BIOSYSTEMIC STUDIES IN RANDOMLY MATED HYBRID PROGENIES OF MANGO (*Mangifera indica* L.)

by

Ms. Khan Salma Mustafa
(Reg. No. 015/64)

A Thesis submitted to the
MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI – 413 722, DIST. AHMEDNAGAR
MAHARASHTRA, INDIA

in partial fulfillment of the requirements for the degree

of

DOCTOR OF PHILOSOPHY (AGRICULTURE)

in

HORTICULTURE (FRUIT SCIENCE)

DEPARTMENT OF HORTICULTURE

POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI VIDYAPEETH
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CANDIDATE'S DECLARATION

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

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Date : / /2022 **(S. M. Khan)**

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CERTIFICATE

This is to certify that the thesis entitled, "**BIOSYSTEMIC STUDIES IN RANDOMLY MATED HYBRID PROGENIES OF MANGO (*Mangifera indica* L.)"** submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (M.S.) in partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE)** in **HORTICULTURE (FRUIT SCIENCE),** embodies the results of a piece of *bona fide* research work carried out by **Ms. KHAN SALMA MUSTAFA,** 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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"When you say "It's hard", it actually means "I'm not strong enough to fight for it" but When one door closes, another opens; but we often look so long and so regretfully upon the closed door that we do not see the one that has opened for us, when I approach the completion of this manuscript, I humbly grab this opportunity to acknowledge reverentially, many people who deserve special mentions for their varied contributions in assorted ways that helped me during my research and the making of this thesis. I could never have embarked and finished the same without their kind support and encouragements.

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LIST OF ABBREVIATIONS

%	:	Percentage
@	:	At the rate of
∑	:	Summation of
^{0}C	:	Degree Celsius
^{0}B	:	Degree brix
A	:	Acute
AFLP	:	Amplified Fragment Length Polymorphism
RAPD	:	Random Amplified Polymorphic DNA
Bp	:	Base pair
C.D.	:	Critical difference
cm	:	Centimeter
cm^2	:	Centimeter square
C:I	:	Chloroform : isoamyl alcohol
C. V.	:	Coefficient of variance
CTAB	:	Cetyl tri-methyl ammonium bromide
DNA	:	Deoxyribonucleic acid
dNTPs	:	Deoxyribonucleoside triphosphates
DW	:	Dry Weight
EDTA	:	Ethylene diamine tetra acetic acid
et al.	:	Et alli (Co-workers)
etc	:	Etcetera
Fig	:	Figure
FW	:	Fresh Weight
g	:	Gram
i.e.	:	That is
ISSR	:	Inter Simple Sequence Repeat
J.	:	Journal
Kg./ha	:	Kilogram per hectare
L.	:	Linnaeus
M	:	Molar
M.S.	:	Maharashtra State
MPKV	:	Mahatma Phule Krishi Vidyapeeth
mg	:	Milligram
min.	:	Minute
ml	:	Millilitre
mm	:	Millimetre
mM	:	Millimolar
MT	:	Metric tonnes
ng	:	Nano gram
nm	:	Nanometre

no.	:	Number
O	:	Obtuse
PCR	:	Polymerase Chain Reaction
PCV	:	Phenotypic coefficient of variation
pH	:	Potenz (-log[H+])
QTLs	:	Quantitative trait loci
RPM	:	Revolution per minute
S.E.	:	Standard error
Sci.	:	Science
Sel.	:	Selection
SSR	:	Simple Sequence Repeat
TSS	:	Total soluble solids
TE buffer	:	Tris-EDTA buffer
U	:	Unit
Univ.	:	University
UV	:	Ultra violet
V	:	Volt
Var.	:	Variety
Viz.	:	Namely
w/v	:	Weight by volume
µg	:	Microgram
µl	:	Microlitre
<	:	Less than
/	:	Per

ABSTRACT

"BIOSYSTEMIC STUDIES IN RANDOMLY MATED HYBRID PROGENIES OF MANGO (*Mangifera indica* L.)"

by

KHAN SALMA MUSTAFA

A candidate for the degree

of

DOCTOR OF PHILOSOPHY (HORTICULTURE)

in

FRUIT SCIENCE

2022

Research Guide	**:**	**Dr. S. A. Ranpise**
Department	**:**	**Horticulture (Fruit Science)**

The present investigation entitled "Biosystemic studies in randomly mated hybrid progenies of mango (*Mangifera indica* L.)" was carried out during the years 2015-2017. The objective of the present investigation was to study the diversity of the hybrid derivatives at morphological, biochemical and molecular level. For this study forty-two hybrid derivatives of mango were selected from existing germplasm at Research-cum-Instructional Farm, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri. All the hybrid derivatives were screened for tree, leaf, inflorescence, fruit, pulp, stone, biochemical, yield, sensory qualities, disease and physiological disorders and molecular characterization. Six promising hybrid derivatives along with six check varieties on the basis of desirable traits were subjected to molecular characterization using SSR markers.

The experimental results showed that large variability was present in the hybrid mango derivatives for morphological, biochemical, yield, sensory evaluation, reaction to diseases and physiological disorders and molecular traits. For tree characters all hybrid derivatives showed variation in tree height (6.47 m to 12.19 m), and volume (100.6 m^3 to 256.54 m^3). In leaf characters the highest leaf length (35.15 cm) and breadth (8.80 cm) was recorded by hybrid-10 and all the hybrid derivatives recorded simple leaf type; for leaf colour twenty-four hybrid derivatives showed dark green coloured leaves, seventeen derivatives showed green and remaining one showed light green coloured leaves. The leaves of all hybrid derivatives showed non-waxy appearance.

The results indicated that the highest number of days required from bud burst to full bloom was recorded by hybrid-6 (62.5 days). Among all the hybrid derivatives studied the inflorescence of eighteen hybrid derivatives were broadly pyramidal, fourteen hybrid derivatives had narrowly pyramidal inflorescences while ten hybrid derivatives had pyramidal inflorescences. The inflorescence length ranged from 13.91 cm to 30.77 cm

and breadth ranged from 6.10 to 16.33 cm. In all hybrid derivatives only two vegetative flushes were observed per year. Green coloured panicles were observed in twenty-four hybrids whereas panicles of six hybrids were yellow, five reddish green, two light green, four reddish and remaining one reddish yellow. Thirty-five hybrid derivatives showed yellow coloured flowers, four light yellow, one yellowish pink, one reddish yellow and one yellowish green coloured flowers. The highest number of hermaphrodite flowers (365.55) and male flowers (971.5) per panicle during the investigation years was recorded in hybrid-26. The sex ratio varied from 0.15 (hybrid-15) to 0.47 (hybrid-6). Number of inflorescence per shoot in all hybrid derivatives observed was one. The number of rachis per panicle ranged from 15.48 to 28.16. There was notable variation (19 to 31.50 days) in the flowering duration among all the hybrid derivatives.

In respect to fruit morphology, the number of days required from fruit setting to mustard stage ranged from 5 to 7 and the number of fruits per panicle at mustard stage ranged from 46.2 to 69.6, the number of days from mustard stage to pea stage ranged from 10.50 to 14 days; the number of days from pea stage to marble stage ranged from 13.50 to 15.50 days. The fruit retension percent ranged from 1.81 to 3.80 and the highest fruit retension per cent was recorded in hybrid-7 (3.80). Fruit shape was elliptic in seventeen hybrids, oblong in eleven hybrids, roundish in eight hybrids, obovoid in five hybrids and ovoid in remaining one hybrid. The fruit length and breadth ranged from 6.46 to 15.04 cm and 4.86 cm to 8.91 cm respectively, the maximum fruit length (15.04 cm) and breadth (8.91 cm) was recorded in hybrid-46. The fruit weight and volume ranged from 94.9 to 583.45 g and 94.04 to 562.58 cm^3 respectively, highest weight and volume of fruit was recorded in hybrid-46 (683.45 g and 562.58 cm^3). Among all the hybrid derivatives studied fruit beak of twenty-five hybrids was recorded as perceptible, eleven as pointed, four mammiformed and two prominent; twenty-nine hybrid derivatives showed obtuse fruit apex, twelve hybrids had acute fruit apex and remaining one hybrid had roundish fruit apex, fruit base of twenty-nine hybrid derivatives was obliquely round, four hybrid derivatives had slightly flattened and extended, three necked, two flattened, one obliquely flattened, one slightly flattened, one round flattened and one slightly obliquely flattened. Almost all the hybrid derivatives produced green coloured fruits when unripe except hybrid-18, 19 and hybrid-23 which showed dark green fruits and hybrid-4 had light green fruits, fruit stalk insertion was vertical in thirty-two hybrid derivatives and in remaining ten hybrid derivatives it was oblique; fruit shoulder of twenty-two hybrids appeared to be ending in long curve, sixteen hybrid derivatives had rising and then rounded fruit shoulder and in remaining four hybrid derivatives it was sloping abruptly. The fruits of thirty-four hybrids were yellow coloured after ripening, three hybrids were having greenish yellow and remaining five hybrids showed no change in colour and appeared green; fruit skin thickness ranged from 0.6 to 1.4 mm; the skin

percentage of fruit ranged between 11.90 to 33.86 per cent. The fruits of twenty-eight hybrids possessed waxy skin while remaining fourteen hybrids had non-waxy fruits.

The pulp colour was yellow in twenty-two hybrid derivatives, orange in twelve hybrid derivatives, creamish in three hybrid derivatives, yellowish orange in three hybrid derivatives and creamish yellow in two hybrid derivatives; thirty hybrid derivatives had soft textured pulp, eight hybrid derivatives had intermediate pulp texture while four hybrid derivatives had firm textured pulp; pulp of twenty hybrid derivatives had intermediate fibrousness, eleven hybrid derivatives recorded low pulp fibrousness, seven hybrid derivatives had high pulp fibrousness and pulp fibrousness was absent in four hybrid derivatives. The pulp percentage ranged from 37.11 to 80.83, the maximum pulp percentage was recorded in hybrid-52 (80.83 %).

The stone shape was recorded as oblong, ellipsoid and reniform; thirty hybrid derivatives recorded oblong shaped stone, nine hybrid derivatives had reniform stone and three hybrid derivatives had ellipsoidal stone. The stone length and width ranged from 4.62 to 12.81 cm and 2.51 to 6.25 cm respectively. The maximum stone length (12.81 cm), width (6.25 cm), weight (85.26 g) and volume (82.50 cm^3) was recorded in hybrid-46.

