Anandakumar (2013) Buttar *et al.* (2008)
		Number of seeds per pod	Manivannan and Anandakumar (2013) Buttar *et al.* (2008)
		Pod length	Hingane and Navale (2008) Arumugarangarajan *et al.* (2000)
		Days to 50 % flowering	Manivannan and Anandakumar (2013)
		Clusters per plant	Arumugarangarajan *et al.* (2000)
		Pods per cluster	Arumugarangarajan *et al.* (2000)

Table 2.14 contd…

Character	Indirect Effect	Through	Reference
	Negative	Pods per plant	Buttar *et al.* (2008)
		Plant height	Manivannan and Anandakumar (2013) Arumugarangarajan *et al.* (2000)
		Pod length	Manivannan and Anandakumar (2013)
		Clusters per plant	Manivannan and Anandakumar (2013) Hingane and Navale (2008)
		Seed yield per plant	Manivannan and Anandakumar (2013)
		Days to 50 % flowering	Hingane and Navale (2008) Arumugarangarajan *et al.* (2000)
		Pods per cluster	Manivannan and Anandakumar (2013) Hingane and Navale (2008)
		Number of seeds per pod	Hingane and Navale (2008) Arumugarangarajan *et al.* (2000)
		Pod yield per plant	Arumugarangarajan *et al.* (2000)
11. Crude gum content	Positive	Branches per plant	Raghu Prakash *et al.* (2009)
		Plant height	Raghu Prakash *et al.* (2009)
		Days to 50 % flowering	Raghu Prakash *et al.* (2009)
		Number of pods per plant	Raghu Prakash *et al.* (2009)
	Negative	Clusters per plant	Raghu Prakash *et al.* (2009)
		Pods per cluster	Raghu Prakash *et al.* (2009)
		Seeds per pod	Raghu Prakash *et al.* (2009)
		100-see weight	Raghu Prakash *et al.* (2009)

2.4 Quality traits

2.4.1 Crude gum content (%)

Jitender *et al*. (2014) reported that highest gum content recorded with FS-277 (29.50%) where as RGC-1017 (22.41%) registered minimum.

Kalyani (2006) reported that highest crude gum content recorded with RGM112 followed by RGC1003 and GAUG 9703.

Raghu Prakash (2006) reported that maximum gum content was recorded by the genotype GAUG- 9808 (33.22%) where as GAUG (28.55%) registered minimum.

Dwivedi *et al.* (1999) reported that gum content varied from 21.77-34.38%.

Veena Jain *et. al.* (1987) stated that significantly higher gum content was recorded in Durgajai as compared to HG 75 and HG 182.

Dabas (1982) reported that gum contents in guar varieties ranged from 15.92 to 31.81% in their study.

2.4.2 Pod Colour

Bode *et al*. (2013) reported that the pods showed light green, green and dark green colours in french bean.

Madakbas and Ergin (2011) in french bean reported that pods showed green, light green and dark green colours.

Pandey *et al*. (2011) studied 18 french bean genotypes and reported that the pods showed light green, normal green, dark green and green colour with red stripes. The results revealed that most of the genotypes produced normal green pods.

Chattopadhyay and Dutta (2010) studied 12 dolichos bean genotypes and reported that considerable variation among genotypes for pod colour. The pods were found to be in light green, green, purple and creamy white colours.

Islam *et al.* (2010) reported that out of 44 genotypes of dolichos bean, 23 had green-coloured pods, 10 had light green colour, 8 were mixed in colour and 3 produced red to purple pods.

Muchui *et al.* (2008) categorized french bean genotypes into different pod colours and found that most of the genotypes had green-coloured pods.

Kar *et al*. (2006) in french bean reported that pods showed light green, green, dark green, purple and brown with red colours.

Sultana (2001) also reported that most of the accessions of dolichos bean had green pod colour followed by mixed colours of green and purple.

CHAPTER III

MATERIAL AND METHODS

A field experiment was conducted during *Kharif,* 2014 to study the **"Studies on Identification of Morphological and Physiological traits in relation to yield and quality of Seed Guar (*Cyamopsis tetragonoloba* (L.) Taub.) cultivars under Rainfed condition"**. The details of material and methods used and the experimental technique adopted during the course of investigation are described below.

3.1 EXPERIMENTAL MATERIAL

The experimental material for this study consisted of fifteen cultivars of seed guar. The particulars of cultivars are furnished in Table 3.1.

3.2 LOCATION OF THE EXPERIMENT

The experiment was laid out at the "Student Research Farm", College of Horticulture, Dr. Y.S.R. Horticultural University, Mojerla, Mahabubnagar, Telangna state.

3.3 CHARACTERISTICS OF THE EXPERIMENTAL SITE

Soil samples were drawn at random (from 0-30 cm depth) from the experimental field and the composite sample was analysed for physico-chemical properties by adopting the standard procedures and the results are presented in Table 3.2.

3.4 WEATHER CONDITIONS DURING THE CROP PERIOD

Mojerla falls under semi arid tropical climate, situated at an altitude of 346 m above the Mean Sea Level. Geographically, it lies at latitude of 16.26^0 N and longitude of 77.56^0 E. The monthly mean meteorological data recorded during the crop growth period (August, 2014 to December, 2014) at Meteorological observatory, Krishi Vigyan Kendra, Madanapuram are presented in Appendix-I. At all the stages of the crop growth, the weather was congenial for growth and development of seed guar.

Table 3.1: List of 15 cultivars of seed guar selected for evaluation

S.No.	Cultivar	Source	Salient characteristic features
1.	RGC 197	Durgapura, Rajasthan	Medium statured plant, branched with serrated, pubescent, normal green coloured leaves with pale purple flowers. Seeds are light grey in colour.
2.	RGC 936	Durgapura, Rajasthan	Medium duration line with short plant height, leaves are deeply serrated, hairy, green coloured and ashy coated with white flowers. Seeds are greyish brown coloured.
3.	RGC 963	Durgapura, Rajasthan	Medium statured plant, branched with serrated, pubescent, normal green coloured leaves with pale purple flowers. Seeds are light grey in colour.
4.	RGC 986	Durgapura, Rajasthan	Medium duration line with medium stature, medium leaves, non-serrated hairy and green coloured with pale purple flowers. Seeds are greyish brown coloured.
5.	RGC 1002	Durgapura, Rajasthan	Medium duration line with medium plant height, medium leaves, hairy, moderately serrated, green coloured and ashy coated with pale purple flowers. Seeds are light grey coloured.

S.No.	Cultivar	Source	Salient characteristic features
6.	RGC 1025	Durgapura, Rajasthan	It is a medium statured plant, branched with serrated, pubescent, normal green coloured leaves with pale purple flowers. Seeds are light grey in colour.
7.	RGC 1031	Durgapura, Rajasthan	Medium statured plant, branched with serrated, pubescent, normal green coloured leaves with pale purple flowers. Seeds are light grey in colour.
8.	RGC 1033	Durgapura, Rajasthan	Medium duration line with medium plant, medium leaves, slightly serrated, hairy and green coloured with pale purple flowers. Seeds are greyish brown coloured.
9.	RGC 1038	Durgapura, Rajasthan	Medium duration line with short stature, small leaves, serrated, hairy with pale purple flowers. Seeds are greyish brown coloured.
10.	RGC 1066	Durgapura, Rajasthan	Medium statured plant, branched with serrated, pubescent, normal green coloured leaves with pale purple flowers. Seeds are light grey in colour.
11.	HG 365	Hisar, Haryana	Medium duration line with medium stature, medium leaves, serrated, hairy and green coloured with pale purple flowers. Seeds are light grey coloured.
12.	HG 884	Hisar, Haryana	Medium duration line with short plant, medium leaves, serrated, green coloured and hairy with pale purple flowers, seeds are light greyish coloured.

S.No.	Cultivar	Source	Salient characteristic features
13.	HG 2-20	Hisar, Haryana	Medium maturity and pubscent leaves with serrated leaf margins, more no. of seeds/pod and longer pods, early flowering and maturity and bold seeded.
14.	JJ-1	Jodhpur, Rajasthan	Medium statured plant, branched with serrated, pubescent, normal green coloured leaves with pale purple flowers. Seeds are light grey in colour.
15.	JG-2	Jodhpur, Rajasthan	Medium statured plant, branched with serrated, pubescent, normal green coloured leaves with pale purple flowers. Seeds are light grey in colour.

Table 3.2 : Physico-chemical properties of the experimental site

	Particulars	Value	Method of analysis
A.	**Pysical Characteristics**		
	Sand (%)	70.3%	Bouyoucos hydrometer (Piper, 1950)
	Silt (%)	7.1%	
	Clay (%)	22.6%	
	Textural class	Sandy Loam	
B.	**Chemical characteristics**		
	pH (1:2.5 soil : water suspension)	6.69	Beckman pH meter glass electrode method (Jackson, 1967)
	EC (dSm^{-1})	0.076	Solubridge method (Jackson, 1967)
	Organic carbon (%)	0.25	Walkley and Black (1934)
	Available N (kg/ha)	201	Alkaline permanganate method (Subbiah and Asija, 1956)
	Available P_2O_5 (kg/ha)	23	Olsen's method (Olsen *et. al.*,1954)
	Available K_2O (kg/ha)	238	Flame photometry (Jackson, 1967)

3.5 DETAILS OF THE EXPERIMENT

For this study, the experiment was conducted during *kharif*, 2014. The experiment was laid out in a Completely Randomized Block Design. Seeds of each cultivar were sown with a spacing of 30 x 30 cm in 3× 2 m plots in three replications.

3.5.1 Details of Layout

1. Crop	: Cluster bean
2. Botanical Name	: *Cyamposis tetragonoloba* (L.) Taub.
2. Number of treatments	: 15 [RGC 197, RGC 936, RGC 963, RGC 986, RGC 1002, RGC 1025, RGC 1031, RGC 1033, RGC 1038, RGC 1066, HG 365, HG 884, HG 2-20, JJ-1, JG-2]
3. Design	: Completely Randomized Block Design (CRBD)
4. Replications	: 3
5. Season	: *Kharif*, 2014
7. Spacing	: 30 cm x 30 cm
8. Location	: Student Research Farm, College of Horticulture, Dr. Y.S.R. Horticultural University, Mojerla, Mahabubnagar.
9. Net Plot Size	: 3× 2 m

3.5.2 Layout of the Experimental plot of seed guar

N

3 m

2 m

HG 2-20		RGC 1025		HG 365
RGC 197	↓	JG-2	↓	RGC 1066
RGC 1066	I	HG 365	I	RGC 197
RGC 1033	R	RGC 1031	R	RGC 1002
RGC 986	R	JJ-1	R	HG 884
RGC 1002	I	RGC 197	I	RGC 936
JJ-1	G	RGC 1038	G	HG 2-20
RGC 1025	A	HG 884	A	JG-2
RGC 963	T	RGC 986	T	JJ-1
RGC 936	I	HG 2-20	I	RGC 1031
HG 365	O	RGC 963	O	RGC 1038
JG-2	N	RGC 1066	N	RGC 986
RGC 1038	↓	RGC 1033	↓	RGC 1025
RGC 1031	C H A N N E L	RGC 936	C H A N N E L	RGC 963
HG 884	↓	RGC 1002	↓	RGC 1033
R-I		**R-II**		**R-III**

3.6 CULTURAL PRACTICES

3.6.1 Land preparation

The experimental area was thoroughly ploughed and brought to a fine tilth. One tonne of FYM ha^{-1} and the recommended basal dose of fertilizers were incorporated in the soil before final harrowing. The entire plot was divided in to three blocks. The main and sub irrigation channels were laid out taking into account the gradient of the site.

3.6.2 Manures and Fertilizers

The recommended dosage of N, P and K (10:50:50 kg per ha) was applied in the form of urea, single super phosphate and murate of potash respectively. Nitrogen was applied in two splits, the first dose as basal application and other split dose at 30 days after planting. The entire dose of phosphorus and potash were applied at the time of sowing as basal dose.

3.6.3 Inoculation of seed with bacterial culture

Guar plant develops nodules on its roots, in which Rhizobium bacteria live and convert the free nitrogen of the atmosphere into a form of fertilizer which is absorbed by the roots of the plant. This symbiotic relation of the bacteria and root nodules is useful in saving cost of nitrogenous fertilizers. Therefore, before sowing the seeds are inoculated with these bacteria so that their population increases in the soil, with the growth of the plant.

10% sugar or jaggery solution was prepared in boiling water. This sugar solution was allowed to cool. On cooling 3-4 packets of guar bacterial culture (*Rhizobium japonicum*) was mixed with solution to make a thin paste. This paste was coated over to the seed. Seed was dried under shade for 30-40 minutes before sowing.

3.6.4 Sowing

After the lay out, the treatments were assigned to different plots in each replication by using random numbers. The seeds of each cultivar were sown by dibbling two to three seeds per hill and irrigation was given immediately after sowing. Sowing of the seeds was done on 6th August 2014 in all the treatments and replications. The gap filling was done by resowing within a week after germination.

3.6.5 Thinning of excess seedlings

The weak seedlings were thinned out leaving only one vigorous seedling per hill after 25 days of sowing. The remaining second half dose of nitrogen was top dressed at 30 days after sowing. All recommended cultural practices were followed to raise a good seed guar crop.

3.6.6 Irrigation

The kharif season crop grown during rainy season as a rule, does not need any irrigation if rains are adequate and well distributed.

Through out the experiment the crop was raised completely as rainfed crop. The excess water was drained off promptly during heavy rains. However, during continuous dry spell light survival irrigation was given to protect the plants from extreme dry soil condition.

3.6.7 Weeding

The weed flora of the experimental area was predominated by the perennials like *Cyperus rotundus* and *Cynodon dactylon*, annual grasses like *Echinoclova colona* and *Digitaria sanguinalis* which were hand weeded thrice i.e., at 20 DAS and 40 DAS and 60 DAS.

3.6.9 Plant protection

During the seedling stage, the crop was affected by *Rhizoctonia* root rot. The disease was controlled by drenching the crop with Copper oxychloride @ 2.5 gram/litre of water. Mancozeb @ 2 gram/litre was sprayed to control anthracnose disease. Wettable Sulphur (80% WP) @ 3 gram/litre was sprayed to control powdery mildew disease. And to control multinutrient deficiency Formula-4 was sprayed @ 3 gram/litre.

Hairy caterpillars and jassids were found causing damage to the crop, which were controlled effectively by spraying Acephate (50% WP) @ 1.5 gram per litre.

3.6.10 Harvesting and Threshing

Harvesting was carried out by sickles. The border rows were harvested first and then bulked. The plants from net plot area were then harvested. The plants were then allowed to dry in the field for 3 days. The threshing of the plants from net plot and border rows was done separately by beating with sticks. Seeds were then separated, winnowed and weighed from each plot.

3.7 OBSERVATIONS RECORDED

Data was recorded on quantitative and qualitative characters on five randomly selected competitive plants in each of the accession at various phenophases of the crop except percentage of germination, days to first flowering, days to 50% flowering and 100-seed weight. The mean values of five competitive plants were averaged and expressed as mean of the respective character. However, the traits *viz*., percentage of germination, days to first flowering, days to 50% flowering and 100-seed weight were recorded on plot basis. The details of data recorded are as follows.

3.7.1 Growth Parameters

3.7.1.1 Percentage of germination

Percentage of germination in a plot was counted one week after sowing.

$$\text{Percentage of germination} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds sown}} \times 100$$

3.7.1.2 Plant height (cm)

Plant height was measured at final harvest from ground level to the tip of the main axis in centimetres.

3.7.1.3 Number of primary branches per plant

Total number of primary branches arising from the main axis at final harvest was recorded.

3.7.1.4 Number of leaves per plant

The green leaves present on the plant were recorded from randomly selected five plants and expressed as number of leaves per plant.

3.7.1.5 Days to first flowering

Number of days taken from the date of sowing to the day when the first flower appeared in a plot was counted.

3.7.1.6 Days to 50 per cent flowering

Number of days taken from the date of sowing to the day when 50 per cent of the plants in a plot flowered was counted.

3.7.1.7 Number of clusters per plant

Total number of pod bearing clusters per branch was counted at the time of harvest.

3. 7.1.8 Number of pods per cluster

The number of pods produced in each cluster of the tagged plants was counted and their mean was calculated.

3.7.1.9 Number of pods per plant

Number of well filled pods on each sample plant was counted and the mean value of the random sample plants was recorded.

3.7.1.10 Pod length (cm)

Mean length of the ten random matured pods was measured and expressed in centimetres.

3.7.1.11 Pod girth (mm)

The mean girth of ten random matured pods from each of the selected tagged plants was measured in millimetres from the center of the pod with the help of vernier calipers.

3.7.2 Yield parameters

3.7.2.1 Number of seeds per pod

Randomly five pods were selected, threshed separately and average number of seeds per pod was calculated.

3.7.2.2 Seed to pod ratio

The ratio of dry seed weight to dry pod weight was calculated. And it is expressed in percentage.

$$\text{Seed to pod ratio} = \frac{\text{Dry weight of seed}}{\text{Pod dry weight}} \times 100$$

3.7.2.3 Pod yield per plant (g)

The dry pods collected from five plants were weighed and mean pod yield per plant was expressed in grams.

3.7.2.4 Pod yield per hectare (q/ha.)

The pods from each net plot were collected and the pod yield was expressed as q/ha.

3.7.2.5 Seed yield per plant (g)

The pods collected from five plants were threshed separately; cleaned, weighed and mean seed yield per plant was expressed in grams.

3.7.2.6 Seed yield per hectare (q/ha.)

The pods from each net plot were shelled and the seed yield was expressed as q/ha.

3.7.2.7 100 seed weight (g)

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

3.7.2.8 Harvest Index (%)

Harvest Index was calculated by using the formula of Donald (1962) and expressed as per cent.

$$\text{HI \%} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.7.3 Physiological Parameters

3.7.3.1 Chlorophyll Stability Index

Green plant pigments are thermo sensitive and its degradation occurs when it is subjected to higher temperature. This method is based on pigment changes induced by heating. The chlorophyll destruction commences rapidly at critical temperatures of 55 to 56°C. Thus chlorophyll stability is a function of temperature. This property of chlorophyll stability was found to correlate well with drought resistance.

Materials required:

1. Glass tubes of 2.5 cm in diameter
2. Acetone (80%) and distilled water
3. Mortar and pestle
4. Balance
5. Water bath with thermostatic control
6. Spectrophotometer

Procedure:

Two clean glass tubes were taken and 1 gram of representative leaf sample was placed in them with 10 ml of distilled water. One tube was then subjected to heat in water bath at 56°C ± 1°C for exactly 30 minutes. Other tube was kept as control. The leaves are then ground in a mortar for 5 minutes with 20 ml of 80% acetone. The slurry was then filtered with Whatman No. 1 filter paper. This chlorophyll extract was further examined immediately for light absorption with spectrophotometer at 652 nm. A parallel leaf sample (1 g in another tube) was then estimated for chlorophyll content without heating simultaneously and light absorption was measured with spectrophotometer. Acetone is used as blank.

The difference in two readings (Reading without heating – Reading after heating at 56°C) is defined as chlorophyll stability index (CSI). This CSI was found to be correlated with drought tolerance. High CSI corresponded with low drought tolerance. Thus, CSI is inversely related with drought tolerance efficiency. The CSI has no units of measurements (Dopte and Rivera, 1988).

