

**“STUDIES ON GENETIC VARIABILITY,
HERITABILITY, CORRELATION AND PATH
COEFFICIENT ANALYSIS IN BOTTLE GOURD
[*Lagenaria siceraria* (Mol.) Standl.] GENOTYPES”**

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Dr. Y. S. R. HORTICULTURAL UNIVERSITY**

JUNE, 2013

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BY

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B.Sc (Hort.)

THESIS SUBMITTED TO THE

Dr. Y. S. R. HORTICULTURAL UNIVERSITY

IN PARTIAL FULFILMENT OF THE REQUIREMENTS

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DEPARTMENT OF VEGETABLE SCIENCE

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JUNE, 2013

DECLARATION

I, Ms. B. DEEPTHI, hereby declare that the thesis entitled “**STUDIES ON GENETIC VARIABILITY, HERITABILITY, CORRELATION AND PATH COEFFICIENT ANALYSIS IN BOTTLE GOURD [*Lagenaria Siceraria* (Mol) Standl.] GENOTYPES**” 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.

Place: Venkataramannagudem

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Date:

I.D.No: VHM/11- 03

CERTIFICATE

Ms. B. DEEPTHI has satisfactorily prosecuted the course of research and that the thesis entitled “**STUDIES ON GENETIC VARIABILITY, HERITABILITY, CORRELATION AND PATH ANALYSIS IN BOTTLE GOURD [*Lagenaria siceraria* (Mol.) Standl.] GENOTYPES**” submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination.

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

Place: Venkataramannagudem

(P. SYAM SUNDAR REDDY)

Date:

Chairman

CERTIFICATE

This is to certify that the thesis entitled “**STUDIES ON GENETIC VARIABILITY, HERITABILITY, CORRELATION AND PATH ANALYSIS IN BOTTLE GOURD [*Lagenaria siceraria* (Mol.) Standl.] GENOTYPES**” 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. B.DEEPTHI 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 investigation have been duly acknowledged by the author of the thesis.

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Venkataramannagudem

Date:

(B. DEEPTHI)

CONTENTS

CHAPTER NO.	TITLE	PAGE NO.
I	INTRODUCTION	
II	REVIEW OF LITERATURE	
III	MATERIAL AND METHODS	
IV	RESULTS AND DISCUSSION	
V	SUMMARY AND CONCLUSIONS	
	LITERATURE CITED	
	APPENDICES	

LIST OF TABLES

Table No.	Title	Page No.
1.	Germplasm accessions of bottle gourd	
2.	Analysis of variance for the characters under study in bottle gourd genotypes	
3.	Variation in morphological features of bottle gourd genotypes	
4.	Mean performance of the characters under study in bottle gourd genotypes	
5.	Estimation of variability, heritability and genetic advance as percent of mean for different characters in genotypes of bottle gourd	
6.	Phenotypic correlation matrix among different characters in genotypes of bottle gourd	
7.	Genotypic correlation matrix among different characters in genotypes of bottle gourd	
8.	Phenotypic path coefficient analysis among different characters in genotypes of bottle gourd	
9.	Genotypic path coefficient analysis among different characters in genotypes of bottle gourd	
10.	Per cent contribution of different characters towards diversity in genotypes of bottle gourd	
11.	Clustering pattern of bottle gourd genotypes by Ward's method	
12.	Average intra and inter-cluster D^2 values for five clusters in genotypes of bottle gourd	
13.	Selection of parents for future use in breeding programme	
14.	Mean values of clusters for different characters in genotypes of Bottle gourd (Ward's method)	

LIST OF PLATES

Plate No.	Title	Page No.
1.	General view of experimental plot	
2.	Phenotypic variation in leaf lobing pattern of bottle gourd genotypes	
3.	Phenotypic variation in leaf lobing pattern of bottle gourd genotypes	
4.	Phenotypic variation in fruits of bottle gourd genotypes	
5.	Phenotypic variation in fruits of bottle gourd genotypes	

LIST OF ILLUSTRATIONS

Figure No.	Title	Page No.
1.	Layout of the Experimental plot of bottle gourd	
2.	Mean performance of tendril length and number of primary branches of different genotypes of bottle gourd	
3.	Mean performance of number of nodes, vine length, internodal length of different genotypes of bottle gourd	
4.	Mean performance of days to first male and female flower of different genotypes of bottle gourd	
5.	Mean performance of node number at first male and female flower of different genotypes of bottle gourd	
6.	Mean performance of days to first harvest of different genotypes of bottle gourd	
7.	Mean performance of fruit weight of different genotypes of bottle gourd	
8.	Mean performance of fruit length and fruit diameter of different genotypes of bottle gourd	
9.	Mean performance of number of fruits per vine of different genotypes of bottle gourd	
10.	Mean performance of yield per vine and total yield of different genotypes of bottle gourd	
11.	Mean performance of number of seeds per fruit of different genotypes of bottle gourd	
12.	Mean performance of 100 seed weight of different genotypes of bottle gourd	
13.	Phenotypic and genotypic coefficient of variation for different characters of bottle gourd	
14.	Heritability, genetic advance and genetic advance as per	

Figure No.	Title	Page No.
	cent of mean for different characters of bottle gourd	
15.	Phenotypic path diagram representing direct and indirect effects for fruit yield per vine of bottle gourd.	
16.	Genotypic path diagram representing direct and indirect effects for fruit yield per vine of bottle gourd.	
17.	Mean inter and intra cluster distances of bottle gourd genotypes	
18.	Relative contribution of different characters to genetic divergence in bottle gourd	

LIST OF SYMBOLS AND ABBREVIATIONS

%	:	per cent
@	:	at the rate of
&	:	and
⁰ C	:	degree Celsius
ANOVA	:	Analysis of variance
A.P.	:	Andhra Pradesh
CD	:	Critical difference
cm	:	centimetre
df	:	degrees of freedom
DFM	:	Days to first male flower appearance
DFE	:	Days to first female flower appearance
DFH	:	Days to first fruit harvest
Dr.YSRHU	:	Dr Y S Rajasekhar Reddy Horticultural University
dSm ⁻¹	:	deci siemen per meter
EC	:	Electrical conductivity
<i>etc.</i> ,	:	and so on
<i>et al.</i>	:	and others
Fig.	:	Figure
FD	:	Fruit diameter
FL	:	Fruit length
FW	:	Fruit weight
FYM	:	Farm yard manure
g	:	gram
G	:	Genotype
GA	:	Genetic Advance
GAM	:	Genetic Advance as per cent of Mean
GCV	:	Genotypic Coefficient of Variation
HC & RI	:	Horticulture College and Research Institute
h ²	:	heritability in broad sense

<i>i.e.</i> ,	:	that is
IL	:	Internodal length
kg	:	kilogram
kg ha ⁻¹	:	kilogram per hectare
m	:	meter
mg	:	milligram
MAS	:	Marker Assisted Selection
MSL	:	mean sea level
MSS	:	mean sum of squares
no.	:	Number
NBPGR	:	National Bureau of Plant Genetic Resources
NFM	:	Node at which first male flower appears
NFF	:	Node at which first female flower appears
NFV	:	Number of fruits per vine
NNV	:	Number of nodes per vine
NPBV	:	Number of primary branches per vine
NSF	:	Number of seeds per fruit
P	:	Phenotype
PCV	:	Phenotypic Coefficient of Variation
pH	:	puissance de hydrogen
RBD	:	Randomised Block Design
RH	:	Relative humidity
SCA	:	Specific Combining Ability
SE(d)	:	Standard error difference
S.Em	:	Standard error mean
SS	:	Sum of Squares
TL	:	Tendril length
TVL	:	Total vine length
t/ha	:	tonne per hectare
W.G.Dist.	:	West Godavari District
<i>viz.</i> ,	:	namely

YV : Yield per vine
100 SW : 100 seed weight

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ABSTRACT

The experiment was taken up to elicit the information on magnitude of genetic variability, heritability and to predict the gains realized through selection, character association, cause and effect relationship and divergence for the quantitative characters in bottle gourd [*Lagenaria siceraria* (Mol) Standl.] genotypes. Twenty three genotypes of bottle gourd along with one check variety Pusa Naveen were evaluated in RBD with three replications during spring summer of 2012 at Horticultural College and Research Institute, Dr. Y. S. R. Horticultural University, Venkataramannagudem, West Godavari district, Andhra Pradesh.

The study revealed significant differences among genotypes for different characters studied. Among all the genotypes studied, genotypes IC 249671 recorded the highest yield per vine and found suitable to the local agro-climatic conditions. The genotypes IC 249663, IC 249672 and check variety Pusa Naveen were also found to be elite for different characters.

Among the characters studied, high PCV and GCV were observed for characters like primary branches per vine, node at which first male flower appears, number of fruits per vine, fruit weight (g), fruit length (cm), fruit diameter (cm), yield per vine (kg), total yield (t/ha), number of seeds per fruit and 100 seed weight (g)

indicating high variability available in the germplasm for these characters for further improvement.

High heritability coupled with high genetic advance as per cent of mean was observed for characters tendril length (cm), number of primary branches, days to first male flower appearance, node at first male flower appears, number of fruits per vine, fruit weight (g), fruit length (cm), fruit diameter (cm), yield per vine (kg), total yield (t/ha), number of seeds and 100 seed weight (g) indicated that these characters were least influenced by the environmental effects, and these characters were governed by additive genes and selection will be rewarding for improvement of such traits.

The fruit yield per vine (kg) had significant positive correlation with traits like tendril length (cm), number of nodes per vine, number of primary branches per vine, total vine length (m), internodal length (cm), number of fruits per vine, fruit weight (g), fruit diameter (cm), number of seeds per fruit and 100 seed weight (g) suggesting the importance of these traits in selection for yield and can be identified as yield attributing characters for the genetic improvement of yield in bottle gourd.

The fruit yield per vine (kg) was result of direct effect of total vine length (m), number of fruits per vine, fruit weight (g). The high direct effect of these traits appeared to be the main factor for their strong association with fruit yield per vine.

Analysis for divergence using D^2 statistic revealed highly significant differences for different traits, grouping the 23 genotypes into 5 clusters. Cluster III had the maximum number of genotypes (11) followed by cluster IV (8). Maximum inter cluster distance was observed between clusters II and V while the intra cluster distance was maximum in cluster I. Highest percent contribution to divergence came from 100 seed weight (g), fruit diameter (cm), number of seeds fruit and fruit length (cm) suggested that selection of one or two elite genotypes from divergent (II & V) and (I & V) clusters based on the above characters and crossing would result in more heterosis and novel hybrids.

Chapter-I

Introduction

CHAPTER – I

INTRODUCTION

Bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] is one of the most popular vegetables of the family, Cucurbitaceae, with a diploid chromosome number, $2n=22$. It is a highly cross pollinated crop due to its monoecious and andromonecious nature (Swiander *et al.*, 1994). It can be grown in both summer and rainy season, but it can't tolerate cold (Rastogi, 1998). The names “lagenaria” and “siceraria” are derived from Latin words “lagena” for bottle and “sicera” for drinking utensil. Cucurbitaceous family is economically most significant family, supplying edible and nutritious fruits to humanity (Bisognin, 2002). Plants of this family, whilst possessing similar characteristics of the sprouting segments, are characterized by great genetic variability in fruit shape, fruit length and texture of fruit, resulting in variability and wide range of diversity.

Bottle gourd originated in Africa (Singh, 1990) and from there by floating on the seas, it travelled to India, where it has evolved into numerous local varieties, and has spread to China, Indonesia and far to New Zealand.

In areas with mild climate, it can be grown throughout the year. In India the exact figures on area and production are not available but it is commercially grown in most of the states like Uttar Pradesh, Bihar, West Bengal, Assam, Punjab, Maharashtra, Karnataka and Gujarat. The total area under cultivation in Andhra Pradesh is approximately 8.28 thousand hectares with an annual production of 1.24 lakh tones (Dept. of Horticulture, A.P, 2011-12). Bottle gourd in India has a tremendous potential for export and has created a huge demand in Gulf markets. Productivity of bottle gourd is still low in India; hence, enhancement of crop yield is still an important goal for bottle gourd breeders in India. In spite of the extensive cultivation and consumption, bottle gourd has not been taken up for systematic research work in order to understand the genetic architecture and endeavour in an improvement programme. Many important features of cultivated crops are not associated with discrete

Mendelian traits, but are of a continuous or quantitative nature. Yielding ability is a prime example of such a trait and is of obvious importance.

Although bottle gourd is a modest source of nutrients, it is very popular among a large section of people. It is easily digestible and is used extensively as vegetable and also recommended during convalescence. Fruits are used in sweets, pickles (especially on hills), kofta, petha, halwa, kopoor kand, paratha and rayata. The young shoots and leaves of a few cultivars are occasionally used as a pot herb. Dry hard shells of the fruits have been used for making a wide range of articles of common use, including bowls, bottles, containers, floats for fishing nets, pipes and musical instruments. In addition, the seeds and seed oil are also edible. Immature fruits are consumed in a number of ways. Bottle gourd has got cooling effect, so in the eastern countries, fruits are often used as cooling vegetable. Fruit pulp is used as purgative and is very useful in coughs. Fruit juice is recommended for heart and diabetic patients. It is an antidote to certain poisons. In Bombay Bottle gourd is sold as cardiotonic and is recommended by the doctors. The cut surface of the small sized fruits is rubbed on the underside of the feet and hands to reduce the effect of heat. The fruit ash with honey is useful to eyes for night blindness. It is ideal for people suffering from jaundice and allied diseases and also very much useful in preventing constipation. Seeds contain oil, which is helpful for brain development and body smoothness. Hence, it is being used in Ayurvedic preparations (Robinson and Decker-Walter, 1999). Besides this, the whole fruit is used in cosmetic and soap industries.

The fruits contain vitamin C (11m.g), thiamine (0.044m.g), riboflavin (0.023m.g), niacin (0.33m.g), mineral matters (0.05%), carbohydrates (2.9%), fats (0.5%) protein (0.2%) and moisture (96.3%) and its different parts possess large number of medicinal properties (Desai and Musmade, 1998).

The basic problem in bottle gourd is low marketable yield. The reduced marketability of the fruits is due to the misshapening of the fruits. The causes for such misshaped fruits have not been clearly documented. Any stress factor during the crop growth could result in misshaped fruits. Apart from stress factors, genetic background could also be a factor determining the misshapening of the fruits. Bottle gourd shows

large variation for various economic traits of which the most interesting variation is found for size, shape and color of fruits. On the basis of fruit shape, the cultivars of bottle gourd are broadly classified into different groups viz.; long fruited, round fruited, bottle shaped *etc.*, Bottle gourd is characterised by differently shaped fruits that can be used as utensils or decorative ornaments, whilst younger juicy fruits are edible and nutritious. Prasad and Prasad (1979) have developed unique bottle gourd varieties in India, primarily for human consumption. It has been used in varied and specific ways in cultures of different nations. Scientists believe that, of all currently known plants, bottle gourd is the only species that had been used worldwide in prehistoric times.

The variation in bottle gourds is sometimes spectacular. The background colour is either light green or dark green. The dark green can be distributed as a solid colour, as regular or irregular stripes, and as an irregular blotch. The size of the fruit varies from 2-12 inches in diameter and from 4-40 inches in length. The fruit can have a sterile (seedless) neck that varies from a few to 15 inches in length and from 1-2 inches in width. Wider necks usually contain seeds, and the neck may have a seed-containing bulge. The seed-containing portion of the fruit varies from flat to round, cylindrical, club-shaped, or long and narrow. The long and narrow forms are best for vegetables.

The essential prerequisite for launching a breeding programme in any crop is the extent of genetic variability and genetic divergence in the breeding material. Wide differences between morphological traits such as size, color, resistance to pest and diseases and yield are of immense importance to the breeders since number of cultivars could be developed to suit various requirements.

Bottle gourd is a monoecious and cross pollinated crop in which large amount of variation has been observed for many economically important traits. Precise information regarding the extent of genetic divergence in the breeding lines is crucial in heterosis breeding programme. The available diversity within the species for desired fruit enables a breeder in choosing the most suitable combinations to use for exploitation of hybrid vigor in a given crop.

The genetic parameters such as heritability, genetic advance, genotypic and phenotypic coefficients of variability provide an effective tool in the hands of a breeder to select a genotype having the most desirable traits for yield.

Many of the quantitative traits such as number of fruits per plant and yield per vine are highly influenced by environmental conditions partitioning the overall variability into heritable and non-heritable components which will be of immense help in any planned breeding programme.

Mahalanobis (1936) set the ground rules for study of variability in a population when he proposed the D^2 statistic. This invariably strengthened the concept of breeding for superior genotypes by defining the levels of exploitable variability and by predicting the results of a breeding programme. D^2 analysis permits precise comparison among all possible pairs of populations before effecting actual cross in modeling the cultivars in a desired genetic architecture.

Therefore, the present investigation entitled “Studies on genetic variability, heritability, correlation and path coefficient analysis in bottle gourd [*Lagenaria siceraria* (Mol) Standl.] genotypes” was carried out at HC&RI, Venkataramanagudem, Dr.Y.S.R.Horticultural University, Tadepalligudem (Mandal), West Godavari district with the following objectives:

1. To study the relative magnitude of genetic variability, heritability and genetic advance in bottle gourd.
2. To estimate phenotypic and genotypic correlation among yield and its component characters.
3. To estimate direct and indirect effects of different component characters on yield using path coefficient analysis.
4. To study genetic divergence using Mahalanobis' D^2 statistic and grouping of germplasm into clusters.

Chapter-II

Review of Literature

CHAPTER - II

REVIEW OF LITERATURE

Bottle gourd is one of the most important and popular vegetable crops grown in India and abroad. The phenotype of a quantitative trait is the joint product of genotype and environment. Hence, the estimates of variability and its heritable components for the yield contributing characters in the available germplasm are pre-requisite for a breeding programme for high yield.

It is necessary to understand the genetic architecture of the various characters of importance and interrelationship among them. In the present investigation, an attempt has been made to study genetic variability, heritability, genetic advance, correlation, path coefficient analysis and genetic divergence in bottle gourd genotypes. A brief review of available literature pertaining to the present investigation in bottle gourd and in other cucurbitaceous vegetable crops has been presented in this chapter under the following headings.

2.1 Variability

2.2 Heritability and genetic advance

2.3 Correlation studies

2.4 Path coefficient analysis

2.5 Genetic divergence

2.1 VARIABILITY

Any crop improvement depends on the magnitude of genetic variability and the extent to which the desirable characters are heritable. The role played by environment in expression of economic characters also needs to be taken into account. No doubt that the efficiency of selection depends mainly on the extent of genetic variability present in the population. However, Burton (1952) suggested that co-efficient of variability together with heritability estimate will give a good picture of amount of genetic advance to be expected from selection. Similarly, Thakur and Choudhary

(1965) reported that high heritability estimates together with high genetic advance and high genotypic coefficient of variability lead to high genetic gain.

Rahman *et al.* (1986) reported very high genotypic and phenotypic variability for fruit length and number of branches per plant, but very low for number of fruits per plant and length of main vine in bottle gourd genotypes.

Sharma and Dhankar (1990) evaluated 35 genotypes of bottle gourd for variability during summer season and found that Hissar local-3, a round genotype was earliest and highest yielder. Pusa summer prolific long, Hissar Sel-1 and Hissar Sel-2 were most promising for earliness and high yield among long types.

Prasad *et al.* (1993) observed 30 genotypes of bottle gourd for their variability and the studies revealed highest genotypic and phenotypic coefficient of variability for fruit yield per plant followed by number of male flowers on primary laterals and fruits per vine. The genotypic differences for all the characters were highly significant. The magnitude of PCV was higher than GCV for all characters suggesting the effect of environment.

Narayan *et al.* (1996) studied 25 diverse populations of bottle gourd and reported high value of GCV for number of primary branches per plant and yield per vine indicating that these two characters had additive gene effect and are more reliable for effective selection.

Mathew *et al.* (2000) evaluated 28 bottle gourd accessions and reported that fruit shape and fruit color exhibited high variation among the various qualitative characters. Significant difference was observed in accessions for vine length, number of primary branches, days to first female flower opening, nodes to first female flower opening, sex ratio, number of fruits per plant, length of fruit, girth of fruit, 100 seed weight, number of seeds per fruit and crude fiber content. The highest GCV and PCV were recorded for number of fruits per plant (38.05 and 50.71) and the lowest for internodal length (0.22 and 6.95).

Singh and Rajesh Kumar (2002) studied 10 lines, 2 testers and 20 F₁s of bottle gourd and reported that the phenotypic coefficient of variation was significantly

higher than genotypic coefficient of variation for fruit yield per plant, fruit diameter, fruit length, number of nodes to first male flower and vine length which were also characterized by high genetic variation.

Munshi and Sirohi (2005) evaluated the performance of 12 bottle gourd cultivars and observed high genotypic and phenotypic coefficient of variation for vine length, number of primary branches per vine, number of nodes on the main axis, number of fruits per plant, fruit length, girth, weight and crop yield.

Yadav *et al.* (2008) studied 18 bottle gourd cultivars based on nine characters namely days to first male flowering, days to first female flowering, number of nodes of first male flowering, number of nodes to first female flowering, days to edible fruit, fruit length, fruit width, number of fruits per plant and yield per plant. All the characters showed considerable amount of variability. The fruit width had the highest coefficients of genotypic and phenotypic variability.

Singh *et al.* (2008) studied genetic variability in bottle gourd in both summer and rainy seasons and recorded the highest genotypic and phenotypic coefficients of variation for yield per vine.

Arvind Kumar *et al.* (2011) evaluated 24 hybrids of bottle gourd obtained by crossing 11 parents and results revealed that the PCV was slightly higher than their corresponding GCV for all the characters studied. It was also observed that genotypic and phenotypic coefficient of variation was higher for fruit yield per plant.

Husna *et al.* (2011) studied variability for different characters in 31 genotypes of bottle gourd and observed high genotypic co-efficient of variation (GCV) for yield per plant, fruit weight whereas low genotypic co-efficient of variation for fruit breadth. In all the cases, phenotypic variances were higher than the genotypic variance. Differences between genotypic and phenotypic co-efficient revealed that the major portion of the phenotypic variance was genetic in nature.

Wide range of variability was recorded in 10 diverse bottle gourd entries for the quantitative traits of fruit, yield and seed characters viz., days to germination 50% (7.23 to 11.01), days to 1st male flower anthesis (42.86 to 54.62), days to 1st female

flower anthesis (51.11 to 61.78), node no. of 1st male flower (4.22 to 9.35), node no. of 1st female flower (5.32 to 11.81), days to 1st fruit harvest (63.20 to 75.90), no. of branches per vine (2.98 to 5.70), vine length (2.86 to 6.28 m), fruit length (13.3 to 60.55 cm), individual edible fruit weight (0.85 to 2.31 kg), no. of fruits per vine (3.25 to 9.25), fruit yield per vine (1.77 to 10.21 kg), no. of seeds per fruit (356.10 to 497.50) and 100-seed mass (7.0 to 30.1 g) (Kamal *et al.* 2012)

Literature pertaining to other cucurbitaceous vegetables

Gopalakrishnan *et al.* (1981) reported significant variability for fruit yield, vine length, fruit weight and their respective components in 18 diverse genotypes of pumpkin. The length of the main vine and fruit weight had the maximum direct effect on yield.

Prasad and Singh (1990) reported high phenotypic and genotypic coefficient of variation for fruit length, yield per plant and vine length in ridge gourd. However, number of fruits and fruit width recorded moderately high estimates of PCV and GCV.

Lawande and Patil (1991) reported high variability estimates for fruit yield per vine, fruit weight, fruit length, fruit diameter and number of fruits per vine in eleven cultivars of bitter gourd.

Rajput *et al.* (1996) reported high PCV and GCV for seeds per fruit and yield per vine in bitter gourd. Mishra *et al.* (1998) studied variability in bitter gourd and reported there was a frequent occurrence of dominant alleles and both additive and non-additive gene action was involved in character expression.

Mathew and Khadar (1999) reported high PCV and GCV for average fruit weight, number of seeds per fruit, fruit yield per plant and fruit length in 34 genotypes of snake gourd.

In ridge gourd, Chowdhary and Sharma (2002) found very high GCV and PCV for vine length and fruit weight. The magnitude of phenotypic coefficient of variation (PCV) was greater than the corresponding genotypic coefficient of variation (GCV) for all the traits under study.

Dora *et al.* (2002) reported high GCV for node at which first female flower appeared followed by number of nodes per plant, weight of fruit, number of fruits per plant and number of branches per plant in pointed gourd.

Rahaman *et al.* (2002) evaluated 24 genotypes of snake gourd and revealed high genotypic coefficient of variation for fruit yield (35.52 t/ha), number of fruits per plant (34.95), fruit length (27.37 cm) and stem length (20.70 cm).

In ridge gourd, Karuppaiah *et al.* (2002) reported high GCV for yield per plant and number of fruits per plants. Singh *et al.* (2002) recorded higher genotypic coefficient of variation for total yield, average fruit weight and dry weight of fruit in ash gourd.

Rai *et al.* (2005) studied variability in chow chow and reported that the phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV) indicating presence of environmental influence.

Yadav *et al.* (2007b) studied variability in chow chow and reported variability in terms of fruit shape, size, colour and presence of spines in different genotypes.

Islam *et al.* (2009) evaluated 20 bitter gourd genotypes and observed high genotypic co-efficient of variation (GCV) for branches per vine, yield per plant and number of fruits per plant whereas low genotypic co-efficient of variation was observed for days to first male and female flowering. Differences between genotypic and phenotypic coefficient of variation revealed that major portion of the phenotypic variance was genetic in nature.

Khan *et al.* (2009) observed moderately high genotypic coefficient of variation for fruit number (5415), yield (410) and fruit weight (172) and high phenotypic coefficient of variation was observed in fruit number (5623), yield (411), fruit weight (173) in per cent in pointed gourd . The influence of environment was minimum while the genotypic and phenotypic coefficient of variation was similar in magnitude. However the magnitude of difference between PCV and GCV was less for all the characters.

Sureja *et al.* (2010) studied 9 parental lines and their 71 F₁ hybrids in ash gourd and observed a wide range of variability along with moderate phenotypic and genotypic coefficient of variation for days to fruit maturity, number of seeds per fruit and seed weight per fruit.

Hossain *et al.* (2010) reported highest GCV for yield per plant (42.75%) , number of fruits per plant (33.41%), fruit length (27.57%), number of lateral shoots (24.19%), average fruit weight (22.14%), petiole length (16.10%) and node order at which male and female flower opened (13.28% and 12.62%) in 58 evaluated long type cucumber genotypes.

In F₂ population of cucumber crosses, Arun Kumar *et al.* (2011) assessed high variability for number of branches per vine, average fruit weight, total number of fruits per vine and total fruit yield per vine while moderate PCV and GCV for total number of fruits per vine, fruit diameter and total fruit yield per vine.

Ten pumpkin accessions were evaluated by Blessing *et al.* (2012) in 2007 and 2008 planting seasons and observed high genotypic variability and heritability for days to 50% emergence, fruit diameter and number of seeds per fruit but low values for number of male and female flowers in both planting seasons.

Jahan *et al.* (2012) while studying the variability in 8 parents and 10 hybrids of pumpkin reported that phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the characters studied indicating that the environment played a considerable role on the expression of these characters.

2.2 HERITABILITY AND GENETIC ADVANCE

Phenotype of an individual is determined by genotype and environment in which it grows. Success of a breeder in changing and improving the heredity of a character depends upon the degree of correspondence between phenotypic and genotypic values. Heritability is a measure that provides this information (Dabholkar, 1992). Heritability in broad sense or degree of genetic determination is proportion of total hereditary variance to phenotypic variance. The more useful estimate i.e. narrow sense heritability or degree of resemblance between relatives is ratio of additive

genetic variance to phenotypic variance (Falconer, 1989). The most important function of heritability in the genetic studies of metric characteristics is its predictive role in expressing the reliability of phenotypic value as a guide to breeding value (Falconer, 1989). Genetic advance means improvement in the performance of selected lines over original population.

Heritable variation can be determined with greater accuracy, when heritability is studied along with genetic advance (Swarup and Chaughale, 1962). High heritability with high genetic gain is associated with additive gene effects (Panse, 1957). On the contrary, non additive gene effect (dominance or epistasis) is associated with characters exhibiting high heritability and low genetic advance.

High heritability and low genetic advance was observed for number of days to first female flower appearance, number of flowers per vine and fruit length in bottle gourd, indicating non-additive gene effects (Johnson *et al.* 1955 and Chowdhary *et al.* 1985).

