

**GENETIC STUDIES IN F₃ AND F₄ GENERATIONS OF
BITTER GOURD (*Momordica charantia* L.)**

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

DOCTOR OF PHILOSOPHY (HORTICULTURE)

in

VEGETABLE SCIENCE

by

Alekar Aadik Nandkumar

(Reg. No. Ph.D.Ag/013/77)

**DEPARTMENT OF HORTICULTURE
POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI VIDYAPEETH
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2016

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RAHURI - 413 722, DIST. AHMEDNAGAR
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2016

CANDIDATE'S DECLARATION

*I hereby declare that this thesis or part
there of has not been submitted
by me or any other person to any
other University or Institute
for a Degree or
Diploma*

Place : MPKV, Rahuri

(A. N. Alekar)

Date : /12 /2016

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Rahuri - 413 722, Dist. Ahmednagar,
Maharashtra, India.

CERTIFICATE

This is to certify that the thesis entitled, **GENETIC STUDIES IN F₃ AND F₄ GENERATIONS OF BITTER GOURD (*Momordica charantia* L.)**, submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra State, India in partial fulfilment of the requirement for the degree of **DOCTOR OF PHILOSOPHY (HORTICULTURE) in VEGETABLE SCIENCE**, embodies the results of a *bona fide* research carried out by **Mr. Alekar Aadik Nandkumar**, 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 acknowledged.

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Date : /12/2016

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Maharashtra, India.

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Place : MPKV, Rahuri

(B. R. Ulmek)

Date : /12/2016

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LIST OF ABBREVIATIONS

%	: Per cent
/	: per
&	: and
σ^2	: Variance
C ₁	: Cross number-1
C ₂	: Cross number-2
C ₃	: Cross number-3
cm	: Centimeter (s)
cv.	: Cultivar
d.f.	: Degrees of freedom
DAS	: Days after sowing
ECV	: Environment coefficient of variation
<i>et al.</i>	: et alli (and others)
etc	: Et cetera
F ₁	: First filial generation
F ₂	: Selfed of F ₁
F ₃	: Selfed of F ₂
F ₄	: Selfed of F ₃
FYM	: Farm yard manure
g	: Gram (s)
G	: Genotypic (correlation coefficient)
G. A.	: Genetic advance
GAM	: Per cent mean of genetic advance
GCV	: Genotypic coefficient of variation
H ² bs	: Broad sense heritability
ha	: Hectare
i.e.	: id est (that is)
kg	: Kilogram (s)

m ²	: Square meter
MT	: Metric tonne
No.	: Number (s)
P	: Phenotypic (correlation coefficient)
P ₁	: Parent one
P ₂	: Parent two
P ₃	: Parent three
P ₄	: Parent four
PCV	: Phenotypic coefficient of variation
PDI	: Per cent incidence of disease
S	: Symbol
Sr. No.	: Serial number
Sig.	: Significant
T.S.S.	: Total soluble solids
<i>viz.</i>	: Namely
x	: Cross with

ABSTRACT

GENETIC STUDIES IN F₃ AND F₄ GENERATIONS OF BITTER GOURD (*Momordica charantia* L.)

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A candidate for the degree

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Mahatma Phule Krishi Vidyapeeth,

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Research Guide	: Dr. K. G. Shinde
Department	: Horticulture

The present investigation entitled “Genetic studies in F₃ and F₄ generation of Bitter gourd (*Momordica charantia* L.)” was conducted during summer seasons of 2014 and 2015. Fifteen F₃ and F₄ progenies of each of crosses Phule Green Gold x Hirkani (C₁: 1 x 2), Hirkani x Phule Ujwala (C₂: 2 x 3) and Hirkani x Konkan Tara (C₃: 2 x 4) were evaluated for yield and yield contributing characters. This investigation highlighted the magnitude of variability, heritability, genetic advance and correlation coefficient in F₃ and F₄ generations of bitter gourd.

Wide range of variability was observed in all quantitative characters in three crosses of F₃ and F₄ generations. Phenotypic coefficient of variation (PCV) was higher than the respective genotypic coefficient of variation (GCV) for all the characters studied in both F₃ and F₄ generations indicating environmental factors influencing their expression to some extent. In F₃ and F₄ generations in most of the crosses the GCV and PCV were higher 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 showed greater phenotypic and genotypic variability among the progenies and sensitiveness of the attributes for making further improvement by selection.

High heritability coupled with high genetic advance as per cent of mean was observed for most of the characters i.e. vine length at last harvest, number of fruits per vine, fruit yield per vine and yield per hectare in most of the crosses of F₃ and F₄ progenies which indicates preponderance of additive gene action. These characters could be improved by pure line selection or mass selection method.

High heritability combined with low genetic advance was observed for some of the traits for which simple selection would not be rewarding. More the less, they could be utilized as a inbred lines in the hybrid development programme. In such condition selection should be delayed so as to minimize the dominance effect.

In all three crosses of F₃ and F₄ generations 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 vine length at last harvest, number of primary branches per vine, number of fruits per vine, average weight of fruit, average length of fruit and average diameter of fruit. Most of these characters were also positively associated among them.

Long fruit shape is an important fruit character in bitter gourd as compared to medium. In the present investigation, among the F₃ and F₄ segregating progenies of the three crosses most of the progenies observed medium shape of fruit.

Among the three crosses, all crosses *viz.*, Phule Green Gold x Hirkani (C₁: 1 x 2), Hirkani x Phule Ujwala (C₂: 2 x 3) and Hirkani x Konkan Tara (C₃: 2 x 4) showed green colour of fruits along with medium prickles in F₃ and F₄ generation.

Eventually from the present investigation the genotypes or progenies were identified in the bitter gourd for further crop improvement based maximum fruit yield per vine with maximum average fruit weight, medium fruit shape, green fruit colour with medium prickles for advancement of F₅ generation through simple pedigree selection method.

1. INTRODUCTION

India has historically been recognized as a land of unique comparative advantage for cultivation of a variety of horticultural crops. The growing economic importance of horticultural crops especially vegetables leads to an increasing demand arising from domestic as well as over distant markets. In vegetables, India is second largest producer with production of 1,62,897 thousand MT and with productivity of 17.30 MT/ha in area of 9396 thousand hectares and in Maharashtra production of vegetables is 10161.8 thousand MT and with productivity of 16.9 MT/ha in area of 726.0 thousand hectares in year 2013-14 (Anonymous, 2014).

Bitter gourd (*Momordica charantia* L.) or Balsam pear is one of the most important vegetable grown throughout the tropical and subtropical regions of the world with native of Tropical Africa and Asia. It is widely distributed in China, Malaysia, India and Tropical Africa. It belongs to Cucurbitaceae family with $2n=22$ chromosome number and grown extensively for its bitter fruits in India. Bitter gourd is luscious, high-climbing vines with slightly fuzzy stems clothed with dark green deeply lobed leaves and yellow monoecious flowers. The immature fruits of bitter gourd are valued for its bitter flavour, considered to bring out the flavour to the ingredients. It is usually eaten fresh (stuffed and /or sliced) but can also be pickled, and has been canned in brine. Its young shoots and leaves are also eaten (Vinning, 1995).

It belongs to genus *Momordica* and species *charantia*. The characteristic taste in the fruits is due to chemical constituent “momordicin”. The related species of this genera are

Momordica cochinchinensis Spreng and *Momordica dioca* Roxb. There is an appearance of various intermediate sex forms like andromonoecious, gynoeceous and trimonoecious. As the name signifies, the fruits are bitter in taste. Bitter gourd has relatively high nutritional value, in respect of iron and ascorbic acid contents.

Bitter gourd is usually grown under kitchen garden as a summer vegetable. But at present it is also being grown as commercial crop near the urban areas. Although the bitterness of bitter gourd might turn some people away, it really sweetens the diet because of its disease preventing and health promoting phyto-chemical compounds. Fresh bitter gourd is an excellent source of vitamin-C (84mg/100g) which is one of the powerful natural antioxidant. It provides very low calories (17 cal per100g) (Chakrabarti, 2001). Bitter gourd notably contains phyto-nutrients, polypeptide-P., a plant insulin known to lower blood sugar levels. In addition it also contain hypoglycaemic agent, which increases glucose uptake and glycogen synthesis in the cells of liver, muscle and adipose tissues, together. These compounds are thought to be responsible for reducing blood sugar levels in the treatment of type-2 diabetes. It is also an excellent source of health benefiting flavonoids such as α -carotene, β -carotene, lutein, zexanthins. It contains considerable amount of water (83-92%), carbohydrates (4.0-10.5%), protein (1.5-2.0%), fat (0.2-1.0%), minerals (0.5-1.0%) and fiber 0.8-1.7%). Ripe fruits are rich source of vitamin-A. Among the all cucurbitaceous vegetables, bitter gourd contains the maximum amount of minerals and vitamins. (Islam *et al.*, 2009).

The yield is a polygenic character and it depends on a number of characters. For any crop improvement, direct

selection for yield will be misleading and inappropriate. Hence, the knowledge of association of quantitative characters with yield and among themselves will be of great significance (Ramchandran *et al.*, 2002). Bitter gourd is monoecious and highly cross-pollinated in nature. Such pollination mechanism can be exploited commercially for hybrid seed production. Moreover, there is a great scope for development of open pollinated varieties by utilizing the existing variability. Large amount of variation provides the better chance of selecting desired genotypes (Vavilov, 1951) and the response to selection of the traits would depend upon the continuous variation (Fisher, 1918). Selection towards this end is dependent upon the nature and magnitude of the variability present in the material for the desired characters and the extent to which it is heritable. Burton (1952) suggested that, genetic variation together with heritability estimates would give the best estimates of genetic advance expected from the selection. Johnson *et al.* (1955) also reiterated the above fact. Information on heritability is a prerequisite for improving the yield traits and the productivity of the crop.

The extent of genetic variability available in crop is a prerequisite for its improvement due to the fact that the efficiency of selection mainly depends on it. A greater yield response is obtained when the character for which indirect selection is practiced has a high heritability and a high correlation with yield. The critical assessment of nature and magnitude of variability is one of the important pre-requisite in formulating effective breeding programme. The efficiency of selection depends mainly on the extent of genetic variability present in the population. The estimates of genotypic and

phenotypic coefficient of variation, heritability and its components are useful in designing an effective breeding programme. Correlation studies are helpful in determining the yield components, which characters contributed towards yield and their relationship. Bitter gourd requires vast genetic studies for substantial improvement in yield and quality. The different progenies derived from different crosses of bitter gourd, with better characters were selected and they were evaluated for yield and yield contributing characters. The variability, heritability genetic advance and correlation were studied in F_3 and F_4 generations of bitter gourd.

As the area and production of bitter gourd are increasing fast but the crop still remains less explored on aspects of crop improvement by breeding methods. Thus, there is much need of cultivars with early fruiting, high yield, and high female to male sex ratio, thick fruits suitable for stuffing, resistance to fruit flies, red pumpkin beetle, mosaic virus, downy and powdery mildew. Therefore, to introgress these horticultural traits, the F_3 and F_4 progenies were assessed for variability, heritability, genetic advance and correlation for the utilization in crop improvement, the present investigation was undertaken with the following objectives-

1. To assess the variability for important qualitative and quantitative traits in F_3 and F_4 generations.
2. To estimate heritability and genetic advance for yield contributing characters in F_3 and F_4 generations.
3. To study the correlation between yield and yield contributing characters in F_3 and F_4 generations.

2. REVIEW OF LITERATURE

The objective of any breeding programme is the improvement of quantitative and qualitative characters of a crop. Information on inheritance of various quantitative traits, particularly of economic importance will be most useful in planning and successful implementation of breeding programme. Information on genetic variability, heritability, genetic advance and correlation for growth, yield and fruit quality in bitter gourd are rather limited. The available literature on these aspects in bitter gourd and related cucurbitaceous crops like bottle gourd, musk melon, ridge gourd, snake gourd, cucumber, ash gourd, melons, pumpkin has been reviewed and presented under the following sub-headings.

2.1 Variability

2.2 Heritability and genetic advance

2.3 Correlation coefficient

2.4 Per cent incidence of diseases and pests

2.5 Fruit characters (Qualitative).

2.1 Variability

The study of genetic variability is an important prerequisite in any successful breeding programme. 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 programme. 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 F1 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 F₂ and F₃ generations of bitter gourd and reported that 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 F₂ and F₃ generations. Thus,

presence of greater amount variability particularly for yield attributes could be further improved by simple selection method.

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

Vijay (1987) observed high phenotypic coefficient of variation for fruits per vine, flesh thickness and yield per vine. High heritability as well as high genetic advance was noticed for fruits per vine, yield per vine and flesh thickness.

Somkumar *et al.* (1997) recorded highest PCV and GCV in muskmelon for per cent disease intensity of downey mildew. The other characters *viz.* average fruit weight, number of fruits per vine and fruit yield per vine recorded high PCV and GCV estimates. Low GCV and PCV estimate was recorded for days to first harvest.

Tarsem and Sanjay (1997) studied genetic variability in muskmelon and reported that high values of variability (PCV & GCV) were recorded for node at which first female flower appeared, average weight of fruit, marketable yield per vine and total yield per vine. Also reported that estimates of PCV were higher than GCV and obtained high mean estimates for fruit yield per vine, average fruit weight and average weight of pulp per fruit in 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 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

Narayan *et al.*, (1996) studied genetic variability in 25 diverse populations of bottle gourd and observed wide range of variation in most of the characters. The high value of GCV was observed for number of primary branches per plant and yield per plant indicated that these two characters had additive gene effect and, therefore, they are more reliable for effective selection

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 wide range of variability was observed for all the characters. 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 & 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

Solanki and Seth (1980) observed considerable phenotypic variability among twenty four varieties of cucumber for vine length, number of leaves per plant and number of days to maturity.

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 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 x White long, BGDL x Hot season and BGDL x Hyderabad cucumber. The high variability in the form of PCV and GCV was observed in BGDL x 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 x Hyderabad cucumber and BGDL x 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.

Ramesh 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 & 32.29 %) followed by number of marketable fruits per plant (25.48 & 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. The values of GCV were smaller than PCV, indicating the effect of environment to some extent in the expression of the characters.

2.1.2.6 Sponge gourd

Arora *et al.* (1983) observed significant varietal differences for all the characters studied. Yield per plant, number of fruits per plant and sex ratio exhibited maximum range of genotypic and phenotypic coefficient of variation in sponge gourd.

Abusaleha and Dutta (1990) recorded genetic variability and heritability for different characters in sponge gourd with forty five genetic stocks. High magnitude of genotypic and phenotypic variance were observed for all characters.

Prasad and Singh (1990) observed that high estimates of phenotypic and genotypic coefficient of variation were observed for fruit length, fruit yield per vine and vine length in sponge gourd. Moderately high GCV and PCV was recorded for number of fruits, number of nodes and fruit width.

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. Also obtained the lower estimation of GCV than the PCV.

2.1.2.7 Summer squash

Raju *et al.* (1998) studied genetic variability in summer squash and observed that the coefficients of variation (PCV and GCV) for number of fruits per vine (36.84 and 36.02 %), vine length (32.39 and 32.35 %) and total fruit yield per vine (30.10 and 30.00 %). Thus, maximum variability in these traits attributed ample scope for effective improvement through selection.

2.1.2.8 Watermelon

Thakur and Nandpuri (1974) observed high variability (PCV and GCV) for 100-seed weight and number of seeds per kg of fruit where as other traits *viz.*, branches per vine, days to first picking and yield per vine indicated low variability in watermelon. The estimation of PCV was higher than GCV. High variability showed ample scope of improvement through selection.

Kadam (1997) evaluated variability in seven cultivars of watermelon for growth and yield attributes. The estimates of PCV were slightly higher than GCV for all the traits studied indicating the minor role of environment in the expression of traits. The estimates of PCV and GCV were high for average number of fruits per vine followed by average weight of fruit, average fruit yield per vine, average number of seeds per fruit, average length of fruit and shelf life of fruits whereas, average number of primary branches, average diameter of fruit, total soluble solids, days required for 50 per cent harvest and female flowering recorded low estimates of PCV and GCV.

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.

2.1.2.9 Snake gourd

Deepa 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.

2.1.3 Other Vegetables

Shirkole (2006) evaluated segregating progenies of tomato involving three F_2 crosses with six divergent parents. The estimates of GCV were low as compared to PCV. The highest GCV was observed for pericarp thickness (40.03) followed by number of locules per fruit (34.86 %). indicating predominance of additive gene effect and greater scope for further selection.

Gupta *et al.* (2009) revealed that, wide range of variability observed in all the characters in chilli. Relatively higher values of phenotypic and genotypic coefficient of variation were observed. The highest phenotypic coefficient of variation was recorded for the traits incidence of virus (41.67 %), number of fruits per plant (31.38 %), fruit yield per plant (26.79 %), fruit weight (24.67 %). The genotypic coefficient of variation were high for number of fruits per plant (30.35 %), incidence of virus (27.42 %), fruit yield per plant (25.98 %), fruit weight (22.98 %) revealing better scope of improvement through selection. Hence, these traits are likely to respond to selection on a better way.

Kshirsagar (2009) observed wide range of variability in F_3 and F_4 generation of tomato. GCV and PCV were higher for fruit yield per plant, average fruit weight and number of locules

per fruit indicates presence of substantial amount of genetic variability.

2.2 Heritability and genetic advance

Phenotype of an individual is determined by genotype and environment in which it grows. Success of a breeder in changing and improving the heredity of 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. The most important function of heritability in the genetic studies is its predictive role in expressing the reliability of phenotypic value as a guide to breeding value (Falconer, 1981).

Heritability is the index of transmissibility of characters from parental to next generation and need to be studied in order to determine the extent to which the observed variation is inheritable. Heritability estimates facilitate evaluation of hereditary and environmental effect of phenotypic variation and thus aids in selection while genetic advance is a product of heritability and indicates the potentiality of selection intensity. Genetic advance as quoted by Johnson *et al.* (1955) when considered along with heritability gives an available assessment of the resultant effect of selection in breeding populations. 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 as below.

2.2.1 Bitter gourd

Srivastava and Srivastava (1976) studied heritability in ten bitter gourd lines for ten different characters under Rajasthan conditions. 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 & 31.45 %), number of branches per vine (92.55 & 66.59 %), number of fruits per vine (94.23 & 36.31 %), average fruit weight (94.23 & 62.32 %) and fruit yield per vine (86.06 & 44.91 %).

Lawande (1987) studied parents and 55 F1 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.

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 percent 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.

2.2.2 Other cucurbits

2.2.2.1 Muskmelon

Somkumar *et al.* (1997) studied heritability and genetic advance as per cent of mean in muskmelon and obtained high heritability and moderate genetic advance as per cent mean for F:C ratio, per cent disease intensity of downey mildew, fruit yield per vine, number of fruits per vine and fruit weight indicated that hybridization followed by selection will be effective for genetic improvement.

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. This

might be due to high additive gene effects and consequently the scope for improvement of yield through selection.

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 & 24.32%), days to first female flower opening (95.56 & 34.12%), days to first harvest of fruit (89.32 & 34.23%), fruit length (92.10 & 24.36%), fruit diameter (90.45 & 21.47%), number of fruits per vine (97.70 & 109.29%), average weight of fruit (99.60 & 41.48%), fruit yield per vine (83.75 & 34.15%), flesh thickness (96.65 & 31.75%), fruit cavity size (99.00 & 114.40%), average weight of pulp per fruit (92.65 & 26.54%), average rind thickness (94.31 & 20.48%) and total soluble solids (84.25 & 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 programme. 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 per cent 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 x 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, downey mildew, powdery mildew, fruit fly and leaf miner. It indicated that most likely high heritability is due to additive gene effects and selection may be effective. 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

Narayan *et al.* (1996) studied heritability in broad sense and genetic advance in 25 diverse populations of bottle gourd. Wide range of variation was observed in most of the characters. The high value of heritability estimates associated with greater genetic advance was observed for number of primary branches per plant and yield per plant indicated that these two characters had additive gene effect and, therefore, they are more reliable for effective selection.

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 where as 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 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

Solanki and Seth (1980) observed considerable high heritability and high expected genetic advance among twenty four varieties of cucumber for length, number of leaves per plant and number of days to maturity and fruit yield. However, higher heritability with low expected genetic advance was recorded for average fruit weight, duration of flowering, number of primary branches per plant and number of fruits harvested per plant.

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 F₂ population of BGD L x White long, BGD L x Hot season and BGD L x Hyderabad cucumber of cucumber. Higher heritability coupled with moderate to low genetic gain was noticed in all F₂ 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 & 55.14 %), fruit length (83.60 & 42.84 %), marketable fruits per vine (82.05 & 47.54 %) and fruit weight (89.09 & 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

Panwar *et al.* (1977) recorded high estimates of heritability along with high genetic advance for fruit length and days to flower in sponge gourd.

Arora *et al.* (1983) observed significant varietal differences for all the characters studied. Yield per plant, number of fruits per plant and sex ratio exhibited maximum range of heritability and genetic advance. Heritability estimates were lower for length of vine, internodal length and fruit diameter in sponge gourd.

Abusaleha and Dutta (1990) recorded heritability for different characters in sponge gourd with forty five genetic stocks. The high estimates of heritability coupled with high genetic advance as per cent mean was observed for fruits per vine, fruit length, vine length and yield per vine.

Prasad and Singh (1990) reported that high heritability accompanied with high genetic advance was observed for yield per vine, fruit length, fruit width whereas the characters vine length and number of nodes per vine showed high

heritability with moderate estimates of genetic advance as per cent mean.

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 Summer squash

Raju *et al.* (1998) reported that the highest values of heritability accompanied with highest genetic advance was recorded for early fruit yield per vine, number of fruits per vine, vine length, fruit weight and total fruit yield per vine indicated that these traits might be under control of additive gene action which can be improved through selection.

2.2.2.7 Watermelon

Kadam (1997) evaluated heritability and genetic advance in seven cultivars of watermelon and reported that heritability estimates were high for average number of fruits per vine followed by average weight of fruit, average fruit yield per vine, average weight of flesh, average number of seeds per fruit, average length of fruit average diameter of flesh, average number of primary branches, average diameter of fruit, total soluble solids, days required for 50 per cent harvest and female flowering and shelf life of fruits. The genetic advance as per cent mean was high for average number of seeds per fruit while it was low for remaining traits.

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.

2.2.2.8 Snake gourd

Deepa 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.

2.2.2.9 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 shows that these characters were least affected by environment. Higher value of genetic advance (>20 %) were observed for fruit diameter and total fruit yield.

2.2.2.10 Pointed gourd

Singh *et al.* (1992) estimated heritability and genetic advance for ten characters in 36 F₁ genotypes of pointed gourd and reported that high heritability coupled with high genetic advance as per cent of mean was observed for fruit yield and number of fruits per vine.

2.2.2.11 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 & 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.

2.2.2.12 Other vegetables

Biradar *et al.* (1993) studied F₁, F₂ and F₃ generations in crosses involving two indigenous and one exotic cowpea line reported importance of additive gene effects for most of the traits. The heritability estimates for all the characters were of moderate to high magnitude and the coupled with high heritability and genetic advance for the most yield components indicated predominance of additive genetic variance and good potential for improvement by selection.

Shirkole (2006) evaluated segregating progenies of tomato involving three F₂ crosses with six divergent parents. The high heritability with high estimates of genetic advance was recorded for days to 50 % flowering (99.30 %, 22.44 %), equatorial diameter (86.49 %, 37.31%), plant height (79.44 %, 35.06 %) and fruit yield per plant (76.61 %, 54.97 %) indicating predominance of additive gene effect and greater scope for further selection.

Gupta *et al.* (2009) revealed that, high heritability with high genetic advance in chilli for the number of fruits per plant (93.55 and 60.47 %), fruit yield per plant (94.03 and 51.89 %) and fruit weight (86.74 and 44.09 %) respectively. Hence, these traits are likely to respond to selection on a better way.

Kshirsagar (2009) observed wide range of variability in F₃ and F₄ generation of tomato. High heritability coupled with high genetic advance was recorded in average fruit weight (97.38 and 35.89 %), number of locules per fruit (98.02 and 29.92 %). Whereas, fruit weight (97.70 and 38.22 %), number of locules per fruit (89.90 and 27.33 %) and fruit yield per plant (85.00 and 26.87 %) for F₃ and F₄ generation of cross M-3-1 X18-1-1 respectively. Also, fruit yield per plant (80.00 and 31.70 %), number of locules (95.00 and 23.89 %) and average fruit weight per fruit (92.48 and 18.48 %) in F₃ generation, whereas, average fruit weight (94.98 and 36.98 %), number of locules per fruit (90.63 and 34.29 %), fruit yield per plant (80.00 and 29.28 %) pericarp thickness (83.20 and 24.79 %) in F₄ generation of cross M-3-1 x H-36 respectively.

2.3 Correlation coefficient

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 programme 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.

2.3.1 Bitter gourd

Khattra *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.

Botau *et al.* (2010) demonstrated that the fruit yield per vine had significant and positive correlation with number of fruits per vine, fruit weight, fruit length and fruit diameter in bitter gourd.

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.

2.3.2 Other cucurbits

2.3.2.1 Muskmelon

Monila *et al.* (1989) observed significant and positive correlation between total fruit yield with average weight of fruit, fruit length, fruit width, flesh thickness and rind thickness in muskmelon.

Tarsem and Sanjay (1997) studied correlation in muskmelon and reported that total fruit yield per vine showed highly significant and positive phenotypic correlation with flesh thickness, marketable fruit yield per vine, average weight per fruit, seed cavity size and vine length. Thus, in breeding programme positive correlations among the characters would be considered desirable. Hence selection for these traits would bring about an improvement of total fruit yield per vine.

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 programme.

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, 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

percent disease intensity for downey mildew 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. Also revealed that estimates of genotypic correlation were slightly higher than their corresponding phenotypic correlation for all the characters.

2.3.2.6 Watermelon

Kadam (1997) studied phenotypic and genotypic correlation coefficient between yield and yield contributing

characters in watermelon and revealed that average fruit yield per vine was highly and positively correlated with average length of main vine, average number of primary branches, average length of fruit, average diameter of fruit, average weight of fruit, average diameter of flesh, average number of seeds per fruit and average weight of flesh.

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 Fruit characters (Qualitative)

Ramaswamy *et al.* (1977) studied inheritance of fruit shape in oblong x flat, flat x round and oblong x round and concluded that fruit shape in muskmelon was inherited in a simple way, and several genes may be involved. The crosses were made between crossed netted type with smooth type of muskmelon and observed netted character was dominant over smoothness. Also made crosses between green fleshed fruit (Durgapura Madhu) with white fleshed (Lucknow Safeda) fruit and obtained all white fleshed fruit in F₁.

Jagtap (2010) conducted experiment on heterosis and combining ability in muskmelon and reported that the progenies of crosses P₄ x P₆ (IVMM-3 x MHY-3), P₄xP₇ (IVMM-3 x Punjab Sunheri), P₂xP₇ (Durgapura Sel x Punjab Sunheri), P₁xP₃ (GMM-3 x Hara Madhu) and P₃xP₄ (Hara Madhu x IVMM-3) were found superior in case of qualitative traits like round fruit shape, greenish yellow with ridges fruit colour, netted fruit surface, flavor and orange pulp colour.

Dalamu *et al.* (2012) in their study on inheritance of fruit colour and surface in bitter melon reported that the crosses sel-1 x Pusa Do Mousami and sel-1 x Pusa vishesh exhibited found green fruit colour of bitter melon. The inheritance of ridgeness in cross sel-1 x Pusa vishesh indicated that the fruit surface (discontinuous ridge) was governed by single dominant gene.

Rajput (2012) reported that the crosses PGG x DVBTG-5, PGG x Delhi Local and Delhi Local x Co-White Long

were found superior for further selection of desirable bitter gourd cultivars where dark green fruits are mostly preferred in export market followed by light green fruits while white in local markets and prickly, smooth fruit surface and long fruit length were observed in F₂ and F₃ progenies.

