

**“VARIABILITY STUDIES OF F₄ GENERATION IN BITTER GOURD
(*Momordica charantia* L.)”**

by

Mr. Daware Mayuresh Digambar

(Reg. No. 2021/312)

A thesis submitted to the
MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI-413 722, DIST- AHMEDNAGAR
MAHARASHTRA, INDIA

In partial fulfilment of the requirements for the degree
of
MASTER OF SCIENCE (HORTICULTURE)
in
VEGETABLE SCIENCE



DEPARTMENT OF HORTICULTURE

POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI-413 722, DIST- AHMEDNAGAR
MAHARASHTRA STATE (INDIA)

2024

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APPROVED BY

Dr. M. N. Bhalekar

(Chairman and Research Guide)

Dr. D. B. Kshirsagar
(Committee Member)

Mrs. D. D. Patil
(Committee Member)

Dr. A. R. Aher
(Committee Member)

DEPARTMENT OF HORTICULTURE

**POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI-413 722, DIST- AHMEDNAGAR
MAHARASHTRA, INDIA**

2024

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part
thereof has not been submitted
by me or any other person to any
other University or Institution
for a Degree or
Diploma.

Place : MPKV., Rahuri.

Date : / /2024

(M. D. Daware)

Dr. M. N. Bhalekar

Ex-Senior Vegetable Breeder,
AICRP on Vegetable crops,
Department of Horticulture,
Mahatma Phule Krishi Vidyapeeth,
Rahuri-413 722, Dist. Ahmednagar,
Maharashtra, India.

CERTIFICATE

This is to certify that the thesis entitled, “**VARIABILITY STUDIES OF F₄ GENERATION IN BITTER GOURD (*Momordica charantia* L.)**” submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar in partial fulfilment of the requirement for the award of the degree of **MASTER OF SCIENCE (HORTICULTURE)** in **VEGETABLE SCIENCE**, embodies the result of a piece of bonafide research work carried out by **Mr. DAWARE MAYURESH DIGAMBAR**, under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

Place: MPKV., Rahuri.

Date: / /2024

(M. N. Bhalekar)

Research Guide

Dr. B. T. Patil

Head,
Department of Horticulture,
Post Graduate Institute,
Mahatma Phule Krishi Vidyapeeth,
Rahuri-413 722, Dist. Ahmednagar,
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Place : MPKV., Rahuri.

Date : / /2024

(B. T. Patil)

Dr. S. B. Kharbade

Associate Dean,
Post Graduate Institute,
Mahatma Phule Krishi Vidyapeeth,
Rahuri-413 722, Dist. Ahmednagar,
Maharashtra, India.

CERTIFICATE

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Place : MPKV., Rahuri.

Date : / /2024

(S. B. Kharbade)

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LIST OF ABBREVIATIONS

%	:	Per cent
C1	:	Cross Number 1
C2	:	Cross Number 2
C3	:	Cross Number 3
CD	:	Critical difference
cm	:	Centimeter
d.f.	:	Degrees of freedom
ECV	:	Environmental coefficient of variation
<i>et. al.</i>	:	<i>et. al.</i>
F ₁	:	First filial generation
F ₂	:	Selfed of F ₁
F ₃	:	Selfed of F ₂
F ₄	:	Selfed of F ₃
g	:	Gram (s)
G	:	Genotypic (Correlation coefficient)
G. A.	:	Genetic advance
GCV	:	Genotypic coefficient of variation
H ² _{bs}	:	Broad sense heritability
ha	:	Hectare
i.e.	:	idest (that is)
kg	:	Kilogram
M. S. S.	:	Mean sum of square
P1	:	Parent one
P2	:	Parent two
P3	:	Parent three
P4	:	Parent four
PCV	:	Phenotypic coefficient of variation
PDI	:	Per cent incidence of diseases
q/ha	:	Quintals per hectare
S.D.	:	Standard Deviation
SE±	:	Standard error
Sr. No.	:	Serial number
Viz.,	:	Namely
×	:	Cross with

ABSTRACT

“GENETIC VARIABILITY OF F₄ GENERATION IN BITTER GOURD (*Momordica charantia* L.)

by

Mr. Daware Mayuresh Digambar

A candidate for the degree

of

MASTER OF SCIENCE (HORTICULTURE)

in

(Vegetable science)

2024

Research Guide	:	Dr. M. N. Bhalekar
Department	:	Horticulture (Vegetable Science)

The research entitled “Genetic variability of F₄ generation in bitter gourd (*Momordica charantia* L.) was carried out at All India Co-ordinated Research Project on Vegetable crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) during the *Kharif* season in the year 2022. The present investigation was carried out with 13 progenies of bitter gourd in Randomized Block Design. Four parents (P1, P2, P3, P4) and three progenies of each cross (P1 × P2, P1 × P3, P1 × P4) were evaluated for their genetic components such as variability, heritability, genetic advance, genetic advance as a per cent mean and correlation and path analysis, genetic divergence for growth, yield and yield attributes.

There were notable variations in the progenies for every feature that was being studied. Qualitative characters such as shape of fruit, color of fruit and prickles were observed to be oblong, green and high dense respectively. For diseases (downy mildew infestation) and pest (fruit fly infestation), the progeny Pr 1 (1×4) and Pr 3 (1×4) were least affected. The analysis of variance was used to determine the importance of variations in replications, genotypes and other significant sources of variation during the *kharif* season.

In three crosses of F₄ generations, a wide range of variability was seen in all quantitative characteristics. The results of this experiment showed that environmental impacts are within close proximity since the phenotypic variation values are higher than the genetic variation values. The higher GCV and PCV were estimated for diameter of fruit, fruit yield per vine, fruit yield, number of fruits per vine, fruit yield per plot, node at which first female flower appeared, sex ratio.

For the majority of the traits, high heritability coupled with high genetic advancement were noted for most of the characters i.e. diameter of fruit (cm), node at which first female flower appeared, node at which first male flower appeared, number of branches per vine, length of fruit (cm), sex ratio, weight of fruit (g), number of female flower per vine, days to last picking, fruit yield (q/ha), fruit yield per plot (kg), fruit yield per vine (kg), number of male flowers per vine, number of fruits per vine.

The present investigation exhibited that, there was significantly positive correlation between fruit yield per plot and yield contributing characters such as number of female flower per vine, weight of fruit, number of fruits per vine, fruit yield per vine.

Genetic divergence was evaluated between the various parents and hybrids. In cluster pattern it was observed that the maximum nine progenies entered in Cluster I, followed by two progenies in Cluster II. Cluster III and IV had each one progeny.

Ultimately, from the current investigation the progenies were identified in the bitter gourd for the further crop improvement based on the maximum fruit yield per vine with maximum weight, fruit size, green fruit color and with high prickles for the advancement of future generation.

1. INTRODUCTION

A wide variety of fresh fruits and vegetables are always available in India because of its diverse climatic conditions. India is acknowledged as a country with a distinct comparative advantage in the production of a wide range of horticultural crops. In light of the increasing economic relevance of agricultural goods, primarily vegetables, there is a rise in demand from local as well as global markets. In terms of global fruit and vegetable output, India comes in second place to China. The production of vegetables was estimated to be 212.91 million tonnes in the year 2022-23 compared to 209.14 million tonnes in the year 2021-22 according to the second advance estimates for the year 2022-23. There was approximately 7.05 million hectares of fruit cultivation plus 11.35 million hectares of vegetable cultivation (Anonymous, 2021).

One of the most significant vegetables cultivated in tropical and subtropical areas of the world is the Bitter gourd (*Momordica charantia* L.), which is additionally known as balsam pear or bitter melon. It is native to tropical Africa and Asia. It is generally accessible throughout Tropical Africa, China, Malaysia and India. It is grown extensively in India for its bitter fruits and is a member of the cucurbitaceae family with chromosome number $2n=22$. The luscious, tall, climbing bitter gourd vines have slightly fuzzy stems that are covered in yellow monoecious flowers and dark green, deeply lobed leaves. The tender fruits are processed (slicing, pickling, stuffing, and dehydrating) besides being used fresh. The fruits, sometimes referred to as bitter melon or balsam pears and are picked at various stages of development until they reach seed maturity. The fruits are usually consumed fresh, but can also be dried and pickled (Vinning, 1995).

The majority of cucurbits, including bitter gourd, are typically grown in modest amounts for local consumption, consequently their contribution to production figures is minimal. The bitter gourd is widely grown throughout India for its soft fruits, which can be cooked in many different ways and are often used as fried, boiled, stuffed and cooked as well as in curries. Nevertheless, they play a significant role in the diets of many people as one or more species may be used in almost all home and commercial vegetable gardens (Whitaker and Bemis, 1979).

Bitter gourd belongs to the genus *Momordica* and the species *Charantia*. "Momordicin" is the chemical component that gives the fruits its distinct flavor. Spiny gourd (*Momordica dioca* Roxb) and Gac (*Momordica cochinchinensis* Spreng) are the related species in this genera. Many intermediate sex forms, such as andromonoecious, gynoecious, and trimonoecious are more common in bitter gourd. As a summer vegetable, bitter gourd is typically grown under kitchen gardens. However, it is currently also grown close to cities as a commercial crop. Due to the phytochemical compounds in bitter gourd that promote health and prevent disease, despite the bitter taste turning off some people, it is in fact an excellent supplement to any diet. One of the

most potent natural antioxidants, Vit-C (84 mg/100 g) is abundant in fresh bitter gourds. It has incredibly few calories (17 cal per 100g) (Chakrabarti, 2001).

One notable phytonutrient found in bitter gourd is polypeptide-P, a plant insulin with the ability to lower blood sugar levels. Furthermore, it has a hypoglycemic agent that promotes the uptake of glucose and the synthesis of glycogen in the cells of the liver, muscles and adipose tissues collectively. In the course of treating type-2 diabetes, these substances are assumed to be in charge of lowering blood sugar levels. Additionally, it is a great source of flavonoids that are beneficial to health, like lutein, zexanthins, κ -carotene, and beta-carotene. It has a significant amount of water (83–92%), fiber (0.8–1.7%), Protein (1.5–2.0%), fat (0.2–1.0%), minerals (0.5–1.0%) and carbs (4.0–10.5%). Vitamin A is abundant in ripe fruits. Among the all cucurbitaceous vegetables, bitter gourd contains the maximum amount of minerals and vitamins (Islam *et al*, 2009).

The yield and characters that contribute to yield of bitter gourd vary greatly. A concrete breeding program should be planned in order to develop suitable cultivars. For this reason, details about the kind and degree of genetic variation present in the breeding population are required. While bitter gourd is increasingly being grown commercially, the enhancement of the current germplasm that is accessible throughout the nation has received comparatively less attention.

A variety of factors influence the yield, which is a polygenic characteristic. A breeding program that is successful must have access to genetic information about variability, gene action, the degree of heterosis and the relationships between various characters. With the aid of this information, one can determine the optimal genotypes, variants and methods for breeding to utilize in order to build plant architecture using various selection indices, exploit hybrid vigor or use pedigree breeding.

A crop's ability to be improved depends on how much genetic variability it possesses, as this determines the efficacy of selection. When a character is subjected to indirect selection and has a high correlation with yield and heritability, a greater yield response is observed. One essential step in creating a successful breeding program is critically evaluating the type and amount of variability. The level of genetic variability that exists in the population has a major impact on selection efficiency. The estimates of components and genotype are helpful in creating an effective breeding program. Studying correlations can help identify which characters contributed to yield and how much, as well as the phenotypic coefficient of variation, heritability and yield components.

The various offspring of various bitter gourd crosses that had superior characteristics were chosen and their yield and traits that correlated to yield were evaluated. In F_4 generations of bitter gourd, the genetic advancement, variability, heritability and genetic divergence have been

studied. Although the bitter gourd crop's area and production are rapidly expanding, there has been little research done on crop improvement through breeding techniques. Therefore, there is an enormous opportunity to improve cultivars that are early, produce a lot of fruit, have a high female to male sex ratio, have thick fruits, can be stuffed, and are immune to downy and powdery mildew, fruit flies, red pumpkin beetles, and mosaic viruses. The current study was conducted with the following goals in mind in order to introgress these horticultural traits, the F_4 progenies were evaluated for variability, heritability, genetic advancement, correlation and path study and genetic divergence for use in crop improvement with the following objectives :

- 1) To study the genetic variability for yield and yield contributing characters.
- 2) To study the nature and extent of genetic diversity among various progenies of Bitter gourd (*Momordica charantia* L.).

2. REVIEW OF LITERATURE

Any breeding program's goal is to improve a crop's quantitative and qualitative characteristics. A crop breeding program's planning and successful execution will be greatly aided by knowledge on the inheritance of various quantitative traits, especially those that are economically significant. Breeders may not have given bitter gourd as much attention as they have other major food crop species, which could explain the crop's slow progress toward improved yield and quality. The literature that is currently available on these topics for bitter gourd and other cucurbitaceous crops has been examined and is organized under the following subsections:

2.1 Genetic variability

2.2 Heritability and genetic advance

2.3 Correlation studies and path analysis studies

2.4 Genetic divergence

2.1 Genetic Variability

The study of genetic variability is an important prerequisite in any successful breeding program. The knowledge of the nature and magnitude of genetic variation in respect of quantitative plant growth characters coupled with yield and its components is essential in efficient crop improvement program. The variability in the population can be estimated by variability parameters like mean, range, genotypic and phenotypic coefficient of variation i.e. GCV and PCV along with heritability and genetic advance.

Genetic variability is the most important parameter of variability helpful for improvement of particular character. Phenotypic coefficient of variation (PCV) represents total variability which normally includes both genotypic and environmental variations. The genotypic variation refers to genetic or inherent variability which remains unaltered by environmental conditions. Therefore, PCV values more or less equal to GCV values denotes that the character is less influenced by environmental factors. High estimates of PCV than the GCV indicating that the trait is particularly affected by environment (Reddy, 1989). High PCV and GCV estimates facilitate more scope for selection of individual among the population.

2.1.1 Bitter gourd

Srivastava and Srivastava (1976) studied variability in ten bitter gourd lines for ten different characters under Rajasthan condition. They observed maximum value of genotypic coefficient of variation for number of fruits per plant and minimum for number of male flowers per plant.

Singh *et al.* (1977) studied the twelve varieties of bitter gourd for genetic variability. The yield and its main components, viz., number of fruits per plant and fruit

length showed high genotypic coefficient of variation (39 and 34 %) while days to flower had least genotypic coefficient of variation (4 %).

Indresh (1982) observed high genotypic coefficient of variation for fruit weight, yield per vine, fruit cavity, leaf area and fruit length, when studied twenty four lines of bitter gourd.

Mangal *et al.* (1983) studied twenty one varieties of bitter gourd for genetic variability. The average fruit yield per vine (39.08 %), number of branches per vine (33.63 %), average fruit weight (31.61 %) and average number of fruits per vine (28.32 %) showed high genetic coefficient of variation. The least genotypic coefficient of variation was observed for number of days to first flower (9.17 %).

Lawande (1987) studied parents and 55 F_1 hybrids of bitter gourd for the yield and its main components, viz., fruit yield per vine, fruit weight, length and diameter of fruit, number of fruits per vine which showed high genotypic and phenotypic coefficient of variation.

Raja *et al.* (2007) studied the forty-six genotypes of bitter gourd collected from diversified areas of the country and assessed under zero irrigation condition for mean, genetic variability in respect of fourteen quantitative characters. The genotype MCC-23 recorded 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 6.37 to 37.25 and 8.37 to 38.63, 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 extent of variability based in these characters.

Rajput (2012) assessed the variability in F_2 and F_3 generations of bitter gourd and reported that the wide range of variability was observed in all quantitative traits. Phenotypic coefficient of variation was noticed higher than genotypic coefficient of variation. The high estimates for both GCV and PCV were observed for number of Primary branches per vine, number of female flowers per vine, sex ratio, number of fruits per vine, fruit yield per vine, average yield per vine, average weight of fruit and fruit flesh thickness in F_2 and F_3 generations.

Pathak *et al.* (2014) studied genetic variability in 20 bitter gourd hybrids and observed wide range of variation in most of the characters. High genotypic (GCV) and phenotypic coefficient of variation (PCV) was observed for number of fruits per plant, fruit weight and fruit length, whereas, low GCV and PCV was observed for days to first male and female flower anthesis (days after sowing). For most of the parameters under study, PCV was found to be higher than GCV.

2.1.2 Other Cucurbits

2.1.2.1 Muskmelon

Rakhi and Rajamony (2005) reported high estimates of GCV and PCV in muskmelon for fruit yield per plant followed by average fruit weight, number of fruits per plant, keeping quality of fruits and 100-seed weight. They also observed high estimates of PCV than GCV with high magnitudinal differences.

Torkadi and Musmade (2007) studied fifty one genotypes of muskmelon for genetic variability and reported that, the PCV was higher than GCV for all the characters. The high phenotypic as well as genotypic coefficient of variation was observed for economically important characters such as number of fruits per vine, average weight of fruit, fruit cavity, average weight of pulp per fruit and average rind thickness. High mean estimates were recorded for average fruit weight and yield per vine.

Mehta *et al.* (2010) conducted experiment on genetic variability for 12 quantitative characters in 44 diverge genotypes of muskmelon and reported that, high genotypic and phenotypic coefficient of variation was observed for fruit yield per plant followed by acidity percentage, number of fruits per plant and total soluble solids, while moderate estimates were obtained for number of node at which first female flower appeared and fruit weight. Higher estimate of PCV were observed as compared to GCV. Besides high mean estimates were obtained for average fruit length, number of fruits per vine and fruit yield.

Ibrahim (2012) obtained high estimates of PCV and GCV for fruit weight followed by fruit yield per plant and fruit length in muskmelon. The estimates of PCV in general were higher than GCV for all the characters, which suggested that the apparent variation is not only due to the genotypes but also due to the influence of environment. More magnitudinal differences were observed between PCV and GCV estimates.

Reddy *et al.* (2013) reported that, highest estimates of PCV and GCV were obtained for fruit yield (28.30 and 26.08 %) followed by fruit cavity length (28.20 and 26.66 %), rind thickness (26.39 and 22.14 %) and average fruit weight (24.01 and 22.82 %) in muskmelon. The estimates of GCV signify that there is greater potential for favorable advance in selection. In general, magnitude of PCV was higher than the corresponding GCV all the traits, which indicated that, these attributes had to some extent 14 interacted with the environment. For some of the characters the PCV and GCV values were close to one another, implying that genotype contributed more to the expression of these characters than environment, suggesting greater possibilities of improvement through selection.

Mali (2015) reported that highest estimates of PCV and GCV for final vine length, number of primary branches per vine, number of male flowers per vine, number of female flowers per vine, sex ratio, number of fruits per vine, fruit yield per vine, average weight of fruit, average rind thickness, average fruit cavity, average weight of pulp per fruit, average weight of seed per fruit and T.S.S. in muskmelon.

2.1.2.2 Bottle gourd

Patil (2010) evaluated twenty five genotypes of bottle gourd for variability analysis and reported that high estimates of GCV and PCV were observed for average fruit weight, number of fruits per vine and fruit yield per vine. Whereas the character days to first harvest showed low estimates of GCV and PCV. The estimates of GCV were lower than that of PCV for all characters.

Arvindkumar *et al.* (2011) studied the magnitude of genetic variability in bottle gourd. Analysis of variance revealed the adequate variability among all genotypes for all characters. The PCV was slightly higher than their corresponding GCV for all characters. The estimates of GCV and PCV were high for fruit yield per vine followed by fruit length and number of seeds per fruit.

Yadav and Kumar (2012) reported that highest estimates of PCV and GCV were recorded for vine length, number of Primary branches, node number of first female flower appearance, number of fruits per vine, average weight of fruit and yield per vine in bottle gourd. PCV estimate was higher than GCV estimate for all the studied traits.

2.1.2.3 Cucumber

Joshi *et al.* (2005) reported that genotypic coefficients of variation and phenotypic coefficients of variation in cucumber ranged from 9.48% to 93.76%, showing sufficient genetic diversity among the genotypes. The traits such as node number with first fruit, number of fruits per vine, fruit yield, fruit circumference and fruit length had 15 high estimates of PCV and GCV which indicated scope for improvement by selection. PCV estimates were higher than GCV estimates.

Gaikwad (2007) observed high degree of variation in all the characters studied in cucumber. The high GCV and PCV was observed for length of fruit, number of fruits per vine, fruit weight and node number of first female flower appearance.