Prasad and Prasad (1979) studied the heritability in genotypically 40 diverse lines of bottle gourd and reported high estimates of heritability for vine length, fruit length and fruit diameter.

Sharma *et al.* (1983) while conducting genetic studies in bottle gourd reported high heritability estimates for days to opening of first male and female flower and marketable maturity. However, low heritability was recorded for fruit weight, number of fruits per vine and total yield. The characters having high heritability failed to express high genetic advance.

Heritability (broad sense) and genetic advance were high for fruit length, fruit diameter and fruit weight per plant in 4 lines of bottle gourd (Rahman *et al.* 1986).

High heritability along with high genetic advance was recorded for male to female flower ratio, vine length, total number of branches and fruits per plant in bottle gourd (Sharma and Dhankar, 1990).

Prasad *et al.* (1993) reported high heritability estimates for all the characters studied and maximum genetic advance for fruit yield per plant. A very high broad

sense heritability (>90 %) was recorded for length of main vine, number of primary branches per plant, node number of first male flower, node number of first female flower, fruit length, fruit weight, number of fruits per plant, fruit yield per plant. High genetic advance (percent of mean) was recorded for sex ratio, fruit length and fruit yield per plant. The sex ratio, fruit length and fruit yield per plant showed high heritability (> 80%) coupled with high genetic advance in bottle gourd.

Heritability in the broad sense was very high for number of male flowers, number of female flowers and fruit yield per plant coupled with high genetic advance in 25 genotypes of bottle gourd (Narayan *et al.* 1996).

Singh *et al.* (1996) studied genetic variability and correlation studies in bottle gourd and reported high magnitudes of heritability for most of the characters studied. However, from selection point of view only that part of heritability is desirable which is due to additive gene effects. High heritability with high genetic advance is considered more useful than heritability estimated alone in predicting resultant effect in the selection programme. Traits like node at which first female flower appeared, fruits per plant, yield per plant could be more responsive to selection in bottle gourd.

High heritability and high genetic advance were recorded for fruit yield per plant, vine length, fruit diameter, fruit length, fruit weight, number of nodes to first male and female flowers, and number of primary branches per vine in 10 lines, 2 testers and 20 F₁'s of bottle gourd (Singh *et al.* 2002).

Fruit length, number of days to first fruit harvest and number of days to first female flower anthesis exhibited moderate to high heritability with moderate genetic advance in 12 bottle gourd genotypes (Munshi and Sirohi, 2005).

Kumar *et al.* (2007) evaluated 20 diverse genotypes of bottle gourd for heritability and reported high genetic advance coupled with high heritability (>90%) for fruit yield per vine, number of fruits per vine, vine length, number of branches per vine, node number of first male flower, 100 seed weight and fruit length.

Singh *et al.* (2008) reported high heritability coupled with high genetic advance for number of female flowers per vine, number of primary branches per vine and yield

per vine in bottle gourd genotypes which indicate that these characters are more reliable for effective selection.

High heritability coupled with high genetic advance were observed for fruit length, fruit width, days to first female flowering, days to first male flowering and yield per plant in 18 bottle gourd strains (Yadav *et al.* 2008).

Heritability was high for fruit yield per plant, number of seeds per fruit and fruit diameter. Genetic advance was high for fruit yield per plant in 24 hybrids obtained by crossing 11 parents of bottle gourd (Aravind Kumar *et al.* 2011).

High heritability with high genetic advance was observed in bottle gourd genotypes for yield per plant and days to first male flowering indicating that yield per plant was under additive gene control and selection for genetic improvement for this trait would be effective (Husna *et al.* 2011).

In 40 diverse genotypes of bottle gourd, Emina *et al.* (2012), recorded a very high heritability estimates (>90%) for plant height, fruit weight, fruit length, fruit circumference and number of seeds per plant where as lower heritability was observed for 100 - seed weight (78.29%).

Literature pertaining to other cucurbits

Panwar *et al.* (1977) observed high estimates of heritability along with high genetic advance for fruit length and days to flower in sponge gourd. However characters like numbers of fruits per plant and fruit diameter recorded lower value for heritability estimates.

Reddy and Rao (1984) found that the magnitude of broad sense heritability estimates is varied among the different characters in ridge gourd. Lowest heritability was recorded for days to first harvest while the fruit diameter showed moderate value. Highest heritability was found in the case of individual fruit height and fruit yield per plant. Fruit size and fruit number per plant showed high heritability in broad sense. Fruit yield, fruit weight and fruit number recorded high genetic advance.

Kadam and Kale (1985) studied genetic variability in ridge gourd and found that days to flowering had the highest heritability (94.82) and high genotypic

coefficient of variation (16.48) and genetic advance (13.70). Similar results were obtained for nodal position of female flower, fruit volume and percent intensity of powdery mildew. High heritability was observed for branches per vine (77.76), percent female flowers (51.51), yield (43.87) and fruit diameter (42.71) but genetic advance was considerably low.

Chaudhari and Kale (1991) studied fifty five F_1 progenies involving 11 true breeding bitter gourd lines and reported high genetic advance for fruit weight (21.32). High heritability and genetic gain values were recorded in yield per plant, weight of fruit and number of fruits per plant.

Singh *et al.* (1992), while estimating the heritability in broad sense and expected genetic advance in 36 genotypes of pointed gourd for fruit yield and nine other characters recorded high heritability coupled with high genetic advance for fruit yield and number of fruits per plant.

Krishna Prasad and Singh (1993) studied the heritability estimates (ranged from 0.20 to 48 per cent) in cucumber and reported low heritability estimates for number of fruits and fruit yield per plot suggesting that the environmental effects contributing to a major portion of the total phenotypic variation. High heritability coupled with high genetic advance for fruit length, fruit breadth and fruit weight might be due to additive gene action and selection could be applied for these characters in cucumber.

In snake gourd, Rahaman *et al.* (2002) found high to moderate heritability and genetic advance for fruit yield per plant (97.44 and 92.57), number of fruits per plant (95.1 and 89.98), fruit length (96.52 and 70.98) and stem length (94.64 and 53.16) in per cent respectively.

Dora *et al.* (2002) observed high heritability and high genetic advance for characters like node at which first female flower appears, vine length and number of fruits per plant in pointed gourd.

Karuppaiah *et al.* (2002) studied 12 genotypes of ridge gourd to assess mean variability, heritability and genetic advance. High heritability was observed for

number of female flowers per plant, yield per plant and flesh thickness. However, when heritability and genetic advance as per cent over mean were considered together, number of female flowers per plant, yield per plant and number of fruits per plant recorded highest values.

Krishna Prasad *et al.* (2002) conducted an experiment on adaptive response and diversity in watermelon and reported high heritability coupled with high genetic advance for yield per plot, number of nodes, days to female flowers appeared and number of fruits per plant.

Pandey *et al.* (2002) reported high estimates of heritability and genetic advance for yield per plant in pumpkin. Singh *et al.* (2002) studied variability, heritability and genetic advance in ash gourd and reported high estimates of heritability for characters like fruit length, fruit diameter, average fruit weight, total yield and number of fruits indicating that the characters were least affected by environment. Higher value of genetic advance (72%) was observed for fruit diameter and total fruit yield.

High heritability with low genetic advance as per cent mean was observed in 20 bitter gourd genotypes for days to first female flowering indicating involvement of non-additive gene for the expression of the character and selection for such trait might not be rewarding. High heritability with high genetic advance as per cent mean was observed for yield per plant and vine length indicating that this trait was under additive gene control and selection for genetic improvement for this trait would be effective (Islam *et al.* 2009).

In an investigation of 71 F₁ hybrids and their 9 parents of ash gourd, Sureja *et al.* (2010) found greater estimates of genetic advance as percentage of mean coupled with high amount of heritability for yield per vine, number of fruits per vine and number of seeds per fruit indicating that these traits are governed by additive genes and continued selection would be helpful in modifying the mean performance of the population.

Jahan *et al.* (2012) found high heritability coupled with high genetic advance in 8 parents and their 10 hybrids of sweet gourd for number of fruits per plant, individual

fruit weight and fruit yield suggesting that the improvement would be effective through phenotypic selection.

2.3 CORRELATION STUDIES

Usually more than one trait is measured on progenies evaluated either for a specific trait in cyclical selection programmes or in applied breeding programmes that require a combination of traits to satisfy growers. Although yield is the primary trait of interest, yield contributing traits are all other corollary traits that a breeder must consider for eventual usefulness of genotypes evaluated. It is natural that the attention is given to associations among traits during selection and testing of genotypes.

Correlation, measured by a correlation coefficient is important in plant breeding because it measures the degree of association, genetic or non-genetic between two or more characters. If genetic association exists, selection for one trait will cause changes in other traits called the correlated response. The cause of correlation can be genetic and/or environmental. Genetic causes may be attributed to pleiotropism and/or linkage disequilibrium. When genes are not closely linked, linkage disequilibrium is not an important cause of correlation between characters in random mating populations. In such cases the existence of genetic correlations is mostly attributable to pleiotropism (Hallauer and Miranda, 1982).

Fruit weight per plant had strong and positive genotypic correlation with days to first picking, length of main vine and fruit diameter and had a negative correlation with fruit length in four bottle gourd lines (Rahman *et al.* 1986).

Prasad *et al.* (1993) undertook correlation studies in thirty genotypes of bottle gourd revealed highly significant and positive association of fruit yield and with number of fruits per vine, average weight of fruit and number of female flowers per vine.

Sharma and Dhankar (1993) studied correlation in 35 genotypes of bottle gourd and observed the positive correlation between yield and number of fruits, which was mainly due to highest and direct effect of number of fruits. Days to first female flowering node showed negative association with vine length.

Narayan *et al.* (1996) reported that yield was positively and significantly correlated with number of fruits per plant and average weight of fruit. Negative and significant correlation between yield and days to anthesis of first male flower was observed in bottle gourd.

Badade *et al.* (2001) reported that the yield was significantly and positively correlated with number of branches per vine and number of fruits per vine in bottle gourd, while it was significantly and negatively correlated with days to first male and female flower appearance at both phenotypic and genotypic levels. At genotypic level, vine length, diameter of fruit, number of seeds per fruit and 100 seed weight showed significant and negative correlation. Fruit length showed positive but non-significant correlation with fruit yield per plant.

Kumar *et al.* (2007) reported that fruit yield per vine had positive and significant correlation with number of branches per vine, vine length, node number of first female flower, length of edible fruits, number of fruits per vine, number of seeds per fruit and 100 seed weight at genotypic and phenotypic levels in bottle gourd. This indicated that fruit yield can be improved by making selection on the basis of number of branches per vine, vine length, nodes number of first female flower, length of edible fruit and number of fruit per vine.

Yadav *et al.* (2007b) while studying 18 strains of bottle gourd revealed that yield per plant was positively and significantly associated with the number of fruits per plant, but had a significantly negative correlation with days to first female flowering both at genotypic and phenotypic levels.

Pandit *et al.* (2009) while evaluating 15 genotypes of bottle gourd revealed that the correlation between both genotypes and phenotypes indicated the over-riding importance of fruit length and fruit width in determining the average fruit weight, which in turn adequately described the increase in fruit yield per plant.

Yadav *et al.* (2010) investigated 15 diverse genotypes of bottle gourd and reported a significant and positive correlation of fruit yield per plant with days to first female flower anthesis, vine length, number of primary branches per plant, length of fruit, fruit weight and number of fruits per plant.

Correlation studies revealed that highest significant association of yield per plant with reproductive characters like number of fruit per plant followed by fruit weight at genotypic and phenotypic level in 31 bottle gourd genotypes evaluated (Husan *et al.* 2011).

Kumar *et al.* (2012) conducted an experiment comprising 24 hybrids of bottle gourd obtained by crossing 11 parents with 3 testers and found that fruit yield of F₁ plants had a high and significantly positive association with days to maturity and number of fruits per plant at genotypic and phenotypic levels.

The fruit yield per vine showed positive and significant correlation with no. of branches per vine, vine length, node number of 1st male flower, node number of 1st female flower, length of edible fruits, number of fruits per vine, number of seeds per fruit and 100-seed mass at genotypic and phenotypic levels in 10 diverse bottle gourd entries (Kamal *et al.* 2012).

Emina *et al.* (2012) studied 40 diverse genotypes of bottle gourd for correlation reported positive correlation of plant height with fruit length, seeds per plant and 100 seed mass but negative correlation with fruit weight.

Literature pertaining to other cucurbits

Solanki *et al.* (1980) observed that all the characters under study were positively and genotypically correlated with fruit yield except secondary branches per plant. However, number of primary branches per plant had the significant genotypic and phenotypic correlation coefficient with fruit yield in cucumber.

Fruit weight showed positive correlation with vine length, days to fruit maturity, fruit size and flesh thickness in pumpkin. While vine length was positively correlated with number of laterals, days to female flowering, days to fruit maturity and flesh thickness. Fruit size also showed positive correlation with flesh thickness in pumpkin (Doijode, 1984).

Choudhary and Mandal (1987) evaluated thirty diverse genotypes of cucumber and revealed high positive correlation of fruit yield with number of female flowers per

vine, number of fruits per vine, fruit length and fruit weight at both genotypic and phenotypic levels.

In ridge gourd, Rao *et al.* (2000) reported significant positive correlation of fruit yield with volume of fruit, fruits per vine and length of the vine at both phenotypic and genotypic levels. While, days to first male and female flower and days to 50% flowering exhibited significant negative correlation with yield per vine.

Sharma and Bhutani (2001) in bitter gourd recorded significant positive correlations of total yield per plant to number of fruits per plant and average fruit weight. Significant positive correlation was also observed between first female flowering node with fruit length and fruit diameter with average fruit weight.

The results of correlation analysis revealed that very significant positive correlation was found between number of fruits per plant and yield per plant respectively. While, very significant negative correlation was found between days to first female flowering, node of first female flower, node of first fruit and yield respectively in bitter gourd (Zhang *et al.* 2002).

An investigation by Rahaman *et al.* (2002) in 24 genotypes of snake gourd for correlation studies revealed that fruit yield had a significant positive correlation with number of fruits per plant, fruit length and stem length.

Dora *et al.* (2002) observed that yield per plant was significantly and positively correlated with number of fruits per plant, fruit set, and fruit retention at both phenotypic and genotypic levels in pointed gourd.

Choudhary and Ram (2003) observed that yield per plant had a significant and positive correlation with fruit weight, number of fruits per plant, number of vines per plant, harvest duration, rind thickness, shelf life and vine length in muskmelon.

Rolonia *et al.* (2003) reported that fruit yield was positively correlated with main vine length, number of primary branches per plant, number of nodes per plant, number of female flowers per plant and number of fruits per plant in watermelon.

Rao *et al.* (2004) reported that yield was positively correlated with fruit weight, fruit length and flesh thickness at both genotypic and phenotypic levels in cucumber.

In an experiment comprising of 50 pumpkin germplasm lines, correlation studies revealed positive and significant association of fruit yield with fruit diameter, vine length and number of fruits per plant. Whereas significant and negative association was observed with days to first male and female flower (Kumar *et al.*, 2005).

In a correlation study of 15 genotypes of pumpkin (5 parents and 10 crosses) from each diallel without reciprocals, the results reported both phenotypic and genotypic correlations between number of fruits and fruit weight were negative and significant for variety diallel, where as those were also negative but not significant, in S₁ diallel. Both number of fruits and fruit weight were positively and significantly correlated with yield in S₁ diallel but not correlated with yield in the varietal diallel (Miguel *et al.* 2006).

Narayankutty *et al.* (2006) revealed that yield was strongly correlated with fruit weight, fruits per plant, fruit girth, days to first harvest, flesh thickness and days to first female flower opening in snake gourd.

In a correlation study of 24 pointed gourd accessions by Khan *et al.* (2009), number of node at first harvest had positive association with fruit weight, number of fruits per plant and fruit yield per hectare, whereas negative correlation was observed with fruit length and weight of fruits per plant.

Islam *et al.* (2009) studied 20 bitter gourd genotypes and the results obtained, showed that yield per plant had high positive and high significant relation with number of nodes per vine.

The correlation co-efficient revealed that, yield per plant had highly positive and significant association with fruit length and diameter, average fruit weight and number of fruits per plant in cucumber (Hossain *et al.*, 2010).

In cucumber, correlation studies revealed that yield had significant and positive association with marketable fruits per plant, fruit length, average fruit weight and harvest duration. While significant and negative correlation was observed with node

number bearing first female flower, days to marketable maturity at both phenotypic and genotypic levels (Kumar *et al.*, 2011).

In correlation studies of F₂ population of cucumber, Arun Kumar *et al.* (2011) reported positively correlated fruit yield with total number of fruits per vine, average fruit weight, fruit length, fruit diameter, number of branches per vine, number of nodes per vine and vine length. While it was significant and negatively correlated with days to first male flower, days to first female flower and days to first fruit harvest.

Correlation co-efficient analysis in 30 ridge gourd genotypes revealed that fruit yield per plant showed positive and significant correlation with number of fruits per plant (0.889 and 0.862), average fruit weight (0.871 and 0.858), fruit yield per plot (0.821 and 0.807), fruit yield per hectare (0.821 and 0.807), fruit length (0.795 and 0.784), fruit diameter (0.726 and 0.683), number of seeds per fruit (0.654 and 0.630), 100 seed weight (0.652 and 0.480), seed yield per fruit (0.547 and 0.643) at genotypic and phenotypic levels respectively. Since, these association characters are in the desirable direction, selection for these traits may improve the yield per plant (Hanumegowda *et al.* 2012).

In a study of 10 pumpkin accessions during 2007 and 2008, number of seeds per fruit had a significant and positive correlation with number of male flowers ($r = 0.480$ and 0.481) and fruit diameter ($r = 0.631$ and 0.619) for both seasons respectively. And also a significant and positive correlation was observed between number of female flowers and number of fruits (0.378 and 0.946) in both planting seasons respectively (Blessing *et al.* 2012).

2.4 PATH COEFFICIENT ANALYSIS

The observed correlation between yield and the yield contributing characters is the net result of the direct effect of the yield component and the indirect effect through other yield attributing characters.

The total correlation between grain yield and its component characters may sometimes be misleading. Since, it may be over or under estimate of its association with other characters. Hence, direct selection on correlated response basis may not be

worthful. The correlation coefficient needs to be split into direct and indirect effects, using path coefficient analysis for critical evaluation as many characters affect a given trait. Thus, the correlation and path analysis in combination can give a better insight into cause and effect relationship between different pairs of characters. As a guideline for interpretation of path analysis results, the following broad points may be kept in view (Singh and Chaudhary, 1977)

- ❖ If the correlation coefficient between a causal factor and the effect is almost equal to its direct effects, then correlation explains the true relationship through this trait will be effective.
- ❖ If the correlation coefficient is positive, but the direct effect is negative or negligible, the indirect effects seem to be cause of positive correlation. In such situations, the indirect causal factors are to be considered simultaneously for selection.
- ❖ Correlation coefficient may be negative but the direct effect is positive and high. Under these circumstances, a restricted simultaneous selection model is to be followed i.e. restrictions to be imposed to nullify the undesirable indirect effects in order to make use of the direct effect.
- ❖ If the correlation coefficient is negative and direct effect is also negative, then we have to drop the selection based on that character.
- ❖ The residual effect determines how best the causal factors account for the variability of the dependent factor. If residual effect is high, some other factors, which have not been considered here, need to be included in this analysis to account fully for the variation in yield.

Rahaman *et al.* (1986) evaluated 4 lines of bottle gourd for path coefficient analysis and revealed that fruit diameter and fruit length had high positive direct effect on fruit weight per plant. Number of fruits per plant also had considerable positive direct effect on fruit weight per plant.

Path coefficient analysis revealed that maximum weightage should be given primarily to days to the first harvest followed by average weight of edible fruit, fruit

number per plant and days to anthesis of first female flower while formulating selection indices for improvement of yield in 25 genotypes of bottle gourd (Narayan *et al.* 1996).

Studies on path coefficient analysis in 18 bottle gourd strains showed that days to first male flowering, number of nodes of first female flowering, days to edible fruit, fruit width, number of fruits per plant and yield per plant had maximum positive direct effect on yield. All the characters except days to first female flowering, number of nodes of first male flowering and fruit length had direct effect on yield. For indirect effects, the number of fruits per plant showed highly significant and positive association with yield per plant due to days to first male flowering, number of nodes of first female flowering, days to edible fruit, fruit width and number of fruits per plant (Yadav *et al.* 2007b).

Yadav *et al.* (2010), examined 15 diverse genotypes of bottle gourd and reported length of fruit, fruit weight and number of fruits per plant had positive and direct effect on fruit yield per plant, thus indicating desirable improvement towards fruit yield and number of fruits per plant with high priority in selection programme for future improvement of bottle gourd.

The results of path co-efficient analysis revealed maximum direct contribution towards yield per plant with of no. of fruit per plant (0.680) followed by fruit weight (0.453) in 31 bottle gourd genotypes (Husna *et al.* 2011).

Path coefficient analysis revealed that the total number of fruits per vine (0.674) had maximum positive direct effect on total fruit yield followed by average fruit weight (0.390), number of branches per vine (0.219), number of nodes per vine (0.170), vine length (0.219) and days to first male flower (0.125). However negative and direct effect was observed for yield through days to first female flower (-0.245), fruit diameter (-0.201), days to first fruit harvest (-0.109) and fruit length (-0.003) in bottle gourd. (Arun Kumar *et al.* 2011).

Literature pertaining to other cucurbits

Path analysis revealed that yield improvement could be achieved by direct selection for days to 50% flowering, fruit girth, fruits per vine and length of the vine in ridge gourd (Rao *et al.* 2000)

In snake gourd, Rahaman *et al.* (2002) recorded the highest positive direct effect for number of fruits followed by average fruit weight.

Positive and direct effect on fruit yield by days to anthesis of first female flower, node numbers to first female flower, fruit diameter and vine length was observed in 50 pumpkin genotypes (Kumar *et al.* 2005).

Miguel *et al.* (2006) evaluated 15 pumpkin genotypes from each diallel without reciprocals and reported that direct effects of fruit number and fruit weight on yield were strong and positive, where as indirect effects were smaller and negative. Direct effects were 300 to 500% greater than indirect effects in line diallel where as, it was 17 to 68% in variety diallel. Effects (direct and indirect) were greater (17 to 500%) when genetic correlations were used rather than phenotypic correlations (42 to 440%) in the path analysis.

Islam *et al.* (2009) studied 20 bitter gourd genotypes and the results of the path analysis revealed that number of fruit per plant had the maximum direct effect (1.789) followed by vine length (1.134), no. of nodes per vine (0.583) and days to first flowering male (0.044). The contribution of yield components like fruit length, number of nodes per vine and days to first male flowering were higher.

Khan *et al.* (2009) studied 24 accessions of pointed gourd and results revealed that days to first flowering had highly negative direct effect (-0.187) on yield per plant where as fruit length (0.482), fruit breadth (1.348) and fruit weight (0.331) had positive direct effect on yield per plant.

Path coefficient analysis in squash pumpkin by Lawal (2009) reported mesocarp thickness (0.58166) and number of leaves per plant (0.03846) were highest and least contributors to pumpkin fruit yield, respectively. The combined contribution of mesocarp thickness through number of days to anthesis (20.368%) was highest

where as the combined contribution of number of seed per fruit through number of days to anthesis was least (-0.902%).

Path analysis showed that the fruit length, diameter, average fruit weight and number of fruits per plant directly contributed towards the yield per plant in the long type cucumber (Hossian *et al.* 2010).

Path coefficient analysis in cucumber genotypes by Kumar *et al.* (2012) reported that average fruit weight had maximum positive direct effect on yield followed by harvest duration and marketable fruits per plant whereas negative direct effect of fruit length and breadth, days to marketable maturity, fruit length and node number bearing first female flower was observed on yield.

Path analysis on 10 pumpkin accessions conducted during 2007 and 2008 planting seasons showed highest positive direct effect of days to 50% flowering on fruit weight. The significant positive correlation between the weight of harvested fruits and fruit diameter in 2007 season was due to the combination of direct and indirect effects of fruit diameter to fruit yield. In 2008 planting, the number of female flowers recorded high positive direct effects on weight of the fruits per plant but its influence was nullified by the high negative indirect effect (-0.46) of number of fruits per plant (Blessings *et al.* 2012).

2.5 GENETIC DIVERGENCE

Murthy and Arunachalam (1965) hypothesized that Mahalanobis' generalised distance, a measure of metric distance between population centroids, could be of useful multivariate statistical tool for effective discrimination among parents on the basis of genetic diversity. Precise information about genetic divergence is critical for a productive breeding programme; as genetically diverse plants are known to produce high heterotic effects consequently yield desirable segregates.

The D^2 statistic gives a result based on the magnitude of divergence independent of the sample size (Rao, 1952). The technique has been extensively used by numerous workers in classifying problems in understanding the nature of genetic divergence and for selecting diverse parents for successful hybridization in out

breeding populations such as self incompatible Brassica (Murthy and Arunachalam, 1965) and self pollinated crops like wheat (Jatasra and Paroda, 1978).

Studies in number of crop species with different breeding systems by means of D^2 statistics suggested that genetic diversity need not to be directly related to the geographic diversity (Murthy and Arunachalam, 1965).

Murthy and Arunachalam (1965) examined the nature of genetic divergence as measured through D^2 statistic and its relationship to components of genetic variation in some out breeding populations, self fertilizing crops and crops showing variable degree of out crossing. It was observed that in general plant weight, days to flowering, grains per plant and grain weight were contributing significantly to total genetic diversity in most of the crops studied.

Successful breeding programme is associated with diversity of the parents within a reasonable range. More the diversity better is the chance of improving economic characters under consideration in the resulting progenies. It also helps to know the relative distance between these strains for the characters under study.

It is thus, seen that considerable genetic diversity and vast range of variation for different characters in different cucurbits in general and bottle gourd in particular would be utilized for breeding purposes. Thorough and critical information obtained through various parameters will be helpful to launch a viable improvement programme.

Badade *et al.* (2001) studied the genetic divergence using Mahalanobis D^2 statistics for seven quantitative characters in a collection of twenty diverse cultivars of bottle gourd reported significantly different cultivars for almost all the characters and were grouped into 10 clusters based on the similarities of D^2 value. Considerable diversity within and between the clusters was noted for the characters like vine length, number of branches, percentage of female flowers, fruits per vine, fruit length, fruit diameter and yield per vine in bottle gourd.

Mathew *et al.* (2001) studied the genetic divergence in bottle gourd using 28 accessions of bottle gourd and assessed the genetic diversity using Mahalanobis D^2

values and the accessions were grouped into eight clusters. Clustering pattern indicated that there was no association between geographical distribution of accessions and genetic divergence.

Islam (2004) studied divergence in bottle gourd and reported that there was no clear relationship observed between geographic origin and genetic diversity.

In a bottle gourd experiment consisting of 12 genotypes, considerable diversity within and between clusters for fruit length, fruit weight, number of primary branches per vine, days to first male and female flower appearance and harvesting date in differentiating bottle gourd germplasm was observed. (Munshi and Sirohi, 2005).

Singh *et al.* (2007) studied divergence in bottle gourd and reported that there was no parallelism between the clustering pattern and geographic origin and maximum genetic diversity was obtained between clusters.

Literature pertaining to other cucurbits

Veralakshmi *et al.* (2003) studied thirteen quantitative characters in twenty one diverse ridge gourd genotypes using Mahalanobis D^2 statistic. The genotypes were grouped into 10 clusters. Maximum genetic divergence was observed between clusters III and VI. The characters namely number of days to first female flower, vine length; number of first female flowering node, fruit weight, number of seeds per fruit, number of fruits per vine and 100 seed weight contributed maximum to divergence.

Rao *et al.* (2004) studied thirty one genotypes to assess genetic divergence by using Mahalanobis D^2 statistic. The genotypes were grouped into 16 clusters based on similarities at D^2 values. Genotypes from different regions were distributed in to various clusters at random, demonstrating that geographical isolation may not be one of the factors for causing biological or genetic diversity in cucumber.

Dey *et al.* (2007) studied divergence in bitter gourd and reported no parallelism between geographic and genetic diversity.

Haribabu (2007) studied eighteen genotypes of cucumber to assess genetic divergence using D^2 statistic. On the basis of D^2 analysis eighteen genotypes were grouped in to eight clusters with substantial genetic divergence between them. The

clusters A, B, and E had 5, 5 and 3 strains respectively and remaining clusters C, D, F, G and H had one strain each. The maximum inter cluster distance was observed between F and H (11.24) and minimum inter cluster distance was observed between C and F (5.33). The cluster pattern revealed that the genetic diversity was not parallel to the geographical distribution of the genotype.

