

**MORPHOLOGICAL CHARACTERIZATION
AND EVALUATION OF SPINE GOURD
(*Momordica dioica* Roxb.) GERMPLASM**

By

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B.Sc. (Hort.)

**THESIS SUBMITTED TO Dr. Y.S.R. HORTICULTURAL
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DECLARATION

I, **Ms. ALIYA FATIMA** hereby declare that the thesis entitled
**“MORPHOLOGICAL CHARACTERIZATION AND
EVALUATION OF SPINE GOURD (*Momordica dioica* Roxb.)
GERMPLASM”** 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.

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

Date:

(Dr. HAMEEDUNNISA BEGUM)

Place: Rajendranagar, Hyderabad.

Chairman

CERTIFICATE

This is to certify that the thesis entitled “**MORPHOLOGICAL CHARACTERIZATION AND EVALUATION OF SPINE GOURD (*Momordica dioica* Roxb.) GERMPLASM**” 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 **MS. ALIYA FATIMA** 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.

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CONTENTS

Chapter no.	Title	Page number
I	INTRODUCTION	
II	REVIEW OF LITERATURE	
III	MATERIALS AND METHODS	
IV	RESULTS AND DISCUSSION	
V	SUMMARY AND CONCLUSION	
	LITERATURE CITED	
	APPENDIX	

LIST OF TABLES

Table No.	Title	Page number
2.1	Summary of review of literature on genetic variability and genetic parameters in <i>Momordica</i> species	
2.2	Summary of review of literature on the association of yield component characters with fruit yield in <i>Momordica</i> species	
2.3	Summary of review of literature on the association among the yield component characters in <i>Momordica</i> species	
2.4	Summary of review of literature on genotypic direct effects of various characters on fruit yield in <i>Momordica</i> species	
2.5	Summary of review of literature on indirect effects of yield contributing characters on fruit yield in <i>Momordica</i> species	
3.1	Descriptor states for various qualitative traits of female genotypes of spine gourd	
4.1	Analysis of variance for yield and yield attributes in spine gourd	
4.2	Mean performance of 50 female genotypes for yield and yield attributes of spine gourd	
4.3	Qualitative traits of 50 female genotypes of spine gourd	
4.4	Estimates of variability, heritability, genetic advance and genetic advance as percent of mean for 50 female genotypes of spine gourd	
4.5	Analysis of variance for dispersion in spine gourd germplasm	
4.6	Clustering pattern of 50 female genotypes of spine gourd (Tocher's method)	
4.7	Inter (above diagonal) and intra (diagonal and bold) cluster distances (D^2 values) among 50 female genotypes of spine gourd	
4.8	Cluster means of 50 female genotypes for twelve characters in spine gourd	
4.9	Percent contribution of different traits towards divergence of 50 female genotypes of spine gourd	
4.10	Phenotypic and genotypic correlation among twelve quantitative traits of spine gourd	
4.11	Direct (diagonal) and indirect (off diagonal) effects of quantitative traits on fruit yield of spine gourd	

LIST OF PLATES

Plate no.	Particulars	Page number
3.1	General view of experimental plot	
4.1	Overall variability in fruit traits of spine gourd	
4.2	Variability in leaf shape of spine gourd	
4.3	Variability in leaf colour of spine gourd	
4.4	Variability in leaf lobing of spine gourd	
4.5	Variability in extent of lobing of spine gourd	
4.6	Variability in petiole lamina juncture shape of spine gourd	
4.7	Variability in female flower bract size of spine gourd	
4.8	Variability in female flower bract position of spine gourd	
4.9	Variability in fruit color of spine gourd	
4.10	Variability in fruit shape of spine gourd	
4.11	Variability in fruit blossom end rostration of spine gourd	
4.12	Variability in fruit spine strength of spine gourd	
4.13	Variability in seed aril color at ripening stage of spine gourd	
4.14	Variability in seed shape of spine gourd	
4.15	Variability in seed sculpturing of spine gourd	
4.16	Variability in extent of seed sculpturing of spine gourd	
4.17	Variability in seed ornamentation of spine gourd	
4.18	Top three horticulturally superior high yielding genotypes of spine gourd	

LIST OF ILLUSTRATIONS

Fig. No.	Title	Page number
1	Genetic parameters for 12 quantitative characters of spine gourd	
2	Dendrogram depicting clustering pattern of 50 female genotypes of spine gourd	
3	Inter and intracluster distances of 50 female genotypes of spine gourd	
4	Percent contribution of different traits towards total divergence of spine gourd	
5	Phenotypic path diagram representing direct and indirect effects on fruit yield of spine gourd	
6	Genotypic path diagram representing direct and indirect effects on fruit yield of spine gourd	

APPENDIX

S.No.	Particulars	Page number
1	Weekly meteorological data recorded At ARI, Rajendranagar during June to November 2012.	

LIST OF SYMBOLS AND ABBREVIATIONS

%	:	per cent
@	:	at the rate of
&	:	and
⁰ C	:	degree Celsius
ANOVA	:	Analysis of variance
ARS	:	Agricultural Research Station
Cd	:	Critical difference
cm	:	centimetre
Df	:	degrees of freedom
Dr.YSRHU	:	Dr Y S Rajasekhar Reddy Horticultural University
<i>et al.</i>	:	and others
Fig.	:	Figure
g	:	gramme
GA	:	Genetic Advance
GAM	:	Genetic Advance as per cent of Mean
GCV	:	Genotypic Coefficient of Variation
h^2	:	heritability in broad sense
<i>i.e.,</i>	:	that is
IU	:	International Units
kg	:	kilogram
m	:	metre
mg	:	milligramme
MSL	:	mean sea level
MSS	:	mean sum of squares
No.	:	Number
PCV	:	Phenotypic Coefficient of Variation
pp	:	page number
RBD	:	Randomised Block Design

RH	:	Relative humidity
r	:	Number of replications
SE(d)	:	Standard error difference
S.Em	:	Standard error mean
<i>viz.</i> ,	:	namely
A.P.	:	Andhra Pradesh

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ABSTRACT

A set of fifty female genotypes of spine gourd (*Momordica dioica* Roxb.) were evaluated in a randomized block design with two replications at the Vegetable Research Station, Rajendranagar during *kharif*, 2012 with an objective of studying their mean performance for 12 quantitative traits and 35 qualitative traits, genetic variability, genetic diversity, character association and contribution.

The analysis of variance revealed significant differences for all the twelve quantitative characters *viz.*, vine length (m), number of stems per plant, days to first female flower appearance, first female flowering node, days to first fruit harvest, days to last fruit harvest, fruiting period (days), fruit length (cm), fruit width (cm), fruit weight (g), number of fruits per plant and fruit yield (kg/plant) under study. Considerable variation was observed in spine gourd germplasm for most of the qualitative traits characterized. Of the 8 qualitative traits of fruits under study, there was considerable variation in spine strength (soft and hard), fruit color (whitish green, light green, green and dark green), fruit surface echination (densely echinate and mild-sparsely echinate), fruit shape (oblong, obovate, oval, round and top), fruit pericarp ripening (slow and sudden) and fruit blossom end rostration (faint, medium and appreciable length). On the basis of mean performance for growth, earliness, fruit attributes and quality traits, the genotypes RNK-224, RNK-197, RNK-200, RNK-196 and RNK-187 were found not only high yielding but also with acceptable fruit quality. However these horticulturally superior and high yielding genotypes thus identified are to be further evaluated in different environments over the years before commercial exploitation.

The phenotypic coefficient of variation was slightly higher in magnitude than genotypic coefficient of variation for all the characters indicating that the apparent variation is not only due to genotypes but also due to influence of environment and selection for such traits sometimes may be misleading. High phenotypic and genotypic coefficient of variation for vine length, number of stems per plant, days to first female flower appearance, first female flowering node, days to first fruit harvest, fruiting period, number of fruits per plant and fruit yield indicated the existence of wider genetic variability for these traits in the genotypes under study. High heritability coupled with high genetic advance as percent of mean for vine length, number of stems per plant, days to first female flower appearance, first female flowering node, days to first fruit harvest, days to last fruit harvest, fruiting period, fruit weight, number of fruits per plant and fruit yield indicated that most likely the heritability is due to additive gene effects and selection may be effective. Spine gourd being highly cross pollinated crop, macro propagation through cuttings or micro propagation is found to be beneficial for the commercial exploitation of the horticulturally superior genotypes.

Genetic divergence analysis based on 12 quantitative traits following Mahalanobis' D^2 statistics revealed distinct clustering pattern, where in 50 genotypes of spine gourd were grouped into eight clusters. The characters number of fruits per plant, number of stems per plant and days to first fruit harvest were the potent factors in differentiating the germplasm of spine gourd under study. The genetically divergent clusters were cluster VI and cluster VIII. The female genotypes with high mean value from the respective clusters for the requisite characters may be used as female parent in future breeding programmes.

The correlation coefficient analysis of 12 quantitative characters revealed that fruit yield per plant had significantly positive association with vine length, number of stems per plant, days to last fruit harvest, fruiting period, fruit length, fruit width, fruit weight and number of fruits per plant, while it had significantly negative association with days to first fruit harvest. Of all the 11 quantitative traits studied for their direct and indirect effects on fruit yield per plant, direct selection is effective for number of fruits per plant, indirect selection is effective for vine length, number of stems per plant, fruit length, fruit width, fruit weight and restricted simultaneous selection is effective for days to first fruit harvest and days to last fruit harvest. The variables studied explain about 79.72% and 93.31% of the variability at phenotypic and genotypic levels, respectively in the fruit yield per plant indicating that some characters which have not been studied here need to be included in this analysis to account fully for the variation in fruit yield per plant. Number of fruits per plant is identified as major yield component in spine gourd.

Chapter I

Introduction

CHAPTER I

INTRODUCTION

Spine gourd (*Momordica dioica* Roxb.) is a rhizomatous, perennial and distinctly dioecious species of family cucurbitaceae, originated in the Indo-Malayan region (Rashid, 1976) and has been cultivated in India, Bangladesh and neighbouring countries for a long time. It is grown widely in many parts of India, mostly confined to Eastern and South Eastern states. It is found in nature in Punjab, Uttar Pradesh, Rajasthan, Madhya Pradesh, Kerala and Maharashtra especially in areas with the least human interference. This is a delicacy for its typical taste, attributed to high seed protein content.

It contains high amount of carotene (162 µg/100 g of edible portion) (Gopalan *et al.*, 1982). It is cheap source of vitamins and minerals (Bhuiya *et al.*, 1977). Nutritive value of kakrol per 100 g of edible part : moisture 84.1%, energy 52 Kcal, protein 3.1 g, fat 1.0 g, minerals 1.1g, fibre 3.0 g, carbohydrate 7.7 g, calcium 33 mg, phosphorus 42 mg and iron 4.6 mg. It possesses several medicinal and curative properties like decoction of leaves reduces fever, tuberous roots help in relieving headache, sweating, stone formation, migraine, while fruit is quite helpful in controlling diabetes and blood pressure. Fruits are also used for treating ulcers, piles, sores and obstruction of liver and spleen and are good for those suffering from cough and other digestible problems. The unripe fruits act as appetizer and astringent. The ripe fruits are sweet, oily and laxative. The seeds are used for chest problems and stimulate urinary discharge. It has prominent position among the cucurbitaceous vegetables owing to its good nutraceutical value, high keeping quality, ability to withstand long distance transportation, high market price and good export potential (Rasul, 2003). In spite of its multiple uses, the crop remained underutilized and underexploited. This vegetable has been gaining popularity in the recent past among consumers of Andhra Pradesh.

Its cultivation has been increasing day-by-day in India, in general and in Andhra Pradesh, in particular.

As a crop, kakrol has a number of problems, including low yield. Fruits become inedible at maturity owing to the presence of large number of hard seeds. Low rate of tuber production (10-20 tuberous pieces per year); germination of seeds is very low or impossible due to hard seed coat (Rashid, 1976), non-availability of improved varieties, difficulties in propagation by seed due to dormancy, dormancy of tubers and unpredictable sex ratio in seedling progeny (Ali *et al.*, 1991).

The productivity of spine gourd in Andhra Pradesh is low when compared to the other countries. This is mainly because of the cultivation of local land races owing to the lack of improved high yielding varieties. Hence, it is essential to develop high yielding varieties of spine gourd.

Germplasm is a pre-requisite for development of varieties. The value of germplasm collection depends not only on the number of accessions but also on genetic diversity present in those accessions for yield and yield components. The role of genetic diversity and its significance has been recognized for the selection of desirable parents to obtain high heterotic response and transgressive segregants. As spine gourd is cross pollinated, high genetic diversity is available in this crop. Mahalanobis D^2 analysis is a useful tool in studying the nature and extent of diversity prevalent in the material.

Improvement in any crop depends upon the magnitude of genetic variability available in the germplasm. Further, partitioning the variability into heritable and non heritable components with suitable genetic parameters such as genotypic and phenotypic coefficient of variation, heritability estimates and genetic advance, cause and effect relations through phenotypic and genotypic correlations and path coefficient analysis help to a great extent to formulate strategies to select suitable genotypes in crop improvement programmes. High values of heritability estimates indicate the potential for substantial improvement using standard selection procedures. Heritability estimates in conjunction with estimates of genetic advance, are more useful in selecting superior genotypes. Knowledge of

the association between yield and its contributing traits will be of great value in planning a breeding programme. Lerner (1958) stressed the importance of correlation of the various characters with yield. The phenotypic correlation indicates the extent of the observed relationship between characters, while genotypic correlation provides an estimate of inherent association between genes controlling any two characters. Path coefficient analysis developed by Wright (1921) proves helpful in partitioning the correlation coefficient into direct and indirect effects. Such information provides realistic basis for allocation of appropriate weightage to various yield components.

Keeping in view the above, there is a constant need to evaluate the germplasm to identify the genetically diverse lines with desirable characters and hence, the present investigation was undertaken with the following objectives:

1. To characterize germplasm based on morpho-agronomic traits for identification of genotypes.
2. To study the nature and extent of genetic diversity among the genotypes.
3. To study the nature and magnitude of variability, heritability and genetic advance for yield and yield components.
4. To study the direction and degree of association among yield and yield components.
5. To study the direct and indirect effects of various component characters on yield.

Chapter II

Review of literature

CHAPTER II

REVIEW OF LITERATURE

Keeping in view the objectives of the present investigation, the available literature on genetic variability, genetic diversity, character association and character contribution in *Momordica* species has been reviewed and presented under the following headings.

2.1 Genetic variability and genetic parameters

2.2 Genetic divergence

2.3 Correlation coefficient analysis

2.4 Path coefficient analysis

2.1 GENETIC VARIABILITY AND GENETIC PARAMETERS

2.1.1 Genetic variability

Knowledge on the nature and magnitude of genotypic and phenotypic variability present in any crop species plays a vital role in formulating successful breeding programme for evolving superior cultivars. It is essential to partition the overall variability into heritable and non heritable components. Genetic parameters like phenotypic and genotypic coefficients of variation enable isolation of superior genotypes by selection if considerable genetic variation exists within the population.

2.1.2 Genetic parameters

2.1.2.1 Heritability

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.

Table 2.1. Summary of review of literature on genetic variability and genetic parameters in *Momordica* species

Character	Coefficient of variation (%)		h^2 (%)	GA (%)	Reference
	PCV	GCV			
Vine length (m)					
<i>Momordica dioica</i>					
	M	M	H	-	Bharathi <i>et al.</i> (2006)
<i>Momordica cochinchinensis</i>					
	-	-	-	-	-
<i>Momordica charantia</i>					
	-	M	M	L	Srivastava and Srivastava (1976)
	H	H	H	H	Mangal <i>et al.</i> (1981)
	H	H	H	H	Rajput <i>et al.</i> (1996)
	M	M	H	H	Islam <i>et al.</i> (2009)
<i>Momordica subangulata</i>					
	M	M	H	L	Rahman <i>et al.</i> (2011)
	L	L	H	H	Naik <i>et al.</i> (2012a)
Number of stems per plant					
<i>Momordica dioica</i>					
	-	-	-	-	-
<i>Momordica cochinchinensis</i>					
	-	-	-	-	-
<i>Momordica charantia</i>					
	-	-	-	-	-
<i>Momordica subangulata</i>					
	M	L	H	L	Naik <i>et al.</i> (2012a)
Days to first female flower appearance					
<i>Momordica dioica</i>					
	-	-	-	L	Ram <i>et al.</i> (2004)
	M	M	H	-	Bharathi <i>et al.</i> (2006)
	L	L	L	L	Singh <i>et al.</i> (2009)
	L	L	-	-	Bharathi <i>et al.</i> (2010)
<i>Momordica cochinchinensis</i>					
	H	H	H	H	Sanwal <i>et al.</i> (2007)
<i>Momordica charantia</i>					
	-	M	H	M	Srivastava and Srivastava (1976)
	M	L	H	M	Mangal <i>et al.</i> (1981)
	M	M	M	-	Dey <i>et al.</i> (2009)
	L	L	H	L	Islam <i>et al.</i> (2009)
<i>Momordica subangulata</i>					
	M	M	H	M	Rahman <i>et al.</i> (2011)
First female flowering node					
<i>Momordica dioica</i>					
	H	M	H	-	Bharathi <i>et al.</i> (2006)

<i>Momordica cochinchinensis</i>					
	-	-	-	-	-

Table 2.1 cont.

Character	Coefficient of variation (%)		h ² (%)	GA (%)	Reference
	PCV	GCV			
<i>Momordica charantia</i>					
	H	H	H	-	Dey <i>et al.</i> (2009)
<i>Momordica subangulata</i>					
	M	M	H	L	Rahman <i>et al.</i> (2011)
Days to first fruit harvest					
<i>Momordica dioica</i>					
	L	L	L	L	Singh <i>et al.</i> (2009)
<i>Momordica cochinchinensis</i>					
	-	-	-	-	-
<i>Momordica charantia</i>					
	L	L	H	L	Rajput <i>et al.</i> (1996)
	M	M	H	-	Dey <i>et al.</i> (2009)
<i>Momordica subangulata</i>					
	-	-	-	-	-
Fruit length (cm)					
<i>Momordica dioica</i>					
	-	-	-	L	Ram <i>et al.</i> (2004)
	H	H	H	-	Bharathi <i>et al.</i> (2006)
	M	L	M	L	Singh <i>et al.</i> (2009)
	M	M	-	-	Bharathi <i>et al.</i> (2010)
<i>Momordica cochinchinensis</i>					
	M	M	H	L	Sanwal <i>et al.</i> (2007)
<i>Momordica charantia</i>					
	-	H	H	L	Srivastava and Srivastava (1976)
	H	H	H	L	Mangal <i>et al.</i> (1981)
	H	H	H	L	Rajput <i>et al.</i> (1996)
	H	H	H	-	Dey <i>et al.</i> (2009)
	M	L	H	M	Islam <i>et al.</i> (2009)
<i>Momordica subangulata</i>					
	M	M	H	L	Rahman <i>et al.</i> (2011)
	L	L	H	L	Naik <i>et al.</i> (2012b)
Fruit width (cm)					
<i>Momordica dioica</i>					
	-	-	-	L	Ram <i>et al.</i> (2004)
	M	M	H	-	Bharathi <i>et al.</i> (2006)
	M	L	L	L	Singh <i>et al.</i> (2009)
	M	M	-	-	Bharathi <i>et al.</i> (2010)
<i>Momordica cochinchinensis</i>					
	M	L	L	L	Sanwal <i>et al.</i> (2007)
<i>Momordica charantia</i>					
	-	M	H	L	Srivastava and Srivastava (1976)
	M	M	H	L	Rajput <i>et al.</i> (1996)
	H	H	H	-	Dey <i>et al.</i> (2009)

	M	M	H	H	Islam <i>et al.</i> (2009)
<i>Momordica subangulata</i>					
	M	M	H	L	Rahman <i>et al.</i> (2011)

Table 2.1 cont.

Character	Coefficient of variation (%)		h ² (%)	GA (%)	Reference
	PCV	GCV			
	H	L	L	L	Naik <i>et al.</i> (2012b)
Fruit weight (g)					
<i>Momordica dioica</i>					
	-	-	-	L	Ram <i>et al.</i> (2004)
	H	H	H	-	Bharathi <i>et al.</i> (2006)
	M	L	L	L	Singh <i>et al.</i> (2009)
	H	H	-	-	Bharathi <i>et al.</i> (2010)
<i>Momordica cochinchinensis</i>					
	M	M	H	M	Sanwal <i>et al.</i> (2007)
<i>Momordica charantia</i>					
	-	H	H	H	Srivastava and Srivastava (1976)
	H	H	H	H	Mangal <i>et al.</i> (1981)
	M	M	H	M	Rajput <i>et al.</i> (1996)
	H	H	H	-	Dey <i>et al.</i> (2009)
	M	L	M	M	Islam <i>et al.</i> (2009)
<i>Momordica subangulata</i>					
	H	H	H	H	Rahman <i>et al.</i> (2011)
	M	M	H	M	Naik <i>et al.</i> (2012a)
Number of fruits per plant					
<i>Momordica dioica</i>					
	H	H	H	-	Bharathi <i>et al.</i> (2006)
	H	M	H	M	Singh <i>et al.</i> (2009)
	H	H	-	-	Bharathi <i>et al.</i> (2010)
<i>Momordica cochinchinensis</i>					
	H	H	H	H	Sanwal <i>et al.</i> (2007)
<i>Momordica charantia</i>					
	-	H	H	H	Srivastava and Srivastava (1976)
	H	H	H	L	Mangal <i>et al.</i> (1981)
	H	H	H	M	Rajput <i>et al.</i> (1996)
	M	M	H	-	Dey <i>et al.</i> (2009)
	M	M	H	H	Islam <i>et al.</i> (2009)
<i>Momordica subangulata</i>					
	H	H	H	L	Rahman <i>et al.</i> (2011)
	M	M	H	L	Naik <i>et al.</i> (2012a)
Fruit yield per plant					
<i>Momordica dioica</i>					
	H	H	H	-	Bharathi <i>et al.</i> (2006)
	H	H	M	H	Singh <i>et al.</i> (2009)
	H	H	-	-	Bharathi <i>et al.</i> (2010)
<i>Momordica cochinchinensis</i>					
	H	H	H	H	Sanwal <i>et al.</i> (2007)
<i>Momordica charantia</i>					
	-	H	H	L	Srivastava and Srivastava (1976)

	H	H	H	H	Mangal <i>et al.</i> (1981)
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Table 2.1 cont.

Character	Coefficient of variation (%)		h ² (%)	GA (%)	Reference
	PCV	GCV			
	H	H	H	L	Rajput <i>et al.</i> (1996)
	H	H	H	-	Dey <i>et al.</i> (2009)
	M	M	H	H	Islam <i>et al.</i> (2009)
<i>Momordica subangulata</i>					
	H	H	H	H	Rahman <i>et al.</i> (2011)
	H	M	H	H	Naik <i>et al.</i> (2012a)

PCV: Phenotypic Coefficient of Variation

GCV: Genotypic Coefficient of Variation

h²: Heritability

GA: Genetic Advance

Categorization of values of		
PCV and GCV	h ²	GA
L: Low (<10%)	L: Low (<30%)	L: Low (<10%)
M: Medium (10-20%)	M: Medium (30-60%)	M: Medium (10-20%)
H: High (>20%)	H: High (>60%)	H: High (>20%)

2.1.2.2 Genetic Advance

It is a measure of genetic gain under selection. Genetic advance is defined as the difference between the mean genotypic value of the selected lines and the mean genotypic value of the parental population.

The available literature on genetic variability and genetic parameters is summarized and presented in Table 2.1

2.2 GENETIC DIVERGENCE

The knowledge of genetic diversity is an important factor for heritable improvement in any crop and the information on nature and degree of divergence would be of immense use in selecting desirable parents from available germplasm for successful breeding programme. Genetic divergence among the parents is essential since the crossing programme involving genetically divergent parents is likely to produce high heterotic effects and also more variability could be expected in the segregating generations. Genetic diversity between the genotypes indicates the differences in gene frequencies. D^2 Statistics is powerful tool to study genetic divergence at inter varietal and sub-species level in classifying the crop plants by determining the degree of divergence between populations and relative contribution of different components to the total divergence.

Mahalanobis D^2 statistics is a powerful tool in quantifying the degree of divergence between biological populations at genetic level and provides a quantitative measure of association between geographic and genetic diversity based on generalized distance (Mahalanobis, 1936).

Parhi *et al.* (1993) following Mahalanobis D^2 statistics grouped 13 varieties of bitter melon into 6 clusters based on similarities of D^2 values. The most divergent clusters were III and V followed by III and IV. It was found that 100 seed weight contributed maximum to divergence followed by number of seeds per fruit and fruit length.

Wahab and Gopalakrishnan (1993) formed 5 clusters from 50 genotypes of bitter gourd. They found maximum genetic distance between clusters IV and V. The clustering pattern indicated that there was no association between ecogeographic distribution of genotypes and genetic divergence as the same group consisted of genotypes from diverse locations and the genotypes of same source fell into different groups also. Similar findings were reported in *M. dioica* (Rasul and Okubo, 2002; Bharathi *et al.*, 2005), *M. charantia* (Kutty and Dharamatti, 2005; Dey *et al.*, 2007; Sundaram, 2008; Islam *et al.*, 2010), *M. cochinchinensis* (Sanwal *et al.*, 2007) and *M. subangulata* (Rahman *et al.*, 2011).

Rasul and Okubo (2002) studied the genetic divergence among 30 *M. dioica* and one *M. cochinchinensis* clones and grouped them into 7 clusters. The wild relative of teasle gourd, CI 31 was clustered as single group in cluster I. The maximum inter cluster distance was observed between the cluster I and V. Characters like chlorophyll content, fruit shape and pedicel length contributed considerably to the total divergence.

Forty genotypes of bitter gourd were grouped into 10 clusters by Kutty and Dharamatti (2005). The genotypes in cluster II had maximum divergence followed by IV and I. The maximum inter cluster distance was found between cluster VI and IX. They observed maximum contribution to genetic divergence by the number of leaves at 50% flowering followed by productive length of vine and fruit weight.

In spine gourd, Bharathi *et al.* (2005a) grouped 32 genotypes into 7 clusters. Inter cluster distance were greater than intra cluster distance, revealing considerable amount of diversity among the genotypes. The maximum inter cluster distance was recorded between cluster VI and VII. They found that considerable diversity was due to yield per plant, number of fruits and fruit weight.

Dey *et al.* (2007) grouped 38 bitter gourd genotypes including two promising gynoeocious lines into 6 clusters. The maximum inter cluster distance was obtained between cluster II and IV. Gynoeocious lines were grouped into cluster IV. Cluster IV followed by cluster III showed superiority for yield and

other desirable traits indicating their potentiality for providing basic material for future breeding programmes.

Forty genotypes of sweet gourd were grouped into 6 clusters by Sanwal *et al.* (2007). The relatively low values of intra cluster distance depicted the presence of narrow range of genetic diversity within a cluster. They found maximum genetic diversity between cluster I and V. The maximum value for fruit length, number of fruits per plant and fruit yield per plant was observed in cluster I.

Sundaram (2008) formed 6 clusters from 22 genotypes of bitter gourd. Among the six clusters, maximum number of genotypes was found in cluster I and the cluster V and VI were found to be mono genotypic. He observed that fruit weight contributed maximum to the divergence followed by yield of fruits per vine and length of fruit.

Bharathi *et al.* (2010) studied genetic diversity among the 26 accessions of spine gourd collected from eastern India and grouped them into 3 clusters following Ward's clustering technique. The maximum inter-cluster distance was observed between clusters I and III. Cluster I was characterized with genotypes early in flowering (except CHSG 119), more number of fruits per plant (> 100), number of seeds per fruit (> 10) and greater yield per plant (> 1.8 kg/plant). Cluster II comprised the accessions having high individual fruit weight and 100-seed weight. The accessions grouped in cluster III recorded lower values for most of the traits studied.

Islam *et al.* (2010) grouped 20 bitter gourd genotypes into 4 clusters. They observed that inter cluster distances were much higher than intra cluster distances. Most divergent clusters were I and II and highest intra cluster means for fruit weight, number of nodes per vine, days to first female flowering and days to first male flowering were obtained from cluster II. They found maximum contribution to the genetic divergence by vine length, yield per plant, branches per vine, days to first male flowering, number of nodes, fruit length and fruit diameter through canonical variate analysis.

Rahman *et al.* (2011) grouped 11 genotypes of sweet gourd into 3 clusters. They found the maximum inter cluster distance between the cluster II and III,

cluster II had highest mean values for node to which first female flower appears, fruit weight, fruit length, fruit diameter, fruit girth, days taken from fruit set to edible maturity and fruit yield per vine.

2.3 ASSOCIATION OF YIELD AND COMPONENTS

Correlation studies are useful in developing an effective basis of phenotypic selection in plant population. 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. A knowledge of genetic correlation among the characters contributing to the yield leads to the most effective method of selection. By this way combination of favourable characters could be brought out by minimizing the effect of antagonistic relations.

Yield component characters exhibit association among themselves and with yield. Unfavourable association between the desired attributes under selection may limit genetic advance. Hence, study of association of component characters with yield would aid in planning of an effective selection programme.

The available literature on association of various quantitative traits with fruit yield of *Momordica* species and among the characters has been presented in Table 2.2 and Table 2.3, respectively.

2.4 PATH COEFFICIENT ANALYSIS

Yield being a complex polygenic character, direct selection may not be a reliable approach on account of being highly influenced by environmental factors. Therefore, it becomes 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, it would not provide an exact picture of relative importance of the direct and indirect contributions of the component characters to 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).

Path coefficient is simply a standardized partial regression coefficient and as such, measures the direct influence of one variable upon another and permits the separation of correlation coefficient into components of direct and indirect effects (Dewey and Lu, 1959).

Selection on the basis of direct and indirect effects is much more useful than selection for yield *per se*. If the correlation between dependent and independent variables is due to the direct effects of the character, it affects a true relationship between them and selection can be practised for such a character in order to improve dependent variable. But if the association is mainly through indirect effect of the character via other component characters, the breeder has to select for the traits through which the indirect effect is exerted.

The literature on the direct and indirect effects of various traits on fruit yield has been presented in Table 2.4 and Table 2.5, respectively.