Regarding biochemical characters, hybrid-6 had the highest (20.85 °B) total soluble solids, the highest total sugar content was recorded in hybrid-26 (17.46 %), highest reducing sugars in hybrid-8 (4.77 %). The highest non-reducing sugar content was recorded in hybrid-26 (14.32 %). The maximum acidity of pulp was recorded in hybrid-46 (0.45 %) and minimum was recorded in hybrid-35 (0.16 %) while the pH of pulp was recorded highest in hybrid-68 (4.90) and lowest in hybrid-46 (2.29). Hybrid-1 revealed highest β- carotene content (2458.5 μg/100g); highest ascorbic acid content was recorded in hybrid-46 (37 mg/100g). TSS to acidity ratio was found highest in hybrid-35 (101.35) while highest sugars to acidity ratio were recorded in hybrid-21 (83.47). The highest fibre content was recorded in hybrid-1 (0.97 %) and lowest was recorded in hybrid-2 (0.11 %).

As regards to the overall acceptability the highest score was obtained for hybrid-10 (8.0) and the least score was obtained for hybrid-15 (5.1).

With respect to yield characters, minimum number of days was recorded in hybrid-10 (107 days). The maximum number of fruits harvested per tree was noticed in hybrid-7 (319.5); the yield per tree varied from 9.12 kg to 128.70 kg and highest yield per tree was recorded by hybrid-26 (128.70 kg). Longest shelf life at ambient condition was documented in hybrid-6 (9.65 days).

The results revealed that the minimum percentage of incidence of malformation was recorded in hybrid-22 (10.0 %) with a rating of grade-5 and was found to be tolerant and minimum percentage of incidence of powdery mildew was observed in hybrid-16 (1.85).

Six promising hybrid derivatives were selected on the basis of desirable characters such as fruit colour, fruit length, pulp colour, pulp percentage, fruit weight, fruit retension percent, TSS, acidity, yield and overall acceptability. Among forty-two hybrid derivatives hybrid-4, 6, 7, 10, 12 and 52 were found promising.

Molecular characterization of promising mango hybrid derivatives was one of the objectives of present study. Among twelve SSR primers, nine primers showed polymorphism and produced total 100 bands out of which all bands were polymorphic and yielded 100 per cent average polymorphism. The overall range of the similarity between twelve mango genotypes was 0.778 to 0.059. The maximum similarity coefficient (0.778) was observed between Ratna and Totapuri, while lowest similarity coefficient (0.059) was observed between Alphonso and H-7 and also between H-4 and H-12. The UPGMA cluster analysis based on SSR analysis showed that one of the parent formed independent cluster. The results of the investigation shows the efficacy of SSR markers for assessment of genetic relationship and diversity.

1. INTRODUCTION

Mango (*Mangifera indica* L.) is the oldest and 'National fruit of India' and rightly known as 'King of fruits' owing to its nutritional richness, unique taste, pleasant aroma and religious and medicinal importance. Mango is believed to be originated to South East Asia, Indo-Burma region, in foot hills of the Himalayas (Mukherjee, 1951). Mango has been originated in the premises of Indian-Myanmar region and distributed to various phytogeographical areas of the world (Jha *et al*., 2010). Due to its good qualities and high medicinal values, it is enjoyed by masses and classes from each corner of the world. It has an intimate association with cultural, religious, aesthetic and economical life of Indians since time immemorial (Chattopadhyay and Nandib, 1976).

The mango is presumed to be the most commonly eaten fresh fruit worldwide. Mango is second most important fruit crop which contributes 34.86 per cent in area and 20.71 per cent in production, in total fruit crops grown all over India. It is being cultivated in India on 2515.97 thousand hectares area with an annual production of 18431.33 thousands MT along with productivity 7.3 MT/ha. Maharashtra has the highest mango production occupying 485 thousands hectares area with 1212.50 thousands MT production along with 2.5 MT/ha productivity (Anon., 2015). India accounts for approximately 40 per cent of total global mango production (Anon., 2016).

Mango is a tropical, evergreen fruit crop having strong tendency towards alternate or biennial bearing habit. Flowering in mango is very complex phenomenon making challenging for physiologists, breeders and growers. Mango is an andromonocious plant and its inflorescence or panicles bear two types of flowers - staminate and hermaphrodite. Flowers are borne on inflorescence (panicles) which are terminal, but panicles may also arise from axillary buds. Flowers are either male or hermaphrodite in a panicle and may vary from 1000 to 6000, depending on the variety (Mukherjee, 1953). The percentage of hermaphrodite flowers varies with cultivar and depends upon early or late emergence of the panicles (Chadha and Pal, 1986). Flowering period in mango is mainly related to weather patterns and to some degree to cultivar differences under the same climatic conditions (Singh, 1960). The flowering period of mango is usually of short duration of 2 to 3 weeks; low temperature may extend it, whereas higher temperature may shorten it. The mango tree does not produce flowers simultaneously in all directions of tree

canopy and at least two distinct flushes are noticed. The panicles located on the eastern and south eastern sides of the tree come first in flowering.

Flowering behaviour, sex expression, yield and physico-chemical attributes of mango varieties are important determinants of assessing their performance. Flowering is a decisive factor in the productivity of mango and is more or less a varietal character mainly influenced by weather conditions. It has been observed that the flowering pattern of mango cultivars expresses differentially under tropical and subtropical conditions (Davenport, 2003). The process associated with mango flowering involves shoot initiation followed by floral differentiation, and panicle emergence (Murti and Upreti, 2000). All these developmental events occur in most of the mango cultivars during October-December under tropical as well as subtropical conditions. The induction of floral bud formation is correlated with the prevailing environmental conditions as well as age of terminal resting shoots (Davenport, 2007).

The sex ratio in different cultivars is greatly influenced by the genotype and environment in which they grown. Even the same cultivars behave differently in different locations/climate. Initial fruit set in mango is directly related to the proportion of perfect flowers, although the final fruit set does not necessarily depend on this ratio (Iyer *et al*., 1989). It appears that the proportion of perfect flowers in a cultivar becomes critical for optimum fruit set only when the proportion drops to 1 per cent. Flowers begin to open early in the morning and anthesis has generally been completed by noon. The greatest number of flowers opens between 9 and 10 a.m. Although the receptivity of the stigma continues for 72 hr after anthesis, it is most receptive during the first 6 hr ; however, there are reports of stigma becoming receptive even before anthesis has occurred (Singh, 1960).

The newly developed hybrids/varieties provide excellent material for the study of growth, quality and yield characters. However, information based on growth, flowering and yield behaviour is still lacking. Hence, the research is being conducted to identify the superior genotypes with desired and acceptable characters.

Morphological characterization is the simplest of the formal, standardized, repeatable method of identifying and presenting mango's genetic diversity. The International Plant Genetic Resources Institute (IPGRI, 2006) descriptors allow for the use of visual assessment tools of morphological traits to characterize mango germplasm.

Complex plant characters such as yield are quantitatively inherited and are influenced by genetic effect as well as genotype/environmental interaction. This poses the need to identify and use highly correlated characters. Detailed and well documented information about the available mango genetic material together with a broad, well maintained varietal diversity are essential for breeding efforts. Characterization and documentation of indigenous mango varieties is important for identifying potential candidates for improved utilization of the genetic resource and future breeding programmes (Ramessur and Sanmukhiya, 2011). Equally important for identifying location-specific most suitable local mango landraces and developing high yielding disease/pest resistant hybrids, and for developing 'conservation through use' strategies to reduce genetic erosion (Sennhenn *et al.,* 2013).

Systematic characterization of physico-chemical characters of available germplasm provides the extent of genetic diversity in the fruits species and facilitate in identifying the superior genotype with desired characters. Morphological and biochemical markers are used on large scale for assessing genetic diversity in fruit crops but they show limited levels of detection of inter-varietal and intra-varietal polymorphisms on account of their environmental plasticity.

Earlier for crop improvement the selection of crop was done by morphological markers, i.e. based on phenotypic/morphological character of the crop plants. This method had a disadvantage that it varied with environmental conditions and takes years for the crop to grow and fruit on the basis of which the quality of plant can be identified. So another method was developed by using biochemical markers i.e. enzymes, secondary metabolites, etc. which was much more reliable, consistent and unaffected by environmental conditions. But this method also has a disadvantage that it varied with the stages of development and tissue used for extraction. This problem was overcome with the development of DNA based markers which is again divided into two types -: PCR based markers and Restriction based markers. In which PCR based markers include RAPD, AFLP, Microsattellites and Restriction based markers includes RFLP.

DNA based molecular markers provide a good and informative approach to estimate the genetic diversity and genetic relationships of horticultural plants. It is the most advanced and most reliable technique among various characterization methods like

molecular, morphological, biochemical characterization. DNA based markers are abundant, highly polymorphic and independent of environment or tissue type. The isoenzyme markers are limiting due to low levels of polymorphisms. Consequently, DNA based techniques such as ISSR and SSR markers are effective in assessing genetic diversity among the cultivars, because they provide unlimited potential markers to reveal differences at molecular level.

Several morphological, biochemical and molecular markers have been extensively used in assessing diversity in mango genotypes. Significant work on the genetic variability and relationships of mango has been carried out in India using array of DNA-based molecular markers. Marker types that have been tested in mango include RAPD, RFLP, AFLP, ISSR, DAMD and SSR. During recent years, SSR type of marker was used to study genetic diversity and relatedness among mango genotypes.

Therefore, considering the above facts and constraints, the present study was undertaken with the following objectives :

1. To study the growth behaviour of hybrid derivatives of mango.
2. To study the quality parameters of hybrid derivatives of mango.
3. To study the molecular characterization of promising hybrid derivatives of mango.

2. REVIEW OF LITERATURE

Mango (*Mangifera indica* L.) belongs to the family Anacardiaceae. It is a predominant fruit crop of India and considered as the 'King of fruits'. India has the richest wealth of mango germplasm (nearly 1000 varieties) and it is the 'National Fruit' of India. Considering the importance of mango in Indian Horticulture, attempts have been made to improve the productivity of this crop in recent past. An important way to increase productivity in any fruit crop is to first select desirable cultivars from existing variation and to use the superior types for crop improvement programmes. Among the various hybrids assessed so far, only few have been found promising. Even amongst the hybrids of the same parentage, enormous variation in fruit size, shape, fruit quality and bearing behaviour has been observed. This is quite natural in a highly heterozygous plant like mango, and this highlights the necessity of raising a very large population of hybrid seedlings of each parental combination to select the desirable ones. It becomes imperative to study the floral biology, fruit set and yield in different cultivars of mango (*Mangifera indica* L.), for regulation of market, consumer's acceptability and greater remuneration. The literature pertaining to the different aspects of present study has been reviewed under following heads :

2.1 Growth characters

Srivastava *et al*. (1987) evaluated fifteen mango varieties for vegetative growth, flowering and fruiting behaviour and physico-chemical parameters of fruits in central India. They found that Langra, Samar Bahist Chausa, Mallika and Baneshan were high volume producers, whereas Bangalora, Swarnarekha, Vanraj, Mulgoa, Alphonso, Fazli, Fernandin and Mankurad as low volume producers. Similarly, under arid irrigated conditions of Punjab, Langra was the most vigorous followed by Mallika, Dashehari and Amrapali (Sharma *et al*., 1999).