Preeti *et al.* (2010) examined 23 germplasm lines of ash gourd and grouped them into 5 clusters based on Mahalanobis' D^2 technique. The clustering pattern indicated that geographical distribution need not necessarily be related to the genetic diversity. Cluster I was very large containing 14 genotypes of summer and 10 genotypes of kharif season. The inter-cluster distance was found maximum between cluster III and cluster IV (*summer*) and cluster II and cluster V in (*kharif*) seasons.

Hossian *et al.* (2010) evaluated 58 long type cucumber genotypes to know the amount of genetic diversity by using D^2 technique and they were grouped into eight clusters. Cluster II contained the highest number of genotypes having 17 followed by cluster III and IV having 12 and 8 genotypes respectively while cluster V, I, VI and VII having 6, 5, 4, 4 and the cluster VII contained the lowest number of genotypes having two followed by others. The clustering pattern of different genotypes did not follow their geographical distribution and was fairly at random suggesting that falling of materials of same origin into different clusters was an indication of broad genetic base of the genotypes belonging to the origin.

Chapter- III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The present investigation on “**Studies on genetic variability, heritability, correlation and path coefficient analysis in bottle gourd [*Lagenaria siceraria* (Mol) Standl.] genotypes**” was undertaken to study the genetic variability, heritability, genetic advance, genotypic and phenotypic correlation and character association between heritable characters.

The details pertaining to materials used, methods adopted and statistical analysis followed during the course of this investigation are described in this chapter.

3.1 LOCATION OF EXPERIMENTAL SITE

The experimental site is located at Horticultural College and Research Institute, Venkataramannagudem, West Godavari District. The location falls under the Agro-climatic zone no.10, East Coast Plain and Hills (Krishna-Godavari zone) with an average rainfall of 900 mm at an altitude of 34 m (112 feet) above mean sea level. Its geographical position is 16.83⁰ N latitude and 81.5°E longitude. It experiences hot humid summer and mild winters.

3.2 WEATHER DURING CROP PERIOD

The meteorological data pertaining to mean maximum and mean minimum temperatures, relative humidity and rainfall recorded during the period of investigation *i.e. spring summer - 2012* season at Horticultural Research Station Venkataramannagudem are presented in Appendix 1.

3.3 EXPERIMENTAL DETAILS

3.3.1 Experimental material

The experimental material consisted of twenty three genotypes of bottle gourd obtained from NBPGR Regional Station, Rajendranagar, Hyderabad with one check *i.e. Pusa Naveen* (Table 1).

Table 1: Germplasm accessions of bottle gourd

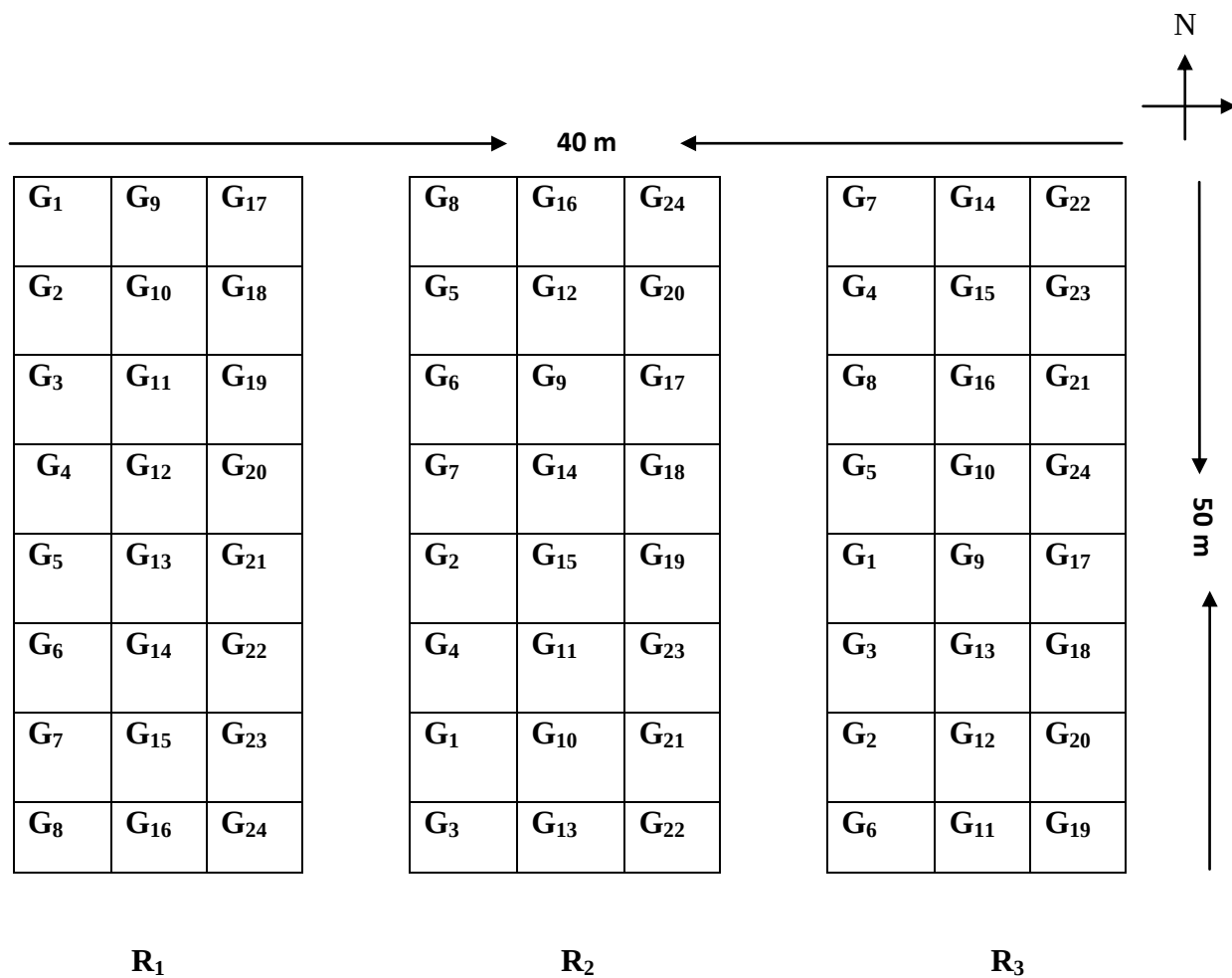
Treatment	Accession number	Source
G ₁	IC 249663	NBPGR Regional Station, Rajendranagar, Hyderabad.
G ₂	PSR 13300	-do-
G ₃	PSR 13156	-do-
G ₄	PSR 13290	-do-
G ₅	RJR 27	-do-
G ₆	PSR 13176	-do-
G ₇	RJR 201	-do-
G ₈	IC 446596	-do-
G ₉	IC 249654	-do-
G ₁₀	IC 249672	-do-
G ₁₁	IC 249671	-do-
G ₁₂	IC 249668	-do-
G ₁₃	IC 446594	-do-
G ₁₄	RJR 533	-do-
G ₁₅	IC 249665	-do-
G ₁₆	IC 249658	-do-
G ₁₇	IC 249653	-do-
G ₁₈	IC 446592	-do-
G ₁₉	IC 249650	-do-
G ₂₀	RJR 420	-do-
G ₂₁	IC 249656	-do-
G ₂₂	IC 256053	-do-
G ₂₃	NSJ 298	-do-
G ₂₄	Pusa Naveen	IARI, New Delhi

3.3.2 Layout of the experiment

The entire germplasm of bottle gourd was laid out in a Randomized Block Design with three replications. Six seeds of each genotype were sown in each replication in 2 rows. Randomization was followed in each replication.

Details of Layout

1. Crop	: Bottle gourd
2. Number of treatments	: 24
3. Design	: Randomized Block Design (RBD)
4. Replications	: 3
5. Season	: Summer
6. Plot size	: 6.0 m x 4.0 m
7. Spacing	: 2 m x 1 m
8. Number vines per plot	: 6
9. Location	: Horticultural College and Research Institute, Venkataramannagudem.



Design : Randomized Block Design

Replications : 3

Genotypes : 24

Plot Size : 6.0 m x 4.0 m

Spacing : 2.0 m x 1.0 m

Fig.1 Layout of the Experimental plot of bottle gourd

3.4 CULTURAL PRACTICES

3.4.1 Characteristics of the soil

The soil was of red sandy loam with good drainage and moderate water holding capacity. The physical composition of the soil was; sand 70%, silt 20% and clay 10%. The soil pH was 6.87 and the E.C. was 0.3 d Sm^{-1} , available nitrogen was 512 kg ha^{-1} , available phosphorus was 17.52 kg ha^{-1} and available potassium was 217.5 kg ha^{-1} , while the available organic carbon of the soil was 0.34%.

3.4.2 Land preparation

The land was brought to fine tilth by ploughing and harrowing. The experimental area was divided into plots of 6.0 m x 4.0 m size. Irrigation channels of 0.6 m size were provided for each row of plots. Pits of 45 cm x 45 cm x 30 cm size were dug at a spacing of 2.0 m x 1.0 m in each plot. Well decomposed farmyard manure @ 25 t ha^{-1} was incorporated into the pits by mixing with the soil uniformly as basal application and filled up to 3- 5 cm above the ground level. Standard recommended cultural practices were followed during the entire crop period.

3.4.3 Sowing

Seeds were sown in the centre of the pit in each replication duly maintaining the spacing of 2.0 m x 1.0 m between and within the rows respectively. A space of 30 centimeters was uniformly left from the borders of the plot. Watering was given immediately after sowing with rose can. Sowing of the seeds was taken up on 1st April 2012 in all the treatments and replications.

3.4.4 Manures and Fertilizers

The recommended dosage of N, P and K at 100: 60: 60 kg ha^{-1} was applied in the form of urea, single super phosphate and murate of potash respectively. The entire dose of phosphorus, potash and one third of nitrogen were applied at the time of filling of pits as a basal dose. The remaining two third nitrogen was applied in two split doses at 30 and 60 days after sowing.

3.4.5 Weeding and Irrigation

The experimental site was kept free from weeds by periodical hand weeding. Irrigation was given at an interval of 2-3 days depending on the soil moisture condition.

3.4.6 Plant protection

Timely and suitable plant protection measures were taken up to protect the plants from pest and disease incidence. Chlorpyrifos 25 EC @ 1.5 per cent spray was taken up to control the pumpkin beetle incidence.

3.5 OBSERVATIONS RECORDED

Data on the following characters were recorded during experimentation. Each block comprised six plants and the data on different characters were recorded from five plants.

3.5.1.1 Total vine length (m)

Length of the vine was measured for five plants from cotyledonary node to the tip of the plant at the time of final harvest and the average was taken and expressed in meters.

3.5.1.2 Number of primary branches per vine

The number of primary branches on the main stem per vine was counted for 5 plants at the time of final harvest and the average was taken.

3.5.1.3 Number of nodes per vine

The total number of nodes on the main vine was counted for five plants and the average was recorded during the final harvest.

3.5.1.4 Internodal length (cm)

The ratio of total vine length to the number of nodes per vine gave the internodal length.

3.5.1.5 Leaf lobing pattern

The leaf lobing pattern of genotypes was noted as low, medium and high.

3.5.1.6 Tendril length (cm)

Tendril length was measured for five plants from the centre of the vine during the fruiting stages.

3.5.1.7 Days to first male flower appearance

The number of days taken from date of sowing to the onset of first male flower on the vine was recorded for five plants and the average was taken

3.5.1.8 Days to first female flower appearance

The number of days taken from date of sowing to the onset of first female flower on the vine was recorded for five plants and the average was taken.

3.5.1.9 Node at which first male flower appears

The node number from the cotyledonous leaves at which the first male flower appeared was recorded for five plants and the average was taken

3.5.1.10 Node at which first female flower appears

The node number from the cotyledonous leaves at which the first female flower appeared was recorded for five plants and the average was taken.

3.5.1.11 Days to first fruit harvest

The number of days taken from date of sowing to the first harvest of fruits was recorded for five plants and the average was taken.

3.5.1.12 Number of fruits per vine

The total number of fruits of all harvests was recorded for five plants and the average was taken.

3.5.1.13 Weight of the fruit (g)

The weight of five individual fruits harvested at the edible stage was recorded and the average was expressed in grams.

3.5.1.14 Fruit length (cm)

Length of five fruits harvested at edible maturity was recorded from base to the apex of fruit and averaged.

3.5.1.15 Fruit diameter (cm)

The diameter of the fruit at horticultural maturity was measured by cutting five fruits with knife at the broadest point and diameter was measured using scale and average was calculated in centimeters.

3.5.1.16 Fruit shape

Fruit shape of the genotypes was noted as round, oval, oblong, cylindrical and bottle.

3.5.1.17 Yield per vine (kg)

The total weight of all marketable fruits obtained per vine was recorded for five plants and the average was expressed in kilograms.

3.5.1.18 Total yield (t/ha)

Yield per hectare was estimated based on net plot yield and expressed in terms of tonnes.

3.5.1.19 Number of seeds per fruit

Number of seeds per fruit was recorded for the dried five fruits after harvesting of the crop.

3.5.1.20 100 seed weight (g)

100 seed weight was taken by weighing the hundred random seeds and it was expressed in grams.

3.6 STATISTICAL ANALYSIS

The mean values of five plants computed for each of the twenty characters for each of the genotype in each replication were subjected to statistical analysis.

3.6.1 Analysis of variance

Data was analyzed by the methods outlined by Panse and Sukhatme (1985) using the mean values of random plants in each replication from all genotypes to find out the significance of genotypes effect. The model of analysis of variance table adopted is given below.

The data for different characters were statistically analysed on the basis of the model suggested by Cochran and Cox (1950) for RBD.

$$Y_{ij} = \mu + b_i + t_j + e_{ij}$$

Where,

Y_{ij} = Performance of the j^{th} genotype in the i^{th} block

μ = general mean

b_i = true effect of i^{th} block

t_j = true effect of j^{th} genotype

e_{ij} = random error associated with i^{th} block and j^{th} genotype.

The analysis of variance for each character was carried out as indicated below:

Sources of variation	Df	SS	MSS	F ratio
Replications	r-1	RSS	RMSS	RMSS/EMSS
Treatments	t-1	T _r SS	T _r MSS	T _r MSS/EMSS
Error	(r-1) (t-1)	ESS	EMSS	
Total	(rt-1)	TSS		

Where,

r = Number of replications

t = Number of genotypes or treatments

df = degrees of freedom

SS = sum of squares

MSS = Mean sum of squares

RSS = Replication Sum of squares

T_rSS = Treatment sum of squares

ESS = Error sum of squares

TSS = Total sum of squares

RMSS = Mean sum of squares due to replications

T_rMSS = Mean sum of squares due to treatments

EMSS = Mean sum of squares due to error

The test of significance was carried out by 'F' table values given by Fisher and Yates (1963).

3.6.2 Components of variance

$$\text{Genotypic variance (V}_g \text{ or } \sigma^2_g) = \frac{\text{Genotype MSS} - \text{Error MSS}}{R}$$

Environmental variance (V_e or σ^2_e) = Error mean sum of squares

Phenotypic variance (V_p or σ^2_p) = $V_g + V_e$

Significance of treatment MSS was assessed by referring to F table values at 1 and 5 percent probabilities. Further, computation was carried out only when the treatment effects were significant.

Critical difference (C.D.)

In order to compare the means of various entries CD was calculated by using the formula.

Critical difference (CD) = S.E(d) x t

$$S.E(d) = \sqrt{\frac{2 \times \text{error MSS}}{r}}$$

Where,

t = is the table value at 5 per cent or 1 per cent probability level, respectively

r = number of replications.

3.7 ESTIMATION OF GENETIC PARAMETERS

The genetic parameters such as genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability in broad sense and genetic advance for different characters were worked out by following the standard procedures for all the genotypes under study.

3.7.1 Genotypic and phenotypic coefficients of variation

Genotypic and phenotypic coefficients of variation were estimated according to Burton and Devane (1953) by using the following formulae.

$$PCV = \frac{\sqrt{\sigma_p^2}}{\text{-----}} \times 100$$

$$GCV = \frac{\frac{\sqrt{\sigma_g^2}}{\bar{X}}}{\bar{X}} \times 100$$

Where,

$$\sigma_g^2 = \text{Genotypic variance} = \frac{T_r \text{MSS} - \text{EMSS}}{r}$$

$$\sigma_e^2 = \text{Environment variance} = \frac{\text{EMSS}}{r}$$

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

$\bar{X}$ = General mean

PCV and GCV were classified (Sivasubramanian and Menon 1973) as shown below.

0-10% = Low

10-20% = Moderate

21% and above = High

3.7.2 Heritability in Broad sense [$h^2(b)$]

Heritability in broad sense was estimated as per the formulae as suggested by Allard (1960).

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

Where,

$h^2(b)$ = Heritability estimates in broad sense

σ_g^2 = Genotypic variance

σ_p^2 = Phenotypic variance

As suggested by Johnson *et al.* (1955), $h^2(b)$ estimates were categorised as

Low = 0-30%

Medium = 31-60%
High = 61% and above

3.7.3 Genetic advance (GA)

This was estimated as per formula proposed by Allard (1960)

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

Where,

K = Selection differential at 5 per cent selection intensity which accounts to a constant value 2.06

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

σ_p = Phenotypic standard deviation

3.7.4 Genetic advance as per cent of mean (GAM)

Genetic advance over mean (GAM) was calculated using the following formula and was expressed in percentage.

$$GAM = \frac{GA}{\bar{X}} \times 100$$

Where,

GA = genetic advance

$\bar{X}$ = general mean of the character

The genetic advance as per cent over mean was categorized as suggested by Johnson *et al.* (1955) and is mentioned below:

0-10% = Low
10-20% = Moderate
21% and above = High

3.8 CORRELATION STUDIES

Phenotypic and genotypic correlations were worked out by using formula suggested by Falconer (1964).

Phenotypic coefficient of correlation (r_p)

$$r(x_i, x_j)_p = \frac{\text{COV}(x_i, x_j)_p}{\sqrt{V(x_i)_p \cdot V(x_j)_p}}$$

Where,

$r(x_i, x_j)_p$ = Phenotypic correlation between i^{th} and j^{th} character.

$\text{COV}(x_i, x_j)_p$ = Phenotypic covariance between i^{th} and j^{th} character.

$V(x_i)_p$ = Phenotypic variance of i^{th} character.

$V(x_j)_p$ = Phenotypic variance of j^{th} character.

Genotypic coefficient of correlation (r_g)

$$r(x_i, x_j)_g = \frac{\text{COV}(x_i, x_j)_g}{\sqrt{V(x_i)_g \cdot V(x_j)_g}}$$

Where,

$r(x_i, x_j)_g$ = Genotypic correlation between i^{th} and j^{th} character.

$\text{COV}(x_i, x_j)_g$ = Genotypic covariance between i^{th} and j^{th} character.

$V(x_i)_g$ = genotypic variance of i^{th} character.

$V(x_j)_g$ = genotypic variance of j^{th} character.

Test of significance

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.

$$t = \frac{r}{\sqrt{1-r^2}} \sqrt{n-2}$$

t = test of significance

r = correlation coefficient

n = number of paired observations

3.9 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.

$$r_{ly} = P_{ly} + r_{12}P_{2y} + r_{13}P_{3y} + \dots + r_{lk}P_{ky}$$

Where,

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

P_{ly} = 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 .

$r_{lk}P_{ky}$ = 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 given below.

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

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

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

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

Where P_{ry} = residual effect

P_{1y} = direct effect of x_1 only

r_{1y} = correlation coefficient of x_1 only

Scales for path coefficients

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

3.10 GENETIC DIVERGENCE

The data collected on different characters were analyzed using Mahalanobis' D^2 analysis to classify the genotypes into different clusters (1928) to determine the genetic divergence among the genotypes (1936).

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.

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, 1967). After testing the difference between genotypes for each of the characters, 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.

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

Where,

Λ = Wilk's criterion

(E) = Determinant of error matrix and

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

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

Where,

$$M = n - (P + Q + 1) / 2$$

n = Degrees of freedom for error + varieties

$$\log e^{\wedge} = 2.3026 \log 10^{\wedge}$$

P = Number of variables or characters (18)

Q = Number of genotypes – 1 (or d.f. for genotypes) 23

V (stat) is distributed as χ^2 with PQ (414 = 18 × 23) degrees of freedom.

3.10.1 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.

3.10.2 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

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

3.10.3 Testing the significance of D^2 values

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

3.10.4 Intra cluster distance

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

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

Where,

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

n = Number of all possible combinations

3.10.5 Inter cluster distance

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

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

Where,

ΣD_i^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

3.10.6 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 was 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.

3.10.7 Grouping of genotypes into various clusters by cluster analysis

Cluster analysis classifies a set of observations into two or more mutually exclusive unknown groups based on combinations of interval variables. In this agglomerative hierarchical clustering technique was followed. The method is agglomerative and hierarchical because the strategy starts from all the individuals as single member groups and forms a complete hierarchy joining single pairs of groups till the process is completed with all members in one group. It is the incremental sum of squares as the strategy fuses the pair of groups at each level of the hierarchy that increases the within group sum of squares the least.

3.10.8 Execution of the clustering method

Distance matrix was converted into dendrogram by using Ward's method where the distance between two clusters is the sum of squares between two clusters summed over all variables. At each stage in the clustering procedure, the within cluster sum of squares was minimized over all partitions obtained by combining 2 clusters from previous stage.

Chapter-IV

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

An experiment entitled “**Studies on genetic variability, heritability, correlation and path coefficient analysis in bottle gourd [*Lagenaria siceraria* (Mol) Standl.] genotypes**” was carried out in twenty three genotypes and one check variety of bottle gourd during spring summer, 2012 at College farm, HC&RI, Venkataramannagudem, W.G.Dist. Observations were recorded for 20 characters *i.e.*, 2 morphological characters and 18 quantitative characters on individual vine basis per plot. The entire recorded data was subjected to statistical analysis to get information on mean performance, variability, heritability, genetic advance as per cent of mean, correlation coefficient, path coefficient analysis and diversity and the results are presented here under the following subheads with appropriate discussion.

4.1 Analysis of variance

4.2 Morphological characters of bottle gourd genotypes

4.3 Mean performance of genotypes

4.4 Variability, heritability and genetic advance

4.5 Character association analysis

4.6 Path coefficient analysis

4.7 Genetic divergence

4.1 ANALYSIS OF VARIANCE

The mean sum of squares for 18 quantitative characters in 23 genotypes and one check variety of bottle gourd were presented in Table 2. Highly significant differences were observed among the genotypes for all the characters that indicates presence of sufficient amount of variability in all the characters under study. This was also in confirmation with the results reported by many workers (Narayan *et al.*, 1996;

Kumar *et al.*, 2007; Pandit *et al.*, 2009; Arvind kumar *et al.*, 2011; Koffi *et al.*, 2009) in bottle gourd, (Fayeun *et al.*, 2012 and Yadegari *et al.*, 2012) in pumpkin, (Kanwar *et al.*, 2003 and Maryam *et al.*, 2012) in cucumber, (Islam *et al.*, 2009) in bitter gourd and (Khan *et al.*, 2009) in pointed gourd.

4.2 MORPHOLOGICAL CHARACTERS OF BOTTLE GOURD GENOTYPES

Morphological characters *viz.*, leaf lobing pattern and fruit shape of all the accessions studied were presented in the Table 3.

4.2.1 Leaf lobing pattern

All the 24 genotypes of bottle gourd based on leaf lobing pattern were divided into three groups *viz.*, low (0-1 lobes), medium (2-3 lobes) and high (>4 lobes) lobing patterns. Among them, maximum number of genotypes had high leaf lobing pattern (more than four lobes) which constituted PSR 13290, RJR 27, RJR 201, IC 446596, IC 446594, RJR 533, IC 249665, IC 249658, IC 249653, IC 446592, IC 249650 and IC 256053 followed by medium leaf lobing pattern (2-3 lobes) which included PSR 13156, IC 249654, IC 249672, IC 249668, IC 249656, NSJ 298 and Pusa Naveen followed by low leaf lobing pattern (0-1 lobes) which comprised IC 249663, PSR 13300, PSR 13176, IC 249671 and RJR 420.

4.2.2 Fruit shape

Based on fruit shape, the genotypes of bottle gourd were grouped into five groups *viz.*, round, oblong, bottle shaped, long and long with crooked neck shapes. Three genotypes had round fruit shape which included IC 249663, IC 249671 and IC 256053 and 3 genotypes had oblong fruit shape which comprised PSR 13290, IC 249668 and IC 256053. The long fruit shaped genotypes (8) included PSR 13176, IC 249654, IC 249672, IC 446594, RJR 533, IC 249665, IC 249653 and Pusa Naveen while long with crooked neck genotypes (10) comprised of PSR 13300, RJR 27, IC 249658, IC 446592, IC 249650, RJR 420, IC 249656 and NSJ 298.

4.3 MEAN PERFORMANCE OF GENOTYPES

The data on the mean performance, which was recorded for eighteen characters, are presented in Table 4.

4.3.1 Tendril length (cm)

Significant variation was observed with respect to tendril length (cm) which ranged from 19.03 to 36.44 cm. The genotype IC 249671 recorded the maximum tendril length of 36.44 cm followed by IC 249663 (33.30 cm), while IC 446596 recorded the minimum length of 19.03 cm.

4.3.2 Number of nodes per vine

Significant variation was observed with respect to number of nodes per vine which ranged from 79.72 to 144.73. The genotype IC 249671 recorded the maximum number of nodes (144.73) followed by IC 249663 (130.90), while IC 446596 recorded the minimum number of nodes (79.72).

4.3.3 Number of primary branches per vine

Significant variation was observed with respect to number of primary branches per vine which ranged from 8.16 to 20.50. The genotype IC 249671 recorded the highest number of primary branches per vine (20.50) followed by IC 249663 (18.66), while the genotype IC 446596 recorded the least number of primary branches (8.16).

4.3.4 Total vine length (m)

The genotypes showed significant differences with respect to vine length (m). The range obtained was from 7.70 to 16.36 m. The maximum vine length (16.36 m) was produced by the IC 249671 followed by IC 249663 (13.88 m), whereas the least vine length (7.70 m) was recorded in IC 446596.

4.3.5 Internodal length (cm)

Low variation was noticed among genotypes for inter nodal length (cm) which ranged from 6.68 to 11.34 cm. PSR 13300 showed minimum internodal length (6.68 cm) where as IC 249671 showed maximum internodal length (11.34 cm) followed by PSR 13156 (10.66 cm) which was statistically on par with IC 249663 (10.61 cm), RJR 420 (10.61 cm), NSJ 298(10.58 cm), IC 249672 (10.55 cm), IC 249658 (10.54 cm) and Pusa Naveen (10.44 cm).

4.3.6 Days to first male flower appearance

Wide variation in days to first male flower appearance from 48.06-94.72 days was noticed among the genotypes. Pusa Naveen took minimum days (48.06 days) to first male flower appearance followed by IC 446596 (50.18 days), whereas PSR 13176 took maximum days (94.72 days) to appearance of first male flower.

4.3.7 Days to first female flower appearance

The earliness or lateness is dependent on the number of days taken for its first female flower. Pusa Naveen was earliest to open first female flower (59.67 days) followed by IC 446596 (67.79 days) and PSR 13156 took maximum number of days (99.07 days) for female flower opening.

4.3.8 Node at which first male flower appears

Significant variation was noticed among the genotypes with respect to node at first male flower appearance which ranged from 12.66 to 56.91. Pusa Naveen showed first male flower at lower node (12.66) followed by RJR 533 (22.07) whilst PSR 13156 showed at higher node position (56.91).

4.3.9 Node at which first female flower appears

Significant variation, ranged from 21.80 to 77.28 was reported among the genotypes with respect to node at first female flower appearance. Pusa Naveen showed lower node (21.80) for appearance of female flower followed by IC 446596 (41.84), whereas PSR 13156 showed higher node position (77.28).

4.3.10 Days to first fruit harvest

Wide variation was observed in days to first fruit harvest which ranged from 75.43 to 117.08 days. IC 446596 took minimum number of days (75.43 days) to first harvest followed by Pusa Naveen (88.89 days) which was statistically on par with RJR

533 (90.46 days), where as PSR 13156 took maximum number of days (117.08 days) to first harvest.

4.3.11 Number of fruits per vine

Considerable variation was recorded for number of fruits among the genotypes which ranged from 2.75 to 10.44. Maximum number of fruits per vine was observed in IC 446596 (10.44) followed by IC 249671 (9.13) and minimum number of fruits per vine was observed in PSR 13176 (2.75) which was statistically on par with RJR 27 (3.02).

