

**GENETIC EVALUATION FOR YIELD AND  
YIELD ATTRIBUTES IN ELITE GENOTYPES  
OF BITTER GOURD  
(*Momordica charantia* L.)**



THESIS SUBMITTED IN PARTIAL FULFILMENT OF  
THE REQUIREMENTS FOR THE DEGREE OF

**Master of Science (Agriculture)**  
in  
**Horticulture**

Supervisor

*Prof. M. M. Syamal*

Submitted by

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**I.D. No. : H-13107**

**2015**

**Enrolment No. : 355587**

*Dedicated to my beloved  
Father  
Late Pitabash Moharana*



*Miss you Bapa.*

*Today*

*Tomorrow*

*Forever.....*

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To,  
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**Through: The Head, Department of Horticulture**

Dear Sir,

I feel great pleasure in forwarding the thesis entitled **“Genetic evaluation for yield and yield attributes in elite genotypes of bitter gourd (*Momordica charantia* L.)”** of **Mr. Durga Prasad Moharana, I.D. No.: H-13107, Enrolment No.: 355587** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science (Agriculture) in Horticulture** from Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi.

I certify that the work has been carried out solely by **Mr. Durga Prasad Moharana** under my supervision and guidance and his findings and data presented herein are genuine and original to the best of my knowledge and belief and no part of the work has been submitted for any other degree or distinction.

**Forwarded:**

Yours faithfully

**M. M. Syamal**  
(Supervisor)

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*Errāre hūmānum est (to err is human).*

*Place: Varanasi*

*Date:*

***Durga Prasad Moharana***

# Contents

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CHAPTER NUMBER	TITLE	PAGE NUMBER
I	INTRODUCTION	1 - 6
II	REVIEW OF LITERATURE	7 - 31
III	MATERIALS AND METHODS	32 - 41
IV	EXPERIMENTAL FINDINGS	42 - 57
V	DISCUSSION	58 - 67
VI	SUMMARY AND CONCLUSION	68 - 70
	BIBLIOGRAPHY	i - ix

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## LIST OF TABLES

---

Table Number	Title	After Page Number
3.1	Weekly meteorological data of Horticulture Unit, BHU, Varanasi (from July 2014 – November 2014)	25
3.2	Physico-chemical characteristics of the soil from experimental site	26
3.3	List of genotypes included in the trial	30
3.4	Skeleton of Analysis of Variance (ANOVA)	
4.1	Analysis of variance for 15 characters in 20 genotypes of bitter gourd	35
4.2	Mean performance of twenty genotypes of bitter gourd	44
4.3	Estimate of variability, heritability and expected genetic advance for 15 characters in bitter gourd	47
4.4	Phenotypic correlation ( $r_p$ ) between yield and yield attributes for fifteen characters of twenty genotypes of bitter gourd	50
4.5	Genotypic correlation ( $r_g$ ) between yield and yield attributes for fifteen characters of twenty genotypes of bitter gourd	53
4.6	Direct and indirect effects of phenotypic path coefficient for 15 characters of 20 genotypes of bitter gourd	55
4.7	Direct and indirect effects of genotypic path coefficient for 15 characters of 20 genotypes of bitter gourd	61
6.1	Superior genotypes based on mean performance for yield per plant and yield attributes	76

## **LIST OF FIGURES**

---

<b>Figure Number</b>	<b>Title</b>
3.1	Layout of the field
4.1	Frequency distribution for yield and yield attributes of bitter gourd
4.2	Diagrammatic representation of different genetic parametres for 15 characters of bitter gourd
4.3	Phenotypic correlation coefficient analysis among 19 characters of bitter gourd
4.4	Genotypic correlation coefficient analysis among 19 characters of bitter gourd
4.5	Phenotypical path diagram for yield per plant and yield attributes of bitter gourd
4.6	Genotypical path diagram for yield per plant and yield attributes of bitter gourd
4.7	General view of fruits of various genotypes of bitter gourd
4.8	Variation among different genotypes of bitter gourd

## ABBREVIATIONS

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%	per cent
/	per
@	at the rate of
C.D.	critical difference
C.V.	coefficient of variation
cm	centimetre
cv.	cultivar
d.f.	degree of freedom
EMS	error mean sum of square
<i>et al.</i>	(et alia) and others
etc.	et cetera
Fig.	figure
g	gram
ha	hectare
Hrs.	hours
i.e.	( <i>Id est.</i> ) that is
IIVR	Indian Institute of Vegetable Research
Kg	kilogram
km	kilometre
m	metre
m <sup>2</sup>	square metre
Max.	maximum
Min.	minimum
mm	millimetre
MSS	mean sum of square
No.	number
NS	non-significant
Morn.	morning
Even.	evening
ppm	parts per million
R.H.	relative humidity
RSS	replication sum of square
S.Em.	standard error of mean
Sl.	serial
Tss	treatment sum of square
TSS	total soluble solids
U.P.	Uttar Pradesh
<i>Viz.</i>	( <i>Videlicet</i> ) namely
°C	degree celsius
°Brix	degree brix
dSm <sup>-1</sup>	deciSiemens per metre
GCV	genotypic coefficient of variation
PCV	phenotypic coefficient of variation

## **INTRODUCTION**

---

Vegetables play an important role in the balanced diet by providing not only energy but also by supplying vital protective nutrients like minerals, antioxidants and vitamins. Consumption in sufficient quantity provides all required essential nutrients and a fair amount of fibres. Vegetables also help in neutralizing the acids produced during digestion of proteins and fatty foods and thus promote digestion and also prevent constipation. Vegetables are an important component of nutritional security and agriculture due to their high productivity, use in diversification, nutritional richness and export potential. Moreover, high economic growth can be achieved by producing more vegetables per unit area which will ultimately boost the socio- economic condition of the farmers. Therefore, it is a must to increase the production and productivity of vegetables to fulfil the need of the hour.

India is blessed with diverse soil and climatic conditions and comprises of several agro-ecological regions. Hence there is an ample opportunity to grow a wide range of vegetable crops in the country. In India, more than 60 cultivated and about 30 less known vegetable crops are grown. Systematic research efforts backed by developmental activities and policies have resulted in development of numerous improved varieties/hybrids and production technologies resulting in phenomenal increase in area, production and productivity of vegetables during the last 6 decades. Increasing population, per capita income, health consciousness, urbanization, and working women are responsible for increasing demand for nutritionally rich foods in the country. High returns, favourable income, elasticity of demand and annual growth rate for domestic demand are also important catalysts for attracting farmers to vegetable cultivation.

According to recommendations given by Indian Council of Medical Research (ICMR), an average adult should consume 300g of vegetables (125g leafy vegetables, 100g root and tuber crops and 75g other vegetables) per day (Thamburaj and Singh, 2001). The regular consumption of vegetables reduces the level of cholesterol,

provides protection against respiratory diseases, intestinal disorders and reduces accumulation of carcinogenic substances in human body.

Remarkable improvement has been made in the recent past in the vegetable production in the country and at present India is the second largest producer of vegetable in the world comprising production of 162.89 million tonnes with an area of 9.4 million hectares and productivity of 17.35 metric tonnes per hectare and stand next only to China in 2013-14 (NHB database, 2015). West Bengal has the highest area and production of 1.38 million hectares and 23.04 million tonnes respectively among all the states in the country. In case of productivity, Tamil Nadu is the leader with 30.0 tonnes per hectare (NHB database, 2015).

Cucurbits possess a special position among different groups of vegetable crops. The term “cucurbits” is coined by Liberty Hyde Bailey for cultivated species of the family cucurbitaceae. There are about 100 genera and 750 species almost equally divided between new and old world tropics in cucurbitaceae (Yamaguchi, 1983). Out of 34 genera with 108 species occurring in India, 38 species are endemic and about another 38 are non-endemic. Wild plant genetic resources of economic importance to the local people and even the international community are often neglected in germplasm expeditions and conservation activities due to lack of documented information on their usefulness. In spite of the introduction of new crops and improved varieties, the role of wild species cannot be ignored especially in the forest and rural areas where many people continue to harvest and consume wild gathered plants as food.

Among various gourds, bitter gourd (*Momordica charantia* L.) well known for its high medicinal values, possesses antioxidant, antimicrobial, antiviral, antihepatotoxic and antiulcerogenic properties. The ethno-medical reports of *M. charantia* indicate that it is used in folkloric medicine for treatment of various ulcers, diabetes, and infections. While the root decoctions have abortifacient properties, leaf and stem decoctions are used in treatment of dysentery, rheumatism, and gout. In addition, juice of *M. charantia* drawn directly from fruit traditionally has been used for medicinal purposes world-wide. Likewise, the extracted juice from leaf, fruit and even whole plant are routinely used for treatment of wounds, infections, parasites (e.g., worms), measles, hepatitis, and fevers. Bitter gourd extracts traditionally used as

vegetable insulin possess hypoglycemic, antioxidative, and antidiabetic agents that are useful in the treatment of diabetes (Behera *et al.*, 2010).

It can fit well both in irrigated as well as in rainfed cropping systems and is one of the most nutritious cucurbits (Gopalan *et al.* 1982, Yuwai *et al.* 1991, Anuradha and Prakash, 1989 and Jaiswal *et al.* 1990) rich in minerals and vitamins.

In terms of nutritive value, bitter gourd ranks first among cucurbits, the most important nutritional contributions being protein, fat, minerals, fibre, especially iron, phosphorus, calcium and ascorbic acid. The fruits contain two alkaloids, *viz.* momordicin and cucurbitacin. The former is more specific to bitter gourd, while the later occurs in other genera of cucurbitaceae (Anon., 1962). Momordicin is the momordicosides, glycosides of tetracyclic triterpenoides with cucurbitane skeleton (Chandravandana and Subash Chandra, 1990).

The genus *Momordica* belongs to subtribe *Thladianthinae*, tribe *Joliffieae*, subfamily *Cucurbitoideae* of the family *Cucurbitaceae* (Jeffrey, 1980). The genus *Momordica* has 45 species domesticated in Asia and Africa (Robinson and Decker-Walters, 1997). The genus *Momordica* has only six valid species in India, which can be grouped under two groups *M. charantia* L. and *M. balsamina* L. representing the monoecious group and *M. dioica* Roxb., *M. sahyadrica* Joseph & Antony, *M. Cochinchinensis* (Lour.) Spreng., and *M. subangulata* Blume representing the dioecious group (Behera *et al.*, 2010).

Indian bitter gourd is classified into two botanical varieties based on fruit size, shape, colour, and surface texture: (1) *M. Charantia* var. *charantia* has large fusiform fruits, which do not taper at both ends, and possess numerous triangular tubercles giving the appearance of a "crocodile's back"; (2) *M. charantia* var. *muricata* (Wild), which develops small and round fruits with tubercles, more or less tapering at each end (Chakravarthy, 1990). Both varieties are widely cultivated throughout tropical and subtropical regions of India (Behera *et al.*, 2010).

The plants are monoecious annuals with medium size vines. Staminate flowers are small, yellow and borne on long slender pedicels. The pistillate flowers are solitary, have small pedicel and are easily distinguishable by oblong to long distinct green colour ovary. Leaves are segmented and have more length than width in the outline. There are five calyces and five corollas. Filaments are three, two are bicour

and one is unilocular. There are three short styles terminated by three bilobed or divided stigma. Anthesis and dehiscence occur early in the morning (Ram, 2005). The somatic chromosome number of bitter gourd is  $2n=2x=22$ . The length of chromosome ranges from 1-2 $\mu$ m. Six chromosome pairs are median (centromere in middle of chromosomes), three submedian (centromere between mid point and terminal end of chromosomes), and two subterminal (centromere near terminal end of chromosome) (Verghese, 1970).

Among the traditional vegetables bitter gourd occupied an important position in export trade. The fruits are used as vegetable after cooking in many ways as fried, stuffed, dried and pickled. The fruits, young shoots and flowers are used for flavourings, the leaves as green and the pulpy arils as a sweet (Morton, 1967). A substance with clinical properties of insulin has been isolated from this species (Baldwa *et al.*, 1977).

The old cultivars of bitter gourd were primarily selected by farmers. Therefore, the adopted varieties in various regions differ in fruiting characters like colour, shape and size. Besides the variation in fruit characteristics, appreciable amount of variation in crop duration, vegetative parts, capability in growing in hot summer to frost free winter of sub-tropical regions, etc. are also present in the genotypes distributed throughout India.

The productivity of the crop in India is very low because of the non availability of high yielding open pollinated and hybrid varieties in spite of a wide range of variability available in this crop for different agronomic and fruit yield characters. Since long years back, bitter gourd for its cross pollinated nature has resulted in a large amount of variation for many economically important traits. In our country, huge range of variability is available, in the landraces or cultivars, in terms of qualitative as well as quantitative characters of bitter gourd but less attention has been given for the genetic improvement of this crop. Germplasm is a prerequisite for any breeding programme which serve as variable source material. Progress in any breeding programme depends upon the magnitude of useful variability present in the population and the extent to which the desirable characters are heritable. Study of variability, heritability and genetic advance in the germplasm will help to ascertain the real potential value of the genotypes. The greater genetic diversity in population,

provide more genetic potentiality and thereby wider scope for the improvement of the crop. The main objective is to develop high yielding varieties with greater fruit number and weight, uniform thick cylindrical fruits free from bitterness, high female: male sex ratio, earliness and resistance to fruit fly infestation.

Depending on genetic diversity and variability present in base population *viz.*, character association, cause and effect relationship, heritability and genetic advance, breeders can make an effective selection in a breeding programme. Genetic variability increases the genetic potentiality and wider scope for improvement in the genotypes. Heritability and genetic advance help in determining the influence of environment in expression of the characters. To explore the purpose of improvement by selection, it is essential to study first the extent of genetic variability and heritability along with genetic advance. Yield is a complex character influenced by several genetic factors interacting with environment and requires better insight to be given for better selection.

Path coefficient analysis as suggested by (Wright, 1921) on the other hand gives a clear picture about cause and effect as it splits the correlation into the estimates of direct and indirect contribution of each character towards yield.

Keeping in view the above mentioned aspects, the present investigation, **“Genetic evaluation for yield and yield attributes in elite genotypes of bitter gourd (*Momordica charantia* L.)”** has been undertaken in order to achieve the following objectives:

1. To estimate the extent of variability for yield and yield attributes in given the set of genotypes.
2. To estimate the extent of phenotypic and genotypic correlation between the yield and yield related characters.
3. To estimate the direct and indirect effects of different yield traits on yield per plant through path coefficient analysis.
4. To identify some superior genotypes for high yield.



## REVIEW OF LITERATURE

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The review of literature cited in this chapter is related to the present investigation entitled “**Genetic evaluation for yield and yield attributes in elite genotypes of bitter gourd (*Momordica charantia* L.)**”. The success of any breeding programme relies on the quantum of genetic variability available for exploitation. The information on the variation in the available genetic materials and the factor exclusively affecting those traits has significant importance for the possible improvement of a crop. Study of genetic variability, correlation, path coefficient analysis is of great interest for the plant breeders as they play a vital role in forming a successful breeding programme. The major objective of plant breeding programme is to develop methodology to predict more precisely and realize the optimum level of variability and genetic gain for desired characters.

Being a cross pollinated crop, the selection breeding is most important technique for improvement of bitter gourd. A brief review of information available on the above aspects under study in bitter gourd has been grouped into the following heads:

- 2.1 Genetic Variability
- 2.2 Heritability and Genetic Advance
- 2.3 Correlation Coefficient
- 2.4 Path coefficient Analysis

### **2.1. Genetic Variability**

Genetic variability is the basis for rational plant breeding. The objective of plant breeder is either to select from a natural population or from one generated by him for one or few desirable characters.

The variability exploited in plant breeding programme is derived from the naturally occurring variants and the wild relative of crops as well as artificially

developed strains and genetic stocks by human efforts. Genetic variability is the raw material over which selection acts to evolve superior genotype or variety in plant breeding programme. Numerous experiments have been conducted to determine the genetic variability for different agronomic and qualitative characters in almost all the crop plants.

Raja *et al.* (2007) conducted an experiment using forty-six genotypes of bitter gourd collected from diversified areas of the country assessed under zero irrigation condition for mean, genetic variability, heritability and genetic advance in respect of fourteen quantitative characters. The genotype MCC-23 was recorded with the highest number of primary branches per plant, fruit yield per plot and fruit weight. The genotypic and phenotypic coefficient of variation for different characters ranged from 6.375 to 37.251 and 8.373 to 38.630 respectively. The highest PCV and GCV were observed for number of female flowers per plant followed by fruit weight and number of primary branches per plant indicating the high extent of variability.

Devmore and Dhonukshe (2007) demonstrated that the genotype Konkan Tara took less period for days to first flowering of both male and female flower. It had lower nodal position for first male flower with higher fruit yield per vine. The genotype Priya recorded minimum nodal position of first female flower. There was a wide range of variation existed among the genotypes for different floral biological components in bitter gourd.

Sanwal *et al.* (2007) observed that the phenotypic coefficient of variation (PCV) were individually higher than their corresponding genotypic coefficient of variation (GCV) in bittergourd.

Agasimani *et al.* (2008) evaluated twelve genotypes of bitter gourd and observed that the genotypic variation for fruit yield, number of fruits per vine and fruit length was significant for all the three traits. Mean square due to environment was significant for fruit yield and for pooled deviation it was non-significant.

Chandraprakash (2008) studied genetic variability, correlation and path coefficient analysis for fruit yield and yield contributing character in 44 germplasms of ash gourd. The studies revealed variances for all eight characters. High heritability was observed for fruit yield per plant. Genotypic coefficient of correlation was found higher than phenotypic. Fruit weight, fruit diameter, number of fruits per plant and fruit length exhibited positive correlation with yield.

Yadav *et al.* (2008) found that maximum vine length was recorded in IC-85635A followed by MC-84, JMC-4, CO-1 and lowest in TZA. Maximum number of primary branches per vine were noted in IC-85639 (37.67) followed by MC-84, improved Jaunpuri and S-17 whereas lowest number of primary branches per vine was recorded in DVBT-G-5. Maximum numbers of days were recorded for first appearance of male flower in IC-85612, Pusa Do Mausami, VRBT-14 and minimum days in MC-84, TZA1, JMC-22 and S-17. Maximum days were recorded to first appearance of female flower in CO-1 followed by Pusa Do Mausami, Preethi and minimum days in TZAI, VRBT-6-9, JMC-22 and Gy-I. Maximum fruit yield per vine was recorded in MC-84 followed by S-17, VRBT-6-4 and NDBT-15. The lower fruit yield per vine was recorded in CO-1, TZA, TZA1 and DVBT-G-5 of bitter gourd.

Singh *et al.* (2008) concluded that the genotypes exhibited variation in days to anthesis of first pistillate flower with range of 39 days for (DAA-GL-07) to 56 for (DRA-01), likewise the number of node to first male flower ranged from 7.20 to 13.83, number of node bearing first female flower ranged from 12.07 to 22.38, length of fruit ranged from 6.25 to 21.25cm, fruit breadth ranged from 4.30 to 8.75cm, the number of fruits per plant (7.16-29.25) in bitter gourd.

Kumar *et al.* (2008) showed Pant Karela-2 gave the good performance for ten characters and occupied first place among all the cultivars under naturally ventilated poly house conditions in bitter gourd.

Dey *et al.* (2009) recorded high phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) for characters like average fruit weight (g), average fruit diameter (cm), average flesh thickness (cm) and fruit yield per plant (g) in bitter gourd. Phenotypic coefficient of variation was higher than genotypic

coefficient of variation for all the characters studied indicating influence of environment in the expression of characters.

Pandit *et al.* (2009) observed considerable variability in all the traits except fruits per plant. The moderate genotypic coefficient of variation and genetic advance in fruit length and fruit weight indicate the probable likelihood of additive gene action. Promising inbreds for traits like fruit yield per plant were BCBG-7, BCBG-17, BCBG-19 and BCBG-33. The correlation between both genotypes and phenotypes indicate the overriding importance of fruit length and fruit width in determining the average fruit weight, which in turn adequately describes the increase in fruit yield per plant in bottle gourd.

Pandey *et al.* (2009) found that high phenotypic and genotypic coefficient of variation was observed for fruit weight and yield per plant in snap melon.

Yadav *et al.* (2009) studied genetic variability, heritability and genetic advance for different characters in 20 cucumber genotypes. The study indicated the existence of considerable amount of genetic variability for all the traits except cavity of fruit at edible stage. The maximum phenotypic and genotypic coefficient (PCV and GCV) were observed for number of days to first pistillate flower anthesis. High estimates of heritability, genotypic coefficient of variation (GCV) and genetic advance were observed.