Reddy *et al*. (2000) under sub-humid alfisols of eastern India, conducted a trial to find out the adaptability of 20 mango cultivars collected from North, South, East and West Zones of India. They observed that some of the south Indian cultivars (Mulgoa and Swarnarekha) and the West Indian cultivars (Kesar and Vanraj) did not bear fruit

even after 10 years of planting. They also reported that cultivar Chausa attained greatest height (5.02 m), girth (74.0 cm) and volume (42.07 m^3).

Nunes *et al*. (2001) evaluated performance of 26 mango cultivars in eastern Brazil, and reported that the American cultivars Eldon and Haden and the Indian cultivars Dashehari and Langra had shown the best tree development and growth.

Kher and Sharma (2002) evaluated five mango cultivars, *viz.* 'Dashehari, Bombay Green, Langra, Chausa and Mallika for their performance under subtropical rainfed regions of Jammu and found the maximum tree height (565 cm) and tree spread (475 cm east-west and 525 cm north-south) in Chausa followed by Mallika.

Chanana *et al.* (2005) evaluated some mango cultivars for vegetative characters under North Indian conditions and reported that Langra had the maximum tree height and spread. Tree volume was also maximum in Langra (311.38 m^3/ tree), while minimum was in Alphonso (58.49 m^3/ tree).

2.2 Flowering characters

Hartless (1913) studied the flowering season of 60 varieties of mango, growing in Saharanpur districts of Uttar Pradesh. He found a difference of 25 days only between the flowering season of the earliest and latest varieties. The length of flowering season varied from 30 days in case of the early varieties to 12 days in the late flowering varieties.

Fraser (1927) concluded that mango inflorescence is terminal with frequent emergence of the multiple axillary panicles. Both perfect (2-70 %) and hermaphrodite flowers occur on the same panicle.

Naik and Rao (1943) studied the sex ratio in 16 varieties of mango and found that only 0.12 per cent of the flowers were hermaphrodite in a 4-year old Imam Pasand tree, while, in the twenty year old tree, the percentage was 11.7.

Mukherjee (1953) had reported that depending on the variety, the total number of flowers in a panicle might vary from 1000 to 6000. The higher number of hermaphrodite flowers was noted in the hybrids Ratna (141.6) and H-151 (140.8) and the lower in Muvandan. The higher percentage of hermaphrodite flowers was noted in Alphonso (44.39 %). The lower percentage of hermaphrodite flowers (15.77 %) was recorded in Muvandan. He also found that the percentage of perfect flowers in some

Indian mango cultivars ranged from 25 to 36.6 per cent. It was also noted that higher percentage of perfect flowers in `Langra' is closely associated to high productivity.

Singh (1954) found that the period of emergence of flower buds commenced in the latter half of January and continued till February in Dashehari and Langra varieties, under Saharanpur conditions.

Mallik (1957) reported that the flowering season of three varieties namely Bombai, Langra and Fazli extended from January to March, the length of the flowering season of individual varieties varied from 25 to 35 days.

Ali (1960) found 78.8 per cent perfect and 21.2 per cent staminate with no pistilate flower in `Dashehari', Majumdar and Mukherjee (1961) observed the higher percentage of perfect flowers on northern side of the trees and the lower on the east side in cv. `Himsagar'. Chad (1964) found 1300 - 1400 flowers from an average sized inflorescence in cultivars Langra, Dashehari and Fazli in India.

Nakhlla (1980) reported that the percentage of perfect flowers varied within the tree and was higher during “on” years than the “off” years.

Desai *et al.* (1985) observed higher percentage of hermaphrodite flowers on the north and least on the eastern side of the mango cultivars Alphonso, Goamankur and Kesar. Three commercial cultivars of mango i.e. Anwar Rataul, Dashehari and Langra were studied for panicle initiation time, total number of flowers and proportion of male to hermaphrodite flowers.

Scholefield and Oag (1986) studied flowering and fruit set of six cultivars of mango and found large differences in final fruit set (0.33-1.39 %) among mango cvs. Bangalora, Batavi, Common, Glenn, Irwin and Kensington.

Srivastava *et al*. (1987) while evaluating the mango varieties in Madhya Pradesh, observed that date of start of flowering and date of full bloom were earliest in variety Vanraj *i.e.* on 7th February and 3rd March, respectively and it was noted late in the variety Neelum, Fazli and Alphonso, and also reported that date of panicle emergence was earlier (4th January) in Vanraj followed by Mankurad and Samar Bahist Chausa, while late in Neelum.

Thimmappaiah and Suman (1987), while working on 13 different cultivars of mango observed that the number of flowers per panicle ranged from 302 in case of

Kurukkan to 994 in Sukhverma and maximum percentage of hermaphrodite flowers in cultivar Langra. Langra depicted higher number of flowers (598.75) with maximum hermaphrodite flowers (473.08; 79 %) on west and southern side of the plant, respectively. Under coastal Karnataka conditions, Alphonso had 428 male flowers per panicle (Uthaiah *et al.,* 1988).

Iyer *et al.* (1989) stated that the initial fruit set is directly related to the proportion of perfect flowers though the final fruit set does not depend on it. Proportion of perfect flowers required for optimum fruit set must not be less than 1% and proportion of perfect to the staminate flowers (sex ratio) is a variable component within panicles, trees and among cultivars but is usually less than 50 per cent.

Narayanaswamy and Thimmaraju (1990) studied sex ratio of two north Indian cultivars (Dushehari and Langra) and one hybrid (Mallika) under south Indian conditions and revealed that Langra had the highest percentage of hermaphrodite flowers (61.4) followed by Dushehari (32.5) and Mallika (25.4). They further mentioned that the change in climatic conditions had not affected the pattern of hermaphrodite flower production.

Kalra and Tondon (1993) evaluated sixteen mango varieties, (mainly North Indian varieties) grown under local condition, and observed that the bud burst took place in February in almost all the varieties except in few varieties. In case of Amin Buland Bagh and Gaurjeet, it was in January, while, fruit set started from the 2nd week of March in all mid season varieties with 2-3 weeks variation for early and late season varieties.

Sharma and Josan (1995) evaluated the performance of mango cultivars under arid-irrigated region of Punjab and found that flowering in Dashehari was earliest (last week of February), followed by Amrapali and Mallika (first week of March), whereas Langra and Alphonso were last to flower (2nd week of March).

Avilan *et al*. (1998) characterized twenty one mango cultivars for flowering behaviour in Venezuela and reported that flower numbers ranged from 601 in cv. Haden to 4,859 in cv. Irwin. The flowering duration was averaged to about six weeks in most of the cultivars. With the exception of three cultivars with a fertile flower percentage of 4 per cent, the potential fruit yield was high. Under arid-irrigated conditions of Punjab, cv. Langra was the most vigorous followed by Mallika, Dushehari and

Amrapali (Sharma *et al*., 1999). Afifi *et al.* (2000) studied the flowering behaviour of mango cultivars Langra and Fazli Kalan grown in Kalubia. The ratio of male/perfect flowers was lower in Langra than in Fajri Kalan, especially in the "on" year (1997) for the former (0.66 vs. 0.90) and "off" year (1997) for the latter (1.35 vs. 1.67).

Schnell and Knight (1998) studied three variables (days to bloom, days in bloom and and fruit) for six years in eight mango cultivars to characterize the phenology of flowering. Significant differences in flowering responses were found for year and cultivars. The year by cultivar interaction was significant for days to bloom only. Individual trees within cultivars in the experimental model were not significantly different. Results indicated that replicate trees of same cultivars responded similarly within given year. Repeatability of each of the flower phenology characters was high indicating that much of this variation is heritable and useful for further breeding.

Anjum *et al.* (1999) conducted the study on flowering behavior, fruit setting and extent of floral malformation in five cultivars of mango viz. Aman Dashehari, Anwar Rataul, Langra, Malda and Samar Bahist and observed that the percentage of hermaphrodite flower was higher in cultivar Samar Bahist and Langa which range from 21 to 96 per cent. The least male flowers (125.75) were also found in ‘Langra’. ‘Anwar Ratual’ depicted minimum number (59.83; 7.25 %) of hermaphrodite flowers. Proportion of hermaphrodite flowers in all the three cultivars was quite variable regarding plant side (Asif *et al.,* 2002).

Mane *et al*. (2001) evaluated six mango cultivars *viz*. Ratna, Pairi, Parbhani Hapus, Totapuri and Fazli. Among these cultivars, Ratna was the earliest to flower (15 January), while Totapuri had the longest flowering period (37 days) and the highest number of fruit set per panicle (86.43).

Muhammad *et al*. (2002) studied the panicle initiation time, total number of flowers and proportion of male to hermaphrodite flowers of three commercial mango cultivars, *i.e.* Anwar Rataul, Dushehari and Langra. They found that early panicle initiation was observed in Dushehari on eastern side of the plant followed by Langra and Anwar Rataul. They also reported that Langra had the highest number of flowers per panicle (598.75) with maximum hermaphrodite flowers (473.08; 79 %) on west and southern side of the plant, respectively and the least male flowers (125.75) were also

found in Langra, while Anwar Rataul depicted minimum number (59.83; 7.25 %) of hermaphrodite flowers.

Singh (2002) studied the performance of 21 mango cultivars at Sabour, Bihar during 1997-98. He reported that Amrapali had the highest panicle length (22.50 cm) and percentage of hermaphrodite flowers (24.90).

Anila and Radha (2003) observed that in mango varieties like Alphonso, Prior, Ugandan and Rant, flowering started during Dec- Jan months but in case of Neelum variety, flowering was observed during the month of April-May.

Kumar and Jaiswal (2003) studied the bearing behaviour of some south and west Indian mangoes and reported that first flowering was observed in Vanraj and Fernandin *i.e.* on 10th February and completed on 10th March (33.83 days of flowering duration), whereas, Alphonso and Keshar started flowering on 17th February and 20th February respectively, and flowering completed within 29.50 days.