Arunkumar *et al.* (2011) studied the genetic variability in F₂ population of BGDL × White long, BGDL × Hot season and BGDL × Hyderabad cucumber. The high variability in the form of PCV and GCV was observed in BGDL × White long for number of misshaped fruits per vine, whereas moderate PCV and GCV was observed for number of good fruits per vine and total number of fruits per vine followed by BGDL × Hyderabad cucumber and BGDL × Hot season.

Azcon (2012) reported that highest variability (PCV and GCV) was recorded for fruit length, fruit shape index, number of fruits per plant and total fruit yield per plant in cucumber genotypes. The estimation of PCV was higher than the GCV estimation.

Kumar *et al.* (2014) observed high degree of variation in all the characters studied in cucumber. The maximum phenotypic and genotypic coefficient (PCV and GCV) was observed for acidity of fruit followed by weight of fruit, total yield per vine, rind thickness and total soluble solids.

2.1.2.4 Pointed gourd

Khan *et al.* (2009) reported that in pointed gourd high GCV and PCV for vine length at final harvest, days required for first female flower appearance, number of node at first harvest, fruit breadth, fruit weight, pulp weight per fruit, number of fruits per vine, average weight of fruit and fruit yield in pointed gourd. Thus, presence of considerable amount of variability indicated wide scope of selection for the improvement of these characters. PCV estimates were observed to be higher than the GCV estimates.

2.1.2.5 Ridge gourd

Karuppaiah *et al.* (2002) studied 12 genotypes of ridge gourd to assess variability and reported high estimates of GCV and PCV for number of female flowers per vine, yield per vine and number of fruits per vine and flesh thickness.

Choudhary and Kumar (2011) conducted genetic study in ridge gourd and reported that, the range of variation was higher in fruit length (3.66-26.93cm) followed by node at which first female flower appeared (2.93-20.27) and fruit weight (18.25-112.16g). The minimum range of variability was recorded in days to first female flower (42.27-53.60). The height GCV and PCV were recorded for node at which first female flower appeared (29.40 and 32.29 %) followed by number of marketable fruits per plant (25.48 and 29.33 %). High magnitude of GCV is an indication of high genetic variability among the genotypes which Provides ample scope for improvement of these characters through selection. Also reported that, the PCV estimates were higher than the GCV estimates.

Rabbani *et al.* (2012) reported that high PCV and GCV was recorded for vine length, petiole length, number of Primary branches at harvest, sex ratio, fruit length, fruit circumference, peduncle length, dry weight of flesh, number of fruits per vine, average fruit weight and fruit yield per vine in ridge gourd.

2.1.2.6 Sponge gourd

Kumar *et al.* (2013) revealed high values of genotypic as well as phenotypic coefficient of variation for total yield per vine, number of seeds per fruit, average weight of fruit and T.S.S. in sponge gourd. The high magnitude of GCV revealed the greater

extent of variability presence in these characters suggesting good scope for improvement through selection.

2.1.2.7 Watermelon

Gusmini and Wehner (2007) studied genetic variance in watermelon and reported that, high estimates of GCV and PCV were observed for number of fruits per vine, average weight of fruit, average fruit yield per vine, average weight of flesh and average number of seeds per fruit. Comparatively higher estimates were observed for phenotypic coefficient of variations than the genotypic coefficient of variations.

2.1.2.8 Snake gourd

Devi and Mariappan (2013) studied genetic variability in 50 genotypes of snake gourd to determine the magnitude of variability in the population and to identify genotypically diverse and economically desirable genotypes for utilization in crop improvement. Higher values of phenotypic coefficient of variation and genotypic coefficient of variation were recorded for fruit length, fruit weight and number of fruits per plant while, moderate phenotypic and genotypic coefficient of variation were observed for yield, fruit girth and number of seeds per fruit indicating the extent of available genetic variability for these traits.

2.2 Heritability and genetic advance

Phenotype of an individual is determined by genotype and environment in which it grows. Success of breeder in changing and improving the heredity of character depends upon the degree of correspondence between phenotypic and genotypic value. Heritability is a measure that provides this information. Heritability in broad sense or degree of genetic determination is proportion of total hereditary variance to phenotypic variance. The more useful estimate i.e. narrow sense heritability or degree of resemblance between relatives is ratio of additive genetic variance to phenotypic variance (Falconer, 1981). The most important function of heritability in the genetic studies of metric characteristics is its Predictive role in expressing the reliability of phenotypic value as a guide to breeding value (Falconer, 1981). Genetic advance means improvement in the performance of selected lines over original population.

A brief summary of work done for estimating heritability and genetic advance of yield and yield contributing characters is reviewed below,

2.2.1 Bitter gourd

Srivastava and Srivastava (1976) studied heritability in ten bitter gourd lines for ten different characters under Rajasthan conditions. The highest percentage of heritability in broad sense (99.31) was observed for number of fruits while, the lowest for number of male flowers. The characters like number of branches, number of female flowers, number

of fruits, fruit length, weight and yield of fruits showed higher percentage of heritability. The values of genetic advance were maximum for number fruits per plant followed by fruit weight and yield per vine.

Singh *et al.* (1977) studied the twelve varieties of bitter gourd for the yield and its main components, viz., number of fruits per plant and fruit length showed high heritability (92, 90 %) and high genetic advance (69, 76 %), while days to flower had least heritability (22 %) and very low genetic advance (4 %).

Indresh (1982) observed high heritability estimates were for all the characters except yield per vine and days for fruit development in bitter gourd.

Mangal *et al.* (1983) studied twenty one varieties of bitter gourd and reported that the high estimates of heritability along with high estimates of genetic advance as per cent of mean was observed for the characters length of vine (87.29 and 31.45 %), number of branches per vine (92.55 and 66.59 %), number of fruits per vine (94.23 and 36.31 %), average fruit weight (94.23 and 62.32 %) and fruit yield per vine (86.06 and 44.91 %).

Lawande (1987) studied parents and 55 F_1 hybrids of bitter gourd for the yield and its main components, viz., number of primary branches, fruit yield per vine, fruit weight, length of fruit, number of fruits per vine except diameter of fruit, shelf life of fruit, node at which first female flower appeared, days to first female flower appearance showed high heritability and high genetic advance.

Chaudhari *et al.* (1991) studied fifty five F_1 progenies involving 11 true breeding bitter gourd lines. High genetic advance was observed for weight of fruit (21.32). The high heritability and genetic gain was recorded in respect of yield/plant, weight of fruit and number of fruit/plant.

Raja *et al.* (2007) studied the forty-six genotypes of bitter gourd collected from diversified areas of the country assessed under zero irrigation condition for heritability and genetic advance in respect of fourteen quantitative characters. The genotype MCC-23 recorded the highest number of Primary branches per plant, fruit yield per plot and fruit weight. High heritability coupled with greater genetic gain was observed for number of female flowers per plant followed by fruit weight, number of Primary branches per plant and yield per plot indicating the additive gene action. Fruit girth showed moderate heritability with low genetic gain.

Rajput (2012) assessed heritability and genetic advance as a per cent of mean in F_2 and F_3 generations of bitter gourd and reported that, high estimates of heritability coupled with high genetic advance as per cent of mean was observed for the characters viz., number of primary branches per vine, number of female flowers per vine, sex ratio, average yield per vine and number of fruits per vine in both F_2 and F_3 generations.

Whereas the high heritability with low genetic advance as per cent of mean was observed for other characters.

Pathak *et al.* (2014) studied the twenty varieties of bitter gourd for the yield and its main components. High heritability with high genetic advance was observed 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. 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.

Alekar *et al.* (2019) revealed that high heritability estimates associated with high values of genetic advance as a per cent mean were observed for number of primary branches per vine, number of fruits per vine, average yield per vine, average weight of fruit, yield tonnes per hectare which indicated additive gene action for these characters, which could be improved by simple selection method.

2.2.2 Other cucurbits

2.2.2.1 Muskmelon

Prasad *et al.* (2004) reported that, heritability and genetic advance as per cent of mean in muskmelon was higher for days to appearance of first female flower, number of male and female flower per vine, node at which male flower appeared and yields per plot.

Pandey *et al.* (2005) recorded high heritability along with high expected genetic advance for number of days to 50 per cent female flower anthesis, T.S.S. and number of days to first male flower anthesis while the characters such as average fruit length and average fruit diameter showed high heritability and low expected genetic advance.

Rakhi and Rajamony (2005) revealed high heritability coupled with high genetic advance as per cent of mean for number of primary branches per vine, fruit length, 100-seed weight, average fruit weight and keeping quality of fruits.

Singh and Lal (2005) revealed that, high heritability coupled with high genetic advance as per cent of mean was observed for node at which first female flower opens followed by rind thickness and fruit weight which implies that, these traits are more reliable for improvement through selection in muskmelon. The characters viz., total sugar contents, average rind and pulp thickness recorded high heritability with low genetic advance as per cent of mean.

Torkadi and Musmade (2007) studied fifty one genotypes of muskmelon for estimation of heritability and genetic advance as a per cent mean and reported that, high heritability (broad sense) coupled with high genetic advance as a per cent mean was recorded for days to first male flower opening (89.24 and 24.32 %), days to first female

flower opening (95.56 and 34.12 %), days to first harvest of fruit (89.32 and 34.23 %), fruit length (92.10 and 24.36 %), fruit diameter (90.45 and 21.47 %), number of fruits per vine (97.70 and 109.29 %), average weight of fruit (99.60 and 41.48 %), fruit yield per vine (83.75 and 34.15 %), flesh thickness (96.65 and 31.75 %), fruit cavity size (99.00 and 114.40 %), average weight of pulp per fruit (92.65 and 26.54 %), average rind thickness (94.31 and 20.48 %) and total soluble solids (84.25 and 35.67 %). The Presence of high heritability along with high genetic advance as per cent mean for the above traits might be attributed due to additive gene effects and is desirable for effective selection in breeding program. They also recorded high heritability along with low genetic advance as per cent mean for total sugars and acidity percentage.

Tomar *et al.* (2008) studied fifty genotypes of muskmelon and found that the heritability (broad sense) for days to first female flower opens, fruit diameter, acidity and total sugar characters was moderate, suggesting that non-additive genetic variance was largely Predominating.

Mehta *et al.* (2010) conducted experiment on heritability and genetic advance for 12 quantitative characters in 44 diverge genotypes of muskmelon and reported that high estimates of heritability accompanied with high genetic advance was observed for node number at which first female flower appeared, number of fruits per vine, fruit yield per vine, average fruit weight and total soluble solid which indicated the importance of additive gene effects and selection based on this would bring significant improvement in the genotypes of muskmelon.

Ibrahim (2012) obtained high estimates of heritability associated with high genetic advance for fruit weight, number of fruits per vine, fruit length, fruit width, flesh thickness and total fruit yield per vine. This indicated the presence of large number of fixable additive factors. Breeding methods based on progeny testing and mass selection could be useful in improving these traits.

Reddy *et al.* (2013) reported that, the traits like days to appearance of first staminate flower, fruit length, average fruit weight, fruit cavity length and width, rind thickness, T.S.S. and seed yield in muskmelon recorded high genetic advance as a percent of mean coupled with high heritability estimates, indicating that these traits were under the strong influence of additive gene action and hence selection based on phenotypic performance of these traits would be more effective. While high heritability and low genetic advance as per cent of mean was observed for days to first fruit harvest, indicated that the character is highly influenced by environmental effects and selection would be ineffective.

Patil (2014) in this study on muskmelon reported high heritability accompanied with high genetic advance was observed in the cross 5 (IVMM-3 $\times$ Punjab Sunheri) for most of the characters like vine length, days required for initiation of male and female flowering, number of female flowers per vine, node at which first female flower appeared, days required for first harvest of fruits, yield per vine, weight of fruit, length of fruit, diameter of fruit, rind thickness, pulp thickness, fruit cavity, weight of pulp per fruit, weight of seed per fruit, total soluble solids, acidity, Downy mildew incidence, powdery mildew, Fruit fly incidence and leaf miner. Whereas highest heritability coupled with lowest genetic advance was observed for the number of primary branches per vine, ascorbic acid, total sugar, reducing sugar, non reducing sugar it indicated that non additive effects involved in controlling the inheritance of characters.

Mali (2015) studied heritability and genetic advance in muskmelon and reported that high estimates of heritability were obtained for characters like final vine length, number of primary branches per vine, number of fruits per vine, fruit yield per vine, average weight of fruit, average pulp and rind thickness, average fruit cavity, average weight of pulp per fruit, average weight of seeds per fruit and T.S.S. in most of the crosses of F_3 and F_4 progenies which indicates preponderance of additive gene action. High heritability combined with low genetic advance was observed for some of the traits for which simple selection would not be rewarding.

2.2.2.2 Bottle gourd

Patil (2010) evaluated twenty five genotypes of bottle gourd for heritability and genetic advance and reported that high estimates of heritability in broad sense were recorded for fruit yield per vine, number of fruits per vine and nodal position of first female flower, whereas, lower values were recorded for days to first male and female flowers. High heritability value with high genetic advance was obtained for fruit yield per vine, indicating additive gene effects in their inheritance and scope for selection.

Arvindkumar *et al.* (2011) studied the magnitude of heritability and genetic advance in bottle gourd. High heritability along with high genetic advance as a per cent of mean was obtained for fruit yield per vine, number of seeds per fruit and fruit diameter indicated presence of additive gene action and further scope for improvement through selection.

Yadav and Kumar (2012) reported that, the highest estimates of heritability coupled with highest genetic advance as per cent of mean for vine length, number of Primary branches, node number of first female flower appearance, number of fruits per vine, fruit length and yield per vine. This might be due to additive gene effects in their inheritance and indicated scope for improvement through selection.

2.2.2.3 Cucumber

Joshi *et al.* (2005) reported that, the high heritability accompanied with high genetic advance as per cent of mean was observed for vine length, number of Primary branches, node number of first fruit, fruit length, fruit circumference, number of fruits per vine and fruit yield revealed the considerable effect of additive genes in these traits.

Kumar *et al.* (2007) reported that, range of heritability values were recorded from 12.50 % to 100.00 % for the studied characters in cucumber. The heritability estimate were high for fruit length, node number bearing first male flower and fruit weight while moderate estimates of heritability was observed for number of days to first female flower anthesis, number of days to 50 per cent germination. The high estimate of genetic advance was recorded for number of days to first fruit harvest, while low estimate of genetic advance were recorded for fruit cavity, number of days to germination and vine length.

Kumar *et al.* (2010) observed low narrow sense heritability for fruit length, fruit diameter, fruit weight and vine length in cucumber. This might be attributed due to Presence of non-additive gene action.

Arunkumar *et al.* (2011) studied the heritability in F_2 population of BGDL $\times$ White long, BGDL $\times$ Hot season and BGDL $\times$ Hyderabad cucumber of cucumber. Higher heritability coupled with moderate to low genetic gain was noticed in all F_2 population for different characters but, number of misshaped fruits per vine where it recorded moderate heritability and genetic gain.

Azcon (2012) reported that, the broad sense heritability was higher for fruit length, fruit shape index, number of fruits per vine and total fruit yield per vine but it was moderate for fruit diameter in cucumber genotypes. Higher values of heritability indicated that phenotypic selection for these traits could be highly efficient.

Ramesh Kumar *et al.* (2014) reported that, the broad sense heritability was higher 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).

2.2.2.4 Ridge gourd

Karuppaiah *et al.* (2002) studied 12 genotypes of ridge gourd to assess variability, heritability and genetic advance. High heritability was observed for number of female flowers per vine, yield per vine, number of fruits per vine and flesh thickness. When heritability and genetic advance as per cent mean were considered together the number of

female flowers per vine, number of fruits per vine and yield per vine were recorded highest values.

Choudhary and Kumar (2011) conducted genetic study in ridge gourd and reported that, the high heritability along with high genetic advance as per cent of mean was observed for node at which first female flower appeared (82.91 and 55.14 %), fruit length (83.60 and 42.84 %), marketable fruits per vine (82.05 and 47.54 %) and fruit weight (89.09 and 45.27 %) indicated the Presence of additive gene action thus these characters could be used in selection on the basis of phenotypic performance.

Rabbani *et al.* (2012) reported that, high heritability was recorded for vine length, sex ratio, fruit length, dry weight of flesh, number of fruits per vine, average fruit weight and fruit yield per vine.

2.2.2.5 Sponge gourd

Kumar *et al.* (2013) revealed that, high values of heritability along with high genetic advance as per cent mean was recorded in sponge gourd for number of Primary branches per vine, number of fruits per vine, fruit length, average weight of fruit, total yield per vine and T.S.S., indicated that these characters had additive gene effect and therefore, they are more reliable for effective selection.

2.2.2.6 Watermelon

Gusmini and Wehner (2007) studied heritability and genetic advance as per cent mean in watermelon and reported that, high estimates of heritability along with high estimates of genetic advance as per cent mean were observed for number of fruits per vine, average weight of fruit, average fruit yield per vine, average weight of flesh and average number of seeds per fruit.

2.2.2.7 Snake gourd

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

2.2.2.8 Ash gourd

Singh *et al.* (2002) studied heritability and genetic advance in ash gourd and reported that, high estimates of heritability were obtained for characters like fruit length, fruit diameter, average fruit weight, total yield and number of fruits per vine. This showed that these characters were least affected by environment. Higher value of genetic advance (>20 %) were observed for fruit diameter and total fruit yield.

2.2.2.9 Pumpkin

Chandrakumar (2006) studied genetic variability in pumpkin and found that T.S.S. had the highest heritability and high genetic advance as a per cent of mean (74.57 and 31.68). Whereas fairly high heritability % was observed for number of Primary branches (42.61), days to first female flowering (65.14), number of fruits per vine (65.27), fruit yield per vine (71.99), fruit length (38.10), fruit diameter (64.67) and flesh thickness (45.29). The genetic advance as a per cent of mean for the above characters was considerably low.

2.3 Correlation studies and path analysis studies.

Direct selection for yield is often misleading as yield is polygenically controlled and also subjected to the effect of fluctuating environment. Efficiency of selection in any breeding program is enhanced and mainly depends on the knowledge of association of characters. The work done for association of relationship between yield and yield contributing characters is reviewed as below.

Path coefficient analysis delivers an effective method of revealing the direct and indirect causes of association and puts forth a critical analysis of the specific forces acting to generate a given correlation and estimates the relative relevance of each causal factor.

2.3.1 Bitter gourd

Khattri *et al.* (1994) reported a significant and positive correlation of total fruit yield per vine with average fruit weight and number of fruits per vine while negative correlation was recorded with days to anthesis of first female flower and days to first harvest in bitter gourd.

Dey *et al.* (2005) studied correlation in bitter gourd and revealed that, the fruit yield had the highest positive correlation with fruit weight followed by number of fruits per vine, flesh thickness, days from fruit set to maturity, fruit index, fruit length and fruit diameter where as other traits like number of male flowers per vine, ascorbic acid, total carotenoids content and days to first male flower exhibited negative correlation coefficient with fruit yield.

Pathak *et al.* (2014) studied correlation in bitter gourd and revealed that number of fruits per plant had significant positive correlation for yield. Further, path coefficient analysis partitioned the correlation into direct and indirect effects. 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.

Gupta *et al.* (2015) studied correlation in bitter gourd with 26 genotypes including check (Solan Hara) for yield and yield components, their direct and indirect influence on total marketable fruit yield. Correlation of various characters with yield is useful and

Provides criteria for direct selection of component characters. The characters average fruit weight, marketable fruits per vine and seeds per fruit exhibited positive phenotypic association while marketable fruits per vine, seeds per fruit, average fruit weight and node at which first female flower appears showed genotypically positive association with total marketable fruit yield per hectare. Marketable fruits per vine had maximum positive direct effect on total marketable fruit yield per hectare followed by average fruit weight, seeds per fruit, number of days to first female flower appearance, branches per plant and node at which first female flower appears.

Yadagiri *et al.* (2017) studied 20 genotypes of bitter gourd for evaluating their performance for various horticultural characters. There was a great deal of significant correlation for all the characters among the genotypes. Correlation analysis revealed that Length of vine, number of branches per vine, number of male flowers per vine, number of female flowers per vine, number of fruits per vine, length of fruit, weight of fruit, number of seeds fruit, seed weight per fruit had significant positive correlation for yield. Further, path coefficient analysis partitioned the correlation into direct and indirect effects. Yield was found to be directly correlated with crop duration, length of vine, number of seeds per fruit and length of fruit hence selection based on these characters would be more rewarding.