Table 2.2. Summary of review of literature on the association of yield component characters with fruit yield in *Momordica* species

Character	Positive association	Negative association
Vine length (m)		
<i>Momordica dioica</i>	Bharathi <i>et al.</i> (2005b)	-
<i>Momordica cochinchinensis</i>	-	-
<i>Momordica charantia</i>	Ramachandran and Gopalakrishnan (1979) Mangal <i>et al.</i> (1981) Bhave <i>et al.</i> (2003b) Sundaram (2010)	Islam <i>et al.</i> (2009)
<i>Momordica subangulata</i>	-	Rahman <i>et al.</i> (2011) Naik and Akhtar (2012)
Number of stems per vine		
<i>Momordica dioica</i>	-	-
<i>Momordica cochinchinensis</i>	-	-
<i>Momordica charantia</i>	-	-
<i>Momordica subangulata</i>	Rahman <i>et al.</i> (2011)	Naik and Akhtar (2012)
Days to first female flower appearance		
<i>Momordica dioica</i>	-	Bharathi <i>et al.</i> (2005b) Singh <i>et al.</i> (2009)
<i>Momordica cochinchinensis</i>	-	Sanwal <i>et al.</i> (2007)
<i>Momordica charantia</i>	Ramachandran and Gopalakrishnan (1979) Islam <i>et al.</i> (2009) Sundaram (2010)	Srivastava and Srivastava (1976) Mangal <i>et al.</i> (1981) Bhave <i>et al.</i> (2003b) Dey <i>et al.</i> (2005)
<i>Momordica subangulata</i>	-	Rahman <i>et al.</i> (2011)
First female flowering node		
<i>Momordica dioica</i>	-	Bharathi <i>et al.</i> (2005b)
<i>Momordica cochinchinensis</i>	-	-
<i>Momordica charantia</i>	Ramachandran and Gopalakrishnan (1979) Sundaram (2010)	Dey <i>et al.</i> (2005)
<i>Momordica subangulata</i>	Rahman <i>et al.</i> (2011)	-
Days to first fruit harvest		
<i>Momordica dioica</i>	Singh <i>et al.</i> (2009)	-
<i>Momordica cochinchinensis</i>	-	-
<i>Momordica charantia</i>	-	Dey <i>et al.</i> (2005)
<i>Momordica subangulata</i>	-	-
Fruiting period (days)		
<i>Momordica dioica</i>	-	-

Table 2.2 cont.

Character	Positive association	Negative association
<i>Momordica cochinchinensis</i>	-	-
<i>Momordica charantia</i>	Bhave <i>et al.</i> (2003b)	-
<i>Momordica subangulata</i>	-	-
Fruit length (cm)		
<i>Momordica dioica</i>	Bharathi <i>et al.</i> (2005b) Singh <i>et al.</i> (2009)	-
<i>Momordica cochinchinensis</i>	Sanwal <i>et al.</i> (2007)	-
<i>Momordica charantia</i>	Mangal <i>et al.</i> (1981) Bhave <i>et al.</i> (2003b) Dey <i>et al.</i> (2005) Islam <i>et al.</i> (2009) Sundaram (2010)	-
<i>Momordica subangulata</i>	Rahman <i>et al.</i> (2011)	-
Fruit width (cm)		
<i>Momordica dioica</i>	Bharathi <i>et al.</i> (2005b) Singh <i>et al.</i> (2009)	-
<i>Momordica cochinchinensis</i>	Sanwal <i>et al.</i> (2007)	-
<i>Momordica charantia</i>	Bhave <i>et al.</i> (2003b) Dey <i>et al.</i> (2005) Islam <i>et al.</i> (2009) Sundaram (2010)	-
<i>Momordica subangulata</i>	Rahman <i>et al.</i> (2011)	-
Fruit weight (g)		
<i>Momordica dioica</i>	Bharathi <i>et al.</i> (2005b) Singh <i>et al.</i> (2009)	-
<i>Momordica cochinchinensis</i>	Sanwal <i>et al.</i> (2007)	-
<i>Momordica charantia</i>	Srivastava and Srivastava (1976) Mangal <i>et al.</i> (1981) Bhave <i>et al.</i> (2003b) Dey <i>et al.</i> (2005) Islam <i>et al.</i> (2009) Sundaram (2010)	-
<i>Momordica subangulata</i>	Rahman <i>et al.</i> (2011) Naik and Akhtar (2012)	-
Number of fruits per plant		
<i>Momordica dioica</i>	Bharathi <i>et al.</i> (2005b) Singh <i>et al.</i> (2009)	-
<i>Momordica cochinchinensis</i>	Sanwal <i>et al.</i> (2007)	-

Table 2.2 cont.

Character	Positive association	Negative association
<i>Momordica charantia</i>	Srivastava and Srivastava (1976) Mangal <i>et al.</i> (1981) Bhave <i>et al.</i> (2003b) Dey <i>et al.</i> (2005) Islam <i>et al.</i> (2009) Sundaram (2010)	-
<i>Momordica subangulata</i>	Rahman <i>et al.</i> (2011) Naik and Akhtar (2012)	-

Table 2.3. Summary of review of literature on the association among the yield component characters in *Momordica* species

Character	Positive association	Negative association
Vine length with		
Number of stems per plant		
<i>Momordica dioica</i>	-	-
<i>Momordica charantia</i>	-	-
<i>Momordica subangulata</i>	-	-
Days to first female flower appearance		
<i>Momordica dioica</i>	-	Bharathi <i>et al.</i> (2005b)
<i>Momordica charantia</i>	Ramachandran and Gopalakrishnan (1979) Mangal <i>et al.</i> (1981) Sundaram (2010)	Bhave <i>et al.</i> (2003b) Islam <i>et al.</i> (2009)
<i>Momordica subangulata</i>	Rahman <i>et al.</i> (2011)	-
First female flowering node		
<i>Momordica dioica</i>	-	Bharathi <i>et al.</i> (2005b)
<i>Momordica charantia</i>	Ramachandran and Gopalakrishnan (1979) Sundaram (2010)	-
<i>Momordica subangulata</i>	-	Rahman <i>et al.</i> (2011)
Fruiting period (days)		
<i>Momordica dioica</i>	-	-
<i>Momordica charantia</i>	-	Bhave <i>et al.</i> (2003b)
<i>Momordica subangulata</i>	-	-
Fruit length (cm)		
<i>Momordica dioica</i>	Bharathi <i>et al.</i> (2005b)	-
<i>Momordica charantia</i>	Ramachandran and Gopalakrishnan (1979) Mangal <i>et al.</i> (1981) Bhave <i>et al.</i> (2003b) Islam <i>et al.</i> (2009) Sundaram (2010)	-
<i>Momordica subangulata</i>	-	Rahman <i>et al.</i> (2011)
Fruit width (cm)		
<i>Momordica dioica</i>	Bharathi <i>et al.</i> (2005b)	-
<i>Momordica charantia</i>	Ramachandran and Gopalakrishnan (1979) Bhave <i>et al.</i> (2003b) Islam <i>et al.</i> (2009)	Sundaram (2010)
<i>Momordica subangulata</i>	-	Rahman <i>et al.</i> (2011)
Fruit weight (g)		
<i>Momordica dioica</i>	Bharathi <i>et al.</i> (2005b)	-
<i>Momordica charantia</i>	Ramachandran and Gopalakrishnan (1979) Mangal <i>et al.</i> (1981) Bhave <i>et al.</i> (2003b) Sundaram (2010)	Islam <i>et al.</i> (2009)

Table 2.3 cont.

Character	Positive association	Negative association
<i>Momordica subangulata</i>	-	Rahman <i>et al.</i> (2011)
Number of fruits per plant		
<i>Momordica dioica</i>	Bharathi <i>et al.</i> (2005b)	-
<i>Momordica charantia</i>	Ramachandran and Gopalakrishnan (1979) Mangal <i>et al.</i> (1981) Bhave <i>et al.</i> (2003b) Sundaram (2010)	Islam <i>et al.</i> (2009)
<i>Momordica subangulata</i>	Rahman <i>et al.</i> (2011)	-
Days to first female flower appearance with		
First female flowering node		
<i>Momordica dioica</i>	Bharathi <i>et al.</i> (2005b)	-
<i>Momordica charantia</i>	Ramachandran and Gopalakrishnan (1979) Dey <i>et al.</i> (2005) Sundaram (2010)	-
<i>Momordica subangulata</i>	-	Rahman <i>et al.</i> (2011)
Days to first fruit harvest		
<i>Momordica dioica</i>	-	Singh <i>et al.</i> (2009)
<i>Momordica charantia</i>	Dey <i>et al.</i> (2005)	-
<i>Momordica subangulata</i>	-	-
Fruiting period (days)		
<i>Momordica dioica</i>	-	-
<i>Momordica charantia</i>	-	Bhave <i>et al.</i> (2003b)
<i>Momordica subangulata</i>	-	-
Fruit length (cm)		
<i>Momordica dioica</i>	Singh <i>et al.</i> (2009)	Bharathi <i>et al.</i> (2005b)
<i>Momordica charantia</i>	Ramachandran and Gopalakrishnan (1979) Mangal <i>et al.</i> (1981) Bhave <i>et al.</i> (2003b) Dey <i>et al.</i> (2005) Sundaram (2010)	Islam <i>et al.</i> (2009)
<i>Momordica subangulata</i>	-	Rahman <i>et al.</i> (2011)
Fruit width (cm)		
<i>Momordica dioica</i>	Singh <i>et al.</i> (2009)	Bharathi <i>et al.</i> (2005b)
<i>Momordica charantia</i>		Bhave <i>et al.</i> (2003b) Dey <i>et al.</i> (2005) Islam <i>et al.</i> (2009) Sundaram (2010)
<i>Momordica subangulata</i>	-	Rahman <i>et al.</i> (2011)
Fruit weight (g)		
<i>Momordica dioica</i>	Singh <i>et al.</i> (2009)	Bharathi <i>et al.</i> (2005b)
<i>Momordica charantia</i>	Srivastava and Srivastava (1976) Ramachandran and Gopalakrishnan (1979) Mangal <i>et al.</i> (1981)	Bhave <i>et al.</i> (2003b) Islam <i>et al.</i> (2009)

Table 2.3 cont.

Character	Positive association	Negative association
<i>Momordica subangulata</i>	-	Rahman <i>et al.</i> (2011)
Number of fruits per plant		
<i>Momordica dioica</i>	Singh <i>et al.</i> (2009)	Bharathi <i>et al.</i> (2005b)
<i>Momordica charantia</i>	-	Srivastava and Srivastava (1976) Ramachandran and Gopalakrishnan (1979) Mangal <i>et al.</i> (1981) Bhave <i>et al.</i> (2003b) Dey <i>et al.</i> (2005) Islam <i>et al.</i> (2009) Sundaram (2010)
<i>Momordica subangulata</i>	Rahman <i>et al.</i> (2011)	-
First female flowering node with		
Days to first harvest		
<i>Momordica dioica</i>	-	-
<i>Momordica charantia</i>	Dey <i>et al.</i> (2005)	-
<i>Momordica subangulata</i>	-	-
Fruit length (cm)		
<i>Momordica dioica</i>	-	Bharathi <i>et al.</i> (2005b)
<i>Momordica charantia</i>	Ramachandran and Gopalakrishnan (1979) Dey <i>et al.</i> (2005) Sundaram (2010)	-
<i>Momordica subangulata</i>	Rahman <i>et al.</i> (2011)	-
Fruit width (cm)		
<i>Momordica dioica</i>	-	Bharathi <i>et al.</i> (2005b)
<i>Momordica charantia</i>	Ramachandran and Gopalakrishnan (1979)	Dey <i>et al.</i> (2005) Sundaram (2010)
<i>Momordica subangulata</i>	Rahman <i>et al.</i> (2011)	-
Fruit weight (g)		
<i>Momordica dioica</i>	-	Bharathi <i>et al.</i> (2005b)
<i>Momordica charantia</i>	Ramachandran and Gopalakrishnan (1979)	Dey <i>et al.</i> (2005) Sundaram (2010)
<i>Momordica subangulata</i>	Rahman <i>et al.</i> (2011)	-
Number of fruits per plant		
<i>Momordica dioica</i>	-	Bharathi <i>et al.</i> (2005b)
<i>Momordica charantia</i>	Ramachandran and Gopalakrishnan (1979) Sundaram (2010)	Dey <i>et al.</i> (2005)
<i>Momordica subangulata</i>	Rahman <i>et al.</i> (2011)	-
Days to first fruit harvest with		
Fruit length (cm)		
<i>Momordica dioica</i>	Singh <i>et al.</i> (2009)	-
<i>Momordica charantia</i>	Dey <i>et al.</i> (2005)	-
<i>Momordica subangulata</i>	-	-

Table 2.3 cont.

Character	Positive association	Negative association
Fruit width (cm)		
<i>Momordica dioica</i>	Singh <i>et al.</i> (2009)	-
<i>Momordica charantia</i>	Dey <i>et al.</i> (2005)	-
<i>Momordica subangulata</i>	-	-
Fruit weight (g)		
<i>Momordica dioica</i>	Singh <i>et al.</i> (2009)	-
<i>Momordica charantia</i>	Dey <i>et al.</i> (2005)	-
<i>Momordica subangulata</i>	-	-
Number of fruits per plant		
<i>Momordica dioica</i>	Singh <i>et al.</i> (2009)	-
<i>Momordica charantia</i>	-	Dey <i>et al.</i> (2005)
<i>Momordica subangulata</i>	-	-
Fruiting period with		
Fruit length (cm)		
<i>Momordica dioica</i>	-	-
<i>Momordica charantia</i>	Bhave <i>et al.</i> (2003b)	-
<i>Momordica subangulata</i>	-	-
Fruit width (cm)		
<i>Momordica dioica</i>	-	-
<i>Momordica charantia</i>	Bhave <i>et al.</i> (2003b)	-
<i>Momordica subangulata</i>	-	-
Fruit weight (g)		
<i>Momordica dioica</i>	-	-
<i>Momordica charantia</i>	Bhave <i>et al.</i> (2003b)	-
<i>Momordica subangulata</i>	-	-
Number of fruits per plant		
<i>Momordica dioica</i>	-	-
<i>Momordica charantia</i>	Bhave <i>et al.</i> (2003b)	-
<i>Momordica subangulata</i>	-	-
Fruit length with		
Fruit width (cm)		
<i>Momordica dioica</i>	Bharathi <i>et al.</i> (2005b) Singh <i>et al.</i> (2009)	-
<i>Momordica charantia</i>	Bhave <i>et al.</i> (2003b) Dey <i>et al.</i> (2005)	Ramachandran and Gopalakrishnan (1979) Islam <i>et al.</i> (2009) Sundaram (2010)
<i>Momordica subangulata</i>	Rahman <i>et al.</i> (2011)	-
Fruit weight (g)		
<i>Momordica dioica</i>	Bharathi <i>et al.</i> (2005b) Singh <i>et al.</i> (2009)	-
<i>Momordica charantia</i>	Ramachandran and Gopalakrishnan (1979) Mangal <i>et al.</i> (1981) Bhave <i>et al.</i> (2003b) Dey <i>et al.</i> (2005) Islam <i>et al.</i> (2009)	-

Table 2.3 cont.

Character	Positive association	Negative association
<i>Momordica charantia</i>	Sundaram (2010)	
<i>Momordica subangulata</i>	Rahman <i>et al.</i> (2011)	-
Number of fruits per plant		
<i>Momordica dioica</i>	Singh <i>et al.</i> (2009)	Bharathi <i>et al.</i> (2005b)
<i>Momordica charantia</i>	Ramachandran and Gopalakrishnan (1979) Bhave <i>et al.</i> (2003b)	Mangal <i>et al.</i> (1981) Dey <i>et al.</i> (2005) Islam <i>et al.</i> (2009) Sundaram (2010)
<i>Momordica subangulata</i>	Rahman <i>et al.</i> (2011)	-
Fruit width with		
Fruit weight (g)		
<i>Momordica dioica</i>	Bharathi <i>et al.</i> (2005b) Singh <i>et al.</i> (2009)	-
<i>Momordica charantia</i>	Ramachandran and Gopalakrishnan (1979) Bhave <i>et al.</i> (2003b) Dey <i>et al.</i> (2005) Sundaram (2010)	Islam <i>et al.</i> (2009)
<i>Momordica subangulata</i>	Rahman <i>et al.</i> (2011)	-
Number of fruits per plant		
<i>Momordica dioica</i>	Singh <i>et al.</i> (2009)	Bharathi <i>et al.</i> (2005b)
<i>Momordica charantia</i>	Ramachandran and Gopalakrishnan (1979) Bhave <i>et al.</i> (2003b) Islam <i>et al.</i> (2009)	Dey <i>et al.</i> (2005) Sundaram (2010)
<i>Momordica subangulata</i>	Rahman <i>et al.</i> (2011)	-
Fruit weight with		
Number of fruits per plant		
<i>Momordica dioica</i>	Singh <i>et al.</i> (2009)	Bharathi <i>et al.</i> (2005b)
<i>Momordica charantia</i>	Ramachandran and Gopalakrishnan (1979) Bhave <i>et al.</i> (2003b)	Srivastava and Srivastava (1976) Mangal <i>et al.</i> (1981) Dey <i>et al.</i> (2005) Islam <i>et al.</i> (2009) Sundaram (2010)
<i>Momordica subangulata</i>	-	Rahman <i>et al.</i> (2011)

Table 2.4. Summary of review of literature on genotypic direct effects of various characters on fruit yield in *Momordica* species

Character	Direction	Direct effect and Degree				
		Negligible (0.00 -0.09)	Low (0.10-0.19)	Moderate (0.20-0.29)	High (0.30-0.99)	Very high (>1.00)
Vine length (m)						
<i>Momordica dioica</i>						
	-Ve	-	Bharathi <i>et al.</i> (2005b)	-	-	-
<i>Momodica charantia</i>						
	+Ve	Bhave <i>et al.</i> (2003a)	Sundaram (2010)	-	-	Islam <i>et al.</i> (2009)
<i>Momordica subangulata</i>						
	+Ve	-	Rahman <i>et al.</i> (2011)	Naik and Akhtar (2012)	-	-
Number of stems per plant						
<i>Momordica subangulata</i>						
	+Ve	Naik and Akhtar(2012)		-	-	-
Days to first female flower appearance						
<i>Momordica dioica</i>						
	-Ve	Singh <i>et al.</i> (2009)	-	Bharathi <i>et al.</i> (2005b)	-	-
<i>Momrdica cochinchinensis</i>						
	+Ve	Sanwal <i>et al.</i> (2007)	-	-	-	-
<i>Momodica charantia</i>						
	+Ve	-	-	Dey <i>et al.</i> (2005) Sundaram (2010)	-	-
	-Ve		Srivastava and Srivastava (1976)	-	-	-
<i>Momordica subangulata</i>						
	+Ve	Rahman <i>et al.</i> (2011)	-	-	-	-

Table 2.4 cont.

Character	Direction	Direct effect and Degree				
		Negligible (0.00 -0.09)	Low (0.10-0.19)	Moderate (0.20-0.29)	High (0.30-0.99)	Very high (>1.00)
First female flowering node						
<i>Momordica dioica</i>						
	-Ve	-	-	-	-	Bharathi <i>et al.</i> (2005b)
<i>Momodica charantia</i>						
	-Ve	-	-	-	Dey <i>et al.</i> (2005) Sundaram (2010)	-
<i>Momordica subangulata</i>						
	-Ve	-	Rahman <i>et al.</i> (2011)	-	-	-
Days to first fruit harvest						
<i>Momordica dioica</i>						
	+Ve	Singh <i>et al.</i> (2009)	-	-	-	-
<i>Momodica charantia</i>						
	-Ve	-	-	-	Dey <i>et al.</i> (2005)	-
Fruiting period (days)						
<i>Momodica charantia</i>						
	-Ve	Bhave <i>et al.</i> (2003a)	-	-	-	-
Fruit length (cm)						
<i>Momordica dioica</i>						
	+Ve	-	-	Bharathi <i>et al.</i> (2005b)	-	-
	-Ve	Singh <i>et al.</i> (2009)	-	-	-	-
<i>Momordica cochinchinensis</i>						
	+Ve	-	Sanwal <i>et al.</i> (2007)	-	-	-
<i>Momodica charantia</i>						
	+Ve	Bhave <i>et al.</i> (2003a)	-	Sundaram (2010)	Dey <i>et al.</i> (2005) Islam <i>et al.</i> (2009)	-

Table 2.4 cont.

Character	Direction	Direct effect and Degree				
		Negligible (0.00 -0.09)	Low (0.10-0.19)	Moderate (0.20-0.29)	High (0.30-0.99)	Very high (>1.00)
<i>Momordica subangulata</i>						
	+Ve	-	-	Rahman <i>et al.</i> (2011)	-	-
Fruit width (cm)						
<i>Momordica dioica</i>						
	+Ve	Singh <i>et al.</i> (2009)	-	-	-	-
	-Ve	-	-	-	Bharathi <i>et al.</i> (2005b)	-
<i>Momordica cochinchinensis</i>						
	-Ve	-	-	Sanwal <i>et al.</i> (2007)	-	-
<i>Momodica charantia</i>						
	+Ve	-	Dey <i>et al.</i> (2005)	-	Sundaram (2010)	-
<i>Momordica subangulata</i>						
	-Ve	Rahman <i>et al.</i> (2011)	-	-	-	-
Fruit weight (g)						
<i>Momordica dioica</i>						
	+Ve	Bharathi <i>et al.</i> (2005b)			Singh <i>et al.</i> (2009)	
<i>Momrdica cochinchinensis</i>						
	+Ve	-	-	-	Sanwal <i>et al.</i> (2007)	-
<i>Momodica charantia</i>						
	+Ve	Sundaram (2010)	-	-	Srivastava and Srivastava (1976) Dey <i>et al.</i> (2005)	-
<i>Momordica subangulata</i>						
	+Ve	-	-	-	Rahman <i>et al.</i> (2011) Naik and Akhtar (2012)	-

Table 2.4 cont.

Character	Direction	Direct effect and Degree				
		Negligible (0.00 -0.09)	Low (0.10-0.19)	Moderate (0.20-0.29)	High (0.30-0.99)	Very high (>1.00)
Number of fruits per plant						
<i>Momordica dioica</i>						
	+Ve	-	-	-	Bharathi <i>et al.</i> (2005b) Singh <i>et al.</i> (2009)	-
Number of fruits per plant						
<i>Momordica cochinchinensis</i>						
	+Ve	-	-	-	Sanwal <i>et al.</i> (2007)	-
<i>Momordica charantia</i>						
	+Ve	Bhave <i>et al.</i> (2003a)	-	-	Srivastava and Srivastava (1976) Dey <i>et al.</i> (2005)	Islam <i>et al.</i> (2009) Sundaram (2010)
<i>Momordica subangulata</i>						
	+Ve	-	-	-	Rahman <i>et al.</i> (2011)	Naik and Akhtar (2012)

Table 2.5. Summary of review of literature on indirect effects of yield contributing characters on fruit yield in *Momordica* species

Character	Direction	Degree of indirect effect		
		Moderate (0.20-0.29)	High (0.30-0.99)	Very high (>1.0)
Vine length through				
First female flowering node				
<i>Momordica charantia</i>				
	-Ve	-	Sundaram (2010)	-
Fruit weight (g)				
<i>Momordica charantia</i>				
	+Ve	Bhave <i>et al.</i> (2003a)	-	-
<i>Momordica subangulata</i>				
	-Ve	Rahman <i>et al.</i> (2011)	Naik and Akhtar (2012)	-
Number of fruits per plant				
<i>Momordica charantia</i>				
	+Ve	Bhave <i>et al.</i> (2003a)	Sundaram (2010)	-
<i>Momordica subangulata</i>				
	-Ve	-	Naik and Akhtar (2012)	-
Number of stems per plant through				
Number of fruits per plant				
<i>Momordica subangulata</i>				
	-Ve	-	Naik and Akhtar (2012)	-
Days to first female flower appearance through				
First female flowering node				
<i>Momordica charantia</i>				
	-Ve	Dey <i>et al.</i> (2005)	Sundaram (2010)	-
Days to first fruit harvest				
<i>Momordica charantia</i>				
	-Ve	-	Dey <i>et al.</i> (2005)	-
Fruit length (cm)				
<i>Momordica cochinchinensis</i>				
	-Ve	-	Sanwal <i>et al.</i> (2007)	-
Fruit width (cm)				
<i>Momordica cochinchinensis</i>				
	-Ve	Sanwal <i>et al.</i> (2007)	-	-
Fruit weight (g)				
<i>Momordica charantia</i>				
	+Ve	-	Srivastava and Srivastava (1976)	-
<i>Momordica cochinchinensis</i>				
	-Ve	-	Sanwal <i>et al.</i> (2007)	-
Number of fruits per plant				
<i>Momordica charantia</i>				
	-Ve	-	Srivastava and Srivastava (1976) Dey <i>et al.</i> (2005) Sundaram (2010)	-

Table 2.5 cont.

Character	Direction	Degree of indirect effect		
		Moderate (0.20-0.29)	High (0.30-0.99)	Very high (>1.0)
<i>Momordica subangulata</i>				
	+Ve	Rahman <i>et al.</i> (2011)	-	-
First female flowering node through				
Days to first female flower appearance				
<i>Momordica charantia</i>				
	+Ve	-	Dey <i>et al.</i> (2005)	-
Days to first fruit harvest				
<i>Momordica charantia</i>				
	-Ve	-	Dey <i>et al.</i> (2005)	-
Number of fruits per plant				
<i>Momordica charantia</i>				
	-Ve	-	Dey <i>et al.</i> (2005)	-
<i>Momordica subangulata</i>				
	+Ve	Rahman <i>et al.</i> (2011)	-	-
Days to first fruit harvest through				
Days to first female flower appearance				
<i>Momordica charantia</i>				
	+Ve	-	Dey <i>et al.</i> (2005)	-
First female flowering node				
<i>Momordica charantia</i>				
	-Ve	Dey <i>et al.</i> (2005)	-	-
Fruit length (cm)				
<i>Momordica charantia</i>				
	+Ve	Dey <i>et al.</i> (2005)	-	-
Number of fruits per plant				
<i>Momordica charantia</i>				
	-Ve	-	Dey <i>et al.</i> (2005)	-
Fruiting period through				
Fruit weight (g)				
<i>Momordica charantia</i>				
	+Ve	Bhave <i>et al.</i> (2003a)	-	-
Number of fruits per plant				
<i>Momordica charantia</i>				
	+Ve	-	Bhave <i>et al.</i> (2003a)	-
Fruit length through				
Days to first female flower appearance				
<i>Momordica charantia</i>				
	+Ve	-	Dey <i>et al.</i> (2005)	-
<i>Momordica cochinchinensis</i>				
	-Ve	-	Sanwal <i>et al.</i> (2007)	-
First female flowering node				
<i>Momordica charantia</i>				
	-Ve	Sundaram (2010)	-	-

Table 2.5 cont.

Character	Direction	Degree of indirect effect		
		Moderate (0.20-0.29)	High (0.30-0.99)	Very high (>1.0)
Days to first fruit harvest				
<i>Momordica charantia</i>				
	-Ve	-	Dey <i>et al.</i> (2005)	-
Fruit width (cm)				
<i>Momordica dioica</i>				
	-Ve	-	Bharathi <i>et al.</i> (2005b)	-
<i>Momordica cochinchinensis</i>				
	+Ve	-	Sanwal <i>et al.</i> (2007)	-
Fruit weight (g)				
<i>Momordica charantia</i>				
	+Ve	-	Bhave <i>et al.</i> (2003a)	-
	+Ve	-	Dey <i>et al.</i> (2005)	-
<i>Momordica cochinchinensis</i>				
	+Ve	-	Sanwal <i>et al.</i> (2007)	-
<i>Momordica subangulata</i>				
	+Ve	-	Rahman <i>et al.</i> (2011)	-
Number of fruits per plant				
<i>Momordica charantia</i>				
	+Ve	-	Bhave <i>et al.</i> (2003a) Sundaram (2010)	-
	-Ve	-	Dey <i>et al.</i> (2005)	-
<i>Momordica cochinchinensis</i>				
	+Ve	-	Sanwal <i>et al.</i> (2007)	-
Fruit width through				
Days o first female flower appearance				
<i>Momordica cochinchinensis</i>				
	-Ve	Sanwal <i>et al.</i> (2007)	-	-
Fruit length (cm)				
<i>Momordica dioca</i>				
	+Ve	Bharathi <i>et al.</i> (2005b)	-	-
<i>Momordicsa cochinchinensis</i>				
	+Ve	-	Sanwal <i>et al.</i> (2007)	-
<i>Momordica subangulata</i>				
	+Ve	Rahman <i>et al.</i> (2011)	-	-
Fruit weight (g)				
<i>Momordica charantia</i>				
	+Ve	Dey <i>et al.</i> (2005)	-	-
<i>Momordicsa cochinchinensis</i>				
	+Ve	-	Sanwal <i>et al.</i> (2007)	-
<i>Momordica subangulata</i>				
	+Ve	-	Rahman <i>et al.</i> (2011)	-
Number of fruits per plant				
<i>Momordica charantia</i>				
	+Ve	-	Dey <i>et al.</i> (2005)	-
	-Ve	-	Sundaram (2010)	-

Table 2.5 cont.

Character	Direction	Degree of indirect effect		
		Moderate (0.20-0.29)	High (0.30-0.99)	Very high (>1.0)
Fruit weight through				
Days to first female flower appearance				
<i>Momordica charantia</i>				
	+Ve	Dey <i>et al.</i> (2005)	-	-
<i>Momordica cochinchinensis</i>				
	-Ve	-	Sanwal <i>et al.</i> (2007)	-
Days to first fruit harvest				
<i>Momordica charantia</i>				
	-Ve	-	Dey <i>et al.</i> (2005)	-
Fruit length (cm)				
<i>Momordica dioca</i>				
	+Ve	Bharathi <i>et al.</i> (2005b)	-	-
<i>Momordica charantia</i>				
	+Ve	-	Dey <i>et al.</i> (2005)	-
<i>Momordica cochinchinensis</i>				
	+Ve	-	Sanwal <i>et al.</i> (2007)	-
<i>Momordica subangulata</i>				
	+Ve	Rahman <i>et al.</i> (2011)	-	-
Fruit width (cm)				
<i>Momordica dioca</i>				
	-Ve	-	Bharathi <i>et al.</i> (2005b)	-
<i>Momordica cochinchinensis</i>				
	+Ve	-	Sanwal <i>et al.</i> (2007)	-
Number of fruits per plant				
<i>Momordica dioca</i>				
	+Ve	Singh <i>et al.</i> (2009)	-	-
<i>Momordica charantia</i>				
	+Ve	Bhave <i>et al.</i> (2003a)	-	-
	-Ve	-	Dey <i>et al.</i> (2005) Sundaram (2010)	Srivastava and Srivastava (1976)
<i>Momordica cochinchinensis</i>				
	+Ve	-	Sanwal <i>et al.</i> (2007)	-
<i>Momordica subangulata</i>				
	+Ve	Naik and Akhtar (2012)	Rahman <i>et al.</i> (2011)	-
Number of fruits per plant through				
Days to first female flower appearance				
<i>Momordica charantia</i>				
	-Ve	Dey <i>et al.</i> (2005)	-	-
<i>Momordica cochinchinensis</i>				
	-Ve	-	Sanwal <i>et al.</i> (2007)	-
Days to first fruit harvest				
<i>Momordica charantia</i>				
	+Ve	-	Dey <i>et al.</i> (2005)	-

Table 2.5 cont.