Patil (2014) reported that the cross 1 (Durgapura Selection x Punjab Sunheri), cross 3 (Hara Madhu x Punjab Sunheri) and cross 5 (IVMM-3 x Punjab Sunheri) were found superior for further selection of desirable muskmelon cultivars with high yield and best quality in respect of round fruit shape, greenish yellow with ridges fruit colour, netted fruit surface, flavor and orange pulp colour.

2.5 Per cent incidence of diseases and pests

Jagtap (2010) reported that by considering overall performance coupled with the minimum incidence of disease (downy mildew, fusarium wilt and gummosis) and pests (fruit fly and leaf miner) in muskmelon the crosses P₄ x P₆ (IVMM-3 x MHY-3), P₄xP₇ (IVMM-3 x Punjab Sunheri), P₂xP₇ (Durgapura Sel. x Punjab Sunheri), P₁xP₃ (GMM-3 x Hara Madhu) and P₃xP₄ (Hara Madhu x IVMM-3) could be effectively exploited for heterosis breeding programme. Whereas the parents Durgapura Selection (P₂), Hara Madhu (P₃), IVMM-3 (P₄) and Punjab Sunheri (P₇) were identified as the best combiner and could be used in further breeding programme for improvement of (OP) cultivars in muskmelon.

Rajput (2012) reported all the four parents and their progenies were observed resistant to downey mildew, powdery mildew, fruit fly and leaf minor in F₂ and F₃ generations in bitter gourd.

Patil (2014) in their study on muskmelon reported that the cross 5 (IVMM-3 × Punjab Sunheri) showed the least incidence of downey mildew (26.04 & 29.11%), powdery mildew (13.34 & 22.14%), fusarium wilt (5.00 and 5.00%), fruit fly (7.71 & 13.05 %) and leaf miner (17.51 & 20.84 %) in both summer and *kharif* seasons respectively in F₂ generation which can be further exploited for obtaining tolerant variety against them.

3. MATERIAL AND METHODS

The present investigation entitled “Genetic studies in F₃ and F₄ generations of Bitter gourd (*Momordica charantia* L.)” was carried out at the All India Coordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) during the summer 2014 and 2015. The details of material used and procedure adopted for the present investigation are given below.

3.1 Material

The seeds of F₂ plant progenies from 3 crosses along with 4 parents were obtained from the previous Ph.D. research work carried out at AICRP on vegetable crops, MPKV., Rahuri. Parents involved in these crosses are..

1. Phule Green Gold (1),
2. Hirkani (2),
3. Phule Ujwala (3)
4. Konkan Tara (4)

Table 3.1.1 Details of crosses and generation wise progenies.

Cross	Symbol	Progenies selected for F ₃ generation	Progenies selected for F ₄ generation
C 1- Phule Green Gold x Hirkani	1 x 2	5	5
C 2- Hirkani x Phule Ujwala	2 x 3	5	5
C 3- Hirkani x Konkan Tara	2 x 4	5	5
Total		15	15

Table 3.1.2 Salient features of parent material used for present investigation.

Code No.	Parent	Source	Salient features
P ₁	Phule Green Gold	MPKV, Rahuri	Selection by cross between Green long x Delhi local, Fruits are dark green, 25-30 cm long with prickles, tolerant to downy mildew, suitable for <i>Kharif</i> and Summer seasons, average yield 230 q/ha.
P ₂	Hirkani	MPKV, Rahuri	Selection from local type, fruits are dark green, 15-20cm long with prickles, crop duration 160 days, suitable for <i>kharif</i> and summer season, average yield 140 q/ha.
P ₃	Phule Ujwala	MPKV, Rahuri	Fruits are green, 17-22cm long with prickles, suitable for <i>kharif</i> and summer season, crop duration 145 days, average yield 190 q/ha.
P ₄	Konkan Tara	Dr.BSKK V, Dapoli	Fruits are green, 15-16cm long with prickles, spindle shaped, suitable for <i>kharif</i> and summer season, crop duration 140 days, average yield 170 q/ha.

3.2 Methods

3.2.1 Design and layout of experiment for F₃ and F₄ generations.

- a. Design : Randomized Block Design
- b. Replications : Two
- c. Number of progenies : 15
- d. Number of parents : 4
- e. Number of crosses : 3
- f. Number of progenies for : 5
each cross
- g. No. of plants progeny⁻¹ : 15
- h. Number of F₃/F₄ plants : 225
per replication

3.2.2 Details of Experiment

F₂ progenies from the three crosses were selected on the basis of earliness, shape of fruit, node at which first female flower appeared, average length and diameter of fruit (cm), colour of fruit, average weight of fruit(g) and yield per vine.

Initially, fifteen progenies along with four parents were sown during summer 2014 and evaluated for F₃ generation. A total of 19 genotypes (15 progenies + 4 parents) were developed from three hybrids and their respective parents. Again 19 F₃ progenies (selections) (15 progenies + 4 parents) were sown in summer 2015 and evaluated for F₄ generation. The F₃ and F₄ generations of both crosses were evaluated in randomized block design with two replications. For evaluation of F₃ and F₄ progenies, 225 vines of selected progenies and parents were planted in two replications for recording the observations. A recommended dose of fertilizer for bitter melon is 20 t FYM +

100:50:50 kg NPK ha⁻¹. The dose of FYM 20 tones ha⁻¹ and the 50 per cent recommended dose of nitrogen (50 kg/ha) and full dose of phosphorus (50 kg/ha) and potassium (50 kg/ha) were incorporated in the furrows and mixed in the soil during both the seasons. Seeds of these generations were sown at a spacing of 1.5m x 1m. The vines were thinned to one seedling per hill after germination. The remaining 50 per cent of nitrogen (50 kg/ha) was applied as a top dress on 30th day after sowing. The vines were allowed to trail on the kniffen system irrigation, weed control and other cultural practices were followed as per the package of practices to grow good healthy crop.

3.3 Observations recorded

In F₃ generation and F₄ generation vine populations of all three crosses and their parents were taken for observations to study the variability, heritability, genetic advance and correlation for yield contributing traits. The observations were recorded for the following characters.

3.3.1 Growth characters

3.3.1.1 Final vine length at last harvest (cm)

The final length of vine at last harvest was measured in centimeter from the base of the vine to the growing tip of the vine at last harvesting.

3.3.1.2 Number of primary branches per vine

All the primary branches on shoot of the vine was recorded at last crop harvest.

3.3.2 Flowering characters

3.3.2.1 Days to first female flower appearance

The number of days required for the appearance of first female flower from date of sowing was recorded separately for each parents and progenies.

3.3.2.2 Node at which first female flower appeared

The node number at which the first female flower appears gives an indication of earliness in cucurbits (Swarup, 1977). Therefore the node at which the first pistillate flower appeared was noted for all the observational plants and mean was calculated.

3.3.2.3 Days required for first harvest of fruit

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

3.3.2.4 Crop duration (days)

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

3.3.3 Yield characters

3.3.3.1 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.

3.3.3.2 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.

3.3.4 Fruit characters (quantitative)

3.3.4.1 Average weight of fruit (g)

The weight of five individual fruits harvested at the full (edible) maturity stage was recorded in gram and the average weight of fruit was calculated.

3.3.4.2 Average length of fruit (cm)

The length of each fruit was measured from the peduncle to the distant end by measuring tape and average was worked out.

3.3.4.3 Average diameter of fruit (cm)

The diameter of each fruit was measured at the centre with the help of digital vernier calliper and average diameter was worked out.

3.3.5 Fruit characters (qualitative)

3.3.5.1 Fruit shape or Fruit size (short, medium, long)

Fruit shape of each progeny of F₃ and F₄ generation was recorded at full mature stage by visual observation as short- 15-20 cm, medium- 20-25 cm and long- 25-30 cm.

3.3.5.2 Fruit colour (light green, green, dark green)

Fruit colour of each progeny of F₃ and F₄ generation was recorded at full mature stage by visual observation as light green, green and dark green.

3.3.5.3 Prickles on fruit (low, Medium, High)

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

3.3.6 Per cent incidence of diseases and pests

3.3.6.1 Per cent incidence of diseases

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

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

3.3.6.2 Per cent incidence of pests

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

$$\text{Per cent incidence of fruit fly} = \frac{\text{Number of infected fruits}}{\text{Total number of fruits}} \times 100$$

3.4 Statistical methodology

The individual vine data was used for statistical and genetical analysis. These have been presented under the following sub-heads.

3.4.1 Estimation of mean and range

The mean value for each character was worked out by using following formula.

$$\bar{X} = \frac{1}{n} (\sum_{i=1}^n X_i)$$

Where, $\sum X_i$ = Sum of total of the character

n = Number of observations

The lowest and the highest value from mean of each character were recorded as range.

3.4.2 Estimation of components of variations

The phenotypic and genotypic variances were calculated by respective mean square values (Johnson *et al.*, 1955a).

- i. Environmental variance (σ^2_e) = MSe
- ii. Genotypic variance (σ^2_g) = MSg – MSe/r
- iii. Phenotypic variance (σ^2_p) = $\sigma^2_g + \sigma^2_e$

Where,

MSg = Genotypic mean sum of square

MSe = Error mean sum of square

r = Number of replication

3.4.3 Estimation of coefficient of variations

The genotypic and phenotypic coefficients of variation were calculated by Burton and De Vane (1953).

i. Phenotypic coefficient of variation (PCV)

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

Where,

σ^2_p = Phenotypic variance

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

ii. Genotypic coefficient of variation (GCV)

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

Where,

σ^2_g = Genotypic variance

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

The PCV and GCV values are categorized by Sivasubramanian (1973) as follows,

Low : Less than 5 %

Moderate : 5 – 10 %

High : More than 10 %

3.4.4 Estimation of heritability (%)

Heritability is the ratio of genotypic variance to the phenotypic variance. Heritability percentage in broad sense was estimated for various characters as below (Lush, 1949).

$$h^2 \text{ (b.s.)} = \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

Where,

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

The heritability in broad sense values are categorized by Johnson *et al.* (1955) as follows,

Low	: Less than 50 %
Moderate	: 50 – 75 %
High	: More than 75 %

3.4.5 Estimation of genetic advance

The genetic advance was calculated as per Johnson *et al.* (1955).

$$GA = \frac{\sigma^2_g}{\sigma^2_p} \times \sqrt{\sigma^2_p} \times K$$

Or

$$GA = K \cdot h^2 \text{ (b.s.)} \times \sqrt{\sigma^2_p}$$

Where,

σ^2_g	= Genotypic variance
σ^2_p	= Phenotypic variance
σ_p	= Phenotypic standard deviation
K	= Selection differential at 5 % selection intensity (i.e. 2.06)
$h^2 \text{ (b.s.)}$	= Heritability broad sense
$\bar{X}$	= Mean of the character

Genetic advance expressed as percentage of mean was calculated by the following formula.

$$\text{GA as percentage of mean} = \frac{GA}{\bar{X}} \times 100$$

The range of genetic advance as per cent of mean values is categorized by Johnson *et al.* (1955) as follows,

Low	: Less than 10 %
Moderate	: 10 – 20 %
High	: More than 20 %

3.4.6 Estimation of correlation coefficient

In order to study the inter relationship between different characters, the genotypic and phenotypic correlation coefficients (r) were calculated for the pooled data were computed by the following formula.

$$r_g = \frac{\text{Co - variance XY (G)}}{\sqrt{\text{Variance X (G) x Variance Y (G)}}}$$

$$r_{ph} = \frac{\text{Co - variance XY (PH)}}{\sqrt{[\text{Variance X (PH) x Variance Y (PH)]}}}$$

Where,

r_g = Genotypic correlation coefficient between character X and Y

r_{ph} = Phenotypic correlation coefficient between character X and Y

X, Y = Two variables under consideration

The significance of these correlation coefficients were compared with statistical table value of correlation coefficient at 1 per cent and 5 per cent level of significance (Snedecor and Cochran, 1967).

4. EXPERIMENTAL RESULTS

Bitter gourd (*Momordica charantia* L.) is an important vegetable crop grown worldwide. Its variability is being used for improvement and thereby developing high yielding varieties and hybrids. The present investigation entitled “Genetic studies in F₃ and F₄ generations of bitter gourd (*Momordica charantia* L.)” was undertaken to study the genetical parameters such as variability, heritability, genetic advance and correlation. The selection pressure was applied to identify the superior genotypes for early fruit harvest, high average fruit weight and fruit yield per vine for development of open pollinated cultivar.

The observations on growth, flowering, yield, fruit quantitative, qualitative characters and incidence of diseases and pest were recorded to study the genetical parameters. The results pertaining to these observations are presented as below.

4.1 Genetical parameters of variability, heritability and genetic advance.

Success of breeding programme is largely depends on the extent of genetic variability present in the population. Since heritable and non-heritable components of variation are important to assess the true breeding nature of a character. Information on heritability is a prerequisite for improving the characters and the productivity, through a systematic breeding programme. Selected fifteen progenies of F₃ and F₄ generations respectively of three crosses *viz.*, Phule Green Gold x Hirkani (C₁: 1 x 2), Hirkani x Phule Ujwala (C₂: 2 x 3) and Hirkani x Konkan

Tara (C₃: 2 x 4) along with their parents were studied for growth, yield and quality traits for genetical parameters. (Table 3 to 8).

4.1.1 Variability, heritability and genetic advance of cross Phule Green Gold x Hirkani (C₁: 1 x 2) for F₃ and F₄ generations.

Fifteen F₃ and F₄ progenies along with their parents were studied for growth, flowering, yield and fruit characters.

4.1.1.1 Vine growth characters

4.1.1.1.1 Final vine length at last harvest (cm)

In F₃ generation wide range of final vine length at last harvest (438.01- 486.64 cm) was recorded with an average value of 458.69 cm. The genotypic co-efficient of variation (GCV) and phenotypic coefficient of variation (PCV) was observed 3.26 % and 3.67 % respectively with environmental co-efficient of variation ECV (1.68 %). The high estimates of heritability (79.65 %), genetic advance (5.97) and genetic advance as per cent mean (27.38 %) were observed (Table 3). Whereas in F₄ generation wide range (453.68- 474.15 cm) with an average value of 464.36 cm was observed for this trait. The GCV (1.80 %) and PCV (1.92 %) were observed with ECV (0.67 %). The high estimates of heritability (87.70 %), genetic advance (2.09) and genetic advance as per cent mean (3.48 %) were observed respectively, indicating preponderance of additive gene action and the character can be improved through simple selection (Table 4).

Table 3. Mean, range, GCV, PCV, ECV, heritability, genetic advance and percent mean of genetic advance of two parents and F₃ population of cross Phule Green Gold X Hirkani (C₁: 1 x 2).

Sr. No.	Character	Mean	Range	GCV (%)	PCV (%)	ECV (%)	h ² bs (%)	GA	GAM (%)
1.	Final vine length at last harvest (cm)	458.69	438.01- 486.64	3.26	3.67	1.68	79.65	5.97	27.38
2.	Number of primary branches per vine	11.96	10.16- 13.15	8.92	10.33	5.20	74.61	1.90	15.87
3.	Days required for appearance of first female flower	57.88	52.47-59.75	4.17	4.78	2.34	76.09	4.34	7.51
4.	Node at which first female flower appeared	24.26	21.28- 28.38	7.37	8.80	8.47	72.42	0.32	1.32
5.	Days required for first harvest of fruit	63.00	57.55- 65.57	4.55	4.87	1.73	87.32	5.52	8.76
6.	Crop duration (days)	143.79	133.62-158.73	5.38	6.38	3.41	71.30	13.47	9.37
7.	Number of fruits per vine	42.05	37.93- 49.64	11.43	12.30	4.52	86.47	9.21	21.91
8.	Average fruit yield per vine (kg)	2.56	2.10- 2.92	14.41	15.63	6.04	85.05	0.70	27.38
9.	Average weight of fruit(g)	61.09	52.29- 68.02	9.25	9.99	3.77	85.76	10.79	17.66
10	Average length of fruit (cm)	20.21	17.53- 23.93	6.99	7.89	3.65	78.56	2.58	12.77
11	Average diameter of fruit (cm)	3.49	3.26- 3.68	4.62	4.75	1.11	94.56	0.32	9.27
12	Fruit yield t/ ha	17.12	14.00- 20.50	14.43	15.64	6.03	85.12	4.69	27.43

Table 4. Mean, range, GCV, PCV, ECV, heritability, genetic advance and percent mean of genetic advance of two parents and F₄ population of cross Phule Green Gold X Hirkani (C₁: 1 x 2).

Sr. No.	Character	Mean	Range	GCV (%)	PCV (%)	ECV (%)	h² bs (%)	GA	GAM (%)
1.	Final vine length at last harvest (cm)	464.36	453.68- 474.15	1.80	1.92	0.67	87.70	2.09	3.48
2.	Number of primary branches per vine	12.37	10.46- 13.53	9.64	10.97	5.24	77.13	2.15	17.44
3.	Days required for appearance of first female flower	56.15	51.70- 60.68	4.79	5.31	2.29	81.40	5.00	8.90
4.	Node at which first female flower appeared	25.49	22.46- 28.79	6.49	7.51	3.78	74.68	2.94	11.55
5.	Days required for first harvest of fruit	61.75	58.13- 66.16	4.02	4.71	2.46	72.78	4.36	7.07
6.	Crop duration (days)	147.71	135.75- 153.48	7.63	8.13	2.81	88.02	21.79	14.75
7.	Number of fruits per vine	42.37	31.93- 50.15	15.08	15.81	4.74	90.98	12.55	29.63
8.	Average fruit yield per vine (kg)	2.64	1.96- 3.57	20.90	21.47	4.88	94.79	1.11	41.94
9.	Average weight of fruit(g)	62.18	56.79- 71.30	10.53	10.82	2.51	94.59	13.12	21.10
10	Average length of fruit (cm)	20.81	18.55- 23.57	8.54	10.05	5.59	72.25	3.11	14.96
11	Average diameter of fruit (cm)	3.48	3.03- 3.66	5.80	6.45	2.82	80.86	0.37	10.74
12	Fruit yield t/ ha	17.64	14.87- 23.78	20.92	21.48	4.89	94.81	7.40	41.96

4.1.1.1.2 Number of primary branches per vine

In F₃ generation the growth character number of primary branches per vine was ranged from 10.16 - 13.15 with mean value 11.96. The close association of GCV and PCV (8.92% and 10.33%) was observed with certain presence of environmental factors ECV (5.20%). The high estimate of heritability (74.61 %) was associated with low genetic advance (1.90) and high genetic advance as per cent mean (15.87 %) (Table 3). Whereas in F₄ generation, it was ranged in between 10.46 to 13.53 with mean value 12.37. Very close values were recorded for GCV (9.64 %) and PCV (10.97 %) with noticeable influence of environmental factor ECV (5.24 %). The high estimate of heritability (77.13 %) was associated with high genetic advance as per cent of mean (17.44 %) and lower value of genetic advance (2.15) (Table 4).

4.1.1.2 Flowering characters

The observations on flowering characters like days to first female flower appearance, node at which first female flower appeared and days required for first harvest of fruits were recorded for F₃ and F₄ progenies.

4.1.1.2.1 Days to first female flower appearance

In F₃ generation wide range of variability was observed for days to first female flower appearance (52.47-59.75 days) with mean value 57.88 days. The close values were recorded for GCV (4.17%) and PCV (4.78%) with noticeable influence of environmental factor ECV (2.34%). The higher estimate of heritability (76.09 %) was observed with moderate values of genetic advance (4.34) and genetic advance as per cent of mean (7.51%) (Table 3). While in F₄ generation it was ranged

from 51.70- 60.68 days with mean value of 56.15 days. Very close values were recorded for GCV (4.79 %) and PCV (5.31 %) with noticeable influence of environmental factor ECV (2.29 %). The high estimate of heritability (81.40 %) was obtained with moderate estimate of genetic advance as per cent of mean (8.90 %) and low value for genetic advance (5.00) (Table 4).

4.1.1.2.2 Node at which first female flower appeared

In case of F₃ generation the character node at which first female flower appeared was ranged in between 21.28 - 28.38 with an average 24.26. The close association of GCV (7.37 %) and PCV (8.80%) was observed with certain presence of environmental factor ECV (8.47%). The high estimate of heritability (72.42 %) was associated with lower genetic advance (0.32). The moderate value was obtained for genetic advance as per cent of mean (1.32%) (Table 3). Whereas in case of F₄ generation it was ranged in between 22.46- 28.79 with an average value of 25.49. The close association of GCV (6.49 %) and PCV (7.51 %) were observed with certain presence of environmental factor ECV (3.78 %). The high value was obtained for heritability (74.68 %) whereas low and moderate values were observed for genetic advance (2.94) and genetic advance as per cent of mean (11.55 %), respectively (Table 4).

4.1.1.2.3 Days required for first harvest of fruit

In F₃ generation the days required for first harvest of fruits was ranged from 57.55- 65.57 days with an average 63.00 days. The close values of GCV (4.55%) and PCV (4.87%) was observed with certain presence of environmental factor ECV (1.73%). The high estimate of heritability (87.32%) was observed with moderate values of genetic advance (5.52) and genetic advance as per cent of mean (8.76%) (Table 3). In F₄ generation it

was ranged from 58.13- 66.16 days with an average 61.75 days. The close association of GCV (4.02 %) and PCV (4.71 %) was observed with certain presence of environmental factor ECV (2.46 %). The higher estimate of heritability observed (72.78 %) with lower genetic advance (4.36 %) and moderate value of genetic advance as per cent of mean (7.07 %), respectively (Table 4).

4.1.1.3 Yield and its contributing character

A detailed study of the extent of variability associated with yield and yield contributing characters and knowledge on their heritability in relation to their contribution towards yield are the prime requisite for an efficient plant breeding programme. Therefore genetical parameters were worked out for number of fruits per vine and fruit yield per vine which one most important for crop improvement.

4.1.1.3.1 Crop Duration (days)

In case of F_3 generation the character crop duration was ranged in between 133.62 - 158.73 with an average value 143.79. The close association of GCV (5.38 %) and PCV (6.38 %) was observed with certain presence of environmental factor ECV (3.41 %). The high estimate of heritability (71.30%) was associated with lower genetic advance (13.47%). The moderate value was obtained for genetic advance as per cent of mean (9.37%) (Table 3). Whereas in case of F_4 generation it was ranged in between 135.75 - 153.48 with an average value of 147.71. The close association of GCV (7.63 %) and PCV (8.13 %) were observed with certain presence of environmental factor ECV (2.81 %). The high value was obtained for heritability (88.02 %) whereas low and moderate values were observed for genetic advance (21.79) and genetic advance as per cent of mean (14.75 %), respectively (Table 4).

4.1.1.3.2 Number of fruits per vine

In case of F_3 generation the number of fruits per vine was ranged between 37.93 - 49.64 per vine with an average 42.05 per vine. The significant contribution of genetic variability GCV (11.43%) and PCV (12.30%) were observed with presence of environmental variability ECV (4.52%). The high estimates were observed for heritability (86.47%) and genetic advance as per cent of mean (21.91%) (Table 3). Whereas in case of F_4 generation it showed wide range 31.93 - 50.15 per vine with an average value of 42.37 per vine. The significant contribution of genetic variability GCV and PCV (15.08% and 15.81% respectively) were observed with environmental variability ECV (4.74%). The highest estimate of heritability (90.98%) and genetic advance as per cent of mean (29.63%) were observed which proves that yield potential can be improved during further selection cycle (Table 4).

4.1.1.3.3 Fruit yield per vine (kg)

In F_3 generation the character fruit yield per vine showed wide range (2.10 - 2.92 kg) per vine with an average 2.56 kg per vine. The contribution of genetic variability GCV (14.41%) and PCV (15.63%) were observed with influence of environmental variability ECV (6.04%). The high value of heritability (85.05%) was associated with high genetic advance as per cent of mean (27.38%) (Table 3). Whereas in F_4 generation it showed wide range of variation in between 1.96 - 3.57 kg per vine with an average value of 2.64 kg per vine. The significant contribution of genetic variability GCV (20.90%) and PCV (21.47%) were observed with environmental variability ECV (4.88%). The high estimates of heritability (94.79%) and genetic advance as per cent of mean (41.94 %) were recorded (Table 4).

4.1.1.3.4 Fruit yield (t/ha)

In F₃ generation the character fruit yield tonnes per hectare showed wide range of 14.00 - 20.50 t/ha with an average 17.12 t/ha. The contribution of genetic variability GCV (14.43%) and PCV (15.64%) were observed with influence of environmental variability ECV (6.03%). The high value of heritability (85.12%) was associated with high genetic advance as per cent of mean (27.43%) (Table 3). Whereas in F₄ generation it showed wide range of variation in between 14.87 - 23.78 t/ha with an average value of 17.64 t/ha. The significant contribution of genetic variability GCV (20.92%) and PCV (21.48%) were observed with environmental variability ECV (4.89%). The high estimates of heritability (94.81%) and genetic advance as per cent of mean (41.96 %) were recorded (Table 4).

4.1.1.4 Fruit characters (quantitative)

4.1.1.4.1 Average weight of fruit (g)

The average weight of fruit is an important yield contributing character in bitter melon. In case of F₃ generation it showed wide range of variation (52.29 - 68.02 g) with mean value 61.09 g. The GCV (9.25%) and PCV (9.99%) were observed with presence of environmental factor ECV (3.77%). The high values were recorded for heritability (85.76%), genetic advance (10.79) and per cent mean of genetic advance (17.66%) (Table 3). Whereas in case of F₄ generation it showed a wide range of variation (56.79 - 71.30 g) with mean value 62.18 g. The close association of GCV (10.53%) and PCV (10.82%) were observed with certain presence of environmental factor ECV (2.51%). The highest estimates of heritability (94.59%), genetic advance (13.12) and genetic advance as per cent of mean (21.10%), were recorded respectively (Table 4).

4.1.1.4.2 Average length of fruit (cm)

In F₃ generation the average length of fruit was ranged in between 17.53 - 23.93 cm with an average of 20.21 cm. The close association of GCV (6.99%) and PCV (7.89%) was observed with certain presence of environmental factor ECV (3.65%). The high value was obtained for heritability (78.56%) whereas lower values were recorded for genetic advance (2.58) and genetic advance as per cent of mean (12.77%) (Table 3). While in F₄ generation it was ranged in between 18.55 - 23.57 cm with an average 20.81 cm. The close association of GCV (8.54 %) and PCV (10.05%) were observed with certain presence of environmental factor ECV (5.59%). The high value was obtained for heritability (72.25%). whereas lower values were recorded for genetic advance (3.11) and genetic advance as per cent of mean (14.96%) (Table 3).

4.1.1.4.3 Average diameter of fruit (cm)

In case of F₃ generation, the average diameter of fruit was ranged from 3.26 - 3.68 cm with an average 3.49 cm. The genetic variability contributed as GCV (4.62%) and PCV (4.75%) with influence of environmental factor ECV (1.11%). The high heritability (94.56%) was associated with low value of genetic advance (0.32) and moderate value of genetic advance as per cent of mean (9.27%) (Table 3). While in case of F₄ generation it showed wide range of 3.03 - 3.66 cm with an average 3.48 cm. The close association of GCV (5.80%) and PCV (6.45%) were recorded with influence of environmental factor ECV (2.82%). The higher estimates of heritability (80.86%) was observed with low and moderate value for genetic advance (0.37) and genetic advance as per cent of mean (10.74%), respectively (Table 3).

4.1.2 Variability, heritability and genetic advance of cross Hirkani x Phule Ujwala (C₂ : 2 x 3) for F₃ and F₄ generations.

Fifteen F₃ and F₄ progenies along with their parents were studied for growth, flowering, yield and fruit characters and are presented in Table 5 and 6.

4.1.2.1 Vine growth characters

4.1.2.1.1 Final vine length at last harvest (cm)

In case of F₃ generation, the final vine length at last harvest was observed in the range of 408.41- 471.48 cm with an average 449.38 cm. The close value of genotypic co-efficient of variation GCV (5.85%) and phenotypic coefficient of variation PCV (5.99%) were observed along with certain presence of environmental co-efficient of variation ECV (1.28%). The high estimates of heritability (95.40%), genetic advance (7.31) and genetic advance as per cent of mean (11.78%) were observed (Table 5). Whereas in case of F₄ generation it showed wide range (437.37 - 493.17 cm) with an average 466.46 cm. GCV (4.33%) and PCV (4.94%) were observed with environmental co-efficient of variance ECV (2.36%). The high estimates of heritability (77.14%), genetic advance (5.12) and genetic advance as per cent of mean (GAM 7.85%) were observed, indicating better scope for improvement through selection (Table 6).