Kumar *et al.* (2018) studied fifteen genotypes of bitter gourd i.e. HABG-22, NDBT-07, NDBT-09, Meghana-2, Selection-5, Preethi, Phul Ujjwala, Priya, Nakhara, Pant Karela-1, Hirkani, VRBT-23, Pusa Vishesh, Pusa Ashaudhi and Arka Harit. Correlation coefficient and direct and indirect effect of fruit yield attributing traits, it is clear that, for bring out designed improvement towards fruit yield in bitter gourd. Average fruit weight and fruits per vine can be used as direct selection parameters.

Kumari *et al.* (2018) studied the existing genetic variability and to assess interrelationship among sixteen yield and its contributing traits in twenty eight genotypes of bitter gourd of Bihar. Correlation analysis revealed that total chlorophyll content; fruit weight and fruit length had a significant and positive association with yield per plant. Path analysis revealed that ascorbic acid, number of seeds per fruit, vine length, TSS, fruit weight, chlorophyll content, node number at which first female flower appear and days to 50% flowering had a positive direct effect on fruit yield. Correlation and path-coefficient analysis, concluded that, ascorbic acid, number of seeds per fruit, vine length, TSS, fruit weight, chlorophyll content, node number at which first female flower appear and days to 50% flowering exhibited maximum positive direct effect on grain yield seems to be primary yield contributing characters and could be relied upon for selection

of genotypes to improve genetic yield potential of Bitter gourd. Hence, utmost importance should be given to these characters during selection for yield improvement.

Moharana *et al.* (2018) studied twenty genotypes of bitter gourd to estimate the character association as well as direct and indirect effects of different yield traits on average yield per plant through correlation and path coefficient analysis. The data demonstrated that the positive and significant interrelationship with average yield per plant was obtained by various traits, viz., node number of first staminate flower, node number of first pistillate flower, vine length, fruit length, fruit circumference, average fruit weight, fruits per plant, and internodal length. The average fruit weight had highest direct positive effect on average yield per plant followed by traits like days to fifty per cent flowering, number of fruits per plant, and number of primary branches per plant whereas maximum direct negative effect was recorded by days to anthesis of first staminate flower followed by internodal length and days to first harvest. The traits with high positive direct effect should be more prioritised for effective selection of promising genotypes for further crop improvement programs.

Alekar *et al.* (2019) revealed that, fruit yield per hectare showed highly significant positive correlation with yield and yield contributing characters. It is suggested that characters viz., number of female flower per vine, number of fruits per vine, average weight of fruit, crop duration, average length of fruit and average diameter of fruit should be given Priority for selecting high yielding genotypes.

Reddy *et al.* (2022) studied twenty seven bitter gourd genotypes were studied for evaluation of correlation and path co-efficient analysis of fruits yield and Yield attributes in bitter gourd (*Momordica charantia* L.). Path coefficient analysis of different yield and yield contributing traits on fruit yield per plant revealed with number of primary branches per vine, days to first male and female flower appearance, nodes at which first male and female flower appearance, days to first and last fruit harvest, average fruit weight, fruit fly infestation per cent and 100 seed weight exhibited positive direct effects on fruit yield these characters play a major role in recombination breeding and suggested that direct selection based on these traits will be rewarded for crop improvement of bitter gourd.

2.3.2 Other cucurbits

2.3.2.1 Muskmelon

Choudhary *et al.* (2003) observed that, fruit yield per vine had significant and positive correlation with average fruit weight, number of fruits per vine, harvest duration, rind thickness, shelf life and vine length in muskmelon.

Chamnan and Kasem (2006) studied correlation coefficient in F₂ generation of muskmelon and revealed that fruit yield per vine had positive and significant correlation

with number of fruits per vine. The results indicated that number of fruits per vine had a close association with the yield. Thus, components of fruit number per vine should be considered for yield improvement in muskmelon breeding program.

Jagtap (2010) studied correlation in muskmelon and reported that yield per vine showed positive and significant association with number of fruits per vine, diameter of fruit, pulp thickness and pulp weight per fruit in both summer and kharif seasons.

Naroui *et al.* (2010) conducted experiment on yield traits relationship in muskmelon and reported that, fruit yield had significant and positive correlation with fruit weight and flesh diameter.

Cheema *et al.* (2011) studied correlation based on 11 morphological traits in muskmelon and reported that fruit yield per vine was positively correlated with number of lateral branches per vine, number of green leaves per vine, fruit weight, number of fruits per vine and total number of leaves per vine. Numbers of green leaves per plant was positively correlated with total soluble solids (T.S.S.) and yield per vine.

Mali (2015) studied correlation in F_3 and F_4 generations of muskmelon and reported that significant and positive correlation was observed both at phenotypic and the genotypic level between fruit yield per vine and the yield contributing characters such as final vine length, number of Primary branches per vine, number of female flowers per vine, number of fruits per vine, average weight of fruit, average length of fruit, average diameter of fruit and average weight of pulp per fruit.

2.3.2.2 Bottle gourd

Patil (2010) assessed twenty five bottle gourd genotypes and revealed that, the fruit yield per vine showed positive correlation with average fruit weight, Fruit Fly incidence incidence, leaf miner incidence, number of Primary branches per vine and number of fruits per vine at genotypic and phenotypic level. The number of fruits per vine showed significant and positive correlation with fruit yield per vine and negative correlation with per cent disease intensity for Downy Mildew incidence and leaf miner incidence at both phenotypic and genotypic levels.

Yadav *et al.* (2010) reported that fruit yield per plant in bottle gourd had positive and significant phenotypic and genotypic correlation coefficient with number of fruits per vine, weight per fruit, length of fruits, number of Primary branches per vine, number of nodes per vine, vine length and days to first female flower anthesis.

Kumar *et al.* (2012) studied correlation in bottle gourd and noticed that, fruit yield per vine had highly significant positive association with days to fruit setting, days to maturity and number of fruits per vine at genotypic and phenotypic level.

Sharma and Sengupta (2012) reported that, fruit yield per vine in bottle gourd exhibited significantly positive correlation with vine length, number of Primary branches per vine, number of female flowers per vine, number of fruits per vine and fruit length.

Yadav and Kumar (2012) studied phenotypic and genotypic correlation coefficient in 15 genotypes of bottle gourd and revealed that fruit yield per vine had positive and highly significant correlation coefficient with average fruit weight followed by days to first female flower anthesis, number of fruits per vine, length of fruit, node number of first female flower and number of Primary branches per vine at phenotypic and genotypic level.

2.3.2.3 Cucumber

Rao *et al.* (2003) reported that, fruit yield was positively correlated with fruit weight, fruit length and flesh thickness at both genotypic and phenotypic levels in cucumber.

Joshi *et al.* (2005) reported that, correlation coefficient of fruit yield was observed positive with vine length, number of Primary branches, node number of first fruit, fruit length, fruit circumference and number of fruits per vine in cucumber.

Bhande *et al.* (2012) revealed that, fruit yield per vine in cucumber showed highly significant positive association with number of fruits per vine, volume of fruit, length of fruit, weight of fruit and girth of fruit where as other traits viz., node at first pistillate flower and days to first harvest exhibited negative and significant association with fruit yield per vine at both genotypic and phenotypic level.

2.3.2.4 Ridge gourd

Choudhary and Kumar (2011) investigated correlation of different yield and yield contributing characters of ridge gourd and revealed that the marketable fruit yield per vine had positive and significant correlation with fruit weight and fruit length at phenotypic level. Days to first fruit harvest exhibited positive and highly significant correlation with days to first female flower opening and node at which first female flower appeared. Also reported that the magnitude of genotypic correlation coefficients was higher than respective phenotypic correlation coefficients which establishes inherent relationship among the characters.

Hanumegowda *et al.* (2012) studied correlation coefficients in ridge gourd and revealed that fruit yield per vine showed positive and significant correlation with number of fruits per vine, average fruit weight, fruit length, fruit diameter, per cent fruit set, number of seeds per fruit, 100 seed weight, seed yield per fruit and rind thickness at genotypic level. Thus, the association of these characters are in the desirable direction, selection for these traits may improve the yield per vine.

Rabbani *et al.* (2012) studied correlation coefficients in 60 genotypes of ridge gourds for yield versus eight important yield contributing traits and reported that fruit yield per vine had highly significant positive relationship with the number of fruits per vine, average fruit weight, vine length at harvest and length of fruit. While sex ratio and circumference of fruit exhibited negative association with fruit yield.

2.3.2.5 Sponge gourd

Khule *et al.* (2011) studied correlation in 30 genotypes of sponge gourd and revealed that marketable fruit yield per vine exhibited significant positive correlation with number of fruits per vine and fruit length. Also noticed that genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients suggesting that the environmental influence reduces the relationship between yield and yield contributing characters.

Kumar *et al.* (2013) observed the correlation in 20 genotypes of sponge gourds for yield and yield contributing characters and reported that total fruit yield per vine exhibited significant and positive correlation with number of fruits per vine, average weight of fruit, number of seeds per fruit and total soluble solids both at genotypic and phenotypic levels. They also revealed that, estimates of genotypic correlation were slightly higher than their corresponding phenotypic correlation for all the characters.

2.3.2.6 Watermelon

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

2.3.2.7 Snake gourd

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

2.3.2.8 Ash gourd

Dewan *et al.* (2014) conducted an experiment to study the correlation between yield and yield contributing characters of 46 accessions of ash gourds. Correlation coefficient indicated that fruit yield per vine had highly significant and positive association with the number of fruits per vine, average weight of fruit, fruit length, fruit diameter, flesh thickness and vine length at the time of harvest while sex ratio exhibited a negative association with yield.

2.3.2.9 Pointed gourd

Khan *et al.* (2009) studied correlation among eight important yield components with fruit yield in 24 accessions of pointed gourd and revealed that, fruit yield exhibits

significant and positive correlation with number of female flowers, single fruit weight and number of fruits per vine. Whereas fruit yield exhibited negative correlation with number of node at first harvest and pulp seed ratio.

2.4 Genetic Divergence

Genetic divergence is helpful for assessing the yield and yield attributes which can be further utilized in crop improvement programs.

2.4.1 Bitter gourd

Kundu *et al.* (2012) studied 36 genotypes of bitter gourd for Mahalanobis's D^2 analysis. Through multivariate analysis based on 22 characters 36 genotypes were grouped into six distant clusters. Cluster VI includes maximum genotypes (12) followed by cluster I (6) and cluster II (6). Cluster V, cluster III and cluster I comprised 5, 4 and 3 genotypes respectively.

Singh *et al.* (2013) studied 30 genotypes of bitter gourd for Mahalanobis D^2 statistics using Tocher's method. Among the 6 clusters, maximum numbers of genotypes were found in cluster V, while clusters III was found to be mono-genotypic. Among the 12 quantitative characters studied, individual fruit weight constituted a maximum of 64.14% contribution to the divergence, followed by days to first female flower appearance. Ranking of genotypes based on intra-cluster mean performance for these characters which are major contributors of genetic diversity revealed its usefulness in selecting parents for heterosis breeding.

Angadi and Mulge (2018) studied 55 bitter gourd genotypes. The genotypes were grouped into 10 clusters based on Mahalanobis D^2 statistics using Tocher's method. The clustering pattern of genotypes revealed that the genetic diversity was independent of the geographical diversity. Ranking of genotypes based on intra cluster mean performance for these characters which are major contributors of genetic diversity revealed its usefulness in selecting parents for heterosis breeding.

Maurya *et al.* (2018) studied thirty genotypes of bitter gourd for genetic divergence using Mahalanobis D^2 statistics. Thirty genotypes were grouped into 6 different non-overlapping clusters. Cluster III had the highest number of genotypes (8) followed by cluster II (7), cluster V (6), cluster IV (5) and cluster I, VI (2) whereas cluster I and VI had only two genotypes. The highest intra-cluster distance was observed for cluster VI recorded for (123.61) followed by cluster V (91.85), cluster I (69.08) and cluster II (62.75), cluster IV (47.92). The maximum inter-cluster distance observed between cluster III to cluster VI (231.577), which suggested that members of these two clusters are genetically very diverse to each other.

Naik *et al.* (2021) studied the nature and magnitude of genetic divergence in 33 bitter gourd genotypes. The genotypes were grouped into 8 clusters based on Mahalanobis D² statistics using Tocher's method. Among the 8 clusters, maximum numbers of genotypes were found in cluster II, while clusters IV, VI, VII and VIII was found to be mono genotypic. Among the twenty quantitative characters studied, individual fruit Diameter constituted a maximum of 37.88% contribution to the divergence, followed by internode length.

Nithinkumar *et al.* (2021) studied genetic divergence of forty bitter gourd genotypes was studied for sixteen different parameters by adopting Mahalanobis D² statistics using Tocher's method. The genotypes were grouped into six clusters irrespective of geographic divergence, indicating no parallelism between geographic and genetic diversity.

Ankitha *et al.* (2023) evaluated 33 bitter gourd genotypes for 17 characters. Characters such as days to first male flower appearance, days to first female flower appearance, node at which first male flower appearance, node at which first female flower appearance etc., Genotypes were grouped into 5 clusters using Mahalanobis D² and a dendrogram was created using ward's approach. Out of the five clusters, cluster I was the largest comprising of 14 genotypes. Maximum inter cluster distance was observed between cluster III and cluster IV, hence diverse parents for hybridization can be selected from these two clusters.

Bhati *et al.* (2023) studied twenty diverse genotypes of bitter gourd were formed in five clusters. The cluster I comprised highest 13 genotypes, Cluster II comprised 3 genotypes, Cluster V comprised 2 genotypes, cluster III and cluster IV comprised 1 genotype each respectively. The maximum intra-cluster distance was recorded in cluster II, cluster V, cluster I, cluster III and cluster IV with minimum intra-cluster distance, suggested that the genotypes of cluster II are more heterogeneous whereas, genotype of cluster II are comparatively homogenous based on intra-cluster distance. The maximum inter-cluster distance was recorded in cluster IV and cluster III whereas, the minimum inter-cluster distance was observed in cluster II and cluster I.

2.4.2 Other cucurbits

2.4.2.1 Bottle gourd

Ara *et al.* (2014) studied twenty eight bottle gourd (*Lagenaria siceraria*) genotypes was estimated using D² and Canonical analysis. The genotypes were grouped into five clusters. The maximum intercluster distance was between cluster III and cluster I, and the minimum was between cluster IV and II.

Visen *et al.* (2015) studied genetic diversity for yield and its contributing traits in 31 bottle gourd genotypes. The cluster analysis grouped all 31 bottle gourd genotypes into 5 major clusters based on D^2 value. Extreme genetic divergence was estimated among clusters. Maximum number of genotypes were grouped into cluster V included ten genotypes, whereas, cluster II included eight genotypes. The cluster I had six genotypes, which is followed by cluster IV and cluster III had only three genotypes in each cluster. Fruit length, fruit girth and average fruit weight contributes maximum towards genetic divergence.

Rambabu *et al.* (2020) studied twenty one genotypes of bottle gourd for sixteen quantitative characters using Mahalanobis' D^2 statistics. The genotypes were grouped into six clusters. Highest inter cluster distance was observed between cluster I and VI followed by cluster V and VI. Highest cluster mean values were observed for most of the traits with the genotypes present in cluster I.

Bhagwat *et al.* (2022) studied thirty four genotypes of bottle gourd in randomized complete block design with two replications to study the genetic diversity among them. The genotypes were grouped into four clusters using Tocher's method. Among four clusters, the cluster I was the largest, comprising of 31 genotypes. While Cluster II, Cluster III cluster IV had one genotype each.

Bhargava *et al.* (2022) studied 4 testers and their 40 F_1 hybrids of bottle gourd for eighteen quantitative characters using Mahalanobis' D^2 statistics. The genotypes were grouped into eight clusters. Clustering pattern of the genotypes of heterogeneous origin, indicating no parallelism between genetic and geographical diversity.

Rai *et al.* (2023) studied forty-three genotypes (10 lines + 3 testers + 30 F_1 's) of bottle gourd were grouped into seven distinct non over lapping clusters. This suggested that the genotypes had a significant amount of variability. Additionally, it was discovered that the genotypes belonging to the same geographic area were clustered together. Thus, there was no consistent relationship between genetic divergence and geographical distribution. Number of genotypes per cluster ranged from fifteen to one. The cluster II was the largest with fifteen genotypes followed by cluster III and cluster I, cluster VII, cluster VI while, cluster IV had one genotype.

3. MATERIALS AND METHODS

The present investigation entitled “Variability studies of F₄ generation in bitter gourd (*Momordica charantia* L.) was carried out at the farm site of All India Co-ordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) during the *Kharif*-2022. The details of material used and procedure adopted for the present investigation are given below.

The details of seed material used and methods adopted for the study of genetic variability, the experimental design adopted and the statistical procedures followed are mentioned under various sub-headings in this chapter.

Program of research work: *Kharif*-2022 - Evaluation of F₄ progenies (Three progenies of each cross).

3.1 Experimental material

The seed of parents and three hybrids (three progenies of each cross) were obtained from All India Coordinated Research Project On Vegetable Crops, Department of Horticulture, MPKV., Rahuri, Dist. Ahmednagar. These parents with three progenies of each cross will be utilized in the present study. The seed material was procured from the previous Ph.D. student and was evaluated during *kharif*- 2022.

3.2 Treatment details

Sr. No.	Parents	Sr. No.	Three F ₁ hybrids
1	P1 – RHRBG-26	1	P1 X P2
2	P2 – RHRBG-24	2	P1 X P3
3	P3 – Akole BG4 – RHRBG-10	3	P1 X P4
4	P4 – Phule Green Gold – RHRBG-29		

3.3 Details of Experiment

The details of experimental techniques employed for the present investigation are described as under:

- | | |
|-------------------------------|--|
| 1) Crop | : Bitter gourd |
| 2) Location | : AICRP on vegetable crops, MPKV., Rahuri. |
| 3) Experimental design | : Randomized Block Design (RBD) |
| 4) Plot size | : 1.5 × 20 m ² |

- 5) **Spacing** : $1.5 \times 1 \text{ m}^2$
 6) **Treatments** : 13 (9 Hybrids + 4 Parents)
 7) **Replication** : 03
 8) **Date of Sowing** : 18/08/2022
 9) **Number of plants per plot** : 20
 10) **Total number of plots** : 39

Plan of Layout

RI		RII		RIII
Pr 4 1 × 2		Pr 3 1 × 4		P4
Pr 3 1 × 2		Pr 3 1 × 4		P3
Pr 2 1 × 2		Pr 1 1 × 4		P2
P4		Pr 4 1 × 3		P1
P3		Pr 2 1 × 3		Pr 4 1 × 4
P2		Pr 1 1 × 3		Pr 3 1 × 4
P1		Pr 4 1 × 2		Pr 1 1 × 4
Pr 1 1 × 3		Pr 3 1 × 2		Pr 4 1 × 3
Pr 2 1 × 3		Pr 2 1 × 2		Pr 2 1 × 3
Pr 4 1 × 3		P1		Pr 1 1 × 3
Pr 1 1 × 4		P2		Pr 4 1 × 2
Pr 3 1 × 4		P3		Pr 3 1 × 2
Pr 3 1 × 4		P4		Pr 2 1 × 2

3.4 Observations recorded:

In evaluation of F₄ generation population of all the three hybrids and their parents were taken and 20 plants from each treatment in each replication were selected randomly to the record for observations to study genetic variability for yield and yield contributing characters.

3.4.1 Growth character:

3.4.1.1 Number of branches per vine

All the primary branches on shoot of the vine were recorded at the time of last harvesting of crop.

3.4.1.2 Length of vine (m)

The final length of vine is taken at the time of last harvesting in meters from base of the vine to the tip

3.4.2 Flowering character:

3.4.2.1 Days to first male flower appearance

The days to appearance of first male flower was recorded separately for parent and progenies from the date of sowing.

3.4.2.2 Days to first female flower appearance

The days to appearance of first female flower was recorded separately for parent and progenies from the date of sowing.

3.4.2.3 Node number at which first male flower appeared

The node at which the first male flower produced was recorded from the first node.

3.4.2.4 Node number at which first female flower appeared

The node at which the first female flower produced was recorded from the first cotyledonary node in numbers.

3.4.2.5 Days to 50% flowering.

The number of days required to 50% flowering from the date of sowing was recorded.

3.4.2.6 Number of male flowers per vine

The total number of male flowers from the date of sowing was recorded for each parent and progenies.