4.3.12 Fruit weight (g)

Significant variation existed among the genotypes which ranged from 197.55 to 1841.49 g with respect to fruit weight (g). Fruit weight was highest in IC 249671 (1841.49 g) which was statistically on par with IC 249663, Pusa Naveen, IC 249672, IC 446594 and IC 446592 (1821.39, 1705.53, 1656.50, 1643.97 and 1605.92 g respectively), whereas lowest weight was observed for IC 446596 (197.55 g).

4.3.13 Fruit length (cm)

There was significant variation was noticed among the genotypes with respect to fruit length (cm) which ranged from 13.75 to 62.98 cm. Fruit length was maximum in NSJ 298 (62.98 cm) closely followed by RJR 420 (62.30 cm) and minimum fruit length was recorded in IC 446596 (13.75 cm).

4.3.14 Fruit diameter (cm)

The genotypes showed moderate difference with respect to fruit diameter (cm) which was ranged from 5.03 to 18.04 cm. IC 249671 had maximum diameter of 18.04 cm followed by IC 249663 (17.10 cm) and minimum fruit diameter (5.03 cm) was recorded in PSR 13156.

4.3.15 Yield per vine (kg)

Considerable variation was found for yield per vine (kg) which ranged from 2.09 to 16.76 kg among the genotypes. Highest yield per vine of 16.76 kg was recorded in IC 249671 followed by IC 249663 (12.26 kg) which was statistically on par with Pusa Naveen and IC 249672 (11.67 and 11.56 kg respectively), where as IC 446596 reported lowest yield per vine (2.09 kg) which was statistically on par with RJR 201 (2.28 kg).

4.3.16 Total yield (t/ha)

Considerable variation was observed with respect to total yield (t/ha) which ranged from 5.22 to 41.91 t/ha. IC 249671 recorded the maximum total yield (41.91 t/ha) followed by IC 249663 (30.66 t/ha) which was statistically on par with Pusa Naveen, IC 249672 (29.19 and 28.91 t/ha respectively), while the genotype IC 446596 recorded the minimum total yield (5.22 t/ha) which was statistically on par with RJR 201 (5.72 t/ha).

4.3.17 Number of seeds per fruit

There was significant variation among the genotypes with respect to number of seeds per fruit which ranged from 98.15-729.63. Maximum number of seeds per fruit was recorded in IC 249671 (729.63) followed by IC 249663 (445.54), while PSR 13156 recorded minimum number of seeds per fruit (98.15).

4.3.18 100 seed weight (g)

Considerable variation was recorded among the genotypes with respect to 100 seed weight (g) which ranged from 6.54 to 18.22 g. It was recorded maximum in IC 249671 (18.22 g) followed by IC 249663 (16.67 g) which was statistically on par with Pusa Naveen (16.08 g), where as minimum weight of 6.54 g was observed in IC 446596 which was statistically on par with PSR 13300 (6.73 g).

Components of variation estimated for all the traits indicated wide range of variability in tendril length (19.03 to 36.40 cm), number of nodes per vine (79.73 to 144.73), number of primary branches per vine (8.17 to 20.50), total vine length (7.69 to 16.36 m), internodal length (6.68 to 11.34 cm), days to first male flower appearance (48.06 to 94.72 days), days to first female flower appearance (59.67 to 99.07 days), node at which first male flower appears (12.66 to 56.91), node at which first female flower appears (21.80 to 77.28), days to first fruit harvest (75.43 to 117.08 days), number of fruits per vine (2.75 to 10.45), fruit weight (197.75 to 1841.49 g), fruit length (13.75 to 62.98 cm), fruit diameter (5.03 to 18.04 cm), yield per vine (2.09 to 16.77 kg), total yield (5.23 to 41.92 t/ha), number of seeds per fruit (98.15 to 729.63)

and 100 seed weight (6.54 to 18.22 g). A wide range of variations existing for various quantitative traits has also been reported in bottle gourd by various workers (Prasad *et al.*, 1993; Narayan *et al.*, 1996; Singh *et al.*, 2008 and Pandit *et al.*, 2009 and Emina *et al.*, 2012); in snake gourd (Rahaman *et al.*, 2002) and (Fayeun *et al.*, 2012) in pumpkin. The studies suggest that it can possible to isolate superior genotypes during the selection process.

4.4. VARIABILITY, HERITABILITY AND GENETIC ADVANCE

The population means, range, genotypic coefficients of variation (GCV) and phenotypic coefficients of variation (PCV), heritability, genetic advance and expected genetic advance as per cent of mean (GAM) for the different characters were studied and were presented in Table 5.

The estimates of phenotypic variance were higher than the corresponding estimates of genotypic variance for all the traits, indicating thereby, the influence of environment in the expression of these traits. Since these estimates solely do not provide means to assess the nature of genetic variability, phenotypic and genotypic coefficient of variation were also estimated. The PCV was significantly higher than GCV for all the traits under study.

4.4.1 Tendril length (cm)

The phenotypic variance and genotypic variance recorded for tendril length were 23.97 and 17.00 respectively with moderate PCV and GCV of 18.74 and 15.79 per cent respectively. This trait recorded high heritability of 70.93 per cent with low genetic advance (7.15) but high genetic advance as per cent of mean (27.39 %).

Moderate PCV and GCV for tendril length revealed that variation among the genotypes for this trait was also medium.

4.4.2 Number of nodes per vine

High phenotypic and genotypic variance of 293.33 and 123.05 respectively were recorded with moderate PCV (14.71 %) and low GCV (9.53 %). Moderate

heritability (41.95 %) with moderate genetic advance (14.80) and moderate genetic advance as per cent of mean (12.72 %) were recorded for this trait.

The estimates of PCV and GCV were quite closer to each other for number of nodes per vine. Similar results were also reported by Prasad and Singh (1994), Hanchinamani (2006) and Arun Kumar *et al.* (2011) in cucumber and Islam *et al.* (2009) in bitter gourd. Moderate heritability with moderate GAM indicates the role of both additive and non additive gene action governing the inheritance of this trait and offers the best possibility of improvement through progeny selection or any modified selection procedures aiming to exploit the additive gene effects. These results are in accordance with the findings of Islam *et al.* (2009) in bitter gourd.

4.4.3 Number of primary branches

The variance due to phenotype (12.76) was higher than genotypic variance (8.39) with high PCV and GCV of 26.89 and 21.80 per cent respectively for number of primary branches per vine. This character exhibited high heritability (65.72 %) coupled with low genetic advance of 4.84 and high genetic advance of mean of 36.42 per cent.

The PCV and GCV were high for days to 50% flowering indicating that variation among the genotypes was also high. These findings are in agreement with Narayan *et al.* (1996) and Kumar *et al.* (2007) in bottle gourd and Kumar *et al.* (2008) in cucumber. Presence of high heritability with high GAM indicates the preponderance of additive gene action governing the inheritance of this character and offers the best possibility of improvement through simple selection procedures. These results are in concurrence with the findings of Narayan *et al.* (1996) Kumar *et al.* (2007), Singh *et al.* (2008) and Arvind Kumar *et al.* (2011) in bottle gourd; Kumar *et al.* (2008) in cucumber and Ramana (2000) in oriental pickling melon.

4.4.4 Total vine length (m)

Low phenotypic and genotypic variance of 6.72 and 3.01 respectively were recorded with high PCV (22.89 %) and moderate GCV (15.32 %). This trait recorded moderate heritability (44.79 %) with low genetic gain of 2.39 and high GAM of 21.12 per cent.

The estimates of PCV and GCV were high and moderate, respectively for this trait. Presence of moderate heritability was in agreement with Arvind Kumar *et al.* (2011) in bottle gourd. High GAM of this trait was in accordance with the conclusion of Fayeun *et al.* (2012) in pumpkin and Rahaman *et al.* (2002) snake gourd.

4.4.5 Internodal length (cm)

The phenotypic variance and genotypic variance recorded for internodal length were low (23.97 and 17.00 respectively) with moderate PCV and low GCV of 16.25 and 7.11 per cent respectively. Low heritability of 19.14 per cent with low genetic advance (0.62) and low GAM (6.41 %) were recorded for internodal length.

Estimates of PCV and GCV were moderate and low for this trait, respectively. Moderate PCV for internodal length was in agreement with the findings of Fayeun *et al.* (2012) in pumpkin. Low GCV for this trait agreed the conclusion of Maryam *et al.* (2012) in cucumber. Low heritability coupled with low genetic advance as per cent of mean was observed for this trait indicating the presence of non-additive gene action in the inheritance and further selection for its improvement is ineffective.

4.4.6 Days to first male flower appearance

High phenotypic and genotypic variance of 202.61 and 181.35 respectively were recorded with high PCV (21.07 %) and moderate GCV (19.93 %). This character exhibited very high heritability (89.50 %) coupled with high genetic gain (26.24) and high GAM (38.85 %).

High heritability of this character was in accordance with findings of Narayan *et al.* (1996) in bottle gourd; Islam *et al.* (2009) in bitter gourd; Reddy and Rao (1984) and Kadam and Kale (1985) in Ridge gourd; Reshmi (2006) in cucumber and Rahaman *et al.* (2002) in snake gourd. High heritability in conjunction with high GAM was observed for this trait which indicates the preponderance of additive gene action governing the inheritance of this character and offers the best possibility of improvement through simple selection procedures. These outcomes are in accordance with the findings of Kumar *et al.* (2007) in bottle gourd and Kumar *et al.* (2008) in cucumber.

4.4.7 Days to first female flower appearance

The phenotypic variance and genotypic variance were high for this trait (131.95 and 64.52 respectively) with moderate PCV of 13.37 per cent and low GCV of 9.35 per cent. Moderate heritability (48.90 %) with moderate genetic advance (11.57) and moderate (GAM 13.47 %) were recorded for this character.

Low GCV for this attribute was in conformity with conclusions of Narayan *et al.* (1996), Kumar *et al.* (2007) and Yadav *et al.* (2008) in bottle gourd; Kumar *et al.* (2008) in cucumber and Dhaliwal *et al.* (1996), Jeeva and Pappiah (2002), Harshawardhan *et al.* (2011), Rakhi and Rajmony (2005) and Torkadi *et al.* (2007) in musk melon. Moderate heritability in conjunction with moderate GAM was observed for this trait which indicates the role of both additive and non additive gene action governing the inheritance of this trait and offers the best possibility of improvement through progeny selection or any modified selection procedures aiming to exploit the additive gene effects. These results are in accordance with the findings of Rahaman *et al.* (2002) in snake gourd.

4.4.8 Node at which first male flower appears

High phenotypic and genotypic variance of 88.83 and 67.28 respectively were recorded with high PCV and GCV of 28.92 and 25.17 per cent respectively. This trait recorded high heritability (75.74 %), moderate genetic gain (14.71) and high GAM of (45.12 %).

The estimates of PCV and GCV were quite closer to each other for this character which reveals that the influence of the environment on this character is negligible and the role of the genotypic performance for the full expression of the phenotype. Similar results are correlated with Rastogi and Aryadeep (1990), Abusaleha and Dutta (1988) and Prasad and Singh (1994) in cucumber. High heritability in conjunction with high GAM was observed for this trait which indicates the preponderance of additive gene action governing the inheritance of this character and offers the best possibility of improvement through simple selection procedures. These results are in harmony with the findings of Kumar *et al.* (2007) in bottle gourd; Singh *et al.* (2008) and Rao *et al.* (2002) in ridge gourd and Yadav *et al.* (2009) and Kumar *et al.* (2008) in cucumber.

4.4.9 Node at which first female flower appears

High phenotypic and genotypic variances (138.90 and 83.27 respectively) were recorded for this trait with high PCV and GCV of 38.76 and 36.09 per cent respectively. High heritability of 59.95 percent coupled with moderate genetic gain (14.56) and high GAM (29.22 %) were recorded.

The estimates of PCV and GCV were high for this trait and the similar results were found by Tomar *et al.* (2008), Torkadi *et al.* (2007), Singh and Lal (2005a) and Jeeva and Pappaiah (2002) in musk melon; Dora *et al.* (2002) in pointed gourd and Kanwar *et al.* (2003) and Hossain *et al.* (2010) in cucumber. High heritability in conjunction with GAM was observed for this trait which indicates the preponderance of additive gene action governing the inheritance of this character and offers the best possibility of improvement through simple selection procedures. These results are in accordance with the findings of Narayan *et al.* (1996) in bottle gourd; Jeeva and Pappaiah (2002), Singh and Lal (2005a), Torkadi *et al.* (2007) and Tomar *et al.* (2008) in musk melon; Dey *et al.* (2009) in bitter gourd and Kumar *et al.* (2008) in cucumber.

4.4.10 Days to first fruit harvest

High phenotypic and genotypic variances (120.97 and 59.12 respectively) were recorded with moderate PCV (10.53 %) and GCV (7.36 %). This trait recorded moderate heritability of 48.87 per cent with moderate genetic advance of 11.07 and moderate GAM 10.60 per cent.

The results of PCV and GCV obtained for days to first harvest were in accordance with conclusions of Deol *et al.* (1980), Swamy *et al.* (1985), Dhaliwal *et al.* (1996), Somkuwar *et al.* (1997), Rakhi and Rajmony (2005), Singh and Lal (2005a), Torkadi *et al.* (2007) and Tomar *et al.* (2008) in musk melon. Presence of moderate heritability coupled with low genetic advance as per cent of mean indicates the presence of moderate genetic variability for these traits and considerable influence of environment was observed in the expression of the above said traits. Similar results were reported by Pandit *et al.* (2009) in bottle gourd.

4.4.11 Number of fruits per vine

Low phenotypic and genotypic variance of 3.93 and 3.41 respectively with high PCV and GCV of 38.76 and 36.09 per cent respectively were recorded for this trait. Very high heritability of 86.69 percent was recorded with low genetic advance (3.54) and a high GAM of 69.23 per cent for this character.

High estimates of PCV and GCV recorded for this trait indicates presence of high degree of genetic variability and thus a greater scope for selection. The present results were in accordance with the findings of Pandit *et al.* (2009) in bottle gourd; Afangideh and Uyoh (2007) in cucumber and Sanwal *et al.* (2008) in chow chow. High heritability coupled with high genetic advance as per cent of mean was observed indicating the preponderance of additive gene action governing the inheritance of this character and offers the best possibility of improvement through simple selection procedures. These results are in accordance with the conclusions of Narayan *et al.* (1996) and Kumar *et al.* (2007) in bottle gourd; Choudhary *et al.* (1985), Saikia *et al.* (1995), Rastogi and Arya Deep (1990) and Kumar *et al.* (2008) in cucumber; Raki and Rajamony (2005) in culinary melon and Sanwal *et al.* (2008) in chow chow.

4.4.12 Fruit weight (g)

Very high phenotypic and genotypic variance of 179892.77 and 159695.84 respectively were recorded with high PCV and GCV of 32.23 and 30.37 per cent respectively. This character exhibited higher heritability (88.77 %) coupled with high genetic gain (775.63) and high GAM of 58.95 per cent.

The PCV and GCV were high for this trait indicating that variation among the genotypes was also high and better scope for the improvement of these characters through selection. These findings are in agreement with Husna *et al.* (2011) in bottle gourd; Ramana (2000) in oriental pickling melon; Jeeva and Pappaiah (2002), Singh and Lal (2005a), Raki and Rajamony (2005), Torkadi *et al.* (2007), Tomar *et al.* (2008) and Harshawardhan *et al.* (2011) in musk melon; Bharathi *et al.* (2006) in spine gourd; Ibrahim *et al.* (2012) in sweet melon and Sanwal *et al.* (2008) in chow chow. High heritability coupled with high genetic advance as per cent of mean was observed for

this trait which indicates the preponderance of additive gene action governing the inheritance of this character and offers the best possibility of improvement through simple selection procedures. These results are similar with findings of Pandit *et al.* (2009), Husna *et al.* (2011) and Emina *et al.* (2012) in bottle gourd; Jeeva and Pappaiah (2002) and Singh and Lal (2005a), Raki and Rajmony (2005) and Harshawardhan *et al.* (2011) in musk melon, Dey *et al.* (2009) in bitter gourd; Kumar *et al.* (2008), Yadav *et al.* (2009) in cucumber and Khan *et al.* (2009) in pointed gourd.

4.4.13 Fruit length (cm)

High phenotypic and genotypic variance (221.52 and 200.60 respectively) was recorded with high PCV and GCV of 41.18 and 39.19 per cent respectively. Very high heritability of 90.56 per cent was recorded with high genetic advance of 27.76 and high GAM of 76.83 per cent for this trait.

The high PCV and GCV for this trait was in accordance with the experimental findings by Pandit *et al.* (2009) in bottle gourd; Sanwal *et al.* (2009) in chow chow and Rahman *et al.* (2002) in snake gourd. High heritability coupled with high GAM was observed for this trait which indicates the preponderance of additive gene action governing the inheritance of this character and offers the best possibility of improvement through simple selection procedures. These results are similar with the findings of Narayan *et al.* (1996), Kumar *et al.* (2007), Pandit *et al.* (2009) and Emina *et al.* (2012) in bottle gourd; Islam *et al.* (2009) in bitter gourd; Jeeva and Pappaiah (2002) and Singh and Lal (2005) in musk melon; Rahman *et al.* (2002) in snake gourd; Kumar *et al.* (2008) and Yadav *et al.* (2009) in cucumber; Sanwal *et al.* (2009) in chow chow.

4.4.14 Fruit diameter (cm)

The phenotypic and genotypic variances (14.33 and 13.96 respectively) were moderate for this trait with high PCV and GCV of 41.44 and 40.89 per cent respectively. This trait exhibited very high heritability of 97.39 per cent coupled with low genetic advance (7.60) and high GAM of 83.13 per cent.

The PCV and GCV were high for this trait indicating that variation among the genotypes was also high and better scope for the improvement of these characters through selection. High heritability coupled with high genetic advance as per cent of mean was observed for this trait which indicates the preponderance of additive gene action governing the inheritance of this character and offers the best possibility of improvement through simple selection procedures. These results are in agreement with the findings of Arvind Kumar *et al.* (2011) in bottle gourd; Arun Kumar *et al.* (2011) in cucumber; Islam *et al.* (2009) in bitter gourd and Sanwal *et al.* (2008) in chow chow.

4.4.15 Yield per vine (kg)

Considerable phenotypic and genotypic variance of 13.12 and 11.64 respectively were recorded with high PCV and GCV (54.90 and 51.73 % respectively). This character recorded higher heritability (88.77 %) with low genetic advance (6.62) and very high GAM of 100.40 per cent.

The estimates of both GCV and PCV were high, respectively for this trait. Similar results were also reported by Kumar *et al.* (2007), Yadav *et al.* (2009), Aravind kumar *et al.* (2011) and Husna *et al.* (2011) in bottle gourd; Raki and Rajamony (2005) in culinary melon; Torkadi *et al.* (2007) in musk melon; Afanigedh and Uyoh (2007), Kumar *et al.* (2008) in cucumber; Blessing *et al.* (2012) in pumpkin and Sanwal *et al.* (2009) in chow chow. High heritability coupled with high genetic advance as per cent of mean was observed indicating the preponderance of additive gene action governing the inheritance of this character and offers the best possibility of improvement through simple selection procedures. These results are in accordance with the findings of Narayan *et al.* (1996), Kumar *et al.* (2007), Yadav *et al.* (2008), Aravind kumar *et al.* (2011) and Husna *et al.* (2011) in bottle gourd; Raki and Rajamony (2005), Torkadi *et al.* (2007) in musk melon; Kumar *et al.* (2008) in cucumber; Islam *et al.* (2009) in bitter gourd and Sanwal *et al.* (2009) in chow chow.

4.4.16 Total yield (t/ha)

The phenotypic and genotypic variances (81.97 and 72.77 respectively) were high for this trait with high PCV and GCV of 54.90 and 51.73 per cent respectively. Higher heritability of 88.77 per cent was recorded with moderate genetic advance 16.56 and very high GAM (100.40 %) for this trait.

The PCV and GCV values were moderate for this trait. Similar results were also reported by Tyagi (1972) in bottle gourd; Reddy and Rao (1984) in ridge gourd and Rahman *et al.* (2002) in snake gourd. High heritability coupled with high genetic advance as per cent of mean was observed for this trait which indicates the preponderance of additive gene action governing the inheritance of this character and offers the best possibility of improvement through simple selection procedures. These results are in agreement with the findings of Tyagi (1972) in bottle gourd; Reddy and Rao (1984) in ridge gourd; Rahman *et al.* (2002) in snake gourd and Prasad and Singh (1994), Hanchinamani (2006) and Arunkumar *et al.* (2011) in cucumber.

4.4.17 Number of seeds per fruit

Very high phenotypic and genotypic variances of 18891.94 and 17402.05 respectively were recorded for this trait with high PCV and GCV (56.06 and 53.80 % respectively). This character exhibited higher heritability of 92.11 per cent coupled with very high genetic gain (260.81) and very high GAM of 106.37 per cent.

High PCV and GCV for this character were in accordance with the findings of Blessing *et al.* (2012) in pumpkin and Khan *et al.* (2009) in pointed gourd. High heritability coupled with high GAM was observed indicating the preponderance of additive gene action governing the inheritance of this character and offers the best possibility of improvement through simple selection procedures. Similar results were reported by Hawlader *et al.* (1999), Gayen and Hossian (2006) and Arvind Kumar *et al.* (2011) in bottle gourd; Rahaman *et al.* (2002) in snake gourd; Blessing *et al.* (2012) in pumpkin and Khan *et al.* (2009) in pointed gourd.

4.4.18 100 seed weight (g)

Low phenotypic and genotypic variances (9.85 and 9.54) were recorded with high PCV and GCV of 26.05 and 25.63 per cent respectively. Very high heritability (96.83 %) was recorded with low genetic advance of 6.26 and GAM (51.95 %) for this trait.

The estimates of PCV and GCV for this trait were high. The present results were in agreement with the conclusions of Singh *et al.* (2002) in ridge gourd and Raki and Rajamony (2005) in musk melon. High heritability coupled with high genetic advance as per cent of mean was observed indicating the preponderance of additive gene action governing the inheritance of this character and offers the best possibility of improvement through simple selection procedures. These results are in accordance with the findings of Kumar *et al.* (2007) and Singh *et al.* (2008) in bottle gourd; Singh *et al.* (2002) and Rao *et al.* (2002) in ridge gourd; Rajput *et al.* (1996) in bitter gourd and Kumar *et al.* (2008) in cucumber.

In the present study, wide variability was recorded for number of primary branches, node at which first male flower appears, number of fruits per vine, fruit weight, fruit length, fruit diameter, yield per vine, total yield, number of seeds per fruit and 100 seed weight indicating the existence of more variability for these traits in the genotypes under study as they have high PCV and high GCV. Moderate to Low variability was recorded for tendril length, number of nodes, internodal length, total vine length, days to first male flower appearance, days to first female flower appearance, node at which first female flower appears and days to first harvest.

High heritability coupled with high genetic advance as per cent of mean indicates operation of additive gene action as in case of tendril length, number of primary branches, days to first male flower appearance, node at which first male flower appears, node at which first female flower appeared, number of fruits per vine, fruit weight, fruit length, fruit diameter, yield per vine, total yield, number of seeds per fruit and 100 seed weight. Hence, directional selection for these traits in genetically diverse material could be effective for desired genetic improvement.

Moderate genetic advance as per cent of mean with high or medium heritability indicates action of both additive and non-additive genes as in case of number of nodes, days to first female flower appearance and days to first harvest which offers the best possibility of improvement through mass selection and progeny selection.

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 bottle gourd.

4.5 CHARACTER ASSOCIATION ANALYSIS

Estimates of correlation coefficients for all pairs of different characters were presented in Table 6 and 7. In general, genotypic correlation coefficients were of higher magnitude than the phenotypic correlation coefficients.

4.5.1 Tendril length (cm)

Tendril length recorded significant positive correlation with number of nodes per vine (0.4045 P, 0.6051 G) and number of primary branches per vine (0.5165 P, 0.8165 G), total vine length (0.3813 P, 0.6383 G), fruit weight (0.4461 P, 0.4988 G), fruit diameter (0.5427 P, 0.6550 G), number of seeds per fruit (0.4971 P, 0.6667 G), 100 seed weight (0.4774 P, 0.5877 G) and yield per vine (0.5894 P, 0.6832 G) at both phenotypic as well as genotypic levels, for total vine length (0.3813 P) only at phenotypic level and for internodal length (0.4997 G) at genotypic level. This character had non-significant positive correlation at both phenotypic and genotypic levels with number of fruits per vine, for internodal length only at phenotype level and for days to first harvest only at genotypic level. However, it showed significantly negative correlation with node at which first female flower appears (-0.2854 G) and fruit length (-0.2507 G) only at genotypic level while non-significant negative correlation at both phenotypic and genotypic levels with days to first male flower, female flower appeared, node at first male appeared, for node at which first female flower appears, days to first harvest, fruit length only at phenotypic level.

4.5.2 Number of nodes per vine (cm)

The character exhibited significantly positive correlation at both phenotypic and genotypic levels with number of primary branches (0.3963 P, 0.7113 G), total vine length (0.6701 P, 0.8692 G), fruit weight (0.5014 P, 0.8394 G), fruit diameter (0.3636 P, 0.5513 G), number of seeds per fruit (0.4917 P, 0.7580 G), 100 seed weight (0.4717 P, 0.7793 G) and yield per vine (0.5499 P, 0.8347 G), for days to first harvest (0.5279 G) only at genotypic level. These results are in accordance with Hanchinamani (2006) and Arun Kumar *et al.* (2011) in cucumber and Raja *et al.* (2007) in bitter gourd. It showed non-significant positive correlation at both phenotypic and genotypic levels with days to first male and female flower appeared, node at which first female flower appears and fruit length, for internodal length, node at which first male flower appears, days to first harvest, number of fruits per vine only at phenotypic level and also shown non-significant negative correlation with node at which first male flower appears and number of fruits per vine at genotypic level.

4.5.3 Number of primary branches per vine

This trait was significantly positively correlated with total vine length (0.5507 P, 0.7953 G), internodal length (0.3791 P, 0.6687 G), fruit diameter (0.4946 P, 0.6494 G), number of seeds per fruit (0.5469 P, 0.7068 G), 100 seed weight (0.5420 P, 0.6842 G) and yield per vine (0.5604 P, 0.6945 G) at both phenotypic and genotypic levels and these findings are in conformity with the previous studies of Narayan *et al.* (1996) and Kumar *et al.* (2007) in bottle gourd; Hanchinamani (2006) and Arun Kumar *et al.* (2011) in cucumber and Raja *et al.* (2007) in bitter gourd and Chhonkar *et al.* (1979), Deol *et al.* (1980), Vijay (1987), Swamy and Dutta (1991), Choudhary *et al.* (2003b), Singh and Lal (2005), Reddy *et al.* (2007) and Rad *et al.* (2010) in musk melon, for number of fruits per vine (0.2470 G) only at genotypic level while non-significantly positively correlated with days to first male flower appearance and days to first harvest at both phenotypic and genotypic levels, for number of fruits per vine only at phenotypic level. It had also shown significant negative correlation with fruit length (-0.2558 G) only at genotypic level, similar result was observed in the findings of

Kumar *et al.* (2008) in cucumber and non-significant negative correlation with days to appearance to first female flower, node at which first male and female appearance at both phenotypic and genotypic levels, for fruit length only at phenotypic level.

4.5.4 Total vine length (m)

Total vine length had shown significant positive correlation at both phenotypic and genotypic levels with internodal length (0.7759 P, 0.8475 G), fruit weight (0.4275 P, 0.6952 G), fruit diameter (0.3648 P, 0.5782 G), number of seeds per fruit (0.4943 P, 0.7853 G), 100 seed weight (0.6082 P, 0.9490 G) and yield per vine (0.5365 P, 0.8642 G) . These results were in accordance with experimental findings of Kumar *et al.* (2007) in bottle gourd; Varalakshmi and Narayana Reddy (1994) in ridge gourd; Arun Kumar *et al.* (2011) in cucumber and Rahaman *et al.* (2002) in snake gourd. For days to first harvest (0.2462 G) only at genotypic level, this finding was in accordance with conclusion of Kumar *et al.* (2008) in cucumber while non-significant positive correlation with days to first male flower appearance and number of fruits per vine, for days to first harvest and fruit length only at phenotypic level. It had also shown non-significant negative correlation with days to first female flower appearance, node at which first male and female flowers appearance at both phenotypic and genotypic levels, for fruit length only at genotypic level.