Character	Direction	Degree of indirect effect		
		Moderate (0.20-0.29)	High (0.30-0.99)	Very high (>1.0)
Fruit length (cm)				
<i>Momordica charantia</i>				
	+Ve	-	Dey <i>et al.</i> (2005)	-
<i>Momordica cochinchinensis</i>				
	+Ve	-	Sanwal <i>et al.</i> (2007)	-
Fruit width (cm)				
<i>Momordica charantia</i>				
	-Ve	-	Islam <i>et al.</i> (2009)	-
Fruit weight (g)				
<i>Momordica dioca</i>				
	+Ve	-	Singh <i>et al.</i> (2009)	-
<i>Momordica charantia</i>				
	+Ve	-	Bhave <i>et al.</i> (2003b)	Srivastava and Srivastava (1976)
	-Ve	Dey <i>et al.</i> (2005)	-	-
<i>Momordica cochinchinensis</i>				
	+Ve	-	Sanwal <i>et al.</i> (2007)	-
<i>Momordica subangulata</i>				
	+Ve	Naik and Akhtar (2012)	-	-

Chapter III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The materials used and the methods followed during the course of the present investigation are briefly described hereunder.

3.1 LOCATION OF THE EXPERIMENT

The present study was carried out at the Experimental Farm, Vegetable Research Station, Dr. Y.S. R. Horticultural University (Dr. YSRHU), Hyderabad during *kharif*, 2012. The experimental field is situated at 17° 19' N latitude, 79° 23' longitude and at an altitude of 546.2 m above mean sea level.

3.2 EXPERIMENTAL MATERIAL

The experimental material for this study consisted of female plants of fifty genotypes (RNK- 182 to RNK-231) of spine gourd (*Momordica dioica* Roxb.), collected and maintained by the Vegetable Research Station, Rajendranagar in collaboration with the National Bureau of Plant Genetic Resources Regional Station, Rajendranagar, Hyderabad.

3.3 WEATHER CONDITIONS DURING THE CROPPING PERIOD

The meteorological data pertaining to mean maximum and mean minimum temperatures, relative humidity and rainfall in weekly averages during the period of investigation *i.e.* *kharif*, 2012 season recorded at the Vegetable Research Station Rajendranagar, Hyderabad are presented in Appendix 1.

3.4 DETAILS OF THE EXPERIMENT

The experiment was conducted during *kharif*, 2012. The experiment was laid out in a randomized block design with 2 replications. Each genotype was raised in a single-row plot of 3.0 m length and 2.5 m width. A row-to-row spacing of 2.5 m and a plant-to-plant spacing of 1.0 m was adopted. A plant population of 3 plants per row, plot and genotype was maintained. The vines were trained on trellis. The plant population in the experimental field had female and male plants at the ratio of 10:1 to ensure effective pollination. The recommended package of practices was followed. Necessary plant protection



TITLE OF DISSERTATION PROBLEM:
MORPHOLOGICAL CHARACTERIZATION AND EVALUATION OF
SPINE GOURD (MOMORDICA DIOICA ROXB) GERMPLASM
NO. OF GENOTYPES: 50 (RNK-182 to RNK-231)
REPLICATIONS: TWO DESIGN: RBD
PLOT SIZE: 3.0 x 2.5m SPACING: 2.5 x 1.0m
SEASON: KHARIF, 2012
NAME AND ADDRESS OF STUDENT: ALIYA FATIMA
ID NO: RHM/2011-01
DEGREE: MSc. (HORTICULTURE)
MAJOR FIELD: VEGETABLE SCIENCE
DEPT. OF VEGETABLE SCIENCE
COLLEGE OF HORTICULTURE, RATENRA NAGAR
MAJOR ADVISOR: DR. HAMEEDUNNISA BEGUM, P.S. (HORTICULTURE)
LOCATION: VEGETABLE RESEARCH STATION, Dr. YSRHU, R. NAGAR

Plate 3.1: General view of the experimental plot

measures were carried out uniformly to safeguard the germplasm lines from major pests and diseases.

3.5 OBSERVATIONS RECORDED

The biometric data were recorded on per plot basis in each genotype in each replication.

3.5.1 QUANTITATIVE CHARACTERS

The data on twelve quantitative characters was recorded on 3 plants in each genotype and in each replication.

3.5.1.1 Vine length (m)

The length of the vine was measured from the base of the plant to tip of the vine at senescence stage.

3.5.1.2 Number of stems per plant

The number of stems arising from the tuber was counted after the establishment of vines at vegetative stage.

3.5.1.3 Days to first female flower appearance

Number of days taken from the date of sprouting to the first appearance of female flower in a plot was recorded at flowering stage.

3.5.1.4 First female flowering

The node number at which first female flower appeared was recorded from the base at flowering stage.

3.5.1.5 Days to first fruit harvest

Days to first fruit harvest was recorded on the basis of number of days taken for the harvest of first fruit from the date of sprouting.

3.5.1.6 Days to last fruit harvest

Days to last fruit harvest was recorded on the basis of number of days taken for the harvest of last fruit from the date of sprouting.

3.5.1.7 Fruiting period (days)

Fruiting period was recorded by counting the number of days from days to first harvest to days to last harvest.

3.5.1.8 Fruit length (cm)

Mean length of 5 fruits picked at edible maturity stage was measured using vernier calipers and expressed in centimetres.

3.5.1.9 Fruit width (cm)

Mean width of 5 fruits picked at edible maturity stage was measured using vernier calipers and expressed in centimetres.

3.5.1.10 Fruit weight (g)

Weight of five fruits picked at edible maturity stage was recorded using weighing balance. The average fruit weight was computed and expressed in grammes.

3.5.1.11 Number of fruits per plant

Total number of green, tender and marketable fruits of each plot recorded under full range of pickings and was averaged by dividing with the number of plants to get number of fruits per plant at fruiting stage.

3.5.1.12 Fruit yield (kg/plant)

Total weight of green, tender and marketable fruits of each plot was recorded under full range of pickings was summed and averaged by dividing with the number of plants to get total yield per plant.

3.5.2 QUALITATIVE CHARACTERS

The data on 35 qualitative characters (Table 3.1.) based on descriptors for *Momordica* species (Joseph and Antony, 2011) were recorded in each genotype on a single plant basis.

Table 3.1. Descriptor states for various qualitative traits of female plants of spine gourd genotypes

Qualitative trait	Descriptor	Qualitative trait	Descriptor	Qualitative trait	Descriptor
Vine tip pubescence	1. Glabrous 2. Scarcely Pubescent 3. Pubescent	Leaf lobing (1. st flowering node)	1. Entire 2. Lobed 3. Mixed occurrence in same plant 4. Other (specify)	Petiole-Lamina juncture shape	1. Subangulate 2. Round 3. Cordate
Leaf shape	1. Ovate 2. Sagitate 3. Palmate 4. Hastate 5. Cordate 6. Elliptic 7. Other	Extent of lobing	1. Shallowly lobed 2. Broadly angled margins 3. Deeply lobed and sub lobed	Tendril robustness	1. Robust 2. Fragile 3. Medium
Leaf margin	1. Entire 2. Serrate 3. Dentate 4. Wavy 5. Other (Specify)	Lobe tip	1. Acute 2. Acuminate 3. Ovate 4. Obovate 5. Other (Specify)	Tendril length (when uncoiled)	1. Short (5.-1.0 cm) 2. Medium (1.1.-2.0 cm) 3. Very long (2.1.-3.0 cm)
Leaf pubescence	1. Glabrous 2. Sparse 3. Medium 4. Dense 5. Woolly	Leaf odour	1. Mild 2. Not foetid 3. Foetid (intense)	Female flower bract size	1. Minute (scar like) 2. Medium large 3. Large
Leaf colour (fresh leaf)	1. Light green 2. Green 3. Dark green	Leaf thickness	1. Thin 2. Medium 3. Thick	Female flower bract position	1. Just below gynoecium 2. Midway on pedicel 3. Near axis
Leaf venation	1. Fine network (areoles) 2. Spaced network 3. Intermediate	Extent of leaf margin dentation	1. Close 2. Spaced 3. Remote	Gynoecium	1. Small 2. Medium 3. Large

Table 3.1 (Cont.)

Qualitative trait	Descriptor	Qualitative trait	Descriptor	Qualitative trait	Descriptor
Ovary surface	1. Smooth 2. Warty 3. Tubercled 4. Echinata (softly) 5. Ridged 6. Other (specify)	Fruit pericarp ripening	1. Slow 2. Sudden	Seed sculpturing	1. Absent 2. Present
Fruit size	1. Small 2. Medium 3. Large	Fruit (blossom end) rostration	1. Faint 2. Medium 3. Appreciable length	Extent of sculpturing	1. Faint 2. Medium 3. Filigree type 4. Pitted and ridged 5. Other (specify)
Immature fruit colour	1. Whitish green 2. Light green 3. Dark green	Calyx persistence	1. Caducous 2. Semi persistent 3. Persistent	Seed ornamentation	1. Absent 2. Present
Fruit surface echination	1. Absent=smooth 2. Mild-sparsely echinate 3. Densely echinate	Fruit bitterness	1. Not bitter 2. Slightly bitter 3. Very bitter	Type of ornamentation	1. Golden lines on black seed coat 2. Other (specify)
Fruit C.S (mature fruit at equatorial point)	1. Uniformly soft echinate 2. Clear cut ridges and echination 3. Ridges faint but echinate 4. Other (specify)	Seed aril colour (at ripening)	1. Yellow 2. Orange 3. Scarlet 4. Blood red	Seed sides (margins)	1. Smooth 2. Wavy = bitten
Fruit shape	1. Round oval 2. Winged 3. Doom shaped 4. Ellipsoid oblong 5. Top shaped 6. Others (specify with drawing)	Seed shape	1. Oval 2. Round 3. Globular 4. Stellate 5. Squarish 6. Cog-wheel 7. Rectangular 8. Other	Fruit spine strength	1. Hard 2. Medium 3. Soft

3.6 STATISTICAL ANALYSIS

The mean replicated data collected on 12 quantitative traits were subjected to biometrical analysis following appropriate biometrical procedures.

3.6.1 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
Replications	r-1	M_1	$\sigma_e^2 + t \sigma_r^2$
Treatments	t-1	M_2	$\sigma^2_e + r \sigma^2_g$
Error	(r-1)(v-1)	M_3	σ^2_e
Total	rv-1	$(M_1 + M_2 + M_3)$	

Where,

r = Number of replications

v = Number of genotypes (treatments)

σ^2_e = Error variance

σ^2_g = Genotypic variance

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

3.6.2 Genotypic and phenotypic variance

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

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

$$\text{Phenotypic variance} = \sigma^2_p = \sigma^2_g + \sigma^2_e$$

Where,

$$\sigma^2_g = \text{Genotypic variance (GV)}$$

$$\sigma^2_p = \text{Phenotypic variance (PV)}$$

$$\sigma^2_e = \text{Environmental variance (EV)}$$

3.6.3 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:

$$\text{GCV} = \frac{\sqrt{GV}}{\bar{X}} \times 100$$

$$\text{PCV} = \frac{\sqrt{PV}}{\bar{X}} \times 100$$

Where,

GCV = Genotypic coefficient of variation

PCV = Phenotypic coefficient of variation

GV = Genotypic variance

PV = Phenotypic variance

\bar{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

3.6.4 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.

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

Phenotypic variance (σ^2_p)

The range of heritability in broad sense was classified as suggested by Johnson *et al.* (1955).

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

3.6.5 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 Johnson *et al.* (1955).

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

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)

σ_p = Phenotypic standard deviation

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

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

Genetic advance as per cent mean was categorized as given below as suggested by Johnson *et al.* (1955).

0- 10% - Low 10.1-20.0% - Moderate >20.1% - High

3.6.6 Genetic divergence analysis

The genetic divergence between genotypes was estimated using Mahalanobis D^2 statistics (1936).

3.6.6.1 Mahalanobis D^2 statistics

The data collected on different characters were analyzed using Mahalanobis D^2 analysis (1936) to determine the genetic divergence among the genotypes. D^2 value between ij^{th} genotypes for 'p' characters was calculated as

$$D^2_{ij} = \sum_{t=1}^p (Y_i^t - Y_j^t)^2$$

Where,

Y_{it} is uncorrelated mean value of i^{th} genotype for 't' characters

Y_{jt} is uncorrelated mean value of j^{th} genotype for 't' characters

D^2_{ij} is D^2 between i^{th} and j^{th} genotypes.

3.6.6.1.1 Test of significance

Variances were calculated for all the characters and test of significance was done. Analysis of covariance for the character pairs was estimated on the basis of mean values (Panse and Sukhatme, 1985). After testing the difference between genotypes for each of the character, a simultaneous test of significance for differences in the mean values of a number of correlated variables with regard to the pooled effect of characters was carried out using 'V' statistic, which in turn utilizes Wilk's criterion. The sum of squares and sum of products of error and error + variety, variance - covariance matrix were used for this purpose. The estimation of Wilk's criterion was done using the following relationship.

$$\hat{\Lambda} = \frac{(E)}{(E+V)}$$

Where,

$\hat{\Lambda}$ = Wilk's criterion

(E) = Determinant of error matrix and

(E + V) = Determinant of error + variety matrix

$$V(\text{Stat}) = -m \log_e \hat{\Lambda} = -n \left[\frac{P+Q+1}{2} \right] \log_e \hat{\Lambda}$$

Where, $m = n - (P + Q + 1) / 2$

n = degrees of freedom for error + varieties

$\log_e \hat{\Lambda} = 2.3026 \log_{10} \hat{\Lambda}$

P = number of variables or characters. (19)

Q = number of genotypes – 1 (or d.f. for genotypes) 47

$V(\text{stat})$ is distributed as χ^2 with PQ ($912 = 19 \times 47$) degrees of freedom.

χ^2 table value at 5 per cent level of significance is 106.50 (approx) distributed with 893 degrees of freedom.

3.6.6.1.2 Transformation of correlated variables

In the present model, computation of D^2 values was reduced to simple summation of the differences in mean values of various characters of the two genotypes *i.e.* Σd_i^2 . Therefore transformation of correlated variables into uncorrelated ones was done before working out the D^2 values. Transformation was done using pivotal condensation method.

3.6.6.1.3 Computation of D^2 values

For the given combination of i^{th} and j^{th} genotype, the mean deviation *i.e.* $Y_i^t - Y_j^t$ for $t = 1, 2 \dots p$ variables are computed and the D^2 values were calculated as

$$D_{ij}^2 = \sum_{t=1}^p (Y_i^t - Y_j^t)^2$$

3.6.6.1.4 Testing the significance of D^2 values

The D^2 value obtained for a pair of population is taken as calculated value of χ^2 and is tested against the tabulated value of χ^2 for P (19) degrees of freedom where P (19) is the number of characters considered.

3.6.6.1.5 Grouping of genotypes into various clusters

The grouping of genotypes into different clusters was done using the Tocher's method as described by Rao (1952). The criterion was that the two genotypes belonging to the same cluster should at least on an average show a smaller D^2 value than those belonging to different clusters. For this purpose, D^2 values of all combinations of each genotype were arranged in ascending order of magnitude in a tabular form as described by Singh and Chaudhary (1977). To start with, two populations having the closest distance from each other were considered, to which the third population having the smallest D^2 value from the first two populations was added. Similarly, the next nearest fourth population was considered and this procedure was continued. At certain stage, when it was felt that after adding a particular population there was an abrupt increase in the average D^2 , that population was not considered for including in that cluster. The genotypes of the first cluster were then eliminated and the rest were treated in a

similar way. This procedure was continued until all the genotypes were included into one or other cluster.

3.6.6.1.6 Intra cluster distance

The average intra cluster distances were calculated by the formula given by Singh and Chaudhary (1977).

$$\text{Square of intra cluster distance} = \Sigma Di^2 / n$$

Where,

ΣDi^2 = sum of distance between all possible combinations.

n = number of all possible combinations

3.6.6.1.7 Inter cluster distance

The average inter cluster distances were calculated by the formulae described by Singh and Chaudhary (1977).

$$\text{Square of inter cluster distance} = \Sigma Di^2 / n_i n_j$$

Where,

ΣDi^2 = sum of distances between all possible combinations ($n_i n_j$) of the entries included in the cluster study.

n_i = number of entries in cluster i

n_j = number of entries in cluster j

3.6.6.1.8 Contribution of individual characters towards genetic divergence

The character contribution towards genetic divergence was computed using the method given by Singh and Chaudhary (1977). In all the combinations, each character was ranked on the basis of $d_i = y_i^j - y_i^k$ values.

Where,

d_i = mean deviation

y_i^j = mean value of the j^{th} genotype for the i^{th} character and

y_i^k = mean value of the k^{th} genotype for the i^{th} character.

Rank 'I' is given to the highest mean difference and rank 'P' is given to the lowest mean difference

Where,

P is the total number of characters.

Finally, the number of times that each character appeared in the first rank is computed and per cent contribution of characters towards divergence was estimated using the formula

$$\text{Percentage contribution of character } x = \frac{N \times 100}{M}$$

N = number of genotype combinations where the character was ranked first.

M = all possible combinations of number of genotypes considered.

3.6.7 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:

$$r_g(xy) = \frac{\text{Cov}_g(xy)}{\sqrt{\sigma_g^2(x) \cdot \sigma_g^2(y)}} \qquad r_p(xy) = \frac{\text{Cov}_p(xy)}{\sqrt{\sigma_p^2(x) \cdot \sigma_p^2(y)}}$$

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.

σ_g^2 and σ_p^2 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.

3.6.8 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.

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

Where,

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

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

$r_{12}P_{2y}$ = 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.

$$\text{Residual effect } (Pr_y) = 1 - R^2$$

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

Pr_y = 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

$$Pr_y = \sqrt{1 - P_{1y} r_{1y} + P_{2y} r_{2y} + \dots + P_{ky} r_{ky}}$$

Where Pr_y = 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

CHAPTER IV

RESULTS AND DISCUSSION

The present investigation was carried out to assess the nature and extent of genetic divergence in spine gourd (*Momordica dioica* Roxb.). The data collected from 50 genotypes of spine gourd on twelve quantitative characters pertaining to growth, earliness and yield attributes were subjected to biometrical analysis and the results obtained are presented under the following headings:

- 4.1 Analysis of variance
- 4.2 Mean performance of genotypes
- 4.3 Variability, heritability and genetic advance
- 4.4 Genetic divergence analysis
- 4.5 Correlation coefficient analysis
- 4.6 Path coefficient analysis

4.1 ANALYSIS OF VARIANCE

The analysis of variance for twelve characters in 50 genotypes of spine gourd is presented in Table 4.1. Highly significant differences were observed among the genotypes for all the characters indicating presence of great amount of variability in all the characters studied.

4.2 MEAN PERFORMANCE OF GENOTYPES

Mean performance pertaining to the twelve quantitative characters are presented in the Table 4.2. Of the twelve characters under study, vine length and number of stems per plant largely determine the fruit bearing surface and thus considered as growth attributes. Spine gourd bears fruits on nodes on all the stems. Days to first female flower appearance, first female flowering node, days to first fruit harvest, days to last fruit harvest and fruiting period are indicators of earliness in spine gourd. Fruit length, fruit width, fruit weight and number of fruits per plant are considered as the fruit attributes which are directly associated with the fruit yield per plant.

Table 4.1. Analysis of variance for yield and yield attributes in spine gourd germplasm

Character	Mean sum of squares		
	Replications (1)	Treatments (49)	Error (49)
Vine length (m)	0.10	0.67**	0.07
Number of stems per plant	0.39	5.41**	0.15
Days to first female flower appearance	23.04	88.65**	8.59
First female flowering node	4.84	61.24**	8.35
Days to first fruit harvest	7.84	379.78**	31.26
Days to last fruit harvest	0.25	557.27**	62.78
Fruiting period (days)	25.00	927.08**	90.89
Fruit length (cm)	0.78	0.53**	0.23
Fruit width (cm)	0.03	0.09**	0.03
Fruit weight (g)	1.60	14.64**	1.82
Number of fruits per plant	50.41	13566.98**	203.75
Fruit yield (kg/plant)	0.13	2.90**	0.05

** Significant at P = 0.01 level of significance

Values in parenthesis indicate degrees of freedom

Table 4.2. Mean performance of female plants for yield and yield attributes of spine gourd genotypes

Accession No	Vine length (m)	Number of stems per plant	Days to first female flower appearance	First female flowering node	Days to first fruit harvest	Days to last fruit harvest	Fruiting period (days)	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	Number of fruits per Plant	Fruit yield (kg/plant)
RNK-182	2.30	3.00	16.00	18.00	35.00	68.00	32.50	3.75	3.00	12.50	18.00	0.14
RNK-183	3.00	2.00	18.00	22.00	36.00	118.00	82.00	4.30	3.20	16.20	78.00	0.82
RNK-184	2.40	2.00	30.00	23.00	52.00	114.00	62.00	4.57	2.50	13.80	55.00	0.73
RNK-185	2.60	3.00	19.00	25.00	22.00	74.00	52.00	3.97	2.50	13.30	68.00	0.89
RNK-186	1.90	4.00	14.00	27.00	52.00	89.00	37.00	4.70	2.70	15.90	65.50	0.97
RNK-187	3.50	7.00	30.00	24.00	36.00	118.00	82.00	5.40	2.93	20.00	218.00	3.61
RNK-188	3.40	3.00	25.00	23.00	66.00	116.00	50.00	4.40	2.83	15.60	36.00	0.53
RNK-189	2.00	2.00	31.00	21.00	76.00	126.00	50.00	3.83	2.58	10.00	110.00	1.27
RNK-190	1.65	1.00	30.00	21.00	36.00	88.00	52.00	3.41	2.40	9.05	54.50	0.56
RNK-191	2.40	2.00	27.00	19.00	54.00	116.00	61.00	4.10	2.60	16.60	97.00	1.40
RNK-192	3.00	5.00	33.00	22.00	54.00	126.00	72.00	5.00	3.22	17.50	129.00	1.58
RNK-193	2.60	4.00	31.00	19.00	54.00	126.00	72.00	4.41	2.72	14.20	122.50	1.74
RNK-194	2.20	4.00	24.00	19.00	27.00	122.00	95.00	4.55	2.83	15.00	149.50	1.90
RNK-195	2.60	2.00	17.00	12.00	54.00	125.50	71.50	4.28	2.63	13.50	181.00	2.28
RNK-196	2.80	5.00	28.00	19.00	31.00	126.00	95.00	4.01	2.70	14.40	297.00	3.74
RNK-197	3.00	6.00	26.00	10.00	31.00	126.00	98.00	5.02	2.82	17.00	317.00	3.97
RNK-198	2.70	4.00	31.00	18.00	55.00	127.00	72.00	4.43	2.65	14.50	197.00	2.94
RNK-199	2.30	2.00	29.00	14.00	42.00	112.00	70.00	4.68	3.03	16.20	175.00	2.45
RNK-200	4.00	7.00	25.00	12.00	39.00	134.00	95.00	5.03	3.13	16.60	277.00	3.97
RNK-201	2.90	3.00	31.00	25.00	58.00	120.00	62.00	4.11	2.73	13.15	158.00	2.15
RNK-202	2.60	2.00	27.00	19.00	48.00	120.00	67.00	4.45	2.92	14.50	134.00	1.93
RNK-203	2.50	3.00	29.00	23.00	48.00	120.00	72.00	4.43	2.55	12.50	150.00	1.86
RNK-204	2.70	2.00	35.00	17.00	58.00	107.00	49.00	4.03	3.03	13.93	111.00	1.49
RNK-205	3.00	3.00	20.00	10.00	69.00	131.00	62.00	4.72	2.73	15.50	185.00	2.52
Grand Mean	2.55	3.16	28.86	20.54	53.94	112.99	58.98	4.34	2.76	14.90	125.15	1.68
S.Em±	0.20	0.28	2.07	2.04	3.95	5.60	6.74	0.35	0.13	0.96	10.09	0.17
C.V (%)	11.00	12.54	10.16	14.07	10.37	7.01	16.16	11.26	6.55	9.07	11.41	14.36
C.D. (5%)	0.56	0.80	5.89	5.81	11.24	15.92	19.16	0.98	0.36	2.72	28.69	0.49

Table 4.2 cont.

Accession No	Vine length (m)	Number of stems per plant	Days to first female flower appearance	First female flowering node	Days to first fruit harvest	Days to last fruit harvest	Fruiting period (days)	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	Number of fruits per Plant	Fruit yield (kg/plant)
RNK-206	2.30	6.00	26.00	11.00	48.00	120.00	72.00	4.72	2.55	15.00	142.50	1.64
RNK-207	2.40	2.00	40.00	12.00	60.00	122.00	62.00	4.73	2.91	16.60	101.50	1.23
RNK-208	2.80	2.00	28.00	25.00	55.00	127.00	72.00	4.70	2.87	16.00	85.00	1.20
RNK-209	1.70	1.00	38.00	16.00	72.00	122.00	50.00	3.80	2.77	12.00	69.50	0.76
RNK-210	2.40	3.00	28.00	19.00	62.00	124.00	62.00	3.67	2.55	11.40	110.00	1.07
RNK-211	2.00	1.00	35.00	21.00	85.00	95.00	10.00	3.47	2.43	10.00	5.50	0.06
RNK-212	1.70	1.00	46.00	18.00	68.00	80.00	12.00	3.31	2.41	12.50	6.50	0.11
RNK-213	2.40	2.00	39.00	22.00	71.00	114.00	43.00	4.13	2.66	13.30	34.50	0.23
RNK-214	1.70	2.00	33.00	23.00	58.00	69.00	11.00	3.83	2.62	12.50	30.00	0.30
RNK-215	1.80	4.00	30.00	17.00	52.00	124.00	72.00	4.47	3.02	14.20	180.00	2.16
RNK-216	3.50	4.00	20.00	10.00	31.00	104.00	73.00	4.13	2.79	14.50	136.50	1.58
RNK-217	2.20	3.00	35.00	24.00	67.00	107.00	40.00	3.85	2.68	12.50	111.00	1.50
RNK-218	2.00	2.00	42.00	20.00	64.00	104.00	40.00	3.35	2.20	11.10	46.00	0.62
RNK-219	1.60	2.00	31.00	24.00	64.00	104.00	40.00	4.17	2.86	15.00	20.00	0.28
RNK-220	2.50	3.00	23.00	23.00	71.00	111.00	40.00	4.47	2.60	15.10	104.00	1.40
RNK-221	3.40	2.00	32.00	18.00	64.00	107.00	43.00	4.13	2.67	15.00	35.00	0.46
RNK-222	2.60	2.00	24.00	19.00	71.00	114.00	43.00	4.55	3.18	16.60	46.00	0.55
RNK-223	1.90	1.00	35.00	22.00	67.00	75.00	8.00	3.95	2.85	15.00	3.00	0.05
RNK-224	3.30	8.00	29.00	20.00	53.00	125.00	72.00	4.78	2.89	18.75	316.00	5.12
RNK-225	3.40	2.00	27.00	25.00	61.00	110.00	49.00	4.05	2.90	16.60	118.00	1.60
RNK-226	3.40	4.00	23.00	25.00	52.00	124.00	72.00	4.78	2.90	19.00	243.00	3.15
RNK-227	2.00	4.00	26.00	27.00	50.00	122.00	72.00	5.57	2.78	24.10	214.00	3.30
RNK-228	3.10	5.00	36.00	27.00	54.00	126.00	72.00	4.45	2.64	18.80	189.00	3.23
RNK-229	1.80	4.00	28.00	30.00	52.00	124.00	72.00	4.35	2.80	17.24	217.00	2.87
RNK-230	3.00	4.00	28.00	33.00	62.00	124.00	62.00	4.53	2.74	14.06	113.50	1.52
RNK-231	2.60	3.00	35.00	34.00	50.00	122.00	72.00	5.45	2.79	16.60	197.50	2.62
Grand Mean	2.55	3.16	28.86	20.54	53.94	112.99	58.98	4.34	2.76	14.90	125.15	1.68
S.Em±	0.20	0.28	2.07	2.04	3.95	5.60	6.74	0.35	0.13	0.96	10.09	0.17
C.V (%)	11.00	12.54	10.16	14.07	10.37	7.01	16.16	11.26	6.55	9.07	11.41	14.36
C.D. (5%)	0.56	0.80	5.89	5.81	11.24	15.92	19.16	0.98	0.36	2.72	28.69	0.49

4.2.1 Growth attributes

Vine length ranged from 1.60 to 4.00 m, with a mean of 2.55 m. Maximum vine length was recorded in RNK-200 (4.00 m) followed by RNK-187 and RNK-216 (3.50 m) and RNK-188, RNK-221, RNK-225 and RNK-226 (3.40 m). Number of stems per plant ranged from 1.00 to 8.00 with a grand mean of 3.16. Maximum number of stems were recorded in RNK-224 (8.00) followed by RNK-187 and RNK-200 (7.00) and RNK-197 and RNK-206 (6.00). Higher the vine length accommodating more number of nodes, with more number of stems per plant, higher is the number of fruits produced per plant. Hence, high mean value is desirable for vine length and number of stems per plant.

4.2.2 Earliness attributes

Number of days to first female flower appearance ranged from 14.00 to 46.00 with a mean of 28.86. Among all the genotypes, RNK-186 (14.00) produced its first female flower earlier followed by RNK-182 (16.00) and RNK-195 (17.00). Node number of first female flower ranged from 10.00 to 34.00 with a mean of 20.54. The genotypes RNK-197, RNK-205 and RNK-216 (10.00) produced their first female flower at the lower node followed by RNK-206 (11.00) and RNK-195, RNK-200 and RNK-207 (12.00). Days to first fruit harvest ranged from 22.00 to 85.00 with a mean of 53.94. Minimum day to first fruit harvest was recorded in the genotype RNK-185 (22.00) followed by RNK-194 (27.00) and RNK-196, RNK-197 and RNK-216 (31.00). Early flowering and days to first fruit harvest not only give early pickings but also widen fruiting period of the plant. Production of first female flower at the lower nodes helps in increasing the number of fruits per plant as well as getting early yields. Low mean value is highly desirable for these three attributes.

Days to last fruit harvest ranged from 68.00 to 134.00 with a mean of 112.99. Days to last fruit harvest was recorded maximum in RNK-200 (134.00) followed by RNK-205 (131.00) and RNK-198 and RNK-208 (127.00). Fruiting period ranged from 8.00 to 98.00 with a mean of 58.98. Longer fruiting period was recorded in RNK-197 (98.00) followed by RNK-194, RNK-196 and RNK-200 (95.00) and RNK-183 and RNK-187 (82.00). Increase in days to last fruit harvest increases the number of pickings and fruiting period. Fruiting period

indicates the duration of harvest. Hence, high mean value is desirable for days to last fruit harvest and fruiting period.

4.2.3 Fruit traits

Fruit length ranged from 3.30 to 5.56 cm with a mean of 4.34 cm. Longest fruits were recorded in RNK-227 (5.56 cm) followed by RNK-231 (5.45 cm) and RNK-187 (5.40 cm). Fruit width ranged from 2.20 to 3.22 cm with a grand mean of 2.76 cm. The genotypes RNK-192 (3.22 cm) followed by RNK-183 (3.20 cm) and RNK-222 (3.18 cm) recorded maximum fruit width. Fruit weight ranged from 9.05 to 24.10 g with a mean of 14.90 g. Maximum fruit weight was recorded in RNK-227 (24.10 g) followed by RNK-187 (20.00 g) and RNK-226 (19.00 g). Number of fruits produced per plant ranged from 3.00 to 317.00 with a grand mean of 125.15. Maximum number of fruits per vine was recorded in RNK-197 (317.00) followed by RNK-224 (316) and RNK-196 (297). These traits are directly associated with the fruit yield per plant, for which high mean value is desirable. High mean values are desired for fruit length, width, weight and number of fruits per plant.