3.4.2.7 Number of female flowers per vine

The total number of female flowers from the date of sowing was recorded for each parent and progenies.

3.4.2.8 Sex ratio

The total number of female flowers was divided by total number of male flowers and sex ratio was obtained.

3.4.2.9 Days to first picking

The number of days required to first fruit harvesting from the date of sowing was recorded for each parent and progenies.

3.4.2.10 Days to last picking

The number of days required to last fruit harvesting from the date of sowing was recorded for each parent and progenies.

3.4.3 Fruit character (Quantitative):**3.4.3.1 Length of fruit (cm)**

The length of the fruit was measured from the pedicel end to tip and average of five fruits taken.

3.4.3.2 Diameter of fruit (cm)

The diameter of five fruit was measured at the wide point with the help of digital Verniers caliper and average of five fruits taken.

3.4.3.3 Weight of fruit (g)

The average weight of the single fruit was measured in grams and average of five fruits taken.

3.4.4 Yield characters:**3.4.4.1 Number of fruits per vine**

Number of fruits per vine were recorded for each picking from all the observational vine separately and summed up after last picking and the average number of fruits per vine were worked out.

3.4.4.2 Fruit yield per vine (kg)

The yield of harvested fruits of all pickings from each observational vine was summed up and the average fruit yield per vine was calculated.

3.4.4.3 Fruit yield per plot (kg)

The yield of harvested fruits of all pickings from each observational plot and calculated.

3.4.4.4 Fruit yield (q/ha)

The total number of fruits per vine was summed up then multiplied by hectare factor.

3.4.5 Fruit characters (Qualitative/ Morphological):**3.4.5.1 Shape of fruit (ovate, oblong, spindle, club shape, triangular)**

Fruit shape was recorded at full mature stage by visual observation as ovate, oblong, spindle, club shape, triangular.

3.4.5.2 Color of fruit (light green, green and dark green)

Fruit color was recorded at full mature stage by visual observation as light green, green and dark green.

3.4.5.3 Prickles – Dense / Sparse (low, Medium, High)

Prickles on fruit of each generation were recorded at full mature stage by visual observation as low, medium and high.

3.4.6. Percent incidence of disease and pest:

3.4.6.1 Percent incidence of disease

Number of plants affected by inestation of Downy mildew infestation were counted and the per cent disease incidence (PDI) was worked out as per following formula.

$$\text{PDI} = \frac{\text{Number of infected plants}}{\text{Total number of plants}} \times 100$$

3.4.6.2 Percent incidence of pest

Number of fruits affected by the infestation of Fruit fly infestation was counted and the per cent incidence was worked out. The percentage of pest incidence was calculated by the following formula.

$$\text{Percent incidence of Fruit fly} = \frac{\text{Number of infected fruits}}{\text{Total number of fruits}} \times 100$$

3.5 Statistical analysis

The statistical analysis of the quantitative data obtained during the course of investigation was done by following statistical models as under:

3.5.1 Analysis of variance

Averages were work out based on individual plant data and same was used for analysis of variance. The Randomized Block Design (RBD) analysis of variance was carried out separately for each character as per Panse and Sukhatme (1985).

Sr. No.	Source of variation	Degree of freedom	SS	MSS	T variation
1	Replications	r-1	RSS	RMSS= RSS/ (r-1)	RMSS
2	Treatments	t-1	TrSS	TrMSS= TrSS/ (t-1)	TrMSS
3	Error	(r-1)(t-1)	ESS	EMSS= ESS per (r-1)(t-1)	
4	Total	Rt-1	TSS		

Where,

- r = Number of replications
- n = Number of treatments
- df = Degree of freedom SS = Sum of square
- RSS = Replication sum of square
- TSS = Treatment sum of square
- ESS = Error sum of square
- MSS = Mean sum of square

3.5.2 Test of Significance

If the variance ratio (MSSTrt/MSSE) was greater than the tabulated value of F, the difference were considered to be significant at 5% and 1% level of significance and we could reject the null hypothesis. If it was lower than the table value, the differences were considered to be non-significant and we would accept the null hypothesis.

3.5.3 Variability Parameters

3.5.3.1 Estimation of Mean

The mean values for each character were worked out by the following formula,

$$\bar{X} = \frac{\sum_{i=1}^N X_i}{N}$$

Where,

- $\bar{X}$ = Mean of character
- $\sum X_i$ = Total of all the observations for character
- N = Number of observations

3.5.3.2 Estimation of Range

The difference between the highest and the lowest values, from mean of each character were recorded as range.

3.5.3.3 Variance

It is expressed as the sum of squares of deviations of all observations of a sample from its mean divided by the degrees of freedom.

3.5.3.3.1 Genotypic variance

Genotypic variance was calculated by following formula,

$$\sigma^2 = \frac{MSSTrt - MSSE}{r}$$

Where,

MSSTrt = Treatment mean sum of squares

MSSE = Error Mean sum of squares

r = Number of replications

3.5.3.3.2 Phenotypic variance

Phenotypic variance was calculated by the following formula

$$\sigma^2_p = \text{Genotypic variance} + \text{Environmental Variance}$$

Where,

Environmental Variance = Mean sum of squares due to error

3.5.3.4 Standard error of mean

Standard error of mean was calculated by the formula,

$$\text{SED} = \frac{\sqrt{2\text{MSSE}}}{r}$$

3.5.3.5 Critical Difference

The following is the formula to calculate critical difference

Standard error of mean was calculated by the formula,

$$\text{CD} = \frac{\sqrt{2\text{MSSE}}}{r} \times t_{\alpha}$$

Where,

t_{α} = “t” Table value at error degree of freedom at 5 % level of significance

R = number of replications

MSSE = Mean sum of square due to error

3.5.3.6 Coefficients of variation

It is an important measure of variability and is the per cent ratio of standard deviation of a sample to its mean. The phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) in this study were calculated by formula given by Burton (1952).

- **Genotypic coefficient of variation (GCV)**

It was estimated as per the formula suggested by Burton (1952).

$$\text{GCV} = \frac{\sqrt{\sigma^2_g}}{\bar{X}} \times 100$$

Where,

σ^2_g = Genotypic variance

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

- **Phenotypic coefficient of variation (PCV)**

It was estimated as per the formula suggested by Burton (1952)

$$PCV = \frac{\sqrt{\sigma^2_p}}{\bar{X}} \times 100$$

Where,

σ^2_p = V_p = Phenotypic Variance

3.5.3.7 Heritability (broad sense)

Heritability denotes the proportion of phenotypic variance that is due to genotype and hence heritable. Heritability (h^2) was worked out by using formula suggested by Lush (1949) and Burton and De vane (1953).

The values of heritability are categorized as follows (Johnson *et al*, 1955)

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

$$h^2 \text{ (broad sense)} = \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

Where,

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

3.5.3.8 Genetic Advance

The formula for genetic advance that means expected genetic gain was suggested by Lush (1949) and Johnson *et al.*, (1955) is presented below,

$$GA = k\sigma_p h^2 (bs)$$

$$GA = k\sigma_p h^2 (bs)$$

Where,

K = Selection differential in standard units which is 2.06 at 5 % of selection intensity (in the present study)

h^2 (bs) = Heritability

σ_p = Phenotypic standard deviation

3.5.3.9 Genetic advance as % of mean (GAM)

$$\text{GAM (\%)} = \frac{\text{GA}}{\text{Grand mean}} \times 100$$

Genetic advance as % of mean values are categorized as follows

High : More than 20 %

Medium : 10 – 20 %

Low : Less than 10 %

3.5.4 Correlation

To understand the association among the characters, genotypic and phenotypic correlation coefficients were worked out by adopting method described by Singh and Choudhary (1977).

3.5.4.1 Phenotypic correlation coefficients

$$\gamma_p = \frac{\text{Covariance } X, Y_{(p)}}{\sqrt{\text{Variance } X_{(p)}, \text{Variance } Y_{(p)}}}$$

Where,

r_p = Phenotypic correlation coefficient between character X and Y

p = Phenotypic

3.5.4.2 Genotypic correlation coefficient

$$\gamma_g = \frac{\text{Covariance } X, Y_{(g)}}{\sqrt{\text{Variance } X_{(g)}, \text{Variance } Y_{(p)}}}$$

Where,

r_g = Genotypic correlation coefficient between character X and Y

g = Genotypic

Significance of correlation coefficients were tested by 't' test (Panse and Sukhatme, 1985)

3.5.5 Path analysis

The direct and indirect influence of components of flower yield path coefficient analysis was done by the methods employed by Dewey and Lu (1959) for the first time in plants. When the cause and effect relationship was well defined the whole systems of variables was represented by "Path Diagram" which was very helpful for solving the simultaneous equations directly. Path coefficient was obtained by solving a set of simultaneous equations as per Dewey and Lu (1959).

$$R_{n_y} = P_{n_y} + r_{n_2} \cdot P_{2y} + e_{n_3} \cdot P_{3x} + \dots$$

Where,

- r_{ny} = Correlation coefficient between one component and yield
 P_{ny} = Path coefficient between character and yield
 R_{n2} = Correlation between that character and each of the other yield component.

Direct effect of the character was given by P_{ny}

Indirect effect of a particular character through other characters was obtained by multiplication of direct paths and respected correlation coefficients between these characters respectively.

$$\text{Indirect effect} = r_{ij} \times P_{ij}$$

$$i = 1 \text{ to } 10 \text{ and } j = 1 \text{ to } 10$$

$$P_{ij} = P_{1y}, P_{2y}, \dots, P_{10y}$$

The Residual effect R was calculated as below,

$$R^2 = 1 - (P_{1y}.r_{1y} + P_{2y}.r_{2y} + \dots + P_{ny}.r_{ny})$$

Where,

$P_{1y}, P_{2y}, \dots, P_{ny}$ = Direct effects of respective characters on fruit yield.

$r_{1y}, r_{2y}, \dots, r_{ny}$ – Correlation coefficient between respective characters and yield.

The scales for path coefficient (Lenka and Mishra, 1973)

Values for Direct or Indirect effects	Rate or Scale
0.00 – 0.09	Negligible
0.1 – 0.19	Low
0.20 – 0.29	Moderate
0.30 – 0.99	High
More than 1.00	Very high

3.5.6 Genetic Divergence

3.5.6.1 D^2 analysis

The generalized distance between any two populations is defined as

$$\Delta^2 = \sum \sum \lambda_{ij} \sigma^i \sigma^j$$

Where,

λ_{ij} = Reciprocal matrix to the common dispersion matrix

σ^i = Difference between the mean values of the two populations for i^{th} character.

$$D^2 = \sum \sum S_{ij} \sigma^i \sigma^j$$

Where,

S_{ij} = sample estimates of σ_{ij}

σ^i = sample estimate of σ_i

This formula requires the inversion of 16th order of determinant and the evaluation of 16 (16 +1/2) terms whose sum is D^2 .

3.5.6.2 Wilk's criteria

A simultaneous test of significance of difference in the values of a number of correlated variables with regard to the Pooled effect of the ten characters considered together was carried using Wilk's criteria (Wilk, 1932)

Where,

$$\Lambda = \frac{|E|}{|E + V|}$$

$|E|$ = Determinant of the error sum of squares and sum of products matrix

$|E + V|$ = Determinant of error sum of squares and sum of products plus population sum of squares and product matrix.

Significance of Λ was estimated by X as

$$X^2_{pq} = -m \log \Lambda$$

Where,

$$m = \frac{p + q + 1}{2}$$

$n = N_1 + \dots + N_{k-1} = \text{Total number of observations} - 1$

p = Number of characters

q = $K - 1$

K = Number of genotypes

3.5.6.3 Mahalanobis's generalized distance (D^2)

The generalized distance between two populations is lined by Mahalanobis (1936) as,

$$D^2 = i.j.d_i.d_j$$

Where,

λ_{ij} = Reciprocal matrix to the common dispersion matrix

d_i = Difference between the mean values of two population for i^{th} character

d_j = Difference between the mean values of two population of j^{th} character

Estimation of D^2 values from the above formula is very complicated in the present study. Since it requires the inversion of tenth order determinant and then the evaluation of $10(10+1)/2$ terms whose sum is D^2 . It was found convenient to work with a set of uncorrelated characters constructed from the original measurements D with such transformed variable is reduced to the evaluation of simple sum of squares. Transformation was done by using pivotal condensation method Singh and Chaudhary (1977). The coefficients for transformation were obtained by dividing the first row of the reduced matrix by the square root of corresponding pivotal condensation elements.

3.5.6.4 Determination of population constellation

Tocher's method as described by Rao (1952) was followed for cluster formation. No formal rules can be laid down for finding the cluster because a cluster is not a well-defined term. The only criteria appears to be that any two groups belonging to the two different clusters. A simple device suggested by K. D. Tocher is to start with the two closely associated groups and find a third group which has the smallest D^2 from the first two. Similarly, the fourth group is chosen to have the smallest D^2 from the first three and so on. If at any stage the average D^2 of a group from those already listed appears to be high, then this group does not fit in the former groups and is therefore taken outside the formal cluster. The groups of the first cluster then omitted and the rest are treated similarly. It is also useful to calculate the change in average D^2 within the cluster due to the inclusion of an additional group. If the changes are appreciable, then the newly added group has to be considered as outside the cluster.

3.5.6.5 Average Intra and Inter-cluster D^2 and D values

3.5.6.5.1 Average Intra-cluster D^2 and D Values

$$D^2 = \frac{\sum D_i^2}{N}$$

Where,

D_i = Sum of distances between all possible combinations (n) of the population included in the cluster.

3.5.6.5.2 Average Inter-cluster D^2

$$D^2 = \frac{\sum \text{distance between the population of cluster } i \text{ and } j}{n_i n_j}$$

Where,

n_i = Number of populations in the cluster i

n_j = Number of populations in the cluster j .

3.5.6.5.3 Cluster mean

Cluster mean where calculated for individual character on the basis of mean performance of the genotypes included in that cluster.

3.5.6.6 Contribution of individual characters towards genetic divergence

The character contribution towards genetic divergence was computed as suggested Singh and Chaudhary (1977). From all combinations, each character was ranked on the basis of $d_i = y_{ij} - y_{ik}$ values. Where, d_i = mean deviation y_{ij} = mean of the j th genotype for the i th character and y_{ik} = mean value of the k th genotype for the character. Rank 'I' is given to the highest mean difference and rank 'P' is given to the lowest mean difference. Where, P is the total characters. For estimation of per cent contribution of characters towards divergence, the number of times that each character appeared in the first rank is computed.

4. RESULT AND DISCUSSION

The best hybrid combination with genetic variability must be chosen in order to produce superior hybrids in plant breeding. Progenies from a variety of diverse crosses will probably show a wide range of genetic variation, giving the breeder ample opportunity to select segregates that yield high yields in subsequent generations.

Based on the details mentioned above, the current research was conducted to evaluate the genetic diversity of three F_1 hybrids along with their parents that were collected from the AICRP on Vegetables, MPKV., Rahuri. It also examined correlation coefficient and path efficiency. The results of the present research entitled, “Variability studies of F_4 generation in bitter gourd (*Momordica charantia* L.)” are presented below with sub headings.

4.1 Study of qualitative characters

4.2 Percent incidence of disease and pest

4.3 Analysis of variance

4.4 Mean performance of progenies

4.5 Genetic variability studies

4.6 Correlation coefficient analysis

4.7 Path analysis study

4.8 Genetic divergence

4.1 Study of qualitative characters (Fruit characters)

Following F_1 hybrids, $C_1 : 1 \times 2$ (RHRBG-26 and RHRBG-24), $C_2 : 1 \times 3$ (RHRBG-26 and RHRBG-10), $C_3 : 1 \times 4$ (RHRBG-26 and RHRBG-29) along with their parents (RHRBG-26, RHRBG-24, RHRBG-10, RHRBG-29) were evaluated for various fruit characters viz., shape of fruit, color of fruit, prickles – dense / sparse.

4.1.1 Shape of fruit

According to the table 4.1 fruit shape were reported to be oblong in shape in the F_4 generations of the crosses namely, $C_1 : 1 \times 2$ (RHRBG-26 and RHRBG-24), $C_2 : 1 \times 3$ (RHRBG-26 and RHRBG-10), $C_3 : 1 \times 4$ (RHRBG-26 and RHRBG-29).

The fruit shape of the parents, RHRBG-26 (1), RHRBG-24 (2), RHRBG-10 (3), and RHRBG-29 (4) was found to be oblong in shape. Thus, fruit shape was controlled by additive variance similar results were reported by, Bahiram *et al.* (2022), Rajput (2012) for bitter gourd. In muskmelon, Jagtap (2010) and Patil (2014).

Table 4.1: Fruit character (Qualitative / Morphological) in F₄ generation of bitter gourd

Treatment	Shape of fruit	Color of fruit	Prickles
Pr 2 (1 × 2)	Oblong	Green	High
Pr 3 (1 × 2)	Oblong	Green	Medium
Pr 4 (1 × 2)	Oblong	Green	High
Pr 1 (1 × 3)	Oblong	Green/Light green	High
Pr 2 (1 × 3)	Oblong	Green	High
Pr 4 (1 × 3)	Oblong	Green	High
Pr 1 (1 × 4)	Oblong	Green	High
Pr 3 (1 × 4)	Oblong	Green	High
Pr 4 (1 × 4)	Oblong	Green	High
P1	Oblong	Green	High
P2	Oblong	Green	High
P3	Oblong	Green	High
P4	Oblong	Green	High

4.1.2 Color of fruits

As shown in table 4.1, three crosses namely C₁ : 1 × 2 (RHRBG-26 and RHRBG-24), C₂ : 1 × 3 (RHRBG-26 and RHRBG-10), C₃ : 1 × 4 (RHRBG-26 and RHRBG-29) exhibited green fruit color. One of the progeny Pr 1 (1 × 3) had exhibited light green color fruit in the F₄ generation. Due to the segregation, fruit color exhibited in the cross Pr 1 (1 × 3) was observed green and light green in color. In the particular cross 27.93 fruits obtained had green color dominant over light green color.

The fruit color of the parents, RHRBG-26 (1), RHRBG-24 (2), RHRBG-10 (3), and RHRBG-29 (4) was found to be green in color as shown in table 4.1. These findings for bitter gourd and muskmelon concurred with those of Dalamu *et al.* (2012), Rajput (2012) and Patil (2014).

4.1.3 Prickles

Table 4.1 shows high prickles on the fruit surface of the fruit in the hybrids C₁:1 × 2 (RHRBG-26 and RHRBG-24), C₂ : 1 × 3 (RHRBG-26 and RHRBG-10) and C₃: 1 × 4 (RHRBG-26 and RHRBG-29). One of the genotype Pr 3 (1 × 2) had medium prickles on their fruit surface. Such continuous and high prickles showed dominant effect over the medium and low prickles on the surface of bitter gourd.

Prickles on surface of the parents exhibited high prickles in RHRBG-26 (1), RHRBG-24 (2), RHRBG-10 (3), and RHRBG-29 (4). Similar results were reported by, Rajput (2012) and Dalamu *et al.* (2012) in bitter gourd.

4.2 Percent incidence of disease and pest

4.2.1 Downy mildew incidence

In the present investigation for disease and pest, maximum intensity of downy mildew was observed in the progeny Pr 4 (1×2) 13.22 (21.32) while minimum intensity was observed in the progeny Pr 1 (1×4) 8.15 (16.59) followed by Pr 3 (1×4) 8.23 (16.67), P4 8.88 (21.35) as shown in table 4.2.

Similar results were also reported by, Rajput (2012) in regards to bitter gourd, Jagtap (2010) and Patil (2014) in regards to muskmelon.

4.2.2 Fruit fly infestation

For pest incidence, maximum intensity of fruit fly was observed in progeny Pr 2 (1×2) 13.85 (21.85), while minimum intensity was observed in the progeny Pr 3 (1×4) 9.75 (18.19) followed by parent P4 9.79 (18.23) and parent P1 10.21 (18.63) as shown in table 4.2.

Similar results were also reported by, Lawande (1987), Rajput (2012) and Patil (2014) for muskmelon and bitter gourd, respectively.