CSI = Reading without heating – Reading after heating at 56°C

3.7.3.2 Relative water content (%)

Relative water content of leaf samples collected for different treatments was determined by following the method described by Slatyer and Mcilroy (1967). Fully expanded and matured leaves were excised from the plants and fresh weight was recorded. The leaves were then immersed in water for one hour and then gently blotted before taking turgid weight. Afterwards leaves were oven-dried at 75°C for two days and weight of these leaves were recorded. The recorded values were substituted in the following formula to determine the relative water content.

$$RWC\ (\%) = \frac{W_f - W_d}{W_t - W_d} \times 100$$

W_f = Weight of fresh leaves

W_t = Weight of turgid leaves

W_d = Weight of oven dried leaves

3.7.3.3 Peroxidase and Catalase enzyme activity

3.7.3.3.1 Peroxidase

Peroxidase activity can be assayed colorimetrically according to Curne and Galston (1959). The enzyme catalyse the oxidation of a substrate by removal of hydrozen which combines with H_2O_2.

$$AH_2 + H_2O_2 \longrightarrow 2H_2O + A$$

Reagents:

1. Phosphate buffer, (0.1 M), pH 6.0
2. Pyrogallol (0.1 N)
3. H_2O_2 (0.02%)

Procedure:

200 mg plant sample was taken and homogenized with 10 ml of Phosphate buffer 0.1 M (pH 6.0). The mixture was centrifuged at 10,000 rpm at 4°C for 30 minutes. The supernatant was collected and stored at low temperature. This supernatant was used for enzyme assay and estimated the enzyme activity as given below.

Reaction Mixture:

Test	**Blank**	**Reagents**
2.0 ml	2.0 ml	Enzyme extract
2.0 ml	3.2 ml	Phosphate buffer
1.0 ml	-	Pyrogallol
0.2 ml	-	H_2O_2
5.2 ml	**5.2 ml**	

Well shaken mixture was kept at 37°C on water bath for 10 minutes for the formation of purpurogallin.

The peroxidase activity was measured at Optical Density (O.D.) 430 nm against blank and expressed result as enzyme unit per gram fresh weight or per gram protein basis.

3.7.3.3.2. Catalase

Catalse activity can be assayed colorimetrically according to method given by Analytical biochemistry (Sinha, 1972). Catalase facilitates the dismutation of H_2O_2 to water and O_2 according to the reaction.

$$H_2O_2 \longrightarrow H_2O + \frac{1}{2} O_2$$

The enzyme plays an important role in association with Super Oxide Dismutase (SOD) as well as in photorespiration and glycolate pathway.

Reagents:

1. Phosphate buffer, (0.1 M), pH 7.0
2. Potassium dichromate acetic acid (5% $K_2Cr_2O_7$ + glacial acetic acid in 1:3 ratio.
3. H_2O_2 (0.2 M)

Procedure:

200 mg plant sample was taken and homogenized with 10 ml of phosphate buffer 0.1 M (pH 7.0). The mixture was centrifuged at 10,000 rpm at 4°C for 30 minutes. The supernatant was collected and stored at low temperature (4-5°C). This supernatant was used for enzyme assay and estimated the enzyme activity as given below.

Reaction Mixture:

Test	Blank	Reagents
1.25 ml	-	H_2O_2
0.50 ml	0.50 ml	Enzyme extract
3.25 ml	4.50 ml	Phosphate buffer
5.00 ml	**5.00 ml**	

The reaction mixture was taken in conical flask and mixed rapidly at 37°C. 2.0 ml reaction mixture was withdrawn after 3 minutes and added 2.0 ml potassium dichromate acetic acid reagent.

This mixture was kept on water bath for 10 minutes and recorded Optical Density (O.D.) at 570 nm against blank and expressed result as enzyme unit per gram fresh weight or per gram protein basis.

3.7.3.4. SPAD meter readings:

The Opti-Sciences CCM-200 plus chlorophyll meter was used for measuring the relative chlorophyll content of leaves. The CCI (Chlorophyll Content Index) values were measured for recent fully expanded leaves at three points of each leaf (upper, middle and lower part). Average of these three readings was considered as SPAD reading of the leaf. This meter enables to obtain instant readings without destroying the plant tissue.

3.7.4 Quality parameters

3.7.4.1. Crude Gum content (%)

Procedure

The procedure was developed by Das *et. al.* (1977) for analysing crude gum content.

Thirty grams of guar seeds were taken and subjected to wet processing (2% NaOH) with vigorous boiling at 98°C for 5 minutes. Solution was sieved through coarse sieve to remove excess NaOH. Leachate was discarded and wet dehusked seeds were acidified slightly for 10 minutes in 0.1 N Hcl and washed with water. Dehusked seeds were air dried for 2 to 3 days.

Dehusked seeds were pulverized to get endosperm splits and germ meal. Germ meal was discarded by using 1 mm sieve.

Endosperm splits were soaked in distilled water in 1:5 proportion and kept for 4-5 hours. Soaked splits were ground in a blender to get viscous solution of thick consistency and it was kept overnight. Thick solution was disturbed by using glass rod and 50 - 100 ml of isopropanol was added. Gum was precipitated on to the top.

Excess isopropanol was removed from the gum (lumps) and lumps were vacuum dried. Dried lumps were powdered in a blender and gum content is expressed as,

$$\text{Gum percentage} = \frac{\text{Weight of gum powder}}{\text{Initial weight of seed taken}} \times 100$$

3.7.4.2. Pod colour:

Data on pod colour was recorded on single plant basis on five randomly selected plants in each cultivar from each replication, as per minimal descriptors of NBPGR developed for Dolichos bean (Srivastava *et al*. 2001). The details of trait, classification and stage of scoring are given in Table 3.3.

Table 3.3: Classification and stage of scoring of pod colour in seed guar

S.No.	Qualitative trait	Classification	Stage of scoring
1.	Pod colour	White Cream Light green Green Dark green Light purple Purple Dark purple Others	Fresh matured pod

3.8 STATISTICAL ANALYSIS

The mean replicated data collected on 19 quantitative traits were subjected to biometrical analysis following appropriate biometrical procedures.

3.8.1 Analysis of Variance

Analysis of Variance was carried out as per the procedure given by Panse and Sukhatme (1985). The structure of analysis of variance is as follows.

Source of variation	**Degrees of freedom**	**Sum of squares**	**Expected MSS**
Replication	r-1	M_1	$\sigma_e^2 + t\,\sigma_r^2$
Treatments	t-1	M_2	$\sigma^2e + r\,\sigma^2g$
Error	(r-1) (v-1)	M_3	σ^2e
Total	rv-1	$(M_1 + M_2 + M_3)$	

Where,

r = Number of replications

v = Number of cultivars (treatments)

σ^2e = Error variance

σ^2g = Genotypic variance

Statistical significance of variation due to cultivars was tested by comparing calculated values to F-table values at one per cent and five per cent level of probability, respectively.

3.8.2 Genotypic and phenotypic variance

The genotypic and phenotypic variances were computed based on the expected mean sum of squares as follows.

Genotypic variance $$\sigma^2g = \frac{M_2 - M_3}{r} + M_3$$

Phenotypic variance = $\sigma^2p = \sigma^2g + \sigma^2e$

Where,

σ^2g = Genotypic variance (GV)

σ^2p = Phenotypic variance (PV)

σ^2e = Environmental variance (EV)

3.8.3 Coefficient of variation

Genotypic and phenotypic coefficients of variation were computed according to Burton and De vane (1953) based on the estimates of genotypic and phenotypic variances as follows:

$$GCV = \frac{\sqrt{GV}}{\overline{X}} x100$$

$$PCV = \frac{\sqrt{PV}}{\overline{X}} x100$$

Where,

GCV = Genotypic coefficient of variation

PCV = Phenotypic coefficient of variation

GV = Genotypic variance

PV = Phenotypic variance

$\overline{X}$ = General mean of character

PCV and GCV were classified as suggested by Sivasubramanian and Menon (1973) and are given below

0-10 %: Low; 11-20 %: Moderate; 21 % and above : High

3.8.4 Heritability

Heritability in broad sense refers to the proportion of genetic variation to the total observed variance in the population. It has been estimated as per the formula given by Allard (1960). Heritability in broad sense is the ratio of genotypic variance to the phenotypic variance and is expressed in percentage.

$$h^2 (b) = \frac{\text{Genotypic variance } (\sigma^2 g)}{\text{Phenotypic variance } (\sigma^2 p)} \times 100$$

The range of heritability in broad sense was classified as suggested by Hanson *et al*. (1956).

Less than 30 %: Low;   30-60 %: Moderate;   More than 60 %: High

3.8.5 Genetic advance (GA)

Genetic advance is the expected genetic gain of superior individual under certain amount of selection pressure. Genetic advance for each character was worked out by adopting the formula given by Hanson *et al*. (1956).

$$GA = K \times \sigma p \times h^2 (b)$$

Where,

GA = Genetic advance.

h^2 (b) = Heritability in broad sense.

k = Selection differential which is equal to 2.06 at 5 % intensity of selection (Lush, 1940)

σp = Phenotypic standard deviation

Further, the genetic advance as per cent of mean was computed by using the following formula

$$\text{GA as per cent of mean} = \frac{\text{GA}}{\text{Grand mean}} \times 100$$

Genetic advance as *per cent* mean was categorized as given below as suggested by Hanson *et al.* (1956).

0- 10%   - Low;   10.1-20% - Moderate;   >20.1% - High

3.8.6 Correlation coefficient analysis

Correlation coefficient analysis reveals the association of characters i.e., a change in one character brought about by a change in the other character. Phenotypic and genotypic correlation coefficients between different variables were calculated by using covariance technique (Al-Jibouri *et al*., 1958). To determine the degree of association of characters with yield and also among the yield components, the correlation coefficients were calculated.

The phenotypic and genotypic correlations among yield and other characters were computed as:

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

Where,

r_g (x y), r_p (x y) are the genotypic and phenotypic correlation coefficients respectively.

Cov_g, Cov_p are the genotypic and phenotypic covariance of xy, respectively.

$\sigma^2{}_g$ and $\sigma^2{}_p$ are the genotypic and phenotypic variance of x and y, respectively.

Significance of correlation coefficients was tested by comparing phenotypic correlation coefficients with the table values (Fisher and Yates, 1963) at (n-2) degrees of freedom at 5 % and 1 % level where 'n' denotes the total number of pairs of observations used in the calculation.

3.8.7 Path coefficient analysis

The direct and indirect contribution of various characters to yield were calculated through path coefficient analysis as suggested by Wright (1921) and elaborated by Dewey and Lu (1959). The following simultaneous equations were formed and solved for estimating various direct and indirect effects.

Path coefficients were obtained by solving the following simultaneous equations.

$$r_{1y} = P_{1y} + r_{12}P_{2y} + r_{13}\, P_{3y} + \ldots\ldots\ldots + r_{1k}\, P_{ky}$$

Where,

r_{1y} = Simple correlation coefficient between x_1 and y and the dependent character Y

P_{1y} = Direct effect of x_1 on y and the dependent character Y

$r_{12}P_{2y}$ = Indirect effect of x_1 on y through x_2.

r_{12} = Correlation coefficient between x_1 and x_2.

$r_{1k}\, P_{ky}$ = Indirect effect of x_1 only through k^{th} variable.

In the same way, equations for r_{2y}, r_{3y}, r_{4y}, upto r_{ky} were obtained. The direct and indirect effects were calculated by solving the simultaneous equations. Besides the direct and indirect effects, the residual effect was computed by using the formula.

Residual effect (P_{ry}) = $1-R^2$

Where, $R^2 = P_{1y}r_{1y} + P_{2y}r_{2y} + P_{3y}r_{3y} + \ldots\ldots\ldots\ldots P_{iy}r_{iy}$

P_{ry} = Residual effect

P_{1y} = Direct effect of x_1 on y.

r_{1y} = Correlation coefficient of x_1 and y

P_{2y} = Direct effect of x_2 on y

r_{2y} = Correlation coefficient of x_2 and y.

P_{3y} = Direct effect of x_3 on y

r_{3y} = Correlation coefficient of x_3 and y

P_{iy} = Direct effect of x_i on y

r_{iy} = Correlation coefficient of x_i and y

$P_{ry} = \sqrt{1 - P_{1y}\, r_{1y} + P_{2y}\, r_{2y} + \ldots\ldots. P_{ky}\, r_{ky}}$

Where P_{ry} = residual effect

P_{1y} = direct effect of x_1 only

r_{1y} = correlation coefficient of x_1 only

Scales for path coefficients

Values of direct (or) indirect effects	**Rate (or) scale**
0.00 to 0.09	Negligible
0.10 to 0.19	Low
0.20 to 0.29	Moderate
0.30 to 0.99	High
> 1.00	Very high

CHAPTER IV

RESULTS AND DISCUSSION

The results of present study entitled "Studies on Identification of Morphological and Physiological traits in relation to yield and quality of Seed Guar (*Cyamopsis tetragonoloba* (L) Taub.) cultivars under Rainfed condition" are presented under the following heads

4.1 Analysis of Variance

4.2 Mean performance of cultivars for various traits studied (quantitative & qualitative traits)

4.3 Variability, heritability and genetic advance

4.4 Correlation studies

4.5 Path analysis

4.1 ANALYSIS OF VARIANCE

The results of analysis of variance for 15 cultivars in seed guar are furnished in Table 4.1. Highly significant differences among the cultivars were observed for all the characters indicating the presence of sufficient amount of variability for all the characters studied.

4.2 MEAN PERFORMANCE OF CULTIVARS FOR VARIOUS TRAITS STUDIED (QUANTITATIVE & QUALITATIVE TRAITS)

Mean performance pertaining to the twenty four quantitative characters and two qualitave characters are presented in the Table 4.2 and Table 4.3.

4.2.1 Growth parameters

4.2.1.1 Percentage of germination

Percentage of germination ranged from 79.67 to 100% with a total mean of 94.53%. Maximum percentage of germination was recorded in RGC 936

(100%), RGC 963 (100%) and JG-2 (100%) and minimum for HG 884 (79.67%). Nine cultivars have exceeded the general mean value.

4.2.1.2 Plant height (cm)

Plant height ranged from 62.33 to 113.00 cm with a total mean of 78.42 cm. Maximum plant height was recorded in RGC 197 (113.00 cm) and minimum for HG 365 (62.33 cm). Seven cultivars have exceeded the general mean value.

4.2.1.3 Number of primary branches per plant

The mean values for number of primary branches per plant in seed guar cultivars ranged from 4.0 to 9.0 with a grand mean of 7. Among the cultivars maximum number of primary branches per plant was recorded in RGC 936 (9.0), RGC 963 (9.0) and HG 884 (9.0), while the minimum number of primary branches was recorded in RGC 1002 (4.0) and RGC 1066 (4.0). Out of 15 cultivars, 7 cultivars have exceeded the general mean value.

4.2.1.4 Number of leaves per plant

The mean values for number of leaves per plant at the stage of maturity in seed guar cultivars ranged from 66 to 118 with a grand mean of 89. Among the cultivars maximum number was recorded in RGC 936 (117.67), while the minimum number of leaves was recorded in RGC 1066 (66.00). Out of 15 cultivars, 7 cultivars have exceeded the general mean value.

4.2.1.5 Days to first flowering

Days to first flowering exhibited a range of 23.00 to 24.67 days with a total mean of 23.84 days. Among the cultivars maximum days to first flowering was recorded in RGC 197 (24.67) and HG 884 (24.67), while RGC 1002 and RGC 1066 showed minimum days to first flowering (23.00).

4.2.1.6 Days to 50 per cent flowering

The character days to 50 per cent flowering exhibited a range of 26.00 to 28.67 days with a grand mean of 27.20 days. Among the cultivars maximum days to 50 per cent flowering was recorded in RGC 197 (28.67 days), while RGC 936 and HG 365 showed minimum days to 50 per cent flowering (26.00).

4.2.1.7 Number of clusters per plant

The mean value of total number of clusters per plant ranged from 15.33 to 40.67 with a grand mean of (26.24). The cultivar RGC 963 recorded the maximum number of clusters per plant (40.67) and the minimum was recorded in RGC 1031 (15.33). Nine cultivars have exceeded the general mean value.

4.2.1.8 Number of pods per clusters

Number of pods per cluster ranged from 3.67 to 7.00 with a grand mean value of 4.91. The maximum number of pods per cluster was recorded in RGC 197 (7.00), while the minimum number of pods per cluster was recorded in RGC 1002 (3.67). Nine cultivars have exceeded the general mean value.

4.2.1.9 Number of pods per plant

The number of pods per plant ranged from 69.67 to 204.00 with a general mean of 127.38. The cultivar RGC 963 recorded the maximum number of pods per plant (204.00) and the minimum was recorded in HG 365 (69.97). Six cultivars have exceeded the general mean value.

4.2.1.10 Pod length (cm)

Length of the pod ranged from 4.73 to 6.37 cm with a total mean of 5.83 cm. The maximum length of pod was recorded in JG-2 (6.37 cm), while the minimum length of pod was recorded in HG 365 (4.73 cm). Nine cultivars have exceeded the general mean value.

4.2.1.11 Pod girth (mm)

The girth of the pod ranged from 19.53 to 23.33 mm with a total mean of 21.93 mm. The cultivar HG 365 recorded as a maximum pod girth (23.33 mm) and the minimum girth of pod was recorded in RGC 1025 (19.53 mm).

4.2.2 Yield parameters

4.2.2.1 Numbers of seeds per pod

Number of seeds per pod ranged from 5.30 to 9.00 with a grand mean of 7.40. The maximum number of seeds per pod was recorded in RGC 986 (9.00) and the minimum number of seeds per pod was recorded in RGC 1031(5.30). Seven cultivars have exceeded the general mean value.

4.2.2.2 Seed to pod ratio

Seed to pod ratio ranged from 45.73 to 50.53% with a grand mean of 48.53%. The maximum seed to pod ratio was recorded in RGC 1038 (50.53%) and the minimum seed to pod ratio was recorded in RGC 1025 (45.73%). Seven cultivars have exceeded the general mean value.

4.2.2.3 Pod yield per plant (g)

The pod yield per plant ranged from 17.33 to 45.00 g with a grand mean of 28.62 g. The cultivar RGC 986 recorded the maximum pod yield per plant (45.00 g) and the minimum pod yield per plant was recorded in RGC 1031 (17.33 g). Five cultivars have exceeded general mean value.

4.2.2.4 Pod yield per hectare (q/ha.)

The pod yield per hectare ranged from 19.25 to 49.99 q/ha. with a grand mean of 31.80 q/ha. The cultivar RGC 986 recorded the maximum pod yield per plant (49.99 q/ha.) and the minimum pod yield per plant was recorded in RGC 1031 (19.25 q/ha.). Five cultivars have exceeded general mean value.

4.2.2.5 Seed yield per plant (g)

The seed yield per plant ranged from 8.17 to 21.93 g with a grand mean of 13.80 g. The cultivar RGC 986 recorded the maximum seed yield per plant (21.93 g) and the minimum seed yield per plant was recorded in RGC 1031 (8.17 g). Five cultivars have exceeded general mean value.

4.2.2.6 Seed yield per hectare (q/ha.)

The seed yield per hectare ranged from 9.07 to 24.36 q/ha. with a grand mean of 15.33 q/ha. The cultivar RGC 986 recorded the maximum seed yield per plant (24.36 q/ha.) and the minimum seed yield per plant was recorded in RGC 1031 (9.07 q/ha.). Five cultivars have exceeded general mean value.

4.2.2.7 100 seed weight (g)

The character 100 seed weight ranged from 3.77 to 4.79 g with a total mean of 4.11 g. The cultivar HG 2-20 recorded the maximum 100 seed weight (4.79 g) and JJ-1 recorded the minimum 100 seed weight (3.77 g). Six cultivars have exceeded general mean value.

4.2.2.8 Harvest Index (%)

Harvest index among 15 cultivars ranged from 66.80 to 79.10 %. Highest value was recorded by the cultivar HG 884 (79.10%), where as lowest was recorded by RGC 197 (66.80 %). Nine cultivars exceeded the general mean value (74.38 %).

4.2.3 Physiological parameters

4.2.3.1 Chlorophyll stability index

Chlorophyll stability index (CSI) among 15 cultivars ranged from 0.016 to 0.951 with a grand mean of 0.27. Highest chlorophyll stability index was recorded by the cultivar RGC 1038 (0.951), where as lowest was recorded in RGC 1066 (0.016).