4.2.4 Fruit yield

Wide range of variability i.e., 0.05 to 5.12 kg per plant was recorded for fruit yield per plant with maximum in RNK-224 (5.12 kg) followed by RNK-197 and RNK-200 (3.97 kg) and RNK-196 (3.74 kg) with a grand mean of 1.68 kg.

The range of mean values could present a rough estimate about the variation in magnitude of variability present among genotypes. The characters showing high range of variation have more scope for improvement. All the twelve characters under study exhibited high variability as evident from the ranges of mean values. However, the characters number of fruits per plant and fruiting period having wide range of variation in mean values indicated the presence of high variability for these characters and thus offering greater scope for selecting desirable genotypes.

4.2.5 Qualitative traits

A preliminary characterization for the morphological qualitative traits has been done for fifty genotypes of spine gourd based on descriptors for *Momordica*

species (Joseph and Antony, 2011). The entire characterization for 35 morphological qualitative traits is presented in the table 4.3. Overall variability in fruit traits of spine gourd is presented in Plate 4.1.

4.2.5.1 Vegetative traits

Vine tip was found to be glabrous in 16 genotypes and scarcely pubescent in 22 genotypes, while remaining 12 genotypes had pubescent vine tip. The study revealed that 38 genotypes had palmate leaf shape, 2 genotypes had hastate and remaining 10 had cordate leaf shape (Plate 4.2). Forty six genotypes exhibited spiny leaf margin, 3 genotypes had serrate and 1 genotype had dentate leaf margin. Characterization based on leaf pubescence revealed that 23 genotypes had medium leaf pubescence, 21 genotypes had dense leaf pubescence and remaining 6 genotypes had sparsely pubescent leaves. Leaf colour was found to be green in 26 genotypes, dark green in 20 genotypes and light green in 14 genotypes (Plate 4.3). Leaves of 46 genotypes had fine network of leaf venation, while 2 genotypes had intermediate venation and 2 genotypes had spaced network venation. Of the 50 genotypes, 34 genotypes had lobed leaves whereas 16 genotypes had entire leaves (Plate 4.4). Study revealed that 19 genotypes had shallowly lobed leaves, 8 genotypes had deeply lobed and sublobed leaves while 7 genotypes had broadly angled leaf margins (Plate 4.5). Thirty two genotypes had acuminate lob tip while 2 genotypes had acute lob tip. Twenty five genotypes exhibited foetid leaf odour, 16 genotypes had mild leaf odour while leaf odour of remaining 9 genotypes was not foetid. Leaves were found to be thin in 26 genotypes, thick in 14 genotypes and, medium thick in 10 genotypes. Leaf margin dentation was found to be close in 31 genotypes, spaced in 12 genotypes and remote in remaining 7 genotypes. Among the 50 genotypes characterized for petiole lamina juncture shape, 34 genotypes exhibited subangulate shape, 14 genotypes had cordate shape and 2 genotypes had round shape at petiole lamina juncture (Plate 4.6). Study revealed that 20 genotypes had fragile tendrils, 19 genotypes had medium robust tendrils and remaining 11 genotypes had robust tendrils. Forty four genotypes had medium long tendrils, 5 genotypes had short tendril and 1 genotype had very long tendril.

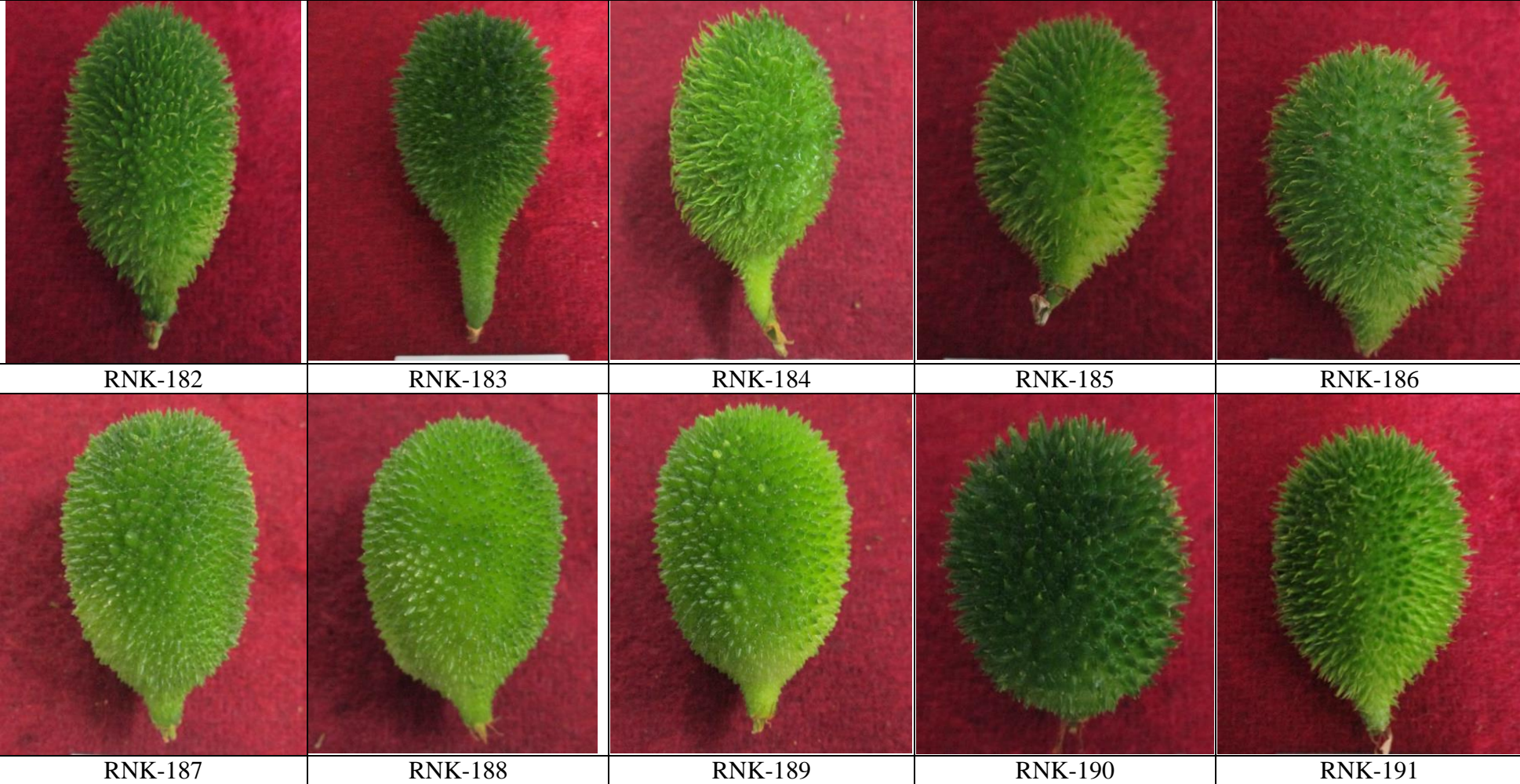
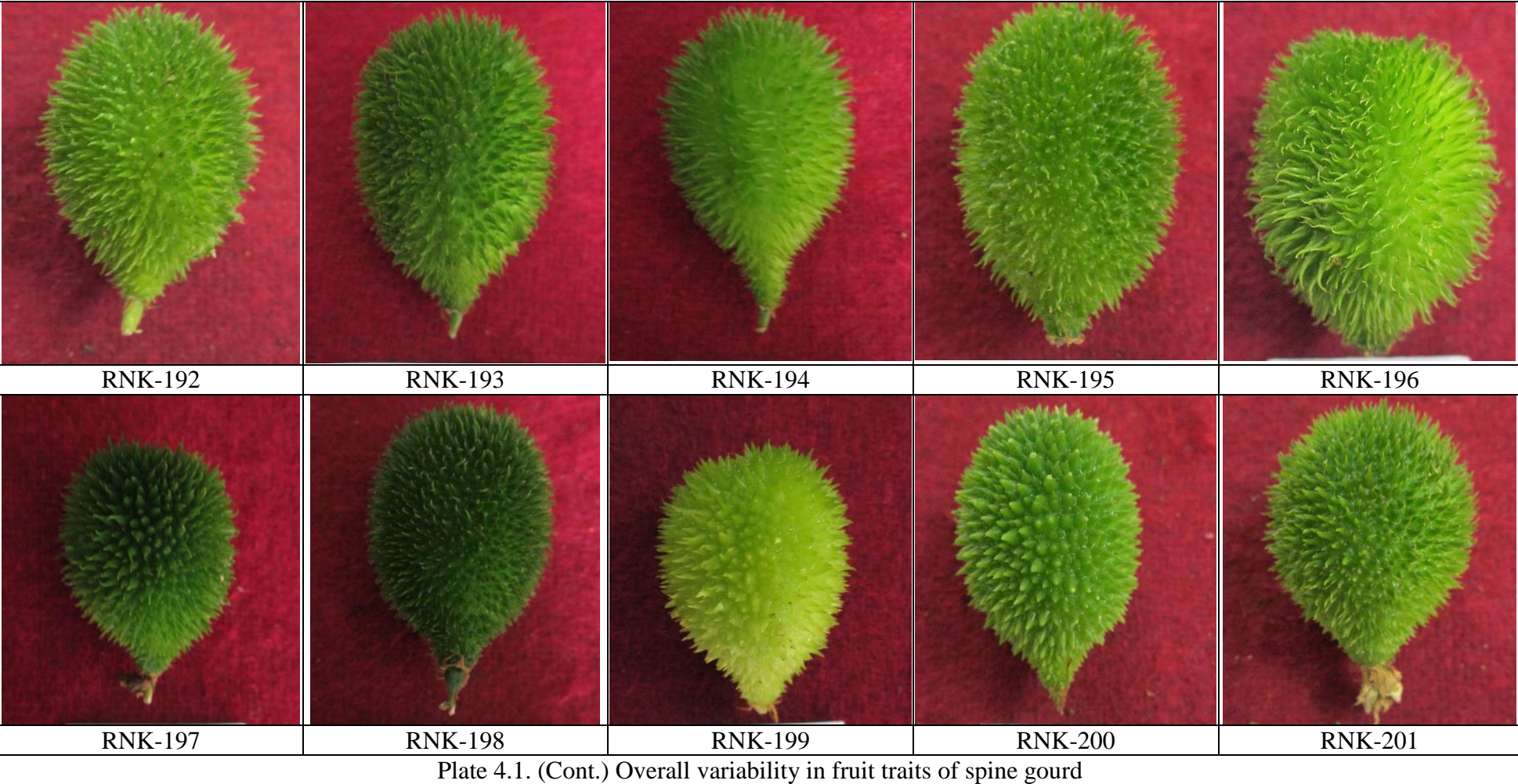












Plate 4.1. Overall variability in fruit traits of spine gourd



				
RNK-202	RNK-203	RNK-204	RNK-205	RNK-206
				
RNK-207	RNK-208	RNK-209	RNK-210	RNK-211
Plate 4.1. (Cont.) Overall variability in fruit traits of spine gourd				

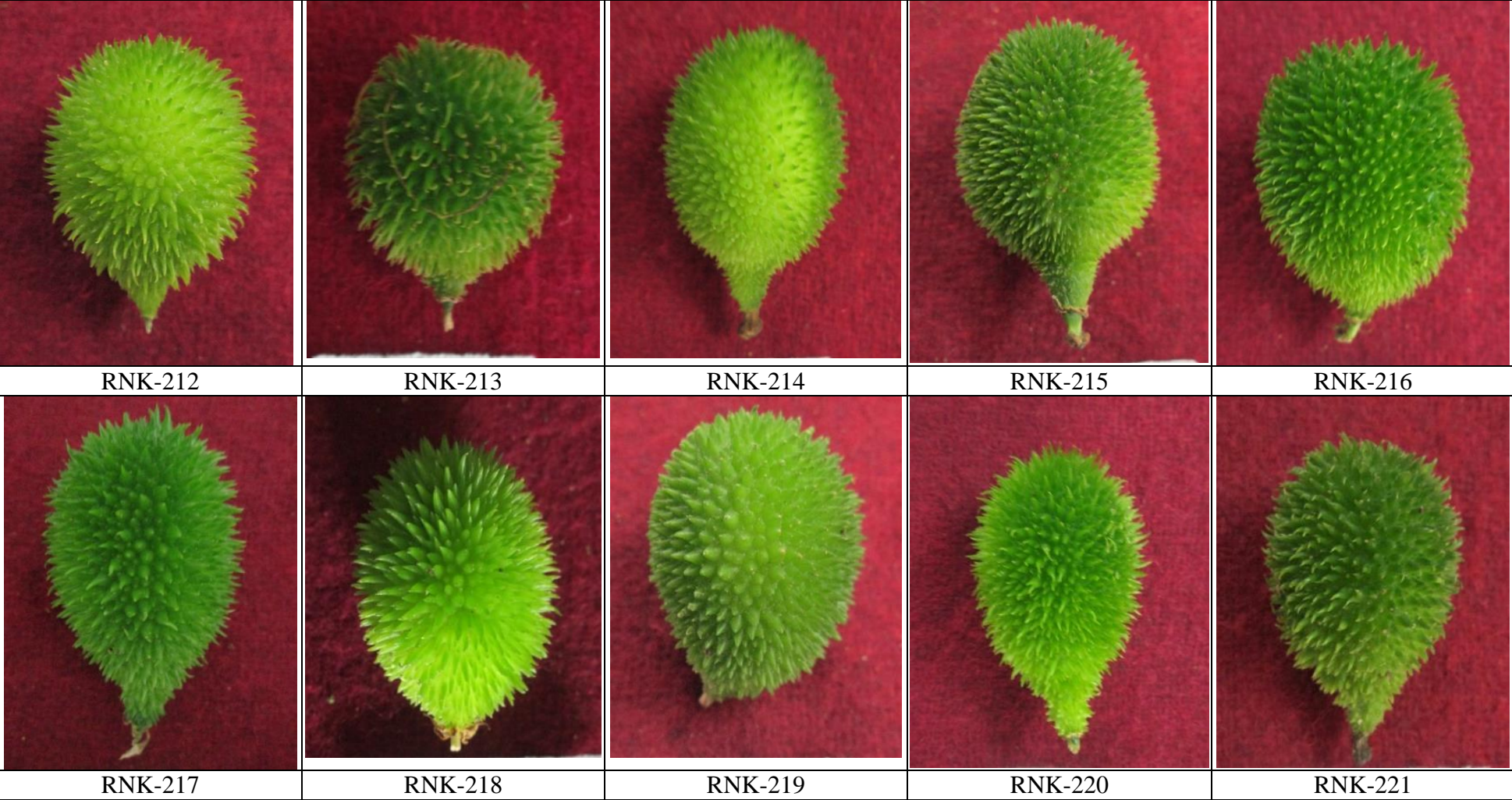


Plate 4.1. (Cont.) Overall variability in fruit traits of spine gourd

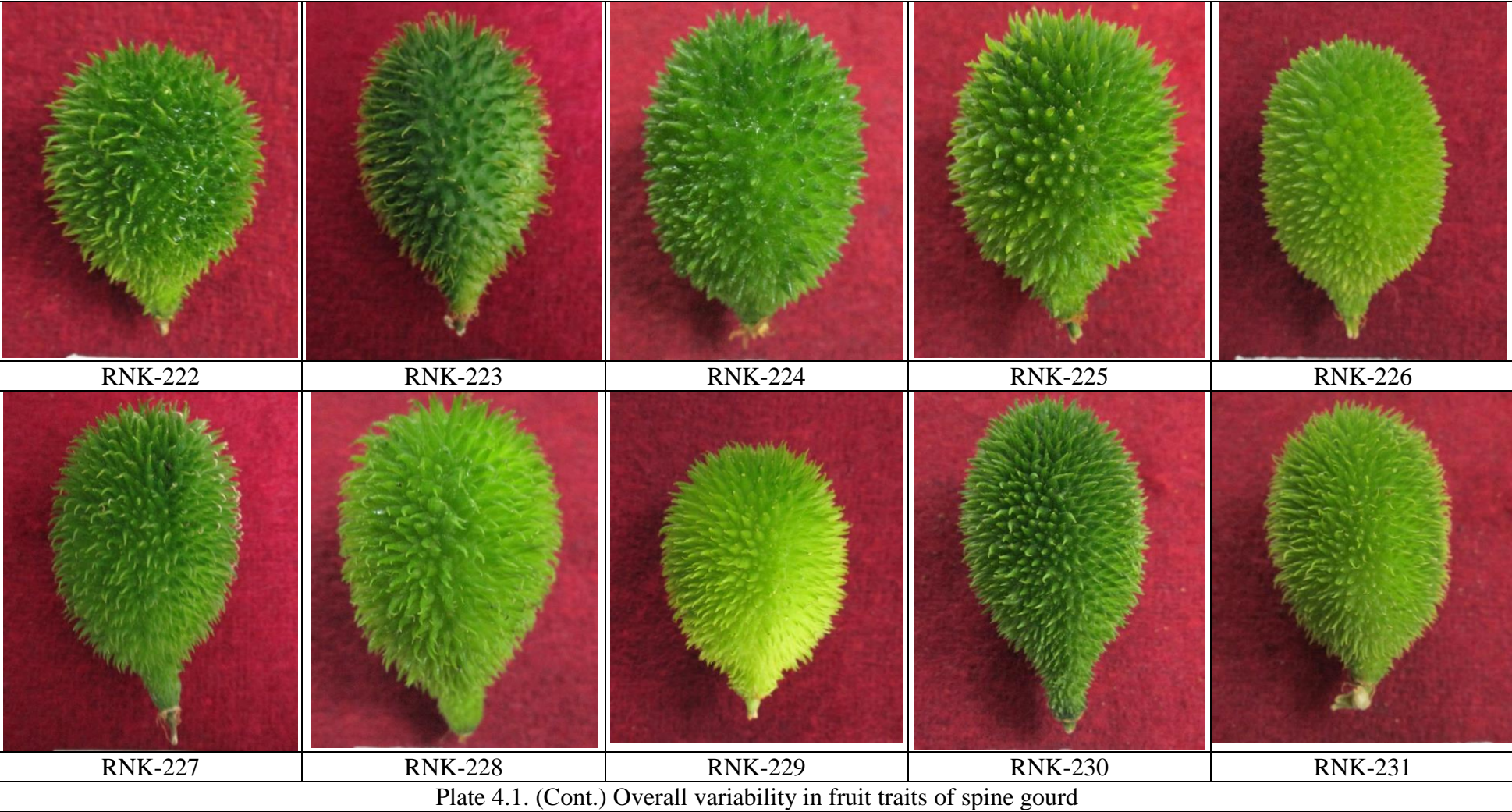


Table 4.3. Qualitative traits of female plants of spine gourd genotypes

Accession number	Vine tip pubescence	Leaf shape	Leaf margin	Leaf Pubescence	Leaf colour	Leaf venation	Leaf lobing
RNK-182	Scarcely pubescent	Palmate	Spiny	Medium	Light green	Fine network	Lobed
RNK-183	Scarcely pubescent	Palmate	Spiny	Dense	Green	Intermediate	Lobed
RNK-184	Scarcely pubescent	Palmate	Spiny	Dense	Dark green	Fine network	Lobed
RNK-185	Pubescent	Hastate	Spiny	Dense	Green	Intermediate	Lobed
RNK-186	Glabrous	Cordate	Dentate	Medium	Dark green	Fine network	Entire
RNK-187	Glabrous	Palmate	Spiny	Sparse	Light green	Fine network	Lobed
RNK-188	Scarcely pubescent	Palmate	Spiny	Sparse	Green	Fine network	Lobed
RNK-189	Scarcely pubescent	Cordate	Spiny	Medium	Green	Fine network	Entire
RNK-190	Glabrous	Palmate	Spiny	Medium	Green	Fine network	Lobed
RNK-191	Pubescent	Palmate	Spiny	Medium	Dark green	Fine network	Entire
RNK-192	Pubescent	Palmate	Spiny	Medium	Green	Fine network	Lobed
RNK-193	Glabrous	Hastate	Spiny	Dense	Green	Fine network	Lobed
RNK-194	Pubescent	Palmate	Spiny	Dense	Green	Fine network	Lobed
RNK-195	Pubescent	Palmate	Spiny	Medium	Dark green	Fine network	Lobed
RNK-196	Glabrous	Palmate	Serrate	Dense	Green	Fine network	Lobed
RNK-197	Glabrous	Palmate	Spiny	Dense	Dark green	Fine network	Lobed
RNK-198	Scarcely pubescent	Palmate	Spiny	Dense	Light green	Fine network	Lobed
RNK-199	Pubescent	Palmate	Spiny	Medium	Green	Fine network	Lobed
RNK-200	Scarcely pubescent	Palmate	Spiny	Dense	Green	Fine network	Lobed
RNK-201	Scarcely pubescent	Cordate	Spiny	Dense	Light green	Fine network	Entire
RNK-202	Scarcely pubescent	Palmate	Spiny	Medium	Green	Fine network	Lobed
RNK-203	Scarcely pubescent	Palmate	Spiny	Medium	Green	Fine network	Lobed
RNK-204	Pubescent	Palmate	Spiny	Dense	Dark green	Spaced network	Lobed
RNK-205	Scarcely pubescent	Palmate	Spiny	Dense	Dark green	Fine network	Entire
RNK-206	Scarcely pubescent	Palmate	Spiny	Dense	Dark green	Fine network	Entire
RNK-207	Glabrous	Cordate	Spiny	Medium	Dark green	Fine network	Entire
RNK-208	Pubescent	Palmate	Spiny	Sparse	Green	Spaced network	Lobed
RNK-209	Glabrous	Palmate	Spiny	Medium	Green	Fine network	Entire
RNK-210	Scarcely pubescent	Cordate	Spiny	Sparse	Dark green	Fine network	Entire
RNK-211	Glabrous	Cordate	Spiny	Dense	Dark green	Fine network	lobed
RNK-212	Glabrous	Palmate	Spiny	Medium	Dark green	Fine network	Entire
RNK-213	Glabrous	Cordate	Spiny	Medium	Green	Fine network	Entire
RNK-214	Glabrous	Palmate	Serrate	Dense	Dark green	Fine network	Lobed
RNK-215	Scarcely pubescent	Cordate	Spiny	Dense	Dark green	Fine network	Entire
RNK-216	Scarcely pubescent	Palmate	Spiny	Dense	Green	Fine network	Entire
RNK-217	Pubescent	Cordate	Spiny	Sparse	Green	Fine network	Entire
RNK-218	Scarcely pubescent	Palmate	Spiny	Medium	Dark green	Fine network	Lobed
RNK-219	Scarcely pubescent	Palmate	Spiny	Medium	Dark green	Fine network	Lobed
RNK-220	Pubescent	Palmate	Spiny	Sparse	Green	Fine network	Lobed
RNK-221	Pubescent	Palmate	Spiny	Medium	Dark green	Fine network	Lobed
RNK-222	Glabrous	Palmate	Spiny	Medium	Green	Fine network	Lobed
RNK-223	Glabrous	Cordate	Serrate	Medium	Dark green	Fine network	Entire
RNK-224	Glabrous	Palmate	Spiny	Dense	Green	Fine network	Lobed
RNK-225	Scarcely pubescent	Palmate	Spiny	Dense	Green	Fine network	Lobed
RNK-226	Pubescent	Palmate	Spiny	Dense	Green	Fine network	Lobed
RNK-227	Glabrous	Palmate	Spiny	Medium	Green	Fine network	Lobed
RNK-228	Scarcely pubescent	Palmate	Spiny	Dense	Dark green	Fine network	Lobed
RNK-229	Scarcely pubescent	Palmate	Spiny	Medium	Green	Fine network	Lobed
RNK-230	Scarcely pubescent	Palmate	Spiny	Medium	Dark green	Fine network	Lobed
RNK-231	Scarcely pubescent	Palmate	Spiny	Medium	Green	Fine network	Entire

Table 4.3 (Cont.)

Accession number	Extent of lobing	Lobe tip	Leaf odour	Leaf thickness	Extent of leaf margin dentation	Petiole-lamina juncture shape	Tendrill robustness
RNK-182	Deeply lobed and sublobed	Acute	Mild	Thin	Close	Subangulate	Medium
RNK-183	Shallowly lobed	Acuminate	Foetid	Medium	Spaced	Subangulate	Fragile
RNK-184	Shallowly lobed	Acuminate	Foetid	Thick	Close	Subangulate	Fragile
RNK-185	Shallowly lobed	Acuminate	Mild	Thick	Remote	Subangulate	Medium
RNK-186	-	-	Foetid (intense)	Thick	Close	Subangulate	Medium
RNK-187	Shallowly lobed	Acuminate	Foetid (intense)	Thin	Close	Cordate	Medium
RNK-188	Shallowly lobed	Acuminate	Mild	Thin	Close	Subangulate	Fragile
RNK-189	-	-	Foetid (intense)	Thin	Spaced	Subangulate	Medium
RNK-190	Shallowly lobed	Acuminate	Not foetid	Medium	Close	Subangulate	Medium
RNK-191	-	-	Mild	Thick	Remote	Cordate	Robust
RNK-192	Shallowly lobed	Acuminate	Foetid (intense)	Thin	Spaced	Subangulate	Fragile
RNK-193	Broadly angled margins	Acuminate	Foetid (intense)	Thin	Spaced	Round	Medium
RNK-194	Shallowly lobed	Acuminate	Mild	Thin	Remote	Subangulate	Fragile
RNK-195	Shallowly lobed	Acuminate	Foetid (intense)	Thick	Close	Cordate	Fragile
RNK-196	Shallowly lobed	Acute	Foetid (intense)	Thin	Spaced	Subangulate	Medium
RNK-197	Shallowly lobed	Acuminate	Mild	Thin	Spaced	Subangulate	Fragile
RNK-198	Deeply lobed and sublobed(deeply)	Acuminate	Foetid (intense)	Thin	Close	Cordate	Medium
RNK-199	Shallowly lobed	Acuminate	Foetid (intense)	Thin	Close	Cordate	Robust
RNK-200	Shallowly lobed	Acuminate	Mild	Thin	Close	Subangulate	Fragile
RNK-201	-	-	Mild	Thin	Close	Subangulate	Robust
RNK-202	Broadly angled margins	Acuminate	Not foetid	Medium	Spaced	Subangulate	Fragile
RNK-203	Shallowly lobed	Acuminate	Foetid (intense)	Medium	Remote	Subangulate	Fragile
RNK-204	Shallowly lobed	Acuminate	Mild	Thick	Remote	Subangulate	Robust
RNK-205	-	-	Not foetid	Thick	Spaced	Subangulate	Robust
RNK-206	-	-	Foetid (intense)	Thin	Spaced	Subangulate	Fragile
RNK-207	-	-	Not foetid	Thick	Close	Subangulate	Robust
RNK-208	Shallowly lobed	Acuminate	Mild	Thin	Close	Subangulate	Robust
RNK-209	-	-	Foetid (intense)	Thin	Close	Cordate	Medium
RNK-210	-	-	Not foetid	Thick	Close	Round	Fragile
RNK-211	Broadly angled margins	Acuminate	Foetid (intense)	Thick	Close	Subangulate	Fragile
RNK-212	-	-	Foetid (intense)	Thin	Close	Subangulate	Fragile
RNK-213	-	-	Foetid (intense)	Thick	Close	Cordate	Medium
RNK-214	Broadly angled margins	Acuminate	Mild	Medium	Close	Cordate	Medium
RNK-215	-	-	Foetid (intense)	Thin	Spaced	Cordate	Fragile
RNK-216	-	-	Mild	Thick	Close	Subangulate	Medium
RNK-217	-	-	Foetid (intense)	Medium	Close	Subangulate	Robust
RNK-218	Broadly angled margins	Acuminate	Mild	Thick	Close	Subangulate	Robust
RNK-219	Deeply lobed and sublobed	Acuminate	Foetid (intense)	Thin	Close	Subangulate	Fragile
RNK-220	Shallowly lobed	Acuminate	Foetid (intense)	Medium	Close	Cordate	Fragile
RNK-221	Shallowly lobed	Acuminate	Not foetid	Thin	Close	Subangulate	Medium
RNK-222	Deeply lobed and sublobed	Acuminate	Foetid (intense)	Thin	Close	Cordate	Fragile
RNK-223	-	-	Mild	Medium	Close	Subangulate	Fragile
RNK-224	Broadly angled margins	Acuminate	Not foetid	Medium	Spaced	Subangulate	Medium
RNK-225	Shallowly lobed	Acuminate	Foetid (intense)	Thin	Close	Cordate	Medium
RNK-226	Deeply lobed and sublobed	Acuminate	Not foetid	Thin	Remote	Cordate	Medium
RNK-227	Deeply lobed and sublobed	Acuminate	Mild	Thin	Close	Subangulate	Medium
RNK-228	Deeply lobed and sublobed	Acuminate	Foetid (intense)	Thick	Remote	Cordate	Robust
RNK-229	Deeply lobed and sublobed	Acuminate	Mild	Medium	Close	Subangulate	Fragile
RNK-230	Broadly angled margins	Acuminate	Foetid (intense)	Thin	Close	Subangulate	Robust
RNK-231	-	-	Not foetid	Thin	Spaced	Subangulate	Medium

Table 4.3 (Cont.)