Devmore *et al.* (2010) suggested that based on the nature and magnitude of genetic variability, heritability accompanied with genetic advance as percentage of mean, fruit length, vine length, fruit number per vine, days to first fruit harvest, node number per vine, primary branches per vine would offer scope for selection in breeding for high fruit yield in bitter gourd.

Nalawade *et al.* (2011) revealed that variety Priya gave best result of growth in terms of germination percentage, length of vine and number of leaves per plant also the yield in terms of yield per vine, per plot and yield per hectare in bitter gourd.

Nalawade *et al.* (2011) observed that Priya gave best result of flowering in terms of nodal position of first female flower, days to appearance of first female flower, number of female flower, sex ratio of flowers and fruiting parameters like weight of fruit, number of fruits per vine in bitter gourd.

Pornsuriya *et al.* (2011) showed high phenotypic coefficient of variation in fruit weight and seeds per fruit and low variation in several traits like petiole length, petal width of both staminate and pistillate flower, fruit width, fruit length and fruit petiole length in bitter gourd.

Khule *et al.* (2011) reported that high magnitude of genotypic and phenotypic variance were observed for all the characters *viz.*, days to appearance of first male flower, days to appearance of first female flower, node number at which first female flower appeared, number of fruits per plant, fruit weight, fruit length, fruit diameter, number of seeds per fruit, 100 seed weight, and marketable fruit yield per plant in sponge gourd.

Singh *et al.* (2012) found maximum phenotypic coefficient of variation in number of fruits per plant in bitter gourd.

Patil and Dhanwate (2012) reported that variety Kokan Tara had the maximum number of leaves, leaf area and number of internodes, while MC-84 variety found to be beneficial with respect to number of branches and internodal length. However, Hirkani variety produced maximum stem diameter in bitter gourd.

Aruna and Swaminathan (2012) found that variety 09-BIGHYB-4 had earlier flowering (78 days) followed by 09-BIGHYB-7 (80 days) and Pusa Do Mausumi (80 days) which were at par. The fruit length was found to be maximum in 09-BIGHYB-7, while increased fruit weight was recorded in MC-84. Number of fruits per plot was high in the entry 09-BIGHYB-4. The MC-84 recorded increased fruit weight, highest fruit yield per plot and total yield per hectare.

Rai *et al.* (2012) observed that phenotypic variance was higher than genotypic variance for all the characters. Phenotypic coefficient of variation ranged from 8.87

(days to 50% flowering) to 44.48 (number of branches) in bitter gourd. Genotypic coefficient of variation ranged from 8.67 (days to 50% flowering) to 43.36 (number of branches).

Ullah *et al.* (2012) found that genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were high for yield per plant, fruits per plant, fruit weight and fruit length in bitter gourd.

Devi and Mariappan (2013) recorded higher values of phenotypic coefficient of variation and genotypic coefficient variation for fruit length, fruit weight and number of fruits per plant in snake gourd.

Kumar *et al.* (2013) reported that the total fruit yield per vine was found to be positively and significantly correlated with number of fruits per vine, average weight of fruit and number of seeds per fruit in sponge gourd.

Yadav *et al.* (2013) reported that the highest range of variation was recorded for fruit yield per hectare followed by fruit weight, number of nodes per vine, days to first appearance of female flower, days to first appearance to male flower, fruit length and maximum variation was observed for the trait fruit yield per vine in bitter gourd.

Burger *et al.* (2013) worked on genetic variability for valuable fruit quality traits in *Cucumis melo* and found large genetic variability in melon germplasm for TSS and sugar concentration. Arka Jeet variety showed highest TSS content followed by Gold King variety.

Kumar *et al.* (2013) observed the significant variations for all the characters in all the genotypes of sponge gourd used in the experiment. Highest genotypic and phenotypic variations were observed for total yield per vine followed by number of seeds per fruit, average weight of fruits and total soluble solids.

Akter *et al.* (2013) found significant variations among the genotypes for most of the characters studied in bitter gourd.

Dubey *et al.* (2013) revealed wide genetic variability among the accessions in ridge gourd. The genotypic coefficient of variation estimates was high in days to 50% germination, vine length, fruit length and fruit yield per plant.

Chakraborty *et al.* (2013) observed high genotypic coefficient of variations and phenotypic coefficient of variations values for characters like fruit yield per vine, fruit weight, number of seeds per fruit, fruit length, seed weight per fruit and number of fruits per vine in bitter gourd.

Dalamu and Behera (2013) demonstrated that the higher genotypic coefficient of variance along with high heritability and genetic advance for number of fruits per plant and fruit weight would also be of great use for indirect selection for improvement in fruit yield per plant in bitter gourd.

Kumar *et al.* (2013) observed that the highest genotypic coefficient of variations and phenotypic coefficient of variations were observed with the character fruit yield per plant followed by number of seeds per fruit in tomato. Whereas, the lowest genotypic coefficient of variations and phenotypic coefficient of variations were recorded by the character days to 50% fruiting followed by days to 50% flowering.

Pathak *et al.* (2014) found that number of fruits per plant, fruit weight and fruit length had high genotypic and phenotypic coefficient of variation whereas low genotypic coefficient of variations and phenotypic coefficient of variations was observed for days to first male and female flower anthesis in bitter gourd. For most of the parameters under this study, phenotypic coefficient of variation was found to be higher than genotypic coefficient of variation.

Singh *et al.* (2014) found a wide range of variation in all characters which represents the variation was high and genotypes were rich in diversity in bitter gourd. The long sized fruits with wide diametre generally exhibited more number of seeds as compared to normal and small fruited. The widest range was recorded for plant height (59.66- 153.53 cm) followed by average fruit weight (14.53-60.51g), number of fruits per plant (8.51-48.57), days to first female flower anthesis (29.34-48.52 days), days to

edible maturity (41.75-58.55 days), 10 plant fruit yield (4.80-19.90 kg), fruit length (4.35-18.56 cm), number of seeds per fruit (6.61-18.19), number of branches per plant (4.23-15.37) and fruit diameter (1.10-4.10 cm).

Jat *et al.* (2014) found that the maximum phenotypic and genotypic coefficient (PCV and GCV) was observed for acidity of fruit (27.46 and 28.73) followed by weight of fruit (24.06 and 24.99), total fruit yield per vine (24.04 and 25.07), rind thickness (22.29 and 24.46) and total soluble solids (20.43 and 21.03) in cucumber.

Sengupta *et al.* (2014) reported that the highest phenotypic and genotypic coefficient of variation were observed for seed yield per plant (31.49 and 31.21%) and primary branches per plant at 120 DAS (20.58 and 15.11%) in fennel.

Singh *et al.* (2014) reported high phenotypic and genotypic coefficients of variation for fruit yield per plant followed by fruit length, fruit width and number of fruits per plant in bitter gourd.

Radharani (2014) found that the genotypes namely IC-044438 followed by IC-033227 and IC-470560 recorded highly significant fruit yield (1.58, 1.38 and 1.36 kg per plant, respectively) and fruit yield related traits like number of fruits per vine (21.6, 20.00 and 22.47, respectively), average fruit weight (73.33, 69.24 and 60.68g respectively), pulp thickness (3.53, 3.69 and 3.48 cm, respectively), while IC-470560 and IC-044438 were found early as they recorded minimum days to first male flower (37.47 and 39.13, respectively), first female flower appeared (47.40 and 45.13 respectively) and sex ratio (male to female) (7.16 and 7.38, respectively) in bitter gourd.

Munawar *et al.* (2015) found considerable genetic variability among genotypes for all traits in tinda.

Singh *et al.* (2015) identified five most promising high yielding genotypes of bitter gourd in order to merit of fruit yield per plant namely NDBT-12, NDBT-10, NDBT-83, Pusa Do Mausami and NDBT-15. NDBT-66 and NDBT-71 was found good for early maturity.

## **2.2 Heritability and Genetic Advance**

Robinson *et al.* (1966) defined heritability in broad sense as “the ratio of total genotypic variance to total phenotypic variance”. Higher magnitude of heritability suggested the major role of the genetic factors in the expression of the characters. Allard (1960) viewed that characters which had low heritability are not dependable because their genotypic expression is super imposed by the environmental influences.

Heritability in other words, is an index to measure transmissibility of characters in a population. Heritability always emphasizes about the selection in relation to the genetic traits. Heritability in broad sense reflects the functioning of genotypes as a whole. In narrow sense it is that part of observed variance which is caused by additive genetic variance. It guides the plant breeders with respect of selecting the individuals from segregating generations for effective improvement. Therefore, it is prerequisite for planning of any breeding programme based on selection technique.

Genetic advance or genetic gain is still more useful tool to estimate the nature of the crop. Genetic advance is directly related with the heritability as it gives an idea about the expected genetic changes on account of selection applied for a particular trait. Heritability often fails to provide the estimates of absolute variability. The estimate of the genetic advance in per cent of mean provides more reliable information regarding the effectiveness of selection in improving a trait because its estimate is derived by involving heritability phenotypic standard deviation selection intensity thus the estimate of heritability and genetic advance are of a great significance to plant breeders in developing suitable selection strategies.

Sanwal *et al.* (2007) observed high heritability coupled with high genetic advance observed for fruit yield per plant, number of fruits per plant and days to flowering, however, high heritability accompanied with low genetic advance values were observed for fruit length, average fruit weight in sweet gourd.

Chandraprakash (2008) observed high heritability along with high genetic advance for fruits in 44 germplasms of ash gourd. Only fruit weight showed high genetic advance.

Dey *et al.* (2009) recorded moderate to high heritability for all the traits in bitter gourd. High heritability along with high genetic advance was revealed for traits like average fruit weight (g), average flesh thickness (cm), fruit yield per plant (g) and node to first female flower.

Khule *et al.* (2011) experimented with sponge gourd [*Luffa cylindrica* (Linn.) M. Roem.] involving 30 genotypes. High estimates of heritability along with high genetic advance were recorded for marketable fruit yield per plant, fruit length and number of fruit per plant which indicated the effectiveness. Thus these traits could be used effectively in developing high yielding varieties of sponge gourd.

Singh *et al.* (2012) found that all the characters in bitter gourd showed high heritability except average fruit weight which indicated moderate heritability. Fruit length followed by fruit diameter showed high heritability in broad sense as well as genetic advance in per cent of mean.

Rai *et al.* (2012) observed that the estimates of heritability ranged from 78 % (number of seeds per pod) to 98.9 % (plant height). Genetic advance expressed as percentage over mean ranged from 1.27 % (pod breadth) to 69.69 % (yield per plant) in cluster bean.

Rani (2012) studied fourteen genotypes of ridge gourd (*Luffa acutangula* L.). A high degree of heritability associated with high expected genetic advance as per cent of mean was observed for fruit length, number of fruits per vine and node number at first fruit harvest.

Ullah *et al.* (2012) found broad sense heritability estimates for various traits ranged from 42.26 % to 89.55% in bitter gourd.

Naik *et al.* (2012) conducted an experiment on five female clones of teasel gourd (*Momordica subangulata* Blume. subsp. renigera). High heritability coupled with high genetic advances were noticed for characters like length of main vine, number of vines per plant, number of leaves per plant, fruit weight at marketable stage, ovary diameter, number of seeds per fruit, number of fruits per plant, yield per plant.

Devi and Mariappan (2013) revealed that high heritability, along with high genetic advance was observed for fruit length, fruit yield, fruit girth and number of fruits per plant, is an indication of additive gene action in control of these traits and phenotypic selection based on these traits in the segregating population is likely to result desired individuals in snake gourd.

Radharani (2013) showed the moderate heritability for number of fruits per vine, average fruit weight, fruit girth, number of seeds per fruit, days to first male and female flower appearance suggesting selection methods for improvement of these characters and low heritability for fruit length, plant height, number of laterals per vine, node number at first male and female flower appearance, sex ratio, pulp thickness and fruit length in bitter gourd, indicated that these characters were more prone to environmental fluctuations.

Kumar *et al.* (2013) studied twenty sponge gourd genotypes and reported that number of seeds per fruit, average weight of fruit and specific gravity showed high heritability with high genetic advance.

Akter *et al.* (2013) observed high heritability coupled with high genetic advance in per cent of mean for number of seeds per fruit, fruit yield per plant, flesh thickness, number of male flowers per plant and number of female flowers per plant in pumpkin.

Dubey *et al.* (2013) revealed that heritability estimates were high in days to 50% germination, vine length, fruit length and fruit yield per plant. However, genotypic coefficient of variation and heritability estimates were low in number of branches per plant and fruit weight in bitter gourd.

Chakraborty *et al.* (2013) observed high heritability coupled with high genetic advance for total fruit yield per vine in bitter gourd.

Kumar *et al.* (2013) observed that the heritability estimates were high for all the characters except number of branches per plant which showed moderate heritability in bitter gourd. The maximum heritability was observed for number of seeds per fruit and average fruit weight. High genotypic coefficient of variations and heritability coupled with high genetic advance were observed for fruit yield per plant.

Choudhury *et al.* (2014) concluded that the fruit length had the highest heritability (93.5%) followed by node at which first hermaphrodite flower appeared (78.0%) in ridge gourd.

Pathak *et al.* (2014) observed high heritability with high genetic advance (GA) for fruit weight, fruit length and number of fruits per plant which is an indicative of greater proportion of additive genetic variance and consequence a high genetic gain from selection in bitter gourd. High heritability with low genetic advance was observed for days to first male and female flower anthesis and days to marketable maturity from anthesis indicated that non-additive gene effects were involved for the expression of these characters.

Muralidhara *et al.* (2014) found that high heritability coupled with high genetic advance per cent as mean was observed for the characters like per cent fruit set, carotene content, days to 50 per cent female flowering, days to first male and female flower flowering, TSS, pulp thickness, weight of fruit and weight of seeds per fruit in pumpkin.

Jat *et al.* (2014) observed high estimates of heritability (broad sense) for days to anthesis of first female flower (96.66 %), weight of fruit (92.67 %) and diameter of fruit (92.51 %) with high genetic advance. The maximum genetic gain in per cent was observed for acidity of fruit (54.06), weight of fruit (47.71) and total yield per vine (47.49) in cucumber.

Munawar *et al.* (2015) found high heritability coupled with low genetic advance for leaf area, fruit length, fruit diameter, number of vines per plant, number of fruits per plant, and fruit yield in bitter gourd. Fruit weight had additive gene action as indicated by high heritability and genetic advance.

Singh *et al.* (2015) recorded highest heritability and genetic advance for number of fruits per plant followed by fruit length which suggested predominance of additive and non-additive gene action in bitter gourd.

### **2.3 Correlation Coefficient**

The studies on correlation provide an estimate of association between the various characters. The estimates of correlation between the various characters in a crop are of utmost importance in an efficient breeding programme. The data available to the plant breeder on two or more plant characteristics of a sample or a group of strains of a particular crop helps immensely in estimating the degree of association among them. The degree of relationship is generally measured in the terms of statistical correlation coefficient which varies from  $-1$  to  $+1$ . The original concept of correlation was presented by Galton (1889) which was further elaborated by Fisher (1918) and Wright (1921).

Sharma and Bhutani (2001) found significant positive correlations for total chlorophyll content, first female flowering node and fruit length with fruits per plant, fruit length and fruit diameter with average fruit weight, fruits per plant and average fruit weight with total fruit yield per plant in bitter gourd.

Bhave *et al.* (2003) reported positive and significant association between fruit yield per vine with flowering duration, harvesting span, fruit length, fruit breadth, number of fruits per vine, average fruit weight, biological yield, dry matter and harvest index at both genotypic and phenotypic levels. Fruit yield showed negative correlation with days to first flowering both at genotypic and phenotypic levels in bitter gourd.

Dey *et al.* (2005) observed that highest positive correlation with fruit weight followed by fruits per plant, flesh thickness, days to fruit set to maturity, fruit index, fruit length and fruit diameter. Fruit weight and fruits per plant also have very high positive direct effect upon fruit yield in bitter gourd.

Sanwal *et al.* (2007) found that fruit yield per plant had positive and high significant correlation with number of fruits per plant (0.988), fruit length (0.575) and average fruit weight (0.478) in sweet gourd.

Kumar *et al.* (2008) revealed positive correlation between fruit yield per vine, number of fruits per vine, average fruit weight, number of nodes per vine and fruit yield in bitter gourd.

Singh *et al.* (2008) observed that the number of seeds per plant had either negative or positive correlation at phenotypic and genotypic level in bitter gourd.

Pandey *et al.* (2009) observed that yield had positive and significant correlation with fruit weight, polar and equatorial circumference of fruit at both phenotypic and genotypic level and with days to first female flower anthesis at genotypic level. Fruit weight, polar and equatorial circumference of fruit had positive correlation coefficient among themselves in snap melon.

Islam *et al.* (2009) found that fruit yield per plant was positively and significantly correlated with number of nodes per vine. It was also revealed that maximum direct contribution towards yield per plant is due to number of fruits per plant followed by vine length in bitter gourd.

Sundaram (2010) observed that the number of female flowers per vine, number of fruits per vine, vine length and fruit weight had significant positive association with fruit yield in bitter gourd. The maximum positive inter correlation was observed between number of female flowers per vine and number of fruits per vine. Sex ratio of male to female flower had shown significant negative association with fruit yield and it had recorded the maximum negative inter correlation with the number of female flowers per vine.

Singh *et al.* (2012) reported that fruit yield per plant was positively and significantly correlated with number of fruits per plant and fruits yield per plant was positively and directly associated with number of fruits per plant at phenotypic as well as genotypic level in bitter gourd.

Resmi and Sreelathakumary (2012) observed that fruit length, fruit girth, average fruit weight, seeds per fruit and 1000 seed weight had positive and significant correlation with fruit yield in ash gourd.

Akter *et al.* (2013) observed that correlation coefficient between fruit yield per plant was positive and highly significant with number of primary branches, number of fruits per plant and single fruit weight in bitter gourd. On the other hand, days to first female flower, number of male flowers per plant showed positive and non significant correlation with fruit yield per plant. But correlation between sugar content and yield per plant was significantly negative.

Dubey *et al.* (2013) observed that vine length, fruit length, number of fruits per plant and fruit weight had a significant ( $P < 0.01$ ) positive correlation with fruit yield per plant in ridge gourd.

Chakraborty *et al.* (2013) found significant positive association of fruit yield per vine with vine length, number of primary branches per vine, fruit weight, fruit length, flesh thickness, number of seeds per fruit and seed weight per fruit in bitter gourd.

Dalamu and Behera (2013) found that ovary length, fruit length and diameter ratio, fruit weight and number of fruits per plant were positively correlated with fruit yield per plant in bitter gourd.

Choudhury *et al.* (2014) found significant positive correlation between fruit yield per plant and fruit weight (0.877), number of fruits per cluster (0.590) and fruit length (0.356) at phenotypic level. Significantly negative and desirable correlation at phenotypic level was observed between fruit yield per plant and days to first fruit harvest (-0.403), days to first hermaphrodite flower (-0.337) and node at which first hermaphrodite flower appeared (-0.315) in ridge gourd.

Rashid *et al.* (2014) revealed that marketable fruit yield per plant exhibit significant positive correlation with number of fruits per plant and fruit length. In general, genotypic correlation coefficient was higher than the corresponding phenotypic correlation coefficient suggesting that the environmental influence reduces the relationship between yield and yield contributing characters of snake gourd.

Munawar *et al.* (2015) found that fruit length, fruit diametre, fruit weight, and number of fruits per plant had a strong positive association, numbers of vines per plant were negatively correlated with yield at genotypic and phenotypic levels in tinda. Fruit weight had the most direct effect on yield, followed by fruit diametre and stem diametre.

Singh *et al.* (2015) found that fruit yield per plant represented highly significant and positive association with number of fruits per plant followed by average fruit weight and negatively associated with node number to anthesis of first pistillate flower at genotypic level in bitter gourd.

Janaranjani and Kanthaswamy (2015) reported that fruit yield was positively and significantly correlated with fruit flesh thickness, number of fruits per vine and number of fruit pickings in bottle gourd.

## **2.4 Path coefficient Analysis**

Path coefficient analysis was proposed by (Wright, 1921). He defined the path coefficient technique as the ratio of the standard deviation of the effect due to a given cause to the total standard deviation of the effect. Path coefficient is the measure of direct influence of one variable upon another which permits the separation of correlation coefficient into component of direct and indirect effects. The use of path coefficient analysis requires a cause and effect situation among variables.

Sharma and Bhutani (2001) indicated that fruits per plant had the highest direct contribution towards fruit yield followed by chlorophyll content, fruit length and fruit diametre, while vine length had the highest indirect contribution towards

fruit yield followed by internode length, average fruit weight, fruit diameter and fruit length via number of fruits per plant in bitter gourd.