Table 4.2: Percent intensity of disease and pest

Sr. No.	Treatment	Disease Incidence percent (%)	Pest Incidence percent (%)
1.	Pr 2 (1×2)	10.98 (19.35)	13.85 (21.85)
2.	Pr 3 (1×2)	11.31 (19.65)	11.49 (19.81)
3.	Pr 4 (1×2)	13.22 (21.32)	11.47 (19.80)
4.	Pr 1 (1×3)	9.87 (18.31)	12.17 (20.42)
5.	Pr 2 (1×3)	10.35 (18.77)	10.82 (19.20)
6.	Pr 4 (1×3)	9.39 (17.84)	11.29 (19.63)
7.	Pr 1 (1×4)	8.15 (16.59)	12.29 (20.52)
8.	Pr 3 (1×4)	8.23 (16.67)	9.75 (18.19)
9.	Pr 4 (1×4)	9.39 (17.84)	11.29 (19.63)
10.	P1	11.35 (19.69)	10.21 (18.63)
11.	P2	11.47 (19.35)	11.08 (19.44)
12.	P3	12.96 (19.65)	12.66 (20.84)
13.	P4	8.88 (21.35)	9.79 (18.23)
	SE (m)	0.32	0.35
	CD	0.96	1.03
	C.V.	5.47	5.35

4.3 Analysis of Variance

Data in table 4.3 revealed that almost all the characters have differed significantly. Among all the crosses and parents there was significant variations for the numbers of branches per vine, length of vine (m), days to first male flower appearance, days to first female flower appearance, node at which first male appeared, node at which first female

flower appeared, days to 50 % flowering, number of male flowers per vine, number of female flowers per vine, sex ratio, days to first picking, days to last picking, length of fruit (cm), diameter of fruit (cm), weight of fruit (g), fruit yield per vine (kg), fruit yield per plot (kg), fruit yield (q/ha). The analysis of variance was used to determine the importance of variations in replications, genotypes, and other significant sources of variation during the *kharif* season. Similar to the present findings, significant differences for the various characters was reported by, Rajput (2012), Pathak *et al.*, (2014), Gupta *et al.*, (2015) and Singh *et al.*, (2017). In bottle gourd Yadav and Kumar (2012).

4.4 Mean performances of progenies and parents

Table 4.4 displays the averaged over replication mean performances of parents and progenies for the nineteen characters that are being studied.

4.4.1 Number of branches per vine

Number of branches per vine showed wide variations and ranges between 9.77 to 14.60. Highest number of branches was observed in the progeny Pr 3 (1×4) (14.60) followed by Pr 1 (1×4) (13.90) and Pr 1 (1×3) (13.58). Lowest number of branches was observed in parent P2 (9.77).

The number of branches per vine is a crucial character since more number of branches per vine correlate with more flowering. Lawande and Patil (1990) and Sarkar and Sirohi (2011) observed similar findings.

4.4.2 Length of vine (m)

Vine length showed variation between 5.19 to 7.28. Highest vine length was observed in the progeny Pr 4 (1×3) (7.28) followed by Pr 4 (1×4) (7.14) and parent P3 (6.56). Lowest vine length (m) was observed in progeny Pr 4 (1×2) (5.19).

The length of the vine is an important factor since a longer vine produces more fruit. Lawande and Patil (1990), Ranpise *et al.* (1992), and Sarkar and Sirohi (2011) reported comparable findings earlier.

4.4.3 Days to first male flower appearance

Days to first male flower appearance varied between 41.23 to 55.20 days. Highest number of days for the appearance of first male flower was observed in Pr 3 (1×4) (55.20 days) which was followed by Pr 3 (1×2) (51.52 days) and Pr 2 (1×2) (49.16 days). Lowest number of days for appearance of first male flower was observed by progeny Pr 1 (1×3) (41.23 days).

Similar finding were reported by Rani (2014), Patil (2014) and Sarkar and Sirohi (2011).

Table 4.3: Analysis of variance for nineteen characters of bitter gourd

Sr. No.	Character	Replication	Treatment	Error
		2	12	24
1.	Number of branches per vine	9.88	76.44	11.03
2.	Length of vine (m)	1.95	15.21	5.64
3.	Days to first male flower appearance	143.50	520.23	291.56
4.	Days to first female flower appearance	1268.69	430.81	205.63
5.	Node at which first male appeared	13.79	88.13	11.79
6.	Node at which first female flower appeared	28.92	253.38	28.42
7.	Days to 50 % flowering	1339.88	257.66	195.80
8.	Number of male flowers per vine	23486.54	14156.75	3597.98
9.	Number of female flowers per vine	336.29	578.24	115.16
10.	Sex ratio	1.20	44.07	7.39
11.	Days to first picking	278.28	894.10	454.05
12.	Days to last picking	2072.96	4338.61	958.80
13.	Length of fruit (cm)	47.36	296.99	45.57
14.	Diameter of fruit (cm)	1.35	21.39	1.08
15.	Weight of fruit (g)	220.39	2942.45	496.70
16.	Number of fruits per vine	120.19	1007.64	258.12
17.	Fruit yield per vine (kg)	1.49	8.67	2.19
18.	Fruit yield per plot (kg)	37.39	216.59	54.85
19.	Fruit yield (q/ha)	6640.82	38498.00	9745.50

4.4.4 Days to first female flower appearance

Days to first female flower appearance ranged between 47.89 to 60.23 days. Highest number of days for appearance of first female flower was observed in Pr 3 (1×4) (60.23 days) which was followed by Pr 4 (1×4) (56.89) and parent P3 (53.89 days). Lowest number of days for appearance of first female flower was observed by progeny Pr 1 (1×3) (47.89 days).

Similar results reported earlier by Alekar *et al.* (2019), Patil (2014) and Sarkar and Sirohi (2011).

4.4.5 Node at which first male flower appeared

The range between node number at which first male flower appeared was between 7.80 to 12.80 node. Highest node number at which first male flower appeared was observed in progeny Pr 4 (1×4) (12.80) followed by Pr 4 (1×2) (12.47) and parent P3 (11.60). Lowest node number at which first male flower appeared was observed in parent P2 (7.80).

Similar result reported earlier by Thangamani (2011), Tyagi *et al.* (2018).

4.4.6 Node at which first female flower appeared

The range between node number at which first female flower appeared was between 11.30 to 20.40 node. Highest node number at which first female flower appeared was observed in progeny Pr 1 (1×4) (20.40) followed by parent P3 (18.00) and parent P4 (16.20). Lowest node number at which first male flower appeared was observed in progeny Pr 1 (1×3) (11.30).

The number of nodes at which the first female flower appears is significant since it affects both the yield and the fruit set. Similar results were earlier reported by Patil (2014) and Thangamani (2011), Tyagi *et al.* (2018)

4.4.7 Days to 50% flowering

Days to 50% flowering varied between 53.12 to 62.01 days. Earliest 50% flowering was observed in parent P4 (62.01) followed by parent P1 (59.39) and parent P3 (59.28). Lowest days to 50% flowering was observed in Pr 4 (1×4) (53.12).

Early flowering has positive effect on fruit set of the crop. Similar results was reported earlier by, Bahiram *et al.* (2022), Kumari *et al.* (2020)

4.4.8 Number of male flowers per vine

Number of male flowers per vine varied between 188.51 to 247.23 flowers. Highest number of male flowers per vine was observed in parent P4 (247.23) followed by cross Pr 4 (1×2) (242.71) and parent P2 (239.83). Lowest number of male flowers per vine was observed in Pr 2 (1×2) (188.51).

4.4.9 Number of female Flowers per vine

Number of female flowers per vine varied between 27.25 to 38.99 flowers. Highest number of female flowers per vine was observed in progeny Pr 3 (1×4) (38.99) followed by progeny Pr 1 (1×4) (38.77) and parent P4 (37.06). Lowest number of female flowers per vine was observed in Pr 4 (1×2) (27.25).

Number of female flowers is important factor because higher the number of female flowering will give more number of fruits and ultimately higher yield. Similar

results are also agreed by Ranpise *et al.* (1992) and Mehta *et al.* (2005) in bitter gourd and ridge gourd respectively.

4.4.10 Sex ratio

Sex ratio ranged between 5.13 to 8.99. Lowest sex ratio was observed in the progeny Pr 1 (1×4) (5.13) followed by parent Pr 3 (1×4) (5.34) and parent Pr 4 (1×4) (5.91). Highest sex ratio was observed in Pr 4 (1×2) (8.99).

The lowest male to female ratio is desirable since it results from having more female flowers. Lower the sex ratio will have good impact on bitter gourds because it directly influences fruit yield. The results obtained are in line with those of Pandey and Singh (2007) in sponge gourd, Munshi and Acharya (2005) in bottle gourd, Rani K (2014) in bitter gourd.

4.4.11 Days to first picking

Days to first picking showed variation between 60.12 to 71.78 days. Minimum number of days required for first picking was recorded in the cross Pr 4 (1×4) (60.12) followed by progeny Pr 1 (1×3) (61.80) and Pr 2 (1×3) (64.96) days. Maximum number of days required for first picking was recorded in parent P4 (71.78) days.

Comparable results regarding the number of days needed for the initial fruit picking have been reported by Purohit *et al.* (2005), Ahsan *et al.* (2011), Laxuman *et al.* (2012) and Verma and Singh (2014), Tyagi *et al.* (2018) in bitter gourd.

4.4.12 Days to last picking

Days to last picking showed variation between 108.61 to 144.46 days. Maximum number of days required for last picking was recorded in the progeny Pr 4 (1×3) (144.46) followed by parent P2 (136.78) and Pr 3 (1×4) (135.68) days. Minimum number of days required for the last picking was recorded in Pr 4 (1×2) (108.61) days.

Similar results were reported by Bahiram *et al.* (2022) in bitter gourd.

4.4.13 Length of fruit (cm)

Length of fruit showed variation between 15.25 to 25.36 cm. Maximum length of fruit was observed in Pr 4 (1×4) (25.36) which was followed by Pr 1 (1×4) (24.18) and parent P1 (22.78) cm. Minimum length of fruit was observed in Pr 1 (1×3) (15.25). Two of the progeny showed superior length than parents.

Yield is greatly influenced by the length of fruit. Similar results reported earlier by Lawande and Patil (1990), Singh *et al.* (2000), Mehta *et al.* (2005), Jadhav *et al.* (2009), Laxuman *et al.* (2012), Mule *et al.* (2012), Talukder *et al.* (2018) and Alekar *et al.* (2019) in bitter gourd.

4.4.14 Diameter of fruit (cm)

Diameter of fruit varied between 2.99 to 5.72 cm. Maximum diameter of fruit was observed in progeny Pr 2 (1×3) (5.72) which was followed by Pr 1 (1×4) (4.55) and Pr 4 (1×2) (4.52) cm. Minimum diameter of fruit was observed in Pr 4 (1×4) (2.99) cm.

Larger diameter of fruit will have long fruit shape and large weight. These results are in correspondence with those reported by Purohit *et al.* (2005), Mehta *et al.* (2005), Laxuman *et al.* (2012), Verma and Singh (2014), Tygai *et al.* (2018) and Ndukauba *et al.* (2019) in bitter gourd.

4.4.15 Weight of fruit (g)

Weight of fruit varied between 78.27 to 104.23 gram. Maximum fruit weight was observed in Pr 1 (1×4) (104.23) which was followed by Pr 3 (1×4) (100.78) and Pr 2 (1×3) (98.91) gram. Minimum fruit weight was observed in parent P2 (78.27) gram.

Maximum the fruit weight will have more yield. Similar results were reported by Lawande and Patil (1990), Thangamani *et al.* (2011) and Verma and Singh (2014, (2018) in bitter gourd.

4.4.16 Number of fruits per vine

Number of fruits per vine showed variation between 20.41 to 35.19 fruits. Maximum number of fruits per vine was observed in the progeny Pr 1 (1×4) (35.19) fruits which was followed by Pr 3 (1×4) (34.88) and parent P4 (33.95) fruits per vine. Minimum number of fruits per vine was observed in the progeny Pr 4 (1×2) 20.41 fruits.

The more number of fruits could be attributed due to long vine length and more number of primary branches. These results similar to the Singh *et al.* (2000)a, Jadhav *et al.* (2009), Laxuman *et al.* (2012), Patil (2014) and Tyagi *et al.* (2018).

4.4.17 Fruit yield per vine (kg)

Fruit yield per vine showed variation between 1.90 to 3.27 kg. Maximum fruit yield per vine was observed in progeny Pr 1 (1×4) (3.27) which was followed by Pr 3 (1×4) (3.23) and parent P4 (3.15) kg. Minimum fruit yield per vine was observed in Pr 4 (1×2) (1.90) kg.

The similar result were reported by, Thangamani *et al.* (2011), Laxuman *et al.* (2012) in bitter gourd.

4.4.18 Fruit yield per plot (kg)

Fruit yield per plot showed variation between 9.48 to 16.36 kg. Maximum fruit yield per plot was observed in the progeny Pr 1 (1×4) (16.36) which was followed by Pr 3 (1×4) (16.16) and parent P4 (15.76). Lowest fruit yield per plot was observed in the progeny Pr 4 (1×2) (9.48) kg.

4.4.19 Fruit yield (q/ha)

Fruit yield (q/ha) showed variation between 126.34 to 218.12 q/ha. Highest fruit yield was observed in the progeny Pr 1 (1×4) (218.12) which was followed by Pr 3 (1×4) (215.43) and parent P4 (210.12) q/ha. Lowest fruit yield was observed in the progeny Pr 4 (1×2) (126.34) q/ha.

Fruit yield (q/ha) is the important factor on which the breeding program is depended. Similar results were reported by Lawande and Patil (1990) and Thangamani *et. al.* (2011) and Alekar *et al.* (2019) in bitter gourd.

Table 4.4: Mean performance of all the progenies/parents for the following characters

Treatment	NBPV (No.)	LV (m)	DFMFA (No.)	DFFFA (No.)	NFMA (No.)	NFFA (No.)	DFE (No.)	NMPV (No.)	NFPV (No.)	SR
Pr 2 (1×2)	13.38	5.85	49.16	50.61	11.08	15.57	53.66	188.51	31.12	6.06
Pr 3 (1×2)	12.38	5.6	51.52	51.22	12.12	12.65	55.58	194.90	33.89	5.80
Pr 4 (1×2)	10.78	5.19	46.2	50.23	12.47	12.8	58.23	242.71	27.25	8.99
Pr 1 (1×3)	13.58	6.49	41.23	47.89	9.6	11.3	53.23	219.44	32.78	6.68
Pr 2 (1×3)	10.78	5.3	44.83	49.56	11.41	12.2	55.96	198.66	29.12	6.82
Pr 4 (1×3)	12.85	7.28	43.23	48.12	9.4	13.5	58.77	203.40	30.78	6.55
Pr 1 (1×4)	13.9	6.27	44.55	50.45	11	20.4	56.19	198.67	38.77	5.13
Pr 3 (1×4)	14.6	6.42	55.2	60.23	9.8	15.4	56.1	208.96	38.99	5.34
Pr 4 (1×4)	11.78	7.14	51.33	56.89	12.8	14.8	53.12	212.45	36.04	5.91
P1	12.12	5.61	47	51.45	10.8	18.2	59.39	236.67	33.66	7.02
P2	9.77	6.28	48.45	53.45	7.8	15.3	57.94	239.83	30.12	8.02
P3	10.55	6.56	47.1	53.89	11.6	18	59.28	215.38	27.34	7.87
P4	11.7	6.49	45.36	52.12	8.2	16.2	62.01	247.23	37.06	6.66
SE (m)	0.39	0.27	2.01	1.69	0.4	0.62	1.64	7.06	1.26	0.32
CD at 5 %	1.14	0.82	5.87	4.93	1.18	1.83	4.81	20.63	3.69	0.93
CV	5.57	7.83	7.37	5.63	6.6	2.48	5.02	5.67	6.67	8.30

NBPV : Number of branches per vine

LV : Length of vine (m)

DFMFA : Days to first male flower appearance

DFFFA : Days to first female flower appearance

NFMA : Node at which first male flower appeared

NFFA : Node at which first female flower appeared

DFE : Days to 50 % flowering

NMPV : Number of male flowers per vine

NFPV : Number of female flowers per vine

SR : Sex ratio

Table 4.4 contd...

Treatment	DFP (No.)	DLP (No.)	LF (cm)	DF (cm)	WF (g)	NFPV (No.)	FYPV (Kg)	FYPP (kg)	FY(q/ha)
Pr 2 (1×2)	66.05	122.4	21.19	4.06	92.79	26.37	2.45	12.26	163.38
Pr 3 (1×2)	65.72	110.17	20.38	3.25	84.85	25.78	2.39	11.97	159.59
Pr 4 (1×2)	68.23	108.61	19.12	4.52	79.13	20.41	1.9	9.48	126.34
Pr 1 (1×3)	61.8	115.01	15.25	4.12	92.68	27.93	2.58	12.91	172.1
Pr 2 (1×3)	64.96	130.49	21.89	5.72	98.91	26.76	2.48	12.42	165.6
Pr 4 (1×3)	68.77	144.46	22.13	3.89	98.79	28.32	2.63	13.15	175.3
Pr 1 (1×4)	70.66	124.95	24.18	4.55	104.23	35.19	3.27	16.36	218.12
Pr 3 (1×4)	67.7	135.68	22.12	3.14	100.78	34.88	3.23	16.16	215.43
Pr 4 (1×4)	60.12	113.46	25.36	2.99	96.14	33.13	3.07	15.36	204.72
P1	68.39	131.45	22.78	3.55	84.13	24.85	2.31	11.53	153.68
P2	68.94	136.78	19.13	3.21	78.27	21.19	1.96	9.82	130.96
P3	69.4	128.23	16.18	4.1	81.29	20.68	1.92	9.61	128.14
P4	71.78	123	20.53	3.2	92.79	33.95	3.15	15.76	210.12
SE (m)	1.95	3.64	0.79	0.12	2.62	1.89	0.17	0.87	11.64
CD at 5 %	5.71	10.65	2.32	4.06	7.67	5.53	0.51	2.55	33.96
CV	5.05	5.06	6.63	5.5	5.04	11.86	11.79	11.78	11.78

DFP : Days to first picking
DLP : Days to last picking
LF : Length of fruit (cm)
DF : Diameter of fruit (cm)
WF : Weight of fruit (g)

NFPV : Number of fruits per vine
FYPV : Fruit yield per vine (kg)
FYPP : Fruit yield per plot (kg)
FY : Fruit yield (q/ha)

4.5 Genetic variability studies

The level of genetic diversity within the population dictates the level of success that a breeding program will have. Any initiative aimed at improving crops is built on genetic diversity. For the development of high yielding varieties it is necessary to test the variability parameters. Higher the variation provides greater room for advancement. Using the genotypic and phenotypic correlation coefficient, genetic advance, and heritability (h^2 in the broad sense), genetic variability can be assessed at both the genotypic and phenotypic levels.

It is therefore important to estimate the real variation in order to determine the externality of the existent variation, as the range of average values does not reflect the whole variation in the researched material. The coefficients of variation (PCV and GCV) that are computed with consideration for the corresponding means are therefore utilized for comparison. For the crosses $C_1 : 1 \times 2$ (RHRBG-26 $\times$ RHRBG-24), $C_2 : 1 \times 3$ (RHRBG-26 $\times$ RHRBG-10), $C_3 : 1 \times 4$ (RHRBG-26 $\times$ RHRBG-29) genetic variability was assessed for growth, yield and quality attributes.

4.5.1 Variance

Table 4.5 revealed that, results of this experiment showed that environmental impacts are within close proximity since the phenotypic variation values are higher than the genetic variation values. The estimated genotypic and phenotypic variations (V_p and V_g) for the nineteen traits of bitter melon, fruit yield (q/ha) showed the highest values of genotypic and phenotypic variations (934.035 and 1340.097) which was followed by number of male flowers per vine (343.271 and 493.187) and days to last picking (107.20 and 144.15). Lowest variance was observed for the character fruit yield per vine (kg) (0.210 and 0.302).

4.5.2 Coefficient of variation

The degree of genetic and non-genetic variation for different desirable traits was shown by the genotypic and phenotypic coefficient of variation. Higher variability and improved selection were indicated by higher GCV and PCV values for these characters.