Accession number	Tendrill length	Female flower bract size	Female flower bract position	Gynoecium	Ovary surface	Fruit size	Immature fruit colour
RNK-182	Medium	Medium large	Near axis	Small	Soft	small	Light green
RNK-183	Short	Medium large	Midway on pedicle	Large	Hard	Medium	Dark green
RNK-184	Medium	Minute Scar like	Near axis	Large	Hard	Medium	Dark Green
RNK-185	Medium	Medium large	Near axis	Large	Soft	Medium	green
RNK-186	Medium	Medium large	Midway on pedicle	Large	Hard	Medium	green
RNK-187	Medium	Large	Midway on pedicle	Large	Hard	Large	Dark green
RNK-188	Medium	Medium large	Midway on pedicle	Small	Hard	Medium	green
RNK-189	Medium	Minute Scar like	Near axis	Large	Hard	Small	green
RNK-190	Very long	Medium large	Midway on pedicle	Large	Hard	small	Dark green
RNK-191	Medium	Medium large	Midway on pedicle	Large	Soft	Medium	Dark green
RNK-192	Medium	Minute Scar like	Midway on pedicle	Large	Soft	Large	Dark green
RNK-193	Medium	Medium large	Near axis	Medium	Soft	Medium	green
RNK-194	Medium	Medium large	Midway on pedicle	Medium	Hard	Medium	Dark green
RNK-195	Medium	Minute Scar like	Midway on pedicle	Medium	Hard	Medium	Light green
RNK-196	Medium	Medium large	Midway on pedicle	Medium	Hard	Medium	Dark green
RNK-197	Medium	Minute Scar like	Midway on pedicle	Medium	Hard	Large	Light green
RNK-198	Medium	Minute Scar like	Near axis	Medium	Soft	Medium	Dark green
RNK-199	Medium	Medium large	Midway on pedicle	Large	Hard	Medium	Dark green
RNK-200	Medium	Medium large	Midway on pedicle	Medium	Soft	Large	Light green
RNK-201	Short	Medium large	Midway on pedicle	Medium	Soft	Medium	Light green
RNK-202	Medium	Minute Scar like	Near axis	Large	Hard	Medium	Light green
RNK-203	Medium	Large	Just below gynoecium	Medium	Hard	Medium	Light green
RNK-204	Medium	Medium large	Midway on pedicle	Medium	Hard	Medium	Light green
RNK-205	Medium	Medium large	Midway on pedicle	Medium	Hard	Medium	Light green
RNK-206	Medium	Medium large	Near axis	Large	Hard	Medium	Whitish green
RNK-207	Medium	Medium large	Near axis	Medium	Soft	Medium	Light green
RNK-208	Medium	Medium large	Near axis	Large	Hard	Medium	green
RNK-209	Medium	Minute Scar like	Midway on pedicle	Medium	Hard	Small	Whitish green
RNK-210	Short	Large	Midway on pedicle	Large	Soft	small	Dark green
RNK-211	Short	Minute Scar like	Midway on pedicle	Large	Soft	small	yellowish green
RNK-212	Medium	Minute Scar like	Just below gynoecium	Medium	Soft	small	Light green
RNK-213	Medium	Minute Scar like	Midway on pedicle	Medium	Soft	Medium	green
RNK-214	Medium	Large	Just below gynoecium	Medium	Hard	Small	green
RNK-215	Short	Large	Just below gynoecium	Medium	Hard	Medium	Dark green
RNK-216	Medium	Large	Just below gynoecium	Medium	Soft	Medium	Dark green
RNK-217	Medium	Minute Scar like	Midway on pedicle	Large	Hard	Small	green
RNK-218	Medium	Medium large	Near axis	Small	Soft	small	green
RNK-219	Medium	Minute Scar like	Near axis	Large	Hard	Medium	Light green
RNK-220	Medium	Minute Scar like	Near axis	Large	Soft	Medium	green
RNK-221	Medium	Medium large	Midway on pedicle	Medium	Soft	Medium	Dark green
RNK-222	Medium	Medium large	Midway on pedicle	Large	Soft	Medium	Dark green
RNK-223	Medium	Minute Scar like	Midway on pedicle	Medium	Hard	Medium	green
RNK-224	Medium	Medium large	Near axis	Large	Hard	Large	Dark green
RNK-225	Medium	Minute Scar like	Near axis	Medium	Hard	Medium	Light green
RNK-226	Medium	Medium large	Midway on pedicle	Medium	Hard	Large	Light green
RNK-227	Medium	Medium large	Midway on pedicle	Medium	Hard	Large	green
RNK-228	Medium	Minute Scar like	Near axis	Medium	Soft	Medium	green
RNK-229	Medium	Minute Scar like	Near axis	Small	Soft	Medium	Whitish green
RNK-230	Medium	Large	Midway on pedicle	Large	Soft	Medium	Dark green
RNK-231	Medium	Large	Just below gynoecium	Large	Hard	Large	Dark green

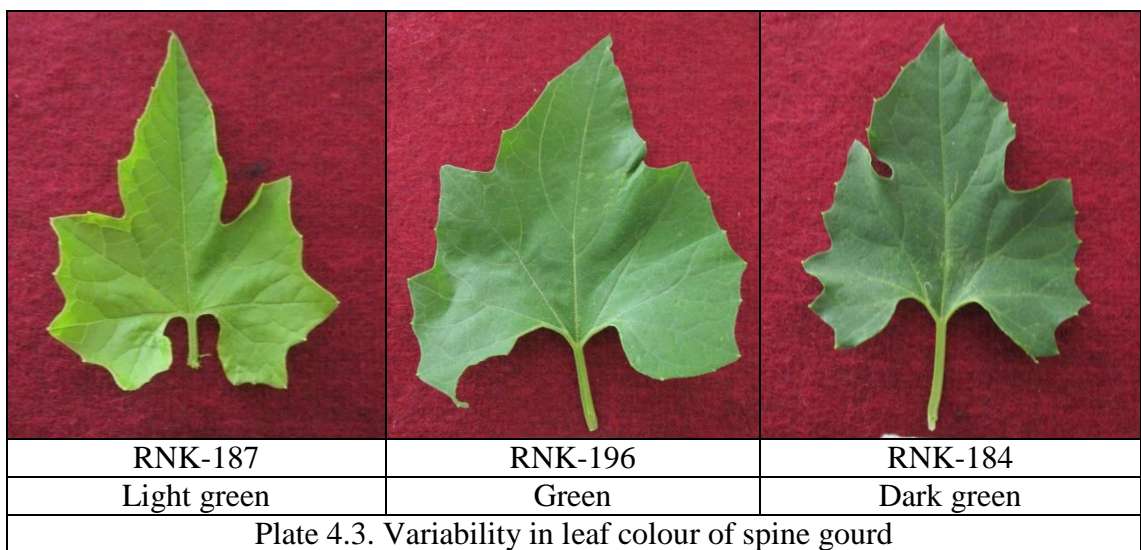
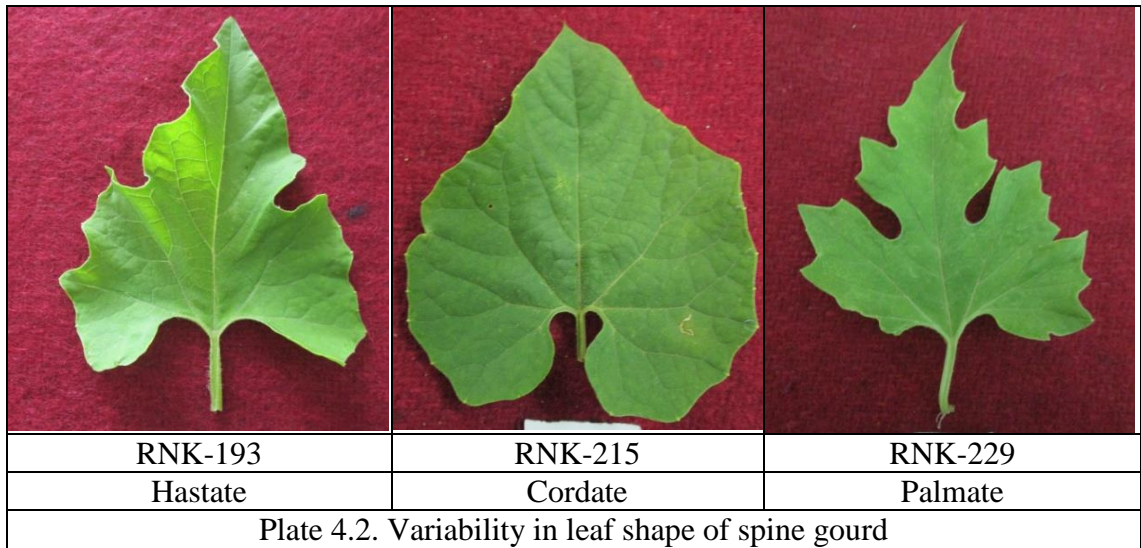
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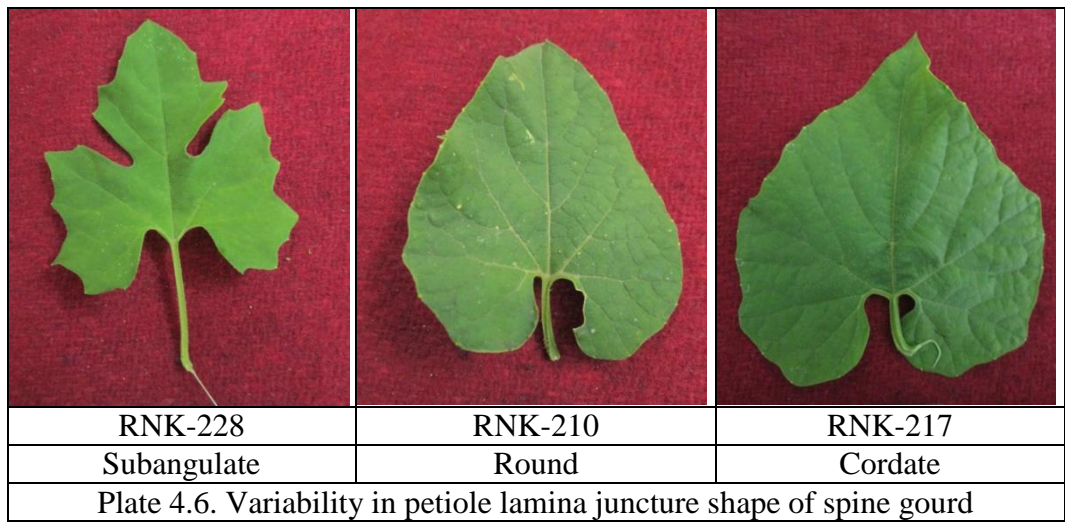
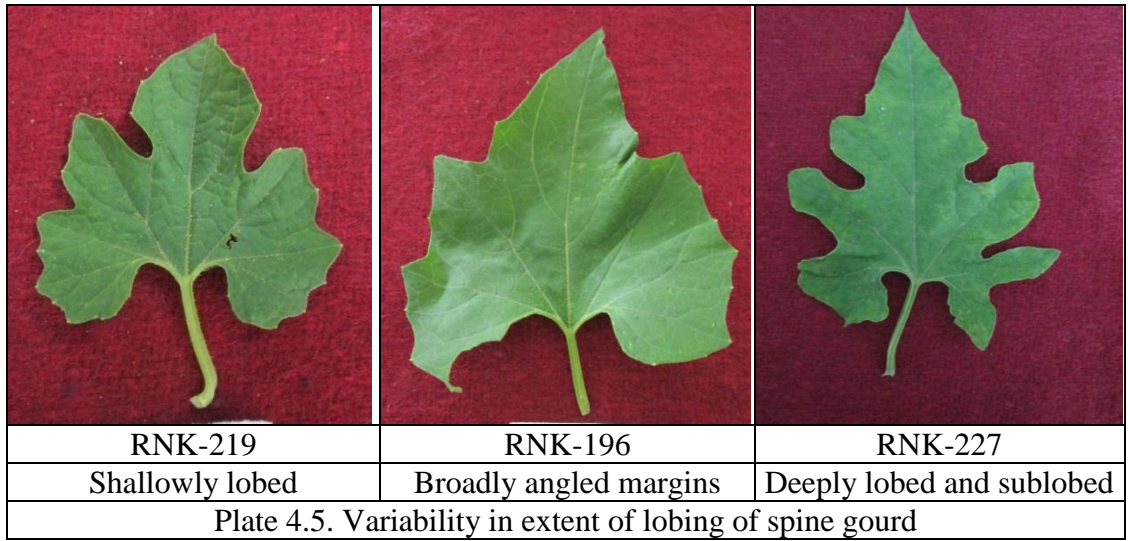
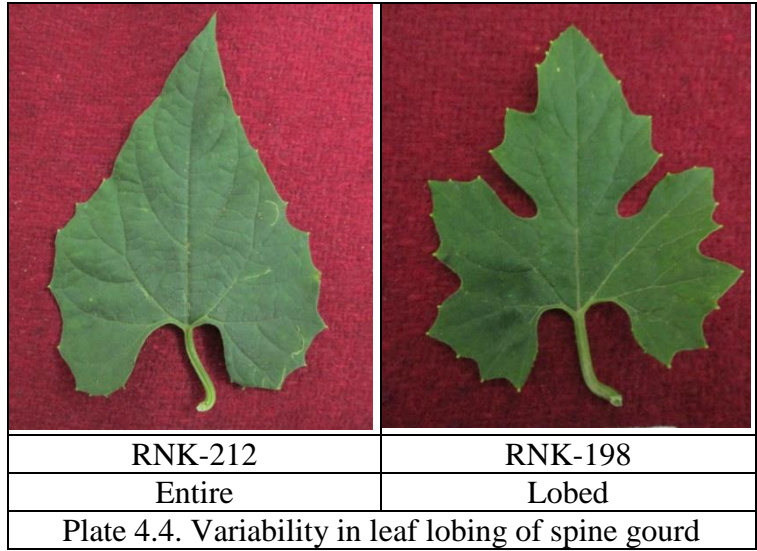
Accession number	Fruit surface echination	Fruit cross section	Fruit shape	Fruit pericarp ripening	Fruit blossom end rostration	Fruit spine strength	Calyx persistence	Fruit bitterness
RNK-182	Densely echinate	U.S	Oblong	Sudden	Appreciable length	Medium	persistent	Not bitter
RNK-183	Densely echinate	U.S	Oblong	Sudden	Appreciable length	Hard	persistent	Not bitter
RNK-184	Densely echinate	U.S	Obovate	Slow	Appreciable length	Soft	persistent	Not bitter
RNK-185	Densely echinate	U.S	Obovate	Sudden	Medium	Medium	persistent	Not bitter
RNK-186	Densely echinate	U.S	Oval	Slow	Medium	Soft	persistent	Not bitter
RNK-187	Densely echinate	U.S	Oblong	Sudden	Medium	Hard	persistent	Not bitter
RNK-188	Densely echinate	U.S	Oblong	Slow	Medium	Hard	persistent	Not bitter
RNK-189	Densely echinate	U.S	Round	Slow	Medium	Hard	persistent	Not bitter
RNK-190	Densely echinate	U.S	Round	Sudden	Faint	Medium	persistent	Not bitter
RNK-191	Densely echinate	U.S	Round	Slow	Medium	Medium	persistent	Not bitter
RNK-192	Densely echinate	U.S	Oval	Sudden	Faint	Medium	persistent	Not bitter
RNK-193	Densely echinate	U.S	Oblong	Sudden	Medium	Medium	persistent	Not bitter
RNK-194	Densely echinate	U.S	Oval	Slow	Appreciable length	Soft	persistent	Not bitter
RNK-195	Densely echinate	U.S	Oblong	Slow	Faint	Hard	persistent	Not bitter
RNK-196	Densely echinate	U.S	Obovate	Slow	Faint	Soft	persistent	Not bitter
RNK-197	Densely echinate	U.S	Obovate	Slow	Faint	Hard	persistent	Not bitter
RNK-198	Densely echinate	U.S	Top	Sudden	Faint	Medium	persistent	Slightly bitter
RNK-199	mild-sparsely echinate	U.S	Top	Slow	Faint	Hard	persistent	Not bitter
RNK-200	Densely echinate	U.S	Oblong	Slow	Faint	Hard	persistent	Not bitter
RNK-201	Densely echinate	U.S	Top	Sudden	Faint	Medium	persistent	Not bitter
RNK-202	Densely echinate	U.S	Oblong	Sudden	Medium	Medium	persistent	Not bitter
RNK-203	Densely echinate	U.S	Obovate	Slow	Medium	Soft	persistent	Not bitter
RNK-204	Densely echinate	U.S	Oblong	Sudden	Medium	Soft	persistent	Not bitter
RNK-205	Densely echinate	U.S	Obovate	Slow	Medium	Medium	persistent	Not bitter
RNK-206	mild-sparsely echinate	U.S	Oblong	Slow	Appreciable length	Hard	persistent	Not bitter
RNK-207	Densely echinate	U.S	Obovate	Slow	Medium	Hard	persistent	Not bitter
RNK-208	Densely echinate	U.S	Cylindrical	Sudden	Medium	Hard	persistent	Not bitter
RNK-209	Densely echinate	U.S	Oblong	Slow	Medium	Medium	persistent	Not bitter
RNK-210	Densely echinate	U.S	Oval	Sudden	Faint	Hard	persistent	Not bitter
RNK-211	Densely echinate	U.S	Oval	Sudden	Medium	Medium	persistent	Not bitter
RNK-212	Densely echinate	U.S	Oval	Sudden	Medium	Medium	persistent	Not bitter
RNK-213	Densely echinate	U.S	Obovate	Slow	Faint	Soft	persistent	Not bitter
RNK-214	Densely echinate	U.S	Oblong	Sudden	Appreciable length	Hard	persistent	Not bitter
RNK-215	Densely echinate	U.S	Round	Slow	Medium	Hard	persistent	Not bitter
RNK-216	Densely echinate	U.S	Obovate	Sudden	Appreciable length	Medium	persistent	Not bitter
RNK-217	Densely echinate	U.S	Oblong	Sudden	Medium	Hard	persistent	Not bitter
RNK-218	Densely echinate	U.S	Round	Slow	faint	Hard	persistent	Not bitter
RNK-219	Densely echinate	U.S	Oval	Slow	Faint	Hard	persistent	Not bitter
RNK-220	Densely echinate	U.S	Obovate	Sudden	Medium	Medium	persistent	Not bitter
RNK-221	Densely echinate	U.S	Oblong	Sudden	Medium	Medium	persistent	Not bitter
RNK-222	Densely echinate	U.S	Oval	Slow	Faint	Soft	persistent	Not bitter
RNK-223	mild-sparsely echinate	U.S	Oblong	Sudden	Medium	Soft	persistent	Not bitter
RNK-224	Densely echinate	U.S	Oblong	Slow	Faint	Hard	persistent	Slightly bitter
RNK-225	mild-sparsely echinate	U.S	Obovate	Sudden	Faint	Hard	persistent	Not bitter
RNK-226	Densely echinate	U.S	Elongated	Slow	Medium	Hard	persistent	Not bitter
RNK-227	Densely echinate	U.S	Oblong	Sudden	Medium	Medium	persistent	Not bitter
RNK-228	mild-sparsely echinate	U.S	Oblong	Slow	Medium	Soft	caducous	Not bitter
RNK-229	Densely echinate	U.S	Oblong	Sudden	Medium	Medium	persistent	Not bitter
RNK-230	Densely echinate	U.S	Obovate	Slow	Appreciable length	Medium	persistent	Not bitter
RNK-231	Densely echinate	U.S	Oblong	Slow	Faint	Soft	persistent	Not bitter

U.S = Uniformly soft echinate

Table 4.3 (Cont.)

Accession number	Seed aril colour	Seed shape	Seed sculpturing	Extent of sculpturing	Seed ornamentation	Type of ornamentation	Seed sides (margins)
RNK-182	Blood red	Globular	Present	Medium	Present	Golden lines on black seed coat	Wavy
RNK-183	Scarlet	Globular	Absent	-	Absent	-	Smooth
RNK-184	Scarlet	Oval	Present	Filigree	Absent	-	Smooth
RNK-185	Red	Globular	Absent	-	Absent	-	Smooth
RNK-186	Scarlet	Oval	Present	Filigree	Present	Golden lines on black seed coat	Wavy
RNK-187	Blood red	Round	Present	Filigree	Present	Golden lines on black seed coat	Smooth
RNK-188	Scarlet	Oval	Present	Medium	Absent	-	Smooth
RNK-189	Red	Globular	Present	Filigree	Absent	-	Wavy
RNK-190	Blood red	Globular	Present	Filigree	Present	Golden lines on black seed coat	Wavy
RNK-191	Scarlet	Globular	Present	Filigree	Present	Golden lines on black seed coat	Smooth
RNK-192	Orange	Oval	Present	Filigree	Present	Golden lines on black seed coat	Wavy
RNK-193	Blood red	Oval	Present	Filigree	Present	Golden lines on black seed coat	Smooth
RNK-194	Red	Oval	Present	Filigree	Present	Golden lines on black seed coat	Wavy
RNK-195	Scarlet	Round	Present	Filigree	Present	Golden lines on black seed coat	Smooth
RNK-196	Scarlet	Globular	Present	Filigree	Present	Golden lines on black seed coat	Smooth
RNK-197	Red	Globular	Present	Filigree	Present	Golden lines on black seed coat	Smooth
RNK-198	Scarlet	Globular	Present	Filigree	Present	Golden lines on black seed coat	Smooth
RNK-199	Blood red	Globular	Present	Filigree	Present	Golden lines on black seed coat	Smooth
RNK-200	Scarlet	Oval	Present	Filigree	Present	Golden lines on black seed coat	Wavy
RNK-201	Scarlet	Globular	Present	Medium	Absent	-	Wavy
RNK-202	Scarlet red	Oval	Present	Filigree	Present	Golden lines on black seed coat	Wavy
RNK-203	Scarlet	Globular	Present	Filigree	Absent	-	Smooth
RNK-204	Scarlet	Round	Present	Medium	Absent	-	Wavy
RNK-205	Blood red	Globular	Present	Filigree	Present	Golden lines on black seed coat	Smooth
RNK-206	Red	Round	Present	Filigree	Absent	-	Wavy
RNK-207	Scarlet red	Globular	Present	Filigree	Absent	-	Wavy
RNK-208	Red	Round	Present	Medium	Present	Golden lines on black seed coat	Smooth
RNK-209	Blood red	Globular	Present	Filigree	Present	Golden lines on black seed coat	Smooth
RNK-210	Scarlet	Globular	Present	Filigree	Absent	-	Smooth
RNK-211	Red	Globular	Present	Medium	Present	Golden lines on black seed coat	Smooth
RNK-212	Blood red	Oval	Present	Filigree	Present	Golden lines on black seed coat	Wavy
RNK-213	Blood red	Globular	Present	Filigree	Absent	-	Smooth
RNK-214	Blood red	Round	Present	Faint	Absent	-	Wavy
RNK-215	Orange	Globular	Present	Filigree	Present	Golden lines on black seed coat	Wavy
RNK-216	Scarlet	Round	Present	Filigree	Present	Golden lines on black seed coat	Wavy
RNK-217	Scarlet	Globular	Present	Filigree	Present	Golden lines on black seed coat	Wavy
RNK-218	Scarlet	Round	Present	Filigree	Present	Golden lines on black seed coat	Smooth
RNK-219	Blood red	Round	Present	Filigree	Absent	-	Smooth
RNK-220	Red	Globular	Present	Medium	Absent	-	Smooth
RNK-221	Blood red	Oval	Present	Filigree	Present	Golden lines on black seed coat	Wavy
RNK-222	Scarlet	Globular	Present	Filigree	Absent	-	Wavy
RNK-223	Scarlet	Oval	Present	Filigree	Present	Golden lines on black seed coat	Smooth
RNK-224	Red	Oval	Present	Filigree	Absent	-	Wavy
RNK-225	Blood red	Globular	Present	Medium	Absent	-	Wavy
RNK-226	Red	Globular	Present	Filigree	Absent	-	Smooth
RNK-227	Blood red	Globular	Present	Filigree	Absent	-	Smooth
RNK-228	Scarlet	Oval	Present	Medium	Present	Golden lines on black seed coat	Wavy
RNK-229	Red	Globular	Present	Filigree	present	Golden lines on black seed coat	Wavy
RNK-230	Light scarlet	Globular	Present	Filigree	Absent	-	Wavy
RNK-231	Scarlet	Round	Present	Filigree	Present	Golden lines on black seed coat	Wavy





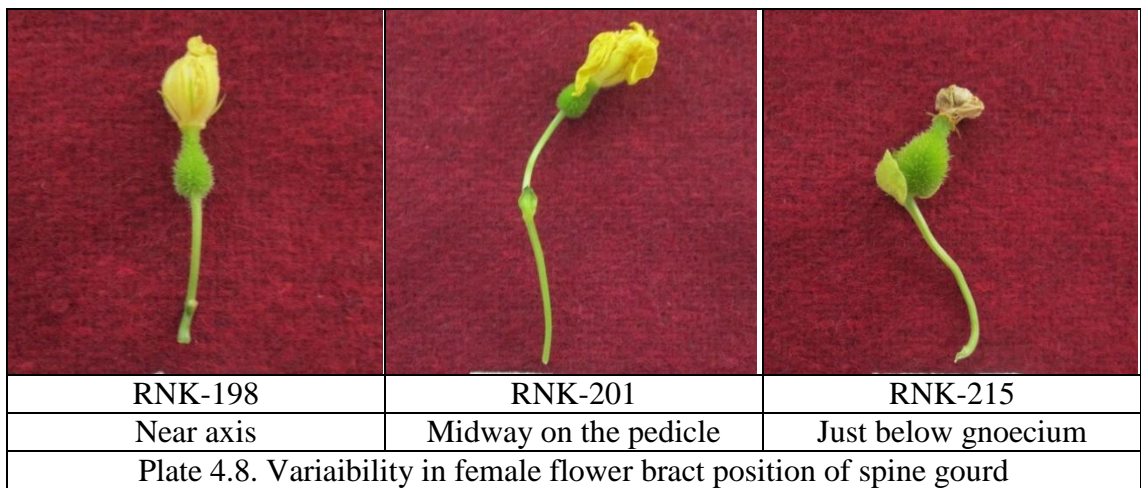
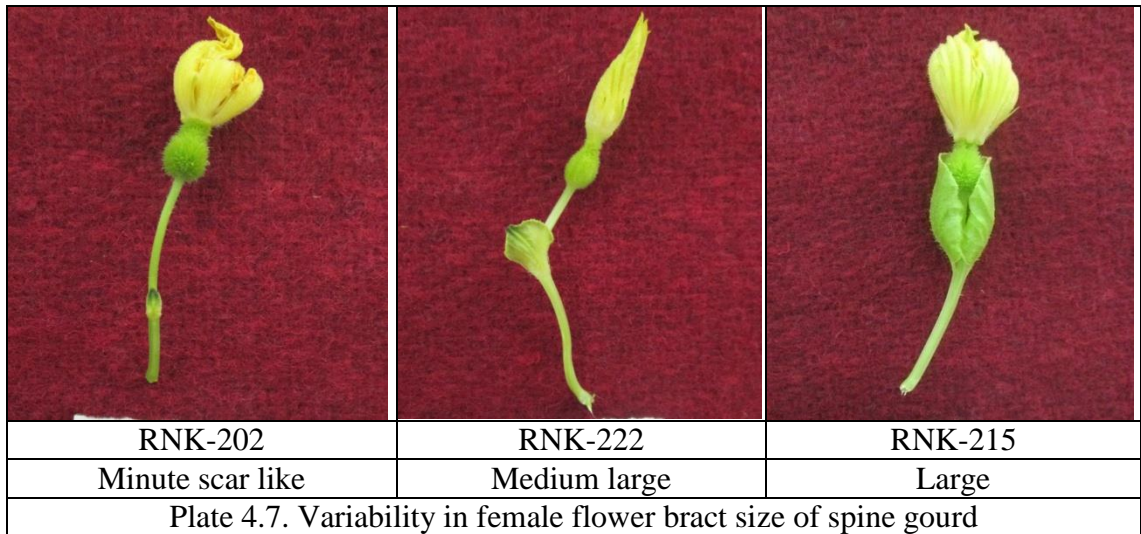
4.2.5.2 Female inflorescence and flower traits

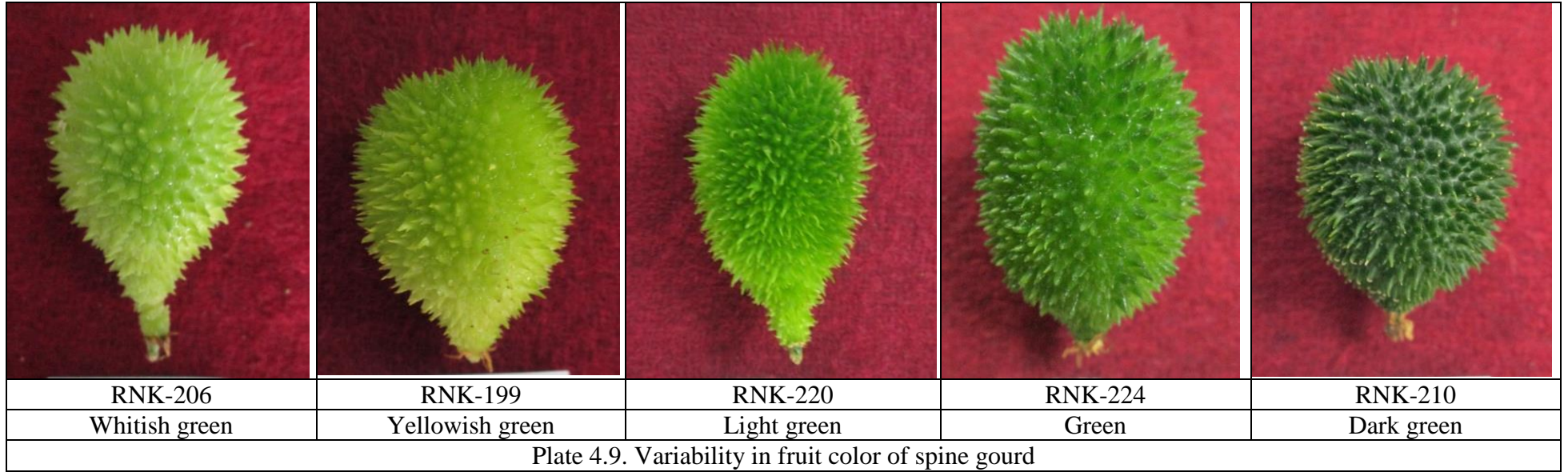
Characterization based on female flower bract size revealed that 24 genotypes had medium large bracts, 18 genotypes had minute scar like bracts and remaining 8 genotypes had large bracts (Plate 4.7). The study revealed that female flower bract was found midway on pedicle in 27 genotypes, near axis in 17 genotypes and just below gynoecium in remaining 6 genotypes (Plate 4.8). Characterization on basis of gynoecium size revealed that 24 genotypes had medium size, 22 genotypes had large size and remaining 4 genotypes had small size gynoecium. Ovary surface was found to be soft in 21 genotypes and hard in 29 genotypes.

4.2.5.3 Fruit traits

Among the 50 genotypes, 32 produced medium sized fruits, 8 produced large fruits and remaining 10 genotypes produced small sized fruits. Morphological characterization based on fruit colour revealed that 18 genotypes produced dark green fruits, 14 genotypes produced green fruits, 14 genotypes produced light green fruits, 3 genotypes produced whitish green fruits and 1 genotype had yellowish green fruits (Plate 4.9). Study revealed that fruits of 45 genotypes were found to be densely echinate, while remaining 5 genotypes had mild-sparsely echinated fruits. Cross section of mature fruits at equatorial point was found to be uniformly soft echinate in all the genotypes studied.