Dora *et al.* (2002) observed that the number of branches per plant, diameter of fruit, fruit length and days taken for fruit to attain marketable maturity, had weak positive and direct correlation with fruit yield. A positive direct and negative correlation with fruit yield was observed in days taken for appearance of fruit, female flowers, fruit weight and number of nodes per plant in pointed gourd.

Bhave *et al.* (2003) reported that strong positive direct effect on yield was observed for leaves per vine, fruit length and average fruit weight, seeds per fruit, fruits per vine, biological yield and keeping quality in bitter gourd.

Dey *et al.* (2005) concluded that fruit weight, number of fruits per plant and node number to first female flower appearance may be most dependable and reliable criteria for selection for improving yield of cultivars in bitter gourd.

Sanwal *et al.* (2007) resulted that the number of fruits per plant, average fruit weight and fruit length exercised maximum direct effect on fruit yield in sweet gourd.

Singh *et al.* (2008) found that the direct effect of primary vine numbers per plant on fruit yield was positive (0.35) and indirect positive effect on yield of fruit via number of days to anthesis of first flower, length of fruit and length of vines in bitter gourd. The direct effect of length of vine (cm) on fruit yield was negative (0.75) and genotypic correlation coefficient was also found to be negative (-0.06) but non significant.

Pandey *et al.* (2009) reported that higher and positive direct effect on yield was exerted by number of fruits per plant followed by fruit weight, polar and equatorial circumference of fruit, days to first male flower anthesis and node at which first female flower appears in snap melon.

Sundaram (2010) showed the highest positive direct effect on yield by number of fruits per vine, while the highest negative direct effect on fruit yield was recorded by number of female flowers per vine in bitter gourd. The number of female flowers

produced per vine had exerted the maximum indirect positive effect on yield through number of fruits per vine, indicating that the number of fruits per vine and number of female flowers produced per vine could be regarded as primary yield determinants in bitter gourd under salt stress.

Resmi and Sreelathakumary (2012) reported that the positive direct effect on yield was revealed by fruit length, average fruit weight and fruits per plant in ash gourd.

Dubey *et al.* (2013) revealed that number of fruits per plant and fruit weight had the highest positive direct effect on fruit yield per plant in ridge gourd.

Chakraborty *et al.* (2013) found that the highest direct effect on fruit yield per vine was through traits like number of fruits per vine followed by fruit weight at phenotypic level in bitter gourd.

Dalamu and Behera (2013) observed that the number of fruits per plant, fruit weight, ovary length and fruit length and diametre ratio also had high phenotypic and genotypic direct effects on fruit yield per plant, revealing that indirect selection for these traits would be effective in improving fruit yield per plant in bitter gourd.

Akter *et al.* (2013) revealed that the maximum direct contribution towards fruit yield was obtained through number of fruits per plant followed by days to first female flower and single fruit weight indicated that these traits should be considered as primary components of fruit yield in pumpkin. Negative direct effect on yield was exerted by number of female flowers per plant and reducing sugar content.

Yadav *et al.* (2013) found that vine length had significant and positive correlation with number of nodes per vine, internode length, fruit diametre and number of fruits per vine in bitter gourd. Number of primary branches per vine had significant and negative correlation with internodal length and significant positive correlation with fruit length.

Choudhury *et al.* (2014) observed that the maximum direct and desirable effect on fruit yield per plant was exerted by fruit length (0.850), number of fruits

(0.334), days to first fruit harvest (- 0.019) and node number at which first flower appeared (- 0.057) at phenotypic level in ridge gourd.

Pathak *et al.*, (2014) found that the number of fruits per plant had significant positive correlation with fruit yield. Fruit yield was found to be directly correlated with fruit weight, number of fruits per plant and fruit length, hence selection based on these characters would be more rewarding in bitter gourd.

Muralidhara *et al.* (2014) reported that yield characters like fruit weight and rind thickness showed positive and highly significant association with fruit yield in pumpkin. A negative relationship has been observed between fruit yield and number of days to first female flowering. The association of number of fruits per vine with fruit weight was negative and significant. This made a clear indication that increase in number of fruits per vine would indirectly affect the total yield which is more dependent on fruit weight. The characters like vine length, number of branches, days to first female flowering, days to first harvest, number of fruits per plant, weight of fruit and TSS were most important characters which had positive and direct effect on fruit yield. But, the direct effects of number of leaves, days to first male flower flowering, sex ratio, days to 50 per cent female flowering and fruit set per cent were negative in their association with fruit yield.

Janaranjani and Kanthaswamy (2015) observed that number of fruits per vine, days to first female flower opening, fruit cavity and fruit weight had positive direct effect on fruit yield in bottle gourd.

Singh *et al.* (2015) found that maximum positive direct effect value was observed in fruit yield per plant by number of fruits per plant followed by average fruit weight while maximum negative direct effect was found in fruit yield per plant contributed by node number to anthesis of first staminate flower followed by node number to anthesis of first pistillate flower via average fruit weight and number of fruit per plant at genotypic level in bitter gourd.



## **MATERIALS AND METHODS**

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The present investigation entitled “**Genetic evaluation for yield and yield attributes in elite genotypes of bitter gourd (*Momordica charantia* L.)**” was conducted during kharif season of 2014. The details about the climatic and edaphic conditions under which the present investigation was carried out, experimental materials used, techniques employed and criteria for evaluation of treatments during the course of investigation have been described below.

### **3.1 GENERAL INFORMATION**

#### **3.1.1 EXPERIMENTAL SITE**

The present experiment was conducted at Vegetable Research Farm, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during rainy season of 2014. The experimental farm comes under the Indo-Gangetic alluvial track in eastern Uttar Pradesh in class II of land capability classification and irrigated by tube well.

#### **3.1.2 LOCATION & CLIMATIC CONDITIONS**

Geographically, Varanasi is situated in eastern part of Uttar Pradesh and subtropical track of north India between latitude 25<sup>o</sup> 15' North and longitude 83<sup>o</sup> 03' East and is located on an elevation of about 128.93 metres above Mean Sea Level (MSL) in north Gangetic plain. The seasonal rainfall is about 1100 mm received mostly from second fortnight of June or first fortnight of July to mid October with a few showers in winter season. On the basis of climatic conditions the entire year could be divided into three distinct seasons:

- a) **Summer season:- Last week of March to third week of June**
- b) **Rainy season:- Last week of June to middle of October**
- c) **Winter season:- November to February**

The seasonal temperature ranges from 32°C to 45°C in the summer. However, the coldest month is January with mean minimum temperature varying from 6 to 9°C with occasional extremes.

The mean weather data such as weekly average temperature (°C), relative humidity (R.H.) in percentage, wind speed(km/hr), evaporation rate (mm) and total rainfall (mm), etc. were recorded during the crop season from meteorological observatory located at Department of agronomy and the data have been presented in Table 1.

**Table 3.1: Weekly meteorological data (July – November, 2014)**

Week No.	Month & Date	Rainfall (mm)	Temperature (°C)		R.H. ( % )		Wind Speed (km/hr)	Sunshine (hours)	Evaporation (mm)
			Max.	Min.	Morn.	Even.			
30	July 23-29	4.6	33.3	26.6	82	65	2.4	4.8	3.3
31	30-05	46.0	32.8	27.7	87	74	5.4	5.7	4.4
32	August 06-12	142.7	32.9	26.4	87	74	5.1	4.1	3.3
33	13-19	42.4	23.6	27.6	86	79	5.4	2.4	2.8
34	20-26	14.0	35.1	27.5	77	60	4.0	6.7	4.4
35	27-02	6.5	33.0	27.1	84	71	7.2	5.3	4.6
36	September 03-09	34.9	32.7	26.4	85	69	5.0	6.0	3.0
37	10-16	11.0	31.9	25.8	91	80	1.8	4.0	3.1
38	17-23	13.7	33.3	26.0	87	72	1.6	5.2	3.4
39	24-30	2.1	33.4	24.3	85	56	3.6	9.3	4.1
40	October 01-07	0.0	32.2	24.2	79	64	1.2	7.2	3.1
41	08-14	50.7	31.2	24.0	88	68	3.7	6.1	2.6
42	15-21	0.0	29.8	19.8	88	69	1.6	6.8	1.7
43	22-28	6.2	29.8	19.2	83	58	0.8	6.8	1.8
44	29-04	0.0	30.4	18.0	85	41	1.2	6.8	2.4
45	November 05-11	0.0	31.4	16.3	86	39	1.3	7.2	2.3

During the experiment, maximum temperature ranged from 23.6°C to 35.1°C and minimum temperature ranged from 16.3°C to 27.7°C.

### 3.1.3 SOIL CHARACTERISTICS OF EXPERIMENTAL FIELD

The soil of the experimental field was Indo-Gangetic alluvial in origin. Surface soil samples (15 cm) depth were initially drawn from randomly selected part of the field before sowing of the crop with the help of soil auger and the composite sample was obtained by mixing them thoroughly. The quantity of soil sample was about one kg through quartering technique.

The soil sample was then subjected to mechanical and chemical analysis in order to determine the textural class and fertility status. The representative sample so drawn was dried and made free from inert and foreign material by passing through 2 mm standard sieve before analysis. The sample so drawn was subjected to physical and chemical analysis using standard method of analysis and the result, collected from Department of Soil Science and Agricultural Chemistry, BHU is given in Table 2.

**Table 3.2: Physico-chemical properties of the experimental field**

Sl. No.	Soil properties	Value
<b>A. Mechanical Analysis</b>		
1.	Coarse sand (%)	0.72
2.	Fine sand (%)	54.80
3.	Silt (%)	22.50
4.	Clay (%)	22.80
5.	Textural class	Sandy loam
<b>B. Physical Analysis</b>		
1.	Bulk density ( $\text{mg m}^{-3}$ )	1.367

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<b>C. Chemical Analysis</b>		
<b>1.</b>	Organic carbon (%)	0.46
<b>2.</b>	Available N (kg ha <sup>-1</sup> )	173.0
<b>3.</b>	Available P <sub>2</sub> O <sub>5</sub> (kg ha <sup>-1</sup> )	16.8
<b>4.</b>	Available K <sub>2</sub> O (kg ha <sup>-1</sup> )	164.0
<b>5.</b>	pH	7.3
<b>6.</b>	Electrical Conductivity (dSm <sup>-1</sup> )	0.26

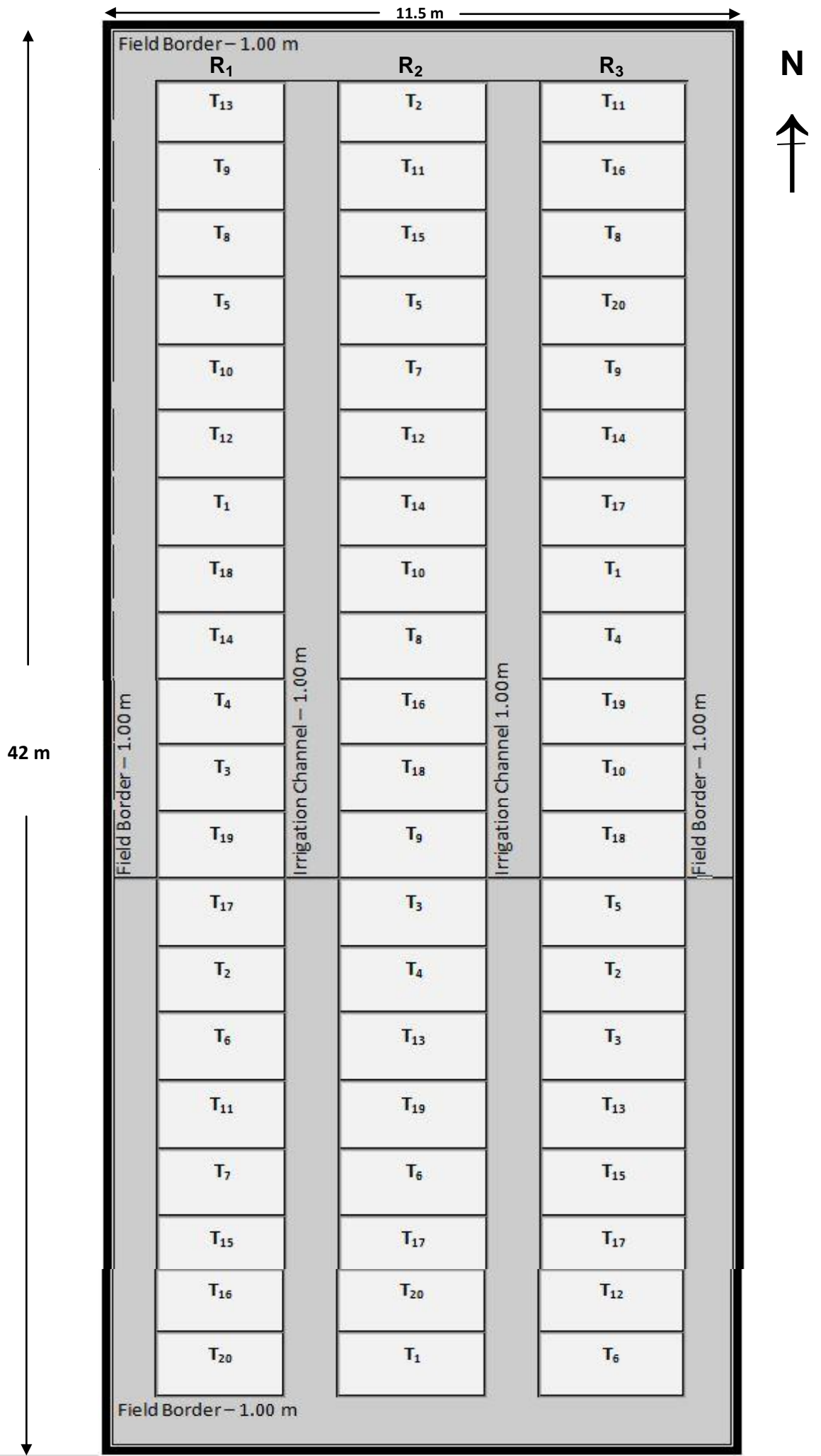
### **3.1.4 EXPERIMENTAL DESIGN AND LAYOUT**

The experiment was laid out with 20 genotypes in Randomized Complete Block Design (RBD) in three replications, thus making a total of 60 plots. The unit plot size was 5 m<sup>2</sup> (2.5 m X 2 m). The plants were planted on the ridges of the row with a spacing of 2 m between the rows and 0.5 m between the plants. There were five plants in each ridge. The genotypes were allocated randomly to a unit plot in each replication. The plan of layout is given in Fig. 1. The details of layout are mentioned in the next page:

**Details of Layout**

Crop	: Bitter gourd
Experimental design	: Randomized Complete Block Design
Total number of genotypes	: 20
Number of replications	: 3
Total number of plots	: 60 (20 X 3)
Field border	: 1.0 m
Plot border	: 0.5 m
Spacing (Row to Row)	: 2.0 m
(Plant to Plant)	: 0.5 m
Irrigation channel	: 1.0 m
Length of each plot	: 2.5 m
Width of each plot	: 2.0 m
Area of each plot (2.5 m×2 m)	: 5 m <sup>2</sup>
Number of plants in each ridge	: 5
Date of sowing	: 10 <sup>th</sup> July, 2014

**Fig. 3.1 Layout of the field**



### 3.1.5 CROP VARIETIES/GERMPLASMS UNDER STUDY

The promising experimental materials (seeds) were collected from Varanasi (Uttar Pradesh), Bidhan Chandra Krishi Viswavidyalaya (BCKV), Mohanpur (West Bengal) and Indian Institute of Vegetable Research (IIVR), Varanasi. The 20 germplasms of bitter gourd, used in this investigation, are enlisted in the Table 4 along with their respective sources.

**Table 3.3: List of genotypes included in the trial**

Sl. No.	Designation	Genotype name	Source
1	T <sub>1</sub>	Jharli	Varanasi, Uttar Pradesh
2	T <sub>2</sub>	Special Bolder Ucha	BCKV, West Bengal
3	T <sub>3</sub>	Meghna No. 2	BCKV, West Bengal
4	T <sub>4</sub>	Vikas	Varanasi, Uttar Pradesh
5	T <sub>5</sub>	Improved Kathai	BCKV, West Bengal
6	T <sub>6</sub>	Arola – D	BCKV, West Bengal
7	T <sub>7</sub>	Dhanraj	BCKV, West Bengal
8	T <sub>8</sub>	NBR-Noble Katahi	BCKV, West Bengal
9	T <sub>9</sub>	Jaunpuri (Special)	Varanasi, Uttar Pradesh
10	T <sub>10</sub>	Preethi	Varanasi, Uttar Pradesh
11	T <sub>11</sub>	PF Uchia	BCKV, West Bengal
12	T <sub>12</sub>	Karola Gor	BCKV, West Bengal
13	T <sub>13</sub>	G.Uchia	Varanasi, Uttar Pradesh
14	T <sub>14</sub>	IC-085608	IIVR, Varanasi
15	T <sub>15</sub>	IC-085609	IIVR, Varanasi
16	T <sub>16</sub>	IC-085610	IIVR, Varanasi
17	T <sub>17</sub>	IC-085611	IIVR, Varanasi
18	T <sub>18</sub>	IC-085612	IIVR, Varanasi
19	T <sub>19</sub>	IC-085613	IIVR, Varanasi
20	T <sub>20</sub>	IC-085615	IIVR, Varanasi

### **3.1.6 CULTURAL OPERATIONS**

#### **3.1.6.1 Field preparation**

The selected field was initially irrigated to have optimum level of moisture. First of all deep ploughing was done with disc plough and weeds were removed. After that the soil was brought to a comparatively fine tilth with the help of cultivator followed by planking in order to level the land.

#### **3.1.6.2 Fertilizer application**

Fertilizer was applied at the rate of 100 kg ha<sup>-1</sup> nitrogen, 50 kg ha<sup>-1</sup> phosphorus, 50 kg ha<sup>-1</sup> potassium (Thamburaj and Singh, 2001). Half dose of the nitrogen and full dose of phosphorus and potassium were applied thoroughly before sowing. The balanced amount of nitrogen was applied at the time of flowering. Fertilizers were applied in a ring at 6 to 7 cm away from the base of the vine.

#### **3.1.6.3 Selection of seeds and sowing time**

Pure and healthy seeds of each genotype were selected for sowing. The seeds are enclosed in hard seed coat so soaked in water for twelve hours to get good germination prior to sowing. Four to five seeds were sown per hill. When the seedlings attained height of 10-15 cm, thinning was done to retain one plant per hill.

#### **3.1.6.4 Intercultural operations**

The experimental area was kept weed free throughout the cropping period by manual weeding. Recommended package of practices were followed to raise a healthy crop.

#### **3.1.6.5 Irrigation**

Before sowing of the crop, a light irrigation is provided after final field preparation and later on irrigations were given depending upon the moisture requirement of the soil.

### **3.1.6.6 Selection of plants for observation**

In a field experiment, detail study of the entire population is rather difficult. For convenience, five plants were selected in a random manner from each plot and tagged for recording the observations.

## **3.2 OBSERVATIONS RECORDED**

The method of random sampling was adopted for recording the observations of various characters of bitter gourd. The observations for fifteen important characters were recorded on five plants excluding the border plants at both the extreme end in each row. Data of five plants were averaged replication wise and mean data was used for statistical analysis. Observations were recorded on following traits:

### **3.2.1 Node number of first staminate flower appearance**

The node at which the first staminate flower appeared was counted from the base of the plant on each labelled plant for recording the observation and average was calculated.

### **3.2.2 Node number of first pistillate flower appearance**

The node at which the first pistillate flower appeared was counted from the base of the plant on each labelled plant for recording the observation and average was calculated.

### **3.2.3 Days to anthesis of first staminate flower**

The number of days taken from the date of sowing to the date of first staminate flower anthesis was observed in all the five selected plants from each replication and average was calculated.

### **3.2.4 Days to anthesis of first pistillate flower**

The number of days taken from the date of sowing to the date of first pistillate flower anthesis was observed in all the five selected plants from each replication and their average was calculated.

### **3.2.5 Days to 50% flowering**

Number of days from sowing date to the date when at least fifty per cent of the plants showed first flower opening was recorded and averaged.

### **3.2.6 Days to first harvest**

First occurring marketable fruits were harvested from randomly selected plants and then averaged.

### **3.2.7 Number of primary branches per plant**

The branches arising from the main stem of the plant were considered as primary branches. The number was recorded while measuring the length of vines at the end of flowering.