Singh (2003) studied the performance of different mango varieties under Bihar conditions and noticed the earlier peak panicle emergence (17th February) in Calcuttia Maldah followed by Gulab Khas, Kanchan Lal, and Hanthi Jhul, whereas, at the last (27th February) in Latkampoo.

Singh and Singh (2003) studied the performance of mango hybrids for flowering, fruiting and fruit quality attributes and found that panicle emergence in Bombai was recorded earliest *i.e.* on 4th February followed by Alfazli and Arka Puneet whereas, it was noted late (on 15th February) in Arka Aruna.

Souza *et al.* (2004) evaluated the flowering date of nineteen mango varieties in Brazil and found that the varieties flowered from June to August, while some of the varieties showed the typical pattern of alternate bearing (Maya, Haden, Itiuba, Bourbon, Irwin and Tommy Atkins), some possesed an erratic pattern of production (Carlotão, Florigon, Kensington, Surpresa, Momi-k, Dusheri & Langra), while other varieties had intermediate pattern (Alphonso, Amarelinha, Comprida Roxa, P. de Amoreira, Zill and Brasil).

Kumar and Singh (2005) reported that panicle emergence was earliest (on 3rd February) in Bombai followed by Baneshan and Langra, whereas it was noted at last (on 16th February) in Dadamian. Kanpure *et al*. (2009) evaluated the mango hybrids for

Kymore plateau of Madhya Pradesh and observed that Amrapali showed the earliest panicle emergence (29th January).

Pandey and Kumar (2006) studied flowering behaviour of 10 mango hybrids (Amrapali, Mallika, Ratna, Neeleshan, Neeluddin, Prabhashankar, Mahmudbahar, IIHR-10, Sabri and IIHR-51), along with a local control (Langra) in terms of duration of panicle emergence, duration of flowering, number of flowers per panicle, sex ratio, fruit set and fruit retention. The maximum duration of panicle emergence was observed in Langra (55.11 days), IIHR-51 (45.39 days), Amrapali (44.86 days) and IIHR-10 (44.41 days). The duration of the flowering season ranged from 34.00 days in Langra to 12.00 days in Prabhashankar. The number of flowers per panicle ranged from 1010.66 in Ratna to 1559.66 in Neeleshan. Sex ratio varied from 2.46 in Amrapali to 4.72 in Sabri. Maximum fruit set (29.26 %) and fruit retention (3.01 %) was recorded in Amrapali.

Uddin *et al.* (2008) studied the floral biology of four varieties of mango namely Golabkash, Pahutan, Langra and Mallika at the Regional Horticulture Research Station, Chapai Nawabgunj in 1997. The longest blooming period (27.67 days) was recorded in Mallika, whereas the shortest (16.67 days) was in Langra. The highest number of bisexual flowers per panicle (254.6) and the highest number of initial fruit set (5.87) was found in Langra, while the lowest number of bisexual flowers (40.73) was in Pahutan and the lowest number of initial fruit set (1.63) was in Mallika.

Kanpure *et al*. (2009) conducted field studies to evaluate selected mango hybrids for Kymore plateau region of Madhya Pradesh. The check variety Langra gave the maximum vegetative growth parameters, while the hybrid Swarn Jahangir and Ratna gave the minimum. Hybrid Amrapali attained the earliest flowering (14th February) and fruit setting (6th March). Floral malformation was highest (66.1 %) in hybrid Neeleshan, while it was lowest (15.0 %) in Amrapali. Hybrid Neelgoa recorded maximum fruit drop (66.8 %) followed by Langra, while it was minimum (26.9 %) in Amrapali. Amrapali and Mallika produced significantly higher number of fruits and fruit yield per tree over the check variety Langra. However, the fruit weight of Mallika was significantly higher (302.6 g) over all the varieties under study except Neeleshan.

Singh *et al.* (2009) studied the flowering and fruiting behaviour of 11 mango cultivars namely Langra, Bombay, Mithua, Gulabkhas, Zardalu, Dushehari, Sepia,

Fazli, Ketaki, Prabhashankar and Mahmood Bahar under Ranchi conditions. First flower opening was observed in Mithua and flowering was observed to be early in Gulabkhas and 100 per cent flowering occurred by 4th February. However, the minimum period for 100 per cent flower opening was recorded in Fazli (16 days). The check cultivar Langra recorded the minimum male flower (74.41 %), however the maximum was recorded in Fazli (85.12 %). Maximum perfect flower was obtained in Langra (28.59 %). Maximum fruit set was observed in Zardalu (1.02 %) and days taken for maturity were recorded maximum in Fazli (136.33 days).

Shu (2009) found that the hermaphrodite flowers tend to open in a relatively high percentage at the early stage and subsequently declines while male flowers were lesser at the early stage and majority opened at the middle stage. Keitt cultivar has the highest sex (hermaphrodite/male) ratio of 1.44, while Haden had the lowest (0.2) ratio.

Hada and Singh (2017) conducted a field experiment to investigate the flowering, fruiting and yield attributes of some mango cultivars for the years 2014-15 and 2015-16. Outcome of the research work revealed that the date of panicle emergence in different mango cultivars varied in both the years. It was observed that the panicle emergence was earliest in Gulabkhas and late in Fazli in both the years. Chausa produced maximum panicle length (35.19 cm) and breadth (24.76 cm). In the year 2014-15, earliest flowering was noted in Gulabkhas (Feb 17-Feb 26) and in the year 2015−16, and it was observed in Bombai (Feb 20-Feb 28) while, flowering was very late in Sepiya for both the years. Maximum number of flowers was observed in Langra (1839.13) while, minimum number of flowers was recorded in Amrapali (954.75). The duration of flowering varied from 22.50 to 36.00 days in different mango cultivars. Maximum value in terms of days was observed with Sepiya (39 days) while it was minimum (22.50 days) in case of Alphonso. The data revealed that date of fruit set ranged from 11th to 8th April. Earliest fruit setting was observed in Bombai (12th to 16th March) during the year 2014-15 while, earliest fruit setting was noted in Gulabkhas (10th March to 16th March) during the year 2015-16. Highest number of fruit set per panicle was recorded in Langra (137.75) while, maximum fruit set per cent was noted in Bombai (41.07 %). Minimum days for maturity was taken by Gulabkhas (90.17 days). Maximum yield (501.00 kg/tree) was recorded in Langra.

Azam *et al.* (2018) studied twenty mango cultivars for the flowering behaviour at Bihar Agricultural University, Sabour and observed earliest bud break in cultivar Bombay Green (19th January) followed by Bombai and Zardalu (26th January). However, SB Chausa, Fazli and Neelum recorded a very late bud break. Maximum number of panicles was found in the cultivar Langra (2275) while the minimum number of panicles was found in Neelum (587). Maximum panicle length was observed in SB Chausa (34.5 cm) while minimum was found in Bombay green (17.25 cm) followed by Neelum (20.75 cm). There were differences between cultivars for the date of first flower opening and in the time and duration of peak flowering. There is, therefore, a possibility of carrying out selection for earliness as well as duration of flowering. In terms of the flower types, staminate flowers were first to appear in all the cultivars followed by hermaphrodite one. The cultivar Langra showed maximum percentage of hermaphrodite flower (73.86 %) while minimum hermaphrodite flowers percentage was found in Swarnarekha.

Kumar *et al.* (2018) studied flowering and fruiting behaviour in five important cultivars of mango *viz*. Langra, Bombai, Zardalu, Bangalora and Hemsagar. The bud break, the appearance of 50 % flower in panicle and fruit set was noticed in different time among the cultivars. The flowering intensity, the percentage of hermaphrodite flower, inflorescence shape and colour, inflorescence length and breadth significantly differed among the cultivars. The fruiting behaviour like fruit set (%), fruit drop (%), number of fruits per tree and fruit weight (g) was also significantly varied among the cultivars. The earlier bud break, the appearance of 50 per cent flower in panicle and fruit set was observed in cv. Bombai and late in cv. Himsagar during both the years 2015 and 2016. The statistically pooled result of the year 2015 and 2016 showed the maximum flowering intensity percentage (62.05 %) and inflorescence length (27.72 cm) was observed in cv. Bangalora, whereas a higher percentage of hermaphrodite flowers (16.55 %) and inflorescence breadth (21.00 cm) was in cv. Zardalu. The maximum fruit set per cent (2.82 %) was found in cv. Himsagar, and maximum fruit drop per cent (97.70 %) was in cv. Langra. A higher number of fruits per tree (348.25 fruits/tree) in cv. Bombai and maximum fruit weight (490.11g) were recorded in cv. Bangalore.

Sinha *et al*. (2018) studied the hybrid genotypes in which results showed the earliest bud break in cultivar Sunderprasad on 24th January however, the late bud break was observed in Fazli on 14th February. The cultivar Fazli took maximum time (124.67 days) while Sunderprasad recorded minimum time (92.67 days) from full bloom to maturity. Cultivar Langra showed the higher percentage (74.18) of hermaphrodite flowers while a lower percentage (37.60) was observed in Jawahar. The hybrids like Hybrid-60-1, Hybrid 140 and Hybrid 60 recorded more than 50 per cent hermaphrodite flowers. Mainly two types of inflorescence shapes were observed viz., conical and pyramidal except for Bombai where the shape of inflorescence was observed to be broadly pyramidal.

2.3 Fruit characters and yield traits

Naik and Rao (1943) observed a positive relationship between the percentage of perfect flowers and number of fruits carried to maturity per panicle.

Singh *et al.* (1962) found that fruit set obtained after selfing in Dushehari and Langra was much less than that obtained from crossing. The adverse effect of selfing was more pronounced in varieties Chausa and Bombay Green, where none of the selfed fruitlets attained even marble size and majority of the selfed fruitlets in varieties Dushehari, Langra, Chausa and Bombay Green dropped within about four weeks of pollination.

Mukherjee *et al.* (1968) reported that out of 966 flowers self-pollinated in Dushehari only two fruits developed beyond pea stage, which also dropped subsequently. Dropped fruits revealed a tiny and shrivelled ovule, creamy white or black in colour. Of the 657 flowers sib-mated, the result was the same as that of selfing, whereas in crossing, a large number of mature fruits were obtained in Dushehari. In Chausa, although the fruit set beyond pea stage was very high in crossed flowers, fruits dropped before these could reach maturity.