4.5.5 Internodal length (cm)

This trait registered significant positive correlation with 100 seed weight (0.3925 P, 0.9187 G) and yield per vine (0.2332 P, 0.6673 G), for number of fruits per vine (0.4037 G), fruit weight (0.3675 G), fruit diameter (0.4303 G) and number of seeds per fruit (0.5717 G) only at genotypic level while non-significant positive correlation with days to first male flower appearance at both phenotypic and genotypic levels, for number of fruits per vine, fruit weight, fruit length, fruit diameter and number of seeds per fruit only at phenotypic level. This character had also shown significant negative correlation with node at which first female flower appears (-0.2673 G) only at genotypic level and showed non-significant negative correlation at both phenotypic and genotypic levels with days to first female flower, node at which

first male flower appears and days to first harvest, for node at which first female flower appears only at phenotypic level and for fruit length only at genotypic level.

4.5.6 Days to first male flower appearance

This character was significantly positively correlated at both phenotypic and genotypic levels with days to first female flower appearance (0.4763 P, 0.6647 G), node at first male appeared (0.7468 P, 0.8324 G), node at which first female flower appears (0.2365 P, 0.3622 G), days to first harvest (0.5925 P, 0.8088 G). This type of desirable association would be helpful for simultaneous improvement of all these characters. These results are in accordance Narayan *et al.* (1996), Kumar *et al.* (2007) and Kamal *et al.* (2012) in bottle gourd; Varalakshmi and Narayana Reddy (1994) in ridge gourd; Geethasri *et al.* (1995) and Islam *et al.* (2009) in bitter gourd and Kumar *et al.* (2008), Hossian *et al.* (2010) and Arun Kumar *et al.* (2011) in cucumber and non-significantly positively correlated with fruit length, for fruit weight only at genotypic level. However, it had shown significant negative correlation with number of fruits per vine (-0.3745 P, -0.4209 G) while non-significant negative correlation with fruit diameter, number of seeds per fruit, 100 seed weight and yield per vine at both phenotypic and genotypic levels, for fruit weight only at phenotypic level.

4.5.7 Days to first female appearance

This character exhibited significant positive correlation at both phenotypic and genotypic levels with node at which first male appearance (0.6239 P, 0.8242 G), node at which first female flower appears (0.6019 P, 0.6938 G) and days to first harvest (0.7430 P, 0.8756 G). These results are in accordance with Kumar *et al.* (2007) and Kamal *et al.* (2012) in bottle gourd; Geethasri *et al.* (1995) in bitter gourd; Krishna Prasad and Singh (1992) and Kumar *et al.* (2008) in cucumber and Rahman *et al.* (2002) in snake gourd while non-significant positive correlation with fruit length, for fruit weight only at genotypic level. It had also reported significant negative correlation at both phenotypic and genotypic levels with number of fruits per vine (-0.4429 P, -0.7126 G), for number of seeds per fruit (-0.3521 G), 100 seed weight (-0.2498 G), yield per vine (-0.3473 G) only at genotypic level. Similar results were

reported by Narayan *et al.* (1996) in bottle gourd and Varalakshi and Narayana Reddy (1994) in ridge gourd and non-significant negative correlation at both phenotypic as well as genotypic level with fruit diameter, for fruit weight, number of seeds per fruit, 100 seed weight and yield per vine only at phenotypic level.

4.5.8 Node at which first male flower appears

Node at which first male flower appears had shown significant positive correlation at both phenotypic and genotypic levels with node at which first female flower appears (0.5669 P, 0.7509 G) and days to first harvest (0.5485 P, 0.7888G). These results were in accordance with Narayan *et al.* (1996) and Kamal *et al.* (2012) in bottle gourd; Varalakshi and Narayana Reddy (1994) in ridge gourd and Kumar *et al.* (2008) in cucumber while non-significant positive correlation with fruit length only at phenotypic level where as fruit diameter only at genotypic level. This character also registered significant negative correlation at both phenotypic as well as genotypic levels with number of fruits per vine (-0.3745 P, -0.3915 G), for 100 seed weight (-0.2442 G), yield per vine (-0.2678 G) only at genotypic level, these findings were on par with conclusions by Varalakshi and Narayana Reddy (1994) in ridge gourd and non-significant negative correlation with fruit weight and number of seeds per fruit at both phenotypic and genotypic levels, for fruit diameter, 100 seed weight, yield per vine only at phenotypic levels and for fruit length only at genotypic level.

4.5.9 Node at which first female flower appears

Node at which first female flower appears had significant positive correlation at both phenotypic and genotypic levels with days to first harvest (0.4841 P, 0.6141 G). These results are in accordance with Lal and Singh (1997) and Reddy *et al.* (2007) in musk melon. However, it exhibited significant negative correlation at both phenotypic and genotypic levels with number of fruits per vine (-0.3298 P, -0.4201 G) and yield per vine (-0.2993 P, -0.3752 G) and for 100 seed weight (-0.2776 G) only at genotypic level. These reports were in agreement with results of Varalakshi and Narayana Reddy (1994) in ridge gourd while non-significant negative correlation with

fruit weight, fruit length, fruit diameter and number of seeds per fruits at both phenotypic and genotypic levels and for 100 seed weight only at phenotypic level.

4.5.10 Days to first fruit harvest

Days to first harvest registered significant positive correlation with fruit weight (0.3142 G) and fruit length (0.3441 G) only at genotypic level. These results are in harmony with Kumar *et al.* (2007) in bottle gourd; Dhaliwal *et al.* (1996), Lal and singh (1997) and Somkuwar *et al.* (1997) in musk melon and Geethasri *et al.* (1995) in bitter gourd while non-significant positive correlation with fruit weight, fruit length, number of seeds per fruit and 100 weight only at genotypic level. This character had also exhibited significant negative correlation at both phenotypic and genotypic levels with number of fruits per vine (-0.5174 P, -0.8406 G) and non-significant negative correlation with fruit diameter and yield per vine at both phenotypic as well as genotypic levels and for number of seeds per fruit and 100 seed weight only at genotypic level.

4.5.11 Number of fruits per vine

This trait was significantly positively correlated at both phenotypic and genotypic levels with fruit diameter (0.4368 P, 0.4745 G), number of seeds per fruit (0.3987 P, 0.4367 G) and yield per vine (0.5100 P, 0.4660 G). These findings are in harmony with the reports of Narayan *et al.* (1996); Kumar *et al.* (2007), Husan *et al.* (2011) and Kamal *et al.* (2012) in bottle gourd; Kumar *et al.* (2008), Hossian *et al.* (2010) and Arun Kumar *et al.* (2011) in cucumber; Blessing *et al.* (2012) in pumpkin; Islam *et al.* (2009) in bitter gourd and Khan *et al.* (2009) in pointed gourd while it was non-significantly positively correlated with 100 seed weight. This character also exhibited significant negative correlation with fruit length (-0.5835 P, -0.6661 G), these reports are on par with Varalakshmi and Narayan Reddy (1994) in ridge gourd and non-significant negative correlation with fruit weight at both phenotypic and genotypic levels.

4.5.12 Fruit weight (g)

Fruit weight exhibited positive significant correlation at both phenotypic and genotypic levels with fruit length (0.3232 P, 0.3330 G), fruit diameter (0.4754 P, 0.5031 G), number of seeds per plant (0.5433 P, 0.5927 G), 100 seed weight (0.6500 P, 0.7111G) and yield per vine (0.7162 P, 0.7418 G). An increase in average fruit weight would simultaneously increase the fruit yield. These results are in accordance with Husan *et al.* (2011) and Kamal *et al.* (2012) in bottle gourd; Choudhary and Mandal (1987), Prasad and Singh (1994), Reshmi (2006) and Arun Kumar *et al.* (2011) in cucumber; Ramana (2000) in oriental pickling melon; Choudhary *et al.* (2003), Singh and Lal (2005), Reddy *et al.* (2007), Tomar *et al.* (2008), Mehta *et al.* (2009) and Rad *et al.* (2010) in musk melon; Islam *et al.* (2009) in bitter gourd; Yadegari *et al.* (2012) in pumpkin; Abdul-Jabbar *et al.* (2010) in summer squash and Khan *et al.* (2009) in pointed gourd.

4.5.13 Fruit length (cm)

Fruit length registered significant negative correlation with fruit diameter (-0.5337 P, -0.5643 G) while non-significant negative correlation with number of seeds per fruit, 100 seed weight and yield per vine at both phenotypic as well genotypic levels. As the length of the fruit increases fruit diameter would decrease and this result is in harmony with Yadegari *et al.* (2012) in pumpkin.

4.5.14 Fruit diameter (cm)

Fruit diameter had shown significant positive correlation at both phenotypic as well genotypic levels with number of seeds per fruit (0.6636 P, 0.6977 G), 100 seed weight (0.6115 P, 0.6300 G) and yield per vine (0.7482 P, 0.8015 G). An increase in average fruit weight would simultaneously increase the fruit weight which leads to increase in fruit yield. These results are on par with previous studies of Kumar *et al.* (2008), Hossian *et al.* (2010) and Arun Kumar *et al.* (2011) in cucumber; Blessing *et al.* (2012) and Yadegari *et al.* (2012) in pumpkin; Islam *et al.* (2009) in bitter gourd

and Thumburaj (1973), Reddy and Rao (1984) and Varalakshmi and Narayana Reddy (1994) in ridge gourd.

4.5.15 Number of seeds per fruit

This trait was significantly positively correlated with 100 seed weight (0.6043 P, 0.6496 G) and yield per vine (0.7645 P, 0.8428 G) at both phenotypic and genotypic levels. These reports are in agreement with previous studies of Kamal Narayan *et al.* (2012) in bottle gourd; Blessing *et al.* (2012) in pumpkin and Chowdhury and Sharma (2002) and Kantharaja (2003) in ridge gourd.

4.5.16 100 seed weight

100 seed weight exhibited positive significant correlation at both phenotypic as well genotypic levels with yield per vine (0.7479 P, 0.8182 G). Similar results were reported by Kumar *et al.* (2007), Kamal *et al.* (2012), Emina *et al.* (2012) in bottle gourd and Yadav and Ram (2002) and Musmade *et al.* (2008) in muskmelon.

The correlation study indicated that the tendril length, number of nodes per vine, number of primary branches per vine, total vine length, internodal length, number of fruits per vine, fruit weight, fruit diameter, number of seeds per fruit and 100 seed weight had significant positive association with seed yield at both phenotypic and genotypic levels. So, improvement in seed yield is possible by taking above characters as criteria in selection scheme.

4.6 PATH COEFFICIENT ANALYSIS

Upon the assessment of apparent relationship between yield and yield components, it was necessary to partition the direct and indirect effects of each character on yield to understand the nature of association at genotypic and phenotypic level. In order to fulfill the requirement, the path coefficient analysis was computed and direct and indirect effects of different characters on yield per plant are presented in the Table 8 and 9.

The yield per vine was considered as effect dependent on 16 independent variables, which are considered as cause. The independent characters were tendril length, number of nodes per vine, number of primary branches per vine, total vine length, inter nodal length, days to first male flower appearance, days to first female appearance, node at which first male flower appears, node at which first female flower appears, days to first harvest, number of fruits per vine, fruit weight, fruit length, fruit diameter, number of seeds per fruit and 100 seed weight.

DIRECT EFFECTS

4.6.1 Tendril length (cm)

At phenotypic and genotypic level, tendril length exhibited low positive direct effect (0.0661 P, 0.0061 respectively) on fruit yield per vine.

4.6.2 Number of nodes per vine

This trait showed high negative direct effects on fruit yield per vine at phenotypic level (-0.3324 P) and very high negative direct effect genotypic level (-1.7114 G).

4.6.3 Number of primary branches per vine

Number of primary branches per vine showed negligible positive direct effects on fruit yield per vine at both the phenotypic and genotypic level (0.0654 P, 0.0460 G respectively). Similar results were obtained by Narayan *et al.* (1996) in bottle gourd; Geethasri *et al.* (1995) in bitter gourd and Abdul-Jabbar *et al.* (2010) in summer squash.

4.6.4 Total vine length (m)

This trait showed high positive direct effects on fruit yield per vine at phenotypic level (0.7082 P) and very high positive direct effect genotypic level (3.3262 G). Similar findings were reported by Narayan *et al.* (1996) in bottle gourd;

Geethasri *et al.* (1995) and Islam *et al.* (2009) in bitter gourd and Rao *et al.* (2004) and Karruapih *et al.* (2005) in cucumber.

4.3.5 Internodal length (cm)

Internodal length registered high negative direct effect on fruit yield per plant at phenotypic level (-0.5384 P) and very high negative direct effect (-1.3616 G) on fruit yield per vine at genotypic level.

4.6.6 Days to first male flower appearance

This trait recorded negligible negative and positive direct effect on fruit yield per vine at phenotypic level (-0.0405 P) and genotypic level (0.0831 G) respectively. Similar conclusion was observed by Kumar *et al.* (2008), Hossian *et al.* (2010) and Arun Kumar *et al.* (2011) in cucumber; Islam *et al.* (2009) in bitter gourd and Rahaman *et al.* (2002) in snake gourd.

4.6.7 Days to first female flower appearance

This trait showed negligible positive direct effect on fruit yield per vine at both the phenotypic level (0.0160 P) and negligible positive direct effect at genotypic level (-0.0365 G). Similar results were obtained by Kumar *et al.* (2008), Hossian *et al.* (2010) and Arun Kumar *et al.* (2011) in cucumber; Lal and Singh (1997) in musk melon and Rahaman *et al.* (2002) in snake gourd.

Eventhough this trait had negligible direct effect on fruit yield, it is very important character to predict the earliness or lateness of genotype.

4.6.8 Node at which first male flower appears

This character had negligible positive direct effect on fruit yield per vine at phenotypic level (0.0684 P) and high negative direct effect (-0.3760 G) at genotypic level. These results are in conformity with the findings of Narayan *et al.* (1996) in bottle gourd.

4.3.9 Node at which first female flower appears

This trait recorded negligible negative direct effect on fruit yield per vine at phenotypic level (-0.0650 P) and low positive direct effect (0.1649 G) at genotypic level. Similar conclusions were found by Varalakshmi and Narayana Reddy (1994) in ridge gourd.

4.6.10 Days to first fruit harvest

This trait showed low positive direct effect on fruit yield per vine at both phenotypic as well as genotypic level (0.1002 P, 0.1222 G respectively). Similar results were obtained by Kumar *et al.* (2008) in cucumber and Lal and Singh (1997) and Choudhary *et al.* (2003) in musk melon.

4.6.11 Number of fruits per vine

This trait showed high positive direct effects on fruit yield per vine at both the phenotypic level (0.5864 P) and genotypic level (0.5953G). Similar results were reported by Narayan *et al.* (1996) and Husna *et al.* (2011) in bottle gourd; Rao *et al.* (2004), Karuapiah *et al.* (2005), Kumar *et al.* (2008), Hossian *et al.* (2010) and Arun Kumar *et al.* (2011) in cucumber; Ramana (2000) in oriental pickling melon, Choudhary *et al.* (2003) and Singh and Lal (2005) in musk melon; Rahaman *et al.* (2002) and Narayanankutty *et al.* (2006) in snake gourd, Reddy *et al.* (2007) and Khan *et al.* (2009) in pointed gourd; Sanwal *et al.* (2008) in chow chow and Mehta *et al.* (2009) in musk melon and Islam *et al.* (2009) in bitter gourd.

4.6.12 Fruit weight (g)

Fruit weight registered high positive direct effect on fruit yield per vine at both phenotypic level and genotypic level (0.6219 P, 0.9012 G respectively). These findings are in agreement with the results of Husna *et al.* (2011) in bottle gourd; Ramana (2000) in oriental pickling melon, Rahman *et al.* (2002) in pointed gourd, Choudhary *et al.* (2003) and Singh and Lal (2005) in musk melon, Narayanankutty *et al.* (2006) in snake gourd; Singh *et al.* (1993) and Khan *et al.* (2009) in pointed gourd;

Rao *et al.* (2004), Karuapih *et al.* (2005), Hossian *et al.* (2010) and Arunkumar *et al.* (2011) in cucumber, Blessing *et al.* (2012) and Yadegari *et al.* (2012) in pumpkin and Sanwal *et al.* (2008) in chow chow.

4.6.13 Fruit length (cm)

Fruit length had negligible negative direct effects on fruit yield per vine at both the phenotypic level (-0.0021 P) and genotypic level (-0.0604 G). The results are in conformity with the findings of Hossian *et al.* (2010) and Arunkumar *et al.* (2011) in cucumber; Islam *et al.* (2009) in bitter gourd and Rahaman *et al.* (2002) in snake gourd.

4.6.14 Fruit diameter (cm)

Fruit diameter showed negligible negative direct effect on fruit yield per vine at phenotypic level (0.0245 P) and moderate positive direct effect (0.2481 G) at genotypic level. Similar results were obtained by Kumar *et al.* (2008), Hossian *et al.* (2010) in cucumber and Blessing *et al.* (2012) in pumpkin.

4.6.15 Number of seeds per fruit

This character registered negligible direct effect on fruit yield per vine at phenotypic level (-0.0101 P) and high negative direct effect at genotypic level (-0.4361 G).

4.3.16 100 seed weight (g)

100 seed weight (0.0865 P, -0.4788 G) had negligible positive direct effect at phenotypic level and high negative direct effect at genotypic level on fruit yield per vine. Similar results were found by Kumar *et al.* (2007) in bottle gourd and Geethasri *et al.* (1995) in bitter gourd.

INDIRECT EFFECTS

Number of nodes per vine had very high negative indirect effect on fruit yield per vine through tendril length (-1.0357 G), number of primary branches (-1.4876 G),

fruit weight (-1.4366 G), number of seeds per fruit (-1.2973 G) and 100 seed weight (-1.3338 G) while it exerted high negative indirect effect via internodal length (-0.7955 G) and fruit diameter (-0.9436 G) at genotypic level. However, it showed weak negative indirect effect at phenotypic level on fruit yield per vine by means of tendril length (-0.1345 P), number of primary branches (-0.1317 P), fruit weight (-0.1667 P), fruit diameter (-0.1209 P), number of seeds per fruit (-0.1635 P), 100 seed weight (-0.1568 P) and it reported moderate negative direct effect on total vine length (-0.2227 P) at phenotypic level.

Total vine length imparted very high positive indirect effect on fruit yield per vine by way of tendril length (2.1232 G), number of nodes per vine (2.8912 G), number of primary branches per vine (2.6542 G), internodal length (2.8188 G), fruit weight (2.3123 G), fruit diameter (1.9233 G), number of seeds per fruit (2.6122 G), 100 seed weight (3.1565 G) where as high positive indirect effect exercised via days to first harvest (0.8188 G), number of fruits per vine (0.6739 G), days to first male flower appearance (0.3707 G) at genotypic level and similar results were found by Hossian *et al.* (2010) in cucumber; Rahaman *et al.* (2002) in snake gourd and Geethasri *et al.* (1995) in bitter gourd. However, it showed high positive indirect effect on fruit yield per vine at phenotypic level through internodal length (0.5495 P), number of nodes per vine (0.4746 P), 100 seed weight (0.4307 P), number of primary branches per vine (0.3900 P), number of seeds per fruit (0.3500 P), fruit weight (0.3027 P). Similar results were reported by the previous studies of Kumar *et al.* (2007) in bottle gourd. It exhibited moderate positive indirect effect by way of tendril length (0.2700 P) and fruit diameter (0.2584 P). It also showed high negative indirect effect via days to first female flower appearance (-0.3398 G) and node at which first female flower appears (-0.3971 G) at genotypic level. Similar results were obtained by Vijay *et al.* (1987) in muskmelon and Varalakshmi and Narayana Reddy *et al.* (1994) in ridge gourd.

Internodal length recorded highest negative indirect effect on fruit yield per vine by means of 100 seed weight (-1.2509 G), total vine length (-1.1539 G) and high negative indirect effect was showed through number of primary branches (-0.9105 G),

number of seeds per fruit (-0.7785 G), tendril length (-0.6804 G), number of nodes per vine (-0.6329 G), fruit diameter (-0.5859 G), number of fruits per vine (-0.5497 G), fruit weight (-0.5004 G) while high positive indirect effect through node at which first female flower appears (0.3639 G) at genotypic level. It had also shown moderate negative and positive indirect effects on fruit yield through days to first male flower appearance (-0.2047 G) and days to first female flower appearance (0.2496 G) respectively at genotypic level and moderate positive indirect effect at phenotypic level was shown through number of primary branches per vine (-0.2041 P).

It was observed that node at which first male flower appears had high negative indirect effect on fruit yield per vine via days to first male flower appearance (-0.3130 G) and days to first female flower appearance (-0.3099 G) where as moderate negative indirect effect was exhibited through node at which first female flower appears (-0.2823 G) and days to first harvest (-0.2965 G) at genotypic level. Similar results were obtained by Narayan *et al.* (1996) in bottle gourd and Varalakshmi and Narayana Reddy *et al.* (1994) in ridge gourd.

Node at which first female flower appears exercised weak positive indirect effect at genotypic level on fruit yield per plant by way of days to first female flower appearance (0.1144 G) and days to first harvest (0.1013 G). Similar results were obtained by Narayanankutty *et al.* (2006) in snake gourd and Geethasri *et al.* (1995) in bitter gourd.

Days to first fruit harvest showed low positive and negative indirect effect on fruit yield per vine through days to first female flower appearance (0.1070 G) and number of fruits per vine (-0.1027 G) at genotypic level respectively. These results are in conformity with findings of Narayan *et al.* (1996) in bottle gourd.

High negative indirect effect was shown by number of fruits per vine on fruit yield per vine at both phenotypic as well as genotypic level via days to first harvest (-0.3034 P, -0.5004 G), fruit length (-0.3421 P, -0.3956 G) and by days to first female flower appearance (-0.4242 G) only at genotypic level and Similar results were obtained by Kumar *et al.* (2007) in bottle gourd; Hossian *et al.* (2010) in cucumber

and Tomar *et al.* (2008) in musk melon. However, it also had medium positive indirect effect on fruit yield per plant at both phenotypic and genotypic level by means of fruit diameter (0.2561 P, 0.2824 G), number of seeds per fruit (0.2338 P, 0.2600 G) and similar results were recorded by Sanwal *et al.* (2008) in chow chow while through internodal length (0.2403 G) only at genotypic level. This trait exerted modest negative indirect effect on fruit yield per vine via internodal length (-0.2196 P, -0.2505 G) both at phenotypic as well as genotypic level and days to female flower appeared (-0.2595 P) only at phenotypic level, whereas through node at which first male flower appears (-0.2352 G) and node at female flower appeared (-0.2501 G) only at genotypic level. These reports are in harmony with conclusions of Varalakshmi and Narayana Reddy (1994) in ridge gourd.

It was reported that fruit weight showed high positive indirect effect at both phenotypic as well as genotypic level on fruit yield per vine through number of nodes per vine (0.3118 P, 0.7564 G), number of seeds per fruit (0.3379 P, 0.5341 G) and 100 seed weight (0.4042 P, 0.6408 G). These are on par with the results of Kumar *et al.* (2007) in bottle gourd. However, it had exhibited high positive indirect effect on fruit yield per vine by means of tendril length (0.4495 G), nodes per vine (0.7564 G), number of primary branches per vine (0.4102 G), total vine length (0.6265 G), internodal length (0.3312 G), fruit length (0.3001 G) and fruit diameter (0.4534 G) only at genotypic level and these results are in agreement with Hossian *et al.* (2010) in cucumber; Geethasri *et al.* (1995) in bitter gourd and Varalakshmi and Narayana Reddy (1994) in ridge gourd. It had also registered moderate positive indirect effect on fruit yield per vine at phenotypic level by way of tendril length (0.2774 P), number of primary branches (0.2137 P), total vine length (0.2658 P), fruit length (0.2010 P) and fruit diameter (0.2956 P) but through days to first harvest only at genotypic level (0.2832 G). Similar results were obtained by Kumar *et al.* (2008) in cucumber; Varalaxmi and Narayana Reddy (1994) in ridge gourd; Tomar *et al.* (2008) and Mehta *et al.* (2009) in musk melon.

Fruit diameter imparted weak positive indirect effect on fruit yield per vine at genotypic level through tendril length (0.1625 G), nodes per vine (0.1368 G), number

of primary branches per vine (0.1611 G), total vine length (0.1435 G), internodal length (0.1068 G), number of fruits per vine (0.1177 G), fruit weight (0.1248 G), number of seeds per fruit (0.1731 G) and 100 seed weight (0.1563 G). It showed low negative indirect effect on fruit yield per vine by way of fruit length (-0.1400 G) at genotypic level. This result was in conformity with findings of Sanwal *et al.* (2008) in chow chow.

High negative indirect effect was shown by number of seeds per fruit at genotypic level via number of nodes per vine (-0.3306 G), number of primary branches per vine (-0.3083 G), total vine length (-0.3425 G) and fruit diameter (-0.3043 G). This trait also had modest negative indirect effect on fruit yield per vine by means of tendril length (-0.2908 G), internodal length (-0.2494 G), fruit weight (-0.2585 G) and 100 seed weight (-0.2833 G) at genotypic level. Similar conclusions were recorded by Geethasri *et al.* (1995) in bitter gourd.

100 seed weight exhibited high negative indirect effect at genotypic level on fruit yield per vine by means of number of nodes per vine (-0.3732 G), number of primary branches per vine (-0.3276 G), total vine length (-0.4544 G), internodal length (-0.4399 G), fruit weight (-0.3405 G), fruit diameter (-0.3016 G) and number of seeds per fruit (0.3110 G), whereas medium negative indirect effect was registered through tendril length (-0.2814 G).

In plant breeding, it is very difficult to have complete knowledge of all component traits of yield. The residual effect permits precise explanation about the pattern of interaction of other possible components of yield. In other words, residual effect measures the role of possible independent variables which were not included in the study of dependent variable. In the present study, the residual effect values were (0.1787 P) at phenotypic and (0.0927 G) at genotypic levels, respectively. This clearly shows the importance of inclusion of some more characters for clear partition of the direct and indirect effects among the yield components.

The path analysis indicated that tendril length, number of primary branches per vine, total vine length, days to first harvest, number of fruits per vine, fruit weight,

fruit diameter had direct positive effects on fruit yield per vine both at phenotypic and genotypic levels.

Based on the results of path analysis, the present study revealed that major emphasis should be laid on selection process with more vine length, number of fruits per plant, fruit weight and fruit diameter and there should be economic balance among these traits to get higher fruit yield per plant.

4.7 GENETIC DIVERGENCE (D^2 STATISTIC)

For a successful breeding programme, the diversity of parents is of utmost importance, since the crosses made between the parents with maximum genetic divergence are more likely to yield desirable recombinants in the progenies. However, it is desirable to select suitable genetically divergent parents based on information about the genetic variability and genetic diversity present in the available germplasm.

The multivariate D^2 analysis using Mahalanobis' D^2 statistic provides a useful statistical tool for measuring the genetic diversity in germplasm collections with respect to the characters considered together. It also provides a quantitative measure of association between geographic and genetic diversity based on generalized distance (Mahalanobis, 1936). Further, the problem of selecting diverse parents for hybridization programme can be narrowed, if one can identify the characters responsible for the discrimination between the populations.

The genetic divergence among 24 genotypes of bottle gourd was quantitatively assessed by adopting Mahalanobis' D^2 statistics.

4.7.1 Relative contribution of different characters towards genetic divergence

The relative ranking of different characters and their contribution towards total genetic divergence is given in Table 10. It is evident from that, 100 seed weight (28.26 %), fruit diameter (23.55 %) and number of seeds per fruit (17.75 %) contributed maximum (more than 69 %) to the total divergence followed by fruit length (11.96

%), days to first male flower appearance (7.25 %), yield per vine (6.88 %), fruit weight (2.54 %), number of fruits per vine (1.45 %) and node at which first female flower appears (0.36 %), whereas, remaining characters like tendril length, number of nodes per vine, number of primary branches per vine, total vine length, internodal length, days to first female flower appearance, node at which first male flower appears and days to first harvest had no contribution towards genetic divergence. Hence, selection for divergent parents based on these characters will be useful for heterosis breeding in bottle gourd.

4.7.2 Clustering pattern of genotypes

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 characters and is used for the final grouping of the genotypes. Ward's statistical procedure has been used to group 24 bottle gourd genotypes into 5 clusters on the basis of their genetic similarity so that genotypes within a cluster had smaller D^2 value among themselves than those belonging to different clusters.

The distribution pattern of entries and clustering was given in Table 11. Cluster III consisted of maximum number of genotypes (11) followed by cluster IV included eight genotypes while cluster I had three genotypes whereas, the remaining clusters II and V were solitary cluster.