4.1.2.1.2 Number of primary branches per vine

In F₃ generation, the wide range of variability was observed for number of primary branches per vine (10.88 - 12.70) with mean value 11.57. Very close values were recorded for GCV (10.31%) and PCV (10.43%) with noticeable influence of environmental factor ECV (1.57 %). The high estimate of heritability (74.37%) was observed with high value of genetic advance as per cent of mean (6.12 %) and low genetic advance (3.93) (Table 5). In F₄ generation it was ranged in between 10.26 - 13.04 with mean value 12.99. Very close values were recorded for GCV (11.93%) and PCV (13.55%) with noticeable influence of environmental factor ECV (6.42%). The high estimate of heritability (77.55%) was recorded with high value of genetic advance as per cent of mean (21.65%) and low value for genetic advance (2.81) (Table 6).

Table 5. Mean, range, GCV, PCV, ECV, heritability, genetic advance and percent mean of genetic advance of two parents and F₃ population of cross Hirkani X Phule Ujwala (C₂: 2 x 3).

Sr. No.	Character	Mean	Range	GCV (%)	PCV (%)	ECV (%)	h² bs (%)	GA	GAM (%)
1.	Final vine length at last harvest (cm)	449.38	408.41- 471.48	5.85	5.99	1.28	95.40	7.31	11.78
2.	Number of primary branches per vine	11.57	10.88-12.70	10.31	10.43	1.57	74.37	3.93	6.12
3.	Days required for appearance of first female flower	55.33	52.86- 59.33	4.91	5.40	2.24	82.71	5.09	9.21
4.	Node at which first female flower appeared	23.67	22.17- 25.82	4.88	5.81	3.15	70.61	2.00	8.46
5.	Days required for first harvest of fruit	61.12	58.46- 64.44	4.12	4.64	2.13	78.79	4.60	7.53
6.	Crop duration (days)	149.25	141.21- 153.84	4.12	4.40	1.54	87.64	11.88	7.95
7.	Number of fruits per vine	38.73	30.99- 44.06	16.80	17.66	5.45	90.48	12.75	32.92
8.	Average fruit yield per vine (kg)	2.49	1.85- 2.75	15.39	16.64	6.33	85.54	0.73	29.33
9.	Average weight of fruit(g)	64.56	54.84- 68.39	5.09	5.78	2.75	77.37	5.95	9.22
10	Average length of fruit (cm)	21.15	17.64-24.02	8.37	10.18	5.79	67.67	3.00	14.19
11	Average diameter of fruit (cm)	3.54	3.36- 3.63	3.55	3.61	0.67	96.50	0.25	7.19
12	Fruit Yield t/ ha	16.62	12.38-18.37	15.44	16.68	6.30	85.72	4.89	29.45

Table 6. Mean, range, GCV, PCV, ECV, heritability, genetic advance and percent mean of genetic advance of two parents and F₄ population of cross Hirkani X Phule Ujwala (C₂: 2 x 3).

Sr. No.	Character	Mean	Range	GCV (%)	PCV (%)	ECV (%)	h² bs (%)	GA	GAM (%)
1.	Final vine length at last harvest (cm)	466.46	437.37- 493.17	4.33	4.94	2.36	77.14	5.12	7.85
2.	Number of primary branches per vine	12.99	10.26- 13.04	11.93	13.55	6.42	77.55	2.81	21.65
3.	Days required for appearance of first female flower	55.11	50.79- 57.19	4.98	5.87	3.10	72.02	4.80	8.71
4.	Node at which first female flower appeared	24.15	22.10- 26.84	6.81	7.94	4.07	73.69	2.91	12.05
5.	Days required for first harvest of fruit	60.89	57.55- 63.20	4.14	5.10	2.97	66.06	4.23	6.94
6.	Crop duration (days)	147.93	133.86- 161.24	5.88	6.28	2.21	87.61	16.79	11.35
7.	Number of fruits per vine	35.77	29.68- 40.45	18.03	20.76	10.30	75.36	11.53	35.24
8.	Average fruit yield per vine (kg)	2.17	1.62- 2.72	18.99	21.06	9.12	81.26	0.76	35.26
9.	Average weight of fruit (g)	61.19	52.06- 67.48	10.28	10.95	3.77	88.11	12.17	19.88
10.	Average length of fruit(cm)	19.32	17.26- 21.88	10.10	11.59	5.68	75.96	3.50	18.14
11.	Average diameter of fruit (cm)	3.51	3.28- 3.70	3.48	3.53	0.58	97.30	0.24	7.09
12.	Fruit Yield t/ ha	14.50	11.30 - 18.15	18.99	21.06	9.10	81.31	5.11	35.28

4.1.2.2 Flowering characters

4.1.2.2.1 Days to first female flower appearance

In F₃ generation the wide range of variability was observed for days to first female flower appearance (52.86 - 59.33 days) with mean value 55.33 days. The close values were recorded for GCV (4.91%) and PCV (5.40%) with noticeable influence of environmental factor ECV (2.24%). The high estimate of heritability (82.71%) was associated with high estimate of genetic advance (5.09) and high genetic advance as per cent mean (9.21%) (Table 5). In F₄ generation it showed wide range of variability (50.79 - 57.19 days) with mean value 55.11 days. While very close values were recorded of GCV (4.98%) and PCV (5.87%) with noticeable influence of environmental factors ECV (3.10%). The high estimate of heritability (72.02%) was associated with low genetic advance (4.80) and moderate genetic advance as per cent of mean (8.71%), (Table 6).

4.1.2.2.2 Node at which first female flower appeared

In case of F₃ generation the node at which first female flower appeared was observed in wider range of 22.17- 25.82 with an average of 23.67. The close association of GCV (4.88%) and PCV (5.81%) was observed with certain presence of ECV (3.15%). The high estimate was obtained for heritability (70.61%) along with genetic advance as per cent mean of (8.46%). While low value was observed for genetic advance (2.00) (Table 5). Whereas in F₄ generation it was ranged in between 22.10 - 26.84 with an average 24.15 days. The close association of GCV (6.81%) and PCV (7.94%) was observed with ECV (4.07%). The high estimates were obtained for heritability (73.69%) and genetic advance as per cent of mean (12.05%) (Table 6).

4.1.2.2.3 Days required for first harvest of fruit

In F₃ generation the wide range of variability was observed for days required for first harvest of fruit (58.46 - 64.44 days) with mean value 61.12 days. The closer value of GCV (4.12%) and PCV (4.64%) was observed with certain influence of environmental factor ECV (2.13%). The high heritability (78.79%) along with genetic advance (4.60) and moderate genetic advance as per cent mean of (7.53%) were recorded (Table 5). In F₄ generation it was ranged from 57.55 - 63.20 days with an average 60.89 days. The close association of GCV (4.14%) and PCV (5.10%) was observed with influence ECV 2.97%). The high value of heritability was observed (66.06%) with moderate genetic advance (4.23) and genetic advance as per cent of mean (6.94%) (Table 6).

4.1.2.3 Yield and yield contributing characters

4.1.2.3.1 Crop duration (days)

In case of F₃ generation the crop duration was observed in wider range of 141.21 - 153.84 with an average of 149.25. The close association of GCV (4.12%) and PCV (4.40%) was observed with certain presence of ECV (1.54%). The high estimate was obtained for heritability (87.64%) along with genetic advance as per cent mean of (7.95%) While low value was observed for genetic advance was (11.88) (Table 5). Whereas in F₄ generation it was ranged in between 133.86 - 161.24 with an average 147.93 days. The close association of GCV (5.88%) and PCV (6.28%) was observed with ECV (2.21%). The high estimates were obtained for heritability (87.61%) and genetic advance as per cent of mean (11.35%) (Table 6).

4.1.2.3.2 Number of fruits per vine

The data presented in Table 5 indicate that, number of fruits per vine in F₃ generation was ranged in between 30.99 -

44.06 per vine with an average 38.73 per vine. For this most important character significant contribution of genetic variability GCV (16.80%) and PCV (17.66%) were observed with noticeable value of environmental variability ECV (5.45%). The high estimates of heritability (90.48%) and genetic advance as per cent of mean (32.92%) were observed (Table 5). While in F₄ generation (Table 6) it showed the wide range in between 29.68 - 40.45 per vine with an average 35.77 fruits per vine. The closer values of GCV (18.03%) and PCV (20.76%) were observed with environmental variability ECV (10.30%). The high estimates of heritability (75.36%) and genetic advance as per cent of mean (35.24%) were observed.

4.1.2.3.3 Fruit yield per vine (kg)

In case of F₃ generation fruit yield per vine was observed in wide range of 1.85 - 2.75 kg per vine with an average 2.49 kg per vine. The close association of GCV (15.39%) and PCV (16.64%) was observed with noticeable value of environmental variability ECV (6.33%). The high estimates of heritability (85.54%) along with high genetic advance as per cent of mean (29.33%) were observed (Table 5). In case of F₄ generation it showed wide range 1.62 - 2.72 kg per vine with an average 2.17 kg fruits per vine. The contribution of genetic variability GCV (18.99%) and PCV (21.06%) were observed with certain influence of environmental variability ECV (9.12%). The high estimates of heritability (81.26%) along with high genetic advance as per cent of mean (35.26%) and low genetic advance (0.76), were observed respectively (Table 6).

4.1.2.3.4 Fruit yield (t/ha)

In F₃ generation, fruit yield (t/ha) showed wide range of 12.38 - 18.37 t/ha with an average 16.62 t/ha. The contribution of genetic variability GCV (15.44 %) and PCV (16.68%) were observed with influence of environmental

variability ECV (6.30%). The high value of heritability (85.72%) was associated with high genetic advance as per cent of mean (29.45%) (Table 5). Whereas in F₄ generation it showed wide range of variation in between 11.3 - 18.15 t/ha with an average value of 14.50 t/ha. The significant contribution of genetic variability GCV (18.99%) and PCV (21.06%) were observed with environmental variability ECV (9.10%). The high estimates of heritability (81.31%) and genetic advance as per cent of mean (35.28%) were recorded (Table 6).

4.1.2.4 Fruit characters (quantitative)

4.1.2.4.1 Average weight of fruit (g)

Average weight of fruit is an important yield contributing character. In F₃ generation it recorded a wide range of variation 54.84 - 68.39 g with mean of 64.56 g. The closer value of genotypic co-efficient of variation GCV (5.09%) and phenotypic co-efficient of variation PCV (5.78%) were observed with certain presence of environmental variation ECV (2.75%). The high estimates of heritability (77.37%), genetic advance (5.95) and per cent mean of genetic advance (9.22%) were observed (Table 5). In F₄ generation it showed a wide range of variation 52.06 - 67.48 g with mean of 61.19 g. The closer value of GCV (10.28%) and PCV (10.95%) were recorded with certain influence of ECV (3.77%). The high estimates were recorded for heritability and genetic advance as per cent of mean was (88.11% and 19.88% respectively) (Table 6).

4.1.2.4.2 Average length of fruit (cm)

In F₃ generation the wide range of variability was observed for average length of fruit (17.64 - 24.02 cm) with an average 21.15 cm. The close association of GCV (8.37%) and PCV (10.18%) was observed with certain presence of environmental

factor ECV (5.79%). The high estimates were obtained for heritability (67.67%) and genetic advance as per cent of mean (14.19 %) (Table 5). In F₄ generation it was ranged in between 17.26 - 21.88 cm with an average 19.32 cm. The close association of GCV (10.10%) and PCV (11.59%) was observed with certain presence of environmental factor (ECV 5.68%). The high estimates were obtained for heritability (75.96%) and genetic advance as per cent of mean (18.14%) with low value for genetic advance (3.50) (Table 6).

4.1.2.4.3 Average diameter of fruit (cm)

In case of F₃ generation, the average diameter of fruit was ranged in between 3.36 - 3.63 cm with an average value of 3.54 cm. The close association of GCV (3.55%) and PCV (3.61%) was observed with low influence of environmental factor ECV (0.67%). The high estimates of heritability (96.50%), low genetic advance (0.25) and moderate genetic advance as per cent of mean (7.19 %) were recorded (Table 5). While in case of F₄ generation it was ranged from 3.28 - 3.70 cm with an average 3.51 cm. The close association of GCV (3.48%) and PCV (3.53%) was observed with certain influence of environmental factor ECV (0.58%). The high value of heritability (97.30%) was observed with low and moderate values of genetic advance (0.24) and genetic advance as per cent of mean (7.09%), respectively (Table 6).

4.1.3 Variability, heritability and genetic advance of cross Hirkani X Konkan Tara (C₃ : 2 x 4) for F₃ and F₄ generations.

Fifteen F₃ and F₄ progenies along with their parents were studied for growth, flowering, yield and fruit quantitative and qualitative traits and presented in Table 7 and 8 respectively.

4.1.3.1 Vine growth characters

4.1.3.1.1 Final vine length at last harvest (cm)

In case of F₃ generation the Final vine length at last harvest (Table 7) showed wide range (405.88 - 453.17cm) with an average of 434.29 cm. The genotypic co-efficient of variation (GCV) and phenotypic coefficient of variation (PCV) were observed as 4.57% and 4.64% respectively. While environmental co-efficient of variation ECV was 0.78%. The high estimates were observed for heritability (97.10%), genetic advance (7.54) and genetic advance as per cent of mean (9.28%). In case of F₄ generation it was ranged in between 403.92 - 462.35 cm with an average of 429.33 cm. The genotypic co-efficient of variance (GCV 4.38%) and phenotypic coefficient of variance (PCV 4.55%) were observed with environmental co-efficient of variance ECV (1.23%). The high estimates were observed for heritability (92.61%), genetic advance (6.43) and genetic advance as per cent of mean (GAM 8.68%), indicating better scope for improvement through selection. (Table 8).

4.1.3.1.2 Number of primary branches per vine

In F₃ generation the number of primary branches per vine was observed in the range of 9.97 - 14.59 with mean value 12.58. Very close values were recorded for GCV (10.78%) and PCV (11.99%) with low influence of environmental factors ECV (5.24%). The high estimate of heritability (80.87%) was recorded with high value of genetic advance as per cent of mean (19.98%) (Table 7). While in F₄ generation it was ranged in between 11.19 - 13.19 with mean value of 11.67. The GCV (10.04%) and PCV (11.56%) were observed with noticeable influence of environmental factor (ECV 5.72%). The high estimate of heritability (75.44%) was associated with high value of genetic advance as per cent of mean (17.96%). The low value was recorded for genetic advance (2.09). (Table 8).

Table 7. Mean, range, GCV, PCV, ECV, heritability, genetic advance and percent mean of genetic advance of two parents and F₃ population of cross Hirkani X Konkan Tara (C₃: 2 x 4).

Sr. No.	Character	Mean	Range	GCV (%)	PCV (%)	ECV (%)	h² bs (%)	GA	GAM (%)
1.	Final vine length at last harvest (cm)	434.29	405.88- 453.17	4.57	4.64	0.78	97.10	7.54	9.28
2.	Number of primary branches per vine	12.58	9.97- 14.59	10.78	11.99	5.24	80.87	2.51	19.98
3.	Days required for appearance of first female flower	53.94	52.04- 57.61	4.04	4.39	1.71	84.85	4.14	7.68
4.	Node at which first female flower appeared	24.04	21.30- 27.21	8.38	9.51	4.50	77.60	3.65	15.20
5.	Days required for first harvest of fruit	60.16	57.08- 64.95	3.05	3.38	1.46	81.25	3.40	5.66
6.	Crop duration (days)	144.37	128.84-158.30	7.10	7.52	2.49	89.06	19.93	13.80
7.	Number of fruits per vine	35.59	27.97- 44.75	16.05	19.42	10.92	68.35	9.73	27.34
8.	Average fruit yield per vine (kg)	2.11	1.68- 3.05	15.55	19.22	11.30	65.43	0.54	25.91
9.	Average weight of fruit(g)	59.81	54.68- 70.33	10.28	10.55	2.38	94.91	12.34	20.64
10	Average length of fruit (cm)	18.54	16.59- 22.75	6.49	8.16	4.95	63.27	1.97	10.64
11	Average diameter of fruit (cm)	3.44	3.30- 3.56	1.50	4.70	2.46	93.20	0.23	6.98
12	Fruit yield t/ ha	14.11	11.24- 20.37	15.56	19.20	11.25	65.66	3.66	25.98

Table 8. Mean, range, GCV, PCV, ECV, heritability, genetic advance and percent mean of genetic advance of two parents and F₄ population of cross Hirkani X Konkan Tara (C₃: 2 x 4).

Sr. No.	Character	Mean	Range	GCV (%)	PCV (%)	ECV (%)	h² bs (%)	GA	GAM (%)
1.	Final vine length at last harvest (cm)	429.33	403.92- 462.35	4.38	4.55	1.23	92.61	6.43	8.68
2.	Number of primary branches per vine	11.67	11.19- 13.19	10.04	11.56	5.72	75.44	2.09	17.96
3.	Days required for appearance of first female flower	54.80	52.95- 58.77	4.63	5.06	2.02	84.03	4.80	8.76
4.	Node at which first female flower appeared	25.05	21.59- 26.95	9.08	10.10	4.40	80.97	4.22	16.84
5.	Days required for first harvest of fruit	60.84	59.73- 65.48	3.79	4.32	2.06	77.13	4.17	6.86
6.	Crop duration (days)	145.95	133.16- 158.34	7.19	8.20	3.94	76.84	18.96	12.99
7.	Number of fruits per vine	35.57	27.79- 41.19	16.91	17.77	5.45	90.57	11.79	33.16
8.	Average fruit yield per vine (kg)	2.31	1.72- 2.78	19.03	20.81	8.43	83.58	0.83	35.84
9.	Average weight of fruit(g)	65.02	58.89-74.82	7.97	9.63	5.40	68.49	8.83	13.58
10.	Average length of fruit (cm)	20.22	18.15- 22.50	8.47	10.36	5.96	66.87	2.88	14.28
11.	Average diameter of fruit (cm)	3.30	3.25- 3.61	5.93	6.19	1.77	91.76	0.38	11.71
12.	Fruit yield t/ ha	15.44	11.48- 18.56	19.03	20.82	8.44	83.53	5.53	35.83

4.1.3.2 Flowering characters

4.1.3.2.1 Days to first female flower appearance

In case of F_3 generation this character was ranged in between 52.04 - 57.61 days with mean value of 53.94 days. The genetic variability was contributed as GCV (4.04%) and PCV (4.39%) along with noticeable influence of environmental factor ECV (1.71%). The moderate estimate of heritability (84.85%) was obtained with genetic advance (4.14) and genetic advance as per cent of mean (7.68%) (Table 7). In case of F_4 generation it showed wide range of variability (52.95 - 58.77 days) with mean value 54.80 days. The close association of GCV (4.63%) and PCV (5.06%) were observed with certain presence of environmental factor ECV (2.02%). The high estimate of heritability (84.03%) was obtained with low genetic advance (4.80) and moderate value of genetic advance as per cent of mean (8.76%). (Table 8).

4.1.3.2.2 Node at which first female flower appeared

In case of F_3 generation the node at which first female flower appeared was ranged in between 21.30 - 27.21 with an average value 24.04. The close association of GCV and PCV (8.38% and 9.51% respectively) was observed with certain presence of environmental factor (ECV 4.50%). The high values were obtained for heritability (77.60%) and genetic advance as per cent of mean (15.20%) (Table 7). In case of F_4 generation it was ranged in between 21.59 - 26.95 with an average 25.05 days. The close association of GCV (9.08%) and PCV (10.10%) were observed with certain presence of environmental factor ECV (4.40%). The high, moderate and low values were obtained for heritability (80.97%), genetic advance as per cent of mean (16.84%) and genetic advance (4.22), respectively. (Table 8).

4.1.3.2.3 Days required for first harvest of fruit

In F₃ generation the wide range of variability was observed for days required for first harvest of fruit (57.08 - 64.95 days) with an average 60.16 days. The closer value of GCV (3.05%) and PCV (3.38%) was observed with influence of environmental factor ECV (1.46%). The high heritability was observed (81.25%) along with high genetic advance (3.40) and moderate genetic advance as per cent of mean (5.66%) (Table 7). While in F₄ generation it was ranged from 59.73 - 65.48 days with an average 60.84 days. The close association of GCV (3.79%) and PCV (4.32%) were observed with noticeable influence of environmental factor ECV (2.06%). The high value of heritability was observed (77.13%) with high genetic advance (4.17) and genetic advance as per cent of mean (6.86%). (Table 8).

4.1.3.3 Yield and it's contributing character

4.1.3.3.1 Crop duration (days)

In case of F₃ generation the crop duration was observed in wider range of 128.84 - 158.30 with an average of 144.37. The close association of GCV (7.10%) and PCV (7.52%) was observed with certain presence of ECV (2.49%). The high estimate was obtained for heritability (89.06%) along with genetic advance as per cent mean of (13.80%) While high value was observed for genetic advance (19.93) (Table 7). Whereas in F₄ generation it was ranged in between 133.16 - 158.34 with an average 145.95 days. The close association of GCV (7.19%) and PCV (8.20%) was observed with ECV (3.94%). The high estimates were obtained for heritability (76.84%) and genetic advance as per cent of mean (12.99%) along with high genetic advance (18.96). (Table 8).

4.1.3.3.2 Number of fruits per vine

In case of F_3 generation the data presented in Table 7 indicate that number of fruits per vine showed wide range (27.97 - 44.75) with an average 35.59 per vine. The close association of genetic variability GCV (16.05%) and PCV (19.42%) were recorded along with certain presence of environmental variability ECV (10.92%). The high estimates were observed for heritability (68.35%) and genetic advance as per cent of mean (27.34%) (Table 7). Whereas in case of F_4 generation it was observed with the range of 27.79 - 41.19 per vine with an average 35.57 per vine. The close association of GCV (16.91%) and PCV (17.77%) were observed with certain presence of environmental variability ECV (5.45%). The high estimates were observed for heritability (90.57%) and genetic advance as per cent of mean (33.16%) along with high genetic advance (11.16). (Table 8).

4.1.3.3.3 Fruit yield per vine (kg)

In F_3 generation the wide range was observed for fruit yield per vine 1.68 - 3.05 kg with an average 2.11 kg per vine. The significant contribution of genetic variability GCV (15.55%) and PCV (19.22%) were observed with environmental variability ECV (11.30%). The high estimates were observed for heritability (65.43%) along with genetic advance as per cent of mean (25.91 %) (Table 7). Whereas in case of F_4 generation it was ranged in between 1.72 - 2.78 kg per vine with an average 2.31 kg per vine. The contribution of genetic variability GCV (19.03%) and PCV (20.81%) were observed with environmental variability ECV (8.43%). The high estimates of heritability (83.58%) along with higher value of genetic advance as per cent of mean (35.84%) was observed. However lower values of genetic advance (0.83) was observed. (Table 8).

4.1.3.3.4 Fruit yield (t/ha)

In F₃ generation the character fruit yield (t/ha) showed wide range of 11.24- 20.37 t/ha with an average 14.11 t/ha. The contribution of genetic variability GCV (15.56%) and PCV (19.2%) were observed with influence of environmental variability ECV (11.25%). The high value of heritability (65.66%) was associated with high genetic advance as per cent of mean (25.98%) (Table 7). Whereas in F₄ generation it showed wide range of variation in between 11.48 - 18.56 t/ha with an average value of 15.44 t/ha. The significant contribution of genetic variability GCV (19.03%) and PCV (20.82%) were observed with environmental variability ECV (8.44%). The high estimates of heritability (83.53%) and genetic advance as per cent of mean (35.83%) were recorded (Table 8).

4.1.3.4 Fruit characters (quantitative)

4.1.3.4.1 Average weight of fruit (g)

In case of F₃ generation the average weight of fruit showed a wide range of variability (54.68 - 70.33 g) with mean value 59.81g. The genotypic co-efficient of variation GCV (10.28%) and PCV (10.55%) were recorded with presence of environmental variability ECV (2.38%). The high estimates of heritability, genetic advance and genetic advance as per cent of mean (94.91%, 12.34 and 20.64% respectively) (Table 7) were recorded. While in case of F₄ generation it recorded a wide range of variation (58.89 - 74.82g) with mean value of 65.02g. The close values of variability GCV (7.97%) and PCV (9.63%) was recorded with noticeable environmental factor ECV (5.40%). The high estimates of heritability (68.49%) and genetic advance as per cent of mean (13.58%) and genetic advance (8.83) were

recorded which proves that the average weight of fruit can be improved during further selection cycle. (Table 8).

4.1.3.4.2 Average length of fruit (cm)

In F_3 generation the average length of fruit was showed wide range in between 16.59 - 22.75 cm with an average 18.54 cm. The close association of GCV (6.49%) and PCV (8.16%) was observed with certain presence of environmental factor ECV (4.95%). The high values were obtained for heritability (63.27%) and genetic advance as per cent of mean (10.64%) (Table 7). Whereas in F_4 generation it showed wide range (18.15 - 22.50 cm) with an average 20.22 cm. The close association of GCV (8.47%) and PCV (10.36%) was observed with certain presence of environmental factor ECV (5.96%). The high values were obtained for heritability (66.87%) and genetic advance as per cent of mean (14.28%) while low genetic advance (2.88) was observed. (Table 8).

4.1.3.4.3 Average diameter of fruit (cm)

In case of F_3 generation the wide range of variability was observed for average diameter of fruit (3.30 - 3.56 cm) with mean value of 3.44 cm. The close association of GCV (1.50%) and PCV (4.70%) was observed with certain influence of environmental factor (ECV 2.46%). The high estimate of heritability (93.20%), lower value for genetic advance (0.23) and moderate value of genetic advance as per cent of mean (6.98%) were observed (Table 7). Whereas in case of F_4 generation it was ranged from 3.25 - 3.61 cm with an average 3.30 cm. The close association of GCV (5.93%) and PCV (6.19%) was observed with certain influence of environmental factor ECV (1.77%). The high heritability (91.76%), low genetic advance (0.38) and moderate

genetic advance as per cent of mean (11.71%), were observed respectively. (Table 8).

4.2 Correlation coefficient between yield and yield contributing characters.

The genotypic and phenotypic co-efficient of correlation for the important yield and yield contributing characters is presented in Table 9-14 for each three crosses in F₃ and F₄ generations respectively. The magnitude of genotypic correlation coefficient was higher than the phenotypic correlation coefficients. However, only the significant correlations of important yield contributing characters are described in foregoing paragraphs.

4.2.1 Correlation coefficient of cross Phule Green Gold x Hirkani (C₁: 1 x 2) in F₃ generations.

Fifteen F₃ progenies were studied for association of relationship between yield and yield contributing characters in F₃ generations and are presented in Table 9.

4.2.1.1 Final vine length at last harvest

The Final vine length at last harvest showed positive correlation with number of primary branches per vine, average weight of fruit, fruit yield per vine, average length of fruit and fruit yield tonnes per hectare at both genotypic and phenotypic levels. While, it had significant negative correlation with days required for first female flower appearance and days required for first harvest of fruit and showed negative correlation with node at which first female flower appeared, crop durations (days), number of fruits per vine, and average diameter of Fruit at both genotypic and phenotypic levels.

Table 9. Genotypic and Phenotypic Correlation co-efficient for yield and yield contributing characters in F₃ generation of cross Phule Green Gold X Hirkani (C₁: 1 x 2).