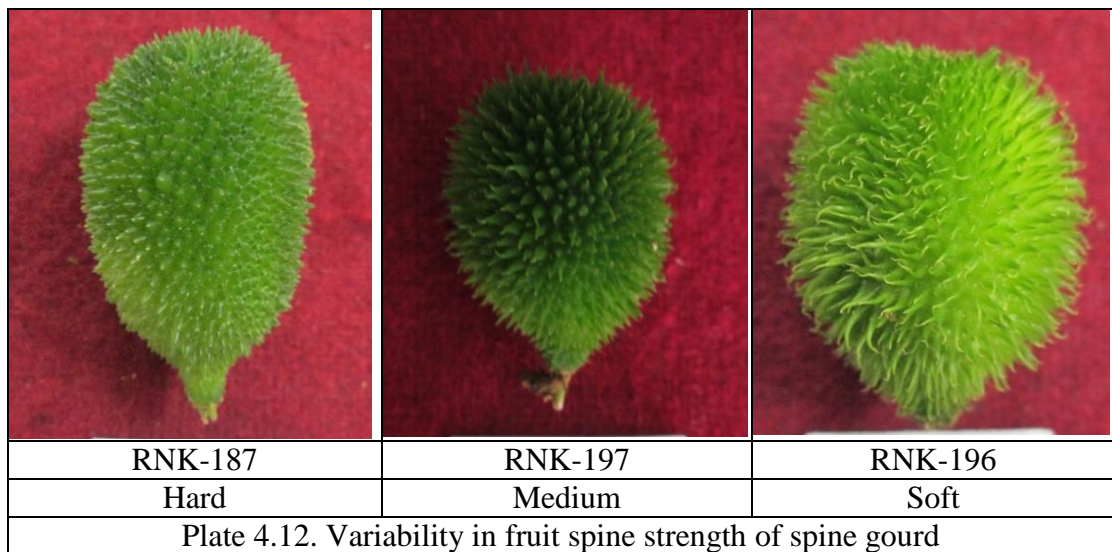
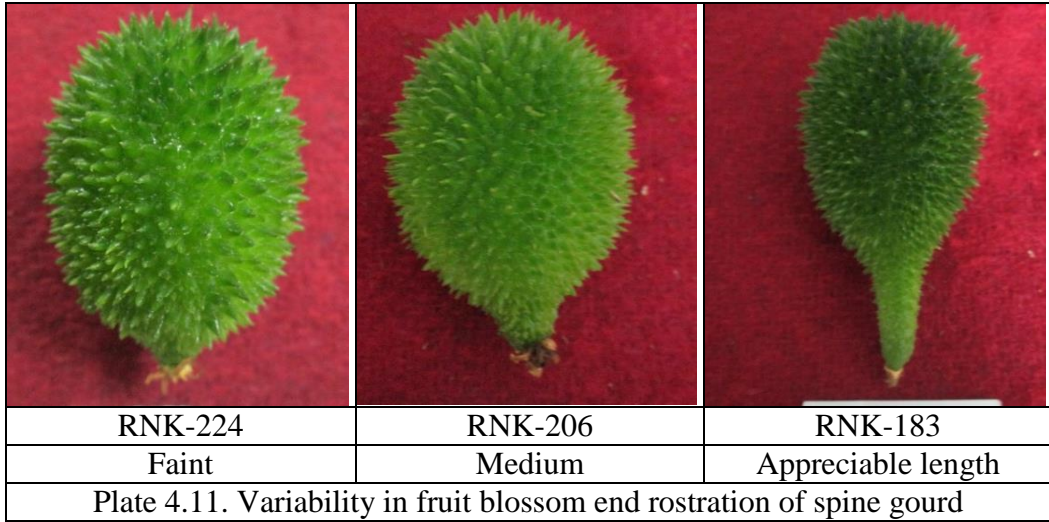
Wide variation was observed with respect to fruit shape among the 50 genotypes studied. Twenty genotypes produced oblong fruits, 12 genotypes produced obovate fruits, 8 genotypes had oval fruits, 5 genotypes produced round fruits, 3 genotypes had top shaped fruits and remaining 2 produced cylindrical fruits (Plate 4.10). Fruit pericarp ripening was found to be slow in 24 genotypes and slow in 26 genotypes. Blossom end rostration of fruits was found to be medium long in 25 genotypes, faint in 17 genotypes and appreciable long in remaining 8 genotypes (Plate 4.11). In the present study, it was found that calyx was persistent on fruits of all the genotypes characterized. Fruits were found to be slightly bitter in 2 genotypes and non bitter in remaining 48 genotypes. Fruit spine strength was found to be hard in 20 genotypes, medium in 19 genotypes and soft in 11 genotypes (Plate 4.12).







RNK-182	RNK-206	RNK-186	RNK-190	RNK-222
Oblong	Obovate	Oval	Round	Top
Plate 4.10. Variability in fruit shape of spine gourd				



4.2.5.4 Seed traits




Wide variation was observed for the seed aril colour at ripening stage. Twenty genotypes had scarlet colour aril, 14 had blood red aril, 11 had red aril, 2 scarlet red, 2 orange and 1 genotype had light scarlet colour aril (Plate 4.13). Seed shape was found to be globular in 27 genotypes, oval in 13 genotypes and round in remaining 10 genotypes (Plate 4.14). Among the 50 genotypes studied, seeds were found sculptured in 48 genotypes and sculpturing was absent in seeds of 2 genotypes (Plate 4.15). Characterization based on extent of sculpturing revealed that 38 genotypes had filigree type, 9 genotypes had medium and 1 genotype had faint sculpturing (Plate 4.16). Among the 50 genotypes characterized, seed ornamentation was present in 29 genotypes and absent in 21 genotypes. Type of seed ornamentation was found as golden lines on black seed coat in 29 genotypes (Plate 4.17). Characterization based on seed sides revealed that 25 genotypes had smooth seed sides and 25 genotypes had wavy seed sides.




Considerable variation for fruit morphological traits such as fruit shape (round, oblong), base (roundish, broad, conical), apex (narrowly round, roundish, conical round), colour at edible maturity (dark greenish, light yellowish), and taste (sweet) was also observed in spine gourd by Ram *et al.* (2001) among 18 female and 2 male lines of diverse nature from Vindhyachal hills.



On the basis of mean performance for growth, earliness, fruit attributes and quality traits, the genotypes RNK-224, RNK-197, RNK-200, RNK-196 and RNK-187 were found not only high yielding but also with acceptable fruit quality (Plate 4.18). However these horticulturally superior and high yielding genotypes thus identified are to be further evaluated in different environments over the years before commercial exploitation.




4.3 VARIABILITY, HERITABILITY (H^2_b) AND GENETIC ADVANCE



The success of a breeding programme for the genetic improvement of quantitative characters depends on the magnitude of genetic variability existing in the germplasm and the extent to which the desirable characters are heritable. The determination of genetic variability and partitioning it into heritable and

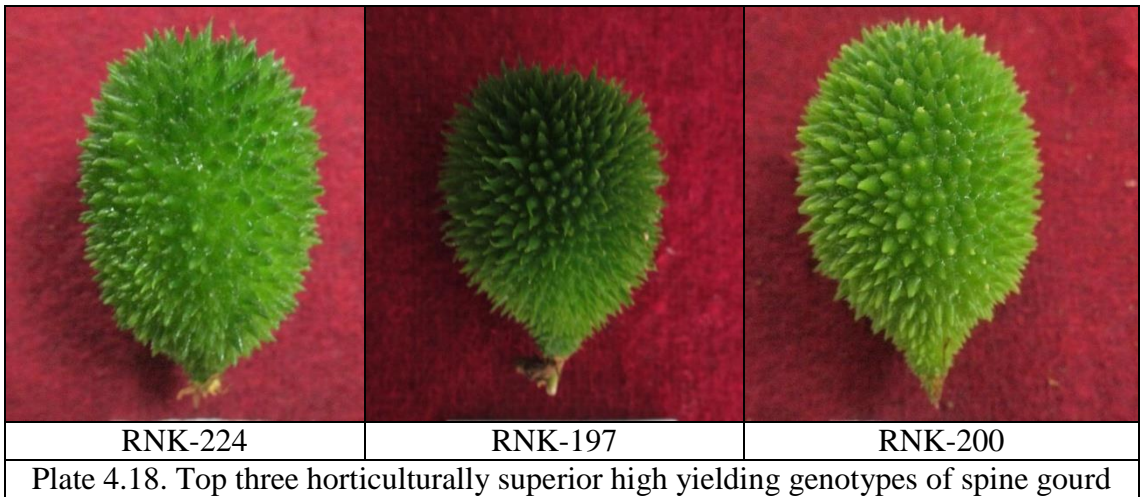
		
RNK-192	RNK-222	RNK-193
Orange	Scarlet	Blood red
Plate 4.13. Variability in seed aril colour at ripening stage of spine gourd		

		
Round	Oval	Globular
RNK-214	RNK-202	RNK-215
Plate 4.14. Variability in seed shape of spine gourd		

	
Sculpturing absent	Sculpturing present
RNK-185	RNK-219
Plate 4.15. Variability in seed sculpturing of spine gourd	

		
Faint	Medium	Filigree
RNK-214	RNK-225	RNK-231
Plate 4.16. Variability in extent of seed sculpturing of spine gourd		

	
Ornamentation absent	Golden lines on black seed coat
RNK-226	RNK-195
Plate 4.17. Variability in seed ornamentation of spine gourd	



RNK-224

RNK-197

RNK-200

Plate 4.18. Top three horticulturally superior high yielding genotypes of spine gourd

non-heritable components using the genetic parameters *viz.*, phenotypic and genotypic coefficients of variation, heritability and genetic advance is necessary to have an insight into genetic nature of yield and its components on which selection can be effectively carried out. Character like yield is complex in inheritance and is improved through its component traits. High yield can be achieved by selection of those yield contributing characters that have high heritability coupled with high genetic advance. Such value of high heritability and high genetic advance may be attributed to the action of additive genes (Panse, 1957) and selection will help in improving these characters.

The results with regard to mean, overall range, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability in broad sense (h_b^2) and expected genetic advance as per cent of mean (GAM) for all the twelve characters are furnished in Table 4.4 (Fig.1). The details of these variability parameters are presented below.

4.3.1 Variability

4.3.1.1 Growth attributes

Very low phenotypic (0.38) and genotypic (0.30) variances were recorded for vine length with high PCV (24.10%) and GCV (21.44%). Number of stems per plant had low phenotypic (2.79) and genotypic (2.63) variances with high PCV (52.83%) and GCV (51.32%).

The PCV and GCV values were high (>20%) indicating wide variation among the genotypes for vine length and number of stems per plant and more chances of improvement of these traits. Similar results were reported by Mangal *et al.* (1981) and Rajput *et al.* (1996) in bitter melon for vine length.

4.3.1.2 Earliness attributes

High phenotypic (48.62) and genotypic (40.03) variances were observed for days to first female flower appearance with high PCV (24.16%) and GCV (21.92%). With regard to first female flowering node, the phenotypic and genotypic variance values were high (34.80 and 26.45, respectively) with high

PCV (28.72%) and GCV (25.04%). High phenotypic (205.53) and genotypic (174.26) variances were recorded for days to first fruit harvest with high PCV

Table 4.4. Estimates of variability, heritability, genetic advance and genetic advance as percent of mean for 50 female genotypes of spine gourd

Character	Range		Mean±S.Em	Variance		Coefficient of variation (%)		h ² (%)	GA	GAM
	Minimum	Maximum		Phenotypic	Genotypic	Phenotypic	Genotypic			
Vine length (m)	1.60	4.00	2.55±0.19	0.38	0.30	24.10	21.44	79	1.00	39.31
Number of stems per plant	1.00	8.00	3.16±0.28	2.79	2.63	52.83	51.32	94	3.25	102.70
Days to first female flower appearance	14.00	46.00	28.86±2.07	48.62	40.03	24.16	21.92	82	11.83	40.98
First female flowering node	10.00	34.00	20.54±2.04	34.80	26.45	28.72	25.04	76	9.24	44.96
Days to first fruit harvest	22.00	85.00	53.94±3.95	205.53	174.26	26.58	24.47	85	25.04	46.42
Days to last fruit harvest	68.00	134.00	112.99±5.60	310.03	247.25	15.58	13.92	80	28.93	25.60
Fruiting period (days)	8.00	98.00	58.98±6.74	508.99	418.09	38.25	34.67	82	38.18	64.73
Fruit length (cm)	3.30	5.56	4.34±0.35	0.39	0.15	14.33	8.86	38	0.49	11.28
Fruit width (cm)	2.20	3.22	2.76±0.13	0.06	0.03	9.10	6.32	48	0.25	9.05
Fruit weight (g)	9.05	24.10	14.90±0.96	8.24	6.41	19.27	16.99	78	4.60	30.88
Number of fruits per plant	3.00	317.00	125.15±10.09	6885.37	6681.61	66.30	65.31	97	165.88	132.54
Fruit yield (kg/plant)	0.05	5.12	1.68±0.17	1.48	1.42	72.33	70.89	96	2.41	143.13

h² = heritability in broad sense; GA = genetic advance; GAM = genetic advance as percent of mean

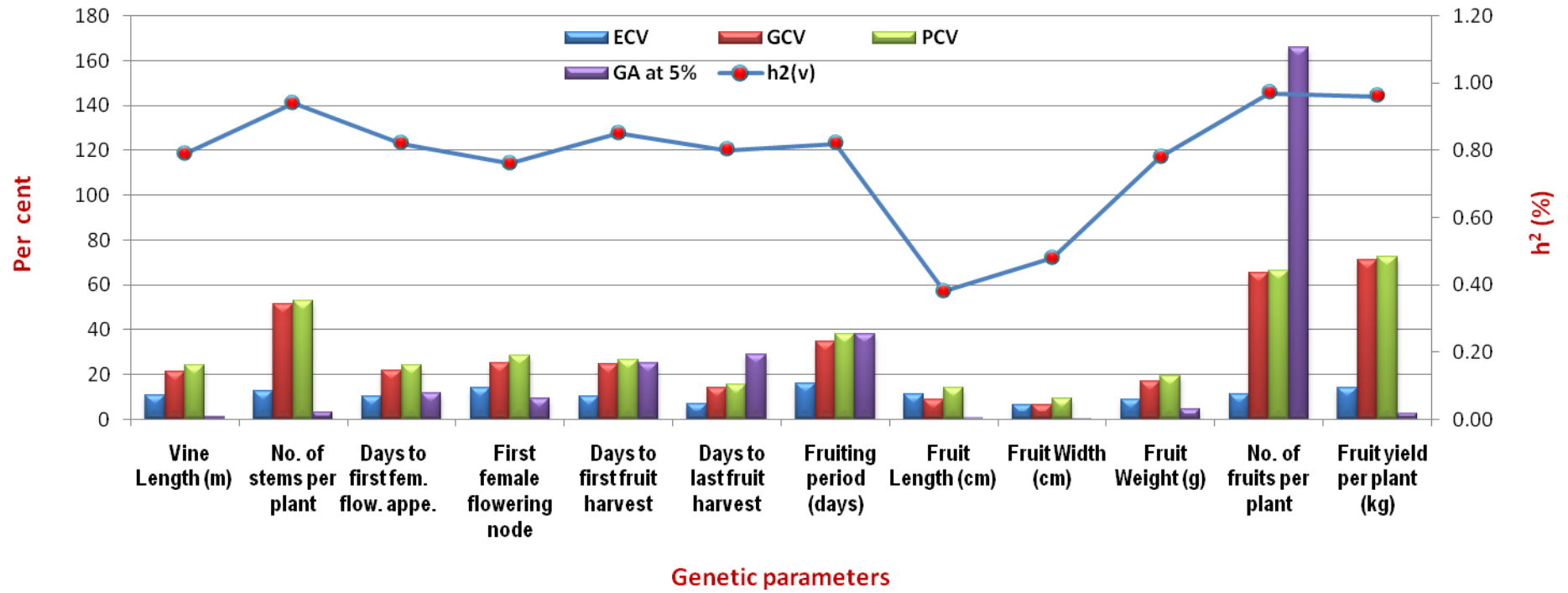


Fig.1 Genetic parameters for 12 quantitative characters of spine gourd

(26.58%) and GCV (24.47%). Days to last fruit harvest had high phenotypic (310.03) and genotypic (247.25) variances with moderate PCV (15.58%) and GCV (13.92%). With respect to fruiting period, higher phenotypic (508.99) and genotypic (418.09) variances with high PCV (38.25%) and GCV (34.67%) were recorded.

The PCV and GCV values recorded for these traits suggested the presence of high degree of genetic variability among the genotypes for days to first female flower appearance, first female flowering node, days to first fruit harvest and fruiting period and moderate genetic variability for days to last fruit harvest indicating that these traits possess better potential for further gain and improvement through selection. These results are in accordance with the findings of Sanwal *et al.* (2007) in sweet gourd for days to first female flower appearance and Dey *et al.* (2009) in bitter gourd for first female flowering node.

4.3.1.3 Fruit traits

Very low phenotypic (0.39) and genotypic (0.15) variances were recorded for fruit length with moderate PCV (14.33%) and low GCV (8.86%). Very low phenotypic (0.06) and genotypic (0.03) variances with low PCV (9.10%) and GCV (6.32%) were recorded for fruit width. Fruit weight had low phenotypic (8.24) and genotypic (6.41) variances with moderate PCV (19.27%) and GCV (16.99%). Number of fruits per plant showed higher phenotypic (6885.37) and genotypic (6681.61) variances with high PCV (66.30%) and GCV (65.31%).

Estimates of PCV and GCV for fruit traits indicated a narrow range of genetic variability among the genotypes for fruit length and fruit width, moderate genetic variability for fruit weight and wide variability for number of fruits per plant. Similar results were also reported by Singh *et al.* (2009) in spine gourd and Islam *et al.* (2009) in bitter gourd for vine length, Singh *et al.* (2009) in spine gourd, Sanwal *et al.* (2007) in sweet gourd and Naik *et al.* (2012b) in teasle gourd for fruit width, Sanwal *et al.* (2007) in sweet gourd, Rajput *et al.* (1996) in bitter gourd and Naik *et al.* (2012a) in teasle gourd for fruit weight, Bharathi *et al.* (2006) and Bharathi *et al.* (2010) in spine gourd, Srivastava and Srivastava (1976), Mangal *et al.* (1981), Rajput *et al.* (1996) in bitter gourd and Rahman *et al.* (2011) in teasle gourd for number of fruits per plant.

4.3.1.4 Fruit yield

Low phenotypic (1.48) and genotypic (1.42) variances were observed for fruit yield with high PCV (72.33%) and GCV (70.89%). The PCV and GCV values recorded for this trait suggested the presence of high genetic variation among genotypes. Similar results were reported by Bharathi *et al.* (2006), Singh *et al.* (2009) and Bharathi *et al.* (2010) in spine gourd, Sanwal *et al.* (2007) in sweet gourd, Srivastava and Srivastava (1976), Mangal *et al.* (1981), Rajput *et al.* (1996) and Dey *et al.* (2009) in bitter gourd and Rahman *et al.* (2011) in teasle gourd.

The study revealed that the magnitude of phenotypic coefficient of variation (PCV) was higher than the corresponding genotypic coefficient of variation (GCV) for all the characters indicating that the apparent variation was not only due to genotype but also due to the influence of environment and selection for these traits sometimes may be misleading. However, there was a close correspondence between the estimates of phenotypic and genotypic coefficients of variation for majority of the characters under study indicating the fact that the environment influence is very low. However, the magnitudinal differences between the estimates of GCV and PCV were highest for fruit length (5.47), followed by first female flowering node (3.68) and fruiting period (3.58) indicating that these traits were influenced by the environmental effects to a large extent and the greater role of environment in the expression of these traits.

High PCV and GCV were recorded for vine length, number of stems per plant, days to first female flower appearance, first female flowering node, days to first fruit harvest, fruiting period, number of fruits per plant and fruit yield indicating the existence of wider genetic variability for these traits in the genotypes under study indicating that these traits possess better potential for further gain and improvement through selection. On the other side, PCV and GCV estimates were low for traits viz., fruit width and low GCV for fruit length suggesting narrow range of genetic variability for these traits. The other characters viz., days to last fruit harvest and fruit weight had moderate PCV and GCV estimates indicating moderate variability among genotypes for these traits.

4.3.2 Heritability and genetic advance

4.3.2.1 Growth attributes

Vine length had high heritability (79%), low genetic advance (1.00) and high genetic advance as per cent of mean (39.31). Number of stems per plant had high heritability (94%), low genetic advance (3.25) and high genetic advance as per cent of mean (102.70). High heritability coupled with high genetic advance as per cent of mean observed for these traits indicated that these traits were under additive gene control and selection would be effective for their genetic improvement. The results are in conformity with Bharathi *et al.* (2006) in spine gourd, Mangal *et al.* (1981), Rajput *et al.* (1996) and Islam *et al.* (2009) in bitter gourd, Rahman *et al.* (2011) in teasle gourd for vine length and Naik *et al.* (2012a) in tealse gourd for number of stems per plant.

4.3.2.2 Earliness attributes

Days to first female flower appearance had high heritability (82%), moderate genetic advance (11.83) and high genetic advance as per cent of mean (40.98). High heritability (76%), low genetic advance (9.24) and high genetic advance (44.96) as per cent of mean were recorded for first female flowering node. Days to first fruit harvest had high heritability (85%), high genetic advance (25.04) and high genetic advance as per cent of mean (46.42). Days to last fruit harvest had high heritability (80%), high genetic advance (28.93) and high genetic advance as per cent of mean (25.60). High heritability (82%), high genetic advance (38.18) and high genetic advance as per cent of mean (64.73) were recorded for fruiting period.

High heritability coupled with high genetic advance as per cent of mean observed for these traits could be regarded as an indication of additive gene action and the consequent high expected genetic gain from selection for these traits. These results are in line with the findings of Sanwal *et al.* (2007) in sweet gourd, Srivastava and Srivastava (1976) in bitter gourd for days to first female flower appearance, Bharathi *et al.* (2006) in spine gourd and Rahman *et al.* (2011) in teasle gourd for days to first female flower appearance and first female flowering node, Dey *et al.* (2009) in bitter gourd for first female flowering node and days to first fruit harvest.

4.3.2.3 Fruit traits

Fruit length had moderate heritability (38%), low genetic advance (0.49) and moderate genetic advance as per cent of mean (11.28). Moderate heritability (48%), low genetic advance (0.25) and low genetic advance as per cent of mean (9.05) were recorded for fruit width. Fruit weight had high heritability (78%), low genetic advance (4.60) and high genetic advance as per cent of mean (30.88). Number of fruits per plant had high heritability (97%), high genetic advance (165.88) with high genetic advance as per cent of mean (132.54). Moderate heritability in conjunction with moderate genetic advance as per cent of mean observed for fruit length indicated the influence of both additive and non-additive genes and friable influence of environment in the expression of the trait. These results are in accordance with the findings of Singh *et al.* (2009) in spine gourd.

Presence of moderate heritability coupled with low genetic advance as per cent of mean for fruit width indicated that moderate heritability value was due to high environmental effects and the trait was influenced by non-additive gene action and selection would be ineffective for improvement of this trait. Low genetic advance as per cent of mean for fruit width was also reported by Ram *et al.* (2004) and Singh *et al.* (2009) in spine gourd, Sanwal *et al.* (2007) in sweet gourd and Naik *et al.* (2012b) in teasle gourd.

High heritability coupled with high genetic advance as per cent of mean observed for fruit weight and number of fruits per plant indicated the presence of larger number of fixable additive factors which help in improvement of these traits through simple selection procedures. These results are in accordance with the findings of Bharathi *et al.* (2006) in spine gourd, Sanwal *et al.* (2007) in sweet gourd, Mangal *et al.* (1981), Rajput *et al.* (1996) and Dey *et al.* (2009) in bitter gourd, Rahman *et al.* (2011) in teasle gourd for fruit weight and number of fruits per plant, Singh *et al.* (2009) in spine gourd and Islam *et al.* (2009) in bitter gourd for number of fruits per plant.

4.3.2.4 Fruit yield

Fruit yield had high heritability (96%), low genetic advance (2.41) and high genetic advance as per cent of mean (143.13). High heritability coupled with

high genetic advance as per cent of mean observed for this trait is an indication of additive gene action and the consequent high expected genetic gain from selection for this trait. These results are in line with the findings of Bharathi *et al.* (2006) in spine gourd, Sanwal *et al.* (2007) in sweet gourd, Srivastava and Srivastava (1976), Mangal *et al.* (1981), Rajput *et al.* (1996), Dey *et al.* (2009) and Islam *et al.* (2009) in bitter gourd, Rahman *et al.* (2011) and Naik *et al.* (2012a) in teasle gourd.

Heritability in conjugation with genetic advance is more effective and reliable in predicting the result and effect of selection (Johnson *et al.*, 1955). High heritability coupled with high genetic advance as per cent of mean indicated operation of additive gene action for vine length, number of stems per plant, days to first female flower appearance, first female flowering node, days to first fruit harvest, days to last fruit harvest, fruiting period, fruit weight, number of fruits per plant and fruit yield. Hence, direct selection for these traits in genetically diverse material could be effective for desired genetic improvement. Moderate genetic advance as per cent of mean with medium heritability suggested the action of both additive and non-additive genes thereby favourable influence of environment in the expression of traits was reported in case of fruit length. The character fruit width recorded moderate heritability coupled with low genetic advance as per cent of mean suggesting that it was mainly affected by non-additive gene action and selection would be ineffective for improvement. However, it could be improved through manifestation of dominance effects through heterosis.

Hence, the breeder should adopt suitable breeding methodology to utilize both additive and non additive gene effects simultaneously, since varietal and hybrid development will go a long way in the breeding programmes especially in case of spine gourd.

4.4 GENETIC DIVERGENCE ANALYSIS

Genetic diversity is an important factor for any heritable improvement. Divergence analysis generates valuable information on the nature and degree of genetic diversity, which is useful for selecting desirable lines from germplasm

for successful breeding programme. Selection of lines based on individual attribute may not be as advantageous as the one based on a number of important traits collectively. Multivariate analysis provides valuable information on the extent of genetic diversity present in the germplasm. Mahalanobis D^2 statistics is based on multivariate analysis and serves to be a good index of genetic diversity. Very often phenotypic diversity has been taken as an index of the genetic diversity.

Mahalanobis D^2 statistics was found to be an useful tool in quantifying degree of divergence between biological populations at genotypic level and to assess the relative contribution of different characters to the total divergence both at inter and intracluster levels. Murthy and Arunachalam (1960) opined that Mahalanobis D^2 statistics is an important breeding tool to evaluate the clustering pattern. This technique, therefore, deserves to be tested on a wide range of crops (Joshi and Dhawan, 1966). The genetic divergence among 50 genotypes of spine gourd was quantitatively assessed by adopting Mahalanobis D^2 statistics.

4.4.1 Analysis of dispersion

The simultaneous significance of mean differences was tested by analysis of dispersion (Table 4.5). The F value was highly significant indicating large differences between the means of the populations based on pooled effect of all the twelve characters and may be continued for further analysis for computing D^2 estimates.

4.4.2 Grouping of genotypes into different clusters (D^2 analysis)

The D^2 value between any two genotypes was calculated as the sum of squares of the differences between the mean values of all the 12 characters and is used for the final grouping of the genotypes. Based on D^2 values, the 50 genotypes were grouped into eight highly distinct clusters (Table 4.6). Dendrogram depicting clustering pattern of 50 female genotypes of spine gourd is shown in Fig.2. Among eight clusters, cluster VII was the largest consisting of 14 genotypes followed by cluster IV, III, VI, I and II with 11, 9, 9, 3 and 2 genotypes, respectively. The cluster V and VIII were solitary with one genotype in each cluster.

Table 4.5. Analysis of variance for dispersion in spine gourd germplasm

Source of Variations	df	Sum of Squares	Mean Squares	F Ratio	Probability	
Varieties	49	5.2366E+14	1.0687E+13	1.8516E+08	0.0000	***
Error	48	2.7705E+06	5.7719E+04			
Total	97	5.2366E+14	5.3986E+12			

Table 4.6. Clustering pattern of 50 female genotypes of spine gourd (Tocher's method)

Cluster	Number of genotypes	Genotypes included in cluster
I	3	RNK-201, RNK-203, RNK-193
II	2	RNK-204, RNK-207
III	9	RNK-210, RNK-217, RNK-189, RNK-220, RNK-191, RNK-208, RNK-184, RNK-225, RNK-202
IV	11	RNK-214, RNK-223, RNK-219, RNK-212, RNK-211, RNK-213, RNK-218, RNK-209, RNK-221, RNK-222, RNK-188
V	1	RNK-199
VI	9	RNK-196, RNK-197, RNK-200, RNK-187, RNK-224, RNK-228, RNK-226, RNK-198, RNK-229
VII	14	RNK-195, RNK-205, RNK-215, RNK-194, RNK-216, RNK-206, RNK-183, RNK-230, RNK-192, RNK-231, RNK-227, RNK-186, RNK-185, RNK-190
VIII	1	RNK-182

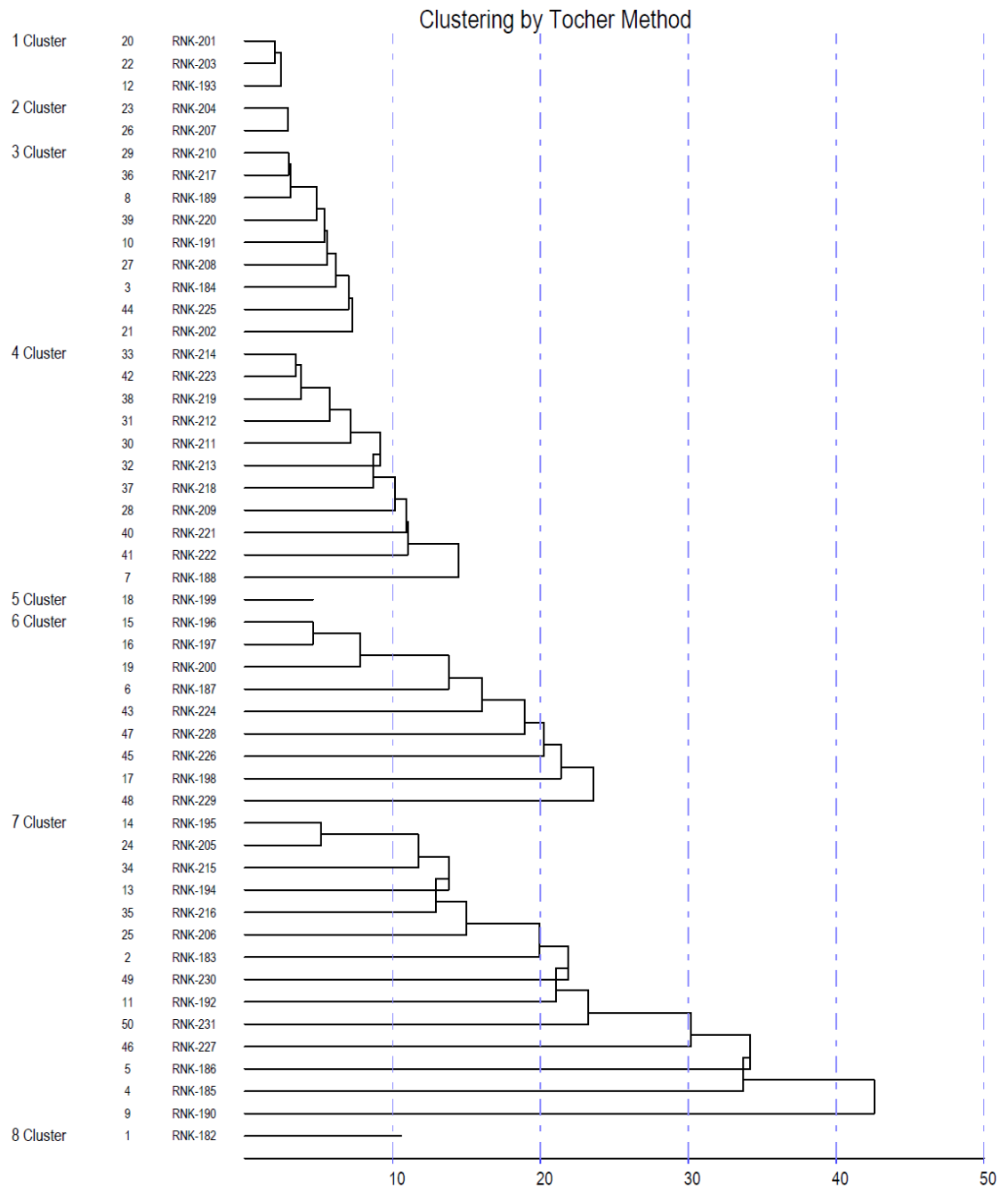


Fig.2 Dendrogram depicting clustering pattern of 50 female genotypes of spine gourd

4.4.3 Average intra and inter cluster distances

The mean intra and inter cluster D^2 values are given in the Table 4.7 (Fig.3). The intra cluster D^2 value ranged from 0.00 (Cluster V and cluster VIII) to 80.963 (Cluster VII). The cluster VII had the maximum D^2 value (80.963) followed by Cluster VI (59.437) and Cluster IV (30.960), while minimum in cluster II (7.835) followed by cluster I (8.345). The intraccluster distance of solitary clusters V and VIII was zero. The intercluster distance was maximum between clusters VI and VIII (368.652) followed by cluster IV and VI (310.199) and cluster III and VI (179.330), while minimum between cluster II and III (25.254) followed by I and III (25.261) and cluster I and II (28.970).