### **3.2.8 Vine length (m)**

The trait was recorded by measuring the length of main vine from the base of the plant up to the tip at the time of last fruit harvest in metres with the help of metre scale.

### **3.2.9 Internode length (cm)**

The distance between two nodes of the plant is called internode length. The length of five internodes on one plant was measured at full foliage stage and average was determined.

### **3.2.10 Fruit length (cm)**

Five fruits from each genotype per replication were harvested at edible maturity stage. Fruit length was measured in centimetre from the peduncle end of the fruit to the blossom scar point. Total sum of length of five fruits was taken and divided by five to obtain average length of fruit of the genotypes.

### **3.2.11 Fruit circumference (cm)**

Circumference of five randomly selected fruits from sampled plant of each replication was noted down and average was used for calculation.

### **3.2.12 Fruit diameter (cm)**

Diameter of fruits were measured on the same five randomly selected fruits from a composite harvest on which fruit length was recorded. Fruits were cut in almost middle in halves and the diameter was measured with the help of digital vernier callipers. Average diameter of fruits was calculated.

### **3.2.13 Average fruit weight (g)**

Five fruits were randomly taken from each genotype (same five fruits selected for fruit length) and the mean fruit weights were measured in gram.

### **3.2.14 Number of fruits per plant**

The number of fruits per plant was obtained by adding the number of fruits of all pickings from the selected plants in each plot and average was calculated.

### **3.2.15 Yield per plant (kg)**

The total edible green fruit yield over all the pickings were recorded and yield per plant was obtained after dividing total yield by number of selected plants and expressed in kilograms.

## **3.3 STATISTICAL AND BIOMETRICAL ANALYSIS**

The mean values of data obtained from the field were subjected to following statistical analysis.

3.3.1 Analysis of variance (ANOVA)

3.3.2 Estimation of various Genetic parametres

3.3.3 Correlation coefficient (genotypic and phenotypic) Analysis

3.3.4 Path coefficient Analysis

### **3.3.1 Analysis of Variance**

Analysis of variance was done for partitioning the total variation into variations due to treatment and replication according to procedure proposed by Panse and Sukhatame (1967). This also facilitates division of the total variance into phenotypic, genotypic and environmental variances. Phenotypic, genotypic and environmental coefficients of variability were calculated as per method proposed by Burton (1952). The skeleton of ANOVA is given in table 3.4:

**Table 3.4: Skeleton of Analysis of Variance (ANOVA)**

Source	df	SS	MSS	F value (Calculated)
Replication	r-1	SSr	$\frac{SSr}{(r-1)} = MSR$	$\frac{MST}{MSE}$
Treatment	t-1	SSt	$\frac{SSt}{(t-1)} = MST$	
Error	(r-1) (t-1)	SSe	$\frac{SSe}{(r-1) (t-1)} = MSE$	
Total	(rt-1)	TSS		

Where,

- r = number of replications
- t = number of treatments
- df = degree of freedom
- SSr = replication sum of squares
- SSt = treatment sum of squares
- SSe = error sum of squares
- TSS = Total sum of squares
- MST = treatment mean sum of squares
- MSR = replication mean sum of squares
- MSE/EMS = error mean sum of squares

**Test of significance**

If the variance ratio (F-calculated value *i.e.* MST /MSE) of the treatment is greater than the F-table value at 5% and 1% level of significance, the differences among treatments are considered to be significant. If the F-calculated value is less than F-tabulated value, the differences among the treatments are considered to be non-significant.

### **3.3.2 Genetic parametres**

#### **3.3.2.1 Mean**

Mean is the average value of the character in a sample, i.e., it is the average of all the observations of a character in sample.

$$\text{Mean (X)} = \Sigma X / N$$

Where,

$\Sigma X$  = Sum of all observations for each character in each replication.

$N$  = Number of treatments

#### **3.3.2.2 Range**

It was taken as the difference between the highest and lowest mean value for each character. It is the simple measure of variability and gives an idea of the dispersion or spread of the observations in sample.

$$\text{Range} = X_h - X_l$$

Where,

$X_h$  = Highest mean value of the character

$X_l$  = Lowest mean value of the character

#### **3.3.2.3 Variance**

It is defined as the average of the square deviation from the mean or it is the square of the standard deviation. It is an effective measure of variability which permits partitioning of various components.

##### **3.3.2.3.1 Genotypic variance**

The genotypic variance ( $V_g$  or  $\sigma^2_g$ ) is the variance due to the genotypes present in the population. This was calculated by the formula suggested by Burton (1952).

$$(\sigma^2_g) = \frac{\text{MST} - \text{EMS}}{\text{No. of replications (r)}}$$

Where,

MST = Treatment Mean sum of squares

EMS = Error mean sum of squares

### **3.3.2.3.2 Phenotypic variance**

Phenotypic variance ( $V_p$  or  $\sigma^2_p$ ) denotes the total variance present in a population for a particular character and is calculated by following formula:

Phenotypic variance ( $\sigma^2_p$ ) = Genotypic variance + Error variance

### **3.3.2.3.3 Environmental variance**

The environmental variance ( $V_e$  or  $\sigma^2_e$ ) is the variance due to environment deviation.

$V_e = EMS$

### **3.3.2.4 Standard error (SE)**

Standard error was calculated by following formula:

$$SE = \sqrt{\frac{2EMS}{r}}$$

### **3.3.2.5 Critical Difference (CD)**

The critical difference was calculated by following formula:

$$CD = \sqrt{\frac{2EMS}{r}} \times t \text{ value}$$

Where,

t value = Table value at error degree of freedom at 5% level of significance

r = Number of replications

EMS = Error mean sum of squares

Significant 'F' value indicates that there is significant difference among the treatments. But to compare any two particular treatments, it is tested against CD value.

### **3.3.2.6 Coefficient of variation (CV)**

A measurement of variance which is independent of the unit of measurement is provided by the standard deviation expressed as percentage of mean. This is known as coefficient of variation (CV).

$$\text{CV (\%)} = \frac{\text{Standard deviation}}{\text{Mean}} \times 100$$

The phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV) and environmental coefficient of variation (ECV) were calculated by the formula given by Burton (1952).

$$\begin{aligned} \text{(a) PCV (\%)} &= \frac{\text{Phenotypic standard deviation}}{\text{Grand mean}} \times 100 \\ &= \frac{\sqrt{V_p}}{\bar{X}} \times 100 \end{aligned}$$

$$\begin{aligned} \text{(b) GCV (\%)} &= \frac{\text{Genotypic standard deviation}}{\text{Grand mean}} \times 100 \\ &= \frac{\sqrt{V_g}}{\bar{X}} \times 100 \end{aligned}$$

$$(c) \quad ECV (\%) = \frac{\text{Error standard deviation}}{\text{Grand mean}} \times 100$$

$$= \frac{\sqrt{V_e}}{\bar{X}} \times 100$$

### 3.3.2.7 Heritability (Broad sense) [ $h^2_{(b)}$ ]

Heritability in broad sense refers to the proportion of genotypic variance to the total variance of the total population. Heritability in broad sense [ $h^2_{(b)}$ ] was calculated according to the formula given by Lush (1940).

$$\text{Broad sense heritability } [h^2_{(b)}] = \frac{V_g}{V_p} \times 100$$

Where,

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

$V_g (\sigma^2_g)$  = Genotypic variance

$V_p (\sigma^2_p)$  = Phenotypic variance ( $V_g + V_e$ )

### 3.3.2.8 Genetic advance

Genetic advance refers to the expected gain or improvement in the next generation by selecting the superior individuals under certain amount of selection pressure. From the heritability estimates, the genetic advance was estimated by the following formula given by Johnson *et al.* (1955).

$$G.A. = \frac{\sigma^2_g}{\sigma^2_p} k. \sigma_p$$

$$= h^2_{(b)}. K. \sigma_p$$

Where,

$h^2_{(b)}$  = Heritability (broad sense)

K = Selection differential standard units which is 2.06 for 5% selection intensity

$\sigma_p$  = Phenotypic standard deviation

G.A. = Genetic advance

### Genetic advance as per cent of mean (GA % M)

It was calculated by using the following formula:

$$\text{Genetic Advance as per cent of mean} = \left( \frac{GA}{\bar{X}} \right) \times 100$$

GA= Genetic advance

$\bar{X}$  = Mean of a character

### 3.3.3 Correlation Coefficient

Correlation coefficient, denoted as 'r', is used to measure the linear association between two attributes and this was computed in terms of genotypic and phenotypic correlation co-efficient based on variance and co-variances which are given below:

#### 3.3.3.1 Genotypic Correlation Coefficient

Genotypic correlation coefficient was calculated by the following formula as suggested by Robinson *et al.* (1951):

$$r_g(x,y) = \frac{\text{Genotypic covariance of x and y}}{\sqrt{\text{Genotypic var.}(x).\text{Genotypicvar.}(y)}}$$

Where,

$r_g(x,y)$  = Genotypic correlation coefficient between x and y

### **3.3.3.2 Phenotypic Correlation Coefficient**

It was calculated by the following formula:

$$r_p(x,y) = \frac{\text{Phenotypic covariance of x and y}}{\sqrt{\text{Phenotypic var.}(x).\text{Phenotypic var.}(y)}}$$

Where,

$r_p(x,y)$  = Phenotypic correlation coefficient between x and y

### **Test of Significance**

The significance of correlation coefficient was tested with the help of ‘r’ value (statistical table by Fisher and Yates) at n-2 degree of freedom at 5% and/or 1% level of significance. If the calculated value of correlation coefficient is greater than the tabulated value of ‘r’ at n-2 degree of freedom, the correlation was considered to be significant, where ‘n’ is number of treatments.

### **3.3.4 Path coefficient Analysis**

Wright (1921) defined the path coefficient as “the ratio of the deviation when all causes are constant, except one in question, the variability of which kept in changed”. It is simply a standardized partial regression coefficient and measures the direct influence of one variable upon another and permits the separation of the correlation coefficient into components of direct and indirect effects. The use of the method requires a cause and effect situation among variables (Dewey and Lu, 1959).

#### **(i) Causal System**

The causal system indicates mutual association as measured by correlation coefficient and the direct influences as measured by path coefficient. The path coefficients were obtained by solving the simultaneous equations which express the basic relationship between correlation coefficient and path coefficient by Dewey and Lu (1959).

**(ii) Computation of Direct Effects**

In order to estimate the direct effects of different component traits, first a path diagram was constructed using the estimates of correlation coefficients. With the help of the path diagram simultaneous equation are developed as follows:

$$r_{x_1y} = P_{x_1y} + r_{x_1x_2} P_{x_2y} + r_{x_1x_3} P_{x_3y} + \dots + r_{x_1x_n} P_{x_ny}$$

$$r_{x_2y} = r_{x_2y_1} + P_{x_2y} + r_{x_2x_3} P_{x_3y} + \dots + r_{x_2x_n} P_{x_ny}$$

.....  
 .....

$$r_{x_ny} = r_{x_nx_1} P_{x_1y} + r_{x_nx_2} P_{x_2y} + r_{x_ny} P_{x_3y} + \dots + P_{x_ny}$$

Where,

$r_{x_iy}$  = Correlation between  $x_i^{th}$  component trait and yield

$P_{x_iy}$  = Path coefficient between the  $x_i^{th}$  trait and yield

$r_{x_ix_j}$  = Coefficient of correlation between  $i^{th}$  and  $j^{th}$  characters

The  $P_{x_iy}$  is the estimate of direct effect of variable  $x_i$  on Y (yield).

**(iii) Computation of Indirect Effects**

The indirect effect of a character via another causal factor was obtained by multiplying the correlation coefficient between the two factors with the direct effect (i.e. path coefficient) of the later upon effect.

**(iv) Computation of Residual Effects**

The residual effects were calculated by following formula.

$$R = \sqrt{1 - (\sum P_{iy}, r_{iy})}$$

Where,

$R$  = Residual effect

$p_{iy}$  = Path coefficient of character (i) with dependent trait

$r_{iy}$  = Correlation co-efficient of character (i) with dependent trait



## EXPERIMENTAL FINDINGS

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The data has been recorded on fifteen quantitative traits of twenty genotypes of bitter gourd. During the course of this investigation these data were subjected to various statistical and biometrical analyses as per standard procedure. The results obtained are presented under following major heads:

4.1 Analysis of Variance

4.2 Mean Performance

4.3 Estimation of various Genetic parametres

4.4 Correlation coefficient Analysis

4.5 Path coefficient Analysis

### 4.1 ANALYSIS OF VARIANCE

Analysis of variance of twenty different genotypes of bitter gourd for fifteen characters is presented in Table 4.1 and illustrated in the Figure 4.1. The analysis of variance of mean was carried out for various yield and yield contributing traits *i.e.* node number of first staminate flower appearance, node number of first pistillate flower appearance, days to anthesis of first staminate flower, days to anthesis of first pistillate flower, days to 50% flowering, days to first harvest, number of primary branches per plant, vine length (m), internodal length (cm), fruit length (cm), fruit circumference (cm), fruit diametre (cm), average fruit weight (g), number of fruits per plant and yield per plant (kg). The data revealed that the treatments significantly differ from each other for all the characters demonstrating that the materials under study have sufficient genetic variability.

Mean sum of squares for treatments and error along with degree of freedom are presented in Table 4.1. The 'F' test indicated that the variance due to treatments were highly significant for almost all the characters under study. Highly significant differences among the genotypes of bitter gourd for all the characters under study

were observed. The result suggested the presence of inherent genetic differences among the genotypes.

## **4.2 MEAN PERFORMANCE OF THE GENOTYPES**

The data collected for all the characters were subjected to statistical analysis as mentioned earlier in materials and methods. The ANOVA for all the characters were found to be highly significant (Table 4.1) thus indicating wide variation among the twenty genotypes. The mean performance of these genotypes is presented in Table 4.2.

### **4.2.1 Node number of first staminate flower appearance**

For node number of first staminate flower appearance, minimum node number was recorded in genotype Special Bolder Ucha (7.58<sup>th</sup>) and maximum node number in genotype Preethi (16.32<sup>th</sup>). The overall mean was found to be 12.15<sup>th</sup> node. The value of other genotypes was in the range of 7.58<sup>th</sup> -16.32<sup>th</sup> node.

### **4.2.2 Node number of first pistillate flower appearance**

For node number of first pistillate flower appearance, minimum node number was recorded in genotype IC-085612 (12.50<sup>th</sup>) and maximum node number in genotype Dhanraj (23.15<sup>th</sup>). The overall mean was 19.36<sup>th</sup> node. The value of other genotypes was in the range of 12.50<sup>th</sup> -23.15<sup>th</sup> node.

### **4.2.3 Days to anthesis of first staminate flower**

The data regarding mean performance and statistical analysis of twenty genotypes of bitter gourd for days to anthesis of first staminate flower indicated that general mean for this character was 48.80 days having a range from 37.33 to 54.00 days. Among all the genotypes, Special Bolder Ucha had earliest first staminate flower anthesis (37.33 days) whereas IC-085611 had the last (54.00 days).

### **4.2.4 Days to anthesis of first pistillate flower**

A general observation is that if less time is taken for first female flowering then it is an indicator of early yielding genotypes. The range for the character days to anthesis of first pistillate flower was recorded from 47.33 days (Special Bolder Ucha)

to 60.67 days in both the varieties (G.Uchia and IC-085609) with a mean of 55.27 days.

#### **4.2.5 Days to 50% flowering**

Days to 50% flowering ranged from 52.23 (Special Bolder Ucha) to 70.74 (IC-085609) days with a general mean of 64.91 days.

#### **4.2.6 Days to first harvest**

Days to first harvest of different genotypes was recorded which ranged from (61.17-81.53). The minimum days to first harvest was recorded in case of genotype Special Bolder Ucha (61.17). The maximum days to first harvest was observed in genotype IC-085609 (81.53). The overall mean for days to first harvest was 73.28.

#### **4.2.7 Number of primary branches per plant**

Number of primary branches per plant ranged from 6.63 (Arola-D) to 10.49 (PF Uchia) with a general mean of 8.70.

#### **4.2.8 Vine length (m)**

Vine length among the genotypes ranged from 1.76 to 3.09 metres with general mean of 2.58 metres. The genotype IC-085615 (3.09 m) showed the maximum vine length, whereas IC-085612 (1.76 m) had minimum vine length.

#### **4.2.9 Internodal length (cm)**

Internodal length ranged from 4.61 cm (IC-085612) to 6.83 cm (Preethi). This character had a general mean of 6.08 cm.

#### **4.2.10 Fruit length (cm)**

The fruit length ranged from 7.42 cm to 16.04 cm in Special Bolder Ucha and Jaunpuri (special) respectively with a general mean value of 11.88 cm.

#### **4.2.11 Fruit circumference (cm)**

Fruit circumference of different genotypes ranged from 7.98 to 13.56 cm with a general mean of 11.03 cm. The genotype IC-085611 had lowest fruit circumference while Arola-D had got the highest.

#### **4.2.12 Fruit diametre (cm)**

Fruit diametre of different genotypes was recorded which ranged from 2.98 to 4.76 cm with a general mean of 3.71 cm. Among all the genotypes, PF Uchia had showed minimum fruit diametre of 2.98 cm whereas Meghna No. 2 had maximum fruit diametre of 4.76 cm.

#### **4.2.13 Average fruit weight (g)**

Average fruit weight among the genotypes ranged from 23.67 to 63.39 g observed in Special Bolder Ucha and Jaunpuri (Special) respectively. General mean for this character was recorded to be 40.48 g.

#### **4.2.14 Number of fruits per plant**

The minimum number of fruits per plant was recorded in genotype IC-085612 (10.44) and maximum was recorded in genotype Special Bolder Ucha (25.31). The general mean value for number of fruits per plant was 16.70.

#### **4.2.15 Yield per plant (kg)**

Fruit yield is the ultimate outcome of almost all experiments. The genotype used for present study had a wide range of variation regarding the fruit yield per plant. Yield of fruits per plant ranged from 0.34 to 1.23 kg and had a general mean of 0.73 kg. The minimum yield was recorded in IC-085612 (0.34 kg), whereas the maximum yield was recorded in Meghna No. 2 (1.23 kg).

### **4.3 ESTIMATION OF VARIOUS GENETIC PARAMETRES**

The estimates of genetic parametres *viz.*, phenotypic and genotypic coefficient of variation (PCV and GCV), heritability in broad sense, genetic advance were computed for fifteen characters and are given in Table 4.3 and illustrated in Figure 4.2. It clearly indicates that phenotypic variance was higher as compare to the genotypic variance for all the characters under studies. From the data given, it is

obvious that the magnitude of phenotypic coefficient of variation was greater than the corresponding genotypic coefficient of variation for all characters.

Heritability is the transmissibility of characters from parents to offspring. It has got fundamental importance in selection, as it acts as predictive instrument in expressing the reliability of phenotypic value for different traits. Genetic advance is the improvement in the mean genotype value of the selected family over the base population after the complete cycle of the selection.

#### **4.3.1 Node number of first staminate flower appearance**

High genotypic coefficient of variation (20.66%) and phenotypic coefficient of variation (22.14%) were recorded for node number of first male flower appearance. High heritability (87.02%) with high genetic advance as percent of mean (39.70%) was observed for this trait.

#### **4.3.2 Node number of first pistillate flower appearance**

Moderate genotypic coefficient of variation (14.75%) as well as moderate phenotypic coefficient of variation (16.68%) were recorded for node number of first pistillate flower appearance. High heritability (78.14%) with high genetic advance as per cent of mean (26.85%) was observed for this trait.

#### **4.3.3 Days to anthesis of first staminate flower**

This character exhibited low genotypic coefficient of variation (9.98%) and moderate phenotypic coefficient of variation (10.80%) with high heritability (85.40%) associated with medium genetic advance as per cent of mean (18.99%).

#### **4.3.4 Days to anthesis of first pistillate flower**

This character exhibited low genotypic coefficient of variation (7.51%) and low phenotypic coefficient of variation (8.34%) with high heritability (80.97%) associated with medium genetic advance as per cent of mean (13.92%).

#### **4.3.5 Days to 50% flowering**

This character showed low genotypic coefficient of variation (7.22%) and phenotypic coefficient of variation (8.33%) with high heritability (75.17%) associated with moderate genetic advance as per cent of mean (12.90%).

#### **4.3.6 Days to first harvest**

Low per cent of both genotypic coefficient of variation (7.01%) and phenotypic coefficient of variation (8.00%) with high heritability (76.66%) associated with moderate genetic advance as per cent of mean (12.64%) were exhibited in this character.