Singh and Gangwar (1985) reported that Dashehari was on the top in respect of yield per unit area of the ground covered by the tree canopy.

Singh *et al*. (1986) reported the highest average yield in cv. Sukul (212.80 kg/tree) and the lowest in Neelum (71.40 kg/tree) in Gangetic plains of North India.

Singh *et al*. (1988) studied 10 mango varieties and observed that the maximum yield/ tree was obtained in Bahadurgarhi (250 kg) followed by Langra Banarasi (236 kg) and Dashehari (180 kg), while Sindhuri yielded the least (22.0 kg) under Patiala, Punjab conditions.

According to Srivastava *et al.* (1987), Neelum, Langra and Bangalora were the highest yielding in Madhya Pradesh.

According to Baghel *et al.* (1988), correlation studies of 15 different characters in cultivar Langra indicated that the number of fruits per square metre could be considered as the most effective parameter for predicting the yield followed by the yield of secondary branches, number of fruits per panicle and number of panicles per square metre.

Badyal and Bhutani (1989) analyzed five-year-old trees of seven mango cultivars at Bagwan, Himachal Pradesh. Mallika was found to be superior in fruit yield (8.49 kg/tree) followed by Dashehari (6.16 kg/tree) and Alphonso (4.64 kg/tree). However, Bombay Green had shown the minimum yield (1.83 kg/tree). Ten-year-old Pairi trees gave 71.06 kg yield/tree in comparison to 32.26 kg/tree in case of Alphonso at Bangalore, Karnataka (Iyer *et al*., 1991).

Santos and Mosqueda (1989) compared 21 varieties and 12 Mexican selections of mango in Central Veracruz. Considerable variation was found among the genotypes studied, overall mean yields ranging from 5.6 kg/tree (0.39 t/ha) for Florigon to 63 kg/tree (4.35 t/ha) for Haden. Fruits of seven mango cultivars were analysed (Jagmohan *et al.,* 1989) for yield characters over 2 seasons (1983 and 1984) in Himachal Pradesh. Yields were the highest in *cv.* Mallika (3.7 and 8.5 kg /plant) over two seasons.

Sharma and Josan (1995) assessed five cultivars, *viz.,* Dashehari, Langra, Mallika, Amrapali and Alphonso introduced from the main mango growing regions of country at arid-irrigated region of Punjab. They found the maximum yield in Mallika (60 kg/tree) followed by Dashehari (50 kg/tree) and Langra (38.0 kg/tree). However, the minimum yield was noted in Alphonso (21 kg/tree). The number of fruits per tree in these five cultivars was 215, 129, 142, 176, 123 and 55, respectively.

Human (1997) assessed trees of 40 mango cultivars and selections for yield, fruit size and fruit quality in South Africa and recommended Neldica as a consistent performer based on yield and fruit size.

Ram and Rajput (1999) reported that under the same conditions, Dashehari fruits could be harvested from the first week of June, whereas Langra fruits were ready for harvest only by the second week of June, indicating varietal variation.

Viswanath *et al.* (1999) reported that varieties Bangalora and Neelum exhibited regular bearing habit while Baramasi produced fruit in two seasons when grown in Oman. Results of a study on path coefficient analysis for some quantitative characters in mango (Das *et al.,* 2001) revealed that the number of fruits per tree and fruit weight had the maximum direct effects on fruit yield.

Tripathi (2000) studied 93 mango germplasm and revealed that the fruit yield of cultivars Anannas, Sensation, Ladavio, Surkhuru-1, Surkhuru-2, Gaurjit, Au-Rumani, Rahri and Mithuwa Malda were higher in terms of kg per square metre and these cultivars were placed in high yielding group under *Tarai* conditions.

Sarkar *et al*. (2001) evaluated 10 mango hybrids for fruit characteristics under Telangana region of Andhra Pradesh, cultivars Ratna, Mahmood Bahar and Swarnajahangir recorded the highest number of fruits (91.5) and yield (15.35 kg) per tree.

Bally *et al*. (2002) reported small yield variations in thirty-three selections of cv. Kensington Pride, with no significant difference among top 19 selections in Queensland, Australia. No single selection had outstanding yield. However, two selections had significantly lower yield than the rest. Their findings indicated the difficulty in significantly improving Kensington Pride mangoes through selection from existing commercial germplasm. Identification, characterization and classification of a total of 75 mango ecotypes had also been done in Ethiopia (Yeshitela and Nessel, 2003).

Barui and Ghosh (2002) investigated the performance of ten mango cultivars of semiarid regions of West Bengal in 1995 -1998. Himsagar produced the highest fruit yield (73.9 kg) and fruit quality.

Kher and Sharma (2002) evaluated five mango cultivars, *viz.* 'Dashehari, Bombay Green, Langra, Chausa and Mallika for their performance under subtropical rainfed regions of Jammu and found that Bombay Green was first to mature during 1st

week of July, whereas Mallika and Chausa were last to mature during 3rd and 4th week of July, respectively.

Singh (2002) evaluated the 21 varieties and found that the maximum yield per plant was recorded in Bangalora (250 kg) followed by Langra, Zardalu, Bombai and Amrapali.

Hoda *et al*. (2003) studied 20 mango cultivars under subtropics of Bihar and reported that the earliest completion of fruit set was observed in Fazli, while the latest in Neelum. On the basis of different ecological groups of mango cultivars, they observed that Mallika (North Indian cultivar) and Bangalora (South Indian cultivar) performed well when compared with local leading cultivars like Bombai, Zardalu and Himsagar on the basis of flowering and yield attributes. Based on overall performance, Mallika showed much potential for cultivation under Bihar conditions.

Chanana *et al.* (2005) evaluated some mango cultivars under north Indian conditions and found that fruit yield was maximum (73.00 kg / tree) in cultivar Mallika followed by Dashehari (66.33 kg / tree), while, other cultivars Langra and Amrapali recorded the fruit yield of 62.00 kg / tree and 45.67 kg/tree, respectively. On the other hand minimum fruit yield (15.67 kg / tree) was recorded in Alphonso. In another study, Amrapali and Mallika produced significantly higher number of fruits (338.8 and 214.1 kg / tree) and fruits yield (69.78 and 64.68 kg / tree) over the control cultivar Langra i. e. 127.2 numbers of fruits and 35.05 kg / tree.

Zaman *et al*. (2007) conducted an experiment to evaluate some local and exotic mango germplasm at Jamalpur. They studied 11 germplasm of five-six years old and concluded that, highest number of fruits per plant at harvest was recorded in the germplasm BARI Aam-3 (45.0), followed by Gopalbhog (30.0) and that of lowest in Hybrid-10 (7.0), with close to Mallika (18.0). Fruit weight per plant was also highest in BARI Am-3 (6.11 kg), and that of Gopalbhog, Mallika and Hybrid-10 were 5.26 kg, 4.96 and 1.39 kg, respectively.

Kanpure *et al.* (2009) reported that the hybrid Ratna and A.U. Rumani attained almost the lowest number of yield and weight of fruits among all the cultivar.

2.4 Physico-chemical characteristics

2.4.1 Fruit weight and size

Lodh *et al.* (1974) studied the physico-chemical characteristics of mango varieties and found that maximum average fruit weight was registered by Totapuri (622.00 g) followed by Mulgoa and Banganpalli (480.00 and 410.00 g, respectively) and minimum fruit weight was attained by Langra (209.00 g). As regards to the fruit size, maximum fruit length was attained by Mulgoa (14.50 cm), whereas, diameter was noted higher in case of Totapuri i.e. 9.31cm. Minimum fruit size was found in Alphonso (10.06 cm length and 5.96 cm diameter).

Jindal and Sharma (1981) assessed six mango cultivars under semi-arid conditions of Hisar, Haryana and noted that fruits of Sipia Sah Pasand were the heaviest (248 g) followed by Bombay Green and Saroli.

Kulkarni and Rameshwar (1981) noticed wide variation in the physical characters of the ripe fruits of 22 important mango cultivars at Sangareddy, Andhra Pradesh. The fruits of Alampur Baneshan were the heaviest (400 g/fruit), while Alphonso and Pairi bore the minimum fruit weight (180 g).

Passam (1982) who compared some local mango cultivars with the introduced ones, observed that the fruits of local cultivars weighed from approximately 100 (Doodooth) to 500 g/fruit (Graham). In contrast, the introduced cultivars (Haden, Sensation and Zill) produced medium to heavy fruits with 250-500 g of weight.

Sadhu and Bose (1982) conducted a comprehensive survey to assess the potentiality of some comparatively less known mango cultivars grown in the district of Murshidabad, West Bengal. The largest fruit was found in Mocha, each weighing over 500 g. However, the maximum length and diameter was found in Burya Fazli (13.9 x 9.2 cm), which was followed by Rumali and Hapus. Out of six Baramasi mango cultivars (Ahra, Mahso, Aghaibhagar, Mallika, Bathua and Creeper), the maximum fruit length and diameter were found in Baramasi Aghaibhagar and the minimum in Baramasi Creeper in Basti, Uttar Pradesh conditions (Upadhyay and Tripathi, 1984).

Ghosh *et al*. (1985) in an evaluation of 10 mango varieties at West Bengal, illustrated that variety Jangale was superior with regard to fruit size, length and breadth.

Bombay Green, Bombay Yellow and Sarikhas were also better in respect of weight, while the fruit of Piarafully, Amriti and Meghlantan were smaller in size.

Bhuyan and Islam (1986) conducted an experiment on physico-chemical studies of 13 varieties of mangos at Nawabganj and recorded highest fruit weight in Fazli (1014.45 g) and the lowest in the variety Gopalbhog (202.88 g). The length and breadth of fruit of Gopalbhog was 8.72 × 6.54 cm.

Scholefield and Oag (1986) found that fruit weight varied from 142 (Dashehari) to 744 g/fruit (Jaya). Similar findings were also reported by Singh and Gangwar (1985), Singh *et al*. (1988) and Syamal and Mishra (1989).

Srivastava *et al.* (1987) while evaluating mango varieties in Madhya Pradesh observed that maximum weight per fruit was obtained in Vanraj (385.7 g) followed by Baneshan (350.0 g), Fazri (312.5 g) and Mallika (292.3 g). The varieties like Neelum, Mankurad, Fernandin and Alphonso produced fruits of lesser weight ranging from 121.81 to 168.0 g per fruits.