Sr. No.	Character		1	2	3	4	5	6	7	8	9	10	11	12
1	Final vine length at last harvest (cm)	G p	1.000 1.000	0.381 0.262	-0.562** -0.548**	-1.017 -0.158	-0.487* -0.459 *	-0.106 -0.154	-0.082 -0.105	0.287 0.219	0.112 0.060	0.364 0.297	-0.327 -0.233	0.110 0.059
2	Number of primary branches per vine	G P	- -	1.000 1.000	-0.365 -0.277	0.990** 0.210	-0.411 -0.336	0.704** 0.533 *	0.353 0.306	0.679** 0.479 *	0.726** 0.554 **	-0.471* -0.300	-0.429 -0.408	0.724** 0.551**
3	Days required for appearance of first female flower	G P	- -	- -	1.000 1.000	0.215 0.116	0.995** 0.912**	0.119 0.083	0.319 0.285	-0.193 -0.144	0.139 0.134	0.440* 0.279	0.494* 0.384	-0.144 -0.137
4	Node at which first female flower appeared	G P	- -	- -	- -	1.000 1.000	0.867** 0.138	0.239 0.151	-0.245 -0.188	-0.437* -0.234	-0.624** -0.006	-0.924** -0.102	-0.744** -0.175	-0.523* -0.015
5	Days required for first harvest of fruit	G P	- -	- -	- -	- -	1.000 1.000	-0.044 -0.016	-0.307 -0.310	-0.263 -0.236	-0.081 -0.095	-0.455* -0.416	-0.487* -0.410	-0.085 -0.098
6	Crop durations (days)	G P	- -	- -	- -	- -	- -	1.000 1.000	0.020 0.060	0.898** 0.722**	0.620** 0.527	-0.318 -0.153	-0.180 -0.146	0.619** 0.527**
7	Number of fruits per vine	G P	- -	- -	- -	- -	- -	- -	1.000 1.000	0.024 0.008	0.757** 0.761**	0.023 0.061	0.557** 0.505*	0.758** 0.761**
8	Average weight of fruit (g)	G P	- -	- -	- -	- -	- -	- -	- -	1.000 1.000	0.633** 0.641**	0.209 0.228	0.029 0.003	0.632** 0.640**
9	Average fruit yield per vine (kg)	G P	- -	- -	- -	- -	- -	- -	- -	- -	1.000 1.000	0.112 0.093	0.395 0.374	0.983** 0.991**
10	Average length of fruit (cm)	G P	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.000 1.000	0.267 0.215	0.439* 0.462*
11	Average diameter of fruit (cm)	G P	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.000 1.000	0.397 0.376
12	Fruit yield t/ ha	G P	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.000 1.000

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

4.2.1.2 Number of primary branches per vine

The number of primary branches per vine exhibited positive significant correlation with node at which first female flower appeared only in genotypic, crop durations, average weight of fruit, fruit yield per vine and fruit yield tonnes per hectare. While positive correlation with node at which first female flower appeared only in phenotypic, number of fruits per vine at both genotypic and phenotypic levels. Whereas negative significant correlation with average length of fruit only in genotypic. While it showed negative significant correlation with average length of fruit only in phenotypic, days required for first female flower appearance, days required for first harvest of fruit, average diameter of fruit at both genotypic and phenotypic levels.

4.2.1.3 Days required for to first female flower appearance

The days required for first female flower appearance were significantly and positively correlated with days required for first harvest of fruit, average length of fruit only in genotypic,, average diameter of fruit only in genotypic. While positive correlation with node at which first female flower appeared, crop durations, number of fruits per vine, average length of fruit only in phenotypic, average diameter of fruit only in phenotypic and fruit yield per vine at both genotypic and phenotypic levels. Negative correlation was observed in average weight of fruit and fruit yield tonnes per hectare at both genotypic and phenotypic levels.

4.2.1.4 Node at which first female flower appeared

Nodal position of first female flower appearance exhibited significant and positive correlation with days required for first harvest of fruit only in genotypic and also showed

positive correlation with days required for first harvest of fruit only in phenotypic level and crop durations at both genotypic and phenotypic levels. It showed significant and negative association with average diameter of fruit, fruit yield tonnes per hectare only in genotypic level whereas, average weight of fruit, fruit yield per vine, average length of fruit, while negative association with average diameter of fruit, fruit yield tonnes per hectare only in phenotypic level while, average weight of fruit, fruit yield per vine, average length of fruit and number of fruits per vine at both genotypic and phenotypic levels.

4.2.1.5 Days required for first harvest of fruit

Days to first harvest negatively and significantly correlated with average length of fruit, average diameter of fruit only in genotypic level and negative association with average length of fruit, average diameter of fruit only in phenotypic level and number of fruits per vine, average weight of fruit, average yield per vine and fruit yield tonnes per hectare at both genotypic and phenotypic levels.

4.2.1.6 Crop durations

Crop durations showed significant and positive association with average weight of fruit, fruits yield per vine and fruit yield tonnes per hectare. whereas, positive association with number of fruits per vine and negative association with average length of fruit and average diameter of fruit at both genotypic and phenotypic levels.

4.2.1.7 Number of fruits per vine

Number of fruits per vine showed significant and positive association with fruit yield per vine, average diameter of fruit and fruit yield tonnes per hectare. Whereas, positive

association with average weight of fruit and average length of fruit at both genotypic and phenotypic levels.

4.2.1.8 Average weight of fruit (g)

Average fruit weight showed significant and positive correlation with fruit yield per vine and fruit yield tonnes per hectare. Whereas, positive correlation with average length of fruit and average diameter of fruit, at both genotypic and phenotypic levels.

4.2.1.9 Fruit yield per vine (kg)

Fruit yield per vine showed significant and positive correlation with fruit yield tonnes per hectare. While positive association with average diameter of fruit and average length of fruit at both genotypic and phenotypic levels.

4.2.1.10 Average length of fruit (cm)

The average length of fruit had significant and positive correlation with and fruit yield tonnes per hectare and positive correlation with average diameter of fruit at both genotypic and phenotypic levels.

4.2.1.11 Average diameter of fruit(cm)

The average diameter of fruit fruit had showed positive association with fruit yield tonnes per hectare.

4.2.2. Correlation coefficient of cross Phule Green Gold x Hirkani (C₁: 1 x 2) in F₄ generations.

Fifteen F₄ progenies were studied for association of relationship between yield and yield contributing characters F₄ generations and are presented in Table 10.

Table 10. Genotypic and Phenotypic Correlation co-efficient for yield and yield contributing characters in F₄ generation of cross Phule Green Gold X Hirkani (C₁: 1 x 2).

Sr. No.	Character		1	2	3	4	5	6	7	8	9	10	11	12
1	Final vine length at last harvest (cm)	G p	1.000 1.000	-0.394 -0.358	0.630** 0.474*	-0.145 -0.149	0.672** 0.475*	0.521* 0.460*	0.305 0.289	-0.000 -0.026	0.203 0.184	0.160 0.162	0.211 0.246	0.203 0.184
2	Number of primary branches	G P	- -	1.000 1.000	0.080 0.086	0.789** 0.498 *	-0.045 -0.022	-0.171 -0.158	0.110 0.090	0.702** 0.621**	0.446* 0.384	-0.756** -0.564**	-0.236 -0.202	0.445* 0.382
3	Days required for appearance of first female flower	G P	- -	- -	1.000 1.000	0.517* 0.288	0.991** 0.967 **	0.602** 0.502*	0.845** 0.677**	0.458* 0.704**	-0.828** -0.308	-0.358 -0.695**	-0.819** -0.384	-0.828** -0.704**
4	Node at which first female flower appeared	G P	- -	- -	- -	1.000 1.000	0.498* 0.217	-0.160 -0.073	0.026 0.066	0.757** 0.662**	-0.413 -0.397	-0.721** -0.522*	-0.192 -0.089	-0.410 -0.396
5	Days required for first harvest of fruit	G P	- -	- -	- -	- -	1.000 1.000	0.639** 0.531 *	0.815** 0.591**	0.455* 0.388	0.810** 0.629**	-0.226 -0.228	-0.881** -0.748**	-0.810** -0.629**
6	Crop durations (days)	G P	- -	- -	- -	- -	- -	1.000 1.000	0.724** 0.616**	0.459* 0.438*	0.750** 0.676 **	-0.217 -0.281	0.634** 0.599**	0.751** 0.677**
7	Number of fruits per vine	G P	- -	- -	- -	- -	- -	- -	1.000 1.000	0.308 0.283	0.859** 0.857**	0.218 0.113	0.801** 0.690**	0.861** 0.859**
8	Average weight of fruit (g)	G P	- -	- -	- -	- -	- -	- -	- -	1.000 1.000	0.749** 0.734 **	0.773** 0.645**	0.277 0.258	0.747** 0.732**
9	Average fruit yield per vine (kg)	G P	- -	- -	- -	- -	- -	- -	- -	- -	1.000 1.000	0.535* 0.639**	0.717** 0.374	0.986** 0.975**
10	Average length of fruit (cm)	G P	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.000 1.000	0.187 0.058	0.534* 0.407
11	Average diameter of fruit (cm)	G P	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.000 1.000	0.718** 0.640**
12	Fruit yield t/ ha	G P	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.000 1.000

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

4.2.2.1 Final vine length at last harvest

The Final vine length at last harvest showed positive and significant correlation with days required for first female flower appearance, days required for first harvest of fruit and crop durations and showed positive correlation with number of fruits per vine, average length of fruit, average diameter of fruit, fruit yield per vine and fruit yield tonnes per hectare at both genotypic and phenotypic levels. While, it had negative correlation with number of primary branches per vine, node at which first female flower appeared, and average weight of fruit at both genotypic and phenotypic levels.

4.2.2.2 Number of primary branches per vine

The number of primary branches per vine exhibited positive significant correlation with fruit yield per vine and fruit yield tonnes per hectare only in genotypic level and node at which first female flower appeared, average weight of fruit. While positive correlation with fruit yield per vine and fruit yield tonnes per hectare only in phenotypic level and number of fruits per vine at both genotypic and phenotypic levels. Whereas it showed negative significant correlation with average length of fruit and showed negative correlation with days required for first harvest of fruit, crop durations, average and diameter of fruit at both genotypic and phenotypic levels.

4.2.2.3 Days to first female flower appearance

The days required for first female flower appearance were significantly and positively correlated with node at which first female flower appeared only in genotypic level, days required for first harvest of fruit, crop durations, average weight of fruit and number of fruits per vine at both genotypic and phenotypic levels. Whereas positive correlation with node at which first

female flower appeared only in genotypic levels. Significant and negative correlation was observed in average fruit yield per vine only in genotypic levels, average length of fruit only in phenotypic levels and average diameter of fruit and fruit yield tonnes per hectare at both genotypic and phenotypic levels. While negative correlation was observed in average fruit yield per vine only in phenotypic level, average length of fruit only in genotypic level.

4.2.2.4 Node at which first female flower appeared

Nodal position of first female flower appearance exhibited significant and positive correlation with days required for first harvest of fruit only in genotypic levels and average weight of fruit at both genotypic and phenotypic levels. While it showed positive correlation with days required for first harvest of fruit only in phenotypic levels and number of fruits per vine at both genotypic and phenotypic levels. It showed significant and negative association with average length of fruit whereas negative association with crop durations, fruit yield per vine, average diameter of fruit and fruit yield tonnes per hectare at both genotypic and phenotypic levels.

4.2.2.5 Days required for first harvest of fruit

Days to first harvest positively and significantly correlated with crop durations, number of fruits per vine, average weight of fruit and average yield per vine and it showed significant and negative association with average diameter of fruit and fruit yield tonnes per hectare while negative association with average length of fruit at both genotypic and phenotypic levels.

4.2.2.6 Crop durations

Crop durations showed significant and positive association with number of fruits per vine, average weight of

fruit, fruit yield per vine, average diameter of fruit and fruit yield tonnes per hectare whereas, negative association with average length of fruit at both genotypic and phenotypic levels.

4.2.2.7 Number of fruits per vine

Number of fruits per vine showed significant and positive association with fruit yield per vine, average diameter of fruit and fruit yield tonnes per hectare. Whereas, positive association with average weight of fruit and average length of fruit at both genotypic and phenotypic levels.

4.2.2.8 Average weight of fruit (g)

Average fruit weight showed significant and positive correlation with fruit yield per vine, average length of fruit and fruit yield tonnes per hectare. Whereas, positive correlation with average diameter of fruit at both genotypic and phenotypic levels.

4.2.2.9 Fruit yield per vine (kg)

Fruit yield per vine (kg) showed positive and significant association with average diameter of fruit, average length of fruit and fruit yield tonnes per hectare at both genotypic and phenotypic levels.

4.2.2.10 Average length of fruit (cm)

The average length of fruit had showed positive and significant association with fruit yield tonnes per hectare and positive correlation with average diameter of fruit at both genotypic and phenotypic levels.

4.2.2.11 Average diameter of fruit (cm)

The average diameter of fruit had showed positive and significant association with fruit yield tonnes per hectare.

4.2.3 Correlation coefficient of cross Hirkani x Phule Ujwala (C₂ : 2 x 3) in F₃ generations.

Fifteen F₃ and F₄ progenies were studied for association of relationship between yield and yield contributing

characters in F₃ and F₄ generations respectively and are presented in Table 11.

4.2.3.1 Final vine length at last harvest

The final vine length at last harvest showed positive and significant correlation with number of primary branches per vine, fruit yield per vine only in genotypic level and average weight of fruit only in phenotypic level while number of fruits per vine and fruit yield tonnes per hectare at both genotypic and phenotypic levels. Whereas it showed positive correlation with number of primary branches per vine, fruit yield per vine only in phenotypic level and average weight of fruit only in genotypic level, node at which first female flower appeared, crop durations, average length of fruit and average diameter of fruit at both genotypic and phenotypic levels. While, it had significant negative correlation with days required for first female flower appearance and days required for first harvest of fruit at both genotypic and phenotypic levels.

4.2.3.2 Number of primary branches per vine

The number of primary branches per vine exhibited positive significant correlation with days required for first female flower appearance, days required for first harvest of fruit, average weight of fruit and average length of fruit only in genotypic level while fruit yield per vine, average diameter of fruit and fruit yield tonnes per hectare at both genotypic and phenotypic levels. Whereas, it showed positive correlation with days required for first harvest of fruit, number of fruits per vine, average weight of fruit and average length of fruit only in phenotypic level. Whereas it showed negative correlation with number of fruits per vine at genotypic level. While days required for first female flower appearance, node at which first female flower appeared and crop durations at phenotypic levels.

Table 11. Genotypic and Phenotypic Correlation co-efficient for yield and yield contributing characters in F₃ generation of cross Hirkani X Phule Ujwala (C₂: 2 x 3).

Sr. No.	Character		1	2	3	4	5	6	7	8	9	10	11	12
1	Final vine length at last harvest (cm)	G P	1.000 1.000	0.685** 0.351	-0.474* -0.467*	0.032 0.104	-0.450* -0.451*	0.008 -0.011	0.704** 0.667**	0.184 0.763**	0.823** 0.383	0.410 0.238	0.244 0.351	0.823** 0.764**
2	Number of primary branches	G P	- 1.000	1.000 -0.111	0.617** -0.137	0.216 -0.137	0.716** 0.005	0.368 -0.110	-0.204 0.382	0.554** 0.099	0.892** 0.436 *	0.695* 0.137	0.623** 0.954**	0.903** 0.435*
3	Days required for appearance of first female flower	G P	- -	- 1.000	1.000 0.428	0.694** 0.959**	0.992** 0.520 *	0.605** 0.520 *	0.176 0.146	-0.909** -0.835**	-0.150 -0.173	0.379 0.318	0.323 -0.111	-0.150 -0.174
4	Node at which first female flower appeared	G P	- -	- -	- 1.000	1.000 0.407	0.695** 0.407	0.496* 0.368	0.507* 0.402	-0.442* -0.269	0.368 0.297	0.527* 0.296	0.597** -0.137	-0.366 -0.296
5	Days required for first harvest of fruit	G P	- -	- -	- -	- 1.000	1.000 0.449 *	0.568** 0.449 *	0.142 0.155	-0.882** -0.793**	-0.174 -0.140	0.524* 0.438 *	0.245 0.005	-0.174 -0.141
6	Crop durations (days)	G P	- -	- -	- -	- -	- 1.000	1.000 0.188	0.245 -0.530 *	-0.632** 0.025	0.016 -0.063	-0.074 -0.110	-0.052 -0.110	0.017 0.026
7	Number of fruits per vine	G P	- -	- -	- -	- -	- -	- 1.000	1.000 -0.292	-0.349 0.937**	0.937** 0.930**	0.324 0.343	0.525* 0.382	0.937** 0.931**
8	Average weight of fruit (g)	G P	- -	- -	- -	- -	- -	- -	- 1.000	1.000 0.074	0.002 0.056	0.045 0.056	0.413 0.099	0.002 0.073
9	Average fruit yield per vine (kg)	G P	- -	- -	- -	- -	- -	- -	- -	- 1.000	1.000 0.359	0.356 0.359	0.404 0.436*	0.971** 0.976**
10	Average length of fruit (cm)	G P	- -	- -	- -	- -	- -	- -	- -	- -	- 1.000	1.000 0.137	0.047 0.137	0.357* 0.375*
11	Average diameter of fruit (cm)	G P	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.000 1.000	0.401* 0.435*
12	Fruit yield t/ ha	G P	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.000 1.000

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

4.2.3.3 Days to first female flower appearance

The days required for first female flower appearance were significantly and positively correlated with node at which first female flower appeared only in genotypic level, days required for first harvest of fruit and crop durations at both genotypic and phenotypic levels. Whereas positive correlation with node at which first female flower appeared only in phenotypic level. While average diameter of fruit only in genotypic level, number of fruits per vine and average length of fruit at both genotypic and phenotypic levels. It showed negatively significant association with average weight of fruit and negative correlation was observed in average diameter of fruit only in phenotypic level. While fruit yield per vine and fruit yield tonnes per hectare at both genotypic and phenotypic levels.

4.2.3.4 Node at which first female flower appeared

Nodal position of first female flower appearance exhibited significant and positive correlation with days required for first harvest of fruit, crop durations, number of fruits per vine, average length of fruit and average diameter of fruit only in genotypic level. Whereas it showed positive correlation with days required for first harvest of fruit, crop durations, number of fruits per vine, average length of fruit only in phenotypic level and fruit yield per vine at both genotypic and phenotypic levels. It showed significant and negative association with average weight of fruit only in genotypic level. While negative association with average length of fruit and fruit yield tonnes per hectare at both genotypic and phenotypic levels.

4.2.3.5 Days required for first harvest of fruit

Days to first harvest positively and significantly correlated with crop durations, average length of fruit and positive correlation with number of fruits per vine and average diameter of fruit. while negatively and significantly correlated with average weight of fruit and negative association with fruit yield per vine and fruit yield tonnes per hectare at both genotypic and phenotypic levels.

4.2.3.6 Crop durations

Crop durations showed positive association with and number of fruits per vine, fruit yield per vine and fruit yield tonnes per hectare. whereas, negatively and significantly correlated with average weight of fruit and negative association with average length of fruit and average diameter of fruit at both genotypic and phenotypic levels.

4.2.3.7 Number of fruits per vine

Number of fruits per vine showed significant and positive association with average diameter of fruit only in genotypic level, fruit yield per vine, and fruit yield tonnes per hectare. Whereas positive association with average diameter of fruit only in phenotypic level and average length of fruit at both genotypic and phenotypic levels. While negative association with average weight of fruit at both genotypic and phenotypic levels.

4.2.3.8 Average weight of fruit (g)

Average fruit weight showed positive correlation with fruit yield per vine, average length of fruit, average diameter of fruit and fruit yield tonnes per hectare at both genotypic and phenotypic levels.

4.2.3.9 Fruit yield per vine (kg)

Fruit yield per vine (kg) showed significant and positive association with fruit yield tonnes per hectare. Whereas, positive association with average diameter of fruit and average length of fruit at both genotypic and phenotypic levels.

4.2.3.10 Average length of fruit (cm)

The average length of fruit had showed significant and positive association with fruit yield tonnes per hectare. While positive correlation with average diameter of fruit at both genotypic and phenotypic levels.

4.2.3.11 Average diameter of fruit(cm)

The average diameter of fruit had showed positive and significant association with fruit yield tonnes per hectare.

4.2.4 Correlation coefficient of cross Hirkani x Phule Ujwala (C₂ : 2 x 3) in F₄ generations.

Fifteen F₄ progenies were studied for association of relationship between yield and yield contributing characters in F₄ generations and are presented in Table 12.

4.2.4.1 Final vine length at last harvest

The final vine length at last harvest showed positive correlation with number of primary branches per vine, days required for first female flower appearance at genotypic level and days required for first harvest of fruit, number of fruits per vine and fruit yield tonnes per hectare at phenotypic level and remaining characters at both genotypic and phenotypic levels. While, it had significant negative correlation with crop durations (days), average length of fruit and average diameter of fruit. while showed negative correlation with node at which first female flower appeared, average weight of fruit and fruit yield per vine at both genotypic and phenotypic levels.

Table 12. Genotypic and Phenotypic Correlation co-efficient for yield and yield contributing characters in F₄ generation of cross Hirkani X Phule Ujwala (C₂: 2 x 3).

Sr. No.	Character		1	2	3	4	5	6	7	8	9	10	11	12
1	Final vine length at last harvest (cm)	G	1.000	0.197	0.126	-0.094	0.238	-0.508*	0.079	-0.300	-0.034	-0.617**	-0.684**	-0.034
		P	1.000	0.088	-0.006	-0.049	0.043	-0.458 *	0.228	-0.293	0.101	-0.478 *	-0.567**	0.101
2	Number Of primary branches	G	-	1.000	-0.106	0.201	-0.066	-0.015	0.699**	0.161	0.833**	0.593**	-0.292	0.832**
		P	-	1.000	-0.031	0.244	0.034	-0.081	0.543 *	0.126	0.663 **	0.419	-0.313	0.664**
3	Days required for appearance of first female flower	G	-	-	1.000	-0.617**	0.978**	-0.196	-0.483*	0.461*	-0.227	-0.275	-0.780**	-0.227
		P	-	-	1.000	-0.574**	0.983**	-0.093	-0.394	0.297	-0.245	-0.114	-0.681**	-0.245
4	Node at which first female flower appeared	G	-	-	-	1.000	-0.627**	0.547*	0.785**	0.051	0.787**	0.553**	0.589**	0.786**
		P	-	-	-	1.000	-0.530 *	0.347	0.592**	0.128	0.659**	0.353	0.472 *	0.659**
5	Days required for first harvest of fruit	G	-	-	-	-	1.000	-0.197	-0.453*	0.467*	-0.192	-0.338	-0.854**	-0.193
		P	-	-	-	-	1.000	-0.100	-0.373	0.315	-0.214	-0.123	-0.720**	-0.215
6	Crop durations (days)	G	-	-	-	-	-	1.000	-0.052	0.762**	0.273	0.153	0.423	0.272
		P	-	-	-	-	-	1.000	-0.103	0.687**	0.174	0.214	0.407	0.173
7	Number of fruits per vine	G	-	-	-	-	-	-	1.000	-0.305	0.880**	0.578**	0.199	0.881**
		P	-	-	-	-	-	-	1.000	-0.312	0.889**	0.444 *	0.164	0.889**
8	Average weight of fruit (gm)	G	-	-	-	-	-	-	-	1.000	0.179	0.195	-0.176	0.177
		P	-	-	-	-	-	-	-	1.000	0.146	0.211	-0.152	0.145
9	Average fruit yield per vine (kg)	G	-	-	-	-	-	-	-	-	1.000	0.706**	0.065	0.920**
		P	-	-	-	-	-	-	-	-	1.000	0.582**	0.055	0.982**
10	Average length of fruit (cm)	G	-	-	-	-	-	-	-	-	-	1.000	0.394	0.706**
		P	-	-	-	-	-	-	-	-	-	1.000	0.347	0.581**
11	Average diameter of fruit (cm)	G	-	-	-	-	-	-	-	-	-	-	1.000	0.065
		P	-	-	-	-	-	-	-	-	-	-	1.000	0.054
12	Fruit yield t/ ha	G	-	-	-	-	-	-	-	-	-	-	-	1.000
		P	-	-	-	-	-	-	-	-	-	-	-	1.000

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

4.2.4.2 Number of primary branches per vine

The number of primary branches per vine exhibited positive significant correlation with number of fruits per vine, fruit yield per vine, average length of fruit and fruit yield tonnes per hectare. while positive correlation with node at which first female flower appeared, average weight of fruit at both genotypic and phenotypic levels. Whereas it showed negative correlation with days required for first female flower appearance, days required for first harvest of fruit, crop durations and average diameter of fruit at both genotypic and phenotypic levels.

4.2.4.3 Days to first female flower appearance

The days required for first female flower appearance were significantly and positively correlated with average weight of fruit only in genotypic level, days required for first harvest of fruit and at both genotypic and phenotypic levels. While, positive correlation with average weight of fruit only in phenotypic level. Whereas negative significant correlation was observed in number of fruits per vine only in genotypic level, node at which first female flower appeared, average diameter of fruit. While negative correlation was observed in number of fruits per vine only in phenotypic level, crop durations, average length of fruit, fruit yield per vine and fruit yield tonnes per hectare at both genotypic and phenotypic levels.

4.2.4.4 Node at which first female flower appeared

Nodal position of first female flower appearance exhibited significant and positive correlation with crop durations, number of fruits per vine, average length of fruit, average diameter of fruit and average yield per vine and fruit yield tonnes per hectare also showed positive correlation with average weight of fruit at both genotypic and phenotypic levels. It

showed significant and negative association with days required for first harvest of fruit at both genotypic and phenotypic levels.

4.2.4.5 Days required for first harvest of fruit

Days to first harvest positively and significantly correlated with average weight of fruit only in genotypic level and positive association with average weight of fruit only in phenotypic level. It showed significant and negative association with number of fruits per vine only in genotypic level and negative association with number of fruits per vine only in phenotypic level, average length of fruit, average diameter of fruit and fruit yield per vine at both genotypic and phenotypic levels.

4.2.4.6 Crop durations

Crop durations showed positive association with average weight of fruit. whereas, positive association with fruit yield per vine, average length of fruit, average diameter of fruit and fruit yield tonnes per hectare. While it had negative association with number of fruits per vine at both genotypic and phenotypic levels.

4.2.4.7 Number of fruits per vine

Number of fruits per vine showed significant and positive association with fruit yield per vine, average length of fruit and fruit yield tonnes per hectare. Whereas, positive association with average diameter of fruit. While negative association with average fruit weight at both genotypic and phenotypic levels.

4.2.4.8 Average weight of fruit (g)

Average fruit weight showed positive correlation with fruit yield per vine, average length of fruit and fruit yield tonnes per hectare. Whereas, negative correlation with average diameter of fruit at both genotypic and phenotypic levels.

4.2.4.9 Fruit yield per vine (kg)

Fruit yield per vine (kg) showed significantly positive association with average length of fruit and fruit yield tonnes per hectare. while positive association with average diameter of fruit at both genotypic and phenotypic levels.

4.2.4.10 Average length of fruit (cm)

The average length of fruit had significantly positive association with fruit yield tonnes per hectare and positive correlation with average diameter of fruit at both genotypic and phenotypic levels.

4.2.1.11 Average diameter of fruit (cm)

The average diameter of fruit had showed positive association with fruit yield tonnes per hectare.

4.2.5 Correlation coefficient of cross Hirkani x Konkan Tara (C₃: 2 x 4) in F₃ generations

Fifteen F₃ progenies were studied for association of relationship between yield and yield contributing characters in F₃ generations and are presented in Table 13.

4.2.5.1 Final vine length at last harvest

The final vine length at last harvest showed positive and significant correlation with fruit yield tonnes per hectare only in genotypic level, number of primary branches per vine, days required for first female flower appearance and days required for first harvest of fruit. Whereas, positive correlation with fruit yield tonnes per hectare only in phenotypic level while, node at which first female flower appeared at both genotypic and phenotypic levels. While, it had significant negative correlation with average diameter of fruit only in genotypic level and showed negative correlation with average diameter of fruit only in phenotypic level, crop durations, number of fruits per vine, average weight of fruit, average length of fruit and fruit yield per vine at both genotypic and phenotypic levels.