#### **4.3.7 Number of primary branches per plant**

Moderate genotypic coefficient of variation (14.32%) and phenotypic coefficient of variation (17.73%) were recorded for number of primary branches per plant. High heritability (65.25%) coupled with high genetic advance as per cent of mean (23.83%) was observed for this character.

#### **4.3.8 Vine length (m)**

Vine length showed that both the genotypic and phenotypic coefficients of variation were found to be moderate *i.e.* 13.83 per cent and 15.70 per cent, respectively. The value of heritability in broad sense (77.59%) as well as genetic advance as per cent of mean (25.09%) were high.

#### **4.3.9 Internodal length (cm)**

Internodal length demonstrated that the genotypic coefficient of variation was found to be low (9.97%) and phenotypic coefficient of variation was moderate (10.86). The value of heritability in broad sense (84.26%) was high and genetic advance as per cent of mean (18.86%) was found to be moderate.

#### **4.3.10 Fruit length (cm)**

Genotypic coefficient of variation (15.35%) and phenotypic coefficient of variation (19.37%) for fruit length were observed to be moderate. High heritability (62.74%) coupled with high genetic advance as per cent of mean (25.04%) was observed for this character.

#### **4.3.11 Fruit circumference (cm)**

Moderate estimates of genotypic coefficient of variation (16.68%) and phenotypic coefficient of variation (19.10%), high heritability (76.25%) coupled with high genetic advance as per cent of mean (30.00%) were observed for this trait.

#### **4.3.12 Fruit diameter (cm)**

Moderate estimates of genotypic coefficient of variation (11.43%) and phenotypic coefficient of variation (13.08%) with high heritability (76.32%) coupled with high genetic advance as per cent of mean (20.57%) were observed for this trait.

#### **4.3.13 Average fruit weight (g)**

Average fruit weight was recorded with high genotypic coefficient of variation (28.17%) and phenotypic coefficient of variation (29.89%) and high heritability (88.83%) coupled with high genetic advance as per cent of mean (54.69%).

#### **4.3.14 Number of fruits per plant**

Number of fruits per plant was recorded with high genotypic coefficient of variation (21.47%) as well as high phenotypic coefficient of variation (25.43%). This character showed high heritability (69.06%) coupled with high genetic advance as per cent of mean (36.75%).

#### **4.3.15 Yield per plant (kg)**

The estimates of both genotypic and phenotypic coefficients of variation were found to be high i.e. 33.73 per cent and 36.47 per cent respectively. The estimate of heritability (85.52 %) coupled with the genetic advance was high as per cent of mean (64.26%) for this trait.

### **4.4 CORRELATION COEFFICIENT ANALYSIS**

The yield of the crop is a complex character and is the ultimate product of action and interaction of various component characters. Further, it is well known that no independent gene system is present for yield, but genes are available only for component characters (Grafius, 1964). Correlation of yield per plant with other characters should be studied because sometimes the selection on the basis of yield may not be effective due to low heritability. The phenotypic and genotypic correlation coefficient between yield per plant and node number of first staminate flower appearance, node number of first pistillate flower appearance, days to anthesis of first staminate flower, days to anthesis of first pistillate flower, days to 50% flowering, days to first harvest, number of primary branches per plant, vine length (m),

internodal length (cm), fruit length (cm), fruit circumference (cm), fruit diameter (cm), average fruit weight (g), number of fruits per plant and yield per plant (kg) were estimated and presented in Table 4.4 and Table 4.5 respectively and illustrated in Figure 4.3 and Figure 4.4.

In general, the result revealed the genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients in magnitude for all characters under study. The result obtained from the phenotypic and genotypic correlation coefficients are presented below character wise.

#### **4.4.1 Phenotypic correlation coefficient**

##### **4.4.1.1 Correlation between yield per plant and other characters**

Characters namely node number of first staminate flower appearance (0.321), node number of first pistillate flower appearance (0.472), vine length (0.338), fruit circumference (0.613), fruits per plant (0.467), average fruit weight (0.641), fruit diameter (0.491) and internodal length (0.225) are positively and significantly correlated with yield per plant, on the other hand, days to anthesis of first staminate flower (- 0.302) and days to first harvest (- 0.294) are negatively and significantly correlated with yield per plant.

##### **4.4.1.2 Mutual correlation between characters**

Node number of first staminate flower appearance showed significant and positive correlation with node number of first pistillate flower appearance (0.648), vine length (0.286), fruit length (0.277) and average fruit weight (0.426).

Node number of first pistillate flower appearance was positively and significantly correlated with vine length (0.369), fruit circumference (0.306), fruit diameter (0.255), average fruit weight (0.404) and fruits per plant (0.526) but showed negative and significant correlation with internodal length (- 0.359).

Days to anthesis of first staminate flower showed positive and significant association with days to anthesis of first pistillate flower (0.847), days to 50% flowering (0.762), days to first harvest (0.730) and number of primary branches per plant (0.301) but showed negative and significant association with vine length (-

0.262), fruit circumference (- 0.356), fruits per plant (- 0.346), fruit diameter (- 0.434), average fruit weight (- 0.076).

Days to anthesis of first pistillate flower showed positive and significant association with days to 50% flowering (0.757), days to first harvest (0.774), number of primary branches per plant (0.281) and fruit length (0.255) but showed negative and significant association with fruit diameter (- 0.345).

Days to 50% flowering showed positive and significant correlation with days to first harvest (0.705), number of primary branches per plant (0.395) and fruit length (0.351) but showed negative and significant association with fruit diameter (- 0.348) and fruit circumference (- 0.273).

Days to first harvest was positively and significantly correlated with number of primary branches per plant (0.260) and showed negative and significant association with vine length (- 0.316), fruit circumference (- 0.305), fruit diameter (- 0.271) and fruits per plant (- 0.304).

Number of primary branches per plant was positively and significantly correlated with vine length (0.328), internodal length (0.415), fruit length (0.274) and negatively and significantly associated with fruit circumference (- 0.298) and fruit diameter (- 0.268).

Vine length was positively and significantly correlated with fruits per plant (0.274).

Internodal length showed negative and significant association with fruit circumference (- 0.426), fruit diameter (- 0.371), fruit weight (- 0.433) and fruits per plant (- 0.270).

Fruit length is positively and significantly correlated with average fruit weight (0.508)

Fruit circumference is positively and significantly correlated with fruit diameter (0.577), average fruit weight (0.596) and fruits per plant (0.424).

Fruit diameter is positively and significantly correlated with fruit weight (0.327) and fruits per plant (0.314)

#### **4.4.2 Genotypic correlation coefficient**

##### **4.4.2.1 Correlation between yield per plant and other characters**

In the present study, characters like node number of first staminate flower appearance (0.375), node number of first pistillate flower appearance (0.540), vine length (0.417), fruit length (0.356), fruit circumference (0.790), fruit diameter (0.607), average fruit weight (0.768) and fruits per plant (0.637) and internodal length (0.300) are positively and significantly correlated with yield while days to anthesis of first staminate flower (- 0.331) and days to first harvest (- 0.355) are negatively and significantly correlated with yield per plant.

##### **4.4.2.2 Mutual correlation between characters**

Node number of first staminate flower appearance showed significant and positive correlation with node number of first pistillate flower appearance (0.770), days to 50% flowering (0.306), vine length (0.342), fruit length (0.499), fruit diameter (0.287) average fruit weight (0.476) and internodal length (- 0.341) showed negative and significant correlation.

Node number of first pistillate flower appearance was positively and significantly correlated with days to 50% flowering (0.296), vine length (0.487), fruit length (0.262), fruit circumference (0.386), fruit diameter (0.339), average fruit weight (0.520) and fruits per plant (0.667) but showed negative and significant correlation with internodal length (- 0.707).

Days to anthesis of first staminate flower showed positive and significant association with days to anthesis of first pistillate flower (0.997), days to 50% flowering (0.910), days to first harvest (0.980), number of primary branches per plant (0.416), internodal length (0.273), fruit length (0.315) but showed negative and significant association with vine length (- 0.313), fruit circumference (- 0.424), fruits per plant (- 0.420) and fruit diameter (- 0.499).

Days to anthesis of first pistillate flower recorded positive and significant correlation with days to 50% flowering (0.971), fruit length (0.255), number of primary branches per plant (0.281) and days to first harvest (0.774) but showed negative and significant association with fruit diameter (- 0.345).

Days to 50% flowering showed positive and significant correlation with days to first harvest (0.859), number of primary branches per plant (0.552) and fruit length (0.434) but showed negative and significant correlation with fruit diameter (- 0.426) and fruit circumference (- 0.404).

Days to first harvest was positively and significantly correlated with number of primary branches per plant (0.392) and internodal length (0.254) and showed negative and significant association with vine length (- 0.395), fruit circumference (- 0.419), fruit diameter (- 0.455) and fruits per plant (- 0.468).

Number of primary branches per plant was positively and significantly correlated with vine length (0.440), internodal length (0.529), fruit length (0.389) and negatively and significantly associated with Fruit circumference (- 0.457), Fruit diameter (- 0.355) and fruits per plant (- 0.372).

Vine length was positively and significantly correlated with fruit length (0.353), average fruit weight (0.307) and fruits per plant (0.403).

Internodal length showed negative and significant association with fruit circumference (- 0.785), fruit diameter (- 0.802), average fruit weight (- 0.636) and fruits per plant (- 0.629).

Fruit length is positively and significantly correlated with average fruit weight (0.662).

Fruit circumference is positively and significantly correlated with fruit diameter (0.650), average fruit weight (0.652) and fruits per plant (0.631).

Fruit diameter is positively and significantly correlated with fruit weight (0.382) and fruits per plant (0.330).

## **4.5 PATH COEFFICIENT ANALYSIS**

Path coefficient analysis is useful for partitioning of correlation coefficient into direct and indirect effects of various characters on fruit yield. It provides an effective way of finding out direct and indirect causes of association and presents a critical examination of the specific forces acting to produce a given correlation and measures the relative importance of each causal factor. The path coefficient analysis of different characters on fruit yield based on phenotypic and genotypic correlations in 20 genotypes of bitter melon are furnished in Table 4.6 and 4.7 respectively and illustrated in Figure 4.5 and Figure 4.6.

### **4.5.1 Phenotypic Path coefficient Analysis**

#### **4.5.1.1 Node number of first staminate flower appearance**

The node number of first staminate flower appearance had direct negative effect towards yield (- 0.0567). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via days to anthesis of first pistillate flower (0.0008) and showed highest negative indirect effect via node number of first pistillate flower appearance (- 0.0378).

#### **4.5.1.2 Node number of first pistillate flower appearance**

The node number of first pistillate flower appearance exerted direct positive effect towards yield (0.0919). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via node number of first staminate flower appearance (0.0613) and showed highest negative indirect effect via number of primary branches per plant (- 0.0179).

#### **4.5.1.3 Days to anthesis of first staminate flower**

The days to anthesis of first staminate flower showed direct negative effect towards yield (- 0.2630). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via fruit circumference (0.0938) and demonstrated highest negative indirect effect via days to anthesis of first pistillate flower (- 0.2227).

#### **4.5.1.4 Days to anthesis of first pistillate flower**

The days to anthesis of first pistillate flower had direct negative effect towards yield (- 0.0095). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via fruit circumference (0.0023) and showed highest negative indirect effect via days to first harvest (- 0.0073).

#### **4.5.1.5 Days to 50% flowering**

The days to 50% flowering demonstrated direct positive effect towards yield (0.2957). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via days to anthesis of first staminate flower (0.2252) and showed highest negative indirect effect via fruit diameter (- 0.1028).

#### **4.5.1.6 Days to first harvest**

The days to first harvest exerted direct negative effect towards yield (- 0.1520). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via vine length (0.0480 ) and showed highest negative indirect effect via days to anthesis of first pistillate flower (- 0.1176).

#### **4.5.1.7 Number of primary branches per plant**

The number of primary branches per plant had direct positive effect towards yield (0.2585). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via days to 50% flowering (0.1022) and showed highest negative indirect effect via fruit circumference (- 0.0770).

#### **4.5.1.8 Vine length (m)**

The vine length had direct positive effect towards yield (0.0011). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via internodal length (0.0006) and showed highest negative indirect effect via days to anthesis of first staminate flower and days to first harvest both having the same value (- 0.0003).

#### **4.5.1.9 Internodal length (cm)**

The internodal length (m) had direct negative effect towards yield (- 0.1621). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via days to anthesis of first staminate flower (0.0290) and showed highest negative indirect effect via vine length (- 0.0860).

#### **4.5.1.10 Fruit length (cm)**

The fruit length (cm) exerted direct negative effect towards yield (- 0.0662). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via fruits per plant (0.0060) and showed highest negative indirect effect via average fruit weight (- 0.0336).

#### **4.5.1.11 Fruit circumference (cm)**

The fruit circumference (cm) showed direct positive effect towards yield (0.0314). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via average fruit weight (0.0187) and showed highest negative indirect effect via days to anthesis of first staminate flower (- 0.0112).

#### **4.5.1.12 Fruit diametre (cm)**

The fruit diametre (cm) demonstrated direct positive effect towards yield (0.2020). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via fruit circumference (0.1166) and showed highest negative indirect effect via days to anthesis of first staminate flower (- 0.0877).

#### **4.5.1.13 Average fruit weight (g)**

The average fruit weight (g) had direct positive effect towards yield (0.5723). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via fruit circumference (0.3410) and showed highest negative indirect effect via days to first harvest (- 0.0741).

#### **4.5.1.14 Number of fruits per plant**

The number of fruits per plant showed direct positive effect towards yield (0.2744). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via node number of first pistillate flower appearance (0.1397) and showed highest negative indirect effect via days to anthesis of first staminate flower (- 0.0950).

#### **4.5.2 Genotypic Path coefficient Analysis**

##### **4.5.2.1 Node number of first staminate flower appearance**

The node number of first staminate flower appearance had direct negative effect towards yield (- 0.2283). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via days to anthesis of first pistillate flower (0.0085) and showed highest negative indirect effect via node number of first pistillate flower appearance (- 0.1814).

##### **4.5.2.2 Node number of first pistillate flower appearance**

The node number of first pistillate flower appearance exerted direct negative effect towards yield (- 0.3887). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via number of primary branches per plant (0.0489) and showed highest negative indirect effect via node number of first staminate flower appearance (- 0.3088).

##### **4.5.2.3 Days to anthesis of first staminate flower**

The days to anthesis of first staminate flower had direct positive effect towards yield (8.8440). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via days to anthesis of first pistillate flower (8.8179) and showed highest negative indirect effect via fruit diameter (- 4.4118).

##### **4.5.2.4 Days to anthesis of first pistillate flower**

The days to anthesis of first pistillate flower had direct negative effect towards yield (-2.8888). Regarding to indirect effect, this trait exhibited highest positive

indirect effect towards yield per plant via fruit diameter (1.2909) and showed highest negative indirect effect via days to anthesis of first staminate flower (- 2.8803).

#### **4.5.2.5 Days to 50% flowering**

The days to 50% flowering exerted direct negative effect towards yield (- 5.5339). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via fruit diameter (2.3586) and showed highest negative indirect effect via days to anthesis of first pistillate flower (- 5.3759).

#### **4.5.2.6 Days to first harvest**

The days to first harvest had direct negative effect towards yield (- 1.8054). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via fruits per plant (0.8451) and showed highest negative indirect effect via days to anthesis of first staminate flower(- 1.7702).

#### **4.5.2.7 Number of primary branches per plant**

The number of primary branches per plant had direct positive effect towards yield (2.3360). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via days to 50% flowering (1.2883) and showed highest negative indirect effect via fruit circumference (- 1.0685).

#### **4.5.2.8 Vine length (m)**

The vine length had direct negative effect towards yield (- 2.9473). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via days to first harvest (1.1647) and showed highest negative indirect effect via internodal length (- 1.9380).

#### **4.5.2.9 Internodal length (cm)**

The internodal length exerted direct positive effect towards yield (0.8720). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via vine length (0.5734) and showed highest negative indirect effect via days to anthesis of first staminate flower (- 0.1826).

#### **4.5.2.10 Fruit length (cm)**

The fruit length had direct positive effect towards yield (2.3366). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via average fruit weight (1.5462) and showed highest negative indirect effect via fruit diameter (- 0.5173).

#### **4.5.2.11 Fruit circumference (cm)**

The fruit circumference demonstrated direct negative effect towards yield (- 4.7088). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via number of primary branches per plant (2.1539) and showed highest negative indirect effect via average fruit weight (- 3.0722).

#### **4.5.2.12 Fruit diameter (cm)**

The fruit diameter exerted direct positive effect towards yield (2.6469). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via fruit circumference (1.7209) and showed highest negative indirect effect via days to anthesis of first staminate flower (-1.3204).

#### **4.5.2.13 Average fruit weight (g)**

The average fruit weight had direct positive effect towards yield (1.6812). Regarding to indirect effect, this trait exhibited highest positive indirect effect towards yield per plant via fruit length (1.1125) and showed highest negative indirect effect via days to first harvest (- 0.2299).

#### **4.5.2.14 Number of fruits per plant**

The Number of fruits per plant had direct positive effect towards yield (5.8768). Regarding to indirect effect, this trait showed highest positive indirect effect towards yield per plant via node number of first pistillate flower appearance (3.7510) and demonstrated highest negative indirect effect via days to first harvest (- 2.7509).





**View of germinating Seed**



**Seedling at initial growth stage**



**Variations among fruits of different genotypes of bitter gourd**



**Field view of male flower**



**Field view of female flower**

# JHARLI



# SPECIAL BOLDER UCHA



# VIKAS



# DHANRAJ



**MEGHNA NO. 2**



**NBR-NOBLE KATAHI**



**AROLA-D**



**IMPROVED KATHAI**



**Table 4.1 Analysis of Variance for 15 characters in 20 genotypes of bitter gourd**

Sl.No.	Character	Mean sum of square		
		Replications (df = 2)	Treatments (df = 19)	Error (df = 38)
1.	Node number of first staminate flower appearance	1.3705	19.850*	0.9431
2.	Node number of first pistillate flower appearance	1.1599	26.729*	2.2793
3.	Days to anthesis of first staminate flower	1.2667	72.978*	3.933
4.	Days to anthesis of first pistillate flower	0.8167	55.705*	4.0447
5.	Days to 50% flowering	11.4098	73.223*	7.2618
6.	Days to first harvest	5.0544	87.080*	8.0219
7.	Number of primary branches per plant	0.3086	5.480*	0.8262
8.	Vine length (m)	0.0337	0.418*	0.0367
9.	Internode length (cm)	0.0389	0.973*	0.0570
10.	Fruit length (cm)	5.5660	11.935*	1.9721
11.	Fruit circumference (cm)	0.7674	11.209*	1.0539
12.	Fruit diameter (cm)	0.1300	0.59*	0.0556
13.	Average fruit weight (g)	33.1271	406.399*	16.3435
14.	Number of fruits per plant	2.8376	44.339*	5.7600
15.	Yield per plant (kg)	0.0019	0.1936*	0.0103

\* Significant at 5%

**Table 4.2 Mean performance of twenty genotypes of bitter gourd**

Character	Node number of first staminate flower appearance	Node number of first pistillate flower appearance	Days to anthesis of first staminate flower	Days to anthesis of first pistillate flower	Days to 50% flowering	Days to first harvest	Number of primary branches per plant	Vine length (m)	Internode length (cm)	Fruit length (cm)	Fruit circumference (cm)	Fruit diameter (cm)	Average fruit weight (g)	Fruits per plant	Yield per plant (kg)
Jharli	10.50	17.35	41.00	50.33	59.42	66.42	7.67	2.45	5.65	12.50	12.06	3.75	52.11	18.46	1.00
Special Bolder Ucha	7.58	18.50	37.33	47.33	52.23	61.17	6.69	2.75	5.10	7.42	12.20	3.98	23.67	25.31	0.60
Meghna No. 2	13.45	19.83	40.67	49.33	60.04	66.51	9.64	2.92	6.09	10.76	12.92	4.76	46.63	18.28	1.23
Vikas	15.67	21.97	45.67	51.00	62.93	67.63	9.96	3.02	5.28	13.23	12.73	3.72	44.00	21.40	1.04
Improved Kathai	14.75	22.83	43.67	50.33	62.91	69.43	7.05	2.60	5.88	11.94	13.24	3.95	59.32	19.39	1.06
Arola - D	12.24	21.92	48.00	56.67	61.83	72.18	6.63	2.82	5.27	12.54	13.56	4.39	55.91	16.29	0.85
Dhanraj	15.01	23.15	50.67	57.33	67.04	79.34	7.25	1.97	4.94	11.88	12.24	4.26	35.15	19.89	0.73
NBR-Noble Katahi	13.58	22.93	50.33	58.33	69.38	71.86	7.86	2.75	5.78	11.91	13.01	3.73	53.21	21.88	1.03
Jaunpuri (Special)	14.79	20.84	52.00	59.00	69.40	75.87	10.00	2.64	6.18	16.04	12.97	3.95	63.39	14.70	0.85
Preethi	16.32	20.82	44.33	53.33	67.83	72.54	9.00	2.91	6.83	11.89	8.10	3.82	27.54	14.57	0.45
PF Uchia	9.08	17.44	53.67	60.33	70.67	76.19	10.49	2.84	5.36	12.90	9.51	2.98	28.79	16.37	0.47
Karola Gor	13.59	21.92	52.67	59.33	68.61	79.30	7.78	2.40	5.11	12.32	9.42	3.03	36.35	18.76	0.66
G.Uchia	9.83	19.71	50.33	60.67	69.90	80.50	10.45	2.94	6.20	13.61	11.85	3.59	42.51	18.86	0.96
IC-085608	11.40	19.72	52.00	58.33	68.47	73.70	7.83	2.35	5.15	10.85	8.97	3.35	33.80	12.89	0.47
IC-085609	12.14	20.39	53.67	60.67	70.74	81.53	10.30	2.57	4.85	10.30	9.72	3.34	34.95	15.29	0.63
IC-085610	8.33	14.12	52.67	58.00	67.70	75.65	9.40	1.96	4.97	10.11	9.54	3.69	24.49	12.39	0.65