For every trait, the estimation of phenotypic and genotypic coefficients of variation was shown in table 4.5. The high GCV and PCV were estimated for diameter of fruit (19.671 and 20.425), fruit yield per vine (17.872 and 21.412), fruit yield (q/ha) (17.868 and 21.403), number of fruits per vine (17.867 and 21.446), fruit yield per plot (17.866 and 21.402), node at which first female flower appeared (17.068 and 18.527), sex ratio (15.852 and 17.899). Moderate GCV and PCV values were observed for node at which first male flower appeared (14.231 and 15.687), length of fruit (13.277 and 14.840), number of female flower per vine (11.580 and 13.364), number of branches per

vine (11.536 and 12.811), weight of fruit (9.578 and 10.822), length of vine (9.480 and 12.297), number of male flowers per vine (8.581 and 10.286), days to last picking (8.285 and 9.706). Low GCV and PCV values were observed for days to 50% flowering (3.702 and 6.237), days to first female flower appearance (5.804 and 8.085), days to first picking (6.618 and 9.408), days to first male flower appearance (6.815 and 10.035).

The high GCV and PCV was found in diameter of fruit (cm), fruit yield per vine (kg), fruit yield (q/ha), number of fruits per vine, fruit yield per plot (kg), node at which first female flower appeared and sex ratio.

Such similar results were reported by Tyagi *et al.* (2018) for days to first picking, node number at which first male flower appeared, node number at which first female flower appeared, length of fruit. Similar results for GCV and PCV are similar with Raja *et al.* (2007), Rajput (2012), Pathak *et al.* (2014), Alekar *et al.* (2019) and Bahiram *et al.* (2022)

4.5.3 Heritability

High value of heritability suggests that, selection based on phenotypic expression could be considered as a playing a major role in genetic constitution for the expression of characters. Thus, high heritability leads to a character's successful selection. Heritability is a measure of the amount of genetic variability that parents pass on to their offspring. According to Lush (1949), heritability in the broad sense is the ratio of total genotypic variance to phenotypic variance, expressed as a percentage.

All the characters exhibited high heritability in the current analysis, ranging from 35.23 to 92.75. High heritability was observed for the characters diameter of fruit (cm) (92.75 %), node at which first female flower appeared (84.87 %), node at which first male flower appeared (82.29 %), number of branches per vine (81.08 %), length of fruit (cm) (80.04 %), sex ratio (78.44 %), weight of fruit (g) (78.34 %), number of female flower per vine (75.09 %), days to last picking (72.85 %), fruit yield (q/ha) (69.70 %), fruit yield per plot (kg) (69.69 %), fruit yield per vine (kg) (69.66 %), number of male flowers per vine (69.60 %), number of fruits per vine (69.41 %). Moderate heritability was observed in the characters like days to 50% flowering (35.23 %), days to first male flower appearance (46.13 %), days to first picking (49.48 %), days to first female flower appearance (51.54 %) and length of vine (m) (53.43 %).

Similar results were reported by, Choudhari *et al.* (1991), Kalloo *et al.* (1983), Swamy *et al.* (1985) in bitter gourd. Also similar results were reported by Dahiya *et al.* (1989), Viswanatha (2003), Prasad *et al.* (2004), Arvindkumar (2004) and Singh and Lal (2005) in muskmelon. Pandey *et al.* (2005), Tokardi and Musmade (2007) and Mishra *et*

al. (2012) reported high heritability estimates for the characters such as node at which first female flower and fruit weight were recorded by Kumar *et al.* (2007) in cucumber.

4.5.4 Genetic advance

Genetic advance explains the degree of gain obtained in a character under a particular selection pressure. High genetic advance coupled with high heritability estimates offers the most suitable condition for selection.

The magnitude of genetic advance observed was very low to extremely high and ranged from 0.7 to 52.56. Genetic advance was observed highest for the characters fruit yield (q/ha) (52.56) which was followed by number of male flowers per vine (31.84) and days to last picking (18.20). Whereas, lowest genetic advance was observed in the characters fruit yield per vine (kg) (0.7) and length of vine (m) (0.9).

These results are similar with those of Srivastava and Srivastava (1976), Singh *et al.* (1977), Lawande (1987), Rajput (2012) and Bahiram *et al.* (2022) in bitter gourd. In muskmelon similar results were reported by, Torkadi and Musmade (2007) and Mehta *et al.* (2010). Similar results were found in cucumber by Kumar *et al.* (2007) and Azcon (2012).

4.5.5 Genetic advance as per cent of mean (%)

Highest genetic advance as per cent mean ($> 20\%$) was observed for the character diameter of fruit (cm) (39.02), node at which first female flower appeared (32.39), fruit yield (q/ha) (30.73), fruit yield per vine (kg) (30.72), fruit yield per plot (kg) (30.72), number of fruits per vine (30.66), sex ratio (28.92), node at which first male flower appeared (26.59), length of fruit (cm) (24.46), number of branches per vine (21.39). Rest characters days to 50% flowering (4.52), days to first female flower appearance (8.52), days to first male flower appearance (9.53), days to first picking (9.58), days to last picking (14.56), number of male flowers per vine (14.74), length of vine (m) (15.05) had moderate genetic advance as per cent of mean (0-20 %). Lowest Genetic advance as per cent of mean was observed for the characters ($< 10\%$) days to first male flower appearance (9.53), days to 50% flowering (4.52) and days to first picking (9.58). There is a lot of room for improvement when heritability and genetic advancement as a percentage of mean are combined.

Similar results were reported with respect to fruit yield per vine, number of fruits, fruit yield (q/ha) by Bahiram *et al.* (2022), Tyagi *et al.* (2018), Talukedar *et al.* (2018), Alekar *et al.* (2012), Chinthan *et al.* (2019), Pradhan *et al.* (2021), in bitter gourd.

The potential for improvement through selection characters with higher estimations of GCV and PCV may not be completely benefited in subsequent selection programs due to the lack of variation within segregating populations. Because of the less

variation observed among segregating populations and the lack of improvement potential through selection, characters with lower estimations of GCV and PCV would be the least used in subsequent selection programs.

Similar results were found identical with Indresh (1982) with high estimations of the GCV for bitter gourd fruit weight, yield per vine, fruit diameter and fruit length. Mangal *et al.* (1983) discovered similar high GCV average fruit yield per vine, number of branches per vine, average fruit weight and average number of fruits per vine.

Table 4.5: Mean, range, GCV, PCV, ECV, heritability, genetic advance and per cent mean of genetic advance

Sr. No.	Character	General Mean	Range	GV	PV	GCV (%)	PCV (%)	ECV (%)	H² (bs)	GA	GA as 5 % Mean
1.	Number of branches per vine	12.16	9.77-14.60	1.97	2.43	11.53	12.81	5.57	81.08	2.6	21.39
2.	Length of vine (m)	6.19	5.19-7.28	0.34	0.57	9.47	12.29	7.83	59.43	0.9	15.05
3.	Days to first male flower appearance	47.32	41.23-55.20	10.40	22.55	6.81	10.03	7.36	46.13	4.5	9.53
4.	Days to first female flower appearance	52	47.89-60.23	9.11	17.67	5.8	8.08	5.62	51.54	4.4	8.52
5.	Node at which first male flower appeared	10.62	7.80-12.80	2.28	2.77	14.23	15.68	6.6	82.29	2.8	26.59
6.	Node at which first female flower appeared	15.1	11.30-20.40	6.64	7.82	17.06	18.52	7.2	84.87	4.8	32.39
7.	Days to 50% flowering	56.9	53.12-62.01	4.43	12.59	3.7	6.23	5.01	35.23	2.5	4.52
8.	Number of male flowers per vine	215.9	188.51-247.23	343.27	493.18	8.58	10.28	5.6	69.6	31.84	14.74
9.	Number of female flower per vine	32.84	27.25-38.99	14.46	19.26	11.58	13.36	6.6	75.09	6.7	20.67
10.	Sex ratio	6.68	5.13-8.99	1.12	1.42	15.85	17.89	8.31	78.44	1.9	28.92
11.	Days to first picking	65.04	54.21-72.39	18.53	37.44	6.61	9.4	6.68	49.48	6.23	9.58
12.	Days to last picking	124.97	108.61 -144.46	107.20	144.15	8.28	9.7	5.05	72.85	18.2	14.56
13.	Length of fruit (cm)	20.78	15.25-25.36	7.61	9.51	13.27	14.83	6.62	80.04	5	24.46
14.	Diameter of fruit (cm)	3.86	2.99-5.72	0.51	0.62	19.67	20.42	5.49	92.75	1.5	39.02
15.	Weight of fruit (g)	90.31	78.27-104.23	74.83	95.53	9.57	10.82	5.03	78.34	15.77	17.46
16.	Number of fruits per vine	27.64	20.68-35.19	24.40	35.16	17.86	21.44	11.86	69.41	8.4	30.66
17.	Fruit yield per vine (kg)	2.56	1.90-3.27	0.21	0.30	17.87	21.41	11.79	69.66	0.7	30.72
18.	Fruit yield per plot (kg)	12.83	9.48-16.36	5.25	7.54	17.86	21.4	11.78	69.69	3.9	30.72
19.	Fruit yield (q/ha)	171.03	126.34-218.12	934.03	1340.09	17.86	21.4	11.78	69.7	52.56	30.73

4.6 Correlation Coefficient Analysis

The correlation coefficient is a statistical technique use to assess the direction and degree of a link between two or more variables. The important yield and yield contributing characters for genotypic and phenotypic coefficients of correlation are displayed in table 4.6.

4.6.1 Association of yield per plot with other characters.

Studies on correlation revealed that, on average, genotypic correlation coefficients were larger than phenotypic correlation coefficients. The following table describes the correlation coefficient between characters for genotypic and phenotypic characters.

The yield per plot had significantly positive correlation with number of female flower per vine ($r_g = 0.7766$ and $r_p = 0.5037$), weight of fruit ($r_g = 0.7317$ and $r_p = 0.6299$), number of fruits per vine ($r_g = 0.7276$ and $r_p = 0.6027$), fruit yield per vine ($r_g = 0.7244$ and $r_p = 0.6030$). Also, yield per plot had significantly negative correlation with days to 50% flowering ($r_g = -0.3804$ and $r_p = -0.4285$), number of male flowers per vine ($r_g = -0.5419$ and $r_p = -0.4298$), sex ratio ($r_g = -0.8847$ and $r_p = -0.6331$).

Apart from this yield per plot had positively non-significant correlation with length of vine (m), days to first male flower appearance, days to first female flower appearance, days to last picking, length of fruit (cm), fruit yield (q/ha) and negatively non-significant correlation with node at which first male flower appeared, days to first picking, diameter of fruit (cm).

4.6.2 Inter correlation of among yield components

4.6.2.1 Number of branches per vine

The number of branches per vine showed a strong positive relationship with the number of female flower per vine, weight of fruit (g), number of fruits per vine, fruit yield vine (kg) at the genotypic and phenotypic levels in contrast, there is a weak negative correlation between the days to 50% flowering, number of male flowers per vine, sex ratio.

4.6.2.2 Length of vine (m)

At both the genotypic and phenotypic levels, the length of the vine was positively correlated with the number of fruits per vine, fruit yield per vine (kg). Diameter of fruit (cm) had significant negative correlations at both the genotypic and phenotypic levels. There was positively non-significant correlation between days to first female flower appearance, node at which first female flower appeared, number of female flower per vine, days to last picking, length of fruit (cm), weight of fruit (g), fruit yield per plot (kg), fruit yield (q/ha) at both genotypic and phenotypic levels. Days to first male flower appearance, node at which first male flower appeared, number of male flowers per vine,

sex ratio, days to first picking had negatively non-significant correlation. Days to 50% flowering had positive non-significant genotypic correlation and negative non-significant phenotypic correlation.

4.6.2.3 Days to first male flower appearance

At both the genotypic and phenotypic levels, the days required for appearance of male flower was positively correlated with days to first female flower appearance. Diameter of fruit (cm) had significant negative correlations at both the genotypic and phenotypic levels. There was positively non-significant correlation between node at which first male flower appeared, number of female flower per vine, length of fruit (cm), number of fruits per vine, fruit yield per vine (kg), fruit yield per plot (kg), fruit yield (q/ha) at both genotypic and phenotypic levels. Days to 50% flowering, number of male flowers per vine, sex ratio, days to first picking, days to last picking had negatively non-significant correlation. Node at which first female flower appeared had positive non-significant genotypic correlation and negative non-significant phenotypic correlation.

4.6.2.4 Days to first female flower appearance

At both the genotypic and phenotypic levels, the days required for appearance of female flower was positively correlated with number of female flower per vine. Diameter of fruit (cm) had significant negative correlations at both the genotypic and phenotypic levels. There was positively non-significant correlation between node at which first male flower appeared, node at which first female flower appeared number of male flower per vine, days to last picking, diameter of fruit (cm), weight of fruit (g), length of fruit (cm), number of fruits per vine, fruit yield per vine (kg), fruit yield per plot (kg), fruit yield (q/ha) at both genotypic and phenotypic levels. Sex ratio, days to first picking had negatively non-significant correlation. Days to 50% flowering had negative non-significant genotypic correlation and positive non-significant phenotypic correlation.

4.6.2.5 Node at which first male flower appeared

At both the genotypic and phenotypic levels, the node at which first male flower appeared was negatively correlated with number of male flower per vine, days to last picking. There was positively non-significant correlation between length of fruit (cm), diameter of fruit (cm) and weight of fruit (g) at both genotypic and phenotypic levels. Node at which first female flower appeared, days to 50% flowering, number of female flower per vine, sex ratio, days to first picking, days to last picking, number fruits per vine, fruit yield per vine (kg), fruit yield per plot (kg), fruit yield (q/ha) had negative non-significant genotypic correlation and phenotypic correlation.

4.6.2.6 Node at which first female flower appeared

There was positively non-significant correlation between days to 50% flowering, number of male flower per vine, number of female flower per vine, days to first picking, days to last picking, length of fruit (cm), weight of fruit (g), number fruits per vine, fruit yield per vine (kg), fruit yield per plot (kg), fruit yield (q/ha). Sex ratio, diameter of fruit (cm) had negative non-significant genotypic correlation and phenotypic correlation.

4.6.2.7 Days to 50% flowering

At both the genotypic and phenotypic levels, days to 50% flowering had significantly positive correlation with number of male flowers per vine. Weight of fruit (g) had significant negative correlations at both the genotypic and phenotypic levels. There was positively non-significant correlation between days to 50% flowering and sex ratio, days to first picking, days to last picking. Length of fruit (cm), diameter of fruit (cm), number of fruits per vine, fruit yield per vine (kg), fruit yield per plot (kg), fruit yield (q/ha) exhibited negative non-significant genotypic correlation and phenotypic correlation.

4.6.2.8 Number of male flowers per vine

At both the genotypic and phenotypic levels, the number of male flowers per vine was positively correlated with sex ratio. Weight of fruit (g) had significant negative correlations at both the genotypic and phenotypic levels. There was positively non-significant correlation between days to first picking at both genotypic and phenotypic levels. Number of female flower per vine, days to last picking, length of fruit (cm), diameter of fruit (cm), number fruits per vine, fruit yield per vine (kg), fruit yield per plot (kg), fruit yield (q/ha) exhibited negative non-significant genotypic correlation and phenotypic correlation

4.6.2.9 Number of female flowers per vine

At both the genotypic and phenotypic levels, the number of female flowers per vine was positively correlated with length of fruit (cm), weight of fruit (g), number of fruits per vine, fruit yield per vine (kg). Sex ratio, diameter of fruit (cm) had significant negative correlations at both the genotypic and phenotypic levels. There was positively non-significant correlation between fruit yield per plot (kg), fruit yield (q/ha) at both genotypic and phenotypic levels. Days to first picking, days to last picking exhibited negative non-significant genotypic correlation and phenotypic correlation.

4.6.2.10 Sex ratio

At both the genotypic and phenotypic levels, sex ratio was positively correlated with days to first picking. Length of fruit (cm), weight of fruit (g), number fruits per vine, fruit yield per vine (kg) had significant negative correlations at both the genotypic and

phenotypic levels. There was positively non-significant correlation between diameter of fruit (cm) at both genotypic and phenotypic levels. Days to last picking, fruit yield per plot (kg), fruit yield (q/ha) exhibited negative non-significant genotypic correlation and phenotypic correlation.

4.6.2.11 Days to first picking

At both the genotypic and phenotypic levels, days to first picking was negatively correlated with weight of fruit (g). There was positively non-significant correlation between diameter of fruit (cm) at both genotypic and phenotypic levels. Days to last picking, length of fruit (cm), number of fruits per vine, fruit yield per vine (kg), fruit yield per plot (kg), fruit yield (q/ha) exhibited negative non-significant genotypic correlation and phenotypic correlation.

4.6.2.12 Days to last picking

There was positively non-significant correlation between length of fruit (cm), weight of fruit (g), number fruits per vine, fruit yield per vine (kg), fruit yield per plot (kg), fruit yield (q/ha) at both genotypic and phenotypic levels. Diameter of fruit (cm) exhibited negative non-significant genotypic correlation and positive non-significant phenotypic correlation.

4.6.2.13 Length of fruit (cm)

At both the genotypic and phenotypic levels, length of fruit (cm) was positively correlated with weight of fruit (g), number of fruits per vine, fruit yield per vine (kg). There was positively non-significant correlation between fruit yield per plot (kg), fruit yield (q/ha) at both genotypic and phenotypic levels. Diameter of fruit (cm) exhibited negative non-significant genotypic correlation and phenotypic correlation.

4.6.2.14 Diameter of fruit (cm)

There was positively non-significant correlation between weight of fruit (g) at both genotypic and phenotypic levels. Number of fruits per vine, fruit yield per vine (kg), fruit yield per plot (kg), fruit yield (q/ha) exhibited negative non-significant genotypic correlation and phenotypic correlation.

4.6.2.15 Weight of fruit (g)

At both the genotypic and phenotypic levels, weight of fruit (g) was positively correlated with number of fruit per vine and fruit yield per vine (kg). There was positively non-significant correlation between fruit yield per plot (kg), fruit yield (q/ha) at both genotypic and phenotypic levels.

4.6.2.16 Number of fruits per vine

At both the genotypic and phenotypic levels, number of fruits per vine was positively correlated with fruit yield per vine (kg). There was positively non-significant

correlation between fruit yield per plot (kg), fruit yield (q/ha) at both genotypic and phenotypic levels.

4.6.2.17 Fruit yield per vine (kg)

At both genotypic and phenotypic levels, fruit yield per vine exhibited a strong and positive correlation with fruit yield per plot and fruit yield (q/ha).

4.6.2.18 Fruit yield per plot (kg)

At both genotypic and phenotypic levels, fruit yield per vine exhibited a strong and positive correlation with fruit yield (q/ha).

4.6.2.19 Fruit yield (q/ha)

At both genotypic and phenotypic levels, fruit yield per vine exhibited a strong and positive correlation with fruit yield per hectare.

Fruit yield per vine and yield contributing characters were observed to be significantly correlated at both the genotypic and phenotypic levels. While the characters, days to 50% flowering, number of male flowers per vine, sex ratio had significantly negative correlation with yield per plot. According to Khattri *et al.*, (1994), days to the first female flower opening and days to the first harvest show a negative association, although average fruit weight, number of fruits produced per vine, and total fruit production per vine show a substantial and positive correlation. Dey *et al.*, (2005), the amount of fruits produced per vine, fruit index, fruit length, fruit diameter, flesh thickness, days from fruit set to maturity and total yield per vine all showed highly significant and positive phenotypic associations with fruit weight. Pathak *et al.*, (2014) discovered that selection based on these traits will offer higher rewards since the yield was directly correlated with fruit weight, fruit length, and number of fruits per plant and it was considerably favorably connected with the number of fruits per plant.

Similar results were reported in conformity in other cucurbitaceous crops. Tarsem and Sanjay (1997), Choudhary *et al.* (2003), Chamnan and Kasem (2006), Jagtap (2010), Naroui *et al.* (2010) and Cheema *et al.* (2011) all have made significant contribution in muskmelon. In Ash Gourd, Dewan *et al.* (2014). Yadav and Kumar (2012) in bottle gourd, Sharma and Sengupta (2012), Patil (2010), Yadav *et al.* (2010), Kumar *et al.* (2012), Yadav and Kumar (2012) in cucumber, Singh *et al.* (2002), Rao *et al.* (2003), Joshi *et al.* (2005) and Bhande *et al.* (2012) in bottle gourd. The pointed gourd was used by Khan *et al.* (2009), the ridge gourd by Choudhary and Kumar (2011), in sponge gourd Hanumegowda *et al.* (2012) and Kumar *et al.* (2013). in watermelon, Kadam (1997) and Rolania *et al.* (2003) discovered that the majority of these traits were positively associated with fruit yield per vine.