Table 13. Genotypic and Phenotypic Correlation co-efficient for yield and yield contributing characters in F₃ generation of cross Hirkani X Konkan Tara (C₃: 2 x 4).

Sr. No.	Character		1	2	3	4	5	6	7	8	9	10	11	12
1	Final vine length at last harvest (cm)	G P	1.000 1.000	0.609** 0.529 *	0.653** 0.549**	0.078 0.061	0.610** 0.524*	-0.222 -0.204	-0.321 -0.258	-0.225 -0.207	-0.426 -0.336	-0.224 -0.143	-0.809** -0.225	0.420* 0.336
2	Number of primary branches	G P	- -	1.000 1.000	-0.769** -0.667 **	-0.343 -0.414	-0.806** -0.688 **	-0.049 -0.033	0.404 0.387	0.172 0.191	0.485* 0.459 *	0.409 0.346	0.569** 0.096	0.487* 0.461*
3	Days required for appearance of first female flower	G P	- -	- -	1.000 1.000	0.079 0.118	0.994** 0.950**	-0.462* -0.437 *	-0.120 -0.054	-0.769** -0.747**	-0.575** -0.419	-0.844** -0.677**	-0.631** -0.651**	-0.576** -0.421
4	Node at which first female flower appeared	G P	- -	- -	- -	1.000 1.000	0.127 0.123	-0.147 -0.097	0.407 0.185	-0.066 -0.104	-0.415 -0.160	-0.107 -0.100	-0.760** -0.158	-0.423* -0.158
5	Days required for first harvest of fruit	G P	- -	- -	- -	- -	1.000 1.000	-0.296 -0.309	-0.049 0.063	-0.725** -0.701**	-0.455* -0.277	-0.737** -0.578**	-0.397 -0.230	-0.457* -0.279
6	Crop durations (days)	G P	- -	- -	- -	- -	- -	1.000 1.000	0.085 0.132	0.753** 0.682**	0.410 0.241	0.755** 0.613**	0.529* 0.554**	0.410 0.242
7	Number of fruits per vine	G P	- -	- -	- -	- -	- -	- -	1.000 1.000	0.404 0.316	0.818** 0.863 **	0.352 0.077	0.469* 0.024	0.817** 0.862*
8	Average weight of fruit (gm)	G P	- -	- -	- -	- -	- -	- -	- -	1.000 1.000	0.193 0.196	0.862** 0.672**	0.633** 0.633**	0.195 0.198
9	Average fruit yield per vine (kg)	G P	- -	- -	- -	- -	- -	- -	- -	- -	1.000 1.000	0.931** 0.124	0.925** 0.948**	0.954** 0.850**
10	Average length of fruit (cm)	G P	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.000 1.000	0.750** 0.380	0.931** 0.441*
11	Average diameter of fruit (cm)	G P	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.000 1.000	0.927** 0.123
12	Fruit yield t/ ha	G P	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.000 1.000

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

4.2.5.2 Number of primary branches per vine

The number of primary branches per vine exhibited positive significant correlation with fruit yield per vine and average diameter of fruit only in genotypic level, fruit yield tonnes per hectare at both genotypic and phenotypic levels. Whereas it showed positive correlation with average diameter of fruit only in phenotypic level, number of fruits per vine, average weight of fruit and average length of fruit at both genotypic and phenotypic levels. Whereas, it showed negative significant correlation with days required for first female flower appearance and days required for first harvest of fruit. Whereas, negative correlation with node at which first female flower appeared and crop durations at both genotypic and phenotypic levels.

4.2.5.3 Days to first female flower appearance

The days required for first female flower appearance were significantly and positively correlated with days required for first harvest of fruit and positive correlation with node at which first female flower appeared at both genotypic and phenotypic levels. Whereas, it showed negative significant correlation with crop durations, average weight of fruit, fruit yield per vine, average length of fruit, average diameter of fruit and fruit yield tonnes per hectare and negative correlation was observed in number of fruits per vine at both genotypic and phenotypic levels.

4.2.5.4 Node at which first female flower appeared

Nodal position of first female flower appearance exhibited positive correlation with days required for first harvest of fruit and number of fruits per vine at both genotypic and phenotypic levels. It showed significant and negative association with fruit yield tonnes per hectare only in genotypic level, average diameter of fruit and negative association with fruit yield

tonnes per hectare only in phenotypic level, while crop durations, average weight of fruit, average yield per vine and average length of fruit at both genotypic and phenotypic levels.

4.2.5.5 Days required for first harvest of fruit

Days to first harvest negatively and significantly correlated with fruit yield per vine and fruit yield tonnes per hectare only in genotypic level, average weight of fruit, average length of fruit and negative association with fruit yield per vine and fruit yield tonnes per hectare only in phenotypic level, crop durations, number of fruits per vine and average diameter of fruit at both genotypic and phenotypic levels.

4.2.5.6 Crop durations

Crop durations showed significant and positive association with average weight of fruit, average length of fruit and average diameter of fruit whereas, positive association with number of fruits per vine, fruit yield per vine and fruit yield tonnes per hectare at both genotypic and phenotypic levels.

4.2.5.7 Number of fruits per vine

Number of fruits per vine showed significant and positive association with fruit yield per vine, average diameter of fruit and fruit yield tonnes per hectare. Whereas, positive association with average weight of fruit and average length of fruit at both genotypic and phenotypic levels.

4.2.1.8 Average weight of fruit (g)

Average fruit weight showed significant and positive correlation with average length of fruit and average diameter of fruit. Whereas positive correlation with fruit yield per vine and fruit yield tonnes per hectare at both genotypic and phenotypic levels.

4.2.1.9 Fruit yield per vine (kg)

Fruit yield per vine (kg) showed significant and positive association with average diameter of fruit, average length

of fruit and fruit yield tonnes per hectare at both genotypic and phenotypic levels.

4.2.5.10 Average length of fruit (cm)

The average length of fruit had significant and positive correlation with average diameter of fruit only in genotypic level and yield tonnes per hectare at both genotypic and phenotypic levels. While positive correlation with average diameter of fruit only in phenotypic levels.

4.2.5.11 Average diameter of fruit(cm)

The average diameter of fruit had showed positive and significant association with fruit yield tonnes per hectare only in genotypic level and positive association with fruit yield tonnes per hectare only in phenotypic level.

4.2.6 Correlation coefficient of cross Hirkani x Konkan Tara (C₃: 2 x 4) in F₄ generations.

Fifteen F₄ progenies were studied for association of relationship between yield and yield contributing characters in F₄ generations and are presented in Table 14.

4.2.6.1 Final vine length at last harvest

The final vine length at last harvest showed positive and significant correlation with crop durations and average diameter of fruit only in genotypic level and fruit yield tonnes per hectare at both genotypic and phenotypic levels. Whereas, positive correlation with crop durations and average diameter of fruit only in phenotypic level, number of primary branches per vine, average length of fruit and node at which first female flower appeared at both genotypic and phenotypic levels. While, it had significant negative correlation with number of fruits per vine and fruit yield per vine and also showed negative correlation with days required for first female flower appearance, days required for first harvest of fruit and average weight of fruit at both genotypic and phenotypic levels.

Table 14. Genotypic and Phenotypic Correlation co-efficient for yield and yield contributing characters in F₄ generation of cross Hirkani X Konkan Tara (C₃: 2 x 4).

Sr. N.	Character		1	2	3	4	5	6	7	8	9	10	11	12
1	Final vine length at last harvest (cm)	G P	1.000 1.000	0.002 0.044	-0.234 -0.177	0.374 0.301	-0.195 -0.118	0.462* 0.369	-0.580** -0.505*	-0.343 -0.340	-0.645** -0.581**	0.249 0.180	0.442* 0.383	0.645** 0.581**
2	Number of primary branches	G P	- -	1.000 1.000	0.581** 0.491*	-0.475* -0.507*	0.690** 0.553 **	-0.331 -0.222	-0.458* -0.432	0.699** 0.333	-0.188 -0.274	0.633** 0.368	0.379 0.308	0.188 0.274
3	Days required for appearance of first female flower	G P	- -	- -	1.000 1.000	-0.609** -0.510 *	0.990** 0.973 **	-0.932** -0.727 **	-0.084 -0.064	0.040 0.024	-0.085 -0.067	-0.331 -0.242	-0.101 -0.078	-0.087 -0.068
4	Node at which first female flower appeared	G P	- -	- -	- -	1.000 1.000	-0.631** -0.526 *	0.740** 0.606 **	-0.344 -0.234	-0.182 0.043	-0.339 -0.145	0.375 0.298	0.179 0.140	-0.341 -0.145
5	Days required for first harvest of fruit	G P	- -	- -	- -	- -	1.000 1.000	-0.938** -0.725**	-0.126 -0.108	0.074 0.040	-0.113 -0.103	-0.239 -0.164	-0.142 -0.111	-0.115 -0.104
6	Crop durations (days)	G P	- -	- -	- -	- -	- -	1.000 1.000	-0.256 -0.172	0.266 0.138	-0.112 -0.068	0.644** 0.395	0.543* 0.434*	0.112 0.067
7	Number of fruits per vine	G P	- -	- -	- -	- -	- -	- -	1.000 1.000	0.059 0.092	0.933** 0.911**	-0.736** -0.616**	-0.723** -0.655* *	0.933** 0.911**
8	Average weight of fruit (gm)	G P	- -	- -	- -	- -	- -	- -	- -	1.000 1.000	0.412 0.490 *	0.617** 0.402	0.252 0.264	0.411* 0.490*
9	Average fruit yield per vine (kg)	G P	- -	- -	- -	- -	- -	- -	- -	- -	1.000 1.000	-0.439 -0.373	-0.569** -0.467 *	0.975** 0.974**
10	Average length of fruit (cm)	G P	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.000 1.000	0.679** 0.471*	0.440* 0.372*
11	Average diameter of fruit (cm)	G P	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.000 1.000	0.569** 0.467*
12	Fruit yield t/ ha	G P	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.000 1.000

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

4.2.6.2 Number of primary branches per vine

The number of primary branches per vine exhibited positive significant correlation with average weight of fruit and average length of fruit only in genotypic level, days required for first female flower appearance, days required for first harvest of fruit and also showed positive correlation with average weight of fruit and average length of fruit only in phenotypic level, average diameter of fruit and fruit yield tonnes per hectare at both genotypic and phenotypic levels. Whereas, it showed negative significant correlation with number of fruits per vine and only in genotypic level and node at which first female flower appeared at both genotypic and phenotypic levels. While negative correlation with number of fruits per vine and only in phenotypic level, crop durations and fruit yield per vine at both genotypic and phenotypic levels.

4.2.6.3 Days to first female flower appearance

The days required for first female flower appearance were significantly and positively correlated with days required for first harvest of fruit and positive correlation with average weight of fruit at both genotypic and phenotypic levels. Whereas, it showed negative significant correlation with node at which first female flower appeared, crop durations, and negative correlation was observed in number of fruits per vine, fruit yield per vine, average length of fruit, average diameter of fruit and fruit yield tonnes per hectare at both genotypic and phenotypic levels.

4.2.6.4 Node at which first female flower appeared

Nodal position of first female flower appearance exhibited significantly and positively correlated with crop durations. while positive correlation with average length of fruit and average diameter of fruit at both genotypic and phenotypic levels. It showed significant and negative association with days

required for first harvest of fruit and negative association with number of fruits per vine, average weight of fruit, fruit yield per vine and fruit yield tonnes per hectare at both genotypic and phenotypic levels.

4.2.6.5 Days required for first harvest of fruit

Days required for first harvest of fruit had positive correlation with average weight of fruit and fruit yield tonnes per hectare. While negatively and significantly correlated with crop durations and negative association with number of fruits per vine, fruit yield per vine, average length of fruit and average diameter of fruit at both genotypic and phenotypic levels.

4.2.6.6 Crop durations

Crop durations showed significant and positive association with average length of fruit and average diameter of fruit. whereas, positive association with average weight of fruit and fruit yield tonnes per hectare. Whereas negative association with number of fruits per vine and fruit yield per vine at both genotypic and phenotypic levels.

4.2.6.7 Number of fruits per vine

Number of fruits per vine showed significant and positive association with fruit yield per vine and fruit yield in tonnes per hectare. Whereas, positive association with average weight of fruit and significantly and negatively correlated with average length of fruit and average diameter of fruit at both genotypic and phenotypic levels.

4.2.6.8 Average weight of fruit (g)

Average fruit weight showed significant and positive correlation with fruit yield per vine only in phenotypic level, average length of fruit only in genotypic level and fruit yield tonnes per hectare. Whereas, positive correlation with fruit yield per vine only in genotypic level, average length of fruit only in

phenotypic level and average diameter of fruit at both genotypic and phenotypic levels.

4.2.16.9 Fruit yield per vine (kg)

Fruit yield per vine (kg) showed significant and positive correlation with fruit yield in tonnes per hectare. Whereas, significant and negative association with average diameter of fruit and negative correlation with average length of fruit at both genotypic and phenotypic levels.

4.2.6.10 Average length of fruit (cm)

The average length of fruit had significant and positive correlation with average diameter of fruit and fruit yield tonnes per hectare at both genotypic and phenotypic levels.

4.2.6.11 Average diameter of fruit(cm)

The average diameter of fruit had showed positive and significant association with fruit yield tonnes per hectare at both genotypic and phenotypic levels.

4.3 Fruit characters (Qualitative)

F₃ and F₄ progenies of crosses Phule Green Gold x Hirkani (C₁: 1 x 2), Hirkani x Phule Ujwala (C₂: 2 x 3) and Hirkani x Konkan Tara (C₃: 2 x 4) along with their parents were studied for the different fruit characters (qualitative) such as fruit shape, fruit colour and prickles were presented in Table 15, 16.

4.3.1 Fruit shape or Size of Fruit

As per features of genotypes presented in Table 15 the parents Phule Green Gold (1), Hirkani (2) Phule Ujwala (3) and Konkan Tara (4) had Medium fruit shape.

In case of F₃ and F₄ generations, in the segregating progenies of three crosses *viz.*, Phule Green Gold x Hirkani (C₁: 1 x 2), Hirkani x Phule Ujwala (C₂: 2 x 3) and

Hirkani x Konkan Tara (C₃: 2 x 4) the Medium fruit shape was observed (Table 16).

Table 15. Fruit character (Qualitative/ Morphological) in F₃ Generation of Bitter gourd.

Parent /crosses	Shape of Fruit or Size of Fruit (short, medium, long)	Colour of fruit (Light green, Green, Whitish)	Prickles (Low, Medium, High)
C1 (Phule Green Gold X Hirkani)	Medium	Green	Medium
C2 (Hirkani X Phule Ujwala)	Medium	Green	Medium
C3 (Hirkani X Konkan Tara)	Medium	Green	Medium

Table 16. Fruit character (Qualitative/ Morphological) in F₄ Generation of Bitter gourd.

Parent /crosses	Shape of Fruit or Size of Fruit (short, medium, long)	Colour of fruit (Light green, Green, Whitish)	Prickles (Low, Medium, High)
C1 (Phule Green Gold X Hirkani)	Medium	Green	Medium
C2 (Hirkani X Phule Ujwala)	Medium	Green	Medium
C3 (Hirkani X Konkan Tara)	Medium	Green	High

4.3.2 Fruit colour

From the Table 15, it was observed that the parents Phule Green Gold (1), Phule Ujwala (3) and Konkan Tara (4) had green fruit colour whereas, Hirkani (2) had dark green fruit colour.

From table 16 it was observed that in F_3 and F_4 segregating progenies, all three crosses *viz.*, Phule Green Gold x Hirkani (C_1 : 1 x 2), Hirkani x Phule Ujwala (C_2 : 2 x 3) and Hirkani x Konkan Tara (C_3 : 2 x 4) showed green fruit colour.

4.3.3 Prickles

As per features of genotypes presented in Table 15, the parents Phule Green Gold had Medium Prickles on fruit surface, the parent Hirkani (2), Phule Ujwala (3) and Konkan Tara (4) had high prickles on fruit surface.

In F_3 and F_4 generations, most of the progenies of three crosses *viz.*, Phule Green Gold x Hirkani (C_1 : 1 x 2), Hirkani x Phule Ujwala (C_2 : 2 x 3) and Hirkani x Konkan Tara (C_3 : 2 x 4) showed medium Prickles on fruit surface (Table 16).

4.4 Per cent incidence of diseases and pests.

As per features of genotypes presented in Table 2, the parent Phule Green Gold was tolerant to downey mildew. The incidence of diseases and pests *viz.*, downey mildew, Powdery mildew and fruit fly of F_3 and F_4 segregating progenies are presented in Table 17 and Table 18.

4.4.1 Per cent incidence of diseases

4.4.1.1 Per cent incidence of downey mildew

Out of four parents, the incidence of downey mildew was found in almost all the parents. The highest incidence of downey mildew was recorded in Konkan Tara (30.16 and 34.12 %) whereas the least incidence of downey mildew was recorded in Phule Green Gold (18.12 and 21.14 %) in both F_3 and F_4 generation respectively (Table 17).

In case of segregating progenies, the highest incidence of downey mildew (28.92 and 23.54 %) was recorded in most of the progenies of the cross Hirkani x Phule Ujwala (C_2 : 2 x 3) and least incidence of downey mildew (23.25 and 19.24 %) was recorded in Phule Green Gold x Hirkani (C_1 : 1 x 2) in F_3 and F_4 generation respectively (Table 17).

4.4.1.2 Per cent incidence of Powdery mildew

Among the parents, low incidence of Powdery mildew at field condition was recorded in the parents Hirkani (25.39 and 21.83 %) while the highest incidence was observed in parent Phule Ujwala (33.24 and 23.54 %) in both F_3 and F_4 generation respectively (Table 17).

TABLE 17. Percent diseases incidence of downey mildew and powdery mildew in F_3 and F_4 generations of Bitter gourd.

Parents / Crosses	Downey mildew (%)		Powdery mildew (%)	
	F_3 generation	F_4 generation	F_3 generation	F_4 generation
Parents				
P₁ (Phule Green Gold)	18.12 (25.19)*	21.14 (27.37)	28.61 (32.33)	34.13 (35.74)
P₂ (Hirkani)	30.12 (33.29)	28.14 (32.04)	25.39 (30.25)	21.83 (27.85)
P₃ (Phule Ujwala)	22.18 (28.10)	27.40 (31.56)	33.24 (35.20)	23.54 (29.04)
P₄ (Konkan Tara)	30.16 (33.31)	34.12 (35.74)	32.19 (34.57)	28.92 (32.53)
Crosses				
C₁: P₁ x P₂	23.25 (28.82)	19.24 (26.35)	20.43 (26.87)	21.32 (27.49)
C₂: P₂ x P₃	28.92 (32.53)	23.54 (29.04)	20.88 (27.19)	24.46 (29.64)
C₃: P₂ x P₄	24.43 (29.62)	20.43 (26.87)	28.78 (35.51)	32.27 (34.61)

*Value in parenthesis are arc sin values.

From Table 17 it was observed that in case of crosses, most of the progenies was recorded the lowest incidence of Powdery mildew (each 20.43 and 21.32 %) at field condition in cross in Phule Green Gold x Hirkani (C_1 : 1 x 2), whereas the highest incidence of Powdery mildew (28.78 and 32.27%) was observed in the cross Hirkani x Kokan Tara (C_3 : 2 x 4) in the F_3 and F_4 generation respectively.

4.4.2 Per cent incidence of pest

4.4.2.1 Per cent incidence of fruit fly

Out of four parents, the infestation of fruit fly at field condition was found almost same in all the parents (Table 18). The highest infestation was found in Kokan Tara (16.22 and 21.10 %) while least infestation was observed in Phule Ujwala (11.09 and 9.56 %) in both F_3 and F_4 generations respectively (Table 18).

TABLE 18. Percent incidence of fruit fly in F_3 and F_4 generations of Bitter gourd.

Parents / Crosses	Fruit fly (%)	
	F_3 generation	F_4 generation
Parents		
P₁ (Phule Green Gold)	15.65(23.30) *	14.32(22.24)
P₂ (Hirkani)	15.65(23.30)	16.32 (23.83)
P₃ (Phule Ujwala)	11.09 (19.45)	9.56 (18.18)
P₄ (Konkan Tara)	16.22 (23.75)	21.10 (27.35)
Crosses		
C₁: P₁ x P₂	14.38 (22.28)	11.18 (19.53)
C₂: P₂ x P₃	10.12 (18.55)	8.47 (16.92)
C₃: P₂ x P₄	14.22 (22.15)	12.23 (19.10)

*Value in parenthesis are arc sin values.

Among the three crosses the cross Hirkani x Phule Ujwala (C_2 : 2 x 3) recorded least infestation of fruit fly (10.12 and 8.47 %) while the cross Hirkani x Kokan Tara (C_3 : 2 x 4) recorded

highest infestation of fruit fly (14.22 and 12.23 %) in both F₃ and F₄ generations respectively (Table 18).

5. DISCUSSION

The Bitter gourd (*Momordica charantia* L.) is considered to be native home of tropical Africa and Asia. It is widely distributed in China, Malaysia, India and tropical Africa. It is also being grown as commercial crop near the urban areas. Although the bitterness of Bitter gourd might turn some people away, it really sweeten because of its disease preventing and health promoting phytochemical compounds. The yield is complex phenomena which depend on a number of characters. Hence, direct selection for yield will be misleading and inappropriate without any knowledge of variability, heritability and genetic advance. The knowledge of association of quantitative characters with yield and among themselves will be of great significance (Ramchandran *et al.*, 2002). Bitter gourd is monoecious and highly cross-pollinated crop. Pollination mechanism can be exploited for development hybrid for its commercial cultivation. There is also a great scope for development of open pollinated varieties by utilizing the existing variability. Success of any breeding programme is largely dependent on the extent of genetic variability and heritability of particular character present in the population. Greater the variability in the material better are the chances for evolving promising and desired types. Maximum utilization of any ideal genotypes for increasing the genetic yield potential, disease resistance is very essential. Studies on genetic parameters of various traits provide information for selection and help in crop improvement. Variability in Bitter gourd is expected to be immense as the fruits vary greatly in shape and size. Studies on

genetic parameters of various traits provide information for selection and helps in crop improvement.

By keeping all above points in mind, present investigation was undertaken where the segregating progenies of three crosses along with their parents were evaluated for their growth, flowering, yield and qualitative characters in F₃ and F₄ generation during Summer 2014 and 2015.

The results in respect of variability heritability, genetic advance and correlation in F₃ and F₄ progenies, in preceding chapter were discussed here under with suitable headings.

5.1 Variability, heritability and genetic advance

5.2 Correlation coefficient

5.3 Per cent incidence of diseases and pests

5.4 Fruit characters (qualitative)

5.1 Variability, heritability and genetic advance

Range of variability, genetic parameters like genotypic coefficient of variation and phenotypic coefficient of variation, environmental coefficient of variation, heritability and genetic advance with their results were discussed subsequently.

5.1.1 Range of variability

The assessment of genotypes for its nature and magnitude of genetic variability is an important prerequisite for developing any variety with high yield potential and the desired morphological characters. This helps the breeder to assess and identify superior genotypes. In the present study, among the fifteen progenies of all three crosses *viz.*, Phule Green Gold x Hirkani (C₁: 1 x 2), Hirkani x Phule Ujwala (C₂: 2 x 3) and Hirkani x Konkan Tara (C₃: 2 x 4) for F₃ and F₄ generations

respectively showed wide range of variability for most of the characters.

The wide range of variability was observed in cross Phule Green Gold x Hirkani (C_1 : 1 x 2) in F_3 generation for most of the characters of Bitter gourd (Table 3). The final vine length at last harvest was ranged from 438.01 to 486.64 cm, number of primary branches per vine from 10.16 to 13.15, days required for first female flower appearance from 52.47 to 59.75, node at which first female flower appeared from 21.28 to 28.38, days required for first harvest of fruit from 57.55 to 65.57, crop duration (days) from 133.62 to 158.73 days, number of fruits per vine from 37.93 to 49.64, average yield per vine from 2.10 to 2.92 kg, average weight of fruit from 52.29 to 68.02 g, average length of fruit from 17.53 to 23.93 cm, average diameter of fruit from 3.26 to 3.68 cm and fruit yield from 14.00 to 20.50 t/ha.

In F_3 generation wide range of variability was also observed for most of the characters in cross Hirkani x Phule Ujwala (C_2 : 2 x 3) (Table 5). The final vine length at last harvest was ranged from 408.41 to 471.48 cm, number of primary branches per vine from 10.88 to 12.70, days required for first female flower appearance from 52.86 to 59.33, node at which first female flower appeared from 22.17 to 25.82, days required for first harvest of fruit from 58.46 to 64.44, crop duration from 141.21 to 153.84 days, number of fruits per vine from 30.99 to 44.06, average yield per vine from 1.85 to 2.75 kg, average weight of fruit from 54.84 to 68.39g, average length of fruit from 17.64 to 24.02 cm and average diameter of fruit from 3.36 to 3.63 cm and fruit yield from 12.38 to 18.37 t/ha.

In the cross Hirkani X Konkan Tara (C_3 : 2 x 4) wide range of variability was observed in F_3 generation for all the

characters of Bitter gourd (Table 7). The final vine length at last harvest was ranged from 405.88 to 453.17 cm, number of primary branches per vine from 9.97 to 14.59, days required for first female flower appearance from 52.04 to 57.61 days, node at which first female flower appeared from 21.30 to 27.21, days required for first harvest of fruit from 57.08 to 64.95, crop duration from 128.84 to 158.30 days, number of fruits per vine from 27.97 to 44.75, average fruit yield per vine from 1.68 to 3.05 kg, average weight of fruit from 54.68 to 70.33 g, average length of fruit from 16.59 to 22.75 cm, average diameter of fruit from 3.30 to 3.56 cm and fruit yield from 11.24 to 20.37 t/ha.

In F_4 generation of cross Phule Green Gold x Hirkani (C_1 : 1 x 2) also observed wide range of variability (Table 4). The final vine length at last harvest was ranged from 453.68 to 474.15 cm, number of primary branches per vine from 10.46 to 13.53, days required for first female flower appearance from 51.70 to 60.68, node at which first female flower appeared from 22.46 to 28.79, days required for first harvest of fruit from 58.13 to 66.16 days, crop duration 135.75 to 153.48 days, number of fruits per vine from 31.93 to 50.15, average yield per vine from 1.96 to 3.57 kg, average weight of fruit from 56.79 to 71.30g, average length of fruit from 18.55 to 23.57 cm, average diameter of fruit from 3.03 to 3.66 cm and fruit yield from 14.87 to 23.78 t/ha.

In the cross Hirkani x Phule Ujwala (C_2 : 2 x 3) wide range of variability was recorded in F_4 generation for most of the characters (Table 6). The final vine length at last harvest was ranged from 437.37 to 493.17 cm, number of primary branches per vine from 10.26 to 13.04, days required for first female flower appearance from 50.79 to 57.19, node at which first female

flower appeared from 22.10 to 26.84, days required for first harvest of fruit from 57.55 to 63.20 days, crop duration from 133.86 to 161.24 days, number of fruits per vine from 29.68 to 40.45, average yield per vine from 1.62 to 2.72 kg, average weight of fruit from 52.06 to 67.48 g, average length of fruit from 17.26 to 21.88 cm, average diameter of fruit from 3.28 to 3.70 cm and fruit yield from 11.30 to 18.15 t/ha.

The wide range of variability was also observed for most of the characters in the cross Hirkani X Konkan Tara (C₃: 2 x 4) in F₄ generation (Table 8). The final vine length at last harvest was ranged from 403.92 to 462.35 cm, number of primary branches per vine from 11.19 to 13.19, days required for first female flower appearance from 52.95 to 58.77 days, node at which first female flower appeared from 21.59 to 26.95, days required for first harvest of fruit from 59.73 to 65.48, crop duration from 133.16 to 158.34 days, number of fruits per vine from 27.79 to 41.19, average yield per vine from 1.72 to 2.78 kg, average weight of fruit from 58.89 to 74.82 g, average length of fruit from 18.15 to 22.50 cm, average diameter of fruit from 3.25 to 3.61 cm and fruit yield from 11.48 to 28.56 t/ha.