CSI is inversely proportion to drought tolerance. Hence, cultivar RGC 1066 may be a drought tolerant among the 15 cultivars studied.

4.2.3.2 Relative water content (%)

Relative water content (RWC) ranged from 75.00 to 95.00 % with a grand mean of 85.47 %. The maximum relative water content was recorded in HG 365 (95.00 %) and the minimum relative water content was recorded in RGC 1002 (75.00 %). 7 cultivars have exceeded the general mean value.

High RWC indicates higher drought tolerance. Hence, the cultivar HG 365 may be a drought tolerant cultivar.

4.2.3.3 Peroxidase enzyme activity (E.U./g)

Peroxidase enzyme activity among 15 cultivars ranged from 78.60 to 244.14 E.U./g with grand mean of 199.76 E.U./g. Highest value was recorded by the cultivar RGC 1002 (244.14 E.U./g), where as lowest was recorded by RGC 1025 (78.60 E.U./g). 9 cultivars exceeded the general mean value.

High peroxidase enzyme activity indicates high drought tolerance. Hence, the cultivar RGC 1002 may be a drought tolerant cultivar.

4.2.3.4 Catalse enzyme activity (E.U./g)

Catalase enzyme activity among 15 cultivars ranged from 379.50 to 824.50 E.U./g with grand mean of 467.95 E.U./g. Highest value was recorded by the cultivar JJ-1 (824.50 E.U./g), where as lowest was recorded by RGC 1038 (379.50 E.U./g). 5 cultivars exceeded the general mean value.

High catalase enzyme activity indicates high drought tolerance. Hence, the cultivar JJ-1 may be a drought tolerant cultivar.

4.2.3.5 SPAD meter reading (CCI)

SPAD meter reading among 15 cultivars ranged from 35.39 to 62.78 CCI with grand mean of 48.97 CCI. Highest value was recorded by the cultivar HG 884 (62.78 CCI), where as lowest was recorded by RGC 936 (35.39 CCI). Five cultivars exceeded the general mean value.

4.2.4 Quality parameters

4.2.4.1 Crude gum content (%)

Crude gum content ranged from 29.26 to 31.71 % with a total mean of 30.08 %. The maximum crude gum content was recorded in RGC 1033 (31.71 %), while the minimum crude gum content was recorded in RGC 197 (29.26 %). 6 cultivars have exceeded the general mean value.

In the present study there was significant variation in galactomannan content between 15 guar cultivars and the gum contents in guar cultivars ranged from 29.26 to 31.71 %. Dabas (1982) reported that gum contents in guar varieties ranged from 15.92 to 31.81% in their study. Dwivedi *et al.* (1999) reported that gum content varied from 21.77-34.38%. Further the collections made from Rajasthan had exhibited more diversity for gum content due to climate and geographical conditions different from that in the other states studied highest crude gum content recorded with RGM112 followed by RGC1003 and GAUG 9703 (Kalyani, 2006).

4.2.4.2 Pod Colour

Among the 15 cultivars studied, pod colour for 11 cultivars exhibited light green colour and 4 cultivars exhibited green colour. Pod colour of fifteen cultivars are shown in Table 4.3.

Bode *et al.* (2013), Madakbas and Ergin (2011), Pandey *et al.* (2011), Muchui *et al.* (2008), Kar *et al.* (2006) have reported genotypic difference in pod colours of french bean. Similar genotypic difference in pod colour of dolichos bean was reported by Chattopadhyay and Dutta (2010), Islam *et al.* (2010), Sultana (2001).

Table 4.3 Pod colour of 15 seed guar cultivars

S.No.	Variety	Pod colour
1.	RGC 197	Light green
2.	RGC 936	Light green
3.	RGC 963	Green
4.	RGC 986	Light green
5.	RGC 1002	Green
6.	RGC 1025	Light Green
7.	RGC 1031	Light green
8.	RGC 1033	Light green
9.	RGC 1038	Light green
10.	RGC 1066	Light green
11.	HG 365	Light green
12.	HG 884	Green
13.	HG 2-20	Light green
14.	JJ-1	Light green
15.	JG-2	Green

4.3 VARIABILITY, HERITABILITY AND GENETIC ADVANCE

The results with regard to mean, overall range, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability in broad sense (h^2) and expected genetic advance as per cent of mean (GAM) for nineteen characters are furnished in Table 4.4. In general PCV was more than GCV for all the characters indicating the influence of environment in expression of characters. The details of these variability parameters are presented below.

4.3.1 Growth parameters

4.3.1.1 Percentage of germination

This character recorded high phenotypic and genotypic variances (41.23 and 40.93, respectively) with low PCV (6.79 %) and GCV (6.77 %), high heritability (99.30%), moderate genetic advance (13.13) and moderate GA as *per cent* of mean (13.89).

The PCV and GCV were low for this trait, indicating a narrow range of genetic variability. These results were in line with the findings of Vikas Kumar and Ram (2015) and Patil (2014) in cluster bean.

High heritability in conjunction with moderate genetic advance as *per cent* of mean was observed for this trait. These findings were in agreement with earlier reports by Patil (2014) in cluster bean.

4.3.1.2 Plant height (cm)

High phenotypic and genotypic variances (194.79 and 188.45, respectively**)** were recorded coupled with moderate PCV and GCV of 17.78 and 17.51 per cent, respectively. This trait showed high heritability (96.70 %), high genetic advance (27.82) and high GA as *per cent* of mean (35.49).

The PCV and GCV values were moderate for this trait, suggesting moderate range of genetic variability and considerable influence of environment in the expression of the trait. These results were in line with the findings of Vikas Kumar and Ram (2015), Manivannan and Anandakumar (2013) in cluster bean, Lal *et al.* (2005) in dolichos bean, Raffi and Nath (2004) in dry bean.

High heritability coupled with high genetic advance as *per cent* of mean was observed for this trait which indicated the preponderance of additive gene action governing the inheritance of this character and offers the best possibility of improvement of this trait through simple selection procedures. Similar findings were reported by Vikas Kumar and Ram (2015), Patil (2014), Bhatkodle *et al*. (2014), Muthuselvi and Shanthi (2013), Shabarish Rai *et al*. (2012), Saini *et al*.(2010), Sabarish (2010), Raghu Prakash *et al*. (2008), Anandhi and Oomen (2007), Saini *et al*.(2004), Singh *et al*. (2004), Hanchinamani (2004), Singh *et al*. (2001), Singh *et al.* (2001) in cluster bean, Rai *et al*. (2004) and Singh *et al.* (2000) in french bean.

4.3.1.3 Number of primary branches per plant

This character recorded low phenotypic and genotypic variances (3.75 and 3.01, respectively) with high PCV (29.23 %) and GCV (26.18 %), high heritability (80.20 %), low genetic advance (3.20) and high GA as *per cent* of mean (48.29).

High estimates of PCV and GCV for this trait indicates that variation among the cultivars was also high. These results were in accordance with the reports of Om Vir and Singh (2015), Muthuselvi and Shanthi (2013), Shabarish Rai *et al*. (2012), Saini *et al*.(2010), Buttar *et al*. (2008), Raghu Prakash *et al*. (2008), Hanchinamani (2004) and Choudhary *et al*. (2003) in cluster bean.

High heritability in conjunction with high genetic advance as *per cent* of mean was observed for this trait. The results were in conformity with the previous studies of Vikas Kumar and Ram (2015), Patil (2014), Rahul Kapoor (2014), Bhatkodle *et al.* (2014), Manivannan and Anandakumar (2013), Muthuselvi and Shanthi (2013), Shabarish Rai *et al*. (2012), Saini *et al*.(2010), Raghu Prakash *et al*. (2008), Anandhi and Oomen (2007), Mahla and Kumar (2006), Shekhawat and Singhania (2005), Hanchinamani (2004) and Singh *et al*. (2001) in cluster bean.

4.3.1.4 Number of leaves per plant

This character recorded high phenotypic and genotypic variances of 204.72 and 200.13, respectively coupled with moderate PCV (16.11 %) and GCV (15.93 %) values, high heritability (97.80 %), high genetic advance (28.81) and high GA as *per cent* of mean (32.44).

The PCV and GCV values were moderate for this trait, suggesting moderate range of genetic variability and considerable influence of environment in the expression of the trait. Similar findings were reported by Prakash and Ram (2014) in french bean.

High heritability in conjunction with high genetic advance as per cent of mean was observed for this trait. The results were in conformity with the previous studies of Rahul Kapoor (2014), Bhatkodle *et al.* (2014), Mahla and Kumar (2006), Shekhawat and Singhania (2005) and Hanchinamani (2004) in cluster bean.

4.3.1.5 Days to first flowering

This character recorded very low phenotypic and genotypic variances of 0.90 and 0.29, respectively coupled with low PCV (3.98 %) and GCV (2.24 %) values, moderate heritability (31.80 %), low genetic advance (0.62) and low GA as *per cent* of mean (2.60).

The PCV and GCV were low for this trait, indicating a narrow range of genetic variability. Similar findings were reported by Vikas Kumar and Ram (2015) in cluster bean.

Presence of moderate heritability coupled with low genetic advance as *per cent* of mean indicated considerable influence of environment in the expression of the above said trait.

4.3.1.6 Days to 50 per cent flowering

This trait recorded very low phenotypic and genotypic variances (1.01 and 0.47, respectively) with low PCV (3.69 %) and GCV (2.52 %), moderate heritability (46.50 %), low genetic advance (0.96) and low GA as *per cent* of mean (3.53).

The PCV and GCV were low for this trait, indicating a narrow range of genetic variability. Similar findings were reported by Vikas Kumar and Ram (2015), Shabarish Rai *et al.* (2012), Raghu Prakash *et al.* (2008), Anandhi and Oomen (2007) in cluster bean.

4.3.1.7 Number of clusters per plant

This trait recorded higher phenotypic and genotypic variances (72.65 and 69.69, respectively), with high PCV (32.48 %) and GCV (31.80 %), high heritability (95.90 %), moderate genetic advance (16.84) with high GA as *per cent* of mean (64.18) estimates.

Estimates of PCV and GCV were high for this trait. Similar findings were reported by Vikas Kumar and Ram (2015), Patil (2014), Bhatkodle *et al*. (2014), Muthuselvi and Shanthi (2013), Shabarish Rai *et al*. (2012), Saini *et al*.(2010), Raghu Prakash *et al.* (2008), Anandhi and Oomen (2007), Hanchinamani (2004), Singh *et al*. (2004) in cluster bean.

High values of heritability coupled with high genetic advance (GA) as *per cent* of mean obtained for number of clusters per plant are indicative of additive gene action and selection based on these parameters would be more reliable. Similar findings were reported by Patil (2014), Bhatkodle *et al*. (2014), Muthuselvi and Shanthi (2013), Shabarish Rai *et al.* (2012), Saini *et al*.(2010), Raghu Prakash *et al*. (2008), Anandhi and Oomen (2007), Singh *et al*. (2001) in cluster bean.

4.3.1.8 Number of pods per cluster

This character recorded very low phenotypic and genotypic variances of 0.07 and 0.06, respectively with high PCV (20.94 %) and moderate GCV (13.79 %) values, moderate heritability (43.40 %), low genetic advance (0.92) and moderate GA as *per cent* of mean (18.71).

High PCV and moderate GCV were observed for this trait. Similar results were reported by Om Vir and Singh (2015), Manivannan and Anandakumar (2013) in cluster bean.

4.3.1.9 Number of pods per plant

Very high phenotypic (2113.32) and genotypic variances (1539.74) were recorded for number of pods per plant with high PCV (36.90 %) and GCV (30.81 %), high values for heritability (72.90%), high genetic advance (68.99) and high GA as *per cent* of mean (54.17).

High estimates of PCV and GCV for this trait indicates that variation among the cultivars was also high. These results were in accordance with the reports of Om Vir and Singh (2015), Bhatkodle *et al.* (2014), Shabarish Rai *et al.* (2012), Saini *et al*.(2010), Raghu Prakash *et al*. (2008), Anandhi and Oomen (2007), Hanchinamani (2004), Shekhawat and Choudhary (2004) in cluster bean.

High heritability coupled with high genetic advance as *per cent* of mean observed for this trait indicated the presence of larger number of fixable additive factors which help in improvement of this trait through simple selection procedures. These results were in line with the findings of Bhatkodle *et al.* (2014), Shabarish Rai *et al*. (2012), Saini *et al*.(2010), Raghu Prakash *et al.* (2008), Anandhi and Oomen (2007), Singh *et al*. (2001) in cluster bean.

4.3.1.10 Pod length (cm)

With regard to pod length, very low phenotypic and genotypic variance were recorded (0.21 and 0.18, respectively) with low PCV (7.79 %) and GCV (7.22 %), high heritability (86.00 %), low genetic advance (0.80) and moderate GA as *per cent* of mean (13.79).

The PCV and GCV were low for this trait, indicating a narrow range of genetic variability. Similar findings were reported by Bhat *et al*. (2012) in soya bean, Pushpa *et al.* (2012) in Fenugreek.

High heritability in conjunction with moderate genetic advance as *per cent* of mean was observed for this trait. Similar findings were reported by Alemu *et al.* (2013) in french bean.

4.3.1.11 Pod girth (mm)

This character recorded low phenotypic and genotypic variances (1.20 and 0.98, respectively) with low PCV (4.99 %) and GCV (4.52 %) values, high heritability (81.90%), low genetic advance (1.85) and low GA as *per cent* of mean (8.43).

The PCV and GCV were low for this trait, indicating a narrow range of genetic variability. Similar findings were reported by Patil (2014) in cluster bean.

High heritability in conjunction with low genetic advance as *per cent* of mean was observed for this trait. Similar findings were reported by Shabarish Rai *et al*. (2012) in cluster bean.

4.3.2 Yield parameters

4.3.2.1 Number of seeds per pod

With respect to number of seeds per pod, low phenotypic (1.17) and genotypic (0.90) variances, moderate PCV (14.61 %) and GCV (12.80 %), high heritability (76.80 %), low genetic advance (1.71) and moderate GA as *per cent* of mean (23.10) estimates were recorded.

The PCV and GCV values were moderate for this trait, suggesting moderate range of genetic variability and considerable influence of environment in the expression of the trait. These results were in accordance with the findings of Shabarish Rai *et al*. (2012) in cluster bean.

High heritability coupled with moderate genetic advance as *per cent* of mean was observed for this trait. Similar results were reported by Vikas Kumar and Ram (2015), Patil (2014), Anandhi and Oomen (2007) in cluster bean.

4.3.2.2 Seed to pod ratio

With regard to seed to pod ratio, low phenotypic and genotypic variance were recorded (2.69 and 2.06, respectively) with low PCV (3.38 %) and GCV (2.96 %), high heritability (76.50 %), low genetic advance (2.59) and low GA as *per cent* of mean (5.33).

The PCV and GCV were low for this trait, indicating a narrow range of genetic variability. High heritability in conjunction with low genetic advance as *per cent* of mean was observed for this trait.

4.3.2.3 Pod yield per plant (g)

High phenotypic and genotypic variances (64.57 and 63.05, respectively) were recorded for pod yield per plant in seed guar cultivars with high PCV (28.07 %) and GCV (27.74 %) values. Pod yield per plant showed high heritability (97.60%), moderate genetic advance (16.16) and high GA as *per cent* of mean (56.47).

High estimates of PCV and GCV for this trait indicates that variation among the cultivars was also high. These results were in accordance with the reports of Patil (2014), Bhatkodle *et al.* (2014), Muthuselvi and Shanthi

(2013), Shabarish Rai *et al*. (2012), Saini *et al*.(2010), Anandhi and Oomen (2007), Hanchinamani (2004) in cluster bean.

High values of heritability coupled with high genetic advance (GA) as *per cent* of mean were obtained for pod yield per plant is indicative of additive gene action and selection based on these parameters would be more reliable. These results were in line with the findings of Vikas Kumar and Ram (2015), Patil (2014), Muthuselvi and Shanthi (2013), Shabarish Rai *et al*. (2012), Shabarish Rai *et al.* (2012), Saini *et al*.(2010), Anandhi and Oomen (2007), Singh *et al*. (2001) in cluster bean, Singh *et al*. (2000) and Rai *et al*. (2004) in french bean.

4.3.2.4 Pod yield per hectare (q/ha.)

High phenotypic and genotypic variances (79.71 and 77.83, respectively) were recorded for pod yield per hectare in seed guar cultivars with high PCV (28.08 %) and GCV (27.75 %) values. Pod yield per hectare showed high heritability (97.60%), moderate genetic advance (17.96) and high GA as *per cent* of mean (56.48).

High estimates of PCV and GCV for this trait indicates that variation among the cultivars was also high. Similar findings were reported by Verma *et al*. (2014) in dolichos bean, Shabarish Rai *et al*. (2012) in cluster bean.

High values of heritability coupled with high genetic advance (GA) as *per cent* of mean were obtained for pod yield per hectare is indicative of additive gene action and selection based on these parameters would be more reliable. These results were in accordance with the findings of Verma *et al*. (2014) in dolichos bean.

4.3.2.5 Seed yield per plant (g)

This character recorded moderate phenotypic and genotypic variances (15.79 and 15.08, respectively) with high PCV (28.78 %) and GCV (28.13 %), high heritability (95.50 %), low genetic advance (7.82) and high GA as *per cent* of mean (56.64).

High estimates of PCV and GCV for this trait indicates that variation among the cultivars was also high. These findings were in agreement with earlier reports by Om Vir and Singh (2015), Patil (2014), Raghu Prakash *et al*. (2008), Buttar *et al.* (2008), Hanchimani Nagaraj *et al*. (2004), Singh *et al*. (2002) in cluster bean.

High heritability coupled with high genetic advance as *per cent* of mean observed for this trait indicated the presence of larger number of fixable additive factors which help in improvement of this trait through simple selection procedures. These results were in accordance with the reports of Vikas Kumar and Ram (2015), Patil (2014), Muthuselvi and Shanthi (2013), Raghu Prakash *et al*. (2008) in cluster bean.

4.3.2.6 Seed yield per hectare (q/ha.)

Moderate phenotypic and genotypic variances (19.49 and 18.61, respectively) were recorded for seed yield per hectare in seed guar cultivars with high PCV (28.78 %) and GCV (28.14 %) values. Seed yield per hectare showed high heritability (95.50%), low genetic advance (8.69) and high GA as *per cent* of mean (56.66).

High estimates of PCV and GCV for this trait indicates that variation among the cultivars was also high. High values of heritability coupled with high genetic advance (GA) as *per cent* of mean were obtained for seed yield per hectare is indicative of additive gene action and selection based on these parameters would be more reliable. Similar findings were reported by Rao *et al.* (2014) in Soya bean.

4.3.2.7 100 seed weight (g)

This character recorded very low phenotypic and genotypic variances (0.09 and 0.06, respectively) with low PCV (7.36 %) and GCV (6.02 %) values, high heritability (67.00 %), low genetic advance (0.42) and moderate GA as *per cent* of mean (10.15).

The PCV and GCV were low for this trait, indicating a narrow range of genetic variability. Similar findings were reported by Patil (2014), Manivannan and Anandakumar (2013) in cluster bean.

High heritability coupled with moderate genetic advance as per cent of mean was observed for this trait. Similar results were reported by Vikas Kumar and Ram (2015), Patil (2014), Manivannan and Anandakumar (2013), Saini *et al.* (2010), Raghu Prakash *et al.* (2008) in cluster bean.

4.3.2.8 Harvest Index (%)

Moderate phenotypic and genotypic variances (14.53 and 14.28, respectively) were recorded for harvest index in seed guar cultivars with low PCV (5.12 %) and GCV (5.08 %) values. Harvest index showed high heritability (98.30 %), low genetic advance (7.72) and moderate GA as *per cent* of mean (10.38).

The PCV and GCV were low for this trait, indicating a narrow range of genetic variability. These results were in accordance with the findings of Paramesh *et al.* (2014) in Mung bean, Kole and Saha (2013), Kole and Mishra (2006), Dash and Kole (2001) in Fenugreek.