Table 4.6: Genotypic and Phenotypic correlation coefficient analysis

Sr.No	Characters		1	2	3	4	5	6	7	8	9	10
1	Number of branches per vine	G	1.000	0.2467	0.1585	0.1197	-0.0606	0.0823	-0.3804**	-0.5419**	0.7766**	-0.8847**
		P	1.000	0.2155	0.0808	0.013	0.0095	0.149	-0.4285**	-0.4298**	0.5037**	-0.6331**
2	Length of vine (m)	G		1.000	-0.0442	0.2809	-0.4269	0.1653	0.0301	-0.0409	0.3768	-0.3343
		P		1.000	-0.027	0.2367	-0.2007	0.131	-0.0606	-0.0805	0.2507	-0.2732
3	Days to first male flower appearance	G			1.000	1.1524**	0.257	0.2255	-0.3253	-0.2277	0.363	-0.3491
		P			1.000	0.5424**	0.2148	-0.0383	-0.0813	-0.1161	0.2924	-0.2594
4	Days to first female flower appearance	G				1.000	0.0282	0.3408	-0.2212	0.0397	0.5221*	-0.2914
		P				1.000	0.0573	0.2125	0.1404	0.1177	0.3196 **	-0.1647
5	Node at which first male flower appeared	G					1.000	-0.0681	-0.5551	-0.4073*	-0.1967	-0.0202
		P					1.000	-0.0398	-0.285	-0.3620*	-0.1517	-0.0601
6	Node at which first female flower appeared	G						1.000	0.4987	0.093	0.4212	-0.2295
		P						1.000	0.2101	0.0312	0.2807	-0.1671
7	Days to 50% flowering	G							1.000	0.8344**	-0.2539	0.6601
		P							1.000	0.4293 **	0.02	0.2228
8	Number of male flowers per vine	G								1.000	-0.1441	0.6639**
		P								1.000	-0.0585	0.6520 ***
9	Number of female flower per vine	G									1.000	-0.827**
		P									1.000	-0.7771 **
10	Sex ratio	G										1.000
		P										1.000
11	Days to first picking	G										
		P										
12	Days to last picking	G										
		P										
13	Length of fruit (cm)	G										
		P										
14	Diameter of fruit (cm)	G										
		P										
15	Weight of fruit (g)	G										
		P										
16	Number of fruits per vine	G										
		P										
17	Fruit yield/vine (kg)	G										
		P										
18	Fruit yield/plot (kg)	G										
		P										
19	Fruit yield (q/ha)	G										
		P										

S: Symbol, G: Genotypic, P: Phenotypic *, ** : Significance at 5% and 1%, respectively

Table 4.6 contd...

Sr.No	Characters		11	12	13	14	15	16	17	18	19
1	Number of branches per vine	G	-0.6003	0.0393	0.2732	-0.1458	0.7317***	0.7276***	0.7244***	0.7251	0.7253
		P	-0.3147	0.0121	0.2403	-0.0962	0.6299***	0.6027***	0.6030***	0.6034	0.6037
2	Length of vine (m)	G	-0.5915	0.3863	0.1699	-0.5272*	0.3514	0.5283	0.5285*	0.5299	0.5302
		P	-0.1956	0.2715	0.0253	-0.3975*	0.2475	0.3326*	0.3256*	0.3262	0.3266
3	Days to first male flower appearance	G	-0.7980	-0.0804	0.3713	-0.6975*	-0.0108	0.1080	0.1113	0.1111	0.1114
		P	-0.2581	-0.0311	0.3143	-0.4018*	-0.0013	0.2019	0.1976	0.1977	0.1976
4	Days to first female flower appearance	G	-0.7554	0.0989	0.4278	-0.6911**	0.0729	0.3502	0.3433	0.3425	0.3427
		P	-0.2393	0.1106	0.0941	-0.4243**	0.0167	0.2710	0.2759	0.2764	0.2764
5	Node at which first male flower appeared	G	-0.2033	-0.6534**	0.2738	0.2940	0.1471	-0.1310	-0.1303	-0.1289	-0.1290
		P	-0.1079	-0.4835**	0.1727	0.2700	0.0632	-0.1571	-0.1558	-0.1551	-0.1552
6	Node at which first female flower appeared	G	0.4020	0.3350	0.3825	-0.1606	0.0488	0.2710	0.2748	0.2745	0.2749
		P	0.2670	0.2073	0.2363	-0.1434	0.0228	0.1609	0.1676	0.1667	0.1672
7	Days to 50% flowering	G	0.7688	0.5699	-0.1072	-0.1382	-0.5972**	-0.2214	-0.2177	-0.2193	-0.2194
		P	0.2593	0.2252	-0.1282	-0.0820	-0.4154**	-0.1330	-0.1283	-0.1290	-0.1293
8	Number of male flowers per vine	G	0.5229**	-0.0729	-0.3134	-0.3312	-0.8014***	-0.3281	-0.3333	-0.3344	-0.3346
		P	0.3543**	-0.0001	-0.2263	-0.2249	-0.5431***	-0.1562	-0.1518	-0.1525	-0.1527
9	Number of female flower per vine	G	-0.3280	-0.0070	0.5930**	-0.4984**	0.5473**	1.0220**	1.0280***	1.0277	1.0278
		P	-0.2895	-0.0080	0.4654**	-0.4200**	0.3919**	0.7291***	0.7194***	0.7194	0.7194
10	Sex ratio	G	0.5392*	-0.0757	-0.6162**	0.2076	-0.8675**	-0.9594**	-0.9657**	-0.9662	-0.9664
		P	0.4043*	-0.0294	-0.4713**	0.1977	-0.5963***	-0.6357***	-0.6263***	-0.6268	-0.6269
11	Days to first picking	G	1.0000	-0.1287	-0.2361	0.3432	-0.6381**	-0.4603	-0.4571	-0.4582	-0.4581
		P	1.0000	-0.1281	-0.2624	0.2665	-0.4169***	-0.2323	-0.2256	-0.2257	-0.2259
12	Days to last picking	G		1.0000	0.1802	-0.0042	0.2641	0.0535	0.0566	0.0548	0.0548
		P		1.0000	0.1261	0.0230	0.2242	0.0608	0.0615	0.0608	0.0610
13	Length of fruit (cm)	G			1.0000	-0.1272	0.5633**	0.6181**	0.6240**	0.6228	0.6227
		P			1.0000	-0.1082	0.5071***	0.5346***	0.5362***	0.5358	0.5357
14	Diameter of fruit (cm)	G				1.0000	0.2876	-0.2712	-0.2680	-0.2684	-0.2686
		P				1.0000	0.2622	-0.1506	-0.1480	-0.1486	-0.1488
15	Weight of fruit (g)	G					1.0000	0.7125**	0.7124**	0.7126	0.7126
		P					1.0000	0.6995***	0.7000***	0.6998	0.7000
16	Number of fruits per vine	G						1.0000	1.0005**	1.0005	1.0005
		P						1.0000	0.9992***	0.9992	0.9992
17	Fruit yield/vine (kg)	G							1.0000	1.0000	1.0000
		P							1.0000	1.0000	1.0000
18	Fruit yield/plot (kg)	G								1.0000	1.0000
		P								1.0000	1.0000
19	Fruit yield (q/ha)	G									1.000
		P									1.000

S: Symbol, G: Genotypic, P: Phenotypic * = Significance at 5% ** = Significance at 1%

4.7 Path analysis study

Path coefficient analysis suggested by Dewey and Lu (1959) is used to reveal information about the direct and indirect character's actual impact on yield. It is a dependable statistical method designed specifically to separate the correlation coefficients into direct and indirect impacts. Table 4.7 gives the estimates of the direct and indirect effects on yield per plot of the various features under examination.

4.7.1 Direct effects

In the path analysis study, 18 traits was under investigation, in which it was observed that fruit yield per vine (0.9773) exhibited maximum direct effect on fruit yield per plot followed by number of fruits per vine (0.0253) and node at which first male flower appeared (0.0045). All this characters have significant and positive correlation with fruit yield per plot.

In addition to this desirable traits, other traits viz., days to 50% flowering, length of vine (cm), days to last picking, number of branches per vine, weight of fruit (g), node at which first female flower appeared, number of male flowers per vine exhibited low positive direct effect on fruit yield per plot. Days to first male flower appearance, days to first female flower appearance, number of female flower per vine, sex ratio, length of fruit (cm), diameter of fruit (cm) exhibited negative direct effect on yield per plot.

This suggested that improving crop yield through direct effects selection based on these qualities will be fruitful. Similar results were in conformity with Gupta *et al.* (2015), Yadagiri *et al.* (2017), Kumar *et al.* (2018), Kumari *et al.* (2018), Moharana *et al.* (2018) and Reddy *et al.* (2022) in bitter gourd.

4.7.2 Indirect effects

4.7.2.1 Number of branches per vine

Days to 50% flowering, number of male flowers per vine, sex ratio, days to first picking, diameter of fruit (cm) exhibited negligible positive indirect effect on fruit yield per plot while the indirect effects via length of vine (cm), days to first male flower appearance, days to first female flower appearance, node at which first female flower appeared, number of female flower per vine, length of fruit (cm), weight of fruit (g), number of fruits per vine and fruit yield per vine (kg) were negative.

4.7.2.2 Length of vine (m)

Number of branches per vine, days to first female flower appearance, node at which first female flower appeared, number of female flower per vine, days to last picking, length of fruit (cm), weight of fruit (g), number of fruits per vine, fruit yield per vine (kg) exhibited negligible positive indirect effects on fruit yield per plot while the

indirect effects via node at which first male flower appeared, sex ratio, days to first picking, diameter of fruit (cm) were negative.

4.7.2.3 Days to first male flower appearance

Days to first female flower appearance, days to 50% flowering, sex ratio, days to first picking, days to last picking, diameter of fruit (cm) exhibited negligible positive indirect effect on fruit yield per plot while the indirect effects via number of branches per vine, node at which first male flower appeared, node at which first female flower appeared, number of female flower per vine, length of fruit (cm), number of fruits per vine, fruit yield per vine (kg) were negative.

4.7.2.4 Days to first female flower appearance

Days to 50% flowering, sex ratio, days to first picking, diameter of fruit (cm) exhibited negligible positive indirect effect on fruit yield per plot while the indirect effects via number of branches per vine, length of vine (cm), days to first male flower appearance, node at which first female flower appeared, number of female flower per vine, days to last picking, length of fruit (cm), weight of fruit (g), number of fruits per vine, fruit yield per vine (kg) were negative.

4.7.2.5 Node at which first male flower appeared

Days to first male flower appearance, days to first female flower appearance, length of fruit (cm), diameter of fruit (cm), weight of fruit (g) exhibited negligible positive indirect effect on fruit yield per plot while the indirect effects via number of branches per vine, length of vine (cm), days to first male flower appearance, node at which first female flower appeared, days to 50% flowering, number of male flowers per vine, number of female flower per vine, sex ratio, days to first picking, days to last picking, number of fruits per vine, fruit yield per vine (kg) were negative.

4.7.2.6 Node at which first female flower appeared

Number of branches per vine, length of vine (cm), days to first male flower appearance, days to 50% flowering, number of male flowers per vine, number of female flower per vine, days to first picking, days to last picking, days to first female flower appearance, length of fruit (cm), weight of fruit (g), number of fruits per vine, fruit yield per vine (kg) exhibited negligible positive indirect effects on fruit yield per plot while the indirect effects via node at which first male flower appeared, sex ratio, diameter of fruit (cm) were negative.

4.7.2.7 Days to 50% flowering

Number of male flowers per vine, Sex ratio, Days to first picking, Days to last picking exhibited negligible positive indirect effects on fruit yield per plot while the indirect effects via weight of fruit (g) were negative.

4.7.2.8 Number of male flowers per vine

Days to first female flower appearance, node at which first female flower appeared, days to 50% flowering, sex ratio, days to first picking exhibited negligible positive indirect effect on fruit yield per plot while the indirect effects via number of branches per vine, length of vine (cm), days to first male flower appearance, node at which first male flower appeared, number of female flower per vine, days to last picking, length of fruit (cm), diameter of fruit (cm), weight of fruit (g), number of fruits per vine, fruit yield per vine (kg) were negative.

4.7.2.9 Number of female flowers per vine

Node at which first male flower appeared, days to 50% flowering, number of male flowers per vine, sex ratio, days to first picking, days to last picking exhibited negligible positive indirect effect on fruit yield per plot while the indirect effects via number of branches per vine, length of vine (cm), days to first male flower appearance, days to first female flower appearance, node at which first female flower appeared, length of fruit (cm), weight of fruit (g), number of fruits per vine, fruit yield per vine (kg) were negative.

4.7.2.10 Sex ratio

Number of branches per vine, length of vine (cm), days to first male flower appearance, days to first female flower appearance, node at which first female flower appeared, length of fruit (cm), weight of fruit (g), number of fruits per vine, fruit yield/vine (kg), node at which first male flower appeared, number of female flower per vine, days to last picking exhibited negligible positive indirect effects on fruit yield per plot while the indirect effects via days to 50% flowering, number of male flowers per vine, days to first picking, diameter of fruit (cm) were negative.

4.7.2.11 Days to first picking

Days to first picking has no indirect effects on the fruit yield per plot.

4.7.2.12 Days to last picking

Length of vine (cm), node at which first female flower appeared, days to 50% flowering, length of fruit (cm), weight of fruit (g) exhibited negligible positive indirect effects on fruit yield per plot while the indirect effects via node at which first male flower appeared were negative

4.7.2.13 Length of fruit (cm)

Node at which first female flower appeared, days to 50% flowering, number of male flowers per vine, sex ratio, days to first picking, diameter of fruit (cm) exhibited negligible positive indirect effects on fruit yield per plot while the indirect effects via number of branches per vine, length of vine (cm), days to first male flower appearance,

days to first female flower appearance, node at which first male flower appeared, number of female flower per vine, days to last picking, weight of fruit (g), number of fruits per vine, fruit yield per vine (kg) were negative.

4.7.2.14 Diameter of fruit (cm)

Number of branches per vine, length of vine (cm), days to first male flower appearance, days to first female flower appearance, number of female flower per vine, node at which first female flower appeared, days to 50% flowering, number of male flowers per vine, length of fruit (cm), number of fruits per vine, fruit yield/vine (kg) exhibited negligible positive indirect effects on fruit yield per plot while the indirect effects via node at which first male flower appeared, sex ratio, days to first picking, weight of fruit (g) were negative.

4.7.2.15 Weight of fruit (g)

Number of branches per vine, length of vine (cm), days to first female flower appearance, node at which first male flower appeared, node at which first female flower appeared, number of female flower per vine, days to last picking, length of fruit (cm), diameter of fruit (cm) number of fruits per vine, fruit yield/vine (kg) exhibited negligible positive indirect effects on fruit yield per plot while the indirect effects via days to 50% flowering, number of male flowers per vine, days to first picking, sex ratio were negative.

4.7.2.16 Number of fruits per vine

Number of branches per vine, length of vine (cm), days to first male flower appearance, days to first female flower appearance, node at which first female flower appeared, number of male flowers per vine, number of female flower per vine, days to last picking, length of fruit (cm), weight of fruit (g), fruit yield per vine (kg) exhibited negligible positive indirect effects on fruit yield per plot while the indirect effects via node at which first male flower appeared, days to 50% flowering, sex ratio, days to first picking, diameter of fruit (cm) were negative.

4.7.2.17 Fruit yield per vine (kg)

Number of branches per vine, length of vine (cm), days to first male flower appearance, days to first female flower appearance, node at which first female flower appeared, number of female flower per vine, days to last picking, length of fruit (cm), weight of fruit (g), number of fruits per vine exhibited negligible positive indirect effects on fruit yield per plot while the indirect effects via node at which first male flower appeared, days to 50% flowering, number of male flowers per vine, sex ratio, days to first picking, diameter of fruit (cm) were negative.

From the estimate of correlation coefficient and direct and indirect effect of fruit yield attributing traits, it is clear that for bring out designed improvement towards fruit

yield in future of bitter gourd average fruit weight and fruits per vine can be used as direct selection parameters.

Similar results were in conformity with Gupta *et al.* (2015), Yadagiri *et al.* (2017), Kumar *et al.* (2018), Kumari *et al.* (2018), Moharana *et al.* (2018) and Reddy *et al.* (2022) in bitter gourd.

Table 4.7: Estimates of Genotypic direct (Diagonal) and indirect effects (above and below diagonal) of various yield and yield components

Sr.No.	Characters	1	2	3	4	5	6	7	8	9	10
1	NBPV	0.001	-0.0002	-0.0002	-0.0001	0.0001	-0.0001	0.0004	0.0005	-0.0008	0.0009
2	LV	0.0001	0.0004	0.0000	0.0001	-0.0002	0.0001	0.0000	0.0000	0.0002	-0.0001
3	DFMFA	-0.0001	0.0000	-0.0009	0.001	-0.0002	-0.0002	0.0003	0.0002	-0.0003	0.0003
4	DFFFA	-0.0001	-0.0002	-0.0008	-0.0007	0.0000	-0.0002	0.0002	0.0000	-0.0004	0.0002
5	NFMA	-0.0003	-0.002	0.0012	0.0001	0.0045	-0.0003	-0.003	-0.002	-0.0009	-0.0001
6	NFFA	0.0001	0.0003	0.0004	0.0005	-0.0001	0.0016	0.0008	0.0001	0.0007	-0.0004
7	DFE	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000	0.0001
8	NMPV	-0.0022	-0.0002	-0.0009	0.0002	-0.002	0.0004	0.0034	0.004	-0.0006	0.0027
9	NFPV	-0.0059	-0.003	-0.0028	-0.004	0.0015	-0.003	0.0019	0.0011	-0.008	0.0063
10	SR	0.0077	0.0029	0.0031	0.0025	0.0002	0.002	-0.006	-0.006	0.0072	-0.009
11	DFP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12	DLP	0.0000	0.0001	0.0000	0.0000	-0.0003	0.0001	0.0002	0.0000	0.0000	0.0000
13	LF	-0.001	-0.0008	-0.0017	-0.002	-0.001	0.0018	0.0005	0.0015	-0.003	0.0029
14	DF	0.0005	0.0018	0.0023	0.0023	-0.001	0.0005	0.0005	0.0011	0.0017	-0.0007
15	WF	0.0011	0.0005	0.0000	0.0001	0.0002	0.0001	-0.006	-0.0010	0.0008	-0.001
16	NFPV	0.0184	0.0134	0.0027	0.0089	-0.0003	0.0069	-0.0009	0.0083	0.0258	-0.024
17	FYPV	0.708	0.5165	0.1088	0.3355	-0.1270	0.2686	-0.213	-0.3260	1.0046	-0.944

Residual effect: 0.0046

NBPV : Number of branches per vine

LV : Length of vine (m)

DFMFA : Days to first male flower appearance

DFFFA : Days to first female flower appearance

NFMA : Node at which first male flower appeared

NFFA : Node at which first female flower appeared

DFE : Days to 50 % flowering

NMPV : Number of male flowers per vine

NFPV : Number of female flowers per vine

SR : Sex ratio

Table 4.7 Contd...

Sr.No.	Characters	11	12	13	14	115	16	17	Corr. Coff.
1	NBPV	0.0006	0.0000	-0.0003	0.0001	-0.0007	-0.0007	-0.0007	0.7251
2	VL	-0.0003	0.0002	0.0001	-0.0002	0.0002	0.0002	0.0002	0.5299
3	DFMFA	0.0007	0.0001	-0.0003	0.0006	0.0000	-0.0001	-0.0001	0.1111
4	DFFFA	0.0006	-0.0001	-0.0003	0.0005	-0.0001	-0.0003	-0.0003	0.3425
5	NFMA	-0.0009	-0.0029	0.0012	0.0013	0.0007	-0.0006	-0.0006	-0.1289
6	NFFA	0.0006	0.0005	0.0006	-0.0003	0.0001	0.0004	0.0004	0.2745
7	DF	0.0001	0.0001	0.0000	0.0000	-0.0001	0.0000	0.0000	-0.2193
8	NMPV	0.0021	-0.0003	-0.0013	-0.0013	-0.0032	-0.0013	-0.0013	-0.3344
9	NFPV	0.0025	0.0001	-0.0045	0.0038	-0.0042	-0.0078	-0.0078	1.0277
10	SR	-0.0047	0.0007	0.0054	-0.0018	0.0076	0.0084	0.0084	-0.9662
11	DFP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.4582
12	DLP	0.0000	0.0004	0.0001	0.0000	0.0001	0.0000	0.0000	0.0548
13	LF	0.0011	-0.0008	-0.0047	0.0006	-0.0026	-0.0029	-0.0029	0.6228
14	DF	-0.0012	0.0000	0.0004	-0.0034	-0.001	0.0009	0.0009	-0.2684
15	WF	-0.001	0.0004	0.0009	0.0004	0.0015	0.0011	0.0011	0.7126
16	NFPV	-0.0116	0.0014	0.0156	-0.0069	0.018	0.0253	0.0253	1.0005
17	FYPV	-0.4468	0.0553	0.6098	-0.262	0.6963	0.9778	0.9773	1
18	FYPP	0.4582	0.0548	0.6228	-0.2684	0.7126	1.0005	1	1

Residual effect : 0.0046

DFP : Days to first picking
DLP : Days to last picking
LF : Length of fruit (cm)
DF : Diameter of fruit (cm)
WF : Weight of fruit (g)

NFPV : Number of fruits per vine
FYPV : Fruit yield per vine (kg)
FYPP : Fruit yield per plot (kg)
FY : Fruit yield (q/ha)

4.8 Genetic divergence

The information generated for thirteen progenies for 19 characters was exposed to Mahalonobis (1936) D^2 statistics, to evaluate the degree of divergence between the various parents and hybrids.