IC-085611	11.50	17.00	54.00	57.67	65.52	79.18	9.33	2.25	5.90	9.96	7.98	3.72	36.20	13.42	0.45
IC-085612	8.63	12.50	45.33	51.33	58.58	73.85	7.33	1.76	4.61	9.88	12.27	3.57	30.50	10.44	0.34
IC-085613	11.37	15.42	48.33	54.67	62.74	72.97	9.15	2.60	5.61	15.85	10.13	3.20	43.98	13.32	0.64
IC-085615	13.33	18.83	45.33	51.33	62.28	69.84	10.17	3.09	6.08	11.59	8.25	3.33	37.09	12.17	0.54
<b>Mean</b>	<b>12.15</b>	<b>19.36</b>	<b>48.08</b>	<b>55.27</b>	<b>64.91</b>	<b>73.28</b>	<b>8.70</b>	<b>2.58</b>	<b>5.54</b>	<b>11.88</b>	<b>11.03</b>	<b>3.71</b>	<b>40.48</b>	<b>16.70</b>	<b>0.73</b>
C.V.	7.98	7.80	4.12	3.64	4.15	3.86	10.45	7.43	4.31	11.83	9.31	6.36	9.99	14.37	13.87
S.E.	21.12	11.73	18.55	13.77	10.08	10.86	6.63	11.39	17.07	6.05	10.64	10.67	24.87	7.70	18.73
C.D. 5%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C.D. 1%	0.56	0.87	1.15	1.16	1.56	1.64	0.52	0.11	0.14	0.81	0.59	0.14	2.33	1.39	0.06
Range Lowest	1.60	2.50	3.28	3.32	4.45	4.68	1.50	0.32	0.39	2.32	1.70	0.39	6.68	3.97	0.17
Range Highest	2.15	3.34	4.39	4.45	5.97	6.27	2.01	0.42	0.53	3.11	2.27	0.52	8.95	5.31	0.23

**Table 4.3 Variability, Heritability and Genetic Advance as per cent of mean for 15 characters in 20 genotypes of bitter gourd**

Sl. No.	Character	Range Min <sup>m</sup> - Max <sup>m</sup>	General Mean	Phenotypic variance	Genotypic variance	Phenotypic coefficient of variation	Genotypic coefficient of variation	Heritability in broad sense (h <sup>2</sup> b)	Genetic Advance as % of mean
1.	Node number of first staminate flower appearance	7.58 - 16.32	12.15	7.24	6.30	22.14	20.66	0.87	39.70
2.	Node number of first pistillate flower appearance	12.50 – 23.15	19.36	10.43	8.15	16.68	14.75	0.78	26.85
3.	Days to anthesis of first staminate flower	37.33 – 54.00	48.08	26.95	23.01	10.80	9.98	0.85	18.99
4.	Days to anthesis of first pistillate flower	47.33 – 60.67	55.27	21.96	17.22	8.34	7.51	0.81	13.92
5.	days to 50% flowering	52.23 – 70.74	64.91	29.25	21.99	8.33	7.22	0.75	12.90
6.	Days to first harvest	61.17 – 81.53	73.28	34.37	26.35	8.00	7.01	0.77	12.64
7.	Number of primary branches per plant	6.63 – 10.49	8.70	2.38	1.55	17.73	14.32	0.65	23.83

*Contd....*

<b>S.No.</b>	<b>Character</b>	<b>Range Max<sup>m</sup>-Min<sup>m</sup></b>	<b>General Mean</b>	<b>Phenotypic variance</b>	<b>Genotypic variance</b>	<b>Phenotypic coefficient of variation</b>	<b>Genotypic coefficient of variation</b>	<b>Heritability in broad sense (h<sup>2</sup>b)</b>	<b>Genetic advance as % of mean</b>
8.	Vine length (m)	1.76 – 3.09	2.58	0.16	0.13	15.70	13.83	0.78	25.09
9.	Internode length (cm)	4.61 – 6.83	5.54	0.36	0.31	10.86	9.97	0.84	18.86
10.	Fruit length (cm)	7.42 – 16.04	11.88	5.29	3.32	19.37	15.35	0.63	25.04
11.	Fruit circumference (cm)	7.98 – 13.56	11.03	4.44	3.39	19.10	16.68	0.76	30.00
12.	Fruit diametre (cm)	2.98 – 4.76	3.71	0.23	0.18	13.08	11.43	0.76	20.57
13.	Average fruit weight (g)	23.67 – 63.39	40.48	146.36	130.02	29.89	28.17	0.89	54.69
14.	Number of fruits per plant	10.44 – 25.31	16.70	18.62	12.86	25.83	21.47	0.69	36.75
15.	Yield per plant (kg)	0.34 – 1.23	0.73	0.07	0.06	36.47	33.73	0.86	64.26

**Table 4.4 Phenotypic correlation ( $r_p$ ) between yield and yield attributes for fifteen characters of twenty genotypes of bitter gourd**

Characters	Node no of first staminate flower appearance	Node no of first pistillate flower appearance	Days to anthesis of first staminate flower	Days to anthesis of first pistillate flower	Days to 50% flowering	Days to first harvest	Number of primary branches per plant	Vine length (m)	Internode length (cm)	Fruit length (cm)	Fruit circumference (cm)	Fruit diametre (cm)	Average fruit weight (g)	Fruits per plant	Yield per Plant (kg)
Node no of first staminate flower appearance	1.000	0.648**	0.021	-0.013	0.241	-0.003	0.047	0.286*	-0.281*	0.277*	0.059	0.236	0.426**	0.120	0.321*
Node no of first pistillate flower appearance		1.000	0.016	0.113	0.239	-0.007	-0.184	0.369**	-0.359**	0.179	0.306*	0.255*	0.404**	0.526**	0.472**
Days to anthesis of 1st staminate flower			1.000	0.847**	0.762**	0.730**	0.301*	-0.262*	0.160	0.216	-0.356**	-0.434**	-0.076	-0.346**	-0.302*
Days to anthesis of first pistillate flower				1.000	0.757**	0.774**	0.281*	-0.135	0.048	0.255*	-0.242	-0.345**	-0.002	-0.229	-0.182
Days to 50% flowering					1.000	0.705**	0.395**	-0.029	0.116	0.351**	-0.273*	-0.348**	0.006	-0.252	-0.098
Days to first harvest						1.000	0.260*	-0.316*	0.168	0.231	-0.305*	-0.271*	-0.130	-0.304*	-0.294*
Number of primary branches per plant							1.000	0.328*	0.415**	0.274*	-0.298*	-0.268*	-0.074	-0.210	-0.001
Vine length (m)								1.000	-0.053	0.215	0.052	0.013	0.253	0.274*	0.338**
Internode length (cm)									1.000	0.157	-0.426**	-0.371**	-0.433**	-0.270*	0.224**

Contd ....

<b>Fruit length (cm)</b>										1.000	0.175	-0.087	0.508**	-0.091	0.220
<b>Fruit circumference (cm)</b>											1.000	0.577**	0.596**	0.424**	0.613**
<b>Fruit diametre (cm)</b>												1.000	0.327*	0.314*	0.467**
<b>Average fruit weight (g)</b>													1.000	0.142	0.641**
<b>Fruits per plant</b>														1.000	0.491**

\* and \*\*Significant at 5% and 1% levels, respectively.

**Table 4.5 Genotypic correlation ( $r_g$ ) between yield and yield attributes for fifteen characters of twenty genotypes of bitter gourd**

Characters	Node no of first staminate flower appearance	Node no of first pistillate flower appearance	Days to anthesis of first staminate flower	Days to anthesis of first pistillate flower	Days to 50% flowering	Days to first harvest	Number of primary branches per plant	Vine length (m)	Internode length (cm)	Fruit length (cm)	Fruit circumference (cm)	Fruit diameter (cm)	Average fruit weight (g)	Fruits per plant	Yield per Plant (kg)
Node no of first staminate flower appearance	1.000	0.770**	0.004	- 0.037	0.306*	0.067	0.077	0.342**	- 0.341**	0.499**	0.123	0.287*	0.476**	0.145	0.375**
Node no of first pistillate flower appearance		1.000	0.016	0.141	0.296*	0.012	- 0.149	0.487**	- 0.707**	0.262*	0.386**	0.339**	0.520**	0.667**	0.540**
Days to anthesis of 1st staminate flower			1.000	0.997**	0.910**	0.980**	0.416**	-0.313*	0.273*	0.315*	- 0.424**	- 0.499**	- 0.079	- 0.420**	- 0.331**
Days to anthesis of first pistillate flower				1.000	0.971**	0.944**	0.380**	- 0.184	0.236	0.356**	- 0.329*	- 0.447**	- 0.044	- 0.256*	- 0.237
Days to 50% flowering					1.000	0.859**	0.552**	- 0.001	0.166	0.434**	- 0.404**	- 0.426**	0.036	- 0.227	- 0.097
Days to first harvest						1.000	0.392**	- 0.395**	0.254*	0.232	- 0.419**	- 0.455**	- 0.137	- 0.468**	- 0.355**
Number of primary branches per plant							1.000	0.440**	0.529**	0.389**	- 0.457**	- 0.355**	- 0.109	- 0.372**	- 0.024

Contd...

<b>Vine length (m)</b>								1.000	- 0.115	0.353**	0.085	0.087	0.307*	0.403**	0.417**
<b>Internode length (cm)</b>									1.000	- 0.041	- 0.785**	- 0.802**	-0.636**	- 0.629**	0.300**
<b>Fruit length (cm)</b>											0.158	- 0.221	0.662**	- 0.127	0.356**
<b>Fruit circumference (cm)</b>											1.000	0.650**	0.652**	0.631**	0.790**
<b>Fruit diametre (cm)</b>												1.000	0.382**	0.330*	0.607**
<b>Average fruit weight (g)</b>													1.000	0.216	0.768**
<b>Fruits per plant</b>														1.000	0.637**

\* and \*\*Significant at 5% and 1% levels, respectively.

**Table 4.6 Direct and indirect effects of phenotypic path coefficient for fifteen characters of twenty genotypes of bitter gourd**

Characters	Node no of first staminate flower appearance	Node no of first pistillate flower appearance	Days to anthesis of first staminate flower	Days to anthesis of first pistillate flower	Days to 50% flowering	Days to first harvest	Number of primary branches per plant	Vine length (m)	Internode length (cm)	Fruit length (cm)	Fruit circumference (cm)	Fruit diametre (cm)	Average fruit weight (g)	Fruits per plant
Node no of first staminate flower appearance	<b>-0.0567</b>	-0.0378	-0.0012	0.0008	-0.0136	0.0002	-0.0027	-0.0162	-0.0244	-0.0157	-0.0033	-0.0134	-0.0241	-0.0068
Node no of first pistillate flower appearance	0.0613	<b>0.0919</b>	0.0012	0.0109	0.0225	0.0014	-0.0179	0.0345	0.0151	0.0151	0.0247	0.0236	0.0359	0.0468
Days to anthesis of 1st staminate flower	-0.0056	-0.0035	<b>-0.2630</b>	-0.2227	-0.2004	-0.1921	-0.0792	0.0690	0.0471	-0.0568	0.0938	0.1141	0.0200	0.0910
Days to anthesis of first pistillate flower	0.0001	-0.0011	-0.0080	<b>-0.0095</b>	-0.0072	-0.0073	-0.0027	0.0013	0.0011	-0.0024	0.0023	0.0033	0.0000	0.0022
Days to 50% flowering	0.0711	0.0724	0.2252	0.2239	<b>0.2957</b>	0.2085	0.1169	-0.0085	0.0401	0.1039	-0.0808	-0.1028	0.0017	-0.0745
Days to first harvest	0.0004	-0.0023	-0.1110	-0.1176	-0.1072	<b>-0.1520</b>	-0.0395	0.0480	0.0161	-0.0351	0.0464	0.0412	0.0197	0.0462
Number of primary branches per plant	0.0122	-0.0502	0.0778	0.0725	0.1022	0.0673	<b>0.2585</b>	0.0848	0.0840	0.0709	-0.0770	-0.0692	-0.0191	-0.0543
Vine length (m)	0.0003	0.0004	-0.0003	-0.0001	0.0000	-0.0003	0.0004	<b>0.0011</b>	0.0006	0.0002	0.0001	0.0000	0.0003	0.0003
Internode length (cm)	-0.0698	-0.0267	0.0290	0.0185	-0.0220	0.0171	-0.0527	-0.0860	<b>-0.1621</b>	-0.0472	0.0136	-0.0288	-0.0554	0.0015

<b>Fruit length (cm)</b>	-0.0184	-0.0109	-0.0143	-0.0169	-0.0233	-0.0153	-0.0182	-0.0143	-0.0193	<b>-0.0662</b>	-0.0116	0.0058	-0.0336	0.0060
<b>Fruit circumference (cm)</b>	0.0019	0.0084	-0.0112	-0.0076	-0.0086	-0.0096	-0.0093	0.0016	-0.0026	0.0055	<b>0.0314</b>	0.0181	0.0187	0.0133
<b>Fruit diametre (cm)</b>	0.0477	0.0518	-0.0877	-0.0697	-0.0702	-0.0548	-0.0541	0.0027	0.0360	-0.0176	0.1166	<b>0.2020</b>	0.0662	0.0634
<b>Average fruit weight (g)</b>	0.2436	0.2235	-0.0436	-0.0010	0.0032	-0.0741	-0.0424	0.1450	0.1955	0.2907	0.3410	0.1874	<b>0.5723</b>	0.0813
<b>Fruits per plant</b>	0.0330	0.1397	-0.0950	-0.0630	-0.0692	-0.0834	-0.0577	0.0753	-0.0026	-0.0251	0.1164	0.0862	0.0390	<b>0.2744</b>
<b>Yield per plant (kg)</b>	<b>0.3212</b>	<b>0.4557</b>	<b>-0.3018</b>	<b>-0.1816</b>	<b>-0.0981</b>	<b>-0.2944</b>	<b>-0.0006</b>	<b>0.3384</b>	<b>0.2245</b>	<b>0.2202</b>	<b>0.6134</b>	<b>0.4674</b>	<b>0.6415</b>	<b>0.4908</b>

Residual effect = 0.5610

Bold: Direct effects

Normal: Indirect effects

**Table 4.7 Direct and indirect effects of genotypic path coefficient for fifteen characters of twenty genotypes of bitter gourd**

Characters	Node no of first staminate flower appearance	Node no of first pistillate flower appearance	Days to anthesis of first staminate flower	Days to anthesis of first pistillate flower	Days to 50% flowering	Days to first harvest	Number of primary branches per plant	Vine length (m)	Internode length (cm)	Fruit length (cm)	Fruit circumference (cm)	Fruit diametre (cm)	Average fruit weight (g)	Fruits per plant
Node no of first staminate flower appearance	<b>-0.2283</b>	-0.1814	-0.0009	0.0085	-0.0698	-0.0153	-0.0176	-0.0781	-0.1084	-0.1139	-0.0281	-0.0654	-0.1086	-0.0331
Node no of first pistillate flower appearance	-0.3088	<b>-0.3887</b>	-0.0115	-0.0525	-0.1198	-0.0055	0.0489	-0.1867	-0.1224	-0.0934	-0.1377	-0.1345	-0.1947	-0.2481
Days to anthesis of 1st staminate flower	0.0359	0.2612	<b>8.8440</b>	8.8179	8.0485	8.6714	3.6756	-2.7690	-1.8516	2.7871	-3.7465	-4.4118	-0.6961	-3.7102
Days to anthesis of first pistillate flower	0.1074	-0.3901	-2.8803	<b>-2.8888</b>	-2.8063	-2.7263	-1.0984	0.5320	0.3074	-1.0294	0.9501	1.2909	0.1279	0.7398
Days to 50% flowering	-1.6927	-1.7061	-5.0361	-5.3759	<b>-5.5339</b>	-4.7549	-3.0519	0.0085	-0.8193	-2.4007	2.2364	2.3586	-0.1989	1.2573
Days to first harvest	-0.1209	-0.0255	-1.7702	-1.7039	-1.5513	<b>-1.8054</b>	-0.7081	0.7134	0.2758	-0.4197	0.7567	0.8206	0.2469	0.8451
Number of primary branches per plant	0.1799	-0.2939	0.9708	0.8882	1.2883	0.9162	<b>2.3360</b>	1.0274	0.8935	0.9093	-1.0685	-0.8285	-0.2552	-0.8692
Vine length (m)	-1.0087	-1.4157	0.9228	0.5428	0.0045	1.1647	-1.2963	<b>-2.9473</b>	-1.9380	-1.0412	-0.2506	-0.2566	-0.9059	-1.1893
Internode length (cm)	0.4140	0.2745	-0.1826	-0.0928	0.1291	-0.1332	0.3335	0.5734	<b>0.8720</b>	0.3829	-0.1089	0.1856	0.3148	0.0010