In present investigation higher mean estimates was observed for fruit yield per vine, average fruit weight, average fruit length, average fruit diameter. Rajput (2012) observed higher mean estimates for fruit yield per vine, average fruit weight and average fruit length in bitter gourd. Tarsem and Sanjay (1997) obtained higher mean estimates for fruit yield per vine, average fruit weight and average weight of pulp per fruit in muskmelon. Torkadi and Musmade (2007), Mehta *et al.* (2010) obtained similar findings in muskmelon. Finker *et al.* (1973)

revealed that high mean values were relatively effective in identifying the superior segregants.

In most of the characters *viz.*, growth, yield contributing and qualitative traits wide range of variations were observed in all three crosses of F₃ and F₄ generations. Singh *et al.* (1977) reported wide range of variability for the traits *viz.*, number of fruits per plant, fruit length and days to flowering in bitter gourd. Pathak (2014) observed wide range of variability for the traits *viz.*, number of fruits per plant, fruit weight, fruit length and days to first male and female flower in bitter gourd. Rajput (2012) observed wide range of variability for the traits *viz.*, average yield per vine, final vine length at last harvest and average fruit weight in bitter gourd. Mehta *et al.* (2010) found significant variation for the traits *viz.*, average yield per vine, final vine length at last harvest and average fruit weight in muskmelon. Similar results reported by Rakhi and Rajamony (2005), Torkadi and Musmade (2007), Ibrahim (2012) and Reddy *et al.* (2013) in muskmelon. Karuppaiah *et al.* (2002), Choudhary and Kumar (2011), Rabbani *et al.* (2012) in ridge gourd. Prasad and Singh (1990), Kumar *et al.* (2013) in sponge gourd.

Thus the wide range of variation for growth, yield and fruit characteristics of Bitter gourd in F₃ and F₄ generations indicated a good scope for selection of desirable genotypes in view of the objectives under investigation.

5.1.2 Genetic parameters i.e. genotypic and phenotypic co-efficient of variation

There were significant differences among the progenies of F₃ and F₄ generations of three crosses for all traits under study. In general the phenotypic coefficient of variation was slightly higher than the corresponding genotypic coefficient

of variation for all the characters in all the three crosses of F₃ and F₄ generation. This indicates the presence of minor role of environment in the expression of characters (Table 3 to 9). Similar results were in agreement with the findings of Rajput (2012), Pathak (2014), Raja *et al.* (2007) in bitter gourd. Rakhi and Rajamony (2005), Torkadi and Musmade (2007), Mehta *et al.* (2010), Ibrahim (2012), Reddy *et al.* (2013) and Mali (2015) in muskmelon. Patil (2010), Arvindkumar *et al.* (2011), Yadav and Kumar (2012) in bottle gourd. Joshi *et al.* (2005), Azcon (2012) in cucumber. Khan *et al.* (2009) in pointed gourd. Chaudhary and Kumar (2011), Rabbani *et al.* (2012) in ridge gourd. Kumar *et al.* (2013) in sponge gourd. Thakur and Nandpuri (1974), Kadam (1997), Gusmini and Wehner (2007) in watermelon.

In F₃ and F₄ progenies of cross Phule Green Gold x Hirkani (C₁: 1 x 2) number of primary branches per vine, number of fruits per vine, average yield per vine, average weight of fruit, yield tonnes per hectare recorded high values of genotypic and phenotypic coefficients of variations. Whereas node at which first female flower appeared, crop duration, days to first female flower appearance, average diameter of fruit only in F₄ generation, average length of fruit exhibited moderate values of genotypic and phenotypic coefficients of variation. Rest of traits such as final vine length at last harvest, days required for first harvest of fruit average diameter of fruit only in F₃ generation recorded low values of genotypic and phenotypic coefficients of variations in F₃ and F₄ generation.

In F₃ and F₄ progenies of the cross Hirkani x Phule Ujwala (C₂ : 2 x 3) number of primary branches per vine, number of fruits per vine, average fruit yield per vine, average weight of fruit, yield tonnes per hectare recorded high values of

genotypic and phenotypic coefficients of variations. While node at which first female flower appeared, crop duration, days to first female flower appearance, average diameter of fruit only in F₄ generation, average length of fruit exhibited moderate values of genotypic and phenotypic coefficients of variation. The character such as final vine length at last harvest, days required for first harvest of fruit, average diameter of fruit only in F₃ generation recorded low values of genotypic and phenotypic coefficients of variations in F₃ and F₄ generation.

In F₃ and F₄ progenies of the cross Hirkani X Konkan Tara (C₃ : 2 x 4) number of primary branches per vine, number of fruits per vine, average fruit yield per vine, average weight of fruit only in F₃ generation, yield tonnes per hectare recorded high values of genotypic and phenotypic coefficients of variations. Whereas node at which first female flower appeared, crop duration, days to first female flower appearance, average diameter of fruit only in F₄ generation, average length of fruit, average diameter of fruit only in F₄ generation exhibited moderate values of genotypic and phenotypic coefficients of variation. Rest of traits such as final vine length at last harvest, days required for first harvest of fruit, average diameter of fruit only in F₃ generation, recorded low values of genotypic and phenotypic coefficients of variations in F₃ and F₄ generation.

Characters which showed higher estimates of GCV and PCV could be fully exploited in further selection programme due to presence of large amount of variations within segregating populations i.e. scope for improvement through selection. While characters which showed lower estimates of GCV and PCV would be least exploited in further selection programme due to small

amount of variations observed within segregating populations i.e. lack of scope for improvement through selection.

These findings were in conformity with Indresh (1982) recorded high estimates of GCV for fruit weight, yield per vine, fruit cavity, leaf area and fruit length in bitter gourd. Mangal *et al.* (1983) revealed high GCV average fruit yield per vine, number of branches per vine, average fruit weight and average number of fruits per vine. The least GCV was observed for number of days to first flower in bitter gourd. Raja *et al.* (2007) noticed that the highest PCV and GCV were observed for number of female flowers per plant, fruit weight and number of primary branches per plant in bitter gourd. Rajput (2012) recorded High GCV and PCV was 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 F₂ and F₃ generations in bitter gourd. Pathak (2014) revealed high GCV and 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 in bitter gourd. The other scientists reported similar results i.e. Tarsem and Sanjay (1997), Rakhi and Rajamony (2005), Torkadi and Musmade (2007), Mehta *et al.* (2010), Reddy *et al.* (2013), Ibrahim (2012) and Mali (2015) in muskmelon. Patil (2010), Arvindkumar *et al.* (2011) and Yadav and Kumar (2012) in bottle gourd. Joshi *et al.* (2005), Gaikwad (2007), Arunkumar *et al.* (2011) and Azcon (2012) in cucumber. Chandrakumar (2006) in pointed gourd. Arora *et al.* (1983), Abusaleha and Dutta (1990) and Prasad and Singh (1990) in spone gourd. Raju *et al.* (1998) in summer squash. Thakur and Nandpuri (1974) and Kadam (1997) in water melon.

However, diameter of fruit showed more magnitudinal differences between genotypic coefficient of variation and phenotypic coefficient of variation in cross Hirkani X Konkan Tara ($C_3 : 2 \times 4$) of F_3 generation. Since, in such traits, genotype x environmental interaction ($G \times E$) is effective, which suggests definite role of environmental effect in the expression of these characters. These results are in agreement with the findings of Raja *et al.* (2007), Rajput (2012), Pathak (2014) in bitter gourd.

5.1.3 Heritability and genetic advance

Heritability (broad sense) was found high for most of the traits in all three crosses of F_3 and F_4 generations. In case of F_3 generation in cross Phule Green Gold x Hirkani ($C_1: 1 \times 2$) heritability was ranged from 71.30 to 94.56 per cent. In cross Hirkani x Phule Ujwala ($C_2: 2 \times 3$) it ranged from 67.67 to 96.50 per cent. In cross Hirkani x Konkan Tara ($C_3: 2 \times 4$) from 63.27 to 97.10 per cent.

In case of F_4 generation in cross Phule Green Gold x Hirkani ($C_1: 1 \times 2$) heritability was ranged from 72.25 to 94.81 per cent. In cross Hirkani x Phule Ujwala ($C_2: 2 \times 3$) it ranged from 66.06 to 97.30 per cent. In cross Hirkani x Konkan Tara ($C_3: 2 \times 4$) from 66.87 to 92.61 per cent broad sense heritability (Table 3 to 9). Above information suggests that, selection based on phenotypic expression could be relied upon as major role of genetic constitution in the expression of these characters. Similar results were reported by Mangal *et al.* (1983), Islam *et al.* (2009), Rajput (2012) and Pathak (2014) in bitter gourd. Torkadi and Musmade (2007) and Mehta *et al.* (2010) in muskmelon. Kumar *et al.* (2007) in bottle gourd. Azcon (2012) in cucumber.

In case of F_3 and F_4 generation, in cross Phule Green Gold x Hirkani ($C_1: 1 \times 2$) the values of genetic advance observed

were low to very high and ranged from 0.32 to 13.47 and 0.37 to 21.79, in cross Hirkani x Phule Ujwala (C_2 : 2 x 3) ranged from 0.25 to 12.75 and 0.24 to 16.79, in cross Hirkani x Konkan Tara (C_3 : 2 x 4) genetic advance ranged from 0.23 to 19.93 and 0.38 to 18.96 in F_3 and F_4 generations, respectively. These findings are in conformity with the findings of Srivastava and Srivastava (1976), Singh *et al.* (1977), Lawande (1987) and Rajput (2012) in bitter gourd. Torkadi and Musmade (2007) and Mehta *et al.* (2010) in muskmelon, Kumar *et al.* (2007) in bottle gourd and Azcon (2012) in cucumber.

Genetic advance as per cent of mean coupled with heritability provide great scope of improvement in present set of materials for the trait studied.

In case of F_3 generation in cross Phule Green Gold x Hirkani (C_1 : 1 x 2) the association of high estimates of heritability with high estimates of genetic advance as per cent of mean were recorded in characters like final vine length at last harvest (79.65 and 27.38%), number of fruits per vine (86.47 and 21.91%), fruit yield per vine (85.05 and 27.38%), yield per hectare (85.12 and 27.43%) Whereas the high estimates of heritability with moderate estimates of genetic advance as per cent of mean was observed for number of primary branches per vine (74.61 and 15.87%), average weight of fruit (85.76 and 17.66%), average length of fruit (78.56 and 12.77%). The high estimates of heritability with lower estimates of genetic advance as per cent of mean was recorded in days to first female flower appearance (76.09 and 7.51%), days required for first harvest of fruit (87.32 and 8.76%), crop duration (71.30 and 9.37%), average diameter of fruit (94.56 and 9.27%) and node at which first female flower appeared (72.42 and 1.32%) showed high

estimates of heritability with low estimates of genetic advance as per cent of mean in F₃ generation.

In F₃ generation, the cross Hirkani x Phule Ujwala (C₂: 2 x 3) the traits like number of fruits per vine (90.48 and 32.92%), fruit yield per vine (85.54 and 29.33%), yield per hectare (85.72 and 29.45%) recorded high estimates of heritability along with high estimates of genetic advance as per cent of mean in F₃ generation. Whereas the characters final vine length at last harvest (95.40 and 11.78%), average length of fruit (67.67 and 14.19%) recorded high estimates of heritability with moderate estimates of genetic advance as per cent of mean. While the character primary branches per vine (74.37 and 6.12%), node at which first female flower appeared (70.61 and 8.46%), days to first female flower appearance (82.71 and 9.21%), days required for first harvest of fruit (78.79 and 7.53%), average weight of fruit (77.37 and 9.22%), average diameter of fruit (96.50 and 7.19%), crop duration (87.64 and 7.95%) showed high estimates of heritability with low estimates of genetic advance as per cent of mean in F₃ generation.

In F₃ generation in cross Hirkani x Konkan Tara (C₃: 2 x 4) characters like number of fruits per vine (68.35 and 27.34%), fruit yield per vine (65.43 and 25.91%), fruit yield per hectare (65.66 and 25.98%) recorded high estimates of heritability along with high estimates of genetic advance as per cent of mean. Whereas the characters number of primary branches per vine (80.87 and 19.48%), node at which first female flower appeared (77.60 and 15.20%), average weight of fruit (94.91 and 20.64 %), average length of fruit (63.27 and 10.64%), crop duration (89.06 and 13.80%) recorded high estimate of heritability with moderate estimate of genetic

advance as per cent of mean. The rest of characters viz. final vine length at last harvest (97.10 and 9.28%), days required for first harvest of fruit (81.25 and 5.66%), days to first female flower appearance (84.85 and 7.68%) and average diameter of fruit (93.20 and 6.98 %), showed the high estimates of heritability with lower estimate of genetic advance as per cent of mean.

In case of F_4 generation, in cross Phule Green Gold x Hirkani (C_1 : 1 x 2) the association of high estimate of heritability with high estimate of genetic advance as per cent of mean were recorded in characters like fruit yield per vine (94.79 and 41.94%), number of fruits per vine (90.98 and 29.63%), average weight of fruit (94.59 and 21.10%), yield per hectare (94.81 and 41.96%) crop duration (88.02 and 14.75%). Whereas the high estimate of heritability with moderate estimate of genetic advance as per cent of mean was observed for number of primary branches per vine (77.13 and 17.44%), node at which first female flower appeared (74.68 and 11.55%), average length of fruit (72.25 and 14.96%), average diameter of fruit (80.86 and 10.74%), While the high estimate of heritability with low estimate of genetic advance as per cent of mean was recorded in final vine length at last harvest (87.70 and 3.48%), days to first female flower appearance (81.40 and 8.90%), days required for first harvest of fruit (72.78 and 7.07 %).

In cross, Hirkani x Phule Ujwala (C_2 : 2 x 3) reported high estimates of heritability along with high estimates of genetic advance as per cent of mean in the characters like number of primary branches per vine (77.55 and 21.65%), number of fruits per vine (75.36 and 35.24%), fruit yield per vine (81.26 and 35.26 %), average weight of fruit (88.11 and 19.88%), yield per

hectare (81.31 and 35.28%), crop duration (87.61 and 11.35%). Whereas the characters node at which first female flower appeared (73.69 and 12.05%), average length of fruit (75.96 and 18.14%) recorded high estimate of heritability with moderate estimate of genetic advance as per cent of mean. While the characters final vine length at last harvest (77.14 and 7.85%), days to first female flower appearance (72.02 and 8.71%), average diameter of fruit (97.30 and 7.09%) and days required for first harvest of fruit (66.06 and 6.94%) showed the high estimate of heritability with low estimate of genetic advance as per cent of mean in the F₄ generation.

In F₄ generation the cross Hirkani x Konkan Tara (C₃: 2 x 4) characters like number of number of fruits per vine (90.57 and 33.16%), fruit yield per vine (83.58 and 35.84%), yield per hectare (83.53 and 35.83%) recorded high estimates of heritability along with high estimates of genetic advance as per cent of mean. Whereas the characters primary branches per vine (75.44 and 17.96%), node at which first female flower appeared (80.97 and 16.84%), average weight of fruit (68.49 and 13.58%), average length of fruit (66.87 and 14.28%), crop duration (76.84 and 12.99%) and average diameter of fruit (91.76 and 11.71%) recorded high estimate of heritability with moderate estimate of genetic advance as per cent of mean. The rest of characters like final vine length at last harvest (92.61 and 8.68%), days to first female flower appearance (84.03 and 8.76%) and days required for first harvest of fruit (77.13 and 6.86%) showed the high estimates of heritability with lower estimate of genetic advance as per cent of mean.

The traits which exhibited high estimates of heritability along with high estimates of genetic advance as per

cent of mean might be due to predominance of additive gene effects. Therefore it appears that selection for characters mentioned in above crosses and their respective generation would be effective.

High heritability coupled with high genetic advance as per cent mean was observed for the characters like number of primary branches per vine, average weight of fruit, and average yield per plant in bitter gourd (Mangal *et al.*, 1983). Rajput (2012) observed high heritability with high genetic advance for characters 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 bitter gourd. Pathak (2014) observed high heritability with high genetic advance for fruit weight, fruit length and number of fruits per plant in bitter gourd.

Similar type of results were reported by Prasad *et al.* (2004), Pandey *et al.* (2005), Singh and Lal (2005), Torkadi and Musmade (2007), Ibrahim (2012), Reddy *et al.* (2013) and Mali (2015) in muskmelon.

The higher estimate of heritability with low genetic advance as per cent mean indicates the presence of non-additive gene effect. Therefore selection may not be effective for these traits. The high heritability and low genetic advance may be attributed due to low phenotypic variation in these traits. Srivastava and Srivastava (1976) reported similar results for character days to first flower, fruit length and total fruit yield. Singh *et al.* (1977) reported high heritability with low genetic advance for character fruit diameter. Mangal *et al.* (1983) also reported similar result for character days to first flower and total fruit yield per vine in bitter gourd. Pathak (2014) reported high heritability with low genetic advance for character days to first

male and female flower indicated that non-additive gene effects in bitter gourd.

Similar findings were also in accordance with Prasad *et al.* (2004), Pandey *et al.* (2005), Rakhi and Rajamony (2005), Singh and Lal (2005), Torkadi and Musmade (2007), Ibrahim (2012) and Reddy *et al.* (2013) in muskmelon. Kumar *et al.* (2007), Arunkumar *et al.* (2011) in cucumber. Karuppaiah *et al.* (2002), Choudhary and Kumar (2011) in ridge gourd.

5.2 Correlation coefficient

In present study the phenotypic and the genotypic correlation co-efficient were worked out in respect of the twelve characters for each three crosses of both F_3 and F_4 generations (Table 9 to 14) and the same are discussed here below.

In case of F_3 and F_4 generation in cross Phule Green Gold x Hirkani (C_1 : 1 x 2) the significant and high positive correlation both at phenotypic and the genotypic level was observed between fruit yield per vine and the yield contributing characters such as final vine length at last harvest, number of primary branches per vine, number of fruits per vine, average weight of fruit, average length of fruit and average diameter of fruit. While, the characters like days required for first female flower appearance, node at which first female flower appeared and days required for first harvest of fruit and crop duration were significantly and negatively correlated with average yield per vine, which were helpful relationships. Most of these characters were also found to be positively associated among them. Similar correlation coefficient both at phenotypic and genotypic level between fruit yield per vine and the yield contributing characters were observed in crosses Hirkani x Phule Ujwala (C_2 : 2 x 3) and Hirkani x Konkan Tara (C_3 : 2 x 4) in F_3

and F₄ generations. These findings in both F₃ and F₄ generations indicate that the ideal vine should have more vine length, more number of primary branches per vine, more number of fruits per vine, more weight of fruit, more length of fruit and more diameter of fruit and less days required for first female flower appearance, lower node position at which first female flower appeared and less days required for first harvest of fruit. The selection of a better yielder should also emphasis for improvement in these components. Khattra *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) reported that, total yield per vine showed highly significant and positive phenotypic correlations 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 in bitter gourd. Botau *et al.* (2010) demonstrated that the fruit yield per vine had significant and positive correlation with number of fruits per vine, fruit weight, fruit length and fruit diameter in bitter gourd. Pathak (2014) observed the yield had significant positive correlation with number of fruits per plant and 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) revealed that fruit yield per vine in bitter gourd had 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.

Similar findings were also in conformity in another cucurbitaceous crops. Tarsem and Sanjay (1997), Choudhary *et al.* (2003), Chamnan and Kasem (2006), Jagtap (2010), Naroui *et al.* (2010), Cheema *et al.* (2011) in muskmelon. Dewan *et al.* (2014) in ash gourd, Kumar and Syamal (2010), Patil (2010), Yadav *et al.* (2010), Kumar *et al.* (2012), Sharma and Sengupta (2012), Yadav and Kumar (2012) in bottle gourd, Singh *et al.* (2002), Rao *et al.* (2003), Joshi *et al.* (2005), Bhande *et al.* (2012) in cucumber. Khan *et al.* (2009) in pointed gourd, Choudhary and Kumar (2011), Hanumegowda *et al.* (2012), Rabbani *et al.* (2012) in ridge gourd, Khule *et al.* (2011), Kumar *et al.* (2013) in sponge gourd. Kadam (1997), Rolania *et al.* (2003) in watermelon found that most of these characters were favorably associated with fruit yield per vine.

5.3 Fruit characters (qualitative)

F₃ and F₄ progenies of crosses Phule Green Gold x Hirakani (C₁: 1 x 2), Hirakani x Phule Ujwala (C₂: 2 x 3) and Hirakani x Konkan Tara (C₃: 2 x 4) along with their parents were studied for the different qualitative traits such as shape of fruit, colour of fruit and prickles on fruit was presented in Table 15 and 16.

5.3.1 Shape of fruits or Size of fruits

Among the F₃ and F₄ segregating progenies of the three crosses *viz.*, Phule Green Gold x Hirkani (C₁: 1 x 2), Hirkani x Phule Ujwala (C₂: 2 x 3) and Hirkani x Konkan Tara (C₃: 2 x 4) observed medium shape of fruits. Whereas some progenies were produced short fruit shape. Thus shape of fruit was governed by additive variance (Ramaswamy *et al.* 1977) Similar results were reported by Rajput (2012) in bitter gourd. Jagtap (2010) and Patil (2014) in muskmelon.

5.3.2 Colour of fruits

In F₃ and F₄ segregating progenies, among the three crosses *viz.*, Phule Green Gold x Hirkani (C₁: 1 x 2), Hirkani x Phule Ujwala (C₂: 2 x 3) and Hirkani x Konkan Tara (C₃: 2 x 4) showed green colour of fruits. These findings were in conformity with the findings of Dalamu (2012) and Rajput (2012) in bitter gourd, Jagtap (2010) and Patil (2014) in muskmelon.

5.3.3 Prickles

In F₃ and F₄ segregating progenies, among the three crosses *viz.*, Phule Green Gold x Hirkani (C₁: 1 x 2), Hirkani x Phule Ujwala (C₂: 2 x 3) and Hirkani x Konkan Tara (C₃: 2 x 4) showed medium prickles on fruit surface (Table 15,16). While high prickles was shown in cross Hirkani x Konkan Tara in F₄ generations. Similar results were reported by of Dalamu (2012) and Rajput (2012) in bitter gourd.

5.4 Per cent incidence of diseases and pests

5.4.1 Per cent incidence of diseases

5.4.1.1 Per cent incidence of downy mildew

As regards per cent incidence of Downey mildew, the parent Phule Green Gold recorded least incidence of downey

mildew (18.12 and 21.14%), while the parent Konkan Tara showed maximum downey mildew incidence (30.16 and 34.12%) in both F₃ and F₄ generation respectively.

The progenies of cross Hirkani x Phule Ujwala (C₂: P₂ x P₃) recorded highest incidence of downey mildew (28.92 and 23.54%) whereas least incidence (23.25 and 19.24%) was observed in the cross Phule Green Gold x Hirkani (C₁: P₁ x P₂) in both F₃ and F₄ generation respectively (Table 17). These results are in conformity with the findings of Rajput (2012) in bitter gourd, Jagtap (2010) and Patil (2014) in muskmelon.

5.4.1.2 Per cent incidence of Powdery mildew

As regards the per cent incidence of Powdery mildew at field condition the low incidence was observed in the parents Hirkani (25.39 and 21.83%) whereas highest incidence was observed in parent Phule Ujwala (33.24 and 23.54%) in both F₃ and F₄ generation generation respectively (Table 17).

The most of the progenies of crosses Phule Green Gold x Hirkani (C₁: 1 x 2) recorded low incidence (20.43 and 21.32%) of Powdery mildew whereas highest incidence of Powdery mildew (28.78 and 32.27%) was observed in the cross Hirkani x Konkan Tara (C₃: 2 x 4) in the F₃ and F₄ generation respectively (Table 17). The low incidence might be due to the presence of moderate resistant against Powdery mildew in parents Phule green gold and Hirkani. Similar type of finding was also reported by Rajput (2012) in bitter gourd. Jagtap (2010) and Patil (2014) in muskmelon.

5.4.2 Per cent incidence of pest

5.4.2.1 Per cent incidence of fruit fly

In case of incidence of fruit fly at field condition the least infestation was found in Phule Ujwala (11.09 and 9.56%) while highest infestation was observed in Kokan Tara (16.22 and 21.10%) in both F₃ and F₄ generation respectively (Table 18).

Among the three crosses the cross Hirkani x Phule Ujwala C₂: 2 x 3) recorded least infestation of fruit fly (10.12 and 8.47%) while the Hirkani x Kokan Tara (C₃: 2 x 4) recorded highest infestation of fruit fly (14.22 and 12.23%) in both F₃ and F₄ generation respectively (Table 18). These findings are in conformity with the findings of Lawande (1987) and Rajput (2012) in bitter gourd, Jagtap (2010) and Patil (2014) in muskmelon.

6. SUMMARY AND CONCLUSIONS

The present investigation entitled as, “Genetic studies in F_3 and F_4 generations of bitter gourd (*Momordica charantia* L.)” was undertaken at All India Coordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) during the summer 2014 and summer 2015.

Fifteen F_3 progenies of each of crosses Phule Green Gold x Hirkani (C_1 : 1 x 2), Hirkani x Phule Ujwala (C_2 : 2 x 3) and Hirkani x Konkan Tara (C_3 : 2 x 4) each cross with 225 plant population along with their parents, whereas fifteen F_4 progenies of cross Phule Green Gold x Hirkani (C_1 : 1 x 2), Hirkani x Phule Ujwala (C_2 : 2 x 3) and Hirkani x Konkan Tara (C_3 : 2 x 4) each cross with 225 plant population were evaluated along with their parents in randomized block design with two replications. Data on seventeen characters was recorded on total plant population in both generation and used for estimation of variability, heritability (broad sense), genetic advance, genetic advance as per cent of mean and correlation coefficients.

6.1 Variability, heritability and genetic advance

A good range of variability was observed for all Fifteen traits of bitter gourd in three crosses for F_3 and F_4 generation. Genotypic coefficient of variation was lower than the phenotypic coefficient of variation in all quantitative traits which indicate role of environment in the expression of traits. In F_3 and F_4 generations of cross Phule Green Gold x Hirkani (C_1 : 1 x 2), high values of genotypic and phenotypic coefficient of variations were recorded for

traits *viz.*, number of primary branches per vine, number of fruits per vine, average fruit yield per vine, average weight of fruit and yield tonnes per hectare.

In F_3 and F_4 generations of the cross Hirkani x Phule Ujwala (C_2 : 2 x 3) number of primary branches per vine, number of fruits per vine, average fruit yield per vine, average weight of fruit, yield tonnes per hectare recorded high values of genotypic and phenotypic coefficients of variations in F_3 and F_4 generations.

In F_3 and F_4 generations of cross Hirkani X Konkan Tara (C_3 : 2 x 4) number of primary branches per vine, number of fruits per vine, average fruit yield per vine, average weight of fruit only in F_3 generation, yield tonnes per hectare recorded high values of genotypic and phenotypic coefficients of variations.

Thus the high amount of genotypic and phenotypic coefficients of variations indicates presence of ample amount of genetic variation for the characters which can be used effectively in crop improvement programme.

High heritability was observed in F_3 and F_4 generations of three crosses *viz.* Phule Green Gold x Hirkani (C_1 : 1 x 2), Hirkani x Phule Ujwala (C_2 : 2 x 3) and Hirkani x Konkan Tara (C_3 : 2 x 4). In cross Phule Green Gold x Hirkani (C_1 : 1 x 2) heritability was ranged from 71.30 to 94.81 per cent. In cross Hirkani x Phule Ujwala (C_2 : 2 x 3) it ranged from 66.06 to 95.40 per cent. In cross Hirkani x Konkan Tara (C_3 : 2 x 4) from 63.27 to 97.10 per cent. It indicated that major role of genetic constitution in expression of characters. Also, range of genetic advance was found high for most of the characters.