Ahmad *et al*. (1989) observed performance of some mango varieties produced in Chittagong, Bangladesh and found that cultivar Kalia had the highest fruit weight. Under Kangra, Himachal Pradesh conditions, Mallika showed higher fruit weight (464.4 g/fruit), length and breadth (15.4 x 11.8 cm) than Bombay Green and Langra (Badyal and Bhutani, 1989). Thirteen polyembryonic varieties were analyzed for various physico-chemical characteristics of ripe fruits at Bangalore. All the varieties were found to be significantly different from each other in most of the characters. The weight of fruits was found to vary from 113.0 g in Mylepelian to 411.3 g in Kensington.

Badiyala and Awasthi (1990) in a study of 19 mango cultivars in red and laterite soils of West Bengal, found that the fruits of cultivar Fazli were significantly superior in fruit weight and length but not in fruit diameter, which was the maximum in Mallika.

Uthaiah *et al*. (1988) collected fruits from twelve-year-old trees of thirty mango cultivars and reported that fruit weight ranged from 146 g for Pahutan to 1005 g for Mohanbhog, but more than 50 per cent selections weighed between 220 to 630 g. While working on physico-chemical composition of six mango cultivars, *viz.* Dashehari, Langra, Totapari Red Small, Local seedling, Late Bhaduran and Amrapali.

Kundu and Ghosh (1992) noted that cultivar Fazli and Himsagar were superior to other cultivars with regard to fruit weight and size. The cultivars Chausa and Krishnabhog were also good in respect of fruit weight and size.

Haque *et al*. (1993) reported that maximum fruits turned to yellow or greenish yellow during ripening while the cvs. Kohitur and Samar Bahist turned to red and reddish yellow. Length of the fruit ranged from 10 to 17 cm and the highest (14.7 cm) breadth was noted in the cv. Badshabhog whereas the shortest (8.5 cm) was in cv. Baromashi. Fruit thickness varied from 4.8 to 8.6 cm. Bigger and heavier fruits were found in the Mohonbhog (670 g) and Fazli (615 g). Fruit weight ranged from 159 to 670 g.

Kalra *et al*. (1994) pointed out that the mean fruit weight of sixteen mango varieties varied from 188 to 343 g at Lucknow. Gaurjit had the minimum fruit weight, which was too small in size but still liked by people because of its early ripening, sweetness and being the sucking type. The varieties Amin Buland Bagh, Gulab Khas, Amin Khurd, Asodia Devband, Bareillywala had on an average fruit weight of less than 200 g, while Gorakhpur Langra had an average weight of 343 g.

Gowda and Ramanjaneya (1994) observed significant differences in fruit weight, length, breadth and volume of different varieties under Bangalore conditions. The fruit weight was maximum in Totapuri followed by Banganpalli, while it was between 250 to 300 g/fruit in Mulgoa, Padiri and Swarnarekha. Moderate fruit weight was observed in Alphonso, Langra and Panakalu. Fruit length was more than 8.5 cm in all the varieties except Alphonso and Panakalu (less than 8 cm). Fruit breadth was less than 5 cm in both Dashehari and Panakalu, while it was higher than 8 cm in case of Mulgoa, Banganpalli and Totapari. Fruit volume was more than 300 ml in three varieties, *viz*., Totapari, Mulgoa and Swarnarekha, while it was less than 200 ml in Janardan Pasand, Dashehari, Panakalu and Kesar.

Singh and Yadav (1994) reported high fruit weight coupled with large fruit length and width in cultivars Baneshan, Bangalora, Fazli, Sunderja and Mallika among the twenty cultivar evaluated. While working on five mango varieties in Punjab.

Sharma and Josan (1995) noted that Mallika fruits were the maximum in weight and size followed by Langra, Amrapali, Dashehari and Alphonso.

Sardar *et al.* (1995) studied the performance of five introduced mango varieties namely Amrapali, Mallika, Carabao, Pahutan and Rad. They stated that under Bangladesh conditions the fruits of all these varieties were excellent in appearance. Mallika produced the biggest fruit (463.4 g) followed by Rad (230.5 g).

Sharma and Josan (1995) studied the performance of mango cultivars under arid- irrigated region of Punjab and reported that fruits of Dashehari and Langra matured during 2nd week of July. Mallika and Amrapali were midseason which ripened during 3rd week of July and Alphonso as Late season (4th week of July-1st week of August).

Chaudhary *et al*. (1997) evaluated the South Indian mango varieties in semi-arid region of Maharashtra and narrated that the quantitative characters like length and diameter of fruits varied from 6.7 to 15.0 cm and 5.5 to 10.2 cm, respectively.

Sardar *et al.* (1998) observed wide range of variability in respect of different physico-chemical characteristics of mango fruits. Skin and pulp color of ripe fruits varied from green to yellow and yellow to orange, respectively. The largest fruit (578.3 g) was recorded in Fazli and the smallest (126.9 g) in Bhabani. Fazli had the longest fruit (15.5 cm) and the shortest (7.6 cm) in Hilsapeti. Fruit breadth and thickness varied from 5.5 to 8.9 cm and 5.0 to 8.2 cm, respectively. The longest (11. 4 cm) and the widest (5.7 cm) stone were found in Fazli whereas that of Hilsapeti was shortest (5.6 cm) as well as narrowest (3.1 cm).

Kumar (1998), who studied the performance of 101 mango varieties at Sabour in Bihar, reported that cv. Fazli had the maximum size, while cv. Safeda Malihabadi had the minimum fruit weight.

Tripathi (2000) reported that the fruit weight and volume of cultivars Mallika, Nariyal, Fazli and Dadamiyan were more than 400 g and 400 ml per fruit, respectively, among 93 germplasm of mango studied in *Tarai* conditions. He found roundish fruit shape in cvs. Samar-e-Behisht, Naspati, Zafrani Gola, Ketiki Bihar, etc., ovate oblong shape in cvs. Langra, Neelum, Sensation, Gaurjit, etc. and oblong shape in cvs. Khader, Husnara, Pairi, Karutha Kolamban etc.

Mitra and Mitra (2001) evaluated local mango strains grown in West Bengal and noted wide variations for average fruit weight from 70.9 g/fruit (Subza) to

372.5 g/fruit (Surya Pasand) and length of fruits from 12.27 cm (Surya Pasand) to 6.76 cm (Subza).

Sarkar *et al*. (2001) reported the longest fruit (10.70 cm) and the maximum stone weight (20 %) in cv. Amrapali, while the maximum fruit weight (285 g/fruit) and fruit breadth (7.95 cm) was obtained in cv. A.U. Rumani among ten mango hybrids evaluated.

Kher and Sharma (2002) reported the maximum fruit weight (440 g), size (length 14.85 cm and breadth 8.26 cm) and pulp per cent (78.78) in Mallika among five mango cultivars in subtropical rainfed regions of Jammu. Bangalora fruits were the maximum in weight (242 g/fruit) and pulp content (67.17 %) followed by Langra among 22 mango varieties evaluated in Bhagalpur, Bihar (Singh, 2002).

Anila and Radha (2003) reported that the fruits of Ratna had the maximum length, breadth, weight, volume, circumference and the minimum contribution of stone to fruit weight under Kerala conditions.

Hoda *et al*. (2003) evaluated twenty mango cultivars in Sabour, Bihar for quality attributes and reported that Fazli produced the heaviest fruits (450.98 g).

Muhammad *et al*. (2004) conducted an experiment to determine the physico-chemical characteristics of some mango cultivars like Sindhuri, Almas, Langra, Chaunsa, Anwar Retaul, Malda, Desi, Dusehri, Totapuri, Fajli, Super Badam and Lahotia. Langra, Fajri, Desri and Dusehri gave the highest fruit weight (501.4 g).

Chanana *et al.* (2005) reported that maximum fruit weight (357.44 g/ fruit) and size (length 13.09 cm and breadth 7.63 cm) was recorded in cultivar Mallika, while Alphonso recorded minimum fruit weight (201.67 g/fruit) and size (length 9.33 cm and breadth 6.13 cm).

Chatterjee *et al.* (2005) observed that highest fruit weight was recorded in Alfazli but maximum fruit length was measured in Mallika and the highest fruit breadth was contained by Langra.

Kumar and Singh (2005) evaluated the mango varieties for flowering, fruiting and fruit quality attributes and observed that Mallika recorded maximum fruit yield (171.00 kg) followed by Bangalora and Langra i.e. 130.00 and 120.00 kg per plant respectively, while least fruit yield (11.00 kg per plant) was found in Alphonso.

Patel and Khimani (2005) studied characterization and evaluation of different cultivars of mango (*Mangifera indica* L.), and found that the fruit weight ranged from 342.69 g to 497.69 g).

Pandey *et al.* (2006) conducted a research on identification of superior clones and elite seedlings of mango from Uttar Pradesh and reported that Langra clone V-3 possessed the heaviest (370 g) fruit. Seedling identified from different places exhibited a wide range of variability. The fruit weight varied from 205.8 g in Chausa seedling to 299.0 g in Janisahab Karkan collected from Saharanpur.

Bhuyan and Kobra (2007) evaluated the fruit characteristics of uncommon mango varieties grown under Joydebpur conditions, Bangladesh, they observed that Maldah recorded the highest weight (407 g). Among the mango cultivars evaluated under Punjab conditions, the heaviest fruit weight (445 g), was observed in Fazli (Syed, 2010).

Singh *et al.* (2013) studied effect of weather parameters (abiotic factors) on flowering fruiting and quality behaviour of mango cultivars and observed that, the maximum mustard size of fruit was noted under Langra (171.25) followed by Sundarja (142.50). The maximum pea size of fruit (23.88), marble size of fruit (6.00), mature fruit (2.63) was noted under Dashehari. The harvesting period of mango varieties did not differed significantly except Dashehari. The earliest harvesting was observed under Dashehari (29th May).

Himabindu *et al.* (2017) conducted a study at Horticultural Research Station, Venkataramannagudem for evaluating the variability of mango cultivars to conserve the elite ones and to identify the superior genotypes based on fruit characters for future crop improvement. Thirty four mango cultivars were characterized using morphological fruit characters in subsequent years from 2012-14 to know the genetic diversity in mango. The cultivars Sora Mamidi, Kowsuri Pasand and Elamandala appeared to be promising donors for fruit yield which showed maximum fruit weight but the cultivars Panukula Mamidi, Hyder, Nuzividu Rasalu, Suvarnarekha Navaneetham, Nalla Rasalu, Chinnarasam, Panchadara Kalasa and Cherukurasam have optimum fruit size weighing 3-4 fruits/kg.