High heritability in conjunction with moderate genetic advance as *per cent* of mean was observed for this trait. Similar findings were reported by Jitender *et al.* (2014) in cluster bean.

4.3.3 Physiological parameters

4.3.3.1 Chlorophyll stability index

`With respect to chlorophyll stability index, very low phenotypic (0.07) and genotypic (0.068) variances, high PCV (97.71 %) and GCV (97.58 %), high heritability (99.70 %), low genetic advance (0.54) and very high GA as *per cent* of mean (200.76) estimates were recorded.

High heritability in conjunction with high genetic advance as *per cent* of mean was observed for this trait. Similar findings were reported by Paramesh *et al.* (2014), Swathi (2013) in Mung bean.

4.3.3.2 Relative water content (%)

This trait recorded moderate phenotypic and genotypic variances (35.94 and 35.67, respectively), with low PCV (7.01 %) and GCV (6.99 %), high heritability (99.20 %), moderate genetic advance (12.26) with moderate GA as *per cent* of mean (14.34) estimates.

The PCV and GCV were low for this trait, indicating a narrow range of genetic variability. Similar findings were reported by Jitender *et al.* (2014) in cluster bean.

High heritability in conjunction with moderate genetic advance as *per cent* of mean was observed for this trait.

4.3.3.3 Peroxidase enzyme activity (E.U./g)

Very high phenotypic and genotypic variances (2515.55 and 2515.26, respectively) were recorded for peroxidase enzyme activity in seed guar cultivars with high PCV (25.11 %) and GCV (25.10 %) values. It showed high heritability (99.90 %), high genetic advance (103.31) and high GA as *per cent* of mean (51.72).

High estimates of PCV and GCV for this trait indicates that variation among the cultivars was also high. High values of heritability coupled with high genetic advance (GA) as *per cent* of mean were obtained for peroxidase enzyme activity is indicative of additive gene action and selection based on these parameters would be more reliable. These results were in accordance with the reports of Singh *et al.* (2010) in Cabbage.

4.3.3.4 Catalse enzyme activity (E.U./g)

With respect to catalse enzyme activity, very high phenotypic (14017.75) and genotypic (14015.48) variances, high PCV (25.31 %) and GCV (25.30 %), high heritability (99.90 %), high genetic advance (243.86) and high GA as *per cent* of mean (52.11) estimates were recorded.

High estimates of PCV and GCV for this trait indicates that variation among the cultivars was also high. These results were in accordance with the reports of Singh *et al.* (2010) in Cabbage.

High values of heritability coupled with high genetic advance (GA) as *per cent* of mean were obtained for catalase enzyme activity is indicative of additive gene action and selection based on these parameters would be more reliable. These results were in accordance with the reports of Hefny (2013) in Lupin bean.

4.3.3.5 SPAD meter reading (CCI)

High phenotypic and genotypic variances (53.60 and 52.89, respectively) were recorded for SPAD meter reading in seed guar cultivars with moderate PCV (14.95 %) and GCV (14.85 %) values, high heritability (98.70%), moderate genetic advance (14.88) and high GA as *per cent* of mean (30.39).

4.3.4 Quality parameters

4.3.4.1 Crude gum content (%)

This character recorded very low phenotypic and genotypic variances (0.49 and 0.48, respectively) with low PCV (2.33 %) and GCV (2.32 %) values, high heritability (99.50%), low genetic advance (1.44) and low GA as *per cent* of mean (4.77).

The PCV and GCV were low for this trait, indicating a narrow range of genetic variability. Similar findings were reported by Jitender *et al.* (2014), Raghu Prakash *et al.* (2008) in cluster bean.

High heritability in conjunction with low genetic advance as *per cent* of mean was observed for this trait. These results were in accordance with the reports of Raghu Prakash *et al.* (2008) in cluster bean.

The study revealed that PCV was higher than the corresponding GCV for all the characters indicating that all characters had interacted with environment to some degree. High PCV and GCV were recorded for morphological characters such as number of primary branches per plant, number of clusters per plant, number of pods per plant, pod yield per plant, pod yield per hectare, seed yield per plant, seed yield per hectare indicating the existence of wider genetic variability for these traits in the cultivars under study.

Also, similar results were recorded for physiological traits such as chlorophyll stability index, peroxidase enzyme activity, catalase enzyme activity indicating the existence of wider genetic variability for these traits in the cultivars under study.

On the other side low PCV and GCV estimates were observed for certain traits such as percentage of germination, days to first flowering, days to 50 % flowering, pod length, pod girth, seed to pod ratio, 100-seed weight, harvest index, relative water content, crude gum content suggesting narrow range of genetic variability for these traits.

The other characters *viz.*, plant height, number of leaves per plant, number of seeds per pod, SPAD meter reading were found with moderate variability. Number of pods per cluster showed high PCV and moderate GCV.

High heritability coupled with high genetic advance as per cent of mean indicating operation of additive gene action was observed for morphological characters such as plant height, number of primary branches per plant, number of leaves per plant, number of clusters per plant, number of pods per plant, number of seeds per pod, pod yield per plant, pod yield per hectare, seed yield per plant, seed yield per hectare. Hence, directional selection for these traits could be effective for desired genetic improvement.

Similar results were observed for physiological traits such as chlorophyll stability index, peroxidase enzyme activity, catalase enzyme activity, SPAD meter reading. Hence, directional selection for these traits could be effective for desired genetic improvement.

Moderate genetic advance as *per cent* of mean with high or medium heritability suggesting the action of both additive and non-additive genes there by favorable influence of environment in the expression of traits was reported in case of percentage of germination, number of pods per cluster, pod length, 100-seed weight, harvest index, relative water content.

The high heritability accompanied with low GA as percent of mean was recorded by pod girth, seed to pod ratio and crude gum content, which indicated the presence of non additive gene action in inheritance of these traits. The high heritability is being exhibited due to favourable influence of environment rather than cultivar hence, selection for these traits may not be rewarding.

The moderate heritability along with low GA as percent of mean was recorded by days to first flowering and days to 50% flowering, which indicated the presence of inheritance of the trait mostly by non additive gene action. Hence, simple selection based on these traits for crop improvement programme would be ineffective.

4.4 CORRELATION STUDIES

Crop yield is the end product of the interaction of a number of other, often interrelated attributes. A thorough understanding of the interaction of characters among themselves had been of great use in plant breeding. The efficiency of selection for yield mainly depends on the direction and magnitude of association between yield and its component characters and also among themselves. Character association provides information on the nature and extent of association between pairs of metric traits and helps in selection for the improvement of the character. Phenotypic and genotypic correlation coefficients were worked out on yield and its component characters in 15 cultivars of seed guar. In general, genotypic correlations were higher than phenotypic correlations, which indicates that though there is strong inherent association between characters studied, its expression is lessened due to influence of environment. The genotypic and phenotypic correlation coefficients among yield and its component characters are presented in Table 4.5.

4.4.1 Plant height (cm)

Plant height exhibited positive significant correlation with number of pods per cluster (0.5892 P, 0.8578 G), pod length (0.5121 P, 0.5658 G) and 100-seed weight (0.3060 P, 0.3516 G) both at phenotypic and genotypic levels, where as negative significant association with the crude gum content (-0.5391 P and -0.5436 G) both at genotypic and phenotypic levels.

These results were in line with the findings of various studies conducted in cluster bean by Shabarish Rai and Dharmatti (2014) for number of pods per cluster and pod length , Manivannan and Anandakumar (2013), Arumugarangarajan *et al.* (2000) for number of pods per cluster.

4.4.2 Number of primary branches per plant

Number of primary branches per plant showed positive significant correlation with number of clusters per plant (0.6826 P, 0.7252 G), number of seeds per pod (0.4924 P, 0.5884 G), pod yield per plant (0.3855 P, 0.4073 G) and seed yield per plant (0.4263 P, 0.4567 G) both at phenotypic and genotypic levels, where as negative significant association with the 100-seed weight (-0.3007 P and -0.4161 G) at genotypic and phenotypic levels, respectively.

These findings were in agreement with earlier reports of various studies conducted in cluster bean by Manivannan and Anandakumar (2013) for seed yield per plant, 100-seed weight, clusters per plant, Anandhi and Oommen (2010),Singh et al. (2002) for number of clusters per plant.

4.4.3 Days to 50 % flowering

Days to 50 % flowering recorded positive, significant correlation with number of pods per cluster (0.5822 G) at genotypic level and it showed negative significant correlation with pod girth (-0.4245 P, -0.7620 G) at genotypic and phenotypic levels.

Similar results were reported by Pan et al. (2004) in dolichos bean and Roy *et al*. (2006) in french bean for pod girth.

4.4.4 Number of clusters per plant

Number of clusters per plant exhibited positive significant correlation with number of seeds per pod (0.7674 P, 0.8762 G), pod yield per plant (0.7503 P, 0.7714 G) and seed yield per plant (0.7470 P, 0.7842 G), number of primary branches per plant (0.6826P, 0.7252 G) both at genotypic and phenotypic levels. This character showed negative significant correlation with number of pods per cluster (-0.3052 G) at genotypic level.

These results were in conformity with the previous studies in cluster bean by Shabarish Rai and Dharmatti (2014), Girish *et al.* (2012b), Saini et al. (2010), Singh *et al.* (2004) for pod yield per plant, Arumugarangarajan *et al.* (2000) for seed yield per plant, Anandhi and Oommen (2010) for number of primary branches per plant, Manivannan and Anandakumar (2013) for primary branches per plant and seed yield per plant.

4.4.5 Number of pods per cluster

Number of pods per cluster exhibited positive significant correlation with pod length (0.4179 P, 0.4778 G), plant height (0.5892 P, 0.8578G) both at genotypic and phenotypic levels, where as days to 50 % flowering (0.5822 G) at genotypic level. This character also exhibited significant negative correlation with crude gum content (-0.3757 P, -0.5722 G) at genotypic and phenotypic levels, where as number of clusters per plant (-0.3052 G) at genotypic level.

Similar findings were reported in cluster bean by Shabarish Rai and Dharmatti (2014), Manivannan and Anandakumar (2013) for plant height, Girish *et al.* (2012b), Saini *et al.* (2010), Arumugarangarajan *et al.* (2000) for plant height and number of clusters per plant.

4.4.6 Pod length (cm)

This trait had positive significant correlation with plant height (0.5121 P, 0.5658 G), number of pods per cluster (0.4179 P, 0.4778 G) both at phenotypic and genotypic levels. This character also exhibited significant negative correlation with pod girth (-0.3028 P, -0.3159 G) and crude gum content (-0.3553 P, -0.3864 G) both at phenotypic and genotypic levels.

These results were in accordance with the reports of Shabarish Rai and Dharmatti (2014) for plant height and pods per cluster in cluster bean, Pan *et al*. (2004) for pod girth in dolichos bean.

4.4.7 Pod girth (mm)

This character exhibited positive significant correlation with 100 seed weight (0.3052 G) at genotypic level and it showed negative significant correlation with days to 50 % flowering (-0.4245 P, -0.7620 G), pod length (-0.3028 P, -0.3159 G) both at phenotypic and genotypic levels, respectively.

These results were in accordance with the findings of Roy *et al.* (2006) in french bean for days to 50 % flowering, Pan *et al*. (2004) for days to 50 % flowering and pod length in dolichos bean.

4.4.8 Number of seeds per pod

This trait exhibited positive significant correlation with pod yield per plant (0.7508 P, 0.8700 G) and seed yield per plant (0.7633 P, 0.8999 G), number of primary branches per plant (0.4924 P, 0.5884 G), number of clusters per plant (0.7674 P, 0.8762 G) both at phenotypic and genotypic levels.

These results were in line with the findings of Anandhi and Oommen (2010) for pod yiled per plant in cluster bean.

This trait has not recorded any negative significant correlation with any other character.

4.4.9 Pod yield per plant (g)

This character showed positive and significant correlation with 100-seed weight (0.3286 P, 0.4038 G) and seed yield per plant (0.9898 P, 0.9979 G), number of primary branches per plant (0.3855 P, 0.4073 G), number of clusters per plant (0.7503 P, 0.7714 G), number of seeds per pod (0.7508 P, 0.8700 G) both at phenotypic and genotypic levels, respectively.

These results were in conformity with the previous studies conducted in cluster bean by Shabarish Rai and Dharmatti (2014) for clusters per plant and Arumugarangarajan *et al.* (2000) for seed yield per plant, clusters per plant, number of seeds per pod.

This trait has not recorded any negative significant correlation with any other character.

4.4.10 100-seed weight (g)

This character exhibited positive significant correlation with plant height (0.3060 P, 0.3516 G), pod yield per plant (0.3286 P, 0.4038 G) both at phenotypic and genotypic levels, where as seed yield per plant (0.3860 G), pod girth (0.3052 G) at genotypic level. This trait has recorded negative significant correlation with number of primary branches per plant (-0.3007 P, -0.4161 G) at phenotypic and genotypic levels.

Similar findings were reported by Manivannan and Anandakumar (2013) for primary branches per plant in cluster bean.

4.4.11 Crude gum content (%)

This trait has recorded negative significant correlation with plant height (-0.5391 P, -0.5436 G), number of pods per cluster (-0.3737 P, -0.5722 G), pod length (-0.3553 P, -0.3864 G) both at phenotypic and genotypic levels, respectively.

These results were in conformity with the previous studies of Girish *et al*. (2012b), Hanchinamani *et al.* (2004) for plant height in cluster bean.

This trait has not recorded any positive significant correlation with any other character.

4.4.12 Seed yield per plant (g)

Phenotypic and genotypic correlations revealed that seed yield per plant showed significant positive association with number of primary branches per plant (0.4263 P and 0.4567 G), number of clusters per plant (0.7470 P and 0.7842 G), number of seeds per pod (0.7633 P and 0.0.8999 G), pod yield per plant (0.9898 P, 0.9979 G) at both phenotypic and genotypic levels, where as 100-seed weight (0.3860 G) at genotypic level.

These results were in line with the findings of various studies conducted in cluster bean by Manivannan and Anandakumar (2013) for number of primary branches per plant, clusters per plant, Arumugarangarajan *et al.* (2000) for clusters per plant, number of seeds per pod, pod yield per plant, Om Vir and Singh (2015), Saini e*t al.* (2010), Singh e*t al.* (2005), Singh e*t al.* (2002), Singh e*t al.* (2001), Patel and Chaudhary (2001) for clusters per plant, number of seeds per pod, Patil (2014) for clusters per plant, number of seeds per pod, pod yield per plant, 100-seed weight, Ibrahim *et al*. (2013), Shah *et al.* (2000) for number of clusters per plant, pod yield per plant, Singh e*t al.* (2004) for clusters per plant, number of seeds per pod, 100-seed weight, Sultan *et al.* (2012), Maria Sultan *et al.* (2012) for clusters per plant, Rai *et al.* (2012) for pod yield per plant, Buttar *et al.* (2008), Brar and Grover (2003) for 100-seed weight.

The correlation study indicated that the number of primary branches per plant, number of clusters per plant, number of seeds per pod and pod yield per plant had significant positive association with seed yield per plant at both genotypic and phenotypic levels and 100-seed weight had significant positive association with seed yield per plant at genotypic level. So improvement in seed yield per plant is possible by taking above characters as criteria in selection scheme.

4.5 PATH ANALYSIS

Path analysis was carried out at phenotypic and genotypic level considering seed yield per plant as dependent variable and its attributes *viz.*, plant height (cm), number of primary branches per plant, days to 50% flowering, number of clusters per plant, number of pods per cluster, pod length (cm), pod girth (mm), number of seeds per pod, pod yield per plant (g), 100-seed weight (g) and crude gum content (%) as independent variables.

Each component has two path actions *viz.*, direct effect on yield and indirect effect through components which are not revealed by correlation studies. The results are presented in Table 4.6 and path showing the cause and effect relationship is shown for phenotypic in Fig.1 and genotypic in Fig.2.

Direct and indirect effects

4.5.1 Plant height (cm)

Plant height recorded positive direct effect (0.0265 P, 0.0081 G) on seed yield per plant at phenotypic and genotypic levels. These findings were in agreement with the results of Patil (2014), Raghu Prakash *et al.* (2009) in cluster bean, Krishnan *et al.* (2002) in urdbean.

This trait exhibited positive indirect effect on seed yield per plant through number of clusters per plant (0.0011 P, 0.0044 G), pod length (0.0100 P, 0.3756 G), pod yield per plant (0.1886 P, 0.5965 G), crude gum content (0.0101 P, 0.4173 G) at phenotypic level and genotypic level respectively, similar results were observed at genotypical level through number of primary branches per plant (0.0069 G), pod girth (0.0117 G) and at phenotypical level through number of seeds per pod (0.0026 P). These results were in conformity with the previous studies conducted in cluster bean by Arumugarangarajan *et al.* (2000) through number of clusters per plant, pod length, pod yield per plant, Manivannan and Anandakumar (2013), through pod length, Raghu Prakash *et al.* (2009) through crude gum content.

This trait also exhibited negative indirect effect on seed yield per plant through days to 50% flowering (-0.0073 P, -0.0203 G), number of pods per cluster (-0.0091 P, -0.9899 G), 100-seed weight (-0.0246 P, -0.1077 G) at phenotypic level and genotypic level respectively, similar results were observed at genotypic level through number of seeds per pod (-0.1008 G) and at phenotypical level through number of primary branches per plant (-0.0009 P), pod girth (-0.0085 P). These results were in accordance with the reports of various studies conducted in cluster bean by Arumugarangarajan *et al.* (2000) through days to 50 % flowering, Raghu Prakash *et al.* (2009) through days to 50 % flowering, pods per cluster, 100-seed weight.

4.5.2 Number of primary branches per plant

Number of primary branches per plant recorded positive direct effect (0.0113 P) at phenotypical level and negative direct effect (-0.0884 G) at genotypcial level on seed yield per plant.

This trait exhibited positive indirect effect on seed yield per plant through days to 50% flowering (0.0050 P, 0.0155 G), number of pods per cluster (0.0023 P, 0.2715 G), pod length (0.0025 P, 0.1593 G), pod yield per plant (0.3964 P, 1.2542 G), 100-seed weight (0.0242 P, 0.1274 G) at phenotypic level and genotypic level respectively, similar results were observed at phenotypical level through pod girth (0.0046 P), number of seeds per pod (0.0174). These results were in line with the findings of various studies conducted in cluster bean by Manivannan and Anandakumar (2013) through pods per cluster, pod length, Buttar *et al.* (2008) through 100-seed weight.

This trait also exhibited negative indirect effect on seed yield per plant through plant height (-0.0020 P, -0.0006 G), number of clusters per plant (-0.0350 P, -0.2756 G), crude gum content (-0.0003 P, -0.0078 G) at phenotypic level and genotypic level respectively, similar results were observed at genotypic level through pod girth (-0.0041 G), number of seeds per pod (-0.9947 G). These results were in conformity with the previous studies conducted in cluster bean by Raghu Prakash *et al.* (2009) through clusters per plant, plant height, Buttar *et al.* (2008) through plant height.

4.5.3 Days to 50 % flowering

Days to 50 % flowering recorded negative direct effect (-0.0396 P, -0.0787 G) on seed yield per plant at phenotypic and genotypic levels. These findings were in agreement with the results of Raghu Prakash *et al.* (2009) in cluster bean.

This trait exhibited positive indirect effect on seed yield per plant through plant height (0.0049 P, 0.0021 G), number of clusters per plant (0.0025 P, 0.0130 G), pod length (0.0018 P, 0.1594 G), pod yield per plant (0.1476 P, 0.6855 G), 100-seed weight (0.0043 P, 0.0408 G) at phenotypic level and genotypic level respectively, similar results were observed at genotypical level through number of primary branches per plant (0.0174 G), pod girth (0.0583 G), number of seeds per pod (0.0414 G). These findings were in agreement with the results of various studies conducted in cluster bean by Manivannan and Anandakumar (2013), Hingane and Navale (2008) through plant height, 100-seed weight, Arumugarangarajan *et al.* (2000) through plant height, pod length, pod yield per plant.