4.7.3 Mean intra and inter cluster distances

The mean inter and intra cluster D^2 values presented in Table 12 showed that the intra cluster D^2 values ranged from 0.00 to 160.20, where maximum distance was reported in cluster III (160.20) followed by cluster I (142.21). The clusters II and V had no intra cluster distance (zero).

The inter cluster D^2 values varied from 239.74 to 3966.51 and maximum genetic divergence existed between clusters II and V (3966.51) followed by cluster I and V (2198.98) indicating wider genetic diversity among the genotypes included in these groups. Selection of parents for use in breeding programme and desirable cross

combinations were showed in the Table 13. Selection of parents for hybridization programme from cluster combinations of II & V and I & V which showed higher inter distance would help in achieving novel recombinants. The minimum genetic divergence was registered between clusters III and IV (239.74) followed by clusters I and II (457.84).

In this experiment, inter cluster distance was always higher than intra-cluster distance. Similar result was found by Sidhu and Gautam (1985) in watermelon and Khatun *et al.* (2010) in snake gourd.

Medium inter-cluster distances were observed between the cluster I and III, I and IV, IV and V, III and V. It is mentioned that the crosses involving parents belonging to medium divergent clusters may also exhibit significant and positive heterosis (Karim *et al.*, 2001 and Mian and Bhal, 1989).

4.7.4 Cluster mean analysis

The cluster means for the eighteen characters studied in bottle gourd genotypes revealed considerable differences among all the clusters. Cluster means were calculated in all the 5 clusters for all the 18 quantitative characters studied and presented in Table 14. Cluster II showed highest mean for tendril length (36.40 cm) followed by clusters I (26.18cm). Lowest mean for tendril length was recorded by cluster V (19.03 cm).

The genotypes in cluster II (144.73) recorded maximum mean for number of nodes per vine after that cluster I (123.99) while the genotypes in cluster V (79.73) exhibited lowest mean for number of nodes per vine.

The maximum cluster mean value (20.50) for number of primary branches per vine was shown by cluster II, closely followed by cluster III (12.78). Lowest mean for number of primary branches per vine was registered by cluster V (8.17).

Cluster mean for total vine length was maximum in cluster II (16.36 m), followed by cluster I (12.74 m). Minimum mean was shown by cluster V (7.70 m) for total vine length.

The cluster II showed highest mean for internodal length (11.34 cm) followed by cluster I (10.25 cm). Lowest mean for internodal length was exercised by cluster III (9.37 cm).

The minimum cluster mean value for days to first male flower appearance was shown by cluster V (50.19 days) which was closely followed by cluster IV (58.98 days). Highest mean for days to first male flower appearance was reported by cluster III (75.19 days).

Cluster V showed lowest mean for days to first female flower appearance (67.79 days) followed by cluster II (80.91 days). Highest mean for days to first female flower appearance was recorded by cluster III (89.78 days).

Cluster mean for node at which first male flower appears was minimum in cluster V (24.67) followed by cluster IV (27.36). Maximum mean was shown by cluster I (37.67).

The cluster II showed lowest mean for node at which first female flower appears (40.74) followed by cluster V (41.84). Highest mean for node at which first female flower appears was recorded by cluster III (53.28).

Cluster mean for days to first harvest was minimum in cluster V (75.43 days), followed by cluster IV (102.29 days) and maximum mean was shown by cluster III (108.77 days).

The genotypes in cluster V (10.45) recorded maximum mean for number of fruits per vine after that cluster II (9.13) whilst the genotypes in cluster III (4.12) exhibited lowest mean for number of fruits per vine.

Cluster mean value for fruit weight was maximum in cluster II (1841.493 g) followed by cluster I (1707.29 g) and minimum in cluster V (197.55 g). For, fruit

length maximum cluster mean was registered in cluster IV (44.05 cm), followed by cluster III (37.97 cm) whereas minimum mean value recorded in cluster V (13.75 cm).

The maximum cluster mean for fruit diameter was found in cluster II (18.04 cm) followed by cluster I (16.45 cm) while, cluster V (6.28 cm) shown minimum mean value.

The genotypes in cluster II (16.77 kg) exhibited highest mean value for fruit yield per vine followed by cluster I (10.74 kg) while lowest mean value (2.09 kg) in cluster V. For, total yield maximum cluster mean value was observed in cluster II (41.92 t/ha) after that cluster I (26.86 t/ha) but minimum value in cluster V (5.23 t/ha).

The mean number of seeds per fruit was highest for cluster II (729.63) followed by cluster II (347.54) and least number in cluster III (155.84). The 100 seed weight was found maximum in cluster II (18.22 g) closely followed by cluster I (15.07 g) and minimum was recorded in cluster V (6.54 g).

Hence, apart from selecting genotypes from the clusters which have high inter-cluster distance for hybridization, one can also think of selecting parents based on extent of genetic divergence with respect to a particular character of interest. This is to mean that, if breeder's intention is to improve fruit yield, he can select parents which are highly divergent with respect to these characters.

Chapter-V

Summary and Conclusions

CHAPTER V

SUMMARY AND CONCLUSIONS

The present investigation entitled “**Studies on genetic variability, heritability, correlation and path coefficient analysis in Bottle gourd [*Lagenaria siceraria* (Mol) Standl.] genotypes**” was undertaken to elicit the information on magnitude of genetic variability, heritability and to predict the gains realized through selection, character association, cause and effect relationship and divergence in bottle gourd genotypes.

The experiment was carried out in a Randomized Block Design with 3 replications in spring summer season of 2012 at Horticultural college and Research institute, Venkataramannagudem, W.G.dist, comprising 23 genotypes along with one check variety (Pusa Naveen) obtained from NBPGR, Hyderabad. Observations were recorded for 20 characters, out of these, 18 were quantitative characters viz., tendril length (cm), number of nodes per vine, number of primary branches per vine, total vine length (m), internodal length (cm), days to first male flower appearance, days to first female flower appearance, node at which first female flower appears, node at which first female flower appears, days to first fruit harvest, number of fruits per vine, fruit weight (g), fruit length (cm), fruit diameter (cm), yield per vine (kg), total yield (t/ha), number of seeds fruit and 100 seed weight (g) and the remaining two were morphological characters viz., leaf lobing pattern and fruit shape. Data was subjected to standard statistical analysis and the results obtained are summarized in the present chapter.

The two morphological characters revealed high variation with genotype to genotype. Maximum genotypes (12) were with high leaf lobing pattern (more than 4 lobes on the leaf) and 10 genotypes had long shaped fruits with crooked neck.

Analysis of variance revealed highly significant differences among the genotypes for all 18 quantitative characters. Based on the mean performance, the genotypes IC 249671, IC 249663 and IC 249672 were found to be elite for the

characters tendril length (cm), number of nodes per vine, number of primary branches per vine, total vine length (m), internodal length (cm), fruit weight (g), fruit diameter (cm), yield per vine (kg), total yield (t/ha), number of seeds per fruit and 100 seed weight in bottle gourd.

Higher magnitude of PCV and GCV ($> 20\%$) were observed for number of primary branches per vine, node at which first female flower appears, number of fruits per vine, fruit weight (g), fruit length (cm), fruit diameter (cm), yield per vine (kg), total yield (t/ha), number of seeds per fruit and 100 seed weight (g) indicating the existence of wide range of genetic variability in the germplasm for these traits. This also indicated broad genetic base, less environmental influence and these traits are under the control of additive genes and hence there is a good scope for the further improvement of these characters through selection.

High Heritability (h_b^2) estimates ($>60\%$) coupled with high estimates from genetic gain as percent of mean ($>20\%$) were observed for tendril length (cm), number of primary branches per vine, days to first male flower appearance, node at which first female flower appears, number of fruits per vine, fruit weight (g), fruit length (cm), fruit diameter (cm), yield per vine (kg), total yield (t/ha), number of seeds and 100 seed weight (g) indicated that most likely the heritability is due to additive gene effects and thus the chances of fixing by selection are more to improve such traits through pure line selection, mass selection, progeny selection, hybridization and selection through pedigree breeding.

For most of the characters genotypic correlation coefficients were higher than phenotypic correlation coefficients indicating lesser phenotypic expression under the influence of environment. Tendril length (cm), number of nodes per vine, number of primary branches per vine, total vine length (m), internodal length (cm), number of fruits per vine, fruit weight (g), fruit diameter (cm), number of seeds per fruit and 100 seed weight (g) registered a positive significant correlation at both phenotypic and genotypic levels with fruit yield per vine indicating the importance of these traits in selection for yield and are identified as yield attributing characters on which selection can be relied upon for the genetic improvement of yield of bottle gourd.

Total vine length (m), number of fruits per vine, fruit weight (g) exerted a high positive direct effect on fruit yield per vine (kg). The high direct effect of these traits appeared to be the main factors for their strong association with fruit yield per vine (kg). Hence, direct selection for these traits should be effective indicating the effectiveness of direct selection. The estimates of residual variability demonstrate that most of the traits have been considered in the evaluation of selective potential of present material.

D² statistics grouped the genotypes into 5 clusters. Cluster III had the maximum number of genotypes (11) followed by cluster IV (8), cluster I (3) whereas the remaining clusters II and V were solitary clusters.

Maximum average inter-cluster D² values were between cluster II and V (3966.505) followed by cluster I and V (2198.979). Maximum intra cluster distance was observed in cluster III (160.201) followed by cluster I (142.207) and cluster II (95.64). Cluster means for different traits exhibited substantial variability. Selection of parents from clusters II and V followed by I and V for hybridization programme would help in achieving novel recombinants.

Maximum contribution towards genetic divergence by the characters viz., 100 seed weight (g), fruit diameter (cm), number of seeds per fruit and fruit length (cm) suggested that selection of one or two elite genotypes from such divergent clusters based on the above characters and crossing would result in more heterosis and through useful segregants.

Considering all factors at a time, it could be concluded that the genetic stocks of bottle gourd used in this investigation had wide range of variability, particularly for flower, fruit and yield character. As such, there is enough scope of improvement of these characters by selection.

Based on the findings of the present investigation the conclusion drawn for further improvement of bottle gourd genotypes for cultivation in Coastal districts of Andhra Pradesh is that genotypes IC 249671(cluster II) and genotypes IC 446596 (cluster V) and genotypes IC 249663, IC 249672 and IC 446594 (cluster III) show a lot of genetic diversity, so crosses between these genotypes are likely to produce new

recombinants with desired traits. Based on the mean performance and genetic parameters, the genotypes IC 249671, IC 249663 and IC 249672 can be selected for further evaluation for their suitability for cultivation in Coastal districts of A.P.

FUTURE LINE OF WORK

The accessions studied in present investigation had very high variability for yield and its attributing parameters. Further,

- Total genetic variation in selected bottle gourd genotypes was high. Thus helps to direct selection can be exercised for improvement of the characters viz., number of fruits per plant, fruit length, fruit diameter and fruit weight
- Yield parameters like vine length, fruit weight, days to first harvest, node at female flower are predominantly controlled by non-additive gene action and hence higher yield be exploited through heterosis breeding or through recurrent selection for SCA.
- The same study has to be carried by using the promising genotypes for one or two season to know the stable expression of the characters and future hybridization programme.
- The genetically divergent genotypes can be used as mapping populations to detect diversity at molecular level and also to identify molecular markers linked to desirable traits for marker assisted selection (MAS).



IC 249663
13156

PSR 13300
PSR 13290

PSR



RJR 27

PSR 13176
IC 446596

RJR 201



IC 249654

IC 249672

IC 249671

IC 249668

Plate 2. Phenotypic variation in leaf lobing pattern of bottle gourd genotypes



IC 446594

RJR 533

IC 249658

IC 249653



IC 249650

IC 256053



RJR 420



IC 249656



Pusa Naveen



NSJ 298



IC 249665



IC 446592

Plate3. Phenotypic variation in leaf lobing pattern of bottle gourd genotypes

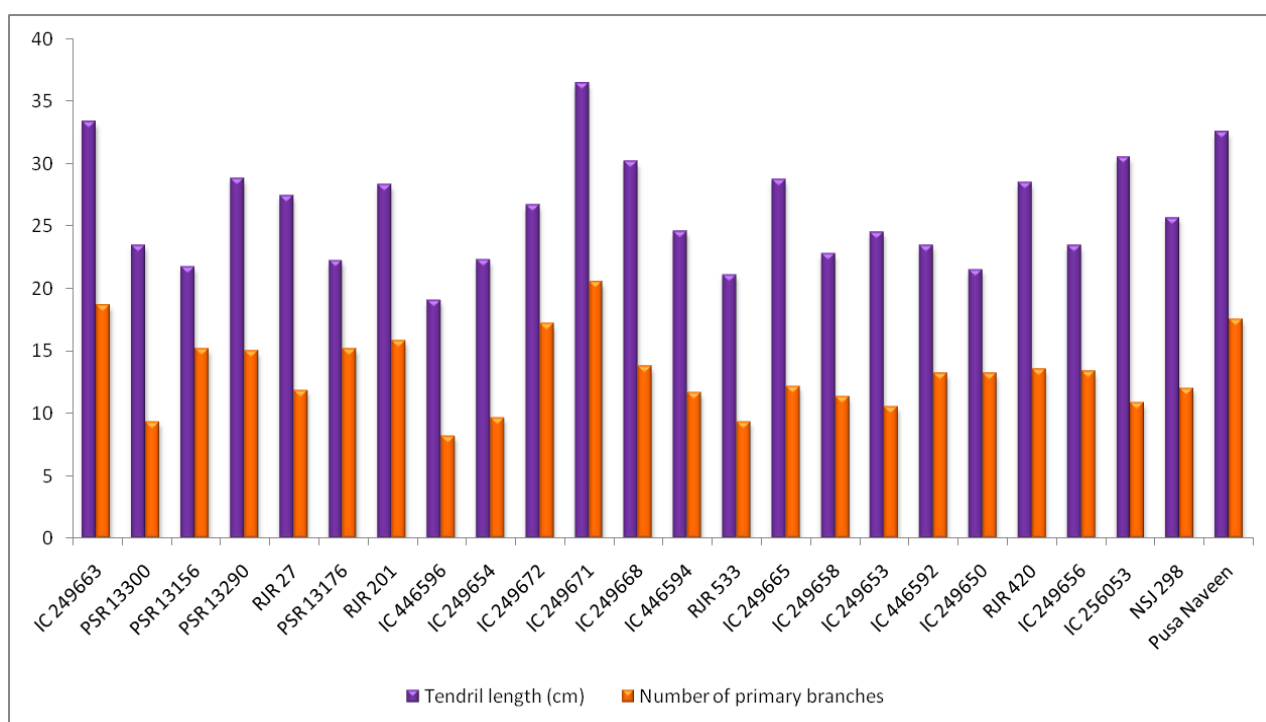


Fig 2: Mean performance of tendril length and number of primary branches of different genotypes of bottle gourd

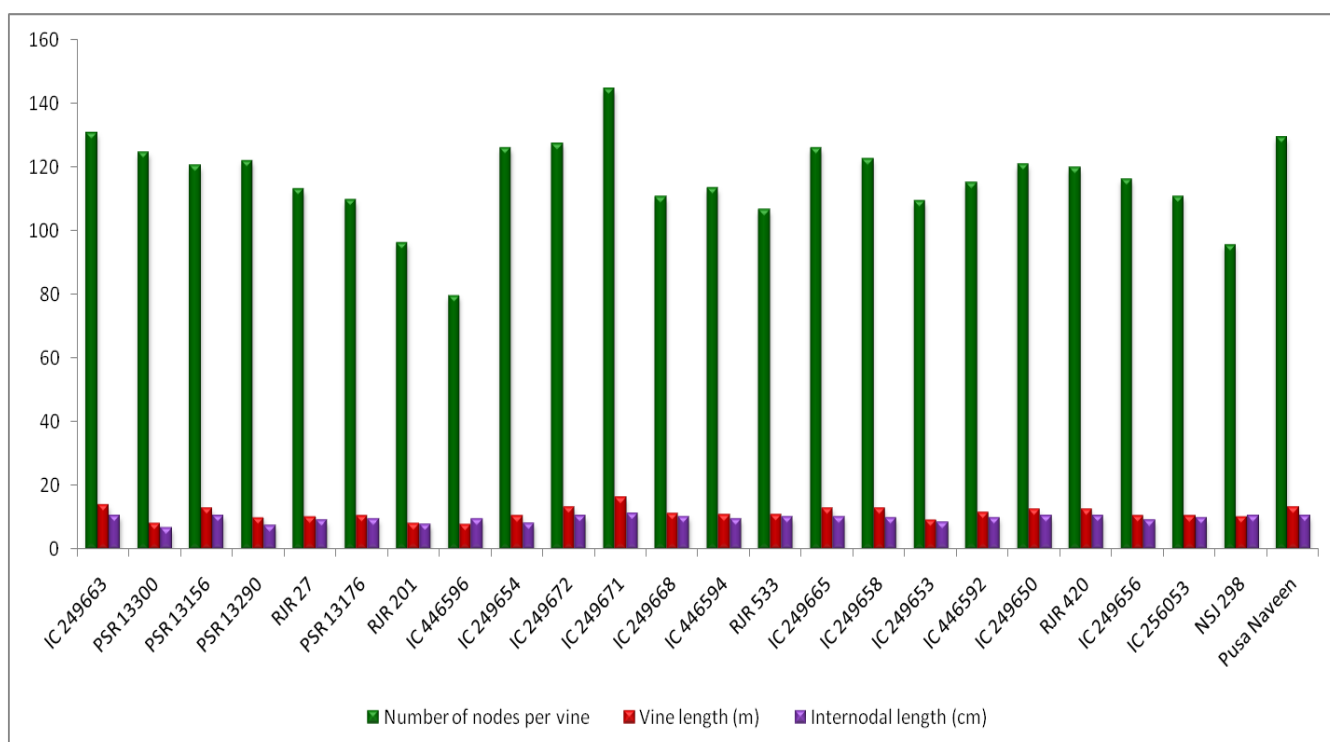


Fig 3: Mean performance of number of nodes, vine length, internodal length of different genotypes of bottle gourd

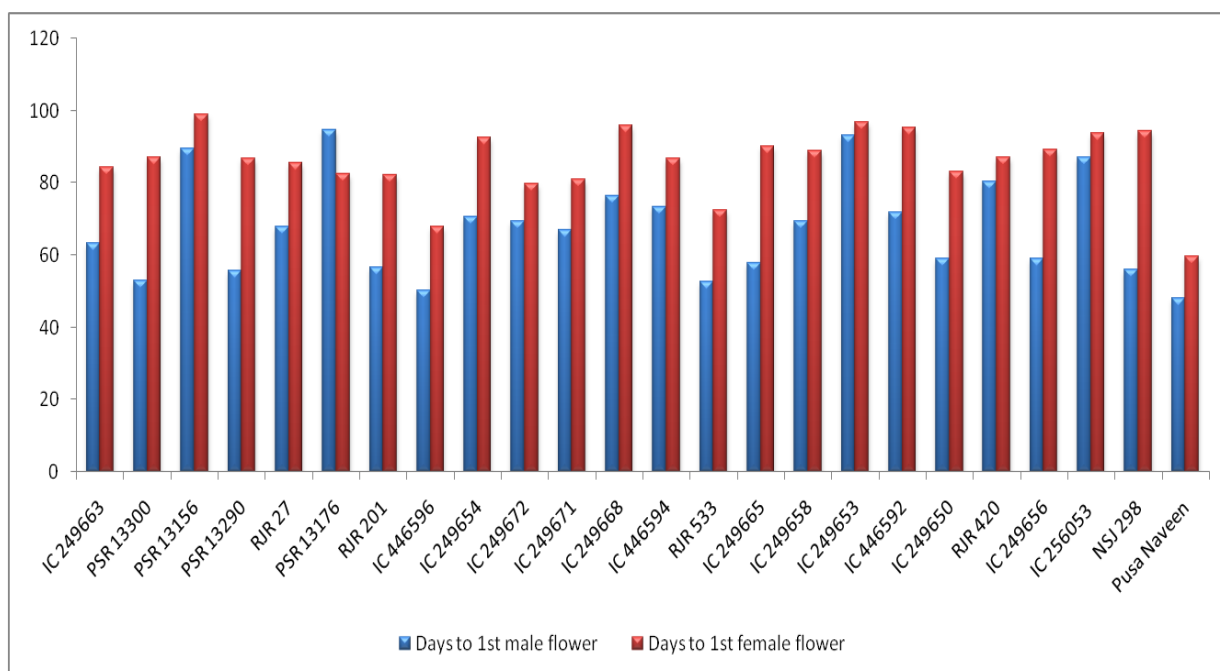


Fig 4: Mean performance of days to first male and female flower of different genotypes of bottle gourd

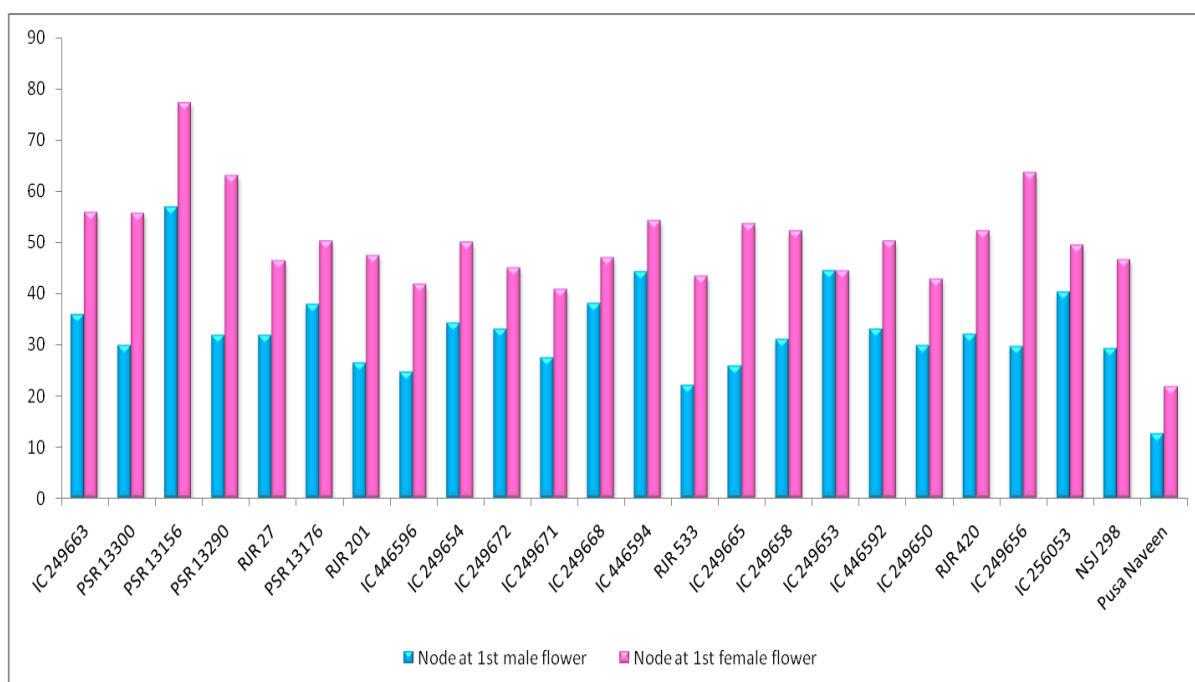


Fig 5: Mean performance of node number at first male and female flower of different genotypes of bottle gourd

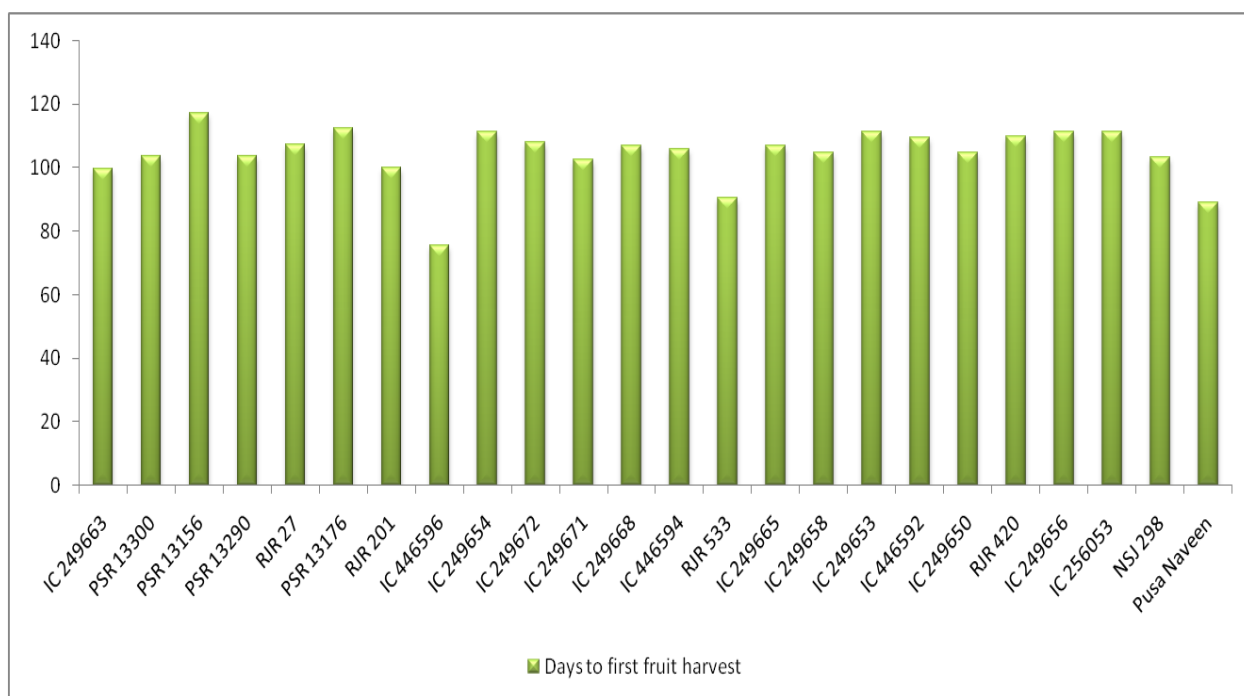


Fig 6: Mean performance of days to first harvest of different genotypes of bottle gourd