Bora *et al.* (2017) evaluated mango fruit crops which have been successfully utilized for studying the performance of varieties under different agro

climatic regions time to time. In the present study cultivars were characterized on the basis of their physico-biochemical attributes. Mallika and Neelgoa were found superior in terms of fruit weight (321.87 g) and size (12.55 cm, 8.13 cm).

2.4.2 Pulp, peel and stone characteristics

Kulkarni and Rameshwar (1981) pointed out that cultivar Vanraj had the maximum pulp (81.0 %) followed by Alampur Baneshan and Banganpalli. The cultivar Chinnarasam had 62.5 per cent pulp at Sangareddy, Andhra Pradesh. They also stated that cv. Vanraj had the minimum peel weight (6.8 %), while Fazli had the least stone weight (9.4 %).

Kalra *et al*. (1982) reported the maximum pulp per cent in Hurr followed by Dashehari, while Lazzat Baksh, Bangalora and Eruwadi Bangalora had the least stone weight, *i.e.*, 9 per cent. However, peel content was the maximum in cultivar Markeara and Gaurjit at Lucknow. Among some Baramasi mango varieties, Baramasi Mahso had the highest stone weight followed by Baramasi Mallika and Baramasi Aghaibhagar, while Baramasi Creeper and Baramasi Bahua had the minimum stone weight at Basti (Upadhyay and Tripathi, 1984). Under West Bengal conditions, the maximum pulp weight was recorded in variety Jangale, while the maximum pulp per cent was found in Bombay Green and it was closely followed by Jangale (Ghosh *et al*., 1985). The total weight of peel was also high in Jangale, Sorikhos, Safdar Pasand, Bombay Green and Bombay Yellow as compared to Piarafully, Meghlantan, Amriti, Sardamani Bhog and Ranipasand. The variety Safdar Pasand, however, showed the maximum peel content compared to Bombay Yellow and Meghlanthan. The stone weight was found to vary between 18.7 to 42.2 g among the different varieties. The maximum stone weight was recorded in variety Jangale but the stone percentage in relation to fruit was high in Safdar Pasand, Sardamani Bhog and Amriiti as compared to other varieties.

Sharma and Ray (1985) observed considerable variation amongst different cultivars in respect of pulp percentage in West Bengal. Surajapuri and Mallika had high pulp percentage, which is one of the most desirable characters of the fruit.

Srivastava *et al*. (1987) observed higher pulp and lower stone percentage in Mulgoa, Vanraj, Baneshan and Fazli under Rewa, Madhya Pradesh conditions. On the contrary, lower pulp content was noted in S.B. Chausa, Neelum, Suvarnrekha and

Mankurad. Peel percentage was high in Neelum, Bangalora, Kesar, S.B. Chausa and Alphonso.

Reddy and Singh (1989) at Bangalore, studied some polyembryonic mango varieties for physical characters and reported that pulp : stone ratio for the fruit at ripe stage varied from 1.68 in cv. Starch to 6.34 in Kensington. Stone weight was found to be significantly higher in cultivar S.B. Rampur than Dashehari.

Syamal and Mishra (1989) analyzed some important mango varieties for physico-chemical parameters in Bihar and recorded the highest pulp to stone ratio in Langra. Patil (1990) observed the highest pulp to stone ratio for variety Ratna and the lowest in Pairi.

Uthaiah *et al.* (1990) studied 30 mango cultivars and observed that the pulp content ranged from 49.5 per cent in Kala Hapus to 80.1 per cent in Kalanghran. Cultivar Banarasi Batti had the highest edible to non-edible ratio.

Badiyala and Awasthi (1990), who studied twelve mango cultivars at Kangra valley in Himachal Pradesh. They observed that the minimum stone weight in S.B. Chausa and the minimum percentage of pulp in Sindhuri. Similar findings have also been reported earlier by Teotia *et al.* (1972) and Jindal and Sharma (1981). Chakraborthy *et al*. (1991) stated that cultivar Lucknow Fazli and Gol Debhadiya had the highest pulp content, while the minimum pulp content (40%) was recorded in Safeda. Kundu and Ghosh (1992) noted the maximum pulp weight of 267.3 g in cultivar Fazli followed by 248.3 g and 218.1 g in Himsagar and Chausa, respectively among 19 mango cultivars evaluated at West Bengal. The pulp percentage was also found to be the maximum in Fazli followed by Langra and the minimum in Safeda Pasand. The maximum stone percentage was recorded in Safdar Pasand, while the minimum in Fazli in relation to fruit weight.

Sardar *et al.* (1995) studied the performance of five introduced mango varieties and found that the maximum edible portion was observed in Mallika (76.1 %) followed by Rad (73.4 %) and Pahutan (73.01 %). Chaudhary *et al*. (1997) evaluated the South Indian mango varieties in semi-arid region of Maharashtra and narrated that less variation was observed in percentage of pulp (46.5 to 68.0), peel (14.3 to 28.0) and stone (16.1 to 27.8).

Kumar (1998) in an experiment with 101 mango varieties at Sabour in Bihar, noted a great variation in pulp content. A range of 56 per cent (Safeda Malihabadi) to 85 per cent (Puttu) pulp was recorded. The minimum peel percentage was observed in Langra, while the minimum stone percentage was observed in Puttu. Three varieties, *viz.* Dalma, Mandhappa and Puttu contained more than 80 per cent pulp, while pulp percentage of 24 varieties ranged between 70 to 79.9 per cent. He therefore found that only 27 out of 101 varieties had high pulp containing values.

Tripathi (2000) reported higher pulp content (above 75 %) in Surkhuru-2, Langra, Kesar and Au-Rumani and higher stone percentage in Rasgulla, Bangalora, Safeda Sharbati, Chausa Dwarf and Pathre. Mitra and Mitra (2001) reported that the average pulp and peel weight in twenty local mango strains of West Bengal varied from 304.75 (Surya Pasand) to 56.25 g (Talabi) and from 39.75 (Subza) to 12.50 g (Rani). The higher pulp:stone ratio in Rugni, Sheeradhar and Surya Pasand indicated their suitability for fruit processing.

Muhammad *et al*. (2004) conducted an experiment to determine the physico-chemical characteristics of some mango cultivars like Sindhuri, Almas, Langra, Chaunsa, Anwar Retaul, Malda, Desi, Dusehri, Totapuri, Fajli, Super Badam and Lahotia. Almas gave the highest pulp weight (79.12 %) and Langra, Fajri, Desri and Dusehri gave the highest peel weight (22.60 %) and stone weight (27.28 %).

Patel and Khimani (2005) studied characterization and evaluation of different cultivars of mango (*Mangifera indica* L.), and found that the average fruit skin thickness (0.115 cm), lower stone percentage (10.3 %) were observed in LSM-8, LSM-9, LSM-10, LSM-11, Sardar, Vanraj and Master Royal.

Das *et al.* (2007) observed that Kali recorded the highest pulp percentage (78.4) with sweet taste and peel percentage (10) was observed in Mitha and minimum stone weight was found in variety Nakei (5.9 g) among the mango germplasm of Orissa.

2.4.3 Biochemical and sensory evaluation

Laxminarayana *et al.* (1970) concluded that, at harvesting maturity, Alphonso had 80 per cent moisture, 3 per cent acidity, 2.3 per cent reducing sugar, 3 to 4 per cent total sugar, 8 to 12 per cent starch and 100 mg of ascorbic acid 100 g-1 of flesh.

Teotia *et al.* (1972) studied the physico-chemical nature of Neelum, Bride of Russia, Anupam, Langra, Kesar and Nisar . Nee1um had the highest vitamin C content, whereas Nisar Pasand had the highest TSS and sugar content. The earliest ripening variety, Bride of Russia having an attractive reddish blush on its shoulder, exhibited minimum acidity (0.243 %). In a study conducted at Bangladesh on mango cultivars, it was seen that the vitamin C content ranged from 12.91 mg per 100 g in Dashehari to 28.08 mg per 100 g in Koa Pahari (Samad *et al.,* 1975). Joshi and Shiralkar (1977) observed a decrease in ascorbic acid and phenolic contents with the development of fruits. Goncalves *et al.* (1998) and Attri and Singh (1999) reported the physico-chemical characteristics of mango varieties grown in Brazil and Andaman and Nicobar Islands, respectively.

Palaniswamy *et al.* (1975) observed that, the smaller sized fruits had high ascorbic acid and considered this one as useful in screening the varieties for blending purposes especially with products needing the supplementation of vitamin C. Among the varieties studied, Kalepad was the only variety containing high vitamin C content with good pulp and less stone percentage.

Gangopadhyay *et al.* (1976) collected green mangoes available from local market and analyzed the pulp, this pulp contained 2.3 per cent sugar, 14.05 per cent total carbohydrates (other than sugars), 0.4 per cent total protein, 0.4 per cent crude fiber, 0.5 per cent fat, 0.6 per cent mineral, 1.25 per cent acidity, 81.5 per cent moisture and 70 mg ascorbic acid 100 g^{-1}.

Jindal and Sharma (1981) assessed six mango cultivars for fruit weight, shape and size, stone weight and size, TSS, acidity and TSS : acid ratio and found that Sipia Shah Pasand and Dashehari produced fruits of good quality under semi-arid conditions.

Kulkarni and Rameshwar (1981) reported that TSS ranged from 13.1 to 27 per cent in Totapari and Dashehari, respectively among some important mango cultivars grown at Sangareddy, Andhra Pradesh. Reducing sugars fraction was around 3 per cent in most cases, while non- reducing sugar content ranged from 6.2 per cent (Totapari) to 18 per cent (Mahmuda Vikarabad). Fazli and Dashehari contained the least acidity (0.1 %), whereas Badami Model had the most (0.62 %). Among table cultivars,

Langra scored the maximum ascorbic acid content (66.6 mg/100 g juice). Langra fruits were richest in vitamin C content. Passam (1982) reported that total soluble solids content varied between 10 per cent in cv. Rose and 23 per cent in cv. Starch.

Sharma *et al*. (1984) studied TSS and acidity contents in some sucking mango cultivars of Punjab. GN-1 (Gurmail Da Amb), GN-2 (Samrali) and GN-3 (Kukian Di Chhalli) showed the TSS content of 19, 25 and 22 per cent, respectively, while cultivars like GN-4 (Bijor Di Bad), GN-5 (Hariana Kanghi) and GN-6 (Punjab Beauty) had the acidity content of 0.64, 0.74 and 0.83 per cent, respectively.

Bhuyan and Islam (1986) revealed that, maximum weight (1014.4 g) and largest stone in Fazli, maximum pulp (81.49 %) in Krishnachura and T.S.S. (21.44 %) in Gopalbhog was observed.