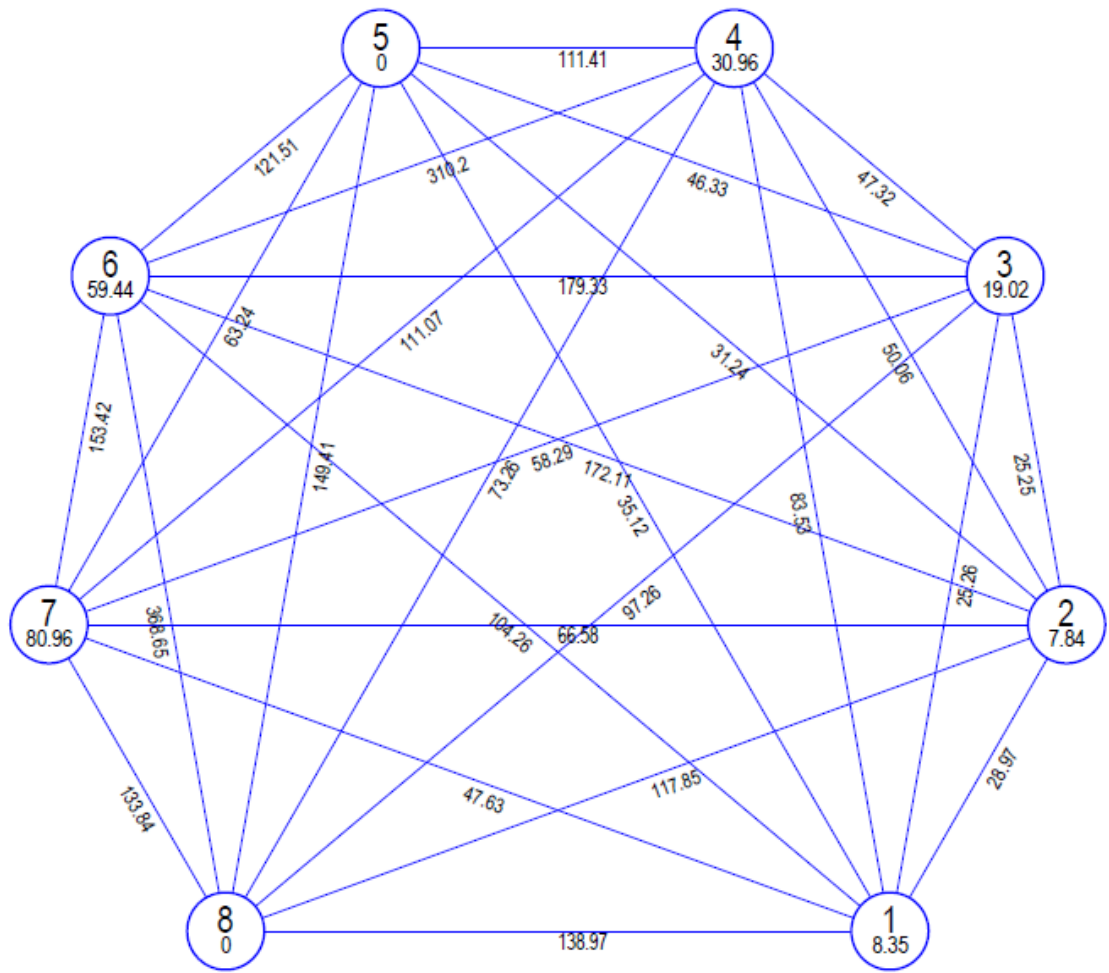
The inter cluster distance was minimum between cluster II and III indicating narrow genetic diversity and maximum between clusters VI and VIII followed by IV and VI indicating wider genetic diversity among the genotypes included in these groups. The female genotypes with high mean value from the respective clusters for the requisite characters may be used as female parent in future breeding programmes. Similar observations were reported by Bharathi *et al.* (2005a) in spine gourd, Sanwal *et al.* (2007) in sweet gourd, Sundaram (2008) Islam *et al.* (2010) in bitter gourd and Rahman *et al.* (2011) in teasle gourd.

Cluster I was nearest to cluster III (25.261) and distant to cluster VIII (138.972). Cluster II exhibited close proximity with cluster III (25.254) and maximum divergence with cluster VI (172.115). Cluster III was nearest to cluster II (25.254), while it was farthest from cluster VI (179.330).

Cluster IV was nearest to cluster III (47.321) and distant from cluster VI (310.199). Cluster V exhibited intimate relation with cluster II (31.235) and wide diversity with cluster VIII (149.415). Nearest and farthest clusters for cluster VI are cluster I (104.265) and VIII (368.652). Cluster VII exhibited close proximity with cluster I (47.626) and maximum divergence with cluster VI (153.422). Cluster VIII was nearest to cluster IV (73.257) and distant from cluster VI (368.652).

4.4.4 Cluster means of characters

The cluster means (Table 4.8) for different characters indicated considerable differences among the clusters. From the data, it can be seen that considerable



Mahalanobis Euclidean² Distance (Not to the scale)

Fig.3 Inter and intracluster distances of 50 female genotypes of spine gourd

Table 4.8. Cluster means of 50 female genotypes for twelve characters in spine gourd

Character	Cluster							
	I	II	III	IV	V	VI	VII	VIII
Vine length (m)	2.67	2.55	2.52	2.22	2.30	3.07	2.51	2.30
Number of stems per plant	3.33	2.00	2.33	1.73	2.00	5.56	3.50	3.00
Days to first female flower appearance	30.33	37.50	28.44	34.55	29.00	28.44	24.29	16.00
First female flowering node	22.33	14.50	22.00	20.55	14.00	20.56	20.71	18.00
Days to first fruit harvest	53.33	59.00	60.67	68.18	42.00	44.78	45.93	35.00
Days to last fruit harvest	122.00	114.50	117.22	100.00	112.00	125.56	113.54	68.00
Fruiting period (days)	68.67	55.50	55.89	31.82	70.00	81.11	67.61	32.50
Fruit length (cm)	4.31	4.38	4.19	3.92	4.68	4.69	4.56	3.75
Fruit width (cm)	2.67	2.97	2.69	2.68	3.03	2.83	2.78	3.00
Fruit weight (g)	13.28	15.27	14.06	13.51	16.20	17.37	15.32	12.50
Number of fruits per plant	143.50	106.25	102.67	30.18	175.00	252.33	135.32	18.00
Fruit yield (kg/plant)	1.92	1.36	1.34	0.36	2.45	3.62	1.74	0.15

differences exist for all the traits studied. The data indicated that cluster mean for vine length ranged from 2.218 to 3.067 m. The highest vine length was recorded in cluster VI (3.067) followed by cluster I (2.667) and cluster II (2.550), while lowest vine length was recorded in cluster IV (2.218) followed by cluster V and VIII (2.300) and cluster VII (2.511). Number of stems per plant was highest in cluster VI (5.556) followed by cluster VII (3.500) and cluster I (3.333) and while the lowest in cluster IV (1.727) followed by cluster II and V (2.000) and cluster III (2.333).

Days to first female flower appearance were minimum in genotype of cluster VIII (16.000) followed by cluster VII (24.286) and cluster III and VI (28.444), while the genotypes of cluster II took maximum number of days to first female flower appearance (37.500) followed by cluster IV (34.545) and cluster I (30.333). Genotypes of cluster V (14.00) produced first female flower at the lowest node followed by cluster II (14.50) and cluster VIII (18.00), while the genotypes of cluster I (22.33) produced first female flower at the highest node followed by cluster III (22.00) and cluster VII (20.714).

Minimum days to first fruit harvest was recorded in the genotypes of cluster VIII (35.00) followed by cluster V (42.00) and cluster VI (44.78), while the genotypes of cluster IV (68.18) took maximum days to first fruit harvest followed by cluster III (60.67) and cluster II (59.00). Days to last fruit harvest was recorded maximum in the genotypes of cluster VI (125.55) followed by cluster I (122.00) and cluster III (117.22), while minimum in cluster VIII (68.00) followed by cluster IV (100.00) and cluster V (112.00). Fruiting period was maximum in the cluster VI (81.11 days) followed by cluster V (70.00 days) and cluster I (68.67 days), while minimum fruiting period was recorded in cluster IV (31.82 days) followed by cluster VIII (32.50 days) and cluster II (55.50 days).

The longest fruits were produced by genotypes of cluster VI (4.69 cm) followed by cluster V (4.68 cm) and cluster VII (4.56 cm), whereas the shortest fruits were produced by genotypes of cluster VIII (3.75 cm) followed by cluster IV (3.92 cm) and cluster III (4.19 cm). The genotypes of cluster V (3.03 cm) produced widest fruits followed by cluster VIII (3.00 cm) and cluster II (2.97

cm), while the narrowest fruits were produced by genotypes of cluster I (2.67) followed by cluster IV (2.68) and cluster III (2.69 cm). Heaviest fruits were produced by the genotypes of cluster VI (17.37 g) followed by cluster V (16.20 g) and cluster VII (15.32 g), while the lightest fruits were produced by cluster VIII (12.50 g) followed by cluster I (13.28 g) and cluster IV (13.51 g).

Total number of fruits produced per plant by the genotypes of cluster VI (252.33) was highest followed by cluster V (175.00) and cluster I (143.50), while lowest by the genotypes of cluster VIII (18.00) followed by cluster IV (30.18) and cluster III (102.67). The genotypes of cluster VI (3.62 kg) produced highest fruit yield per plant followed by cluster V (2.45 kg) and cluster I (1.92 kg), while the lowest fruit yield per plant was recorded by the genotypes of cluster VIII (0.15 kg) followed by cluster IV (0.36 kg) and cluster III (1.34 kg).

The comparison of cluster means for different characters indicated that the genotypes included in cluster VI recorded maximum vine length, number of stems per plant, days to last fruit harvest, fruiting period, fruit length, fruit weight, number of fruits per plant and fruit yield. Thus this cluster holds great promise as apparent to obtain promising hybrids and create further variability for these characters. Cluster VIII recorded minimum days to first female flower appearance and days to first fruit harvest. Cluster V produced first female flower on the lower node and wider fruits.

4.4.5 Relative contribution of different characters towards divergence

The per cent contribution of each character towards divergence is presented in Table 4.9 (Fig.4). It was observed that number of fruits per plant contributed the highest towards divergence (46.45%) followed by number of stems per plant (17.55%), days to first fruit harvest (7.67%), days to first female flower appearance (6.94%), first female flowering node (5.31%), days to last fruit harvest (5.22%), fruit yield per plant (3.76%), vine length (3.59%), fruit weight (2.69%), fruit width (0.49%), fruit length (0.24%) and fruiting period (0.08%). Hence, there is greater scope for selection of divergent female parents based on these characters in the material under study. Based on the genetic distances, clustering pattern and mean performance, breeding programme may be initiated involving genotypes of cluster VI, VIII and IV as female parent. The genotypes

Table 4.9. Per cent contribution of different traits towards divergence of 50 female genotypes of spine gourd

Character	Number of Times Ranked first	Contribution towards divergence %
Vine length (m)	44	3.59
No. of stems per plant	215	17.55
Days to first female flower appearance	85	6.94
First female flowering node	65	5.31
Days to first fruit harvest	94	7.67
Days to last fruit harvest	64	5.22
Fruiting period (days)	1	0.08
Fruit length (cm)	3	0.24
Fruit width (cm)	6	0.49
Fruit weight (g)	33	2.69
No. of fruits per plant	569	46.45
Fruit yield (kg/plant)	46	3.76

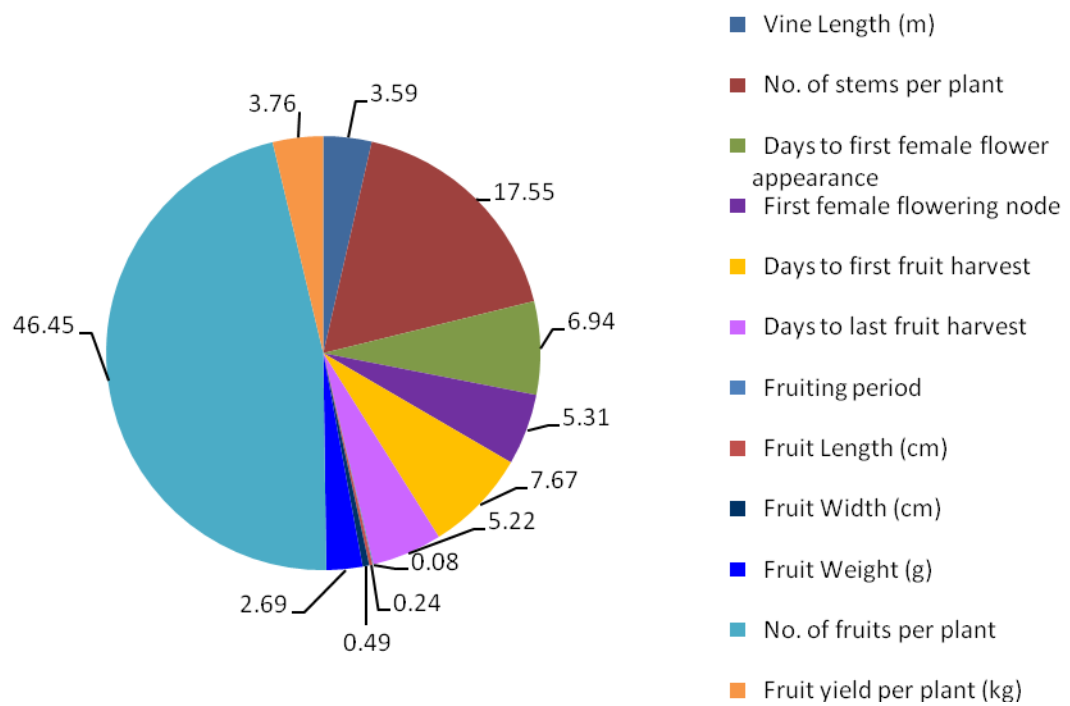


Fig.4 Per cent contribution of different traits towards total divergence of spine gourd

of solitary clusters RNK-199 (cluster V) with heavier fruits being divergent from others may also serve as potential female parents for breeding programmes.

4.5 CORRELATION COEFFICIENT ANALYSIS

The phenotypic (P) and genotypic correlation (G) coefficients were worked out for twelve characters in spine gourd genotypes and the results are presented in Table 4.10. In general, it was observed that genotypic correlation coefficients were higher than that of phenotypic correlation coefficients, indicating a strong inherent association of the characters under study with a probable influence of environment on the expression. Similar results were also reported by Bharathi *et al.* (2005b) and Singh *et al.* (2009) in spine gourd and Rahman *et al.* (2011) in teasle gourd.

4.5.1 Growth attributes

Vine length had significantly positive correlation with number of stems per plant (0.481 P, 0.569 G), days to last fruit harvest (0.386 P, 0.485 G), fruiting period (0.456 P, 0.559 G), fruit length (0.295 P, 0.710 G), fruit width (0.329 P, 0.507 G), fruit weight (0.391 P, 0.480 G), number of fruits per plant (0.433 P, 0.501 G) and fruit yield (0.454 P, 0.527 G). Increase in vine length was accompanied with increase in all the above mentioned traits leading to increased yield per vine. This type of desirable association would be helpful for simultaneous improvement of all these characters. Similar association of vine length with fruit length, fruit width, fruit weight and number of fruits per plant was reported by Bharathi *et al.* (2005b) in spine gourd and Ramachandran and Gopalakrishnan (1979) and Bhave *et al.* (2003b) in bitter gourd. Islam *et al.* (2009) reported similar correlation with fruit length and fruit width in bitter gourd. Rahman *et al.* (2011) also reported positive correlation of vine length with number of fruits per plant in teasle gourd. Positive correlation with fruit yield was in accordance with results of Bharathi *et al.* (2005b) in spine gourd and Ramachandran and Gopalakrishnan (1979), Mangal *et al.* (1981), Bhave *et al.* (2003b) and Sundaram (2010) in bitter gourd

Vine length also showed significantly negative correlation with days to first female flower appearance (-0.298 P, -0.304 G) and days to first fruit harvest

Table 4.10 Phenotypic and genotypic correlation among twelve quantitative traits of spine gourd

Trait		Vine length (m) (1)	Number of stems per plant (2)	Days to first female flower appearance (3)	First female flowering node (4)	Days to first fruit harvest (5)	Days to last fruit harvest (6)	Fruiting period (days) (7)	Fruit length (cm) (8)	Fruit width (cm) (9)	Fruit weight (g) (10)	Number of fruits per plant (11)	Fruit yield per plant (kg) (12)
1	rp	1.000	0.481 ^{**}	-0.298 ^{**}	-0.097	-0.246 [*]	0.386 ^{**}	0.456 ^{**}	0.295 ^{**}	0.329 ^{**}	0.391 ^{**}	0.433 ^{**}	0.454 ^{**}
	rg	1.000	0.569 ^{**}	-0.304 ^{**}	-0.13	-0.278 ^{**}	0.485 ^{**}	0.559 ^{**}	0.710 ^{**}	0.507 ^{**}	0.480 ^{**}	0.501 ^{**}	0.527 ^{**}
2	rp		1.000	-0.255 [*]	-0.07	-0.430 ^{**}	0.401 ^{**}	0.596 [*]	0.507 [*]	0.216 [*]	0.497 [*]	0.751 [*]	0.769 ^{**}
	rg		1.000	-0.262 ^{**}	-0.05	-0.448 ^{**}	0.464 ^{**}	0.680 ^{**}	0.807 ^{**}	0.360 ^{**}	0.577 ^{**}	0.770 ^{**}	0.810 ^{**}
3	rp			1.000	0.086	0.445 ^{**}	-0.039	-0.318 ^{**}	-0.202 [*]	-0.259 ^{**}	-0.201 [*]	-0.207 [*]	-0.16
	rg			1.000	0.100	0.508 ^{**}	-0.007	-0.326 ^{**}	-0.440 ^{**}	-0.319 ^{**}	-0.238 [*]	-0.214 [*]	-0.194
4	rp				1.000	0.122	-0.117	-0.179	0.056	-0.049	0.134	-0.121	-0.061
	rg				1.000	0.136	-0.092	-0.155	0.175	-0.143	0.197 [*]	-0.146	-0.082
5	rp					1.000	0.01	-0.622 ^{**}	-0.254 [*]	-0.186	-0.228 [*]	-0.420 ^{**}	-0.385 ^{**}
	rg					1.000	0.025	-0.636 ^{**}	-0.390 ^{**}	-0.275 ^{**}	-0.266 ^{**}	-0.466 ^{**}	-0.433 ^{**}
6	rp						1.000	0.768 ^{**}	0.435 ^{**}	0.229 [*]	0.357 ^{**}	0.619 ^{**}	0.576 ^{**}
	rg						1.000	0.761 ^{**}	0.777 ^{**}	0.333 ^{**}	0.407 ^{**}	0.702 ^{**}	0.685 ^{**}
7	rp							1.000	0.502 ^{**}	0.302 ^{**}	0.422 ^{**}	0.758 ^{**}	0.702 ^{**}
	rg							1.000	0.858 ^{**}	0.420 ^{**}	0.493 ^{**}	0.847 ^{**}	0.810 ^{**}
8	rp								1.000	0.396 ^{**}	0.642 ^{**}	0.494 ^{**}	0.542 ^{**}
	rg								1.000	0.789 ^{**}	1.158 ^{**}	0.818 ^{**}	0.811 ^{**}
9	rp									1.000	0.444 ^{**}	0.224 [*]	0.233 [*]
	rg									1.000	0.673 ^{**}	0.338 ^{**}	0.320 ^{**}
10	rp										1.000	0.487 ^{**}	0.546 ^{**}
	rg										1.000	0.572 ^{**}	0.651 ^{**}
11	rp											1.000	0.969 ^{**}
	rg											1.000	0.992 ^{**}

r_g= Genotypic correlation coefficient; r_p= Phenotypic correlation coefficient. *, ** Significant at the 0.05 and 0.01 probability levels, respectively

(-0.246 P, -0.278 G), indicating that longer vines were early in production of female flowers and fruits compared to shorter vines. Negative correlation with days to first female flower appearance was also reported by Bharathi *et al.* (2005b) in spine gourd and Bhave *et al.* (2003b) and Islam *et al.* (2009) in bitter gourd.

Number of stems per plant had significantly positive correlation with vine length (0.481 P, 0.569 G), days to last fruit harvest (0.401 P, 0.464 G), fruiting period (0.596 P, 0.68 G), fruit length (0.507 P, 0.807 G), fruit width (0.216 P, 0.360 G), fruit weight (0.497 P, 0.577 G), number of fruits per plant (0.751 P, 0.770 G) and fruit yield (0.769 P, 0.810 G). Increase in number of stems per plant increases the fruit bearing area per plant. Rahman *et al.* (2011) also reported the positive association of number of stems per plant with fruit yield. It had significantly negative correlation with days to first female flower appearance (-0.255 P, -0.262 G) and days to first fruit harvest (-0.430 P, -0.448 G) at both phenotypic and genotypic levels.

The correlation of vine length and number of stems per plant with fruit yield need physiological explanation. These traits probably increase the number of leaves and hence the photosynthetic efficiency. Arnon (1975) reported that an increase in photosynthetic efficiency increased the dry matter and finally the economic yield.

4.5.2 Earliness attributes

Days to first female flower appearance had significantly positive correlation with days to first fruit harvest (0.445 P, 0.508 G) and had significantly negative correlation with vine length (-0.298 P, -0.304 G), number of stems per plant (-0.255 P, -0.262 G), fruiting period (-0.318 P, -0.326 G), fruit length (-0.202 P, -0.440 G), fruit width (-0.259 P, -0.319 G), fruit weight (-0.201 P, -0.238 G) and number of fruits per plant (-0.207 P, -0.214 G) at both phenotypic and genotypic levels.

Positive correlation of days to first female flower appearance with days to first fruit harvest suggested that early flowering gives early pickings. Similar association was also reported by Dey *et al.* (2005) in bitter gourd. Its negative correlation with vine length is in line with findings of Bharathi *et al.* (2005b) in

spine gourd and Bhave *et al.* (2003b) and Islam *et al.* (2009) in bitter gourd. Negative correlation with fruiting period indicating that early flowering extends the harvesting span, as was also reported by Bhave *et al.* (2003b). Negative correlation with fruit length, width, weight and number of fruits per plant suggested that early flowering genotypes produce more number of fruits per plant with higher fruit length, width and weight compared to late flowering genotypes. Similar findings on correlation between days to first female flower appearance and fruit length, fruit width and fruit weight were reported by Bharathi *et al.* (2005b) in spine gourd, Islam *et al.* (2009) in bitter gourd and Rahman *et al.* (2011) in teale gourd. Negative association with number of fruits per plant was also reported in spine gourd (Bharathi *et al.*, 2005b) and bitter gourd (Bhave *et al.*, 2003b; Dey *et al.*, 2005; Islam *et al.*, 2009; Sundaram, 2010).

First female flowering node had positively significant correlation with fruit weight (0.197 G). This finding is conformity with the works of Ramachandran and Gopalakrishnan (1979) in bitter gourd and Rahman *et al.* (2011) in teale gourd.

Days to first fruit harvest had significantly positive correlation with days to first female flower appearance (0.445 P, 0.508 G) and significantly negative correlation with vine length (-0.246 P, -0.278 G), number of stems per plant (-0.430 P, -0.448 G), fruiting period (-0.622 P, -0.636 G), fruit length (-0.254 P, -0.390 G), fruit width (-0.275 G), fruit weight (-0.228 P, -0.266 G), number of fruits per plant (-0.420 P, -0.466 G) and fruit yield (-0.385 P, -0.433 G). This result indicated that decrease in days to first harvest was accompanied with increase in fruiting period, fruit length, fruit width, fruit weight and number of fruits per plant resulting in higher fruit yield per plant. Similar result on correlation between days to first fruit harvest and days to first female flower appearance and fruit yield was reported by Dey *et al.* (2005) in bitter gourd.

Days to last fruit harvest had significantly positive correlation with vine length (0.386 P, 0.485 G), number of stems per plant (0.401 P, 0.464 G), fruiting period (0.768 P, 0.761 G), fruit length (0.435 P, 0.777 G), fruit width (0.229 P, 0.333 G), fruit weight (0.357 P, 0.407 G), number of fruits per plant (0.619 P,

0.702 G) and fruit yield (0.576 P, 0.685 G). The present finding suggests that genotypes with higher vine length and number of stems per plant produce fruits for a longer period extending harvesting span and increase in days to last fruit harvest is accompanied by increase in fruit length, width, weight and number of fruits per plant thus resulting in increased fruit yield.

Fruiting period had significantly positive correlation with vine length (0.456 P, 0.559 G), number of stems per plant (0.596 P, 0.680 G), days to last fruit harvest (0.768 P, 0.761 G), fruit length (0.502 P, 0.858 G), fruit width (0.302 P, 0.420 G), fruit weight (0.422 P, 0.493 G), number of fruits per plant (0.758 P, 0.847 G) and fruit yield (0.702 P, 0.810 G) and had significantly negative correlation with days to first female flower appearance (-0.318 P, -0.326 G) and days to first fruit harvest (-0.622 P, -0.636 G). This indicates that early flowering and fruiting widens the fruiting period.

The findings of Bhave *et al.* (2003b) in bitter melon support the results of present study on association of fruiting period with days to first female flower appearance, fruit length, fruit width, fruit weight, number of fruits per plant and fruit yield.

4.5.3 Fruit traits

Fruit length had significantly positive correlation with vine length (0.295 P, 0.710 G), number of stems per plant (0.507 P, 0.807 G), days to last fruit harvest (0.435 P, 0.777 G), fruiting period (0.502 P, 0.858 G), fruit width (0.396 P, 0.789 G), fruit weight (0.642 P, 1.158 G), number of fruits per plant (0.818 P, 0.224 G) and fruit yield (0.542 P, 0.811 G) and had significantly negative correlation with days to first female flower appearance (-0.202 P, -0.440 G) and days to first fruit harvest (-0.254 P, -0.390 G).

Fruit width had significantly positive correlation with vine length (0.329 P, 0.507 G), number of stems per plant (0.216 P, 0.360 G), days to last fruit harvest (0.229 P, 0.333 G), fruiting period (0.302 P, 0.420 G), fruit length (0.396 P, 0.789 G), fruit weight (0.444 P, 0.673 G), number of fruits per plant (0.224 P, 0.338 G) and fruit yield (0.233 P, 0.320 G) and had significantly negative correlation with days to first female flower appearance (-0.259 P, -0.319 G) and days to first fruit harvest (-0.275 G).

Fruit weight had significantly positive correlation with vine length (0.391 P, 0.480 G), number of stems per plant (0.497 P, 0.577 G), first female flowering node (0.197 G), days to last fruit harvest (0.357 P, 0.407 G), fruiting period (0.422 P, 0.493 G), fruit length (0.642 P, 1.158 G), fruit width (0.444 P, 0.673 G), number of fruits per plant (0.487 P, 0.572 G) and fruit yield (0.546 P, 0.651 G) and had significantly negative correlation with days to first female flower appearance (-0.201 P, -0.238 G) and days to first fruit harvest (-0.228 P, -0.266 G).

Number of fruits per plant had significantly positive correlation with vine length (0.433 P, 0.501 G), number of stems per plant (0.751 P, 0.770 G), days to last fruit harvest (0.619 P, 0.702 G), fruiting period (0.758 P, 0.847 G), fruit length (0.494 P, 0.818 G), fruit width (0.24 P, 0.338 G), fruit weight (0.487 P, 0.572 G) and fruit yield (0.651 P, 0.969 G) and had significantly negative correlation with days to first female flower appearance (-0.207 P, -0.214 G) and days to first fruit harvest (-0.420 P, -0.466 G).

Significant positive correlation was observed among all the fruit traits. Increase in fruit length and fruit width resulted in increase in fruit weight which ultimately increased the total fruit yield per plant. Hence direct selection for traits like fruit length, fruit width, fruit weight and number of fruits per plant could be effective for improvement of the yield. Similar correlation among fruit length, fruit width and fruit weight was reported by Bharathi *et al.* (2005b) and Singh *et al.* (2009) in spine gourd, Bhave *et al.* (2003b) and Dey *et al.* (2005) in bitter gourd and Rahman *et al.* (2011) in teasle gourd. Positively significant correlation of fruit length, fruit width and fruit weight with number of fruits per plant is in accordance with the findings of Singh *et al.* (2009) in spine gourd, Ramachandran and Gopalakrishnan (1979) and Bhave *et al.* (2003b) in bitter gourd. Rahman *et al.* (2011) also reported positive correlation of number of fruits per plant with fruit length and fruit width.

Positively significant correlation of all fruit traits with fruit yield is in line with results of Bharathi *et al.* (2005b) and Singh *et al.* (2009) in spine gourd, Bhave *et al.* (2003b), Dey *et al.* (2005), Islam *et al.* (2009) and Sundaram (2010) in bitter gourd and Rahman *et al.* (2011) in teasle gourd. Naik and Akhtar (2012)

reported positive correlation of fruit yield with fruit weight and number of fruits per plant in teasle gourd. Sanwal *et al.* (2007) also reported similar association of fruit yield with fruit length, fruit weight and number of fruits per plant in sweet gourd.

4.5.4 Fruit yield

Fruit yield was positively and significantly correlated with the vine length (0.454 P, 0.527 G), number of stems per plant (0.769 P, 0.810 G), days to last fruit harvest (0.576 P, 0.685 G), fruiting period (0.702 P, 0.810 G), fruit length (0.542 P, 0.811 G), fruit width (0.233 P, 0.320 G), fruit weight (0.546 P, 0.651 G) and number of fruits per plant (0.969 P, 0.992 G). Significantly negative correlation (-0.385 P, -0.433 G) was observed between days to first fruit harvest and fruit yield per plant.