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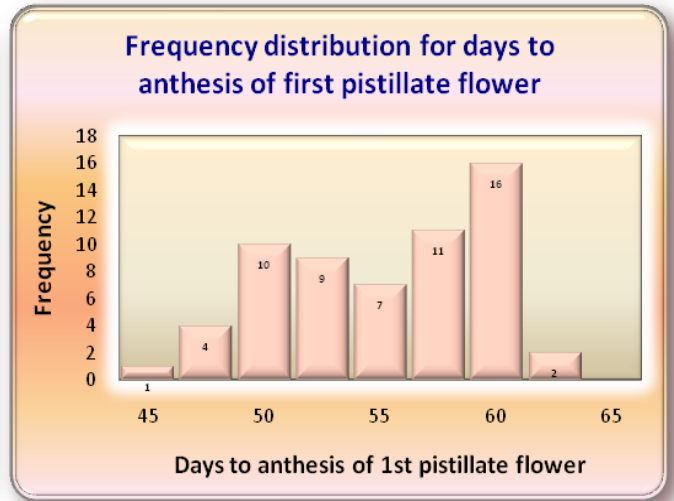
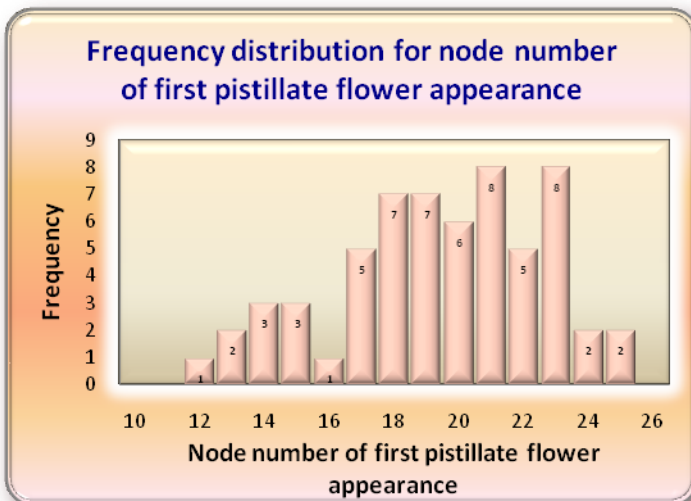
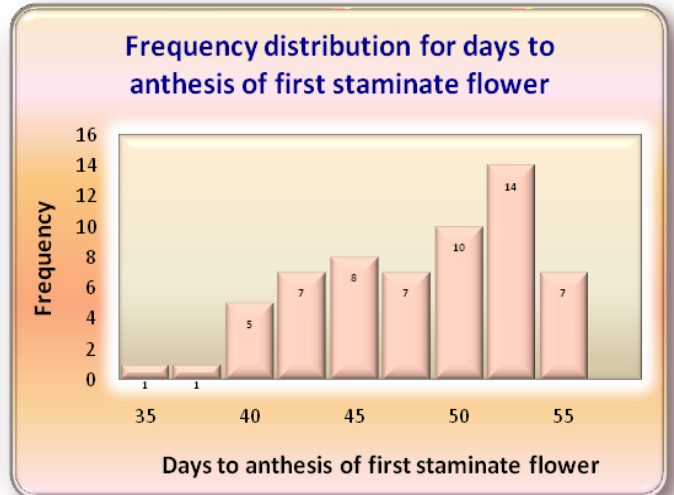
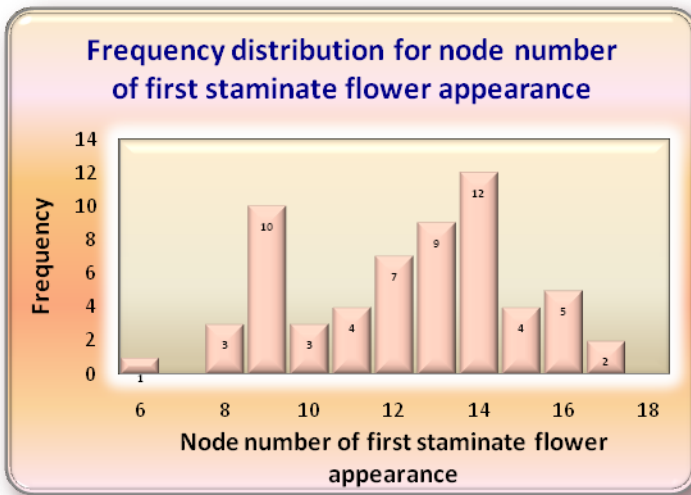
<b>Fruit length (cm)</b>	1.1655	0.5612	0.7364	0.8326	1.0137	0.5432	0.9095	0.8254	1.0262	<b>2.3366</b>	0.3683	-0.5173	1.5462	-0.2965
<b>Fruit circumference (cm)</b>	-0.5788	-1.6680	1.9947	1.5486	1.9029	1.9736	2.1539	-0.4004	0.5881	-0.7423	<b>-4.7088</b>	-3.0615	-3.0722	-2.9726
<b>Fruit diametre (cm)</b>	0.7585	0.9156	-1.3204	-1.1828	-1.1281	-1.2031	-0.9387	0.2304	0.5633	-0.5860	1.7209	<b>2.6469</b>	1.0111	0.8728
<b>Average fruit weight (g)</b>	0.7997	0.8421	-0.1323	-0.0745	0.0604	-0.2299	-0.1836	0.5168	0.6070	1.1125	1.0969	0.6422	<b>1.6812</b>	0.3638
<b>Fruits per plant</b>	0.8522	3.7510	-2.4654	-1.5050	-1.3352	-2.7509	-2.1867	2.3714	0.0070	-0.7458	3.7100	1.9378	1.2718	<b>5.8768</b>
<b>Yield per plant (kg)</b>	0.3748	0.5362	-0.3308	-0.2372	-0.0969	-0.3552	-0.0238	0.4170	0.3006	0.3561	0.7901	0.6070	0.7681	0.6375

Residual effect = 0.6142

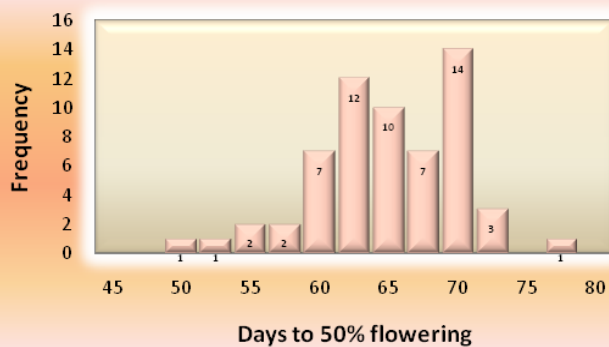
**Bold: Direct effects**

Normal: Indirect effects

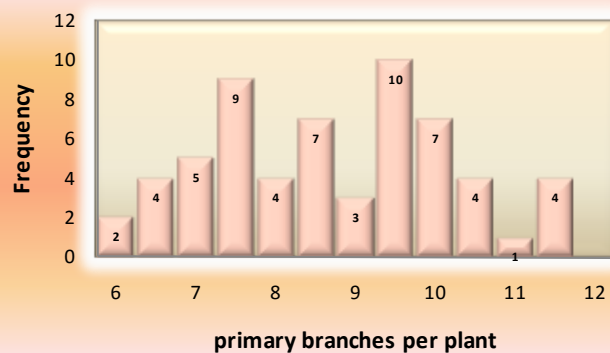
**Figure 4.1** Frequency distribution for yield and yield attributes of bitter gourd



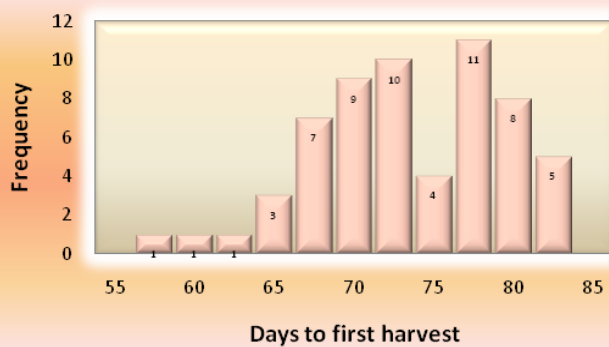
**Frequency distribution for days to 50% flowering**



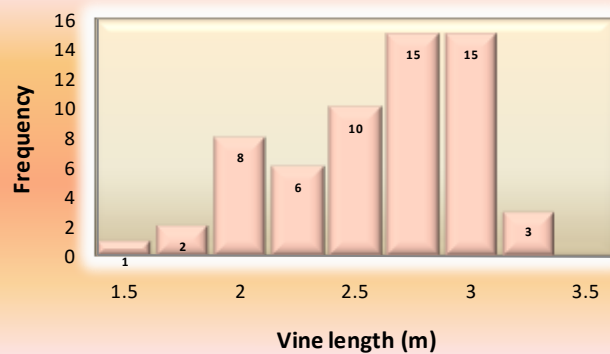
**Frequency Distribution for primary branches per plant**



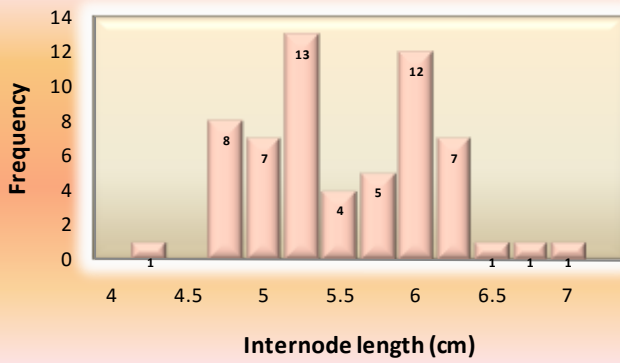
**Frequency distribution for days to first harvest**



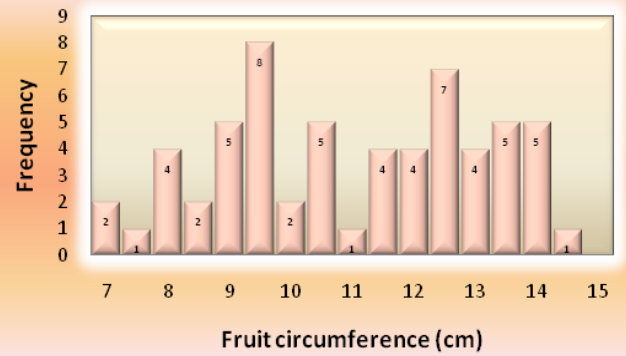
**Frequency Distribution for Vine length (m)**



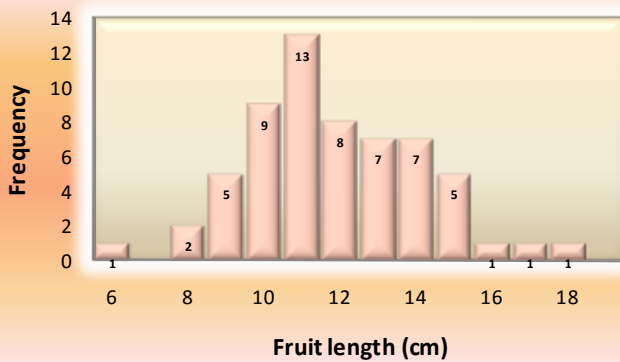
**Frequency Distribution for Internode length (cm)**



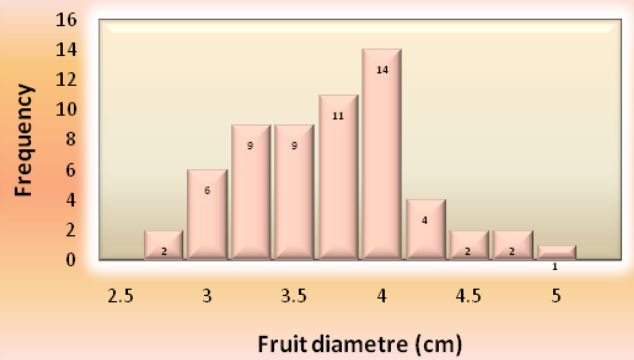
**Frequency Distribution for Fruit circumference (cm)**



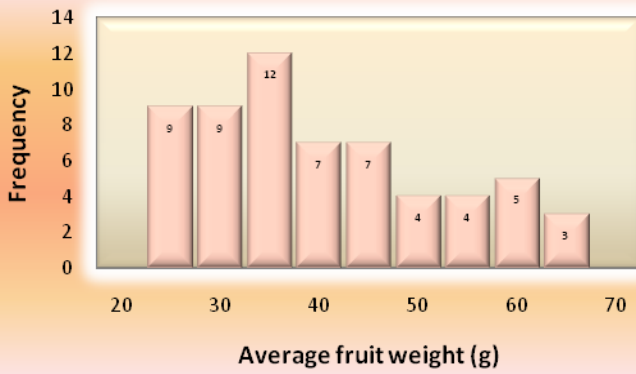
**Frequency Distribution for Fruit length (cm)**



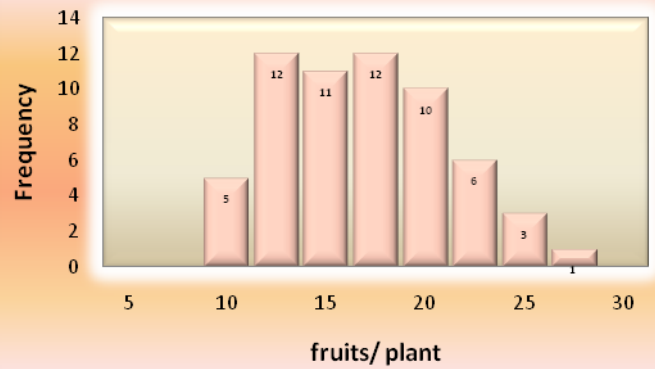
**Frequency Distribution for Fruit diameter (cm)**



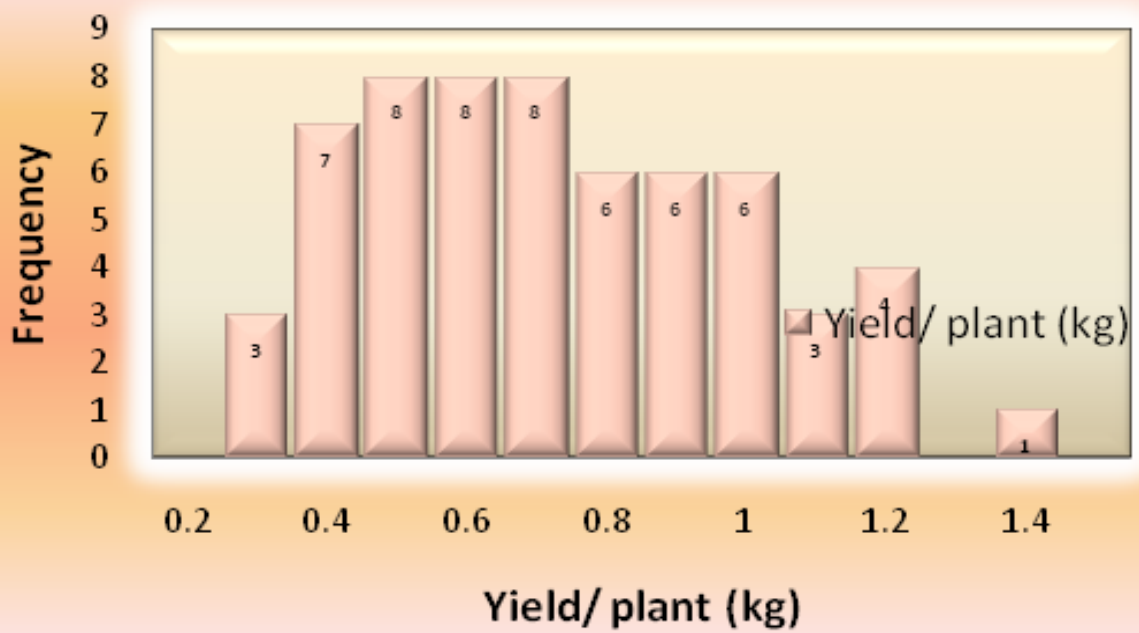
Frequency Distribution for Average fruit weight (g)



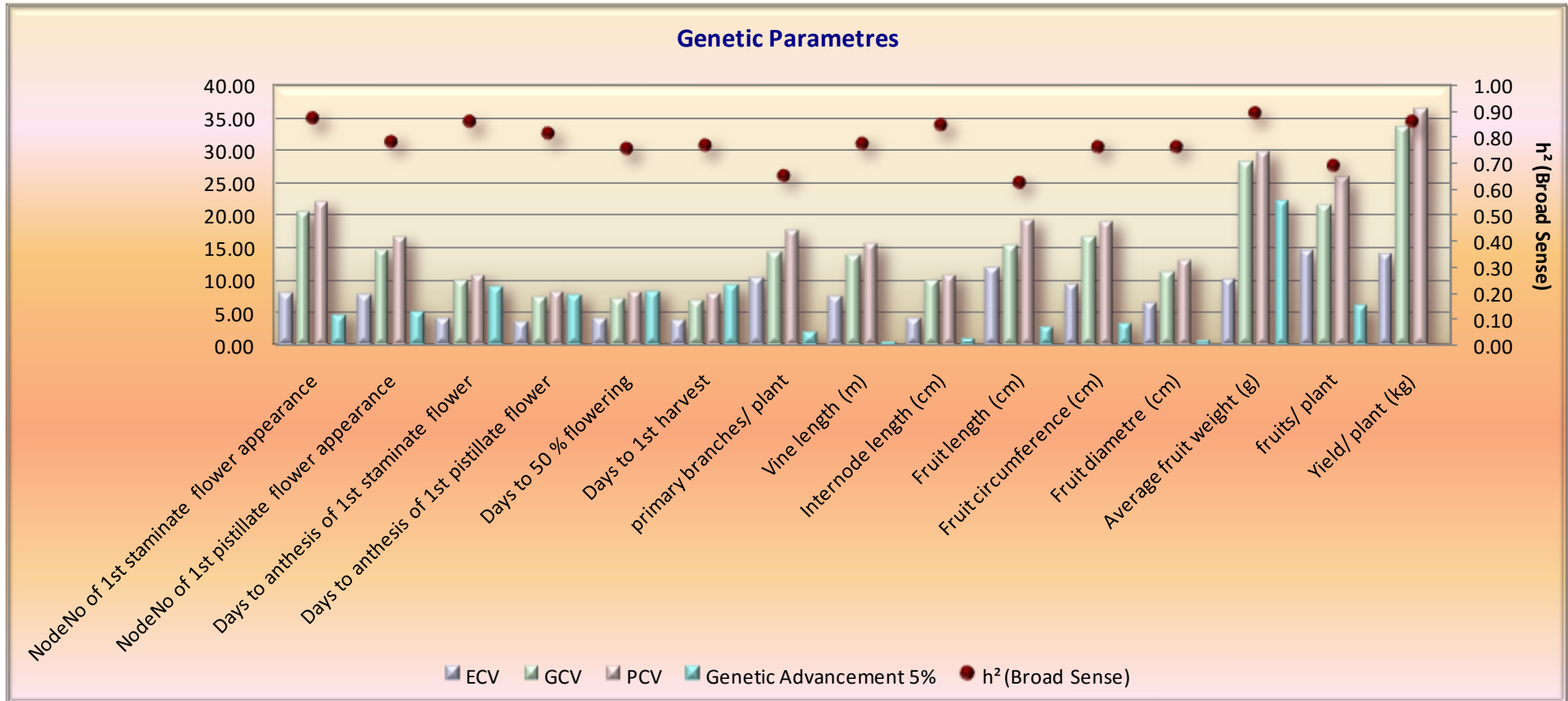
Frequency Distribution for fruits/ plant



Frequency Distribution for Yield/ plant (kg)



**Figure 4.2 Diagrammatic representation of different genetic parameters for 15 characters of bitter gourd**



## DISCUSSION

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Bitter gourd (*Momordica charantia* L.) is one of the most important cucurbitaceous vegetable crops grown in tropical and subtropical parts of India. It is well known for its high medicinal and nutritive properties but still is one of the underexploited vegetable crops. However there is a vast scope to evolve high productive varieties to cope with different agro-climatic conditions of the country. Germplasm collection, maintenance and evaluation for economically important traits are the prerequisites for genetic improvement of any crop and it is also a need to carry the investigation on genetic variability present in the germplasm for further improvement.

However, insufficient work has been done to exploit the available variability for the yield and quality improvement of bitter gourd. The reports and information with respect to systematic exploitation of variability in different crops of world are available even in pre-mendelian period which is attributed to cause significant increment in the yield and quality of the crops.

The potential of commercially grown cultivars is highly affected by variable environments. In addition to the genetical behavior of different desirable genotypes, they also vary due to outcrossing/open or natural pollination.

Almost all the breeding programmes ultimately aim at improving the characters of plants for agronomic and economic superiority. In this context, a sound knowledge of the nature and extent of genetic variability present in the germplasm or breeding materials are of paramount significance for a plant breeder while planning for a better breeding programme. Two facts always have high significance during every selection programme, the first one that the selection acts primarily upon the heritable variation and the second one is that the selection never creates genetic variability instead, it exploits the existing variability. It is well known that, an association of several other traits controls the yield, being a complex trait. Thus being acquainted with the yield attributes and their direct and indirect effects on yield is

considered very handy in order to achieve success in any breeding programme. In general, the yield is a polygenic trait and has relatively low heritability and that is why most of the times, the direct selection for increased yield is not proved effective.

Grafius (1964) pointed out that it would be more meaningful if the structure of yield is probed through its components rather than in itself yield. For improving yield through breeding, it is necessary to study these components and their inter relationships with yield. The phenotypic and genotypic correlations reveal the extent of association between different characters. Thus, it helps to base selection procedure to a required balance, when two opposite desirable characters affecting the principal characters are being selected. It also helps to improve different characters simultaneously (Falconer, 1981). As a preliminary step of heterosis breeding, it is desirable to investigate nature and degree of genetic variance in a population of different crops to develop high yielding varieties.

Therefore, in the present investigation, “**Genetic evaluation for yield and yield attributes in elite genotypes of bitter gourd (*Momordica charantia* L.)**” an attempt was made to characterize the germplasm accessions for the estimation of variability, broad sense heritability, predicted genetic advance, character association and path coefficient analysis with respect to 15 quantitative traits in 20 genotypes of bitter gourd. The results obtained from the experiment are discussed under following headings:

5.1 Mean Performance

5.2 Genetic Parametres

5.3 Correlation Studies

5.4 Path coefficient Analysis

## **5.1 MEAN PERFORMANCE**

The present investigation was undertaken to study the mean performance of twenty genotypes of bitter gourd. Perusal of the mean data for different yield and

yield contributing characters clearly showed change in ranking order of genotypes for some of the characters (Table 4.2).