This trait also exhibited negative indirect effect on seed yield per plant through number of pods per cluster (-0.0024 P, -0.6719 G), crude gum content (-0.0014 P, -0.0813 G) at phenotypic level and genotypic level respectively, similar results were observed at phenotypical level through number of primary branches per plant (-0.0014 P), pod girth (-0.0234 P), number of seeds per pod (-0.0004). These results were in conformity with the previous studies conducted in cluster bean by Manivannan and Anandakumar (2013), Arumugarangarajan *et al.* (2000) through pods per cluster, Raghu Prakash *et al.* (2009) through crude gum content.

4.5.4 Number of clusters per plant

Number of clusters per plant recorded negative direct effect (-0.0513 P, -0.3800 G) on seed yield per plant at phenotypic and genotypic levels. These findings were in agreement with the results of Raghu Prakash *et al.* (2009) in cluster bean, Krishnan *et al.* (2002) in urdbean.

This trait exhibited positive indirect effect on seed yield per plant through days to 50% flowering (0.0019 P, 0.0027 G), number of pods per cluster (0.0029 P, 0.3522 G), pod length (0.0029 P, 0.1154 G), pod yield per plant (0.7716 P, 2.3754 G) at phenotypic level and genotypic level respectively, similar results were observed at genotypical level through pod girth (0.0062 G) and at phenotypical level through number of seeds per pod (0.0271 P). These results were in conformity with the previous studies conducted in cluster bean by Raghu Prakash *et al.* (2009) through days to 50 % flowering, pods per cluster, Manivannan and Anandakumar (2013) through pod length, Arumugarangarajan *et al.* (2000) through pod length, pod yield per plant.

This trait also exhibited negative indirect effect on seed yield per plant through plant height (-0.0006 P, -0.0001 G), number of primary branches per plant (-0.0074 P, -0.0641 G), 100-seed weight (-0.0081 P, -0.0340 G), crude gum content (-0.0026 P, -0.1082 G) at phenotypic level and genotypic level respectively, similar results were observed at genotypical level through number of seeds per pod (-1.4813 G) and at phenotypical level through pod girth (-0.0045 P). These results were in conformity with the previous studies conducted in cluster bean by Arumugarangarajan *et al.* (2000) through plant height, Manivannan and Anandakumar (2013) through primary branches per plant, 100-seed weight.

4.5.5 Number of pods per cluster

Number of pods per cluster recorded negative direct effect (-0.0155 P, -1.1541 G) on seed yield per plant at phenotypic and genotypic levels. These findings were in agreement with the results of Krishnan *et al.* (2002) in urdbean.

This trait exhibited positive indirect effect on seed yield per plant through plant height (0.0156 P, 0.0070 G), number of clusters per plant (0.0096 P, 0.1160 G), pod length (0.0082 P, 0.3171 G), pod yield per plant (0.0895 P, 0.3903 G), crude gum content (0.0070 P, 0.4393 G) at phenotypic level and genotypic level respectively, similar results were observed at genotypical level through number of primary branches per plant (0.0208 G), pod girth (0.0169

G), number of seeds per pod (0.0941 G). These results were in conformity with the previous studies conducted in cluster bean by Manivannan and Anandakumar (2013) through pod length, Arumugarangarajan *et al.* (2000) through clusters per plant, pod length, pod yield per plant.

This trait also exhibited negative indirect effect on seed yield per plant through days to 50 % flowering (-0.0062 P, -0.0458 G), 100-seed weight (-0.0100 P, -0.0766 G) at phenotypic level and genotypic level respectively, similar results were observed at phenotypical level through number of primary branches per plant (-0.0077 P), pod girth (-0.0151 P), number of seeds per pod (-0.0009 P). These results were in line with the findings of various studies conducted in cluster bean by Manivannan and Anandakumar (2013) through days to 50 % flowering, 100-seed weight, Arumugarangarajan *et al.* (2000) through days to 50 % flowering.

4.5.6 Pod length (cm)

Pod length recorded positive direct effect (0.0195 P, 0.6638 G) on seed yield per plant at phenotypic and genotypic levels. These findings were in agreement with the results of Hingane and Navale (2008) in cluster bean.

This trait exhibited positive indirect effect on seed yield per plant through plant height (0.0136 P, 0.0046 G), pod yield per plant (0.0283 P, 0.0871 G), crude gum content (0.0066 P, 0.2967 G) at phenotypic level and genotypic level respectively, similar results were observed at genotypical level through pod girth (0.0242 G) and at phenotypical level through number of primary branches per plant (0.0015 P), number of seeds per pod (0.0051 P). These results were in conformity with the previous studies conducted in cluster bean by Hingane and Navale (2008) through plant height, Arumugarangarajan *et al.* (2000) through plant height, pod yield per plant.

This trait also exhibited negative indirect effect on seed yield per plant through days to 50 % flowering (-0.0037 P, -0.0189 G), number of clusters per plant (-0.0076 P, -0.0661 G), number of pods per cluster (-0.0065 P, -0.5514 G), 100-seed weight (-0.0045 P, -0.0195 G) at phenotypic level and genotypic level respectively, similar results were observed at genotypical level through number of primary branches per plant (-0.0212 G), number of seeds per pod (-0.3594 G) and at phenotypical level through pod girth (-0.0167 P). These results were in conformity with the previous studies conducted in cluster bean by Hingane and Navale (2008), Arumugarangarajan *et al.* (2000) through days to 50 % flowering, clusters per plant, pods per cluster, 100-seed weight.

4.5.7 Pod girth (mm)

Pod girth recorded positive direct effect (0.0552 P) at phenotypical level and negative direct effect (-0.0765 G) at genotypcial level on seed yield per plant.

This trait exhibited positive indirect effect on seed yield per plant through days to 50% flowering (0.0168 P, 0.0600 G), number of clusters per plant (0.0042 P, 0.0310 G), number of pods per cluster (0.0042 P, 0.2549 G), crude gum content (0.0005 P, 0.0243 G) at phenotypic level and genotypic level respectively, similar results were observed at genotypical level through number of seeds per pod (0.1807 G) and at phenotypical level through number of primary branches per plant (0.0009 P). These results are in line with the findings of Shabarish Rai and Dharmatti (2014) through clusters per plant in cluster bean.

This trait also exhibited negative indirect effect on seed yield per plant through plant height (-0.0041 P, -0.0012 G), pod length (-0.0059 P, -0.2097 G), pod yield per plant (-0.0457 P, -0.1834 G), 100-seed weight (-0.0220 P, -0.0935 G) at phenotypic level and genotypic level respectively, similar results were observed at genotypic level through number of primary branches per plant (-0.0049 G) and at phenotypical level through number of seeds per pod (-0.0038 P). These results are in line with the findings of Malaghan *et al.* (2014) through plant height in cluster bean.

4.5.8 Number of seeds per pod

Number of seeds per pod recorded positive direct effect (0.0354 P) at phenotypical level and negative direct effect (-1.6905 G) at genotypcial level on seed yield per plant.

This trait exhibited positive indirect effect on seed yield per plant through plant height (0.0019 P, 0.0005 G), days to 50% flowering (0.0004 P, 0.0019 G), number of pods per cluster (0.0004 P, 0.0643 G), pod length (0.0028 P, 0.1411 G), pod yield per plant (0.7721 P, 2.6790 G), crude gum content (0.0031 P, 0.1410 G) at phenotypic level and genotypic level respectively, similar results were observed at genotypical level through pod girth (0.0082 G) and at phenotypical level through number of primary branches per plant (0.0056 P). These results were in accordance with the reports of various studies conducted in cluster bean by Manivannan and Anandakumar (2013) through days to 50 % flowering, Hingane and Navale (2008) through number of pods per cluster, Buttar *et al*. (2008) through plant height, Arumugarangarajan *et al.* (2000) through plant height, days to 50 % flowering, number of pods per cluster, pod yield per plant.

This trait also exhibited negative indirect effect on seed yield per plant through number of clusters per plant (-0.0394 P, -0.3329 G), 100-seed weight (-0.0130 P, -0.0606 G) at phenotypic level and genotypic level respectively, similar results were observed at genotypic level through number of primary branches per plant (-0.0520 G) and at phenotypical level through pod girth (-0.0060 P). These results were in conformity with the previous studies conducted in cluster bean by Manivannan and Anandakumar (2013) through clusters per plant, Buttar *et al.* (2008) through 100-seed weight, Arumugarangarajan *et al.* (2000) through clusters per plant, 100-seed weight.

4.5.9 Pod yield per plant (g)

Pod yield per plant recorded positive direct effect (1.0283 P, 3.0792 G) on seed yield per plant at phenotypic and genotypic levels. These findings were in agreement with the results of Patil (2014) in cluster bean.

This trait exhibited positive indirect effect on seed yield per plant through plant height (0.0049 P, 0.0016 G), pod length (0.0005 P, 0.0188 G) at phenotypic level and genotypic level respectively, similar results were observed at genotypical level through pod girth (0.0046 G) and at phenotypical level through number of primary branches per plant (0.0044 P), number of seeds per pod (0.0266 P). These results are in line with the findings of Arumugarangarajan *et al.* (2000) through plant height, pod length in cluster bean.

This trait also exhibited negative indirect effect on seed yield per plant through days to 50 % flowering (-0.0057 P, -0.0175 G), number of clusters per plant (-0.385 P, -0.2931 G), number of pods per cluster (-0.0013 P, -0.1463 G), 100-seed weight (-0.0264 P, -0.1236 G), crude gum content (-0.0004 P, -0.0189 G) at phenotypic level and genotypic level respectively, similar results were observed at genotypical level through number of primary branches per plant (-0.0360 G), number of seeds per pod (-1.4708 G) and at phenotypical level through pod girth (-0.0025 P).

4.5.10 100-seed weight (g)

100-seed weight recorded negative direct effect (-0.0804 P, -0.3062 G) on seed yield per plant at phenotypic and genotypic levels. These findings were in agreement with the results of Patil (2014), Raghu Prakash *et al.* (2009), Hingane and Navale (2008), Buttar *et al.* (2008), Singh *et al.* (2002), Arumugarangarajan *et al.* (2000) in cluster bean.

This trait exhibited positive indirect effect on seed yield per plant through plant height (0.0081 P, 0.0029 G), days to 50 % flowering (0.0021 P, 0.0105 G), pod length (0.0011 P, 0.0423 G), pod yield per plant (0.3379 P, 1.2434 G), crude gum content(0.0009 P, 0.0453 G) at phenotypic level and genotypic level respectively, similar results were observed at genotypical level through number of primary branches per plant (0.0368 G) and at phenotypical level through pod girth (0.0151 P), number of seeds per pod (0.0057 P). These results were in accordance with the reports of various studies conducted in cluster bean by Buttar *et al.* (2008) through plant height, Manivannan and Anandakumar (2013) through days to 50 % flowering, Hingane and Navale (2008) through plant height and pod length, Arumugarangarajan *et al.* (2000) through pod length.

This trait also exhibited negative indirect effect on seed yield per plant through number of clusters per plant (-0.0052 P, -0.0422 G), number of pods per cluster (-0.0019 P, -0.2885 G) at phenotypic level and genotypic level respectively, similar results were observed at genotypical level through pod girth (-0.0234 G), number of seeds per pod (-0.3347 G) and at phenotypical level through number of primary branches per plant (-0.0034 P). These results are in line with the findings of Manivannan and Anandakumar (2013), Hingane and Navale (2008) through clusters per plant, pods per cluster in cluster bean.

4.5.11 Crude gum content (%)

Crude gum content recorded negative direct effect (-0.0187 P, -0.7677 G) on seed yield per plant at phenotypic and genotypic levels.

This trait exhibited positive indirect effect on seed yield per plant through number of pods per cluster (0.0058 P, 0.6603 G), pod yield per plant (0.0236 P, 0.0756 G), 100-seed weight (0.0039 P, 0.0181 G) at phenotypic level and genotypic level respectively, similar results were observed at genotypical level through pod girth (0.0024 G), number of seeds per pod (0.3105 G) and at phenotypical level through number of primary branches per plant (0.0002 P).

This trait also exhibited negative indirect effect on seed yield per plant through plant height (-0.0143 P, -0.0044 G), days to 50 % flowering (-0.0030 P, -0.0083 G), number of clusters per plant (-0.0072 P, -0.0535 G), pod length (-0.0069 P, -0.2565 G) at phenotypic level and genotypic level respectively, similar results were observed at genotypical level through number of primary branches per plant (-0.0009 G) and at phenotypical level through pod girth (-0.0015 P), number of seeds per pod (-0.0059 P). These results are in line with the findings of Raghu Prakash *et al.* (2009) through number of clusters per plant in cluster bean.

Although correlation coefficients indicate the nature of association among the characters, path analysis splits the correlation coefficients into measures of direct and indirect effects, thus providing an understanding on the direct and indirect contribution of each character towards yield.

Path coefficient analysis showed that pod yield per plant and pod length at genotypic level exhibited high positive direct effect on seed yield per plant and pod yield per plant recorded significant, positive correlation with seed yield per plant. It clearly indicates that direct selection based on these characters would be effective for an increase in seed yield per plant.

Further among the traits studied, pod yield per plant had significant positive correlation with seed yield along with high variability, high heritability coupled with high genetic advance as percent of mean. From these results it can be concluded that more emphasis should be given for selection of this trait to improve the seed yield in seed guar.

The residual effect of the present study was 0.126 for genotypic level and 0.099 for phenotypic level indicating that the characters studied contributed 87.4% of the yield at genotypic level and 90.1% at phenotypic level, respectively. It is suggested that maximum emphasis should be given on the above characters for selecting seed guar cultivars with higher yield.

.

Table 4.2. Mean performance of fifteen cultivars of seed guar (*Cyamopsis tetragonoloba* (L.) Taub.) for seed yield and the twenty four component characters

Cultivars	Percentage of germination	Plant height (cm)	No. of 1° branches per plant	No. of leaves per plant	Days to first flowering	Days to 50 % flowering	No. of clusters per plant	No. of pods per cluster	No. of pods per plant	Pod length (cm)	Pod girth (mm)	No. of seeds per pod	Seed to pod ratio
RGC 197	89.67	**113.00**	5.00	74.00	**24.67**	**28.67**	17.00	**7.00**	119.67	6.13	21.53	6.67	48.21
RGC 936	**100.00**	88.67	**9.00**	**118.00**	23.33	**26.00**	29.00	4.33	126.00	6.23	23.27	7.33	50.00
RGC 963	**100.00**	95.33	**9.00**	103.00	23.33	26.33	**40.67**	5.00	**204.00**	6.16	21.93	8.67	50.19
RGC 986	95.33	84.00	8.00	99.00	24.33	28.00	38.00	5.00	189.33	5.60	22.00	**9.00**	49.07
RGC 1002	99.00	68.67	**4.00**	79.00	**23.00**	27.33	21.00	**3.67**	76.67	5.53	23.27	6.00	46.72
RGC 1025	99.33	76.67	6.00	76.00	24.33	27.67	28.33	4.33	122.67	5.87	**19.53**	7.67	**45.73**
RGC 1031	99.00	77.67	6.00	82.00	**24.67**	26.67	**15.33**	5.33	81.67	5.63	21.93	**5.33**	47.12
RGC 1033	87.33	64.67	8.00	103.00	23.67	27.67	29.00	4.67	134.67	5.30	22.00	7.33	48.19
RGC 1038	88.67	66.33	7.00	102.00	23.67	27.00	31.67	5.00	158.33	5.67	21.73	7.67	**50.53**
RGC 1066	93.33	87.33	**4.00**	**66.00**	**23.00**	26.67	14.00	6.00	84.33	6.10	22.13	7.33	50.02
HG 365	99.33	**62.33**	5.00	73.00	**23.00**	**26.00**	17.33	4.00	**69.67**	**4.73**	**23.33**	7.00	48.30
HG 884	**79.67**	66.33	**9.00**	93.00	**24.67**	27.67	28.00	4.33	121.33	5.83	21.53	8.00	50.52
HG 2-20	88.00	79.00	6.00	92.00	23.67	27.00	36.33	5.00	182.00	6.00	22.07	8.67	47.85
JJ-1	99.33	79.33	5.00	84.00	25.00	28.33	21.00	5.00	105.00	6.23	20.27	6.67	46.95
JG-2	**100.00**	67.00	8.00	88.00	23.33	27.00	27.00	5.00	135.33	**6.36**	22.47	7.67	48.54
Mean	**94.53**	**78.42**	**7.00**	**89.00**	**23.84**	**27.20**	**26.24**	**4.91**	**127.38**	**5.83**	**21.93**	**7.4**	**48.53**
Range lowest	79.67	62.33	4.00	66.00	23.00	26.00	15.33	3.67	69.67	4.73	19.53	5.3	45.73
Range highest	100.00	113.00	9.00	117.67	24.67	28.67	40.67	7.00	204.00	6.36	23.33	9	50.53
C.V. (%)	0.57	3.21	13.001	2.41	3.28	2.69	6.56	15.75	18.80	2.92	2.12	7.04	1.64
S.E. ±	0.31	1.45	0.497	1.24	0.45	0.42	0.99	0.44	13.82	0.09	0.26	0.30	0.46
C.D. at 5%	0.91	4.21	1.44	3.58	1.31	1.22	2.88	1.29	40.06	0.28	0.78	0.87	1.33
C.D. at 1%	1.23	5.68	1.94	4.83	1.77	1.65	3.88	1.75	54.04	0.38	1.05	1.18	1.79

Table 4.2: contd…

Cultivars	Pod yield per plant (g)	Pod yield per ha. (q/ha)	Seed yield per plant (g)	Seed yield per ha. (q/ha)	100 seed weight (g)	Harvest Index (%)	Chlorophyll stability index	Relative water content (%)	Peroxidase enzyme activity (E.U./g)	Catalase enzyme activity (E.U./g)	SPAD meter reading (CCI)	Crude gum content (%)
RGC 197	29.00	32.22	13.70	15.22	4.39	**66.80**	0.049	92.67	94.25	435.50	56.37	**29.26**
RGC 936	27.67	30.73	13.67	15.18	4.17	70.93	0.094	81.67	181.06	422.75	**35.39**	30.05
RGC 963	33.33	37.03	16.73	18.59	4.03	72.25	0.201	75.33	192.83	437.25	40.92	29.34
RGC 986	**45.00**	**49.99**	**21.93**	**24.36**	4.09	69.15	0.467	87.67	197.08	497.75	47.01	29.83
RGC 1002	19.33	21.48	9.03	10.03	4.36	78.75	0.180	**75.00**	**244.14**	392.75	47.99	31.06
RGC 1025	27.33	30.37	12.50	13.89	4.03	76.45	0.177	81.33	**78.60**	546.75	48.89	30.78
RGC 1031	**17.33**	**19.25**	**8.17**	**9.07**	3.88	78.00	0.144	84.67	241.18	480.75	53.66	30.15
RGC 1033	35.33	39.25	17.03	18.92	3.84	74.60	0.571	80.33	231.36	394.50	47.99	**31.71**
RGC 1038	27.67	30.73	13.00	14.44	4.17	71.03	**0.951**	85.00	216.22	**379.50**	39.30	30.69
RGC 1066	24.00	26.66	12.00	13.33	4.24	74.80	**0.016**	90.33	229.89	398.00	51.41	29.42
HG 365	24.00	26.66	11.67	12.95	4.09	78.80	0.044	**95.00**	221.30	383.25	59.63	29.57
HG 884	27.00	29.99	13.63	15.14	3.86	**79.10**	0.169	87.67	239.88	429.50	**62.78**	29.66
HG 2-20	44.33	49.25	21.07	23.40	**4.79**	72.67	0.506	92.00	220.94	606.75	46.19	30.15
JJ-1	23.00	25.55	10.80	11.99	**3.77**	76.75	0.044	84.67	220.87	**824.50**	48.67	29.71
JG-2	25.00	27.77	12.13	13.48	3.88	75.63	0.419	88.67	186.81	389.75	48.40	29.83
Mean	**28.62**	**31.80**	**13.80**	**15.33**	**4.11**	**74.38**	**0.27**	**85.47**	**199.76**	**467.95**	**48.97**	**30.08**
Range lowest	17.33	19.25	8.17	9.07	3.77	66.80	0.016	75.00	78.60	379.50	35.39	29.26
Range highest	45.00	49.99	21.93	24.36	4.79	79.10	0.951	95.00	244.14	824.50	62.78	31.71
C.V. (%)	4.31	4.31	6.09	6.09	4.23	0.66	4.99	0.61	0.27	0.32	1.71	0.17
S.E. ±	0.71	0.79	0.48	0.54	0.10	0.29	0.008	0.30	0.30	0.87	0.48	0.03
C.D. at 5%	2.06	2.29	1.41	1.56	0.29	0.83	0.023	0.87	0.89	2.52	1.40	0.09
C.D. at 1%	2.78	3.09	1.90	2.10	0.39	1.11	0.030	1.18	1.20	3.40	1.89	0.12