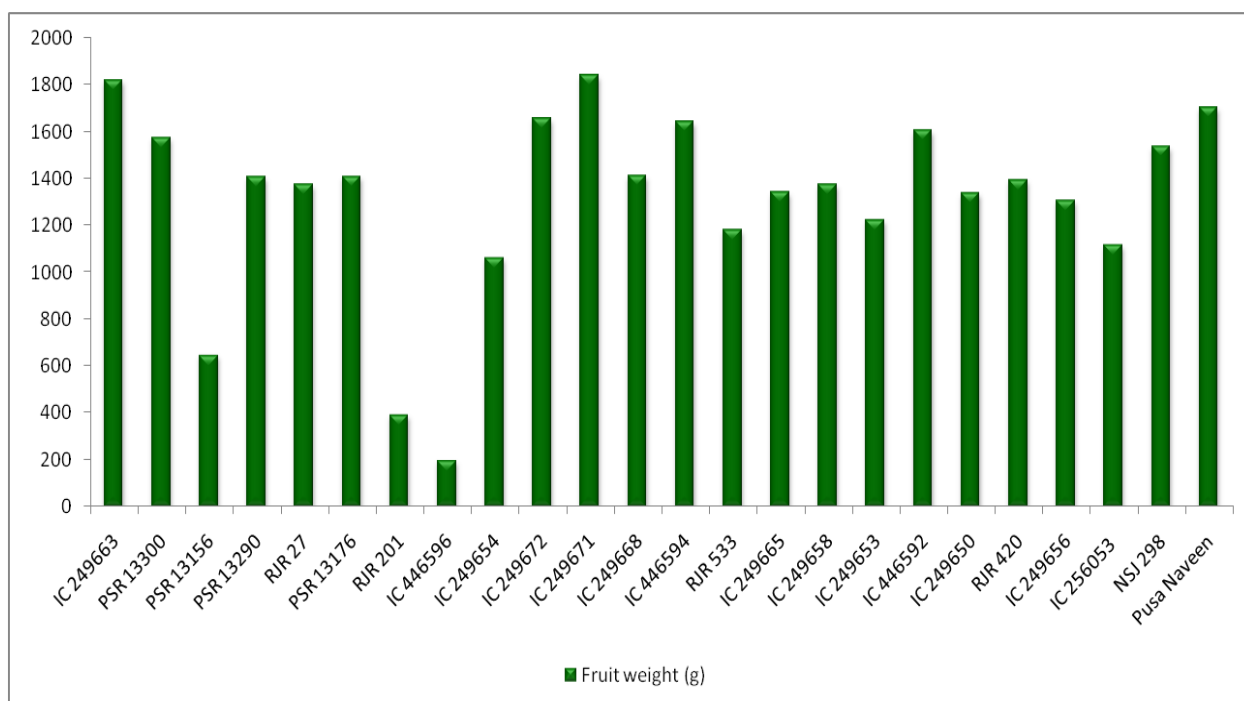


Fig 7: Mean performance of fruit weight of different genotypes of bottle gourd

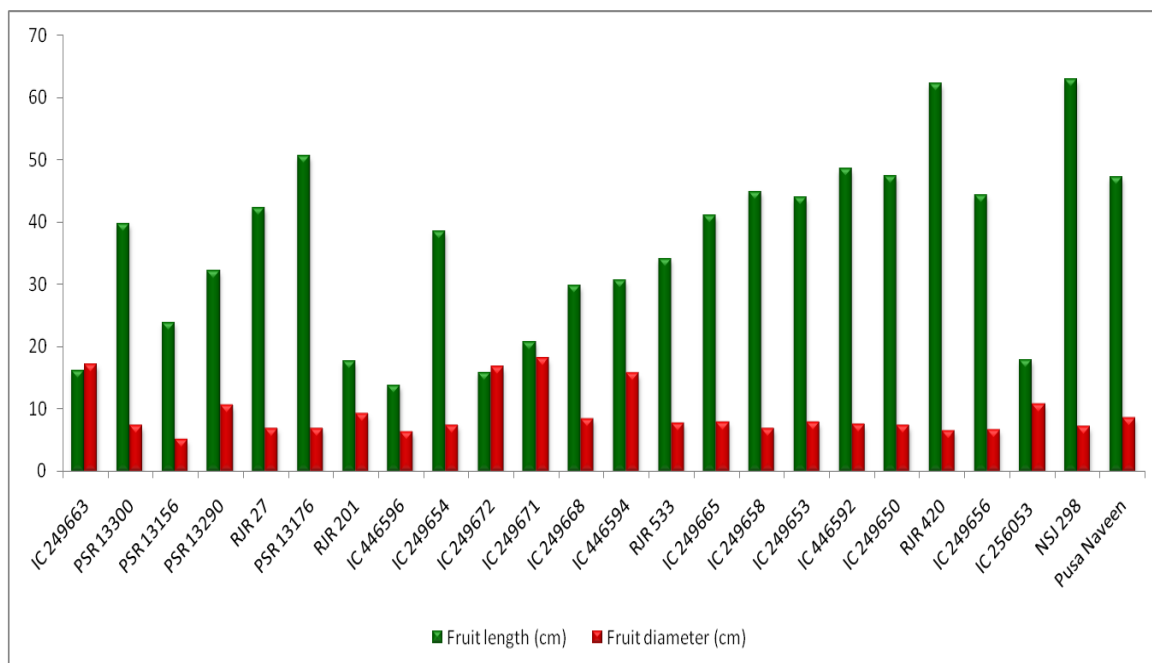


Fig 8: Mean performance of fruit length and fruit diameter of different genotypes of bottle gourd

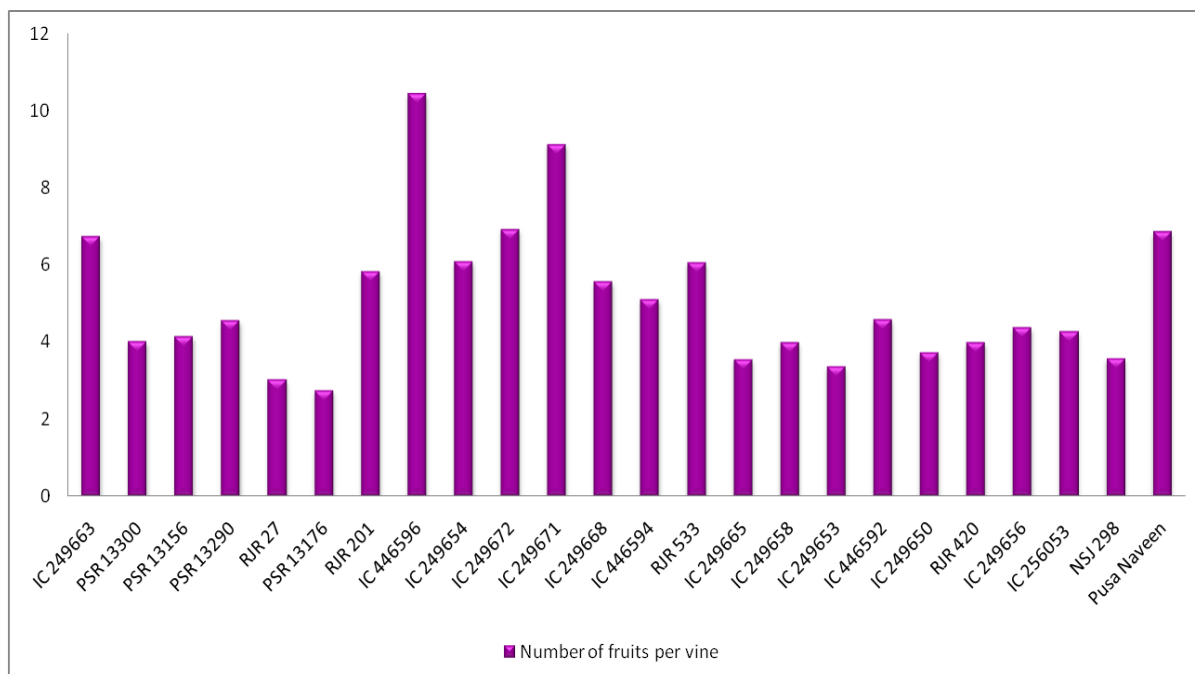


Fig 9: Mean performance of number of fruits per vine of different genotypes of bottle gourd

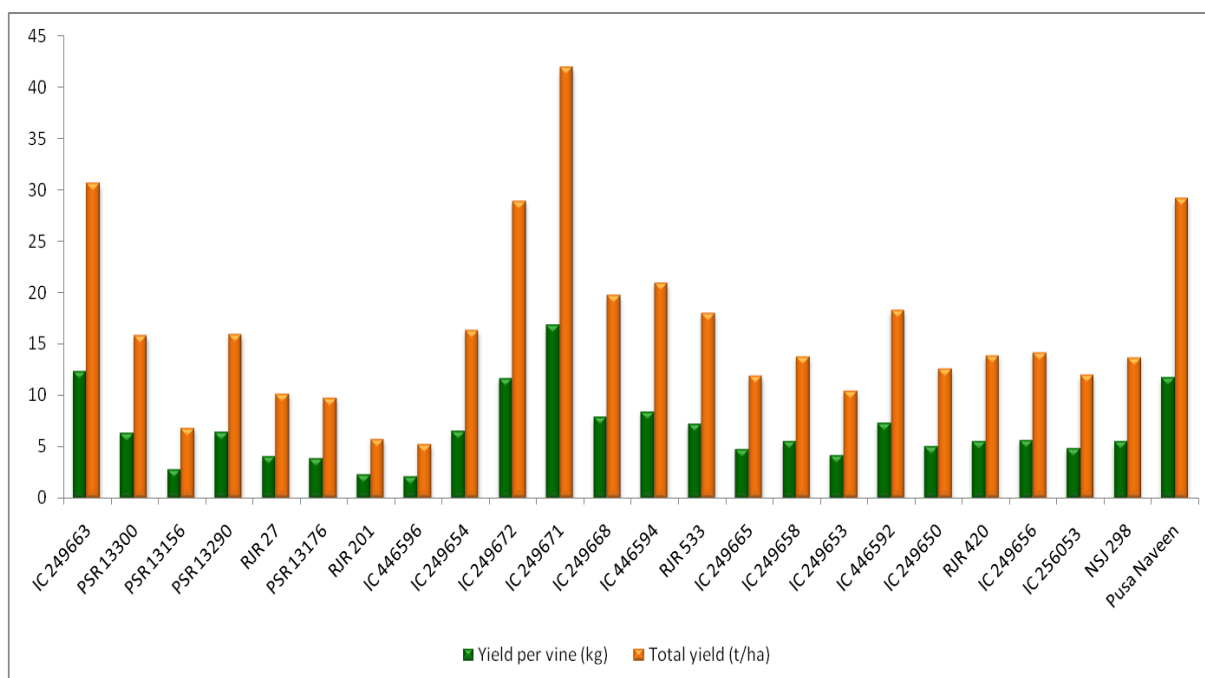


Fig 10: Mean performance of yield per vine and total yield of different genotypes of bottle gourd

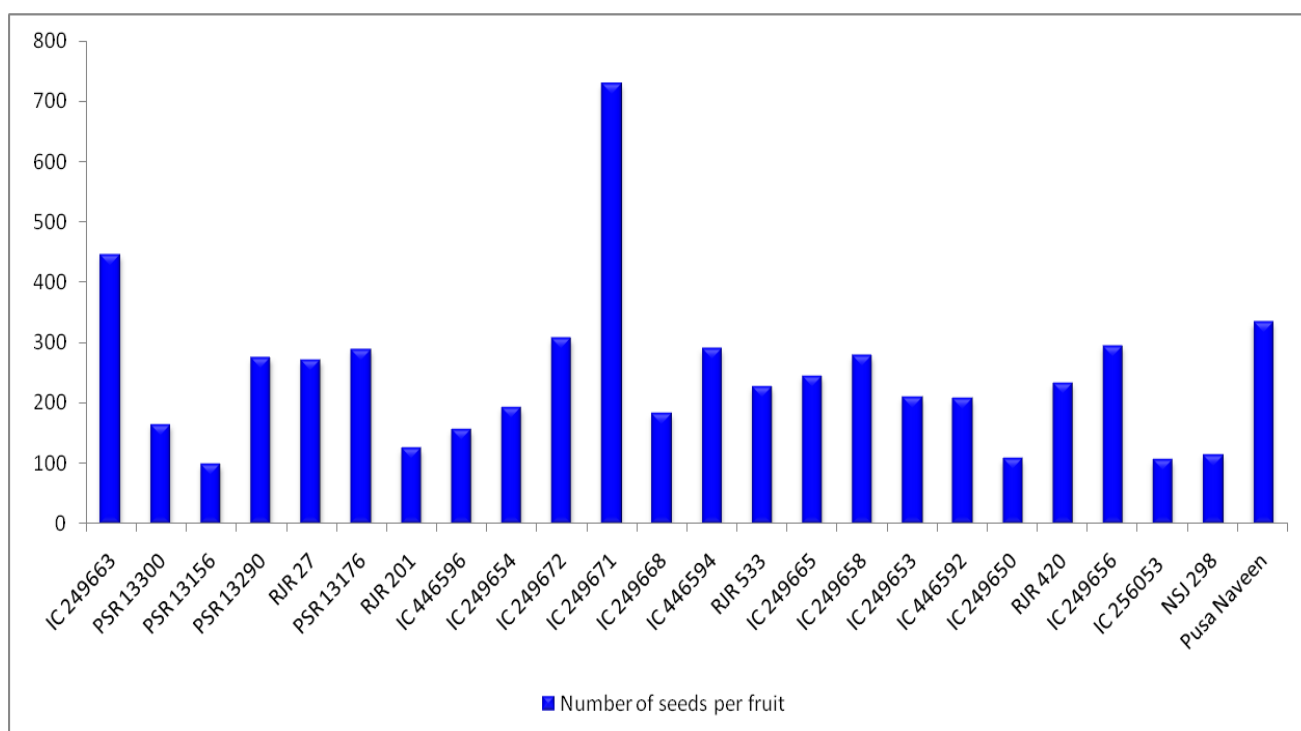


Fig 11: Mean performance of number of seeds per fruit of different genotypes of bottle gourd

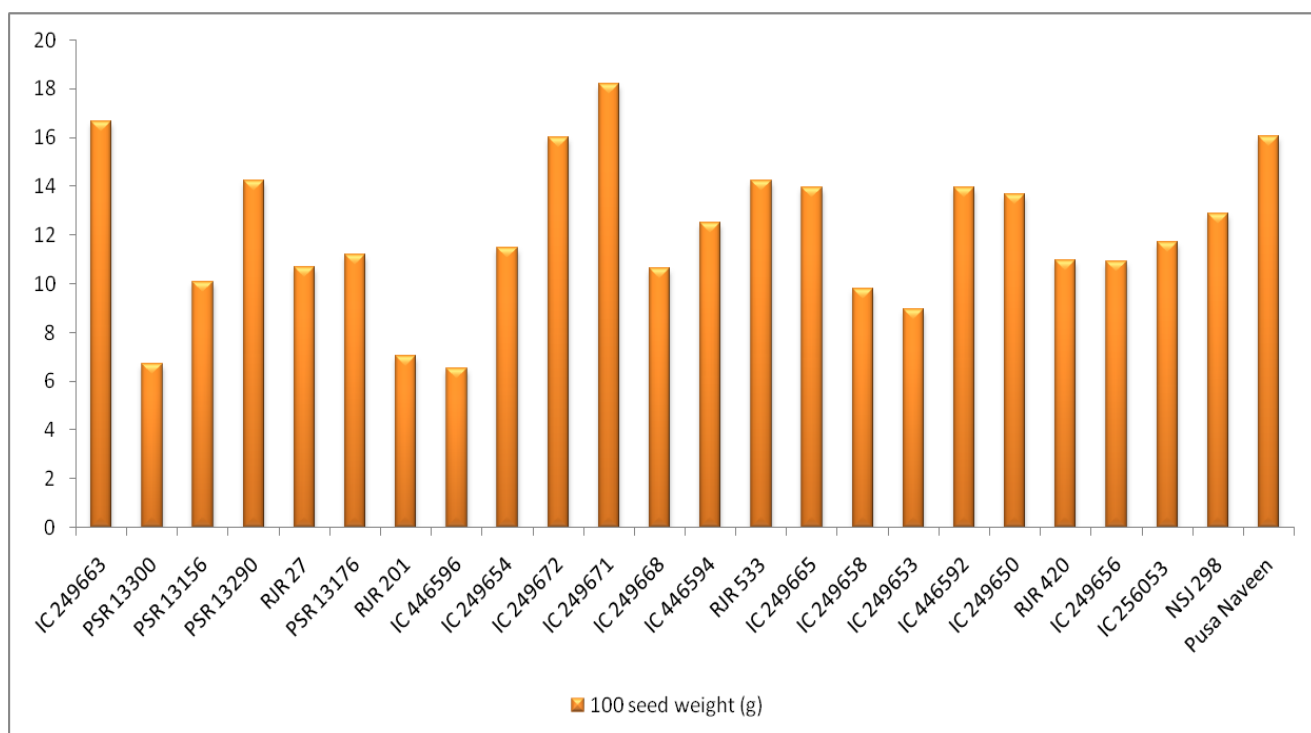


Fig 12: Mean performance of 100 seed weight of different genotypes of bottle gourd

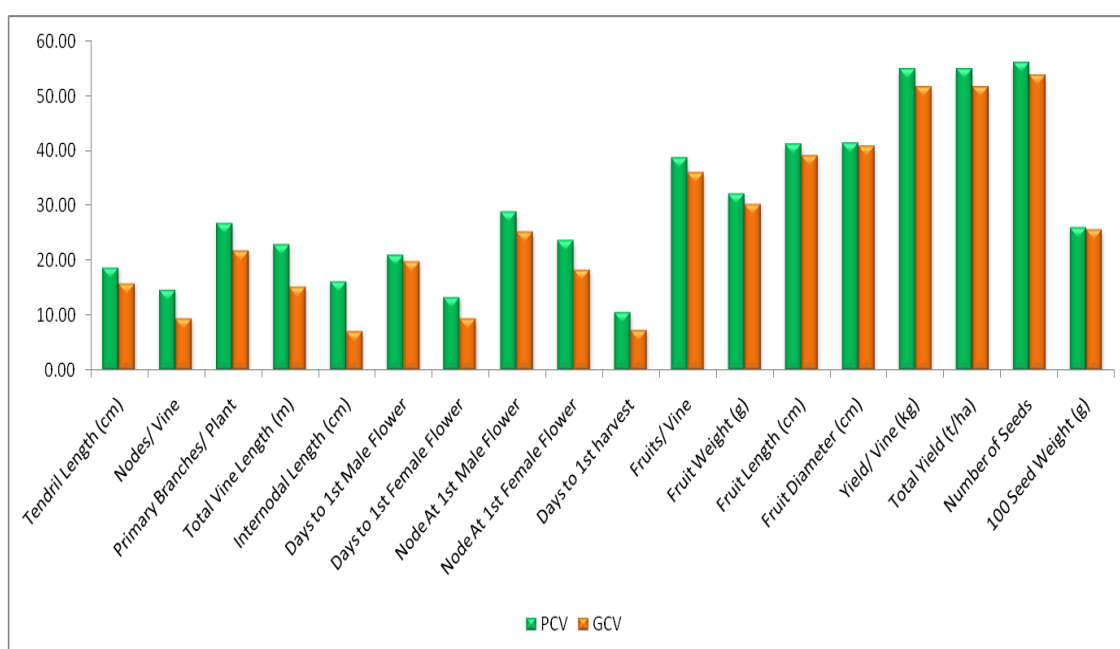


Fig 13: Phenotypic and genotypic coefficient of variation for different characters of bottle gourd

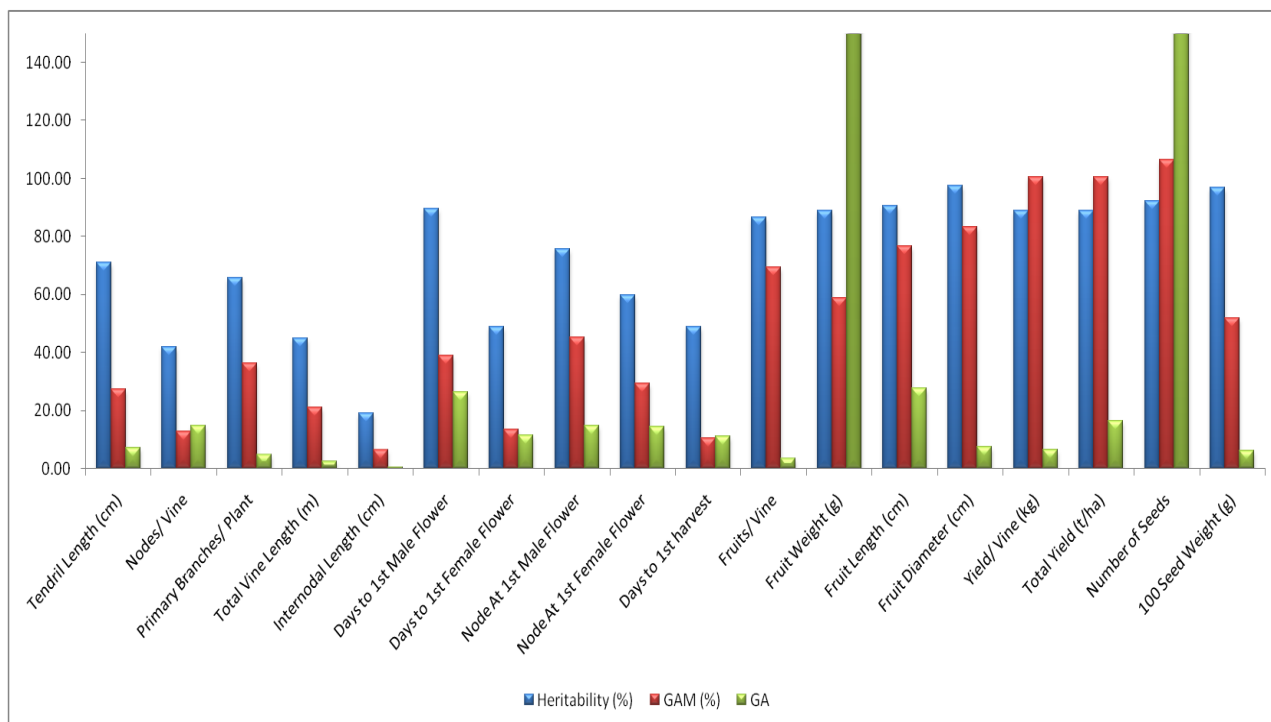


Fig 14: Heritability, genetic advance and genetic advance as per cent of mean for different characters of bottle gourd



**Plate 4: Phenotypic variation in fruits of bottle gourd
genotypes**

**Plate 5: Phenotypic variation in fruits of bottle gourd
genotypes**



**Fig 17: Mean inter and intra cluster distances of bottle
gourd genotypes**

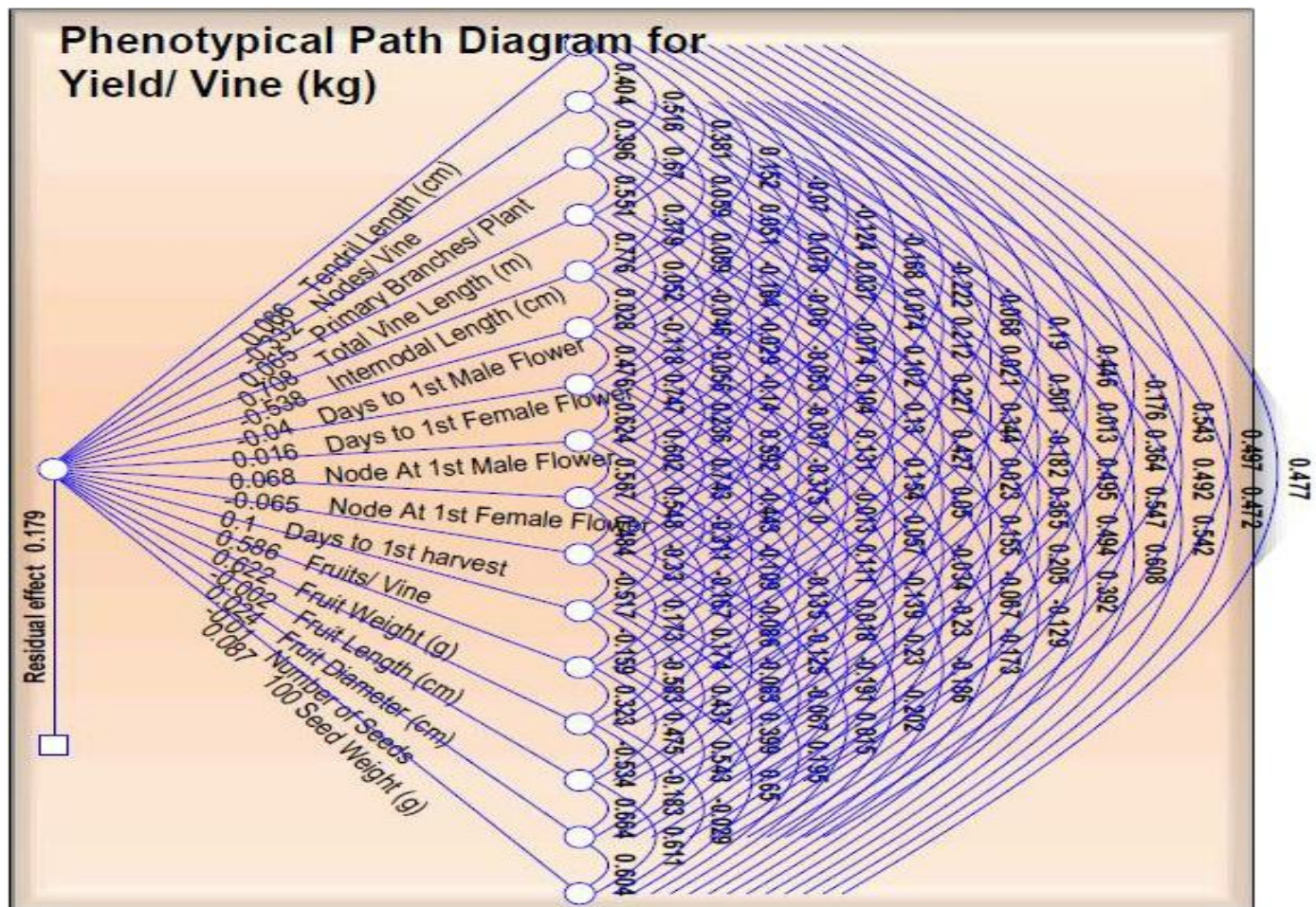


Fig 15: Phenotypic path diagram representing direct and indirect effects for fruit yield per vine of bottle gourd.

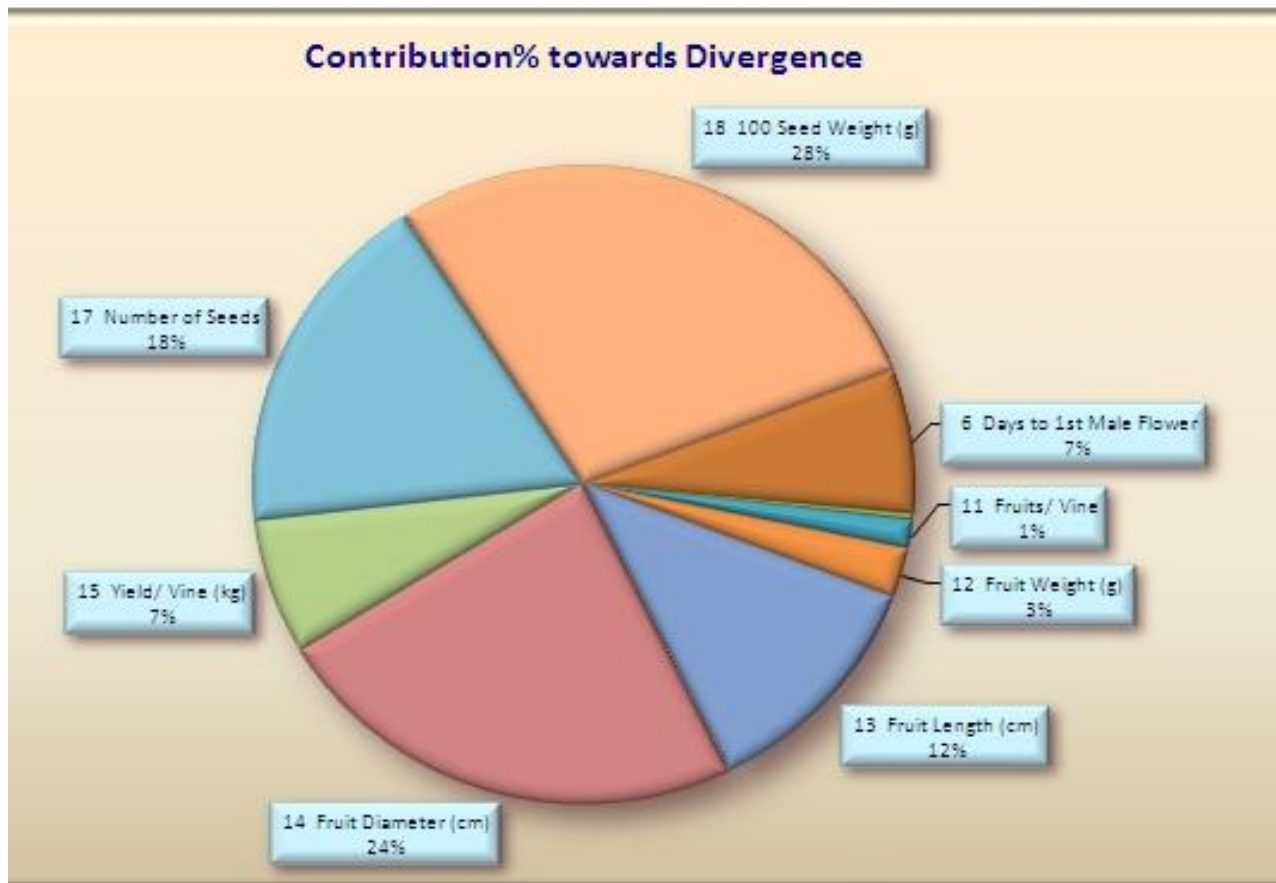


Fig 18: Relative contribution of different characters to genetic divergence in bottle gourd

Plate 1: General view of experimental plot



Table 2: Analysis of variance for the various characters in bottle gourd genotypes

Sources of variation	Degrees of freedom	Mean sum of Squares																	
		Tendrils Length (cm)	Number of nodes per vine	Number of primary branches	Total vine length (m)	Internodal length (cm)	Days to 1 st male flower appearance	Days to 1 st female flower appearance	Node at which 1 st male flower	Node at which 1 st female flower	Days to first fruit harvest	Number of fruits per vine	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Yield per vine (kg)	Total yield (t/ha)	Number of seeds	100 seed weight (g)
Replications	2	7.13	228.50	7.25	5.43	0.70	43.68	4.12	17.05	73.18	2.53	5.03	22004.58	10.30	0.11	6.99	43.71	454.52	0.35
Genotypes	23	57.98**	539.42**	29.53**	12.73**	3.84**	565.31**	260.99**	223.39*	305.45**	239.21**	10.75**	499284.45*	622.73**	42.25*	36.40**	227.50**	53696.05**	28.92**
Error	46	6.97	170.28	4.37	3.71	1.69	21.27	67.43	21.55	55.63	61.85	0.52	20196.93	20.92	0.37	1.47	9.20	1489.89	0.31

*, ** = significant at 5% and 1% level respectively.