The present investigation was carried out to assess the variability with respect of fifteen characters among twenty genotypes of bitter gourd and illustrated in Table 4.3. The mean sum of squares for treatments and error along with degree of freedom were presented in Table 4.1. The 'F' test indicated that the variance due to treatments were highly significant for almost all the characters under study. Highly significant differences among the genotypes of bitter gourd for all the characters under study were observed. The result suggested the presence of inherent genetic differences among the genotypes.

### **5.1.1 Range and mean**

In the present study, the range of variation was found to be highest for average fruit weight (23.6733 - 63.3900 g) followed by days to first harvest (61.1667 - 81.5267), days to 50% flowering (52.2270 - 70.7433), days to anthesis of first staminate flower (37.3333 - 54.0000), fruits per plant (10.4423 - 25.3130), days to anthesis of first pistillate flower (47.3333 - 60.6667), node no of first pistillate flower appearance (12.5000 - 23.1453), node no of first staminate flower appearance (7.5833 - 16.3183), fruit length (7.4190), fruit circumference (7.9830 - 13.5577), number of primary branches per plant (6.6300 - 10.4867), internode length (4.6060 - 6.8333), fruit diameter (2.9823 - 4.7560), vine length (1.7600 - 3.0933) and yield per plant (0.3423 - 1.2343). This is in accordance with research on different cucurbits by various workers like by Akter *et al.* (2013) in pumpkin, Khule *et al.* (2011) and Kumar *et al.* (2013) in sponge gourd.

Maximum numbers of days were recorded for anthesis of first staminate flower in IC-085611, PF Uchia and IC-085609. The days of first appearance of male flower play an important role in deciding the earliness or lateness of crops in general. Similar findings were reported by Yadav *et al.* (2008), Singh *et al.* (2012) and Yadav *et al.* (2013) in bitter gourd.

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## 5.2 GENETIC PARAMETRES

### 5.2.1 Genetic variability

Variability is a key factor which determines the amount of progress expected from selection and to be more accurate, it becomes necessary to split the phenotypic variability into heritable and non-heritable components with the help of genetic parametres such as genotypic and phenotypic coefficient of variation, heritability and genetic advance to facilitate selection (Table 4.3). Hence, an insight into the magnitude of genetic variability available is of paramount importance to a plant breeder for starting a judicious breeding programme. The present study was undertaken to evaluate twenty genotypes of bitter gourd in term of variability.

Variance is the statistical parametre, which measures variation within a particular trait. But it does not provide real picture for the comparison of variation between different attributes. The phenotypic coefficient of variation was in general, higher than the genotypic coefficient of variation. But the differences between phenotypic and genotypic coefficient of variation was less suggesting the less influence of environment for the traits like days to anthesis of first staminate flower (0.82), anthesis of first pistillate flower (0.83), internode length (0.89). The disparity between phenotypic and genotypic coefficient of variation recorded for all characters were very less in the investigation, indicating that the characters are not much susceptible to environmental fluctuations. Similar result was reported in bitter gourd by Raja *et al.* (2007) and Singh *et al.* (2012).

Phenotypic coefficient of variation was of higher magnitude than that of genotypic coefficient of variation for all the traits showing that the environment had an important role in influencing the expression of the traits.

The highest phenotypic coefficient of variation was observed for yield per plant i.e. 36.47 followed by average fruit weight (g), number of fruits per plant and number of first staminate flower appearance. The highest genotypic coefficient of variation was observed for yield per plant i.e. 33.73 followed by average fruit weight (g), number of fruits per plant and number of first staminate flower appearance. These findings are in close conformity with findings of Dey *et al.* (2009) in bitter gourd,

Sengupta *et al.* (2014) in fennel, Rai *et al.* (2012) in cluster bean and Ullah *et al.* (2012) in cucumber.

Moderate coefficient of variation at phenotypic level was observed for node number of first pistillate flower appearance, days to anthesis of first staminate flower, number of primary branches per plant, vine length (m), internode length (cm), fruit length (cm), fruit circumference (cm), and fruit diameter (cm). Moderate coefficient of variation at genotypic level was observed for node number of first pistillate flower appearance, number of primary branches per plant, vine length (m), fruit length (cm), fruit circumference (cm), and fruit diameter (cm).

Low coefficient of variation at phenotypic level was observed for days to anthesis of first pistillate flower, days to 50% flowering and days to first harvest. Low coefficient of variation at genotypic level was observed in days to anthesis of first staminate flower, days to anthesis of first pistillate flower, days to 50% flowering, days to first harvest and internode length.

Similar results were also reported by Pandey *et al.* (2009) in snap melon and Kumar *et al.* (2013) in tomato.

### **5.2.2 Heritability and Genetic Advance**

The genotypic coefficient of variation provides a measure for comparison of variability among different traits and sometimes gives some indication regarding validity of traits for selection. However, it does not provide clear picture of the extent of genetic gain to be expected from selection of phenotypic traits, unless heritable fraction of variation (heritability) is known (Burton, 1952). The effectiveness of selection for a trait depends in the expression of phenotypic differences among the genotypic in a population referred to as heritability. The heritability of a character has major impact on the method chosen for population improvement.

The heritability is the measure of the fraction of the phenotypic variation caused by the action of the genes. For making effective improvement in a trait under selection, heritability has been adopted by the large number of workers as a reliable indicator. Heritability in broad sense according to Lush (1949) is the ratio of total

genotypic variance to phenotypic variance, generally expressed in percentage. The estimates of heritability are more advantageous when expressed in terms of genetic advance. Johnson *et al.* (1955) suggested that the estimate of heritability without genetic advance will not be of practical value and he emphasized the concurrent use of genetic advance along with heritability.

In the present investigation, heritability and genetic advance have been calculated for all the fifteen characters under study. The magnitude of heritability ranged from 62.74% (fruit length) to average fruit weight (88.83%). High heritability is found in all the characters (> 60%).

High heritability observed in a character indicates that environment had less effect in controlling that particular character. Hence, direct selection for this trait will be more effective. The above findings are in close agreement with those of Singh *et al.* (2015) in bitter gourd, Radharani *et al.* (2013) in bitter gourd, Rahman *et al.* (2002) in snake gourd.

The estimate of genetic advance as per cent of mean showed a wide range from 12.64% (days to first harvest) to 64.26% (yield per plant). The other traits expressing high genetic advance as per cent of mean of are average fruit weight (g), node number of first staminate flower appearance, node number of first pistillate flower appearance, number of primary branches per plant, vine length (m), fruit length (cm), fruit circumference (cm), fruit diameter (cm) and number of fruits per plant. These results are in conformity with the findings of Jat *et al.* (2014) and Singh *et al.* (2008) in bitter gourd and Khule *et al.* (2011) in sponge gourd.

Heritability in broad sense is not true indicator of inheritance of traits, since only additive component of genetic variance is efficiently transferred from generation to generation. Therefore, heritability in broad sense may mislead in judging the effectiveness of selection for the trait. Considering heritability in broad sense along with genetic advance may reveal the prevalence of specific components (additive or non additive) of genetic variance for the trait more accurately. In the present study most of the characters recorded high heritability estimates and selection would be

effective if based on phenotypic values. However, high heritability estimates coupled with high genetic advance render the selection most effective (Johnson *et al.*, 1955).

In the present study, high heritability was accompanied with high genetic advance as per cent of mean for average fruit weight (88.83, 54.69), yield per plant (85.52, 64.26), node number of first staminate flower appearance (87.02, 39.70), node number of first pistillate flower appearance (78.14, 26.85), vine length (77.59, 25.09), number of fruits per plant (69.06, 36.75), number of primary branches per plant (65.25, 23.83) and fruit length (62.74, 25.04). High heritability coupled with good level of genetic advance for these characters indicate the effectiveness of selection for the improvement of these traits. Similar results were also reported by Raja *et al.* (2007) in bitter melon, Akter *et al.* (2013) and Muralidhara *et al.* (2014) in pumpkin.

### **5.3 CORRELATION STUDIES**

The aim of correlation studies is primarily to know the suitability of various characters for indirect selection because selection for one or more traits results correlated response for several traits and the pattern of variation will also be changed (Robinson *et al.*, 1966).

The information of interrelationship of the important economic traits may be useful in the prediction of correlated response to direct selection indices and detection of some characters, which may have no value on themselves but may be useful as indicator of the important characters (Robinson *et al.*, 1951) and (Johnson *et al.*, 1955). The utility of estimates of correlation is considerably increased by partitioning it into phenotypic, genotypic and environmental components (Burton, 1952).

Correlation studies provide better understanding of yield components which helps the plant breeders during selection (Johnson *et al.*, 1995). It measures degree and direction of association between two or more characters. Correlation coefficient measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for genetic improvement in yield. This kind of analysis could help the breeders to design their selection strategy to improve the fruit yield. Grafius (1964) put it as “there is no way in which yield can be changed without changing one or more of the components.” The knowledge of

correlation between complex characters like yield and its component characters, is of considerable use towards improvement of the yield.

The present investigation revealed that genotypic correlation coefficient was higher in magnitude than respective phenotypic correlation coefficient for most of the characters (Table 4.4) which may be attributed to the masking effect of the environmental factors in revealing the true association. This is in conformity with works on different cucurbits by Rashid *et al.* (2014) in snake gourd, Islam *et al.* (2009) and Singh *et al.* (2014) in bitter gourd.

In present investigation, significant positive correlation exhibited by node number of first staminate flower appearance with fruit length, average fruit weight and yield per plant suggests that node number of first staminate flower can be used for indirect selection for yield improvement as it had shown high heritability and genetic advance. Similar findings were correlated by Singh *et al.* (2014), Bhave *et al.* (2003) in bitter gourd.

Node number of first pistillate flower appearance showed significant positive correlation with yield per plant and some yield traits like fruits per plant, vine length, fruit circumference, fruit diameter and average fruit weight which indicates the potentiality of this trait to be utilized in selection programme aiming at yield improvement as it also has shown high heritability and genetic advance. These results are in agreement with the findings of Singh *et al.* (2012) in bitter gourd and Dubey *et al.* (2013) in ridge gourd.

Vine length recorded with high heritability and genetic advance demonstrated significant positive correlation with yield per plant and fruits per plant showing the utility of this trait for further selection programme regarding yield improvement. Similar types of findings were also reported by Dey *et al.* (2005) in bitter gourd.

Fruit circumference showed high significant positive correlation with yield per plant along with major yield traits like fruit diameter, fruits per plant and average fruit weight. This trait also has potentiality to be used in selection of high yielding genotypes as high heritability and genetic advance is found for this trait. These results are in agreement with the findings of Akter *et al.* (2013) in pumpkin.

Average fruit weight and fruits per plant (which had shown high heritability coupled with genetic advance) are important yield traits as their association with yield has been found to be highly significant. Similar findings were reported by Pandit *et al.* (2009) in bottle gourd and Narayan *et al.* (2006) in bitter gourd.

On the other hand, significant negative correlation with yield per plant and yield traits like fruit diameter, average fruit weight and fruits per plant was exhibited by internode length interpreting that higher the internode length, lower will be the yield.

Similarly days to anthesis of first staminate flower exerted significant negative correlation with yield per plant and yield traits like fruits per plant, fruit diameter and fruit circumference demonstrating the lines with less number of days to anthesis of male flower are comparatively high yielders.

Days to first harvest exhibited significant negative correlation with yield per plant and yield traits like vine length, fruit circumference, fruits per plant and fruit diameter showing that genotypes which were early in days to first harvest are usually high yielders.

### **5.3 PATH COEFFICIENT ANALYSIS**

Path coefficient analysis gives an insight into a complex relationship among different characters in a biological system and provides information whether the observed correlation is due to the direct influence or indirect influence via other variables, thus, path coefficient analysis specifies the cause and also gives the relative importance of the character.

Path coefficient analysis is the partitioning of the total correlation into direct and indirect effects of causal factor to the effect. This technique was developed by Wright (1921). In correlation analysis, too much confidence is usually placed. Significant correlation does not necessarily signify high direct causal relationship. When more numbers of causal variables are considered in the correlation, indirect association becomes more and more complex. Thus, to overcome these problems, and to know the direct and indirect contribution of causal factor, the path coefficient is done. Path coefficient is defined as the proportion of standard deviation of dependent variable “Y” arising as a result of the variation in the independent variable “X”. Path

coefficient is similar to correlation in respect that it is an absolute number without any physical unit. Path analysis is now being frequently used in plant breeding. The first case of application was reported by Dewey and Lu (1959). After 1960, the path analysis was conducted by number of workers in different crops.

Path coefficient analysis was used to compute direct and indirect effects of fifteen characters on marketable fruit yield in the present study.

Results indicated that highly significant positive association of node number of first pistillate flower appearance with yield per plant was mainly due to its indirect effect on yield via other traits like average fruit weight and fruits per plant as it had very small magnitude of direct effect. So the emphasis should be given on average fruit weight and fruit per plant rather than direct selection for node number of first pistillate flower appearance.

Node number of first staminate flower appearance had highly significant positive association with yield plant chiefly due to its indirect effect on yield via other traits like average fruit weight and number of first pistillate flower appearance as it showed very low direct effect. So focus should be given on average fruit weight and number of first pistillate flower appearance instead of direct selection of its own.

Highly significant positive association of vine length with yield was mainly as a result of its indirect effect on yield per plant via other traits like average fruit weight and number of primary branches per plant as it had very less magnitude of direct effect. So the prime importance should be given on average fruit weight and number of primary branches per plant rather than direct selection for vine length.

Fruit length had highly significant positive association with yield chiefly due to its indirect effect on yield per plant via average fruit weight and days to 50% flowering and its negative direct effect is nullified by its indirect effects. So, direct selection for fruit length is not advisable.

Fruit circumference showed highly significant positive association with yield chiefly due to its indirect effect on yield per plant via traits like average fruit weight and fruit diameter as it had very minute magnitude of direct effect. So the prime importance should be given on average fruit weight and fruit diameter rather than direct selection for fruit circumference.

Fruit diameter showed highly significant positive association with yield mainly due to its direct effect on yield per plant. So, prime focus should be given on direct selection this trait itself.

Average fruit weight showed highly significant positive association with yield mainly due to its direct effect on yield per plant. So, more importance should be given on direct selection for this trait itself.

Fruits per plant showed highly significant positive association with yield mainly due to its direct effect on yield per plant. So, more importance should be given on direct selection for this trait itself.

Internode length showed highly significant positive association with yield mainly due to its indirect effect on yield per plant via traits like average fruit weight and number of primary branches per plant and its negative direct effect is nullified by its indirect effects. So, direct selection for internode length is not advisable.

The results are in accordance with the findings of Sundaram (2008), Pathak *et al.* (2014), Sanwal *et al.* (2007), Bhave *et al.* (2003), Dalamu and Behera (2013), Singh *et al.* (2015), Akter *et al.* (2013) in bitter gourd..

Days to anthesis of first staminate flower demonstrated highly significant negative correlation mainly due to its direct effect on yield per plant. So, more importance should be given on selection of the genotypes which exhibit earlier days to anthesis of first staminate flower for yield improvement.

Days to first fruit harvest exhibited highly significant negative association chiefly due to its direct effect on yield per plant. So, major focus should be given on selection of the genotypes which are earlier to first fruit harvest for improvement of yield.

Similar results were also observed by Singh *et al.* (2015) in bitter gourd and Akter *et al.* (2013) in pumpkin.

In this study, the residual effects of phenotypic and genotypic path coefficient were found to be 0.5610 and 0.6142 respectively indicating that some traits which are not included in study may have higher importance in relation to yield. These results are in conformity with the findings of Dey *et al.* (2005), Sundaram (2010), Singh *et al.* (2012) and Pandey *et al.* (2012).



## SUMMARY AND CONCLUSION

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The present investigation entitled “**Genetic evaluation for yield and yield attributes in elite genotypes of bitter gourd (*Momordica charantia* L.)**” was carried out at the Vegetable Research Farm, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.) during kharif season of 2014. The experiment was conducted in Randomized Complete Block Design (RBD) involving twenty elite genotypes of bitter gourd with three replications.

The data on fifteen characters namely node number of first staminate flower appearance, node number of first pistillate flower appearance, days to anthesis of first staminate flower, days to anthesis of first pistillate flower, days to 50% flowering, days to first harvest, number of primary branches per plant, vine length (m), internode length (cm), fruit length (cm), fruit circumference (cm), fruit diameter (cm), average fruit weight (g), number of fruits per plant and yield per plant (kg) were recorded from five randomly selected plants for each genotypes. The experiment was conducted to achieve following objectives:

1. To estimate the extent of variability for yield and yield attributes in given the set of genotypes.
2. To estimate the extent of phenotypic and genotypic correlation between the yield and yield related characters.
3. To estimate the direct and indirect effects of different yield traits on yield per plant through path coefficient analysis.
4. To identify some superior genotypes for high yield.

The data were subjected to analysis of variance, genetic variability (genotypic and phenotypic coefficient of variation), heritability and genetic advance at per cent mean. At the same time correlation coefficient analysis along with path coefficient analysis were also calculated.

The results obtained on different aspects are summarized below:-

1. Analysis of variance indicated highly significant differences among the genotypes for all the characters including the presence of wide range of variability in the genotypes studied showing ample opportunity for further improvement of all the traits studied.
2. Higher magnitude of GCV and PCV were observed for the traits like yield per plant (kg), average fruit weight (g), fruits per plant and node number of first staminate flower appearance showing relatively higher variation for these traits.
3. Selection for traits like yield per plant (kg), average fruit weight (g), node number of first staminate flower appearance and fruit circumference (cm) will be fruitful as they possess high heritability coupled with high genetic advance.
4. High positive correlation coefficient with yield was demonstrated by average fruit weight (g), fruit circumference (cm), fruits per plant and node number of first pistillate flower appearance.
5. Traits like days to anthesis of first staminate flower and days to first fruit harvest exhibited high negative correlation coefficient with yield.
6. Path coefficient analysis revealed that average fruit weight (g) had maximum direct positive effect on yield per plant. Traits like days to 50% flowering, fruits per plant and number of primary branches per plant had also shown high positive effect on yield per plant.
7. High indirect positive effect was observed by node number of first staminate flower, node number of first pistillate flower, vine length (cm) and internode length (m).

8. High direct negative effect was exhibited by days to anthesis of first staminate flower and days to first harvest.
9. High indirect negative effect was showed by days to anthesis of first staminate flower and days to first harvest.

### **Conclusion**

Generally, yield is the ultimate objective of a breeding programme.

High heritability coupled with high genetic advance associated with average fruit weight, number of fruits per plant and number of primary branches per plant suggest their applicability for identification of high yielding lines as these traits had shown high direct positive effect on yield.

In the present study in relation to yield, the genotypes Meghna No. 2, Improved Kathai and Vikas were among the high yielding lines.

On the basis of days to first fruit harvest, the genotypes like Jharli, Special Bolder Ucha and Meghna No. 2 can be recommended for early capturing of market to fetch high price.

As Meghna No. 2 possess both high yielding nature along with early days to first harvest so it can be the genotype of choice for higher return.



**Table 6.1 Superior genotypes based on mean performance for yield per plant and yield attributes**

Characters	Promising genotypes		
	I.	II.	III.
<b>Node no of first staminate flower appearance</b>	Preethi	Vikas	Dhanraj
<b>Node no of first pistillate flower appearance</b>	Dhanraj	NBR-Noble Kathai	Improved Kathai
<b>Days to anthesis of 1st staminate flower</b>	IC-085611	PF Uchia	IC-085609
<b>Days to anthesis of first pistillate flower</b>	G.Uchia	IC-085609	PF Uchia
<b>Days to 50% flowering</b>	IC-085609	PF Uchia	G.Uchia
<b>Days to first harvest</b>	IC-085609	G.Uchia	Dhanraj
<b>Number of primary branches per plant</b>	PF Uchia	G.Uchia	IC-085609
<b>Vine length (m)</b>	IC-085615	Vikas	G.Uchia
<b>Internode length (cm)</b>	Preethi	G.Uchia	Jaunpuri (Special)
<b>Fruit length (cm)</b>	Jaunpuri (Special)	IC-085613	G.Uchia
<b>Fruit circumference (cm)</b>	Arola - D	Improved Kathai	NBR-Noble Kathai
<b>Fruit diametre (cm)</b>	Meghna No. 2	Arola - D	Dhanraj
<b>Average fruit weight (g)</b>	Jaunpuri (Special)	Improved Kathai	Arola - D
<b>Fruits per plant</b>	Special Bolder Ucha	NBR-Noble Kathai	Vikas
<b>Yield per plant (kg)</b>	Meghna No. 2	Improved Kathai	Vikas

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