Similar results on association of fruit yield with vine length were reported by Bharathi *et al.* (2005b) in spine gourd, Bhave *et al.* (2003b) and Sundaram (2010) in bitter gourd, number of stems per plant by Rahman *et al.* (2011) in teasle gourd, fruiting period by Bhave *et al.* (2003b) in bitter gourd, fruit length, fruit width, fruit weight and number of fruits per plant by Bharathi *et al.* (2005b) and Singh *et al.* (2009) in spine gourd, Sanwal *et al.* (2007) in sweet gourd, Bhave *et al.* (2003b), Dey *et al.* (2005), Islam *et al.* (2009) and Sundaram (2010) in bitter gourd and Rahman *et al.* (2011) in teasle gourd. Naik and Akhtar (2012) also reported positive correlation with fruit weight and number of fruits per plant in teasle gourd. Negative correlation with days to first fruit harvest was in agreement with results of Bharathi *et al.* (2005b) and Singh *et al.* (2009) in spine gourd, Sanwal *et al.* (2007) in sweet gourd, Bhave *et al.* (2003b), Dey *et al.* (2005) in bitter gourd and Rahman *et al.* (2011) in teasle gourd.

Phenotypic and genotypic correlation coefficient analysis revealed that the fruit yield had significantly positive association with the vine length, number of stems per plant, days to last fruit harvest, fruiting period, fruit length, fruit width, fruit weight and number of fruits per plant, while it had significantly negative association with days to first fruit harvest.

4.6 PATH COEFFICIENT ANALYSIS

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 analysis was carried out at phenotypic and genotypic levels considering fruit yield as dependent character and its attributes as independent characters. 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 4.11 and path showing the cause and effect relationship is shown for phenotypic in Fig.5 and genotypic in Fig.6.

Direct and indirect effects

4.6.1 Growth attributes

Vine length had negligible positive direct effects on fruit yield per vine at both phenotypic (0.048) and genotypic levels (0.047). Indirect causal factors are to be considered simultaneously for selection as it showed significantly positive correlation (0.454 P, 0.527 G), and negligible positive direct effect on fruit yield per vine. Similar results were obtained by Bhave *et al.* (2003a) in bitter gourd.

Number of stems per plant displayed negligible positive direct effect on fruit yield at both phenotypic (0.053) level and genotypic (0.031) level. Indirect causal factors are to be considered simultaneously for selection as it showed significantly positive correlation (0.769 P, 0.810 G), and negligible positive direct effect on fruit yield per vine. Similar results were reported by Naik and Akhtar (2012) in teasle gourd.

4.6.2 Earliness attributes

Days to first female flower appearance had negligible positive direct effect on fruit yield at both phenotypic (0.057) and genotypic (0.034) levels. This finding is in conformity with results of Singh *et al.* (2009) in spine gourd, Sanwal *et al.* (2007) in sweet gourd and Rahman *et al.* (2011) in teasle gourd. Since its correlation with fruit yield was non-significant and direct effect being negligible, this trait cannot be considered for direct selection. First female flowering node

Table 4.11 Direct (diagonal) and indirect (off diagonal) effects of quantitative traits on fruit yield of spine gourd

Trait		Vine length (m) (1)	Number of stems per plant (2)	Days to first female flower appearance (3)	First female flowering node (4)	Days to first fruit harvest (5)	Days to last fruit harvest (6)	Fruiting period (days) (7)	Fruit length (cm) (8)	Fruit width (cm) (9)	Fruit weight (g) (10)	Number of fruits per plant (11)	'r' with fruit yield per plant (12)
1	P	0.048	0.023	-0.014	-0.004	-0.012	0.018	0.022	0.014	0.016	0.019	0.021	0.454**
	G	0.047	0.027	-0.014	-0.006	-0.013	0.023	0.026	0.033	0.024	0.023	0.024	0.527**
2	P	0.025	0.053	-0.013	-0.003	-0.022	0.021	0.031	0.027	0.011	0.026	0.040	0.769**
	G	0.017	0.031	-0.008	-0.006	-0.015	0.014	0.021	0.025	0.011	0.017	0.024	0.810**
3	P	-0.017	-0.014	0.057	0.005	0.025	-0.002	-0.018	-0.011	-0.015	-0.011	-0.012	-0.160
	G	-0.010	-0.009	0.034	0.003	0.017	0.000	-0.011	-0.015	-0.011	-0.008	-0.007	-0.194
4	P	-0.002	-0.002	0.002	0.028	0.003	-0.030	-0.005	0.001	-0.001	0.003	-0.003	-0.061
	G	0.000	0.000	0.000	-0.006	0.000	0.000	0.001	-0.001	0.000	-0.001	0.001	-0.082
5	P	0.009	0.015	-0.016	-0.004	-0.036	0.000	0.022	0.009	0.006	0.008	0.015	-0.385**
	G	-0.082	-0.144	0.150	0.040	0.295	0.007	-0.187	-0.115	-0.081	-0.078	-0.137	-0.433**
6	P	0.004	0.005	0.000	0.001	0.000	0.012	0.009	0.005	0.002	0.004	0.007	0.576**
	G	-0.192	-0.184	0.002	0.036	-0.010	-0.397	-0.302	-0.308	-0.132	-0.161	-0.279	0.685**
7	P	-0.057	-0.075	0.043	0.022	0.078	-0.097	-0.126	-0.063	-0.038	-0.053	-0.096	0.702**
	G	0.184	0.224	-0.107	-0.051	-0.210	0.251	0.330	0.283	0.138	0.162	0.279	0.810**
8	P	0.018	0.032	-0.013	0.003	-0.016	0.027	0.032	0.064	0.025	0.041	0.031	0.542**
	G	0.104	0.119	-0.065	0.026	-0.057	0.114	0.126	0.147	0.116	0.171	0.120	0.811**
9	P	-0.003	-0.002	0.002	0.000	0.001	-0.002	-0.003	-0.004	-0.010	-0.004	-0.002	0.233*
	G	-0.051	-0.036	0.032	0.014	0.027	-0.033	-0.042	-0.079	-0.101	-0.068	-0.034	0.320**
10	P	0.021	0.027	-0.010	0.007	-0.012	0.019	0.022	0.034	0.024	0.054	0.026	0.546**
	G	0.014	0.017	-0.007	0.006	-0.008	0.012	0.015	0.035	0.020	0.030	0.017	0.651**
11	P	0.407	0.706	-0.194	-0.114	-0.395	0.582	0.713	0.465	0.211	0.458	0.941	0.969**
	G	0.493	0.764	-0.210	-0.144	-0.458	0.691	0.833	0.805	0.333	0.563	0.983	0.992**

G= Genotypic; P= Phenotypic r = Correlation coefficient *, ** Significant at the 0.05 and 0.01 probability levels, respectively

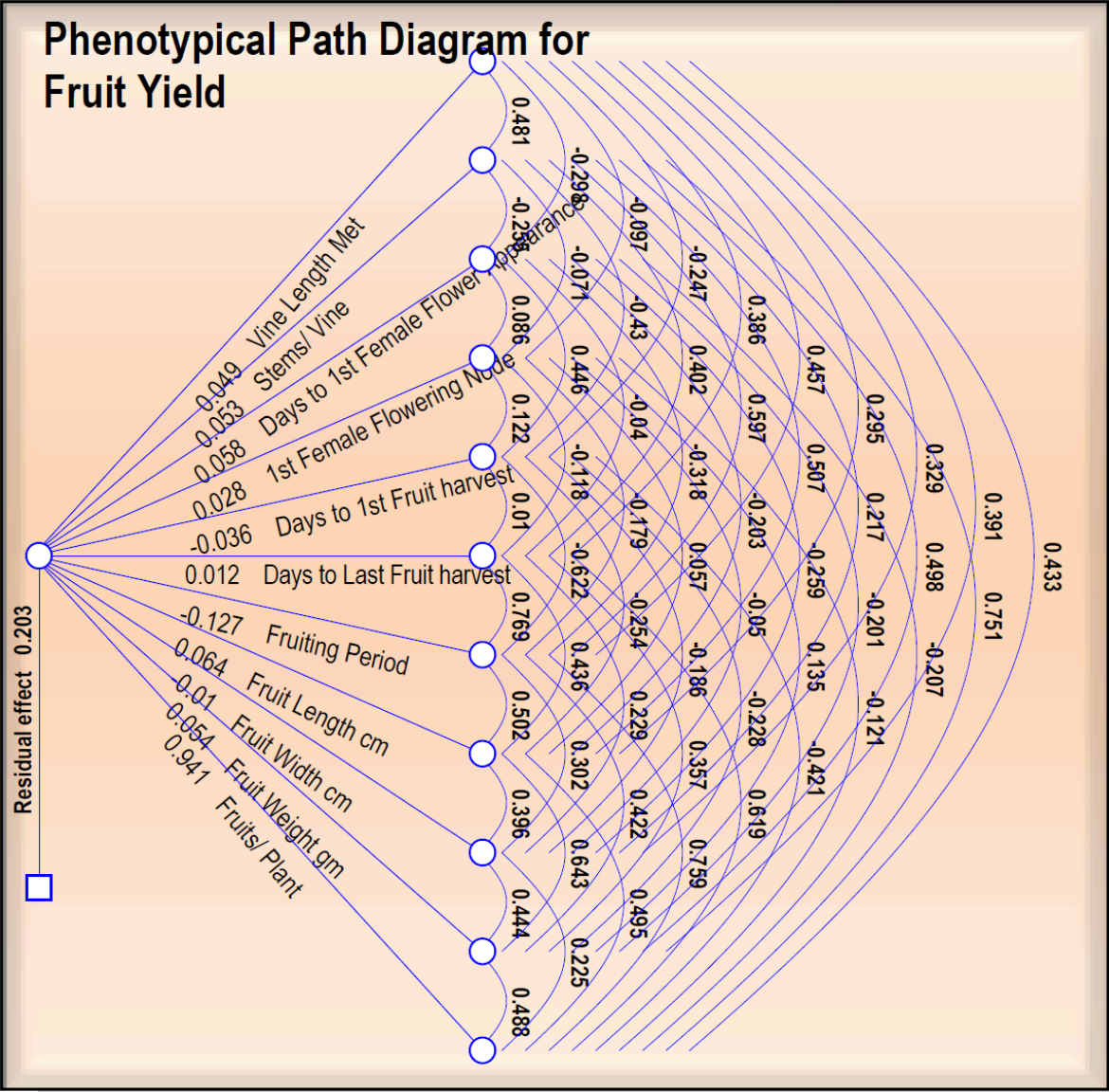


Fig.5 Phenotypic path diagram representing direct and indirect effects on fruit yield of spine gourd

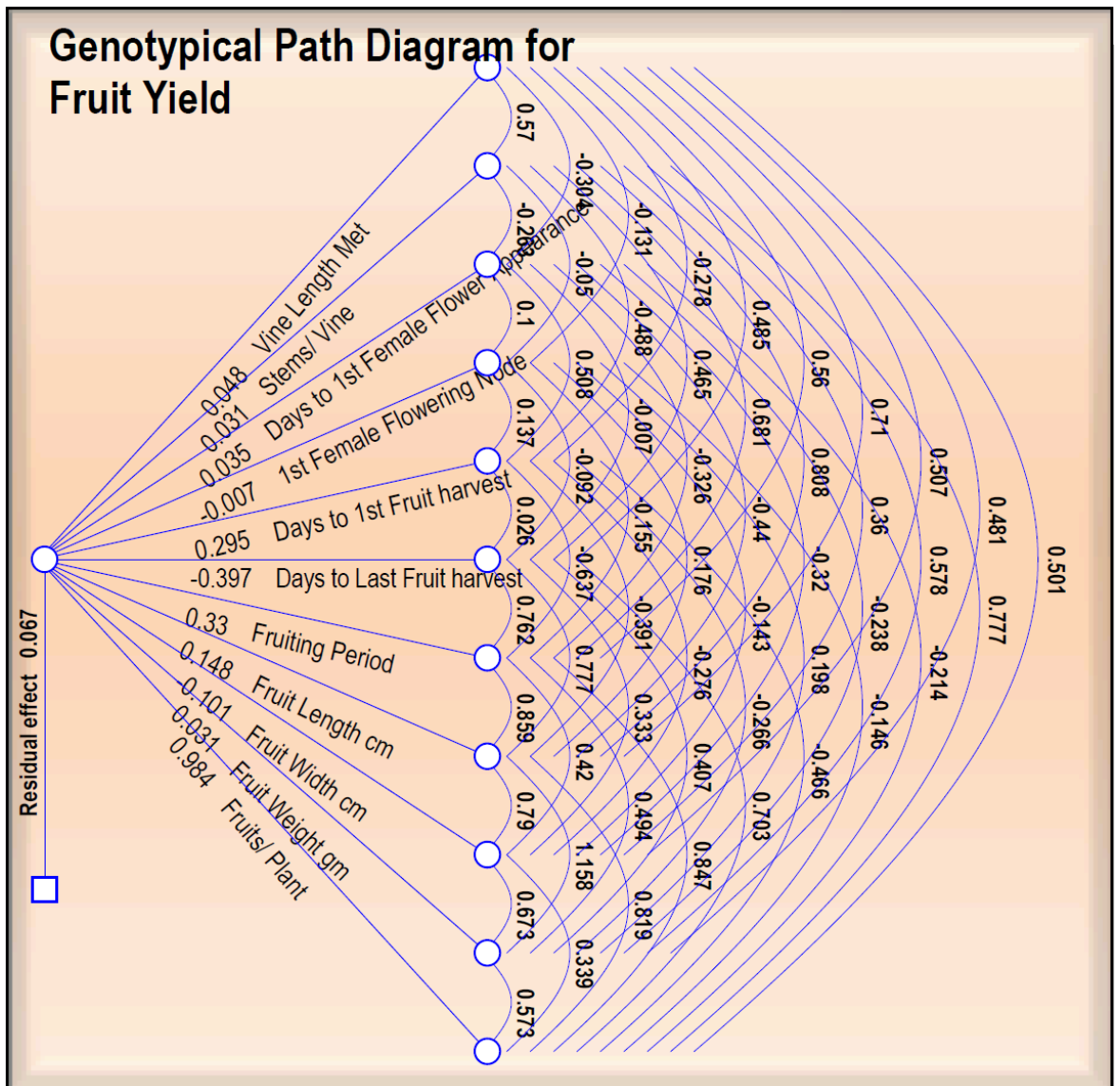


Fig.6 Genotypic path diagram representing direct and indirect effects on fruit yield of spine gourd

had negligible positive direct effect at phenotypic (0.028) level and negligible negative direct effect at genotypic (-0.006) level. Since its correlation with fruit yield was non-significant and direct effect being negligible, first female flowering node cannot be considered for direct selection.

Days to first fruit harvest had negligible negative direct effect at phenotypic (-0.036) level and moderate positive direct effect at genotypic (0.295) level. Similar result was reported by Dey *et al.* (2005) in bitter melon. This trait showed significantly negative correlation (-0.385 P, -0.433 G) and had moderate positive direct effect on fruit yield indicating the need for a restricted simultaneous selection model i.e. restrictions are to be imposed to nullify the undesirable indirect effects in order to make use of the direct effect (Singh and Kakar, 1977). This trait had positively low indirect effect on yield through days to first female flower appearance (0.150) and negatively low indirect effect through number of stems per plant (-0.144), fruiting period (-0.187), fruit length (-0.115) and number of fruits per plant (-0.137) at genotypic level.

Days to last fruit harvest had negligible positive direct effect at phenotypic (0.012) level and high negative direct effect at genotypic (-0.397) level. This trait exhibited significantly positive correlation (0.576 P, 0.685 G) and had high negative direct effect on fruit yield hence, restricted simultaneous selection model is to be followed i.e. restrictions are to be imposed to nullify the undesirable indirect effects in order to make use of the direct effect (Singh and Kakar, 1977). This trait displayed negatively low indirect effect through vine length (-0.192), number of stems per plant (-0.184), fruit width (-0.132) and fruit weight (-0.161) and had negatively moderate indirect effect through number of fruits per plant (-0.279), high negative indirect effect through fruiting period (-0.302) and fruit length (-0.308) at genotypic level.

Fruiting period had negatively low direct effect at phenotypic (-0.126) level and positively high direct effect at genotypic (0.330) level. It had positively low indirect effect through vine length (0.184), fruit width (0.138) and fruit weight

(0.162), negatively low indirect effect on fruit yield through days to first female flower appearance (-0.107) and positively moderate indirect effect through number of stems per plant (0.224), days to last fruit harvest (0.251), fruit length (0.283), number of fruits per plant (0.279), while it had negatively moderate indirect effect through days to first fruit harvest (-0.210) at genotypic level.

4.6.3 Fruit traits

Fruit length had positively negligible direct effect on fruit yield at phenotypic (0.064) level and positively low direct effect at genotypic (0.147) level. This result is in consonance with the findings of Sanwal *et al.* (2007) in sweet gourd. It had positively low indirect effect on fruit yield through vine length (0.104), number of stems (0.119), days to last fruit harvest (0.114), fruiting period (0.126), fruit width (0.116), fruit weight (0.171) and number of fruits per plant (0.120) at genotypic level. Fruit width had negatively negligible direct effect on fruit yield at phenotypic (-0.010) level and negatively low direct effect at genotypic (-0.101) level. At phenotypic and genotypic levels, fruit weight exhibited positively negligible direct effect (0.054, 0.030 respectively) on fruit yield per vine. Similar results were obtained by Bharathi *et al.* (2005b) in spine gourd and Sundaram (2010) in bitter gourd. Number of fruits per plant had positively high direct effect on fruit yield at both phenotypic (0.941) and genotypic (0.983) levels. This result is in line with reports of Bharathi *et al.* (2005b) and Singh *et al.* (2009) in spine gourd, Sanwal *et al.* (2007) in sweet gourd, Dey *et al.* (2005) in bitter gourd and Rahman *et al.* (2011) in teasle gourd.

At phenotypic level, number of fruits per plant displayed negatively low indirect effect through days to first female flower appearance (-0.194) and first female flowering node (-0.114), positively moderate indirect effect through fruit width (0.211), while positively high indirect effect through vine length (0.407), number of stems per plant (0.706), days to last fruit harvest (0.582), fruiting period (0.713), fruit length (0.465) and fruit weight (0.458) whereas negatively high indirect effect on fruit yield was reported through days to first fruit harvest (-0.395).

Number of fruits per plant had negatively low indirect effect on fruit yield through first female flowering node (-0.144), negatively moderate indirect effect through days to first female flower appearance (-0.210) and positively high indirect effect through vine length (0.493), number of stems per plant (0.764), days to last fruit harvest (0.691), fruiting period (0.833), fruit length (0.805), fruit width (0.333) and fruit weight (0.563) while it had negatively high indirect effect through days to first fruit harvest (0.458) at genotypic level.

Similar results on indirect effect through days to first female flower appearance were reported by Dey *et al.* (2005) in bitter gourd. High positive indirect effect through fruit length was also reported by Dey *et al.* (2005) in bitter gourd and Sanwal *et al.* (2007) in sweet gourd. High positive indirect effect through fruit weight was in conformity with works of Singh *et al.* (2009) in spine gourd and Sanwal *et al.* (2007) in sweet gourd.

The direct effect of number of fruits per plant at phenotypic (0.941) and genotypic (0.983) level was almost equal to its correlation coefficient at phenotypic (0.969^{**}) and genotypic (0.992^{**}) level suggesting that correlation coefficient explains the true relationship and a direct selection through this trait will be effective. The characters vine length, number of stems per plant, fruit width and fruit weight had negative or negligible direct effect but had significantly positive correlation with fruit yield per plant, the indirect effects seem to be the cause of correlation. In such situations, the indirect causal factors are to be considered simultaneously.

The direct effect of days to first fruit harvest with fruit yield per plant was positive and high but its correlation coefficient was significantly negative. The days to last fruit harvest had high negative direct effect on fruit yield but their correlation was significantly positive. Under these circumstances, a restricted simultaneous selection model is to be followed, i.e. restrictions are to be imposed to nullify the undesirable indirect effects. Selection of genotypes which fruit early with extended period of harvest, producing more number of fruits per plant is desirable for improved yield in spine gourd.

Residual effects

The residual factor determines how best the causal factors account for the variability of the dependent factor, the fruit yield per plant in this case. The residual effects were 0.2028 and 0.0669, which were of moderate and negligible magnitude at phenotypic and genotypic levels, respectively. The variables studied explain about 79.72% and 93.31% of the variability at phenotypic and genotypic levels, respectively in the fruit yield per plant. It indicates that some characters which have not been studied here need to be included in this analysis to account fully for the variation in fruit yield per plant.

Future line of work

From the present investigation, the genotypes RNK-224, RNK-197, RNK-200, RNK-196 and RNK-187 were found to be superior with respect to yield and majority of the yield components coupled with good fruit quality traits which can be used as female parents in future breeding programmes. Since spine gourd being highly cross pollinated seed propagation does not ensure true to type progeny. Macro propagation through cuttings or micro propagation is found to be beneficial for the commercial exploitation of these horticulturally superior genotypes. However these horticulturally superior and high yielding genotypes thus identified are to be further evaluated in different environments over the years before commercial exploitation.

Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSIONS

The present investigation “Morphological characterization and evaluation of spine gourd (*Momordica dioica* Roxb.) germplasm” was carried out at the Vegetable Research Station, Rajendranagar, Hyderabad during *kharif*, 2012 with the objective of characterizing the germplasm for 35 qualitative traits, studying mean performance, genetic variability, diversity, association among characters and direct and indirect effects of yield components on yield for 12 traits in 50 germplasm lines of spine gourd.

Considerable variation was observed in spine gourd germplasm for most of the qualitative traits characterized. The analysis of variance indicated highly significant differences for all the 12 characters among 50 genotypes of spine gourd. Maximum vine length was recorded in RNK-200, whereas minimum in RNK-219. Maximum number of stems per plant was produced by genotype RNK-224, whereas minimum by RNK-190, RNK-209, RNK-211, RNK-212 and RNK-223. With respect to days to first female flower appearance, genotypes RNK-186 followed by RNK-182 and RNK-195 were found to be early. Genotypes RNK-197, RNK-205 and RNK-216 produced their first female flower at the lower node followed by RNK-206, RNK-195, RNK-200 and RNK-207. RNK-185 was precocious with respect to first fruit harvest followed by RNK-194, RNK-196, RNK-197 and RNK-216. Maximum days to last fruit harvest was recorded in RNK-200 followed by RNK-205, RNK-198 and RNK-208. Fruits were produced for longer period in RNK-197, RNK-194, RNK-196, RNK-200 followed by RNK-183 and RNK-187. However, genotypes RNK-194, RNK-196, RNK-197, RNK-200 and RNK-216 were found to be early. Longest fruits were

produced in RNK-227 followed by RNK-231 and RNK-187. The genotype RNK-192 followed by RNK-183 and RNK-222 recorded maximum fruit width. Genotype RNK-227 followed by RNK-187 and RNK-226 produced fruits with maximum fruit weight. Maximum number of fruits per vine was recorded in RNK-197 followed by RNK-224 and RNK-196. In general, RNK-187, RNK-197 and RNK-222 were found to be superior in all the fruit traits. Considerable variation was observed in spine gourd germplasm for most of the qualitative traits characterized. Of the 8 qualitative traits of fruits under study, there was considerable variation in spine strength (soft and hard), fruit colour (whitish green, light green, green and dark green), fruit surface echination (densely echinate and mild-sparsely echinate), fruit shape (oblong, obovate, oval, round and top), fruit pericarp ripening (slow and sudden), fruit blossom end rostration (faint, medium and appreciable length). On the basis of mean performance for growth, earliness, fruit attributes and quality traits, the genotypes RNK-224, RNK-197, RNK-200, RNK-196 and RNK-187 were found not only high yielding but also with acceptable fruit quality.

Fifty spine gourd genotypes were grouped into eight clusters based on D^2 values. The cluster VII had maximum D^2 value whereas minimum in cluster II. Clusters V and VIII with zero intercluster distance were represented by single genotype. The intercluster distance was maximum between clusters VI and VIII followed by cluster IV and VI indicating wider genetic diversity among genotypes in these clusters. Higher cluster mean values for the characters like vine length, number of stems per plant, days to last fruit harvest, fruiting period, fruit length, fruit weight, number of fruits per plant and fruit yield were observed with the genotypes in cluster VI. For the traits like days to first female flower appearance and days to first fruit harvest, minimum cluster means were observed among genotypes of Cluster VIII. Cluster V had high cluster mean value for fruit width and low cluster mean for first female flowering node. The characters number of fruits per plant, number of stems per plant and days to first fruit harvest were the potent factors in differentiating the germplasm of spine gourd under study. Hence, the above characters are to be taken into consideration while attempting crop improvement studies. The genotypes RNK-187, RNK-200 and

RNK-224 from cluster VI, RNK-199 from cluster V, RNK-182 from cluster VIII and RNK-209 from cluster IV were identified as unique with respect to growth, earliness and fruit traits.

The genotypic and phenotypic coefficients of variation were high for vine length, number of stems per plant, days to first female flower appearance, first female flowering node, days to first fruit harvest, fruiting period, number of fruits per plant and fruit yield indicating wider genetic variability for these traits which can be improved through selection. The traits days to last fruit harvest and fruit weight recorded moderate GCV and PCV values indicating moderate variability. Low estimates of PCV and GCV were observed for fruit length and fruit width suggesting a narrow range of genetic variability for this trait. The values of PCV were larger than the corresponding values of GCV but the difference was narrow indicating low environmental influence on the expression of these characters. However, the magnitudinal differences between the estimates of GCV and PCV were highest for fruit length (5.47) followed by first female flowering node (3.68) and fruiting period (3.58) indicating that these traits were influenced by the environmental effects to a large extent and the greater role of environment in the expression of these traits.

The characters vine length, number of stems per plant, days to first female flower appearance, first female flowering node, days to first fruit harvest, days to last fruit harvest, fruiting period, fruit weight, number of fruits per plant and fruit yield had high heritability in conjunction with high genetic advance as per cent of mean indicating the predominance of additive gene action and hence direct selection will be rewarding for improvement of these traits. Moderate genetic advance as per cent of mean with medium heritability suggesting the action of both additive and non-additive genes, thereby favourable influence of environment in the expression of traits was reported in case of fruit length.

Correlation coefficient analysis revealed that fruit yield per vine had significantly positive association with traits like vine length, number of stems per plant, days to last fruit harvest, fruiting period, fruit length, fruit width, fruit weight and number of fruits per plant, while it had significantly negative

association with days to first fruit harvest. Hence, in selection programme, emphasis on these traits will result in improved fruit yield.

Path coefficient analysis showed that magnitude and direction of correlation coefficient and direct effect of number of fruits per plant on fruit yield were almost equal suggesting that direct selection through this trait will be effective in improvement of fruit yield per vine. The characters vine length, number of stems per plant, fruit width and fruit weight had negative or negligible direct effect but had significantly positive correlation with fruit yield per plant, the indirect effects seem to be the cause of correlation suggesting that indirect selection through these traits would be effective. Days to first fruit harvest had high positive direct effect on fruit yield and its correlation coefficient with fruit yield was significantly negative, days to last fruit harvest had high negative direct effect on fruit yield but its correlation was significantly positive. Under these circumstances, a restricted simultaneous selection model is to be followed, i.e. restrictions are to be imposed to nullify the undesirable indirect effects.

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

1. On the basis of mean performance for fruit yield and its components and acceptable fruit quality traits, the genotypes RNK-187, RNK-196, RNK-197, RNK-200 and RNK-224 were found to be horticulturally superior.
2. Based on genetic distances and clustering pattern the most divergent genotypes *viz.*, RNK-187, RNK-200 and RNK-224 from cluster VI, RNK-199 from cluster V, RNK-182 from cluster VIII and RNK-209 from cluster IV may be used as female parent in future breeding programmes.
3. Correlation and path analysis revealed that selection of genotypes which fruit early with extended period of harvest, producing more number of fruits per plant is desirable for improved yield in spine gourd. Number of fruits per plant is regarded as primary yield contributing components in spine gourd.

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* 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

APPENDIX

Weekly meteorological data recorded at ARI, Rajendranagar during June to November 2012

Week number	Period	Temperature (°C)		R.H. (%)		Rainfall (mm)	Rainy days	Sun shine (hrs.)	Wind speed (km/hr)	Evapo ration (mm)	Mean temp. (°C)
		Max.	Min.	I	II						
22	28-03 JUN	40.7	28.5	46.1	21.1	0.0	0	5.4	12.4	6.4	34.6
23	04-10	38.3	26.7	65.7	40.3	2.2	0	9.6	12.9	6.7	32.5
24	11-17	36.0	25.6	70.3	40.6	10.8	1	4.6	10.0	5.6	30.8
25	18-24	30.6	23.6	82.1	59.6	90.5	2	1.6	11.9	4.0	27.1
26	25-01 JUL	33.1	24.9	83.6	60.3	36.0	3	1.5	12.4	4.3	29.0
27	02-08	30.6	23.7	81.9	59.6	24.7	1	2.6	12.7	3.6	27.2
28	09-15	31.5	22.9	78.9	62.3	36.0	3	6.1	6.5	3.2	27.2
29	16-22	28.3	22.2	92.0	81.9	186.2	5	0.4	9.5	2.4	25.3
30	23-29	29.9	23.4	85.4	66.3	14.7	2	2.7	11.6	3.1	26.6
31	30-05 AUG	29.4	22.3	89.3	67.4	7.2	2	3.0	12.9	2.9	25.8
32	06-12	30.9	22.5	85.9	62.9	17.9	3	5.6	8.6	3.1	26.7
33	13-19	30.6	23.0	84.3	62.4	4.0	0	8.1	8.2	3.3	26.8
34	20-26	30.5	22.7	86.7	68.0	56.6	2	4.0	6.3	3.0	26.6
35	27-02 SEP	29.2	21.9	87.1	72.4	13.7	2	4.0	8.7	2.5	25.6
36	03-09	29.3	22.3	87.7	70.1	43.1	3	4.9	9.4	2.7	25.8
37	10-16	29.2	22.0	89	70	27.2	2	4.2	7.6	2.7	25.6
38	17-23	30.6	23.2	91	62	13.6	2	5.3	3.5	3.1	26.9
39	24-30	31.6	21.3	87	61	29.0	2	5.6	1.9	3.3	26.4
40	01-07 OCT	29.2	21.9	94	69	45.3	4	3.0	2.6	2.6	25.6
41	08-14	31.7	16.7	84	40	0.0	0	8.8	1.4	3.8	24.2
42	15-21	30.7	16.7	84	43	13.6	1	7.7	2.7	4.5	23.7
43	22-28	29.9	19.5	87	52	0.0	0	7.0	2.8	3.4	24.7
44	29-04 NOV	27.5	18.5	85	65	47.0	2	4.4	4.8	2.7	23.0
45	05-11	29.0	17.3	90	49	0.0	0	6.3	1.2	3.2	23.1
46	12-18	27.9	11.0	86	28	0.0	0	8.9	2.5	3.1	19.4
47	19-25	29.9	16.6	81	52	0.0	0	6.8	2.2	3.5	23.3
48	26-02 DEC	30.0	15.7	84	45	0.0	0	7.0	2.4	3.2	22.8