Table 4.4 Mean, variability, GCV, PCV, heritability (broad sense), genetic advance and genetic advance as per cent of mean for seed yield and its components in seed guar (*Cyamopsis tetragonoloba* (L.) Taub.) cultivars

S.No.	Character	Mean	Range		Variance		GCV (%)	PCV (%)	Heritability in broad sense (h^2) (%)	Genetic advance	Genetic advance as per cent of mean (5%)
			Minimum	Maximum	Genotypic	Phenotypic					
1.	Percentage of germination	94.53	79.67	100.00	40.93	41.23	6.77	6.79	99.30	13.13	13.89
2.	Plant height (cm)	78.42	62.33	113.00	188.45	194.79	17.51	17.78	96.70	27.82	35.49
3.	Number of primary branches per plant	6.62	4.00	9.00	3.01	3.75	26.18	29.23	80.20	3.20	48.29
4.	Number of leaves per plant	88.80	66.00	117.67	200.13	204.72	15.93	16.11	97.80	28.81	32.44
5.	Days to first flowering	23.84	23.00	24.67	0.29	0.90	2.24	3.98	31.80	0.62	2.60
6	Days to 50% flowering	27.20	26.00	28.67	0.47	1.01	2.52	3.69	46.50	0.96	3.53
7.	Number of clusters per plant	26.24	15.33	40.67	69.69	72.65	31.80	32.48	95.90	16.84	64.18
8.	Number of pods per Cluster	4.91	3.67	7.00	0.06	0.07	13.79	20.94	43.40	0.92	18.71
9.	Number of pods per plant	127.38	69.67	204	1539.74	2113.32	30.81	36.90	72.90	68.99	54.17
10.	Pod length (cm)	5.83	4.73	6.37	0.18	0.21	7.22	7.79	86.00	0.80	13.79
11.	Pod girth (mm)	21.93	19.53	23.33	0.98	1.20	4.52	4.99	81.90	1.85	8.43
12.	Number of seeds per pod	7.40	5.30	9.00	0.90	1.17	12.80	14.61	76.80	1.71	23.10

Table 4.4 contd….

S.No.	Character	Mean	Range		Variance		GCV (%)	PCV (%)	Heritability in broad sense (h^2) (%)	Genetic advance	Genetic advance as per cent of mean (5%)
			Minimum	Maximum	Genotypic	Phenotypic					
13.	See to pod ratio	48.53	45.73	50.53	2.06	2.69	2.96	3.38	76.50	2.59	5.33
14.	Pod yield per plant (g)	28.62	17.33	45.00	63.05	64.57	27.74	28.07	97.60	16.16	56.47
15.	Pod yield per hectare (q./ha.)	31.80	19.25	49.99	77.83	79.71	27.75	28.08	97.60	17.96	56.48
16.	Seeds yield per plant (g)	13.80	8.17	21.93	15.08	15.79	28.13	28.78	95.50	7.82	56.64
17.	Seed yield per hectare (q./ha.)	15.33	9.07	24.36	18.61	19.49	28.14	28.79	95.50	8.69	56.66
18.	100-seed weight (g)	4.11	3.77	4.79	0.06	0.09	6.02	7.36	67.00	0.42	10.15
19.	Harvest Index	74.38	66.80	79.10	14.28	14.53	5.08	5.12	98.30	7.72	10.38
20.	Chlorophyll stability index	0.27	0.016	0.951	0.068	0.070	97.58	97.71	99.70	0.54	200.76
21.	Relative water content	85.47	75.00	95.00	35.67	35.94	6.99	7.01	99.20	12.26	14.34
22.	Peroxidase enzyme activity	199.76	78.60	244.14	2515.26	2515.55	25.10	25.11	99.90	103.31	51.72
23.	Catalase enzyme activity	467.95	379.50	824.50	14015.48	14017.75	25.29	25.30	99.90	243.86	52.11
24.	SPAD meter reading	48.97	35.39	62.78	52.89	53.60	14.85	14.95	98.70	14.88	30.39
25.	Crude gum content (%)	30.08	29.26	31.71	0.48	0.49	2.32	2.33	99.50	1.44	4.77

PCV and GCV : 0-10 % - Low; 11-20 % - Moderate; 21 % and above – High.
Heritability : Less than 30 % - Low; 30-60 % - Moderate; More than 60 % - High
Genetic advance as per cent of mean : 0- 10% - Low; 10.1-20% - Moderate; >20.1% - High

Table 4.5 Genotypic and Phenotypic correlation coefficients of seed yield and its components in seed guar (*Cyamopsis tetragonoloba* (L) Taub.) cultivars

Character		Plant height (cm)	Number of primary branches per plant	Days to 50% flowering	Number of clusters per plant	Number of pods per cluster	Pod length (cm)	Pod girth (mm)	Number of seeds per pod	Pod yield per plant (g)	100-seed weight (g)	Crude gum content (%)	Correlation with Seed yield per plant (g)
Plant height (cm)	G		-0.0778	0.2578	-0.0116	0.8578**	0.5658**	-0.1534	0.0596	0.1937	0.3516*	-0.5436**	**0.2019**
	P		-0.0766	0.1840	-0.0213	0.5892**	0.5121**	-0.1550	0.0727	0.1834	0.3060*	-0.5391**	**0.1884**
Number of primary branches per plant	G			-0.1967	0.7252**	-0.2352	0.2400	0.0553	0.5884**	0.4073**	-0.4161**	0.0101	**0.4567****
	P			-0.1251	0.6826**	-0.1476	0.1291	0.0833	0.4924**	0.3855**	-0.3007*	0.0136	**0.4263****
Days to 50% flowering	G				-0.0342	0.5822**	0.2402	-0.7620**	-0.0245	0.2226	-0.1332	0.1059	**0.1859**
	P				-0.0479	0.1554	0.0928	-0.4245**	-0.0102	0.1436	-0.0530	0.0749	**0.0924**
Number of clusters per plant	G					-0.3052*	0.1739	-0.0815	0.8762**	0.7714**	0.1112	0.1409	**0.7842****
	P					-0.1878	0.1480	-0.0825	0.7674**	0.7503**	0.1005	0.1408	**0.7470****
Number of pods per cluster	G						0.4778**	-0.2208	-0.0557	0.1268	0.2500	-0.5722**	**0.1250**
	P						0.4179**	-0.2738	-0.0257	0.0870	0.1244	-0.3737*	**0.0806**
Pod length (cm)	G							-0.3159*	0.2126	0.0283	0.0637	-0.3864**	**0.0399**
	P							-0.3028*	0.1431	0.0276	0.0555	-0.3553*	**0.0357**
Pod girth (mm)	G								-0.1069	-0.0596	0.3052*	-0.0316	**-0.0185**
	P								-0.1081	-0.0444	0.2731	-0.0270	**0.0004**
Number of seeds per pod	G									0.8700**	0.1980	-0.1837	**0.8999****
	P									0.7508**	0.1612	-0.1660	**0.7633****
Pod yield per plant (g)	G										0.4038**	0.0246	**0.9979****
	P										0.3286*	0.0229	**0.9898****
100-seed weight (g)	G											-0.0590	**0.3860****
	P											-0.0488	**0.2800**
Crude gum content (%)	G												**-0.0244**
	P												**-0.0240**

* and ** significant at P = 0.05 and P = 0.01 level of significance , respectively; P=Phenotypic level and G =Genotypic level

Table 4.6 Estimation of direct and indirect effects of yield and its components in seed guar (*Cyamopsis tetragonoloba* (L.) Taub.) cultivars

Character		Plant height (cm)	Number of primary branches per plant	Days to 50% flowering	Number of clusters per plant	Number of pods per cluster	Pod length (cm)	Pod girth (mm)	Number of seeds per pod	Pod yield per plant (g)	100-seed weight (g)	Crude gum content (%)	Seed yield per plant (g)
Plant height (cm)	G	**0.0081**	0.0069	-0.0203	0.0044	-0.9899	0.3756	0.0117	-0.1008	0.5965	-0.1077	0.4173	**0.2019**
	P	**0.0265**	-0.0009	-0.0073	0.0011	-0.0091	0.0100	-0.0085	0.0026	0.1886	-0.0246	0.0101	**0.1884**
Number of primary branches per plant	G	-0.0006	**-0.0884**	0.0155	-0.2756	0.2715	0.1593	-0.0041	-0.9947	1.2542	0.1274	-0.0078	**0.4567****
	P	-0.0020	**0.0113**	0.0050	-0.0350	0.0023	0.0025	0.0046	0.0174	0.3964	0.0242	-0.0003	**0.4263****
Days to 50% flowering	G	0.0021	0.0174	**-0.0787**	0.0130	-0.6719	0.1594	0.0583	0.0414	0.6855	0.0408	-0.0813	**0.1859**
	P	0.0049	-0.0014	**-0.0396**	0.0025	-0.0024	0.0018	-0.0234	-0.0004	0.1476	0.0043	-0.0014	**0.0924**
Number of clusters per plant	G	-0.0001	-0.0641	0.0027	**-0.3800**	0.3522	0.1154	0.0062	-1.4813	2.3754	-0.0340	-0.1082	**0.7842****
	P	-0.0006	-0.0077	0.0019	**-0.0513**	0.0029	0.0029	-0.0045	0.0271	0.7716	-0.0081	-0.0026	**0.7470****
Number of pods per cluster	G	0.0070	0.0208	-0.0458	0.1160	**-1.1541**	0.3171	0.0169	0.0941	0.3903	-0.0766	0.4393	**0.1250**
	P	0.0156	-0.0077	-0.0062	0.0096	**-0.0155**	0.0082	-0.0151	-0.0009	0.0895	-0.0100	0.0070	**0.0806**
Pod length (cm)	G	0.0046	-0.0212	-0.0189	-0.0661	-0.5514	**0.6638**	0.0242	-0.3594	0.0871	-0.0195	0.2967	**0.0399**
	P	0.0136	0.0015	-0.0037	-0.0076	-0.0065	**0.0195**	-0.0167	0.0051	0.0283	-0.0045	0.0066	**0.0357**
Pod girth (mm)	G	-0.0012	-0.0049	0.0600	0.0310	0.2549	-0.2097	**-0.0765**	0.1807	-0.1834	-0.0935	0.0243	**-0.0185**
	P	-0.0041	0.0009	0.0168	0.0042	0.0042	-0.0059	**0.0552**	-0.0038	-0.0457	-0.0220	0.0005	**0.0004**
Number of seeds per pod	G	0.0005	-0.0520	0.0019	-0.3329*	0.0643	0.1411	0.0082	**-1.6905**	2.6790	-0.0606	0.1410	**0.8999****
	P	0.0019	0.0056	0.0004	-0.0394	0.0004	0.0028	-0.0060	**0.0354**	0.7721	-0.0130	0.0031	**0.7633****
Pod yield per plant (g)	G	0.0016	-0.0360	-0.0175	-0.2931	-0.1463	0.0188	0.0046	-1.4708	**3.0792**	-0.1236	-0.0189	**0.9979****
	P	0.0049	0.0044	-0.0057	-0.0385	-0.0013	0.0005	-0.0025	0.0266	**1.0283**	-0.0264	-0.0004	**0.9898****
100-seed weight (g)	G	0.0029	0.0368	0.0105	-0.0422	-0.2885	0.0423	-0.0234	-0.3347	1.2434	**-0.3062**	0.0453	**0.3860****
	P	0.0081	-0.0034	0.0021	-0.0052	-0.0019	0.0011	0.0151	0.0057	0.3379	**-0.0804**	0.0009	**0.2800**
Crude gum content (%)	G	-0.0044	-0.0009	-0.0083	-0.0535	0.6603	-0.2565	0.0024	0.3105	0.0756	0.0181	**-0.7677**	**-0.0244**
	P	-0.0143	0.0002	-0.0030	-0.0072	0.0058	-0.0069	-0.0015	-0.0059	0.0236	0.0039	**-0.0187**	**-0.0240**

Genotypic residual effect = **0.1260** and Phenotypical residual effect **= 0.0995;** P=Phenotypic level and G =Genotypic level

* and ** significant at $P = 0.05$ and $P = 0.01$ level of significance , respectively; Diagonal values indicate direct effect, Off- diagonal values indicate indirect effect

Table 4.1. Analysis of variance for yield and yield components in fifteen cultivars of seed guar (*Cyamopsis tetragonoloba (L) Taub.*)

S.No.	Character	Mean sum of squares		
		Replications (d.f=2)	Treatments (d.f=14)	Error (d.f=28)
1.	Percentage of germination	0.87	123.09**	0.295
2.	Plant height (cm)	3.89	571.69**	6.341
3.	Number of primary branches per plant	1.62	9.76**	0.74
4.	Number of leaves per plant	11.40	604.99**	4.59
5.	Days to first flowering	1.09	1.47*	0.61
6.	Days to 50% flowering	0.47	1.94**	0.54
7.	Number of clusters per plant	0.56	212.02**	2.96
8.	Number of pods per Cluster	0.62	1.98**	0.59
9.	Number of pods per plant	510.49	5192.80**	573.58
10.	Pod length (cm)	0.08	0.56**	0.03
11.	Pod girth (mm)	0.58	3.16**	0.22
12..	Number of seeds per pod	0.87	2.92**	0.27
13.	See to pod ratio	1.54	6.81**	0.63
14.	Pod yield per plant (g)	3.36	190.66**	1.52
15.	Pod yield per hectare (q./ha.)	4.15	235.37**	1.88
16.	Seeds yield per plant (g)	1.03	45.95**	0.71
17.	Seed yield per hectare (q./ha.)	1.27	56.72**	0.87
18.	100-seed weight (g)	0.01	0.21**	0.03

Table 4.1: contd…

S. No.	Character	Mean sum of squares		
		Replications (d.f=2)	Treatments (d.f=14)	Error (d.f=28)
19.	Harvest Index (%)	0.68	43.09**	0.24
20.	Chlorophyll stability index	0.001	0.207**	0.00
21.	Relative water content (%)	0.87	107.28**	0.27
22.	Peroxidase enzyme activity (E.U./g)	0.46	7546.06**	0.29
23.	Catalse enzyme activity (E.U./g)	2.20	42048.70**	2.27
24.	SPAD meter reading (CCI)	0.97	159.40**	0.703
25.	Crude gum content (%)	0.002	1.467**	0.003

* and ** significant at P = 0.05 and P = 0.01 level of significance , respectively

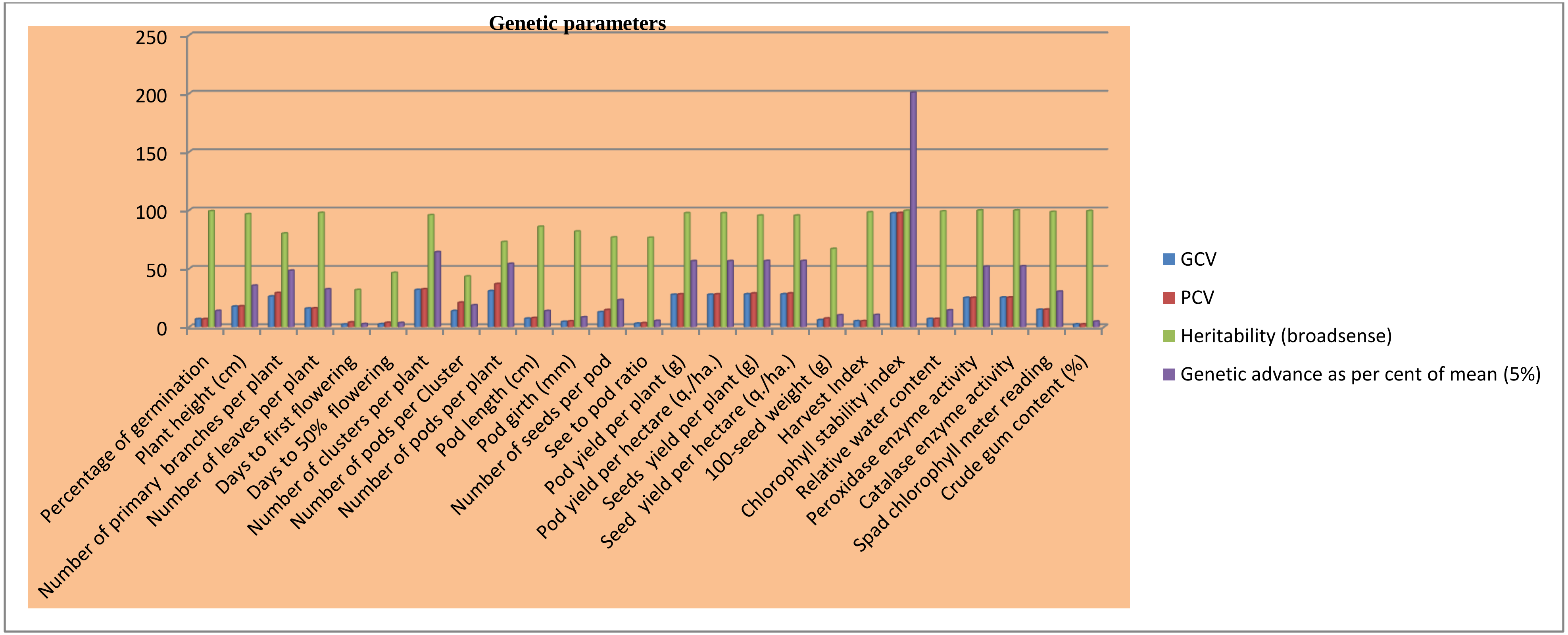

Figure 1. Estimation of variability, heritability and genetic advance as percent of mean for 25 characters in 15 cultivars of seed guar