Table 6: Phenotypic correlation matrix among different characters in genotypes of bottle gourd

	TL	NNV	NPBV	TVL	IL	DFM	DFF	NFM	NFF	DFH	NFV	FW	FL	FD	NSF	100 SW	YV
TL	1.0000	0.4045**	0.5165**	0.3813**	0.1515	-0.0698	-0.1237	-0.1676	-0.2220	-0.0678	0.1896	0.4461**	-0.1758	0.5427**	0.4971**	0.4774**	0.5894**
NNV		1.0000	0.3963**	0.6701**	0.0595	0.0513	0.0776	0.0373	0.0735	0.2120	0.0212	0.5014**	0.0130	0.3636**	0.4917**	0.4717**	0.5499**
NPBV			1.0000	0.5507**	0.3791**	0.0586	-0.1638	-0.0597	-0.0740	0.1019	0.2270	0.3437**	-0.1820	0.4946**	0.5469**	0.5420**	0.5604**
TVL				1.0000	0.7759**	0.0516	-0.0463	-0.0288	-0.0534	0.1041	0.1298	0.4275**	0.0231	0.3648**	0.4943**	0.6082**	0.5365**
IL					1.0000	0.0279	-0.1176	-0.0562	-0.1405	-0.0374	0.1312	0.1545	0.0501	0.1547	0.2047	0.3925**	0.2332*
DFM						1.0000	0.4763**	0.7468**	0.2365*	0.5925**	-0.3745**	-0.0130	0.0569	-0.0343	-0.0671	-0.1289	-0.1732
DFF							1.0000	0.6239**	0.6019**	0.7430**	-0.4429**	-0.0004	0.1106	-0.1389	-0.2301	-0.1733	-0.2157
NFM								1.0000	0.5669**	0.5485**	-0.3745**	-0.0130	0.0569	-0.0343	-0.0671	-0.1289	-0.2142
NFF									1.0000	0.4841**	-0.3298**	-0.1669	-0.0861	-0.1248	-0.1910	-0.2019	-0.2993*
DFH										1.0000	-0.5174**	0.1729	0.1739	-0.0628	0.0673	0.0149	-0.0761
NFV											1.0000	-0.1594	-0.5835**	0.4368**	0.3987**	0.1949	0.5100**
FW												1.0000	0.3232**	0.4754**	0.5433**	0.6500**	0.7162**
FL													1.0000	-0.5337**	-0.1828	-0.0293	-0.1822
FD														1.0000	0.6636**	0.6115**	0.7482**
NSF															1.0000	0.6043**	0.7645**
100 SW																1.0000	0.7479**

*Significant at 5 per cent level;

** Significant at 1 per cent level

TL – Tendril length NNV – No. of nodes per vine NPBV – No. of primary branches per vine TVL – Total vine length
appearance

IL – Internodal length

DFM – Days to first male flower

DFF – Days to first female flower appearance
per vine

NFM – Node at which first male flower appears

NFF – Node at which first female flower appears

DFH – Days to first harvest

NFV – No. of fruits

FW – Fruit weight

FL – Fruit length

FD – Fruit diameter

YV – Yield per vine

NSF – No. of seeds per fruit

100 SW – 100 seed weight.

Table 7: Genotypic correlation matrix among different characters in genotypes of bottle gourd

	TL	NNV	NPBV	TVL	IL	DFM	DFF	NFM	NFF	DFH	NFV	FW	FL	FD	NSF	100 SW	YV
TL	1.0000	0.6051**	0.8165**	0.6383**	0.4997**	-0.0325	-0.0517	-0.2043	-0.2854*	0.0923	0.2306	0.4988**	-0.2507*	0.6550**	0.6667**	0.5877**	0.6832**
NNV		1.0000	0.7113**	0.8692**	0.4648**	0.0582	0.0138	-0.0297	0.0492	0.5279**	-0.0433	0.8394**	0.0070	0.5513**	0.7580**	0.7793**	0.8347**
NPBV			1.0000	0.7953**	0.6687**	0.0212	-0.1861	-0.0365	-0.0596	0.1295	0.2470*	0.4552**	-0.2558*	0.6494**	0.7068**	0.6842**	0.6945**
TVL				1.0000	0.8475**	0.1113	-0.1022	-0.0510	-0.1194	0.2462*	0.2026	0.6952**	-0.0464	0.5782**	0.7853**	0.9490**	0.8642**
IL					1.0000	0.1503	-0.1833	-0.0529	-0.2673*	-0.1267	0.4037**	0.3675**	-0.0518	0.4303**	0.5717**	0.9187**	0.6673**
DFM						1.0000	0.6647**	0.8324**	0.3622**	0.8088**	-0.4209**	0.0112	0.0476	-0.0278	-0.0731	-0.1398	-0.1803
DFF							1.0000	0.8242**	0.6938**	0.8756**	-0.7126**	0.0605	0.2225	-0.1808	-0.3521**	-0.2498*	-0.3473**
NFM								1.0000	0.7509**	0.7888**	-0.3951**	-0.1096	-0.1854	0.0413	-0.2166	-0.2442*	-0.2678*
NFF									1.0000	0.6141**	-0.4201**	-0.1841	-0.1060	-0.1333	-0.2157	-0.2776*	-0.3752**
DFH										1.0000	-0.8406**	0.3142**	0.3441**	-0.0417	-0.1143	-0.0011	-0.1415
NFV											1.000	-0.1888	-0.6661**	0.4745**	0.4367**	0.2200	0.4660**
FW												1.0000	0.3330**	0.5031**	0.5927**	0.7111**	0.7418**
FL													1.0000	-0.5643**	-0.1827	-0.0319	-0.2208
FD														1.0000	0.6977**	0.6300**	0.8015**
NSF															1.0000	0.6496**	0.8428**
100 SW																1.0000	0.8182**

*Significant at 5 per cent level; ** Significant at 1 per cent level

TL – Tendril length NNV – No. of nodes per vine NPBV – No. of primary branches per vine TVL – Total vine length

IL – Internodal length DFM – Days to first male flower appearance

DFF – Days to first female flower appearance per vine

NFM – Node at which first male flower appears

NFF – Node at which first female flower appears

DFH – Days to first harvest

NFV – No. of fruits

FW – Fruit weight

FL – Fruit length

FD – Fruit diameter

YV – Yield per vine

NSF – No. of seeds per fruit

100 SW – 100 seed weight.

Cluster	No. of genotypes	Genotypes
I	3	IC 249663, IC 249672, IC 446594
II	1	IC 249671
III	11	PSR 13300, RJR 201, RJR 27, IC 249658, IC 249656, PSR 13176, RJR 420, IC 249653, IC 249668, IC 256053, PSR 13156

Table 11: Clustering pattern of bottle gourd genotypes by Ward’s method

IV	8	PSR 13290, IC 249654, RJR 533, IC 249665, IC 446592, IC 249650, NSJ 298, Pusa Naveen
V	1	IC 446596

Table 4: Mean performance of the characters under study in bottle gourd genotypes

S. No.	Genotype	Tendril Length (cm)	Number of nodes per vine	Number of primary branches	Total vine length (m)	Internodal length (cm)	Days to 1 st male flower	Days to 1 st female flower	Node at 1 st male flower	Node at 1 st female flower	Days to first fruit harvest	Number of fruits per vine	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Yield per vine (kg)	Total yield (t/ha)	Number of seeds per fruit	100 seed weight (g)
1	IC 249663	33.30	130.90	18.66	13.88	10.61	63.16	84.37	35.78	55.91	99.71	6.74	1821.39	16.18	17.10	12.26	30.66	445.53	16.67
2	PSR 13300	23.46	124.74	9.33	8.15	6.72	52.91	87.06	29.91	55.70	103.63	4.01	1575.37	39.78	7.21	6.33	15.82	164.76	6.73
3	PSR 13156	21.73	120.53	15.16	12.84	10.66	89.44	99.06	56.91	77.27	117.08	4.14	648.61	23.90	5.03	2.72	6.82	98.14	10.06
4	PSR 13290	28.80	122.15	15.00	9.98	7.65	55.75	86.78	31.75	63.03	103.63	4.55	1407.52	32.18	10.54	6.37	15.94	275.51	14.23
5	RJR 27	27.41	113.11	11.83	10.25	9.04	67.92	85.60	31.74	46.35	107.19	3.02	1375.51	42.35	6.83	4.05	10.14	271.65	10.70
6	PSR 13176	22.23	109.74	15.16	10.40	9.48	94.72	82.32	37.84	50.27	112.40	2.75	1410.45	50.63	6.83	3.88	9.70	289.07	11.20
7	RJR 201	28.30	96.43	15.83	8.17	7.92	56.61	82.16	26.39	47.44	100.13	5.84	392.29	17.63	9.11	2.28	5.72	124.55	7.03
8	IC 446596	19.03	79.72	8.16	7.69	9.62	50.18	67.78	24.66	41.84	75.42	10.44	197.55	13.75	6.28	2.09	5.22	155.84	6.53
9	IC 249654	22.26	126.18	9.66	10.40	8.25	70.53	92.54	34.33	50.06	111.25	6.10	1063.06	38.56	7.36	6.54	16.36	192.31	11.49
10	IC 249672	26.66	127.62	17.16	13.42	10.55	69.23	79.78	32.97	45.11	108.16	6.93	1656.50	15.85	16.66	11.56	28.91	306.79	16.02

11	IC 249671	36.44	144.73	20.50	16.36	11.34	66.86	80.91	27.50	40.74	102.49	9.13	1841.49	20.76	18.04	16.76	41.91	729.62	18.21
12	IC 249668	30.16	110.71	13.76	11.32	10.24	76.49	95.97	38.01	47.08	107.06	5.57	1412.85	29.82	8.40	7.89	19.72	182.82	10.63
13	IC 446594	24.56	113.45	11.66	10.91	9.58	73.20	86.58	44.27	54.20	105.76	5.11	1643.97	30.70	15.58	8.39	20.98	290.29	12.50
14	RJR 533	21.08	106.69	9.33	11.03	10.13	52.48	72.37	22.06	43.35	90.46	6.07	1180.81	34.19	7.69	7.21	18.02	227.29	14.25
15	IC 249665	28.73	126.19	12.16	13.05	10.35	57.91	90.22	25.87	53.61	106.94	3.56	1341.98	41.16	7.85	4.74	11.86	244.58	13.97
16	IC 249658	22.75	122.69	11.33	12.98	10.04	69.51	88.75	31.00	52.15	104.86	4.00	1375.49	44.94	6.84	5.49	13.73	278.39	9.78
17	IC 249653	24.50	109.44	10.50	9.12	8.53	93.05	96.90	44.36	44.46	111.33	3.36	1225.56	43.97	7.77	4.17	10.43	209.93	8.95
18	IC 446592	23.43	115.15	13.16	11.68	9.99	71.94	95.37	33.02	50.27	109.57	4.58	1605.92	48.56	7.41	7.30	18.26	207.66	13.95

Table 4 (Contd...)

S. No.	Genotype	Tendrill Length (cm)	Number of nodes per vine	Number of primary branches	Total vine length (m)	Internodal length (cm)	Days to 1 st male flower	Days to 1 st female flower	Node at 1 st male flower	Node at 1 st female flower	Days to first fruit harvest	Number of fruits per vine	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Yield per vine (kg)	Total yield (t/ha)	Number of seeds	100 seed weight (g)
19	IC 249650	21.50	120.92	13.16	12.54	10.47	59.00	82.93	29.86	42.90	104.72	3.73	1339.11	47.50	7.22	5.03	12.59	107.45	13.68
20	RJR 420	28.49	119.91	13.50	12.71	10.61	80.27	86.98	32.06	52.30	109.96	3.99	1395.95	62.30	6.52	5.55	13.88	233.49	10.94
21	IC 249656	23.40	116.27	13.33	10.71	9.23	58.93	89.17	29.70	63.57	111.46	4.37	1308.54	44.41	6.60	5.65	14.13	294.87	10.92
22	IC 256053	30.53	110.99	10.83	10.44	9.75	87.16	93.59	40.15	49.45	111.27	4.27	1116.76	17.88	10.76	4.78	11.96	105.50	11.71
23	NSJ 298	25.66	95.72	12.00	10.20	10.58	56.11	94.33	29.26	46.68	103.42	3.57	1536.45	62.97	7.05	5.48	13.71	114.48	12.89
24	Pusa Naveen	32.50	129.56	17.50	13.43	10.44	48.05	59.66	12.66	21.80	88.89	6.86	1705.53	47.28	8.50	11.67	29.19	334.16	16.07
SEm ±		1.52	7.53	1.20	1.11	0.75	2.66	4.74	2.68	4.30	4.54	0.41	82.05	2.64	0.35	0.70	1.75	22.28	0.32

CV (%)	10.10	11.21	15.73	17.00	13.45	6.82	9.56	14.24	14.97	7.53	14.14	10.80	12.65	6.69	18.39	18.39	15.74	4.63
CD (P=0.05)	4.33	21.44	3.43	3.16	2.14	7.57	13.49	7.63	12.25	12.92	1.18	233.57	7.51	1.00	1.99	4.98	63.43	0.91

Table 8: Phenotypic path coefficient analysis among different characters in genotypes of bottle gourd

	TL	NNV	NPBV	TVL	IL	DFM	DFF	NFM	NFF	DFH	NFV	FW	FL	FD	NSF	100 SW	YV
TL	<u>0.0661</u>	0.0267	0.0341	0.0252	0.0100	-0.0046	-0.0082	-0.0111	-0.0147	-0.0045	0.0125	0.0295	-0.0116	0.0359	0.0328	0.0315	0.5894
NNV	-0.1345	<u>-0.3324</u>	-0.1317	-0.2227	-0.0198	-0.0171	-0.0258	-0.0124	-0.0244	-0.0705	-0.0071	-0.1667	-0.0043	-0.1209	-0.1635	-0.1568	0.5499
NPBV	0.0338	0.0259	<u>0.0654</u>	0.0360	0.0248	0.0038	-0.0107	-0.0039	-0.0048	0.0067	0.0148	0.0225	-0.0119	0.0323	0.0358	0.0354	0.5604
TVL	0.2700	0.4746	0.3900	<u>0.7082</u>	0.5495	0.0365	-0.0328	-0.0204	-0.0378	0.0738	0.0919	0.3027	0.0164	0.2584	0.3500	0.4307	0.5365
IL	-0.0816	-0.0320	-0.2041	-0.4178	<u>-0.5384</u>	-0.0150	0.0633	0.0303	0.0756	0.0201	-0.0706	-0.0832	-0.0270	-0.0833	-0.1102	-0.2113	0.2332
DFM	0.0028	-0.0021	-0.0024	-0.0021	-0.0011	<u>-0.0405</u>	-0.0193	-0.0302	-0.0095	-0.0240	0.0152	0.0005	-0.0023	0.0014	0.0027	0.0052	-0.1732
DFF	-0.0020	0.0012	-0.0026	-0.0007	-0.0019	0.0076	<u>0.0160</u>	0.0100	0.0097	0.0119	-0.0071	0.0000	0.0018	-0.0022	-0.0037	-0.0028	-0.2157
NFM	-0.0115	0.0026	-0.0041	-0.0020	-0.0038	0.0511	0.0427	<u>0.0684</u>	0.0388	0.0375	-0.0212	-0.0075	-0.0092	0.0012	-0.0157	-0.0127	-0.2142
NFF	0.0144	-0.0048	0.0048	0.0035	0.0091	-0.0153	-0.0391	-0.0368	<u>-0.0650</u>	-0.0315	0.0214	0.0108	0.0056	0.0081	0.0124	0.0131	-0.2993
DFH	-0.0068	0.0212	0.0102	0.0104	-0.0037	0.0594	0.0744	0.0549	0.0485	<u>0.1002</u>	-0.0518	0.0173	0.0174	-0.0063	-0.0067	0.0015	-0.0761
NFV	0.1112	0.0124	0.1331	0.0761	0.0769	-0.2196	-0.2597	-0.1821	-0.1934	-0.3034	<u>0.5864</u>	-0.0935	-0.3421	0.2561	0.2338	0.1143	0.5100
FW	0.2774	0.3118	0.2137	0.2658	0.0961	-0.0081	-0.0003	-0.0678	-0.1038	0.1075	-0.0991	<u>0.6219</u>	0.2010	0.2956	0.3379	0.4042	0.7162

FL	0.0004	0.0000	0.0004	0.0000	-0.0001	-0.0001	-0.0002	0.0003	0.0002	-0.0004	0.0012	-0.0007	<u>-0.0021</u>	0.0011	0.0004	0.0001	-0.1822
FD	0.0133	0.0089	0.0121	0.0089	0.0038	-0.0008	-0.0034	0.0004	-0.0031	-0.0015	0.0107	0.0116	-0.0131	0.0245	0.0163	0.0150	0.7482
NSF	-0.0050	-0.0050	-0.0055	-0.0050	-0.0021	0.0007	0.0023	0.0023	0.0019	0.0007	-0.0040	-0.0055	0.0018	-0.0067	<u>-0.0101</u>	-0.0061	0.7645
100 SW	0.0413	0.0408	0.0469	0.0526	0.0340	-0.0112	-0.0150	-0.0161	-0.0175	0.0013	0.0169	0.0562	-0.0025	0.0529	0.0523	<u>0.0865</u>	0.7479

Phenotypic Residual effect = 0.1787; Diagonal (under lined) values indicate direct effects, P: Phenotypic

TL – Tendril length NNV – No. of nodes per vine NPBV – No. of primary branches per vine TVL – Total vine length

IL – Internodal length

DFM – Days to first male flower appearance

DFF – Days to first female flower appearance per vine

NFM – Node at which first male flower appears

NFF – Node at which first female flower appears

DFH – Days to first harvest

NFV – No. of fruits

FW – Fruit weight

FL – Fruit length

FD – Fruit diameter

YV – Yield per vine

NSF – No. of seeds per fruit

100 SW – 100 seed weight.

Table 9: Genotypic path coefficient analysis among different characters in genotypes of bottle gourd

	TL	NNV	NPBV	TVL	IL	DFM	DFF	NFM	NFF	DFH	NFV	FW	FL	FD	NSF	100 SW	YV
TL	0.0061	0.0037	0.0050	0.0039	0.0030	-0.0002	-0.0003	-0.0012	-0.0017	0.0006	0.0014	0.0030	-0.0015	0.0040	0.0041	0.0036	0.6832
NNV	-1.0357	-1.7114	-1.2174	-1.4876	-0.7955	-0.0997	-0.0236	0.0508	-0.0843	-0.9036	0.0742	-1.4366	-0.0120	-0.9436	-1.2973	-1.3338	0.8347
NPBV	0.0375	0.0327	0.0460	0.0366	0.0307	0.0010	-0.0086	-0.0017	-0.0027	0.0060	0.0114	0.0209	-0.0118	0.0299	0.0325	0.0315	0.6945
TVL	2.1232	2.8912	2.6542	3.3262	2.8188	0.3703	-0.3398	-0.1698	-0.3971	0.8188	0.6739	2.3123	-0.1543	1.9233	2.6122	3.1565	0.8642
IL	-0.6804	-0.6329	-0.9105	-1.1539	-1.3616	-0.2047	0.2496	0.0720	0.3639	0.1725	-0.5497	-0.5004	0.0706	-0.5859	-0.7785	-1.2509	0.6673
DFM	-0.0027	0.0048	0.0018	0.0093	0.0125	0.0831	0.0553	0.0692	0.0301	0.0673	-0.0350	0.0009	0.0040	-0.0023	-0.0061	-0.0116	-0.1803
DFF	0.0019	-0.0005	0.0068	0.0037	0.0067	-0.0243	-0.0365	-0.0301	-0.0253	-0.0320	0.0260	-0.0022	-0.0081	0.0066	0.0129	0.0091	-0.3473
NFM	0.0768	0.0112	0.0137	0.0192	0.0199	-0.3130	-0.3099	-0.3760	-0.2823	-0.2965	0.1486	0.0412	0.0697	-0.0155	0.0814	0.0918	-0.2678
NFF	-0.0471	0.0081	-0.0098	-0.0197	-0.0441	0.0597	0.1144	0.1238	0.1649	0.1013	-0.0693	-0.0304	-0.0175	-0.0220	-0.0356	-0.0458	-0.3752
DFH	0.0113	0.0645	0.0158	0.0301	-0.0155	0.0988	0.1070	0.0964	0.0750	0.1222	-0.1027	0.0384	0.0420	-0.0051	-0.0140	-0.0001	-0.1415

NFV	0.1373	-0.0258	0.1470	0.1206	0.2403	-0.2505	-0.4242	-0.2352	-0.2501	-0.5004	<u>0.5953</u>	-0.1124	-0.3956	0.2824	0.2600	0.1310	0.4660
FW	0.4495	0.7564	0.4102	0.6265	0.3312	0.0101	0.0546	-0.0988	-0.1659	0.2832	-0.1702	0.9012	0.3001	0.4534	0.5341	0.6408	0.7418
FL	0.0151	-0.0004	0.0155	0.0028	0.0031	-0.0029	-0.0134	0.0112	0.0064	-0.0208	0.0402	-0.0201	-0.0604	0.0341	0.0110	0.0019	-0.2208
FD	0.1625	0.1368	0.1611	0.1435	0.1068	-0.0069	-0.0449	0.0102	-0.0331	-0.0103	0.1177	0.1248	-0.1400	<u>0.2481</u>	0.1731	0.1563	0.8015
NSF	-0.2908	-0.3306	-0.3083	-0.3425	-0.2494	0.0319	0.1536	0.0945	0.0941	0.0499	-0.1905	-0.2585	0.0797	-0.3043	-0.4361	-0.2833	0.8428
100 SW	-0.2814	-0.3732	-0.3276	-0.4544	-0.4399	0.0669	0.1196	0.1169	0.1329	0.0005	-0.1054	-0.3405	0.0153	-0.3016	-0.3110	-0.4788	0.8182

Genotypic Residual effect=0.0927; Diagonal (under lined) values indicate direct effects; G: Genotypic

TL – Tendril length NNV – No. of nodes per vine NPBV – No. of primary branches per vine TVL – Total vine length

IL – Internodal length

DFM – Days to first male flower appearance

DFF – Days to first female flower appearance per vine

NFM – Node at which first male flower appears

NFF – Node at which first female flower appears

DFH – Days to first harvest

NFV – No. of fruits

FW – Fruit weight

FL – Fruit length

FD – Fruit diameter

YV – Yield per vine

NSF – No. of seeds per fruit

100 SW – 100 seed weight.

Table 3: Variation in morphological features of bottle gourd genotypes

Genotypes	Accession No.	Leaf lobing pattern	Fruit shape
G ₁	IC 249663	Low	Round
G ₂	PSR 13300	Low	Long with crooked neck
G ₃	PSR 13156	Medium	Bottle
G ₄	PSR 13290	High	Oblong
G ₅	RJR 27	High	Long with crooked neck
G ₆	PSR 13176	Low	Long

G ₇	RJR 201	High	Bottle
G ₈	IC 446596	High	Bottle
G ₉	IC 249654	medium	Long
G ₁₀	IC 249672	Medium	Long
G ₁₁	IC 249671	Low	Round
G ₁₂	IC 249668	Medium	Oblong
G ₁₃	IC 446594	High	Long
G ₁₄	RJR 533	High	Long
G ₁₅	IC 249665	High	Long
G ₁₆	IC 249658	High	Long with crooked neck
G ₁₇	IC 249653	High	Long
G ₁₈	IC 446592	High	Long with crooked neck
G ₁₉	IC 249650	High	Long with crooked neck
G ₂₀	RJR 420	Low	Long with crooked neck
G ₂₁	IC 249656	Medium	Long with crooked neck
G ₂₂	IC 256053	High	Oblong
G ₂₃	NSJ 298	Medium	Long with crooked neck

G ₂₄	Pusa Naveen	Medium	Long
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Table 5: Estimation of variability, heritability and genetic advance as percent of mean for different characters in bottle gourd genotypes

Characters	Range		Variance		Coefficient of variation (%)		Heritability h ² (%)	Genetic Advance	Genetic Advance as per cent of mean
	Minimum	Maximum	Phenotypic	Genotypic	PCV	GCV			
Tendril length (cm)	19.03	36.40	23.97	17.00	18.74	15.79	70.93	7.15	27.39
Number of nodes per vine	79.73	144.73	293.33	123.05	14.71	9.53	41.95	14.80	12.72
Number of primary branches per vine	8.17	20.50	12.76	8.39	26.89	21.80	65.72	4.84	36.42
Total vine length (m)	7.70	16.36	6.72	3.01	22.89	15.32	44.79	2.39	21.12
Internodal length (cm)	6.68	11.34	2.49	0.48	16.25	7.11	19.14	0.62	6.41
Days to 1 st male flower appearance	48.06	94.72	202.61	181.35	21.07	19.93	89.50	26.24	38.85
Days to 1 st female flower appearance	59.67	99.07	131.95	64.52	13.37	9.35	48.90	11.57	13.47
Node at which 1 st male appearance	12.66	56.91	88.83	67.28	28.92	25.17	75.74	14.71	45.12
Node at which 1 st female appearance	21.80	77.28	138.90	83.27	23.66	18.32	59.95	14.56	29.22
Days to 1 st harvest	75.43	117.08	120.97	59.12	10.53	7.36	48.87	11.07	10.60
Number of fruits per vine	2.75	10.45	3.93	3.41	38.76	36.09	86.69	3.54	69.23

Fruit weight (g)	197.55	1841.49	179892.77	159695.84	32.23	30.37	88.77	775.63	58.95
Fruit length (cm)	13.75	62.98	221.52	200.60	41.18	39.19	90.56	27.76	76.83
Fruit diameter (cm)	5.03	18.04	14.33	13.96	41.44	40.89	97.39	7.60	83.13
Yield per vine (kg)	2.09	16.77	13.12	11.64	54.90	51.73	88.77	6.62	100.40
Total yield (t/ha)	5.23	41.92	81.97	72.77	54.90	51.73	88.77	16.56	100.40
Number of seeds per fruit	98.15	729.63	18891.94	17402.05	56.06	53.80	92.11	260.81	106.37
100 seed weight (g)	6.54	18.22	9.85	9.54	26.05	25.63	96.83	6.26	51.95

Table 10: Per cent contribution of different characters towards diversity in genotypes of bottle gourd.

S. No.	Character	Times ranked 1st	Per cent contribution
1	Tendril length (cm)	0	0.00
2	Nodes per vine	0	0.00
3	Number of primary branches per vine	0	0.00
4	Total vine length (m)	0	0.00
5	Internodal length (cm)	0	0.00
6	Days to 1 st male flower appearance	20	7.25
7	Days to 1 st female flower appearance	0	0.00
8	Node at which 1 st male flower appeared	0	0.00
9	Node at which 1 st female flower appeared	1	0.36
10	Days to first harvest	0	0.00
11	Number of fruits per vine	4	1.45
12	Fruit weight (g)	7	2.54
13	Fruit length (cm)	33	11.96
14	Fruit diameter (cm)	65	23.55
15	Yield per vine (kg)	19	6.88
16	Number of seeds per fruit	49	17.75
17	100 seed weight (g)	78	28.26

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The pattern of 'literature cited' presented above is in accordance with the 'Guidelines for thesis presentation for 'Dr. Y. S. R. Horticultural University'.

* Original not seen

Appendices



Appendix I

Monthly meteorological data recorded during the period of study

Month and Year	TEMPERATURE (°C)		R.H. (%)		Rain fall (mm)	Rainy days
	Maximum	Minimum	8.00 hrs	14.00 hrs		
April, 2012	36.20	26.96	78.86	47.43	43.0	4
May, 2012	39.41	28.19	78.83	50.12	46.1	5
June, 2012	36.25	26.56	74.60	51.93	69.8	7
July, 2012	30.87	25.90	87.47	72.22	124.6	8
Aug, 2012	31.96	24.90	80.03	66.29	156.3	12
Sept, 2012	31.76	24.96	88.50	66.13	73.4	6
Oct, 2012	32.67	23.64	81.96	59.38	20.2	2