Association of high heritability with high genetic advance as per cent of mean was recorded in F_3 generation of the cross Phule Green Gold x Hirkani (C_1 : 1 x 2) for the characters like final vine length, number of fruits per vine, fruit yield per vine and yield per hectare. Whereas the high estimates of heritability with moderate estimates of genetic advance as per cent of mean was observed for number of primary branches per vine, average weight of fruit, average length of fruit. The characters days to first female flower appearance, days required for first harvest of fruit, crop duration, average diameter of fruit and node at which first female flower appeared showed high estimates of heritability with low estimates of genetic advance as per cent of mean in F_3 generation.

In cross Hirkani x Phule Ujwala (C_2 : 2 x 3) the traits like number of fruits per vine, fruit yield per vine, yield per hectare recorded high estimates of heritability along with high estimates of genetic advance as per cent of mean in F_3 generation. Whereas the characters number of final vine length, average length of fruit, recorded high estimates of heritability with moderate estimates of genetic advance as per cent of mean. While the character primary branches per vine, node at which first female flower appeared, days to first female flower appearance, days required for first harvest of fruit, average weight of fruit, average diameter of fruit and crop duration showed high estimates of heritability with low estimates of genetic advance as per cent of mean in F_3 generation.

In cross Hirkani x Konkan Tara (C_3 : 2 x 4) characters like number of fruits per vine, fruit yield per vine, yield per hectare recorded high estimates of heritability along with high estimates of

genetic advance as per cent of mean. Whereas the characters number of primary branches per vine, node at which first female flower appeared, average diameter of fruit, average weight of fruit, average length of fruit, crop duration recorded high estimate of heritability with moderate estimate of genetic advance as per cent of mean. The rest of characters like final vine length, days required for first harvest of fruit, days to first female flower appearance showed the high estimates of heritability with lower estimate of genetic advance as per cent of mean in F_3 generation.

In case of F_4 generation, in cross Phule Green Gold x Hirkani (C_1 : 1 x 2) the association of high estimate of heritability with high estimate of genetic advance as per cent of mean were recorded in characters like number of fruits per vine, fruit yield per vine, average weight of fruit, yield per hectare, crop duration. Whereas the high estimate of heritability with moderate estimate of genetic advance as per cent of mean was observed for number of primary branches per vine, node at which first female flower appeared, average length of fruit, average diameter of fruit. While the high estimate of heritability with low estimate of genetic advance as per cent of mean was recorded in final vine length, days to first female flower appearance, days required for first harvest of fruit.

In cross Hirkani x Phule Ujwala (C_2 : 2 x 3) reported that high estimates of heritability along with high estimates of genetic advance as per cent of mean in the characters like number of primary branches per vine, number of fruits per vine, fruit yield

per vine, average weight of fruit, yield per hectare, crop duration. Whereas the characters, node at which first female flower appeared, average length of fruit recorded high estimate of heritability with moderate estimate of genetic advance as per cent of mean. While the characters like final vine length, days to first female flower appearance, average diameter of fruit and days required for first harvest of fruit showed the high estimate of heritability with low estimate of genetic advance as per cent of mean in the F_4 generation.

In cross Hirkani x Konkan Tara (C_3 : 2 x 4) characters like number of fruits per vine, fruit yield per vine, yield per hectare recorded high estimates of heritability along with high estimates of genetic advance as per cent of mean. Whereas the characters *viz.* primary branches per vine, node at which first female flower appeared, average weight of fruit, average length of fruit, Crop duration and average diameter of fruit recorded high estimate of heritability with moderate estimate of genetic advance as per cent of mean. The rest of characters final vine length, days to first female flower appearance and days required for first harvest of fruit showed the high estimates of heritability with lower estimate of genetic advance as per cent of mean.

Hence presence of high heritability along with high genetic advance as per cent of mean might be attributed due to the dominance of additive gene effect. Therefore phenotypic selection will be effective in further breeding programme.

High heritability with low genetic advance as per cent of mean indicates non-additive gene effect. Thus selection for such characters will not be effective in further breeding programme.

6.2 Correlation coefficient

In case of F_3 and F_4 generations of all three crosses the significant and high positive correlation both at phenotypic and the genotypic level was observed between fruit yield per vine and the yield contributing characters such as final vine length, number of primary branches per vine, number of fruits per vine, average weight of fruit, average length of fruit and average diameter of fruit. While, the characters like days required for first female flower appearance, node at which first female flower appeared and days required for first harvest of fruit and crop duration were significantly and negatively correlated with average yield per vine, which were helpful relationships. Most of these characters were also found to be positively associated among themselves.

6.3 Fruit characters (Qualitative)

In case of fruit shape, the F_3 and F_4 segregating progenies of crosses Phule Green Gold x Hirkani (C_1 : 1 x 2), Hirkani x Phule Ujwala (C_2 : 2 x 3) and Hirkani x Konkan Tara (C_3 : 2 x 4) observed medium shape of fruits. In case of fruit colour, green colour of fruits was observed in crosses Phule Green Gold x Hirkani (C_1 : 1 x 2), Hirkani x Phule Ujwala (C_2 : 2 x 3) and Hirkani x Konkan Tara (C_3 : 2 x 4) in the F_3 and F_4 generations. In case of prickles on fruit surface, Phule Green Gold x Hirkani (C_1 : 1 x 2), Hirkani x Phule Ujwala (C_2 : 2 x 3) and Hirkani x Konkan Tara (C_3 : 2 x 4) showed medium prickles on fruit surface. While some progeny of

cross Hirkani x Konkan Tara was showed high prickles in F₄ generations.

6.4 Per cent incidence of diseases and pests

The highest incidence of downey mildew was recorded in Konkan Tara (30.16 and 34.12 %) whereas the least incidence of was recorded in Phule Green Gold (18.12 and 21.14 %) in both F₃ and F₄ generation respectively. In case of segregating progenies, the highest incidence of downey mildew (28.92 and 23.54 %) was recorded in most of the progenies of the cross Hirkani x Phule Ujwala (C₂: P₂ x P₃) and least incidence of downey mildew (23.25 and 19.24 %) was recorded in Phule Green Gold x Hirkani (C₁: P₁ x P₂) in F₃ and F₄ generations respectively.

The low incidence of Powdery mildew at field condition was recorded in the parents Hirkani (25.39 and 21.83 %) while the highest incidence was observed in parent Phule Ujwala (33.24 and 23.54 %) in both F₃ and F₄ generations respectively. In case of crosses, most of the progenies was recorded the lowest incidence of Powdery mildew (20.43 and 21.32 %) at field condition in cross Phule Green Gold x Hirkani (C₁: P₁ x P₂) whereas, the highest incidence of Powdery mildew (28.78 and 32.27%) was observed in the cross Hirkani x Kokan Tara (C₃: 2 x 4) in the F₃ and F₄ generations respectively.

The highest infestation of fruit fly was found in Kokan Tara (16.22 and 21.10 %) while least infestation was observed in Phule Ujwala (11.09 and 9.56 %) in both F₃ and F₄ generations respectively. Among the three crosses, the cross Hirkani x Phule Ujwala C₂: 2 x 3) recorded least infestation of fruit fly (10.12 and

8.47 %) while the Hirkani x Kokan Tara (C_3 : $P_2 \times P_4$) recorded highest infestation of fruit fly (14.22 and 12.23 %) in both F_3 and F_4 generations respectively.

6.5 Conclusion

1. The maximum phenotypic and genotypic coefficient of variation was observed for characters *viz.* number of primary branches per vine, number of fruits per vine, fruit yield per vine, average weight of fruit and fruit yield per hectare in bitter gourd and remaining character shows moderate PCV and GCV in three crosses *viz.*, C_1 (Phule Green Gold X Hirkani), C_2 (Hirkani X Phule Ujwala) and C_3 (Hirkani X Konkan Tara) in F_3 and F_4 generations. The characters showing wide range of variation provide ample scope for selecting the desirable plant types.
2. Phenotypic coefficient of variation (PCV) was higher than the respective genotypic coefficient of variation (GCV) for all the characters of F_3 and F_4 generations of three crosses denoting environmental factors influencing their expression to some degree. Wide difference between PCV and GCV indicates the role of environmental factors where as narrow difference between PCV and GCV suggested that these characters are least influenced by environment.
3. High estimates of heritability for all characters of three crosses of F_3 and F_4 generations indicating that they were least affected by environment and selection based on phenotypic performance would be reliable.

4. High estimates of genetic gain were observed for most of the yield and yield contributing characters in three crosses of F_3 and F_4 generations thus they could be improved to a large extent through selection.
5. High heritability with high genetic advance as per cent of mean was observed for the characters final vine length, number of fruits per vine, fruit yield per vine, average weight of fruit and fruit yield per hectare in three crosses of F_3 and F_4 generations and phenotypic selection for their improvement could be achieved by selection pressure.
6. High heritability with low genetic advance as per cent of mean was observed for average length of fruit, average diameter of fruit and days required for first harvest of fruit in different crosses for which selection would not be rewarding, in such cases selection should be delayed.
7. In all three crosses of F_3 and F_4 generations the significant and positive correlation both at phenotypic and the genotypic level was observed between fruit yield per vine and the yield contributing characters. Thus association of characters should be considered for improvement.
8. Out of 225 progenies in each cross, the six superior progenies were identified for future crop improvement *i.e.* raising of F_5 generation based on more fruit yield per vine with green colour, medium shape and prickles on fruit. The progenies *viz.* Cross-1 (progeny 2, 3) Cross-2 (progeny 3, 4) and Cross-3 (progeny 2, 3) are important for further studies. Such types of progenies are extremely helpful in crop improvement

programme for development of cultivar or variety with maximum fruit yield per vine by simple selection method.

9. For improvement of bitter gourd the characters such as vine length, number of primary branches, days required for first female flower appearance, node at which first female flower appeared, days required for first harvest of fruit, crop durations, number of fruits per vine, average fruit weight, average length of fruit, average diameter of fruit and fruit yield per vine should be considered for development of ideal genotypes.

Future line of work –

In present investigation, all three crosses of bitter gourd studied for F_3 and F_4 progenies showed certain difference of variability, heritability and genetic advance which can be exploited in future crop improvement work. The PCV was higher than GCV for almost all the characters studied. For development of superior genotypes in bitter gourd, the yield contributing and qualitative characters should be considered. The heritability and genetic advance was high for most of the characters. The selection based on high heritability and genetic advance for different characters should be kept in mind while selecting better genotypes. The yield per hectare has positive and significant association with almost all yield contributing characters. which should be considered, while selecting the ideal genotypes in bitter gourd. The progenies of cross 1 (progeny 2, 3) cross-2 (progeny 3, 4) and cross-3 (progeny 2, 3) should be exploited for F_5 generation to obtain high yield with better quality fruit in bitter gourd.

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*** Originals not seen.**

8. VITA

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A candidate for the degree

of

DOCTOR OF PHILOSOPHY (HORTICULTURE)

in

VEGETABLE SCIENCE

Title of thesis : “Genetic studies in F₃ and F₄ generations of Bitter gourd (*Momordica charantia* L.)”

Major field : Horticulture

BIOGRAPHICAL INFORMATION

Personal : Born at Shrigonda, Dist. Ahmednagar on 9th July, 1988. Son of Shri. Nandkumar and Sau. Pushpa Alekar, having two sister Sau. Surekha, Meena and brother Mahendra.

Educational : ➤ Attended Primary School at Z. P. Marathi School, Mehetre vasti, Tah: Shrigonda, Dist: Ahmednagar and Secondary School at Sharda Madhyamik Vidyalaya, Shrigonda, Ahmednagar.

➤ Higher Secondary School at Shrigonda, Maharaja Jivajirao Shinde Mahavidyalya, Shrigonda, Ahmednagar.

- Received Bachelor of Science (Horti.) degree from College of Agriculture, Dapoli (Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli) in 2010.
 - Received Master of Science (Horti.) degree from Dr. Panjabrao Deshmukh Krishi Vidhyapeeth, Akola, in 2012.
 - Qualified the **NET** examination in 2016.
- Academic performance**
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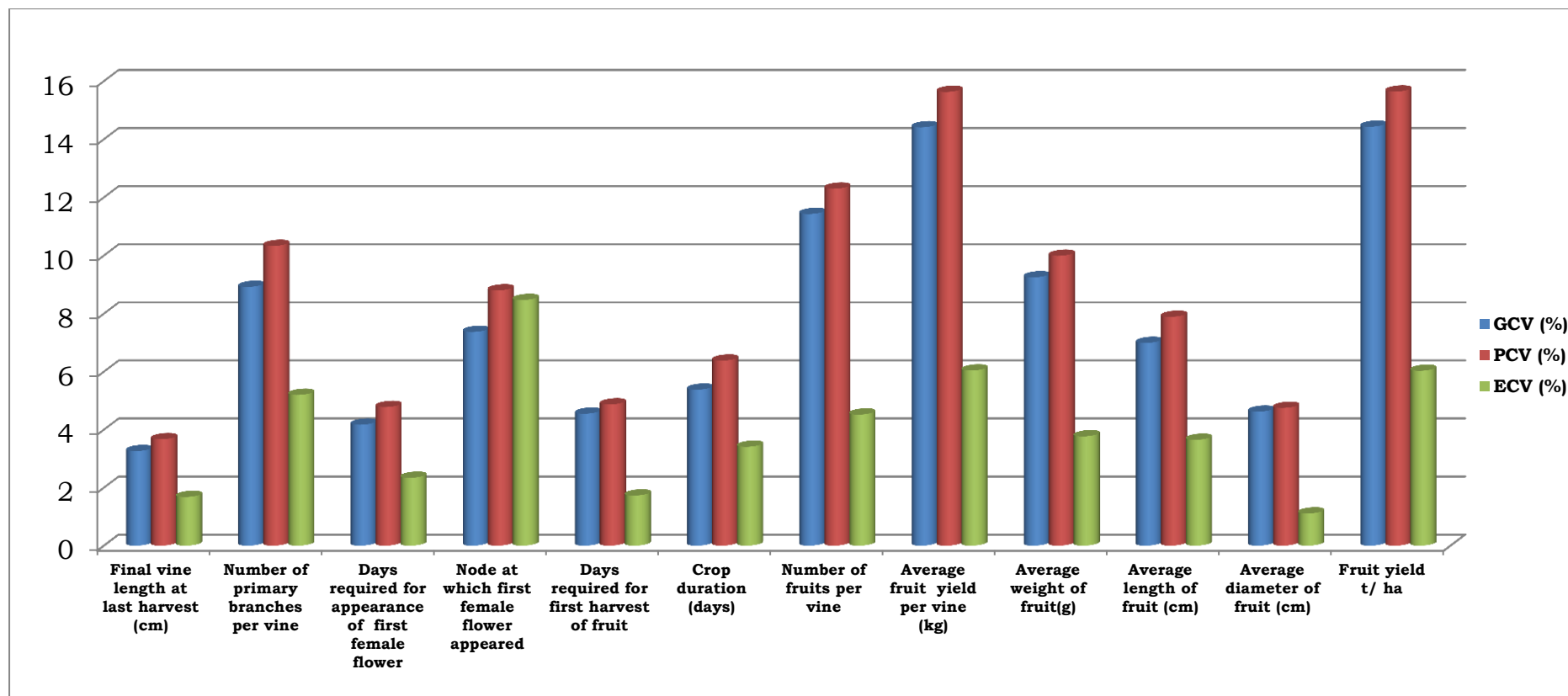


Fig. 1: GCV, PCV, ECV of two parents and F₃ population of cross Phule Green Gold X Hirkani (C₁: 1 x 2).

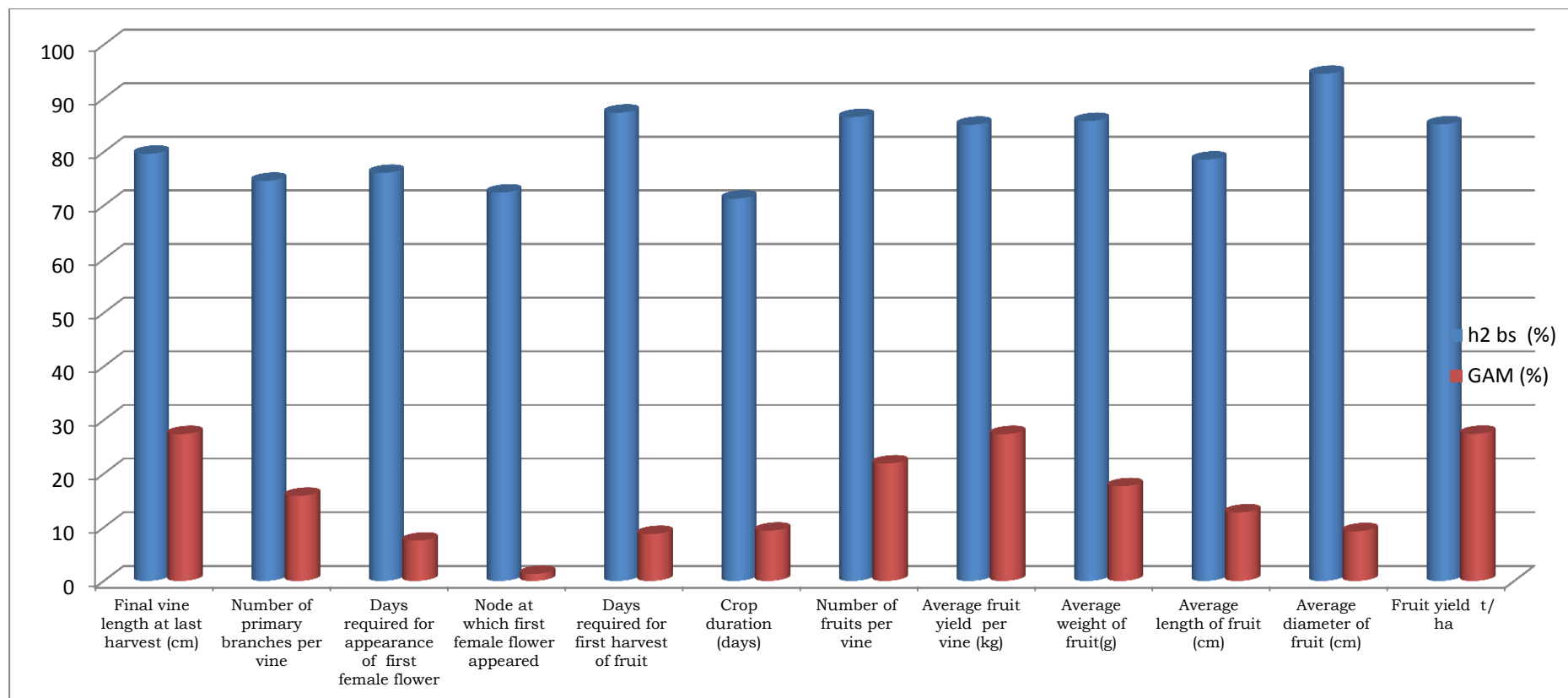


Fig. 2: Heritability and percent mean of genetic advance of two parents and F₃ population of cross Phule Green Gold X Hirkani (C₁: 1 x 2).

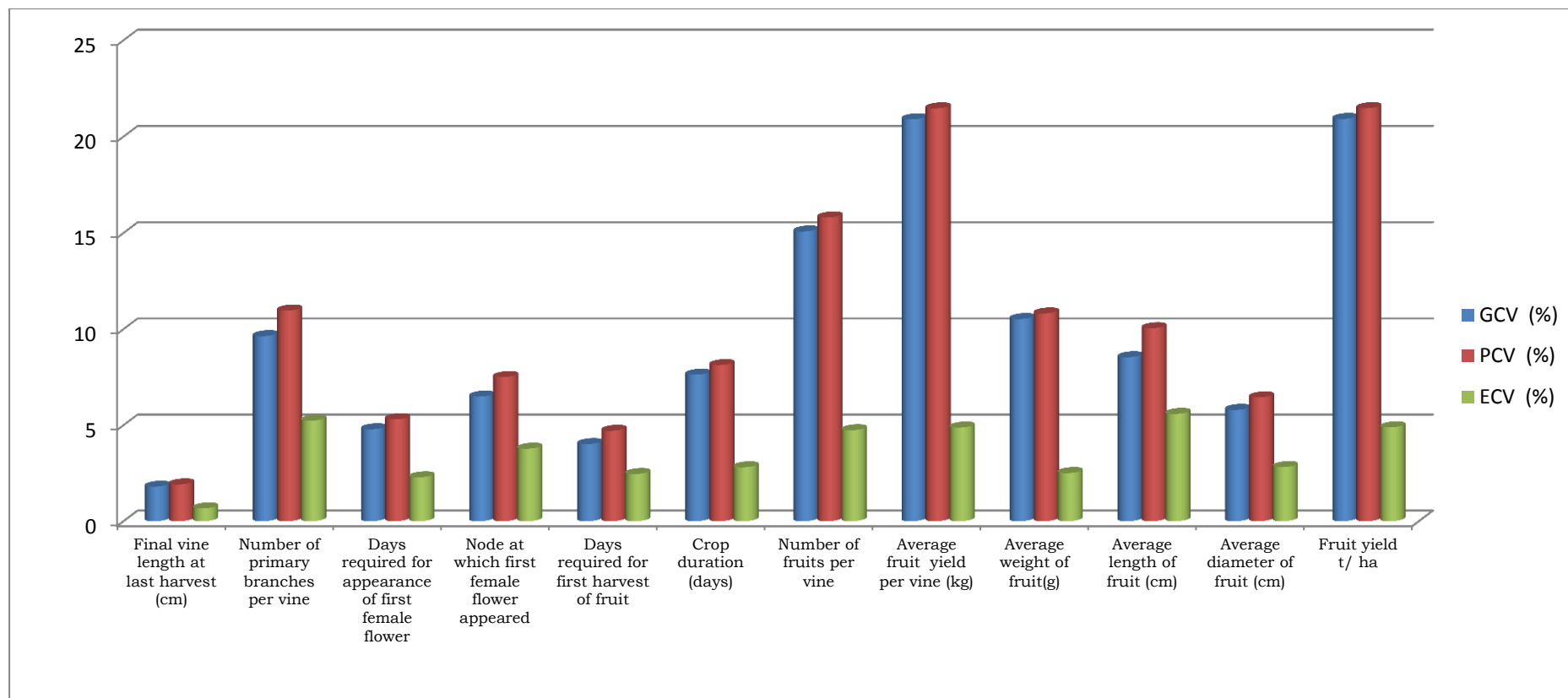


Fig. 3: GCV, PCV, ECV of two parents and F₄ population of cross Phule Green Gold X Hirkani (C₁: 1 x 2).

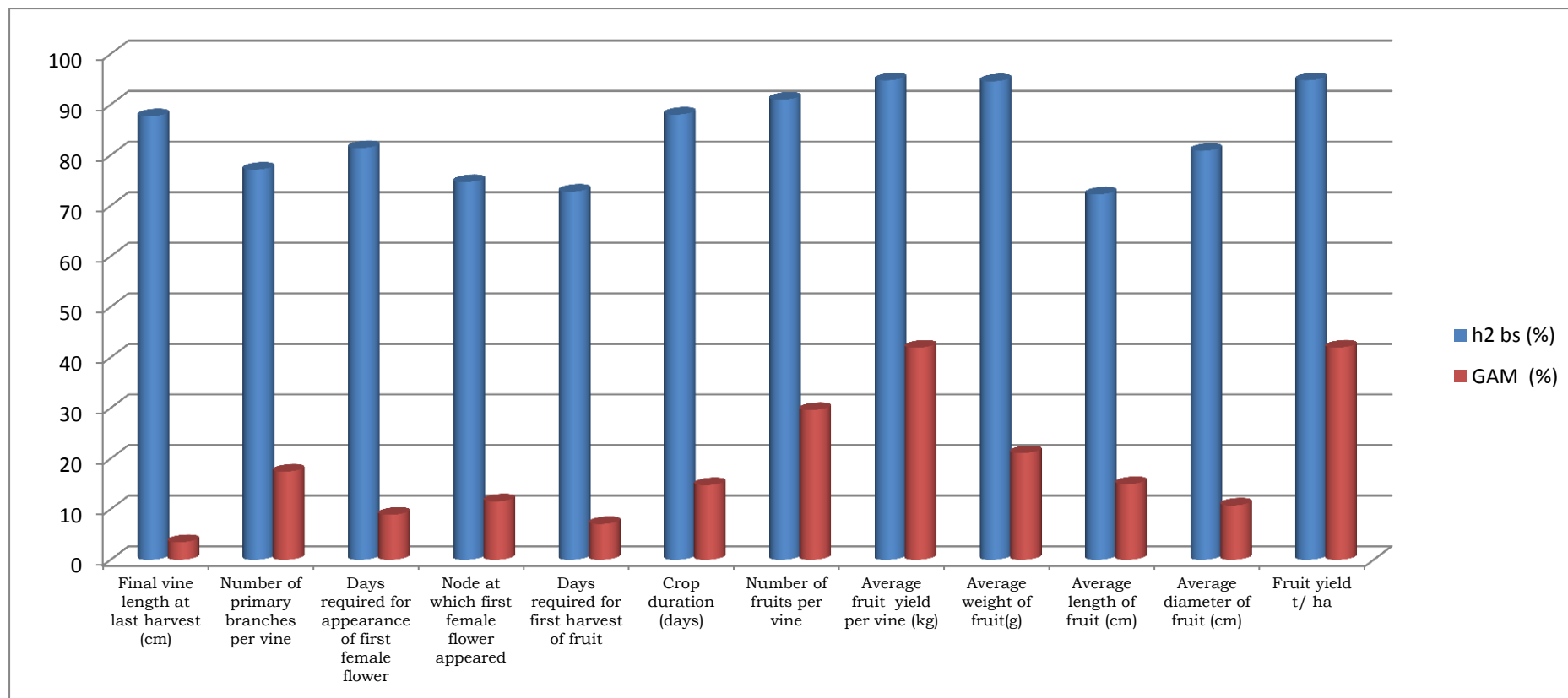


Fig. 4: Heritability and percent mean of genetic advance of two parents and F₄ population of cross Phule Green Gold X Hirkani (C₁: 1 x 2).

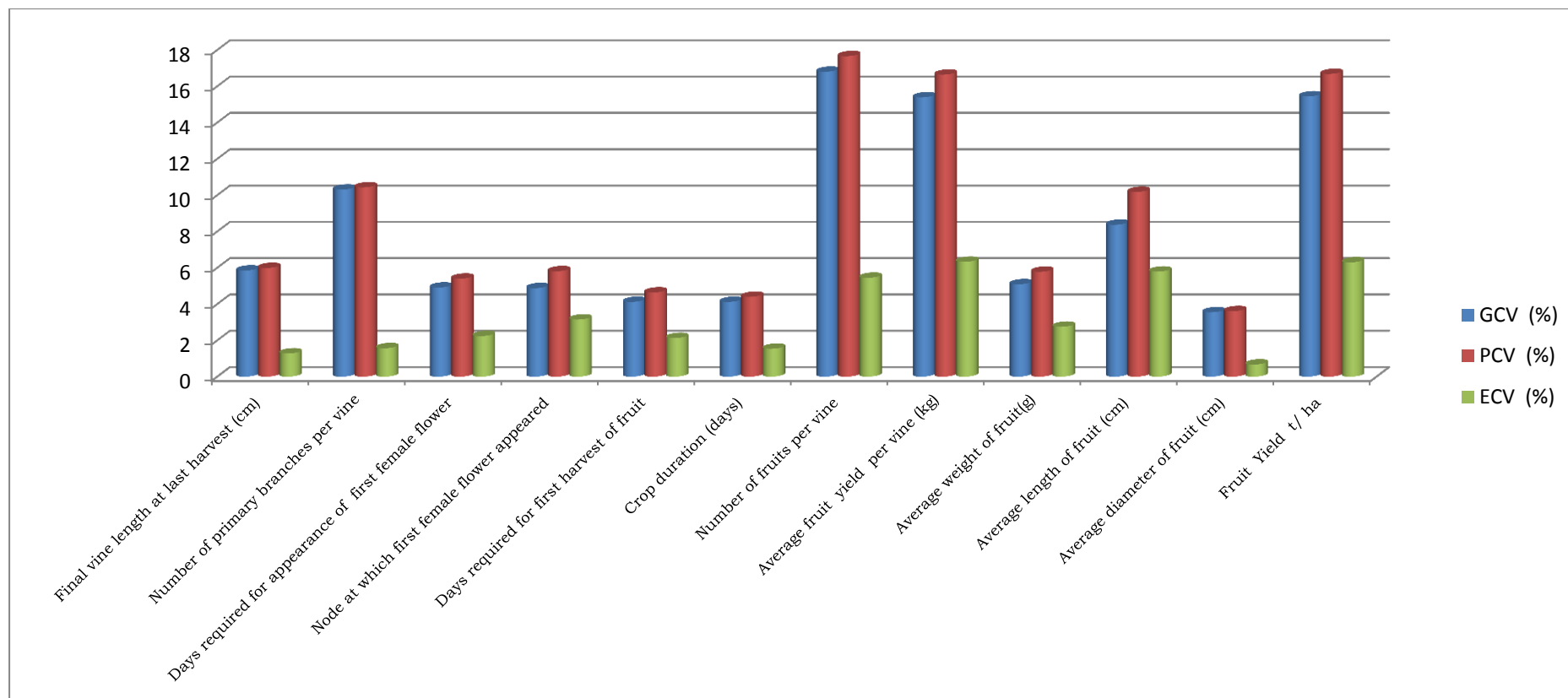


Fig. 5: GCV, PCV, ECV of two parents and F₃ population of cross Hirkani X Phule Ujwala (C₂: 2 x 3).