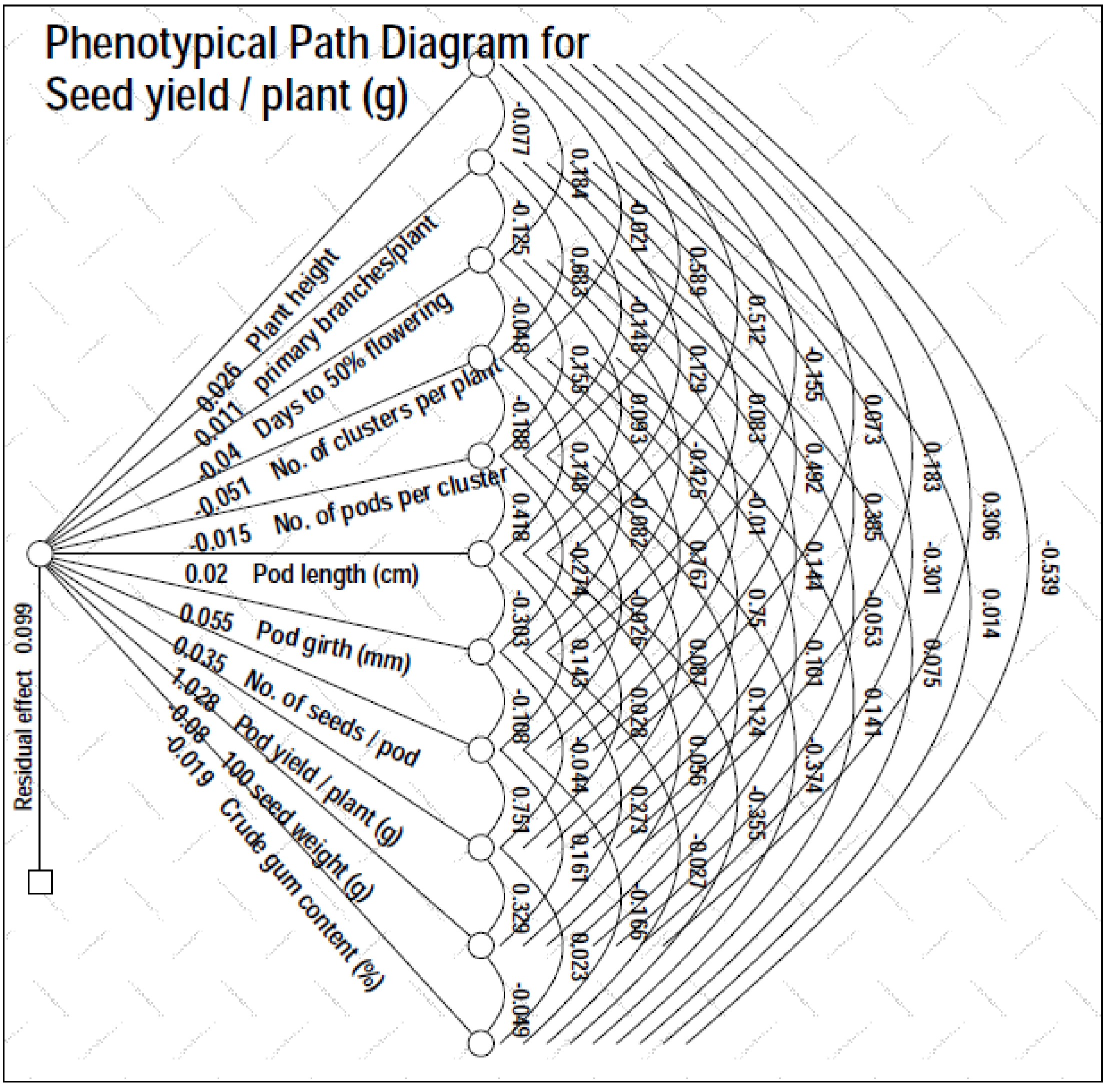

Figure 2. Phenotypic path diagram representing direct and indirect effects of component traits on seed yield per plant of seed guar

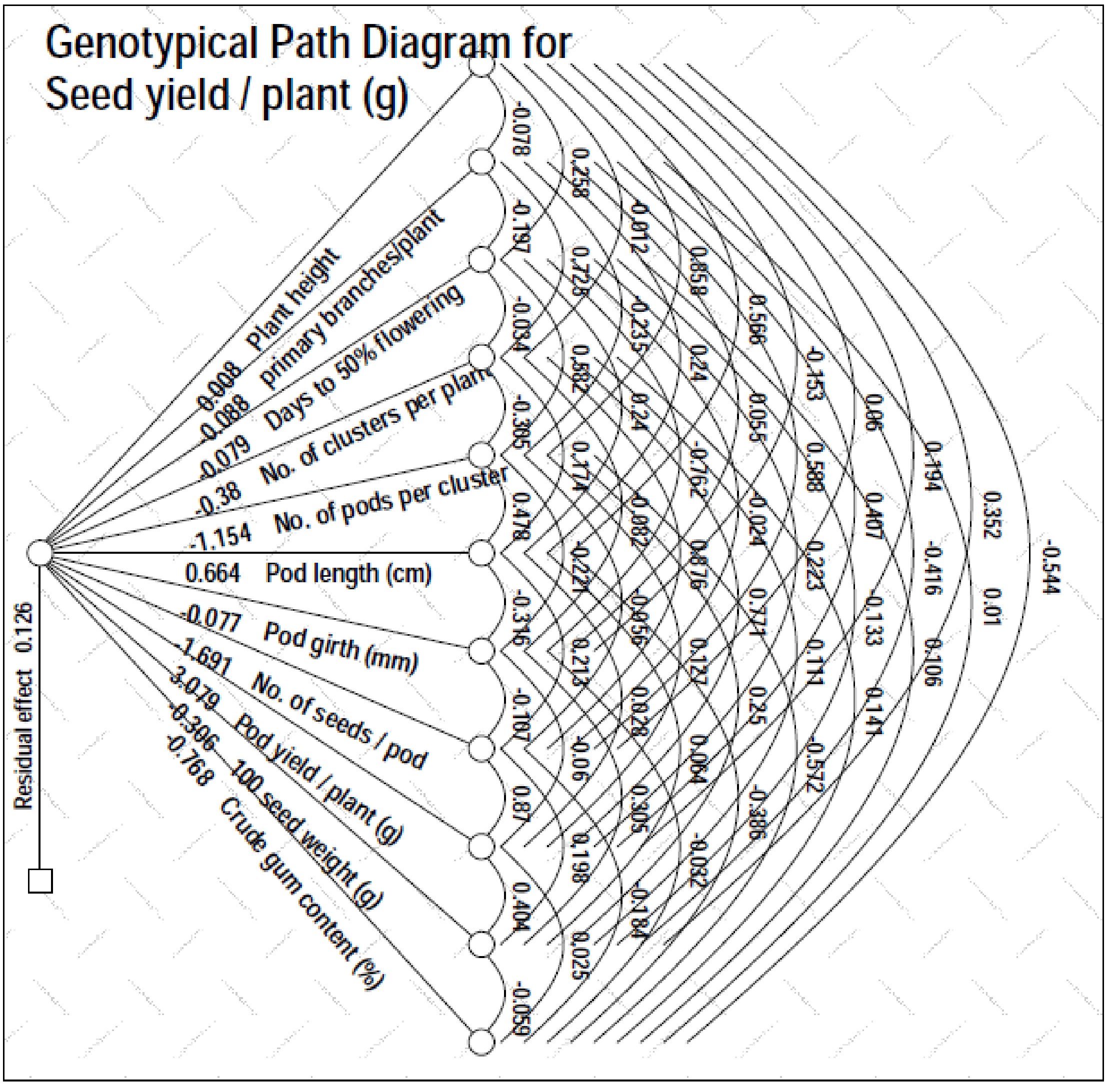

Figure 3. Genotypic path diagram representing direct and indirect effects of component traits on seed yield per plant of seed guar

Plate No. 1 : General view of the experimental plot

Plate No. 2 : Different stages of seed guar clusters in the filed

Chapter V

SUMMARY AND CONCLUSIONS

The present investigation on "Studies on Identification of Morphological and Physiological traits in relation to yield and quality of Seed Guar (*Cyamopsis tetragonoloba* (L.) Taub.) cultivars under Rainfed condition" was carried out at Student Research Farm, College of Horticulture, Dr. Y.S.R. Horticultural University, Mojerla, Mahabubnagar, Telangana during *kharif*, 2014 to know the mean performance, genetic variability, association among characters, direct and indirect effects of yield components on yield and quality traits in 15 cultivars.

The analysis of variance indicated highly significant differences for all the 25 characters among 15 cultivars of seed guar. Among the cultivars studied RGC 936, RGC 963, JG-2 recorded maximum percentage of germination. RGC 936, RGC963, HG 884 recorded maximum number of primary branches. RGC 936 recorded maximum number of leaves per plant while RGC 1002, RGC 1066, HG 365 were found to be early in terms of days to first flowering and RGC 936, RGC 1066 were early in the terms of days to 50% flowering. RGC 963 produced the maximum number of clusters per plant, number of pods per plant. The cultivar RGC 197 produced the maximum plant height at harvest, number of pods per cluster. Among the cultivars JG-2 recorded maximum pod length and HG 365 recorded maximum pod girth, relative water content. However, RGC 986 recorded the maximum number of seeds per pod, pod yield per plant, pod yield per hectare, seed yield per plant, seed yield per hectare. The cultivar RGC 1038 recorded the maximum seed to pod ratio, chlorophyll stability index. The highest 100-seed weight was recorded in HG 2-20. The cultivar HG 884 recorded the maximum harvest index, SPAD meter reading. RGC 1002 recorded the maximum peroxidase enzyme activity while JJ-1 recorded the maximum catalase enzyme activity. Among the cultivars RGC 1033 recorded the highest crude gum content.

The genotypic and phenotypic coefficient of variations were high for morphological characters such as number of primary branches per plant, number of clusters per plant, number of pods per plant, pod yield per plant, pod yield per hectare, seed yield per plant, seed yield per hectare. Also similar results were recorded for physiological traits such as chlorophyll stability index, peroxidase enzyme activity, catalase enzyme activity indicating the existence of wider genetic variability for these traits in the cultivars under study. The traits like percentage of germination, days to first flowering, days to 50 % flowering, pod length, pod girth, seed to pod ratio, 100-seed weight, harvest index, relative water content, crude gum content were found with low PCV and GCV suggesting narrow range of genetic variability for these traits. Number of pods per cluster showed high PCV and moderate GCV and the traits like plant height, number of leaves per plant, number of seeds per pod, SPAD meter reading were found with moderate variability. The values of PCV were observed to be higher than the corresponding values of GCV but the difference were narrow indicating low environmental influence in the expression of these characters.

The morphological characters *viz.*, number of primary branches per plant, number of clusters per plant, number of pods per plant, pod yield per plant, pod yield per hectare, seed yield per plant, seed yield per hectare and physiological characters *viz.*, chlorophyll stability index, peroxidase enzyme activity, catalase enzyme activity were observed with high genetic variability, high heritability in conjunction with high genetic advance as percent of mean indicating the predominance of additive gene action in determining these characters and hence direct selection will be rewarding for improvement of these traits in seed guar.

In the present investigation correlation study revealed that seed yield per plant had significant positive association with traits like number of primary branches per plant, number of clusters per plant, number of seeds per pod and pod yield per plant and 100-seed weight. Hence in selection programme, emphasis on these traits will result in improved seed yield. In general the magnitudes of genotypic correlation coefficients were higher than phenotypic correlation coefficients indicating strong association among various characters studied.

Path coefficient analysis showed that pod yield per plant and pod length at genotypic level exhibited high positive direct effect on seed yield per plant and pod yield per plant recorded significant, positive correlation with seed yield per plant. It clearly indicates that direct selection based on these traits would result in improved seed yield per plant.

Among the quality parameters studied, the highest crude gum content (31.71%) was recorded with RGC 1033, while the lowest gum content (29.26%) was obtained with RGC 197. Pod colour also indicated considerable variability ranging from light green to green colour among the 15 cultivars studied.

Based on the results of the present investigation the following conclusions could be drawn.

1. On the basis of mean performance of the cultivars for all the traits studied, RGC 963, RGC 986, RGC 1033 and HG 2-20 were found to be superior in terms of yield and quality characters. Hence these cultivars may be tested for their stable performance in different locations and may be selected as parental source for future breeding programmes.
2. Cultivars such as RGC 1066 recorded low chlorophyll stability index, HG 365 recorded high relative water content, high peroxidase enzyme activity was observed in RGC 1002 and high catalase enzyme activity was observed in JJ-1. Since, these physiological parameters are drought tolerance contributing traits, the above cultivars may be having drought tolerance. Further, these cultivars may be used for crop improvement programme for drought tolerance.
3. According to correlation and path analysis studies the trait pod yield per plant is considered as primary yield contributing component as it showed highly significant positive correlation coefficient effect and high positive direct effect on seed yield. So emphasis should be given on this trait during selection programme to improve the seed yield in seed guar.

LITERATURE CITED

Ahlawat, A, Pahuja, S.K and Dhingra, H.R. 2013. Studies on interspecific hybridization in Cyamopsis species. *African Journal of Agriculture.* **8**(27): 3590-3597.

*Alemu, Y, Alamirew, S and Dessalegn, L. 2013. Genetic variability in Snap bean (*Phaseolus vulgaris L.*) genotypes in central rift valley of Ethiopia. *International Journal of Plant Breeding and Genetics.* 7(2): 124 – 131.

Al-Jibouri, H.A, Miller, P.A and Robinson, H.F. 1958. Genotypic and environmental variation and correlation in upland cotton cross of interspecies origin. *Agronomy J*. 50(10): 633-636.

*Allard, R.W. 1960. Principles of Plant Breeding. Jhon Wiley and Sons Inc, New York, USA, pp 485.

Anandhi, K and Oommen, S. K. 2007. Variability and heritability of yield and related characters in clusterbean (*Cyamopsis tetragonoloba* (L.) Taub.). *Legume Research*. 30(4):287-289.

Anandhi, K and Oommen, S. K. 2010. Correlation studies in clusterbean.. *Legume Research*. 33(3):227-228.

Anjani, K.S, Singh, A.P, Singh, S.B and Vineeta Singh. 2009. Relationship and path analysis for green pod yield and its contributing characters over environments in french bean (*Phaseolus vulgaris* L.) *Legume Research.* 32(4): 270-273.

Arumugarangarajan, P, Jebaraj, S and Backiyarani, S. 2000. Relationship among major economic characters in cluster bean (*Cyamopsis tetragonoloba*). *South Indian Horticulture*. 48(1/6):64-68.

*Bewal, S, Purohit, J, Kumar, A, Khedasana, R and Rama Rao, S. 2009. Cytogenetical investigations in colchicines induced tetraploids of *Cyamopsis tetragonoloba L. Czech J. Genet. Plant Breed.*, 45: 143-154.

Bhat, S, Basavaraja, G.T and Salimath, P.M. 2012. Analysis of variability in segregating generation of soybean [*Glycine max* (L.) Merrill]. *Karnataka J. Agric. Sci*. 25 (2) : 176-178.

Bhatkodle, G.S, Indiresh, K.M, Muralidhara, M.S. 2014. Assessment of genetic variability for yield and quality attributes in vegetable type cluster bean (*Cyamopsis tetragonoloba* Linn. Taub.). *Indian Horticulture Journal*. 4(3/4): 141-143.

Bode, D, Elezi, F and Gixhari, B. 2013. Morphological characterization and interrelationships among descriptors in *Phaseolus vulgaris* accessions. *Agriculture and Forestry*. 59(2): 175 – 185.

Brar, K.S and Grover, K.K. 2003. Genetic architecture of seed yield and its components in clusterbean. *Advances in arid legumes research.* 23-25.

Burton, G.W and Devane, E.H. 1953. Estimating heritability in tall fescue (*Festuca arundinaceae*) from replicated clonal material. *Agronomy Journal*. 45: 478-481.

Buttar, G.S, Brar, K.S and Sudeep Singh. 2008. Genetic architecture of seed yield and its attributing traits in clusterbean (*Cyamopsis tetragonoloba*) grown under semi-arid region of Punjab. *Indian Journal of Agricultural Sciences*. 78(9):795-797.

Chattopadhyay, A and Dutta, S. 2010. Characterization and identification of selection indices of pole type dolichos bean. *Vegetable crops research bulletin*. 73: 33 – 45.

Chaudhary, S. P. S, Choudhary, A. K, Shekhawat, S. S, Singh, N. P. 2003. Quantitative genetic analysis in some genotypes of cluster bean. *Advances in arid legumes research*. pp 9-13.

CRIDA. 2012. A report of the ICAR expert team on agriculture situation in Ananthapur District, Andhra Pradesh, Pages 48-49.

Curne, D.C and Galston, A.W. 1959. Inverse effect of gibberellins in peroxidase activity during growth in dwarf strain of pea and corn. *Pl. Physiol*. 34 : 416-418.

*Dabas, B.S, Mital, S.P and Arunachalam, V. 1982. An evaluation of germplasm accessions in Guar. *Indian J Genset*. 42(1): 56-59.

Das, B, Arora, S.K and Luthra, Y.P. 1977. A rapid method for determination of gum in guar (*Cyamopsis tetragonoloba* (L.) Taub.). *Proceedings of Ist ICAR GuarResearch Workshop, Jodhpur*. 117–123.

Dash, S.R and Kole, P.C. 2001. Studies on variability, heritability and genetic advance in fenugreek. *J. Interacad*. 5: 7-10.

Dewey, D.R and Lu, K.H. 1959. A Correlation and path coefficient analysis of components of crested Wheat grass. *Agronomy Journal.* 51:515-518.

Donald, C.M. 1962. In search of yield. *Journal of Australian Institute of Agriculture.* 28: 171-178.

Dopte, M.A and Rivera,M.M. 1988. "Useful techniques for plant scientists"

Durga, K.K. 2012. Variability and divergence in horse gram (*Dolichos uniflorus*). *Journal of Arid Land.* 4(1): 71−76.

Dwivedi, N.K, Bhandari, D.C, Neelam Bhatnagar and Dabas, B.S. 1999. Characterizing cluster bean (Cyamopsis tetragonaloba (L.) Taub) germplasm for yield components and quality traits. *Annals of Arid Zone*. 38(2):151-156.

*Fisher, R.A. and Yates. 1963. *Statistical tables for biological, agricultural and medical research.* Longam Group Limited, London. 132-154.

Girish, M.H, Gasti, V.D, Shantappa, T, Mastiholi, A.B, Thammaiah, N, Kerutagi, M.G and Mulge, R. 2012a. Genetic divergence studies in clusterbean genotypes [*Cyamopsis tetragonoloba* (L.) Taub.]. *Karnataka Journal of Agricultural Sciences*. 25: 245-247.

Girish, M.H, Gasti, V.D, Shantappa, T, Mastiholi, A.B, Thammaiah, N, Kerutagi, M.G and Mulge, R. 2012b. Correlation and path analysis for growth, pod yield, seed yield and quality characters in cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.]. *Karnataka Journal of Agricultural Sciences*. 25(4): 498-502.

Hanchimani Nagaraj, G, Patil, M.P, Ravindra, M and Madalageri, M.B. 2004. Genetic variability studies for seed yield and quality characters in cluster bean. *National Symposium on Arid Legumes for Sustainable Agriculture and Trade.* I-7: p5.

*Hanchinamani, N.C. 2004. Studies on genetic variability and genetic divergence in cluster bean (*Cyamopsis tetragonoloba* (L.) Taub.). *M. Sc. (Hort.) Thesis*, Univ. Agric. Sci., Dharwad (India).

Hanson, C.H, Robinson, H.F and Comstock, R.E.1956. Biometrical studies of yield in segregating population of Korean Lespedeza. *Agronomy Journal*.48(6): 268-272.

Hefny, M.M. 2013. Use of genetic variability estimates and interrelationships of agronomic and biochemical characters for selection of Lupin genotypes under different irrigation regimes. *African Crop Science Journal*. 21(1): 97 - 108.

Henry, A and Mathur, B.K. 2008. Correlation studies of quality parameters, seed yield and maturity period in cluster bean. *Journal of Arid Legumes* 5 (1): 70-74.

Hingane, A.J and Navale, P.A. 2008. Path analysis in cluster bean (*Cyamopsis tetragonoloba* (L) Taub). *Journal of Maharashtra Agricultural Universities*. 33(3):419-420.

Ibrahim, E.A, Abdalla, A.W.H and Rahman, M.E.A. 2013. Genotypic and phenotypic correlations between yield and yield components in some guar (*Cyamopsis tetragonoloba* (L.) Taub.) genotypes under rainfed. *African J. of Agriculture*. 8(18): 1864-1871..

Ibrahim, E.A, Abdalla, A.W.H, Rahman, M.E.A and Naim, M.E. 2012. Path coefficient and selection indices in sixteen guar (*Cyamopsis tetragonoloba* (L.) Taub.) genotypes under rainfed. *International J. of Agriculture and Forestry*. 2(1): 79-83.