4.8.1 Mahalonobis D^2 Values

The Genetic diversity for the thirteen progenies was evaluated by using Mahalonobis D^2 . Thirteen progenies mean values [(X1) (X2)] were transformed into unstandardized, correlated mean values [(Y1) (Y2)]. D^2 values were calculated for each and every combination that could be feasible i.e. $13(13-1)/2$, is equal to 78 pairs.

4.8.2 Wilk's test and Analysis of variance for dispersion.

Wilk's " λ " (Statistics) criterion was applied for assessing for significant differences between parents and hybrids based on the pooled effects of every characteristic. The statistical significance of λ values was examined using χ^2 at 228 degrees of freedom. The value of ' λ ' (Statistics) was 855.04, indicating a substantial difference in treatments when every attribute were taken into consideration at the same time. ANOVA for dispersion had been shown in the table 4.8.

Table 4.8: Analysis of variance for dispersion for parents and progenies

Source of variation	Degree of freedom (df)	Mean sum of squares
Genotype	12	-1.7288E18
Error	23	2.5760E-02
Total	35	- 5.9272E17

4.8.3 Cluster formation

The process of clustering was studied for nineteen different parameters by adopting Mahalonobis D^2 statistics using Tocher's method, suggested by Rao (1952). Table 4.9 shows that 13 progenies were categorized into four clusters. The maximum nine progenies (Parents and Hybrids) entered in Cluster I, followed by two progenies in Cluster II. Cluster III and IV had each one progeny.

With the single progeny in the cluster shows better utilization for future breeding program. Similar results were reported by, Naik *et al.* (2021), Nithinkumar *et al.* (2021) and Ankitha *et al.* (2023) in bitter gourd. In Bottle gourd similar results were reported by Rambabu *et al.* (2020) and Rai *et al.* (2023).

Table 4.9: Distribution of 13 progenies and parents into different clusters

Sr. No.	Cluster	Number of Progenies/parents	Source	Progenies/parents
1	I	9	AICRP on Vegetables, MPKV, Rahuri	P1, P2, P4, Pr 2 (1 × 2) Pr 3 (1 × 2) Pr 4 (1×3) P3, Pr 4 (1×4) Pr 1 (1×4)
2	II	2	AICRP on Vegetables, MPKV, Rahuri	Pr 4 (1 × 2) Pr 2 (1 × 3)
3	III	1	AICRP on Vegetables, MPKV, Rahuri	Pr 3 (1 × 4)
4	IV	1	AICRP on Vegetables, MPKV, Rahuri	Pr 1 (1 × 3)

4.8.4 Intra-cluster and inter cluster distance

By using the D^2 statistics method the distances between intra and inter-cluster were calculated. The intra- D^2 and inter-cluster distances were measured using the mean D^2 values of the cluster constituents.

The maximum intra-cluster distance was discovered by cluster I ($D^2 = 144.96$) and cluster I and IV had least intra-cluster distance ($D^2 = 0$) and such clusters are called solitary clusters or mono-genotypic clusters. The maximum inter cluster distance was discovered between cluster II and III ($D^2 = 598.29$) followed by cluster III and IV ($D^2 = 598.29$).

Cluster I had maximum inter cluster distance with cluster IV ($D^2 = 480.48$), cluster II had maximum inter cluster distance with cluster III ($D^2 = 664.60$) and cluster III had maximum inter cluster distance with cluster IV ($D^2 = 598.29$).

The D^2 values of intra cluster were lesser than that of the inter cluster values, which indicates that lesser divergence within the clusters than among the clusters. This findings is agreement with the results reported by Islam *et al.* (2010), Maurya *et al.* (2018), Jatav *et al.* (2019) and Bhati *et al.* (2023) in bitter gourd. In bottle gourd similar results were reported by Bhagwat *et al.* (2022).

Table 4.10: Average intra (Bold) and inter cluster distance D and D² values

Clusters	I	II	III	IV
I	12.04 (144.96)	16.75 (280.56)	15.49 (239.94)	21.92 (480.48)
II		10.16 (103.22)	25.78 (664.60)	19.30 (372.49)
III			0.00	24.46 (598.29)
IV				0.00

4.8.5 Cluster means

The cluster mean for different characters studies are given in the table 4.11. These mean value for individual cluster are described below.

4.8.5.1 Number of branches per vine

Number of branches per vine was observed high in cluster III (14.60) followed by cluster IV (13.58) and cluster I (12.05).

4.8.5.2 Length of vine (m)

Vine length (m) was observed highest in cluster IV (6.49) followed by cluster III (6.42) and cluster I (6.34).

4.8.5.3 Days to first male flower appearance

Days to first male flower appearance was found early in in cluster IV (41.23) followed by cluster II (45.52) and cluster I (47.52).

4.8.5.4 Days to first female flower appearance

Days to first female flower appearance was found early in in cluster IV (47.89) followed by cluster II (49.90) and cluster I (52.02).

4.8.5.5 Node at which first male flower appeared

First male flower was appeared at lower node in the cluster IV (9.60) followed by cluster III (9.80) and cluster I (10.53).

4.8.5.6 Node at which first female flower appeared

First female flower was appeared at lower node in the cluster IV (11.30) followed by cluster II (12.50) and cluster III (15.40).

4.8.5.7 Days to 50% flowering

Days to 50% flowering was minimum in cluster IV (53.23) followed by cluster III (56.41) and cluster II (57.10).

4.8.5.8 Number of male flowers per vine

Number of male flowers per vine was maximum in cluster II (220.69) followed by cluster IV (219.44) and cluster I (215.22).

4.8.5.9 Number of female flower per vine

Number of female flowers per vine was maximum in cluster III (38.99) followed by cluster I (33.20) and cluster IV (32.78).

4.8.5.10 Sex ratio

Sex ratio was least in cluster III (5.34) followed by cluster I (6.56) and cluster IV (6.68).

4.8.5.11 Days to first picking

Days to first picking was minimum for number of days in cluster III (54.21) and cluster IV (63.45) cluster I (65.94).

4.8.5.12 Days to last picking

Days to last picking was maximum for number of days in cluster III (135.68) and cluster I (126.10) cluster II (119.55).

4.8.5.13 Length of fruit (cm)

Length of fruit (cm) was found to be highest in cluster III (22.12) followed by cluster I (21.32) and cluster II (20.51).

4.8.5.14 Diameter of fruit (cm)

Diameter of fruit (cm) was maximum in the cluster II (5.12) followed by cluster IV (4.12) and cluster I (3.64).

4.8.5.15 Weight of fruit (g)

Weight of fruit (g) was found to be highest in cluster III (100.78) followed by cluster IV (92.68) and cluster I (89.18)

4.8.5.16. Number of fruits per vine

Number of fruits per vine was maximum in cluster III (34.88) followed by cluster IV (27.93) and cluster I (27.72).

4.8.5.17 Fruit yield per vine (kg)

Fruit yield per vine (kg) was recorded maximum in the cluster III (3.23) followed by cluster IV (2.58) and cluster I (2.57).

4.8.5.18 Fruit yield per plot (kg)

Fruit yield per plot (kg) was found to be maximum in the cluster III (16.16) followed by cluster IV (12.91) and cluster I (12.87).

4.8.5.19 Fruit yield (q/ha)

Fruit yield (q/ha) was recorded maximum in the cluster III (215.43) followed by cluster IV (172.10) and cluster I (171.56).

Similar results for cluster mean were reported by Kundu *et al.* (2012), Singh *et al.* (2013), Angadi and Mulge (2018) in bitter gourd.

Table 4.11: Cluster mean performance for various characters of bitter gourd

Sr. No.	Characters	I	II	III	IV
1	No. of branches per vine	12.05	10.78	14.60	13.58
2	Length of vine (m)	6.34	5.25	6.42	6.49
3	Days to first male flower appearance	47.52	45.52	55.20	41.23
4	Days to first female flower appearance	52.02	49.90	60.23	47.89
5	Node at which first male flower appeared	10.53	11.94	9.80	9.60
6	Node at which first female flower appeared	16.07	12.50	15.40	11.30
7	Days to 50% flowering	57.33	57.10	56.41	53.23
8	Number of male flowers per vine	215.22	220.69	208.96	219.44
9	Number of female flower per vine	33.20	28.19	38.99	32.78
10	Sex ratio	6.56	7.91	5.34	6.68
11	Days to first picking	65.94	67.23	54.21	63.45
12	Days to last picking	126.10	119.55	135.68	115.01
13	Length of fruit (cm)	21.32	20.51	22.12	15.25
14	Diameter of fruit (cm)	3.64	5.12	3.14	4.12
15	Weight of fruit (g)	89.18	89.02	100.78	92.68
16	No. fruits/vine	27.72	23.59	34.88	27.93
17	Fruit yield/vine (kg)	2.57	2.19	3.23	2.58
18	Fruit yield/plot (kg)	12.87	10.95	16.16	12.91
19	Fruit yield (q/ha)	171.56	145.97	215.43	172.10

4.8.6 Per cent contribution of nineteen characters for divergence

D^2 analysis is a powerful method for measuring the degree of genetic divergence in biological populations. Its usefulness in determining the relative contributions of different plant characteristics to genetic divergence makes it even more potent. The per cent contribution of nineteen traits towards genetic divergence is presented in table 4.12.

The maximum contribution by the trait was observed by length of fruit (35.90 %) followed by fruit yield per vine (23.08 %), diameter of fruit (21.79 %), fruit yield (7.69 %), fruit yield per plot (3.85 %). Days to last picking and number of fruits per vine had contributed 2.56 % of total contribution. And least contribution was observed by node at which first male flower appeared (1.28 %) and node at which first female flower appeared (1.28 %)

4.8.7 Identification of hybrids for future Hybridization

The genetic diversity increases with the distance between clusters. By considering the genetic diversity for the hybridization program depends upon the performance and cluster means of various characters. Based on inter-cluster and intra cluster distance, cluster mean and as per the performance, cross Pr 3 (1 × 4), Pr 1 (1 × 3) are suggested to utilize for future breeding program.

In order to obtain potentially transgressive segregants and to facilitate unique gene recombination within the gene pool, genetic divergence has been identified as a

crucial component in the discrimination of genetically distinct parents for an effective and successful hybridization program.

Table 4.12: Per cent contribution of nineteen characters

Sr. No.	Source	Times Ranked 1st	Contribution %
1	Number of branches per vine	0	0.00 %
2	Length of vine (m)	0	0.00 %
3	Days to first male flower appearance	0	0.00 %
4	Days to first female flower appearance	0	0.00 %
5	Node at which first male flower appeared	1	1.28 %
6	Node at which first female flower appeared	1	1.28 %
7	Days to 50% flowering	0	0.00 %
8	Number of male flowers per vine	0	0.00 %
9	Number of female flower per vine	0	0.00 %
10	Sex ratio	0	0.00 %
11	Days to first picking	0	0.00 %
12	Days to last picking	2	2.56 %
13	Length of fruit (cm)	28	35.90 %
14	Diameter of fruit (cm)	17	21.79 %
15	Weight of fruit (g)	0	0.00 %
16	Number of fruits per vine	2	2.56 %
17	Fruit yield per vine (kg)	18	23.08 %
18	Fruit yield per plot (kg)	3	3.85 %
19	Fruit yield (q/ha)	6	7.69 %

5. SUMMARY AND CONCLUSION

The current investigation entitled, “Variability studies of F₄ generation in bitter gourd” was carried out at All India Coordinated Research Project on Vegetable crops, Department of Horticulture, MPKV., Rahuri while keeping following objectives in mind:

- 1) To study the genetic variability for yield and yield contributing characters.
- 2) To study the nature and extent of genetic diversity among various progenies of bitter gourd (*Momordica charantia* L.)

There were nine progenies and four parents under investigation which were received from All India Coordinated Research Project on Vegetable crops, Mahatma Phule Krishi Vidyapeeth, Rahuri (Maharashtra). These progenies were assessed in Randomized Block Design with three replications. The research was carried out in *Kharif* season during the year 2022.

The treatments were examined for the variability, heritability, genetic advance, correlation association studies, path analysis along with appeared, days to 50% flowering, number of male flowers per vine, number divergence for various growth and yield contributing characters, viz., number of branches per vine, length of vine (m), days to first male flower appearance, days to first female flower appearance, node at which first male flower appeared, node at which first female flower of female flower per vine, sex ratio, days to first picking, days to last picking, length of fruit (cm), diameter of fruit (cm), weight of fruit (g), number of fruits per vine, fruit yield per vine (kg), fruit yield per plot (kg), fruit yield (q/ha). Also qualitative characters and incidence of disease and pests were studied.

5.1 Qualitative characters

All the thirteen progenies are classified according to shape of fruit, color of fruit and prickles. All the progenies along with the parents were observed oblong in shape and green color except the progeny Pr 1 (1 × 3) which was observed light green colour. Except the progeny Pr 3 (1 × 2) all other progenies had high prickles on the surface of the fruit. Progeny Pr 3 (1 × 2) had medium size prickles on their surface.

5.2 Percent of disease and pest

In the present investigation for disease and pest, minimum intensity of downy mildew was observed for progeny Pr 1 (1×4), Pr 3 (1×4)) and parent P4. For pest intensity, minimum intensity of fruit fly was observed for progeny Pr 3 (1×4) followed by parent P4 and parent P1.

5.3 **Variability, Heritability and Genetic Advance**

For each of the nineteen traits included in the study, there was a considerable amount of genotypic variability that was evident in the mean sum of squares values. The high GCV and PCV were estimated for diameter of fruit (cm), fruit yield per vine (kg), fruit yield (q/ha), number of fruits per vine, fruit yield per plot (kg), node at which first female flower appeared, sex ratio while moderate GCV and PCV were observed for node at which first male flower appeared, length of fruit (cm), number of female flower per vine, number of branches per vine, weight of fruit (g), length of vine (m), number of male flowers per vine, days to last picking. Low GCV and PCV was observed for traits days to 50% flowering, days to first male flower appearance, days to first female flower appearance, days to first picking.

Heritability ranged from 35.23 to 92.75. High heritability was observed for the characters diameter of fruit (cm), node at which first female flower appeared, node at which first male flower appeared, number of branches per vine, length of fruit (cm), sex ratio, weight of fruit (g), number of female flower per vine, days to last picking, fruit yield (q/ha), fruit yield per plot (kg), fruit yield per vine (kg), number of male flowers per vine, number of fruits per vine. Moderate heritability was observed in the characters like days to 50% flowering, days to first male flower appearance, days to first picking, days to first female flower appearance and length of vine (m).

The magnitude of genetic advance observed was very low to extremely high and ranged from 0.7 to 52.56. Genetic advance was observed highest for the characters fruit yield (q/ha) which was followed by number of male flowers per vine and days to last picking. Whereas, lowest genetic advance was observed in the characters fruit yield per vine (kg) and length of vine (m).

5.4 **Correlation and path analysis**

The yield per plot had significantly positive correlation with number of female flower per vine, weight of fruit, number of fruits per vine, fruit yield per vine. Also, yield per plot had significantly negative correlation with days to 50% flowering, number of male flowers per vine, sex ratio.

In path analysis study fruit yield per vine exhibited maximum direct effect on fruit yield per plot followed by number of fruits per vine and node at which first male flower appeared. Days to first male flower appearance, days to first female flower appearance, number of female flower per vine, sex ratio, length of fruit (cm), diameter of fruit (cm) exhibited negative direct effect on yield per plot.

5.5 Genetic divergence

Process of clustering was carried out by Tocher's method, suggested by Rao (1952). The 13 progenies were categorized into four clusters, in which Cluster I had maximum number progenies (9) followed by cluster II which had 2 progeny and cluster III and IV had each one progeny which is called as monogenotypic cluster.

The maximum intra-cluster distance was discovered by cluster I ($D^2 = 144.96$) and cluster I and IV had least intra-cluster distance ($D^2 = 0$). The maximum inter cluster distance was discovered between cluster II and III ($D^2 = 598.29$) followed by cluster III and IV ($D^2 = 598.29$)

The maximum contribution by the trait was observed by length of fruit followed by fruit yield per vine, diameter of fruit. And least contribution was observed by node at which first male flower appeared and node at which first female flower appeared.

Conclusion:

From above discussion we could conclude that,

- 1) According to Analysis of variance table, fruit yield (q/ha), number of male flowers per vine showed high variations, which means such characters should be considered for further exploitation.
- 2) Based on mean performance, for yield contributing and growth characters in general, the progenies Pr 1 (1×4), Pr 1 (1×3) and Pr 4 (1×4) were found to be superior for most of the characters. Also for yield, these progenies were found to be superior.
- 3) The progenies from the above conclusion, viz., Pr 1 (1×4), Pr 3 (1×4) and P4 were highly resistance to downy mildew and progenies Pr 3 (1×4), P4 and P1 had minimum infestation and should be considered for resistant breeding.
- 4) Phenotypic variance and coefficient of variation are both marginally larger than genotypic variance and coefficient of variation.
- 5) The characters such as diameter of fruit (cm), fruit yield per vine (kg), fruit yield (q/ha), number of fruits per vine, fruit yield per plot (kg), node at which first female flower appeared, sex ratio had high GCV and PCV value while moderate GCV and PCV value were observed for node at which first male flower appeared, length of fruit (cm), number of female flower per vine, number of branches per vine, weight of fruit (g), length of vine (m), number of male flowers per vine, days to last picking.
- 6) Genetic advance was observed highest for the characters fruit yield (q/ha). Whereas, lowest genetic advance was observed in the characters fruit yield per vine (kg) and length of vine (m).
- 7) The yield per plot had significantly positive correlation with number of female flower per vine, weight of fruit, number of fruits per vine, fruit yield per vine. In path analysis study

fruit yield per vine exhibited maximum direct effect on fruit yield per plot followed by number of fruits per vine and node at which first male flower appeared.

- 8) Four clusters were obtained in which cluster I had maximum progenies in it. Maximum intra cluster distance was observed for cluster I ($D^2 = 144.96$) and minimum for cluster I and IV ($D^2 = 0$).
- 9) The maximum contribution by the trait was observed by length of fruit and least contribution was observed by node at which first male flower appeared.

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7. VITAE

MR. MAYURESH DIGAMBAR DAWARE

A candidate for the degree of
MASTER OF SCIENCE (HORTICULTURE)
IN
(VEGETABLE SCIENCE)
2024

Title of thesis	:	“Variability studies of F ₄ generation in bitter gourd (<i>Momordica charantia</i> L.)”
Major field	:	Horticulture (Vegetable Science)
Biographical information :		
Personal		
Date of birth	:	06 th October 1999
Place of birth	:	At post - Talkat, Tal - Dodamarg, Dist - Sindhudurg
Father's name	:	Digambar Devaji Daware
Mother's name	:	Daya Digambar Daware
Educational :		
Bachelor Degree Obtained	:	B. Sc. (Hons) (Agriculture) in 2021 from Rajarshee Chattrapati Shahu Maharaj College of Agriculture, Kolhapur.
Class	:	First Class
Name of University	:	Mahatma Phule Krishi Vidyapeeth, Rahuri.
Address	:	Bl. No. 12, Naik complex, New khasilwada, Tal- Sawantwadi, Dist- Sindhudurg.
E-mail ID	:	mayureshdaware6@gmail.com
Contact number	:	9156177139