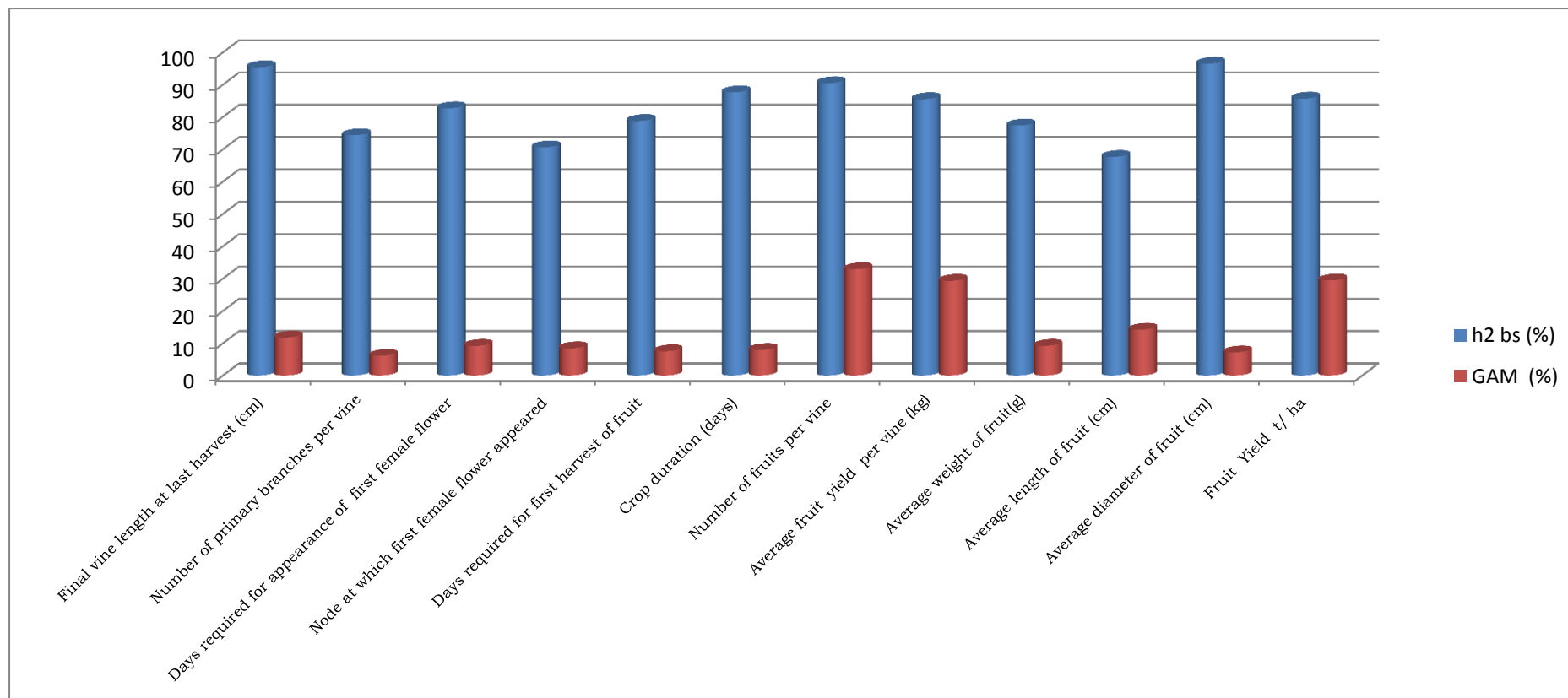


Fig. 6: Heritability and percent mean of genetic advance of two parents and F_3 population of cross Hirkani X Phule Ujwala (C_2 : 2 x 3).

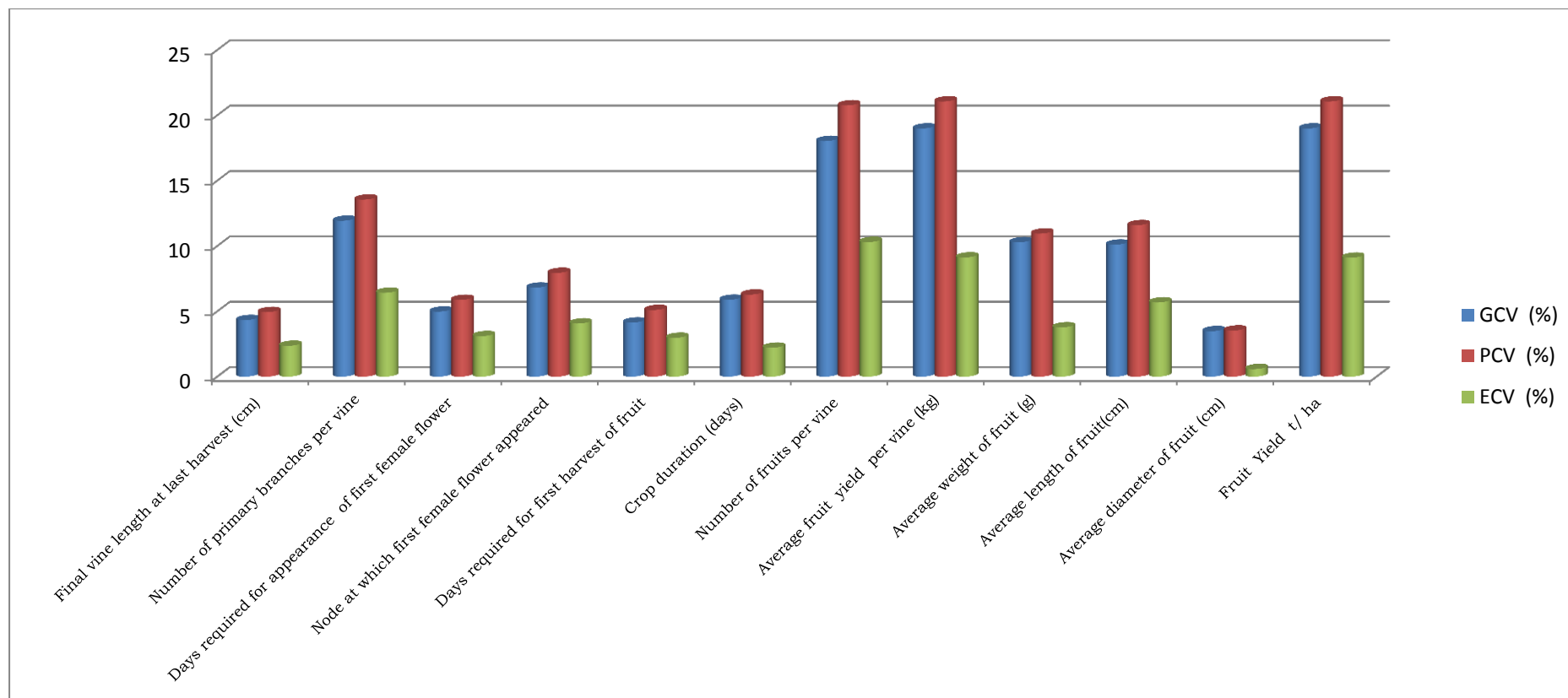


Fig. 7: GCV, PCV, ECV of two parents and F₄ population of cross Hirkani X Phule Ujwala (C₂: 2 x 3).

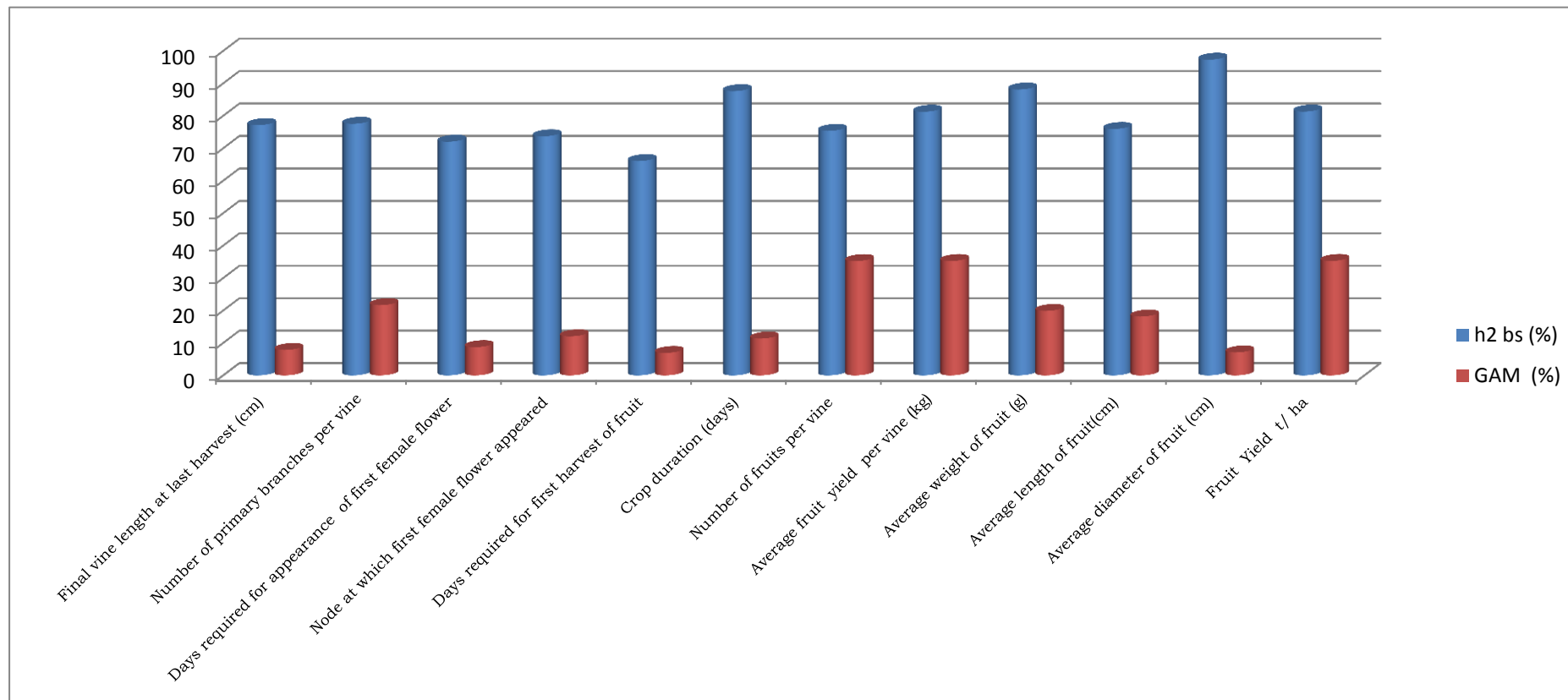


Fig. 8: Heritability and percent mean of genetic advance of two parents and F₄ population of cross Hirkani X Phule Ujwala (C₂: 2 x 3).

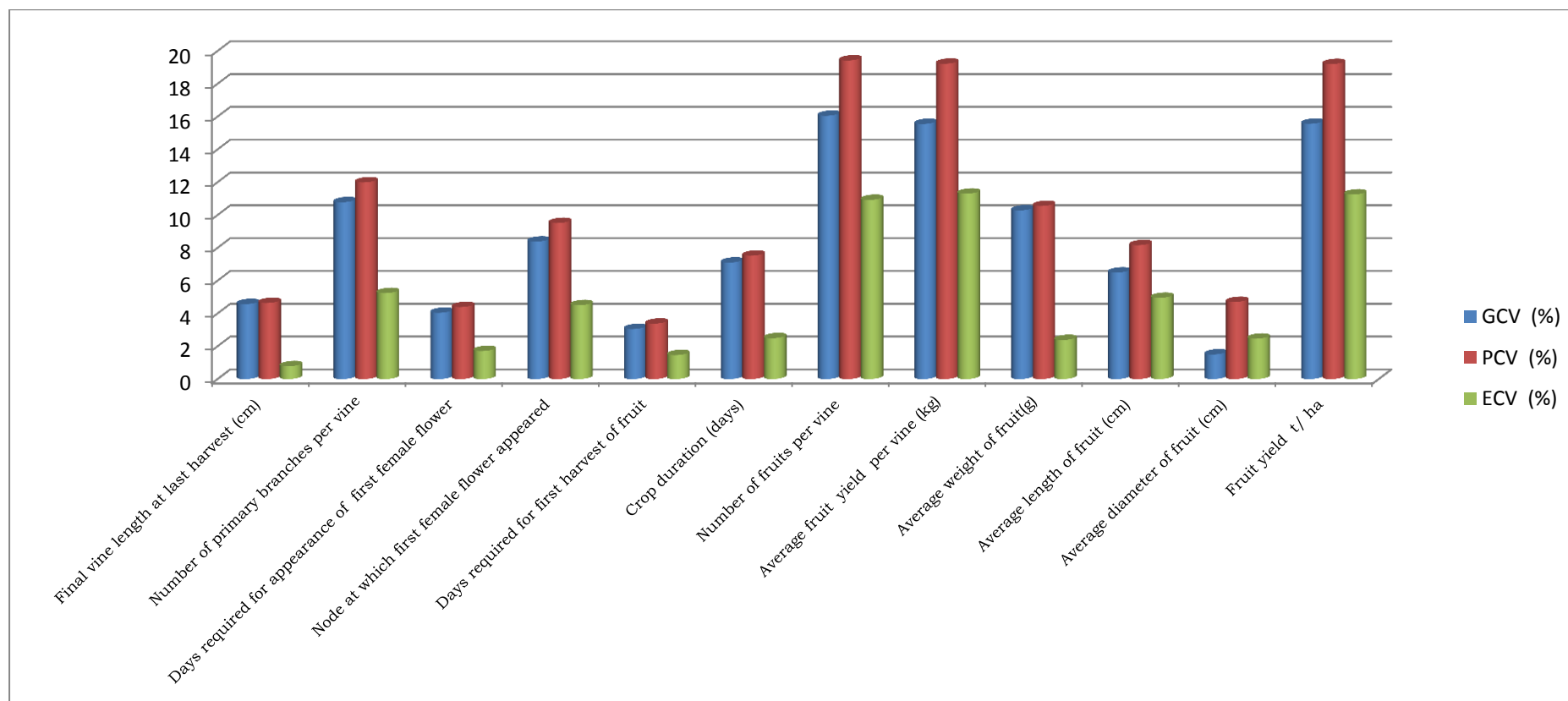


Fig. 9: GCV, PCV, ECV of two parents and F_3 population of cross Hirakani X Konkan Tara (C_3 : 2 x 4).

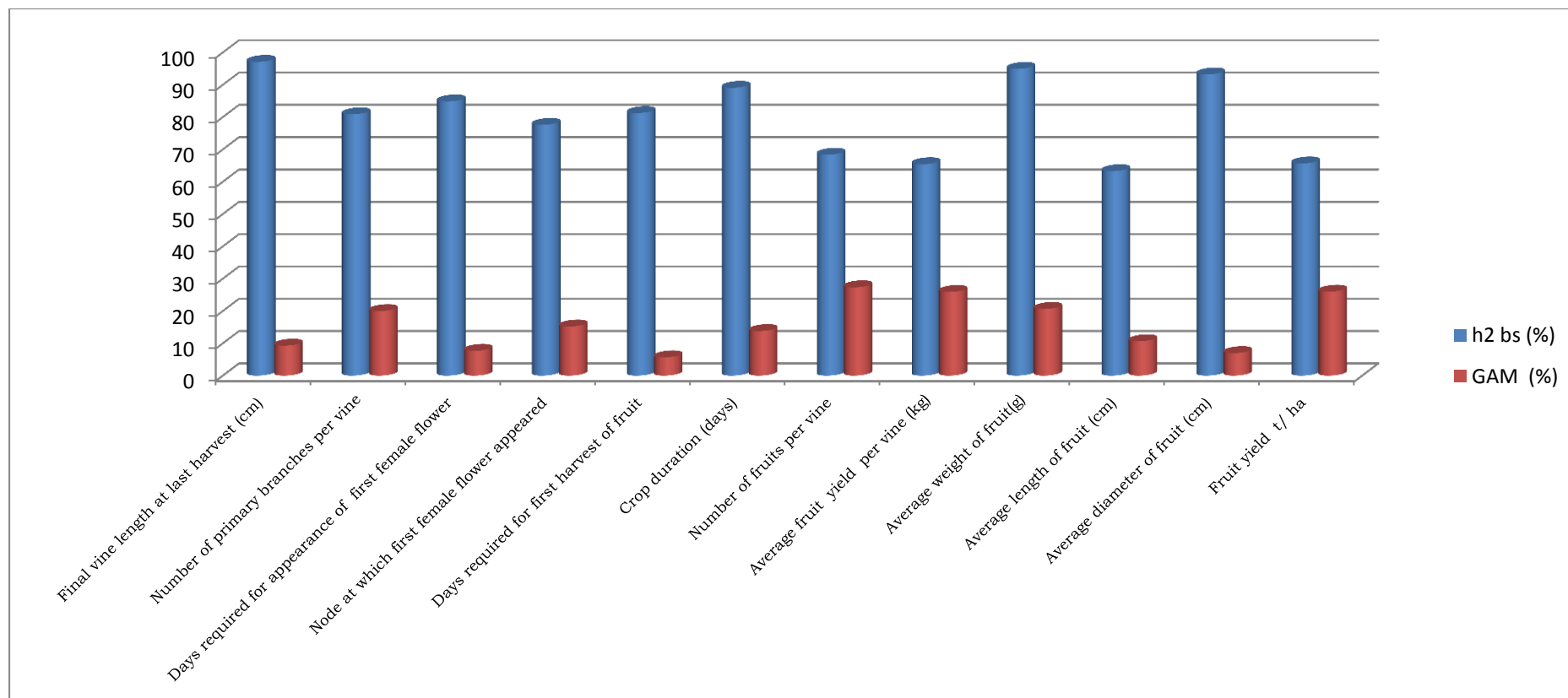


Fig. 10: Heritability and percent mean of genetic advance of two parents and F₃ population of cross Hirkani X Konkan Tara (C₃: 2 x 4).

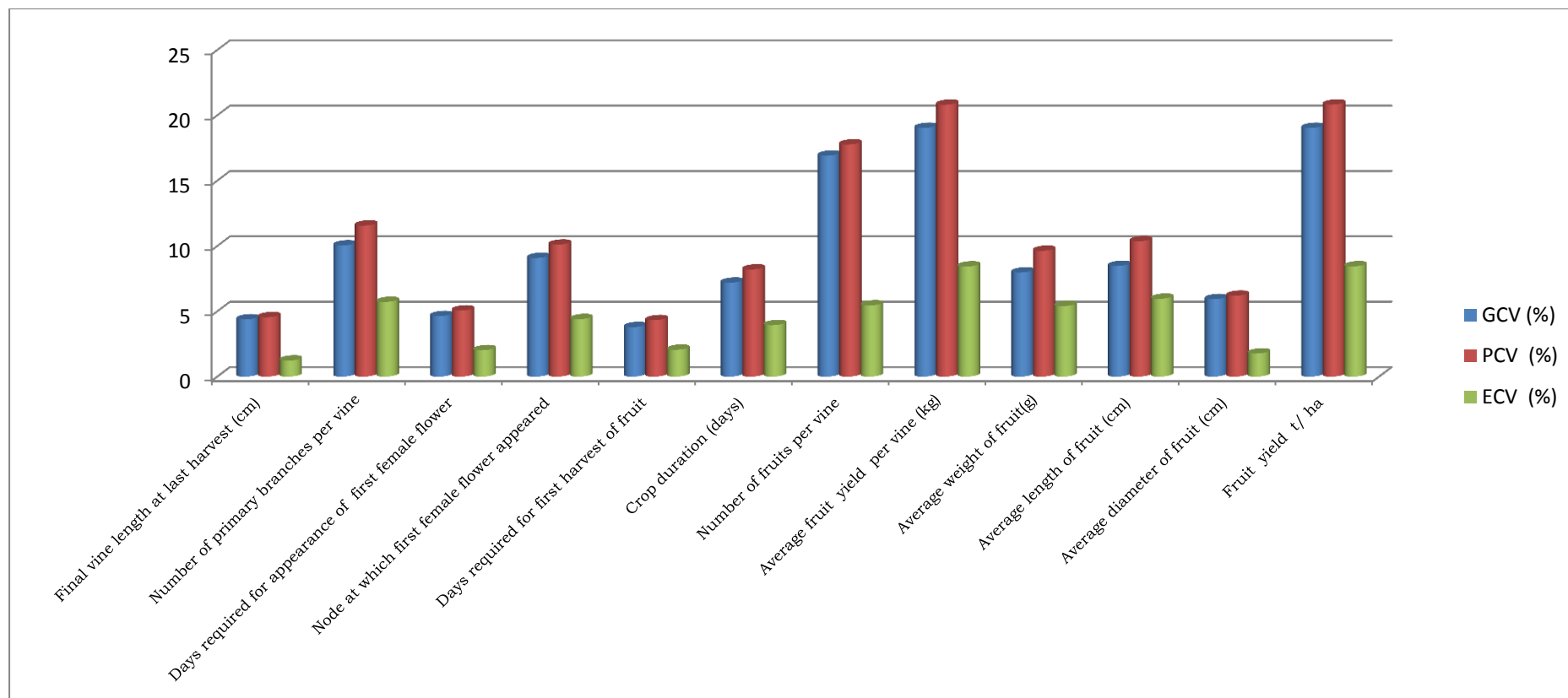


Fig. 11: GCV, PCV, ECV of two parents and F₄ population of cross Hirakani X Konkan Tara (C₃: 2 x 4).

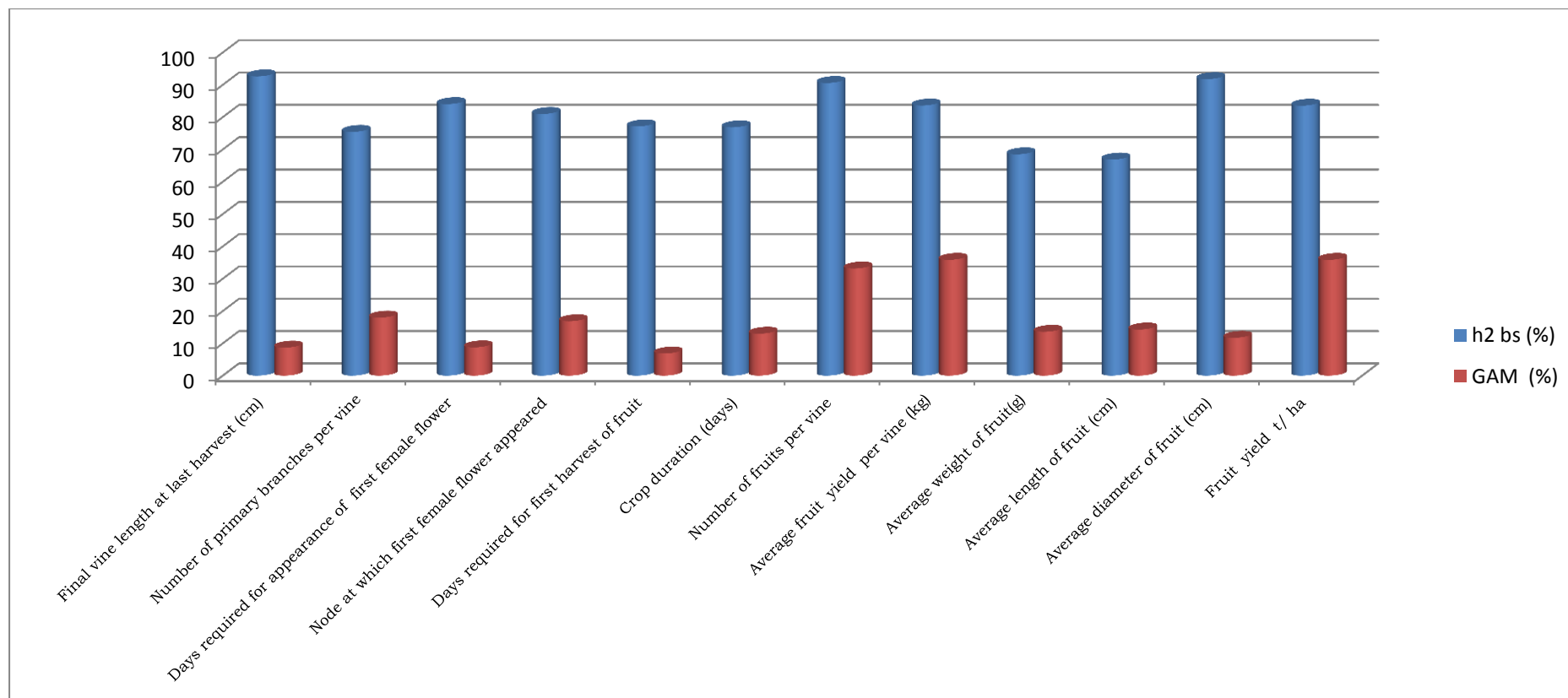


Fig. 12: Heritability and percent mean of genetic advance of two parents and F₄ population of cross Hirakani X Konkan Tara (C₃: 2 x 4).



P_1



P_2



$P_1 \times P_2$



Progeny - 2



Progeny - 3

**Plate II. Promising selections of cross Phule
Green Gold x Hirkani ($C_1: 1 \times 2$)**



P_2



P_3

$\downarrow$
 $P_2 \times P_3$

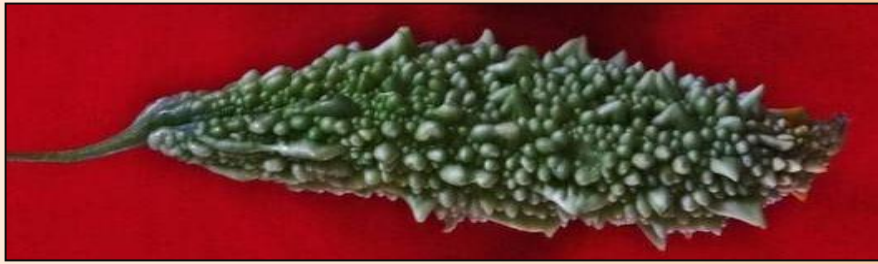


Progeny - 3



Progeny - 4

**Plate III. Promising selections of cross Hirkani x
Phule Ujwala (C_2 : 2 x 3)**



P_2



P_4

↓

$P_2 \times P_4$



Progeny - 2



Progeny - 3

**Plate IV. Promising selections of cross Hirkani x
Konkan Tara (C_3 : 2 x 4).**



View of Experimental plot in Summer 2014 Season.



View of Experimental plot in Summer 2015 season.

Plate I



**Plate III. Promising selections of cross Phule
Green Gold x Hirkani (C₁: 1 x 2)**