Islam, M.S, Rahman, M.M and Hossain, T. 2010. Physico-morphological variation in hyacinth bean (*Lablab purpureus* L.). *Bangladesh J. Agri. Res*. 35(3): 431–438.

Jackson, H.L. 1967. Soil chemical analysis. Prentice Hall of India Private Limited, New Delhi, pp : 495.

Jitender, Pahuja, S.K, Verma, N and Bhusal, N. 2014. Genetic variability and heritability for seed yield and water use efficiency related characters in Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.]. *Forage Res*. 39(4) : 170-174.

Kalyani, D.L. 2006. Performance of rainfed Guar (*Cyamopsis tetragonoloba* L.) under varied time of sowing. *Msc (Ag) Thesis ANGRAU*, Hyderabad, India.

Kamleshwar, K, Yogendra, P, Mishra, S.B, Pandey, S.S and Ravi, K. 2013. Study on genetic variability, correlation and path analysis with grain yield and yield attributing traits in green gram (*Vigna radiata* (L) wilczek). *The Bioscan.* 8(4): 1551-1555.

Kar, A, Gogoi, H.K and Gogoi, P.J. 2006. Study on bean variability in Arunachal pradesh. *Bulletin of Arunachal Forest Research.* 22 (1&2): 40 – 44.

Kole, P.C and Mishra, A.K. 2006. Pattern of variability and correlation in fenugreek. *Indian Agric.* 50: 93-96.

Kole, P.C and Saha, A. 2013. Studies on variability and heritability for different quantitative characters in fenugreek under different environments. *Journal of Plant Breeding and Crop Science.* 5(11): 224-228.

Krishnan, A.G, Shekar, M.R, Reddy, K.R and Reddy, K.S. 2002. Character association and path analysis in urdbean (*Vigna mungo* (L.) Hepper). *Madras Agric. J.* 89(4-6): 315-318.

Kumar, D. 2002. Guar in India, Scientific Publishers Ltd., India.

Lal, H, Rai, M, Verma, A and Vishwanath. 2005. Analysis of genetic divergence of Dolichos bean (*lablab purpureus*) genotypes. *Vegetable Science.* 32(2): 129 -132.

Lush, J.L. 1940. Intrasine correlation and regression of offspring on dams as a method of estimating heritability of character. *Proc. Amer. Soc. Anim. Nutr*. 32: 293-301.

Madakbas, S.Y and Ergin, M. 2011. Morphological and phenological characterization of Turkish bean (*Phaseolus vulgaris* L.) genotypes and their present variation states. *African Journal of Agricultural Research*. 6(28): 6155 – 6166.

Mahla, H. R and Kumar, D. 2006. Genetic variability, correlation and path analysis in clusterbean [*Cyamopsis tetragonoloba* (L.) Taub]. *Journal of Arid Legumes*. 3(1):75-78.

Malaghan, S.N, Madalageri, M.B and Kotikal, Y.K. 2014. Correlation and path analysis in cluster bean ((*Cyamopsis tetragonoloba* (L.) Taub) for vegetable pod yield and its component characters. *The Bioscan*. 9 (4): 1609-1612.

Manivannan, A and Anandakumar, C.R. 2013. Genetic variability, character association and path analysis in clusterbean (*Cyamopsis tetragonoloba* (L.) Taub). *Journal of Food Legumes* 26(3 & 4): 34-37.

Maria Sultan, Rabbani, M.A, Shinwari, Z.K and Masood, M.S. 2012. Phenotypic divergence in Guar (*Cyamopsis tetragonoloba*) landrace genotypes of *Pakistan. Pakistan Journal of Botany*. 44(1):203-210.

Mathur, O.P, Joshi, I.K, Menaria, K.L and Mathur, N.K. (1986). Removal of cyanide and heavy metals from industrial effluent using insoluble functionalized polysaccharide derivatives.*Bul. Electrochem.*, 2: 141-142 (Cf. *Guar Res. Annals,* 5: 51).

Muchui, M.N, Ndegwa, A, Wachiuri, S, Muthama, B and Kimamira, J. 2008. Post harvest evaluation of introduced French bean (*Phaseolus vulgaris* L.) varieties. *Afr. J. Hort.Sci.* 1: 116–120.

Muthuselvi, R and Shanthi, A. 2013. Variability, heritability and genetic advance in cluster bean [*Cyamopsis tetragonoloba* (L.) Taub]. *Advance Research Journal of Crop Improvement*. 4(2):106-109.

Olsen, S.R, Cole, C.V, Watanbe, F.S and Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction of sodium bicarbonate. United States Department of Agriculture pp.939.

Om Vir and Singh, A.K. 2015. Variability and correlation analysis in the germplasm of cluster bean (*Cyamopsis tetragonoloba* (L.) Taub.) in hyper hot arid climate of Western India. *Legume Reasearch*. 38(1): 37-42.

Pan, R.S, Singh, A.K, Rai, M, Krishna Prasad, V.S.R and Kumar, S. 2004. Genetic variation and character association in photo insensitive Dolichos bean *(Lablab purpureus* L. sweet). *Vegetable Science.* 31(1): 22 – 25.

Pandey, Y.R, Gautam, D.M, Thapa, R.B, Sharma, M.D and Paudyah, K.P. 2011. Variability of French bean in the western mid hills of Nepal. *Kasetsart J. (Nat. Sci.).* 45: 780 – 792.

Panse, V.G and Sukhatme, P.V. (Revised by Sukhatme, P.V and Amble, V.N.). 1985. *Statistical Methods for Agricultural Workers*. ICAR, New Delhi, India. 187-202.

Paramesh, D.M.M, Reddy, M, Priya, S, Sudhakar, P and Narasimhulu, R. 2014. Analysis of genetic parameters for morphophysiological traits in Mungbean (*Vigna radiata* L. WILCZEK). *Indian Journal of Plant Sciences*. 3 (2): 1-6.

Patel, B.V and Chaudhari, F.P. 2001. Component analysis of yield in cluster bean. *Forage Res*. 27(2): 123-125.

Pathak, R, Singh, M and Henry, A. 2009. Genetic divergence in cluster bean (*Cyamopsis tetragonoloba* (L.) Taub.) for seed yield and gum content under rainfed conditions. *Indian J. Agric., Sci.* 79(7):559-561.

Pathak, R, Singh, S.K, Singh, M and Henry, A. 2010. Molecular assessment of genetic diversity in cluster bean *Cyamopsis tetragonoloba*) genotypes. *J. Genet.* 89: 243–246.

Patil, D.V. 2014. Genetic variability and sowing dates effect of cluster bean (*Cyamopsis tetragonoloba* (L.) Taub.) genotypes in semi arid region of Maharashtra, India. *Plant Archives.* 14(1): 1-6.

Piper, C.S. 1950. Soil and plant analysis. *Inter Science Publishers*, New Delhi.

Prakash, J and Ram, R.B. 2014. Genetic variability, correlation and path analysis for seed yield and yield related traits in french bean (*Phaseolus vulgaris* L.) under Lucknow conditions. *International Journal of Innovative Science, Engineering & Technology*. Vol. 1 Issue 6.

Purseglove, J.W. 1981. Leguminosae. *Tropical Crops: Dicotyledons*. Longman Group Ltd, Essex, U.K. Pp-250-254.

Pushpa, T.N, Chandregowda, M, Srikantaprasad, D and Mallikarjuna Gowda, A.P. 2012. Evaluation of fenugreek (*Trigonella foenum-graecum* L.) genotypes for growth and seed yield. *Crop Res*. 43 (1, 2 & 3) : 238-244.

Raffi, S.A and Nath, U.K. 2004. Variability, heritability, genetic Advance and relationships of yield and yield contributing characters in Dry bean (*Phaseolus vulgaris L*.). *Journal of Biological Sciences.* 4(2): 157 – 159.

Raghu Prakash, K.R, Prashanthi, L and Reddy Shekhar, M. 2008. Genetic variability studies for seed yield, physiological and quality attributes in guar (*Cyamopsis tetragonoloba* (L.) Taub.). *The Asian and Australasian Journal of Plant Science and Biotechnology*. 2(1): 36-38.

Raghu Prakash, K.R, Prashanthi, L and Reddy Shekhar, M. 2009. Studies on selection indices in guar (*Cyamopsis tetragonoloba* (L.) Taub.). *The Asian and Australasian Journal of Plant Science and Biotechnology*. 3(1): 26-30.

Raghu Prakash. 2006. Genetic analysis of physiological traits, seed yield and quality attributes in Guar (*Cyamopsis tetragonaloba* (L.) Taub). *M. Sc. (Ag) Thesis*, ANGRAU, Hyderabad, India.

Rahul Kapoor. 2014. Genetic variability and association studies in guar [*Cyamopsis tetragonoloba* (L.) Taub.) for green fodder yield and quality traits. *Electronic Journal of Plant Breeding*. 5(2): 294-299.

Rai, N, Awasthi, B.S, Yadav, D.S and Singh, A.K. 2004. Genetic analysis in French bean (*Phaseolus vulgaris* L.). *Veg. Sci.* 31(2): 138-141.

Rai, P.S, Dharmatti, P.R, Shashidhar, T.R, Patil, R.V and Patil, B.R. 2012. Genetic variability studies in clusterbean [*Cyamopsis tetragonoloba* (L.) Taub]. *Karnataka Journal of Agricultural Sciences*. 25(1):108-111.

Rao, S.S.S, Singh, V.J, Gampala, S and Rangare, N.R. 2014. Assessment of genetic variability of the main yield related characters in Soybean. *International Journal of Food, Agriculture and Veterinary Sciences.* 4(2): 69-74.

Roy, S.K, Karim, A, Islam, A.K.M.A, Bari, N, Mian, M.A.K and Tetsushi, H. 2006. Relationship between yield and its component characters of Bush bean (*Phaseolus vulgaris* L.). *South Pacific Studies.* 27(1): 13 – 23.

Sabarish, P.R. 2010. Genetic Variability studies in clusterbean (*Cyamopsis tetragonoloba* (L.) Taub) genotypes. *M. Sc. Thesis*, University of Agricultural Sciences, Dharwad, Karnataka.

Saini, D.D, Chaudhary, S.P.S, Singh, N.P, Singh, R.V and Singh, J. 2004. Estimation of genetic parameters in clusterbean. *National symposium on Arid Legumes for Sustainable Agriculture and trade*. I-10: p6.

Saini, D.D, Singh, N.P, Singh, Chaudhary, S.P.S, Chaudhary, O.P and Khedar, O.P. 2010. Genetic variability and association of component characters for seed yield in clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.]. *J. Arid legumes*. 7(1) :47-51.

Shabarish Rai, P and Dharmatti, P.R. 2014. Correlation and path analysis for clusterbean vegetable pod yield. *The Bioscan*. 9(2):811-814.

Shabarish Rai, P, Dharmatti, P.R, Shashidhar, T.R, Patil, R.V and Patil, B.R. 2012. Genetic variability studies in clusterbean (*Cyamopsis tetragonoloba* (L.) Taub.). *Karnataka J. Agric. Sci.* 25(1): 108-111.

Shah, S.A, Saleem, M.I, Hussain, M.A and Ahmad, T. 2000. Unidirectional and Alternate Pathway Impacts of Yield Components on Grain Yield of Guar (*Cyamopsis tetragonoloba* (L) Taub.). *Journal of Arid Legumes*. 7(1): 47-51.

Shekhawat, S.S and Singhania, D.L. 2005. Correlation and path analysis in clusterbean. *Forage Res. 30(4) 196-199.*

Singh, B.K, Sharma, S.R and Singh,B. 2010. Antioxidant enzymes in cabbage: Variability and inheritance of superoxide dismutase, peroxidase and catalase. *Scientia Horticulturae.* 124: 9–13.

Singh, B.K, Singh, B.P and Ram, H.H. 2000. Variability and correlation studies in bush type French bean (*Phaseolus vulgaris* L.) in relation to green pod yield. *Prog. Hort.* 32(2):176-182.

Singh, J.V, Punia, A, Subhash Chander and Vivek Gupta. 2002. Characterization and evaluation of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.] germplasm. *Forage Research*. 28(3):130-133.

Singh, J.V, Subhash Chander and Anita Punia. 2002. Studies on characters association in clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.]. *National Journal of Plant Improvement*. 4(1):71-74.

Singh, J.V, Subhash Chander and Sudhir Sharma. 2004. Correlation and path coefficient analysis in clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.]. *National Journal of Plant Improvement.* 6(2):128-129.

Singh, J.V, Subhash Chander, Anita Punia and Jatasra, D.S. 2001. Studies on variability, heritability and genetic advance in clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.]. *Annals of Biology*. 17(2):177-178.

Singh, N.P, Choudhary, A.K and Chaudhary, S.P.S. 2001. Variability and correlation studies in some genotypes of clusterbean. *Adv. Arid Legume Research,* Jodhpur. 2(1): 14-18.

Singh, N.P, Singh, R.V, Chaudhary, S.P.S and Jabar Singh. 2004. Variability and correlation among quantitative characters in clusterbean. *National symposium on Arid Legumes for Sustainable Agriculture Trade*. I-12: p8.

Singh, N.P, Singh, R.V, Chaudhary, S.P.S and Jabar Singh. 2005. Variability and correlation among quantitative characters in clusterbean. *Journal of Arid Legumes.* 2(1):97-101.

*Singh, R.P, Singh, J, Desmukh, S.R and Kumar, A. 1985. The effect of grafted and engrafted gum on turbulent flow of water and hydraulic conductivity of soil. Proceedings of Influence Polym. Addit, Velocity Temp. Fields Symp. Ed. Bornhard, C., Springerberlin, F.R.G., pp. 431-439 (Cf. Chem. Abstr., 104:128921).

Singh, U.P, Tripati, S.N and Natarajan, S. 2009. Guar. *Crop profile.* Website: http://www.igfri.ernet.in/crop_profile_guar.html

Sinha, A.K. 1972. Colorimetric assay of catalase. *Analytical Biochemistry*. 47: 389 - 394.

Sivasubramanian, S and Menon, M. 1973. Heterosis and inbreeding depression in Rice. *Madras Agricultural Journal*. 60: 1139-1149.

Slatyer and Mcilroy. 1967. Practical micro climatology with special reference to the water factor in soil plant atmosphere relationships. UNESCO, Paris.

Smith, P.M. 1976. *Evolution of Crop Plants* (ed. N.W.Simmonds), Longman, London and New York, pp.311-312.

Srivastava, U, Mahajan, R.K, Gangopadhyay, K.K, Singh, M and Dhilon, B.S. 2001. Minimal Descriptors of Agri-Horticultural crops, Vegetable crops, part-II.

Subbiah, B.V and Asija G,E. 1956 A rapid procedure for the determination of available nitrogen in soils. *Current Science*. 25(8) : 259–260.

Sultan, M, Rabbani, M.A, Shinwari, Z.K and Masood, M.S. 2012. Phynotypic divergence in guar (*Cyamopsis tetragonoloba*) land race genotype of Pakistan. *Pakistan Journal of Botany*. 44: 203-210.

Sultana, N. 2001. Genetic Variation of Morphology and Molecular Markers and Its Application to Breeding in Lablab Bean. *PhD. dissertation, Kyushu University, Fukuoka, Japan*. 143 pp.

Swathi, L. 2013. Genetic diversity analysis using morpho-physiological and molecular markers for breeding yield and drought tolerance in mungbean(*Vigna radiata* (L.) Wilczek). *M.Sc. (Ag) Thesis*. Acharya N.G. Ranga Agricultural University, Hyderabad.

Veena Jain, Yadav, B.D, Sharma, B.D and Taneja, K.D. 1987. Effect of dates of sowing, row spacing and varieties on yield and quality of clusterbean (*Cyamopsis tetragonoloba* (L.) Taub.). Indian Journal of Agronomy 32(4) : 378–382.

Venkataratnam, L. 1973. *Beans in India*. Directorate of Extenstion, Ministry of Agriculture, New Delhi. p. 64.

Verma, A.K, Jyothi, K.U and Rao, A.V.D.D. 2014. Genetic variability, heritability and genetic advance studies in Dolichos bean (*Lablab purpureus* L.) genotypes. *Electronic Journal of Plant Breeding*. 5(2): 272-276.

Vidhya, C and Sunny, K. 2002. Correlation and path analysis in yard-long bean. *J. of Tropical Agric*. 40: 48-50.

Vikas Kumar and Ram, R.B. 2015. Genetic variability, correlation and path analysis for yield and yield attributing traits in cluster bean (*Cyamopsis tetragonoloba* (L.) Taub.) genotypes. *International Journal of Pure & Applied Bioscience*. 3(1): 143-149.

Walkley and Black, C.A. 1934. An examination of Degitijaroff method for determining soil organic matter and proposed modification of the chromic acid titration method. *Soil Science*. 37 : 29–34.

Wright, S. 1921. Correlation and causation. *Journal of Agricultural Research.* 20:557-585.

*Yoshyuki, I. 1985. Guar gum with special effects, sizing, barrier and filter retention effects of Meyproid. *Kami Parufu Gi 74 stu Taimusu*., pp. 45-47 (*Cf. Guar Res. Annals, 5: 525*).

---

* Original not seen

The pattern of "Literature Cited" presented above is in accordance with the "Guidelines" for thesis presentation for Dr. Y.S.R. Horticultural University, Venkataramannagudem.

APPENDIX - I

WEEKLY METEOROLOGICAL DATA RECORDED AT KVK, MADANAPURAM DURING 2014 - 2015

Date		Month	Temperature (° C)		R.H (%)		Rainfall (mm)	Rainy days	Wind speed (km/hr)	Mean Temp (° C)
From	To		Max	Min	Max	Min				
06-08-13	11-08-13	August	33.8	22.9	78.6	42.6	0.3	2	3.75	28.4
12-08-13	17-08-13	August	34.1	23.7	73.2	42.7	3.7	1	1.9	28.9
18-08-13	24-08-13	August	36.3	24	82.1	39.9	4.4	3	3.2	30.2
25-09-13	31-08-13	August	30.6	23	90	60.2	16.1	6	4.6	26.8
01-09-13	06-09-13	September	31.6	23	83.6	55.3	2.5	3	2.6	27.3
07-09-13	12-09-13	September	31.2	22.2	89	55.1	3.4	4	3.05	26.7
13-09-13	18-09-13	September	32.3	22.5	91.4	56.2	15.4	6	4.9	27.4
19-09-13	24-09-13	September	32.2	22.9	91.7	58.5	0.21	1	2.7	27.5
25-09-13	30-09-13	September	34.05	23.2	91.6	57.4	0	0	3.7	28.6
01-10-13	06-10-13	October	35.9	23.3	80.6	45.1	2	1	3.5	29.6
07-10-13	12-10-13	October	35.2	22.8	84.9	44.4	23.5	2	2.8	29
13-10-13	18-10-13	October	35.9	22.2	83.7	34.8	0.75	1	4.5	29.05

19-10-13	24-10-13	October	34.8	20.9	86.8	35.9	0	0	3.25	27.9
25-10-13	31-10-13	October	30.1	18.9	88.2	45.9	35.8	2	3.6	24.5
01-11-13	06-11-13	November	33.3	16.2	79.6	27.2	0.2	3	0.92	24.8
07-11-13	12-11-13	November	32.6	18.9	78.5	34.1	1.95	2	1.98	25.8
13-11-13	18-11-13	November	31.3	20.4	90.5	47.6	1.2	2	2.34	25.9
19-11-13	24-11-13	November	32.4	18.5	90.3	41.5	0	0	1.4	25.5
25-11-13	30-11-13	November	32.6	15.1	83.5	34.9	0	0	1.15	23.9
01-12-13	06-10-13	December	32.2	13.7	75.6	23.9	0	0	1.94	22.95
07-12-13	12-10-13	December	31.7	18.2	84.2	34.2	0	0	1.98	24.95
13-12-13	18-10-13	December	30.2	18.8	80.2	43.4	0	0	1.64	24.5
19-12-13	24-10-13	December	29.9	14.7	78.8	26.6	0	0	3.4	22.3