Srivastava *et al.* (1987) evaluated fifteen mango varieties in Madhya Pradesh. The varieties with the best quality characters were Langra, Mallika, Dashehari and Alphonso. Langra had the highest ascorbic acid, TSS and sugar contents, and the lowest total acidity. Fruits of seven mango cultivars were analysed by (Jagmohan *et al.,* 1989) for biochemical characters over two seasons (1983 and 1984) in Himachal Pradesh. The total soluble solids content was the highest in Alphonso (21.7 % in both seasons) and the reducing sugar content was the highest in Dashehari (2.7 and 2.9 %).

Salvi and Gunjate (1988) had reported the T.S.S. of Ratna fruits as 23.0, Neelum 17.50 and Alphanso 19.0° Brix and the length and breadth of Ratna fruits as 10.69 and 8.36 cm, respectively.

Badiyal and Awasthi (1990) in their study found that the per cent acidity of the pulp of all twelve cultivars ranged between 0.21 and 0.45 per cent with the lowest in Krishanbhog and the highest in S.B. Rampur at Kangra valley of Himachal Pradesh. The reducing sugars were significantly high in Alphonso, whereas the content of non-reducing sugars was the highest in Dashehari. In West Bengal, out of 19 varieties Piari had the maximum sugar content of 14.68 per cent and Dashehari, which had the sugar of 14.65 per cent, closely followed it. The lowest total sugars were found in cultivar Sorikhos (Chakraborthy *et al*., 1991).

Majumder and Sharma (1990) reported that the composition of mango fruit in general differed with the cultivar and stage of maturity.

Haryati *et al.* (1991) stated that at the stage of maturity, mango flesh indicated T.S.S. of 5.9 ^{o}Brix, 1.5 % titrable acidity and T.S.S./Acidity ratio of 3.8.

Gowda and Ramanjaneya (1994) studied the physico-chemical characteristics of eleven mango varieties and reported that the fibre content was the least in Dashehari. Langra, Mulgoa, Qashehari and Alphonso possessed very viscous pulp/juice. The pulp of some mangoes are fibrous throughout while the fibre may be absent or very little in others and the flesh may also be firm, soft or juicy, acidic or sweet and richly sweet smelling.

Kalra *et al*. (1994) at Lucknow, estimated variation in total soluble solids content of nine mango varieties, the minimum being in Nazuk Badan and the maximum in Saheb Pasand. Cultivars Amin Khurd, Gaurjit, Nisar Pasand and Shorab Shah, however, had a TSS content of more than 20^{0}Brix. Gowda and Ramanjaneya (1994) observed higher vitamin C content in Langra followed by Alphonso. In the remaining nine cultivars the ascorbic acid content was less than 10 mg/100 g pulp.

Kumar (1998) reported high TSS value of 26 per cent in Anannas, Bharatbhog, Husnara and Kalapedy and lower between 15-16 per cent in Kurukkan, Pahutan, Puttu and Taimurlang. As far as the acidity content was concerned, the fruits of variety Cluster showed the highest values of 0.71 per cent, while Husnara and Safeda Sharbati contained 0.06 and 0.03 per cent, respectively. Langra and Bombay with the acidity content of 0.24 and 0.12 per cent, respectively, were moderately acidic. Although the study revealed that Langra and Malda fruits contained as high as 150 and 125 mg/100 g fruit vitamin C, respectively, yet mango fruit could never be regarded as a fruit rich in vitamin C because the fruits of Mohanbhog contained as low as 6.2 mg ascorbic acid/100 g juice.

Sharma *et al*. (1999) reported that Dashehari had the highest total soluble solids (20.04 %), reducing sugar content (3.87 %), TSS : acid ratio (75.42) and sugar : acid ratio (14.33) among four cultivars evaluated under arid-irrigated conditions of Punjab.

Kumar and Kumar (2000) studied the pulp characters of 101 varieties. Twenty-two cultivars had fibreless pulp. Pulps of Baramasia and Sukul cultivars were much fibrous, while the rest had some or less fibre. Pulps of 48 cultivars were soft, 44

were firm and the remaining nine were loose. One hundred and fifty four mango cultivars were evaluated for their productivity (tree height upon reaching maturity and fruit bearing index) and fruit quality (including average weight, shape of fruit, colour and texture of pulp, colour of flesh and fruit covering and fibre content) (Avilan *et al.,* 2001). A scale of one to three was used for various attributes. Haden, Kent, Irwin, Davis-Haden and Tommy Atkins which were selected in Florida and are now found world wide and Araque and Rangel, found in Venezuela are some of the cultivars selected for their superior quality.

Mitra *et al*. (2000) studied physico-chemical characteristics of 21 mango varieties growing in West Bengal and reported that Jagannathbhog had the highest TSS (22.33 %), whereas Jhumko Rani showed the highest sugar content (14.83 %). The lowest titratable acidity (0.14 %) and the highest ascorbic acid content (123.33 mg/100 g) were observed in fruits of Jahanara and Kashir Langra, respectively.

Reddy *et al*. (2000) reported highest TSS (24.20ºB) and total sugars (18.67 %) in cv. Mallika, whereas Chausa recorded the highest TSS : acid ratio and was adjudged the most palatable mango cultivar among 20 cultivars evaluated in Ranchi, Bihar. Tripathi (2000) reported high TSS in Bijoragarh, Amrapali, Surkhuru-2, Lucknow Safeda, Dashehari, Mallika, Sepia, Dadha Peda and Surkhuru-1, whereas the minimum acidity was recorded in Chausa Dwarf, Langra, Dashehari, Chausa and Alphonso. Cultivars like Kazalio, Pulihora and Langra were found to be high in ascorbic acid content. An evaluation study of twenty local mango strains of mango grown in West Bengal showed that the TSS of the fruits was the maximum in cv. Rani and the minimum in Tephala, whereas the highest total sugars content was recorded in Safdar Pasand (Mitra *et al*., 2001). The lowest titratable acidity (0.09 %) was observed in Saradamani Bhog and Sita Bhog, whereas highest ascorbic acid was reported in Shah Pasand. Based on high TSS : acid ratio (more than 100) cv. Rugni, Safdar Pasand, Saradamani Bhog, Sita Bhog and Totapari Red Small were recommended for table purpose.

Mitra and Mitra (2001) studied nineteen mango varieties of West Bengal in which the highest total soluble solids (22.66 °B) and sugar/acid ratio (226.6) and the lowest titrable acidity (0.1 %) were recorded for Misti Bhog. Lata Bombai showed the

highest total sugar (16.23 %), while Lohajang had the greatest ascorbic acid (104.66 mg/100 g). The highest reducing sugar content (6.2 %) was observed in Mohan Bhog.

Singh (2001) evaluated thirty-one genotypes of mango based on higher TSS, total sugars and ascorbic acid content during ripening. He observed that collection number 20/80 was most suitable for processing purpose.

Kher and Sharma (2002) observed that Dashehari fruits were superior in TSS, TSS : acid ratio, reducing sugars and sugar : acid ratio than other four cultivars taken for performance study and recommended the cultivation of Dashehari in rainfed region of Jammu. Singh (2002) reported the maximum TSS (23%), total sugars (15.17%), reducing sugars (4.78 %) and total carotenoids content (8.17 mg/100 g) in Amrapali followed by Langra and Zardalu from 21 cultivars studied in Bhagalpur, Bihar conditions.

Anila and Radha (2003) studied physico-chemical characteristics of four cultivars and two hybrids under Kerala conditions and recorded the highest values of total soluble solids (TSS), sugars and ascorbic acid in the fruits of Ratna and H-151. They concluded that Ratna had all the desirable characteristics in terms of fruit length, breadth, weight, volume, circumference, the minimum stone weight, TSS and sugar content.

Hoda *et al.* (2003) evaluated twenty mango cultivars planted in Sabour during 1980 for fruit quality in 1997/99. Mallika recorded the greatest total carotenoid (4.95 mg per 100g) contents. The highest contents of TSS, total sugar, reducing sugar and ascorbic acid were recorded for Dashehari.

Uddin *et al*. (2006) conducted an investigation on some bio-chemical characteristics of twenty two germplasm of mango. Total soluble solids content of 22 mango germplasm were measured at ripe stage. It was observed that the variation in TSS among different germplasm was highly significant. Pahlam contained the highest TSS (26.27 %) followed by Langra (25.20 %), Khirsapat (25.17 %) and Rad (25.50 %). The lowest total soluble solids (19.73 %) was recorded in Tommy Atkin.

Das *et al.* (2007) studied genetic variability in mango germplasm of Orissa and reported that Lori variety recorded the highest TSS (26%) among the different genotypes. Bhuyan and Kobra (2007) evaluated the fruit characteristics of uncommon mango varieties grown under Joydebpur conditions, Bangladesh and found that Nakua Goote had the highest total soluble solids content (26 %).

Syed (2009) evaluated mango cultivars for productive and commercial plantation under Punjab conditions of Pakistan and observed that maximum vitamin C contents were recorded in cultivars Sanglakh and Chaunsa (145 mg) followed by Alphonso (98.5 mg) and Zafran (93.5 mg) per 100 g of pulp, maximum TSS (24.7 °Brix) was in Dusehri and maximum acidity (0.82) was in Sanglakhi.

Rajwana *et al.* (2010) carried out an experiment in which he found that a newly evolved hybrid Faiz Kareem (Anwar Ratole X Chaunsa) expressed better firmness, which indicates it's potential for extended shelf-life. However, total sugars (23.71 %, total soluble solids (25.54 °Brix) and total carotenoids (24.60 µg/ g) were lower than it male parent Chaunsa but higher than female parent Anwar Rataul, which can be an advantage for extended storage and for sugar conscious consumers.

Sethi *et al.* (2011) compared time required for ripening, post ripening life, cumulative physiological loss in weight during storage, peel colour and sensory quality of newly developed 12 mango hybrids with the important mango hybrids Pusa Arunima and Amrapali. Among hybrids, Pusa Arunima and H 3-2 took longer time for ripening (6.2 and 6.4 days, respectively) while hybrids H 4-12 and H 2-14 ripened faster (3.8 and 4.0 days, respectively). Total post-harvest life was maximum in hybrid H 3-2 (9.8 days), followed by Pusa Arunima (9.4 days).

Bora *et al.* (2017) evaluated mango fruit crops which has been successfully utilized for studying the performance of varieties under different agro climatic regions time to time. In the present study cultivars were characterized on the basis of their physico-biochemical attributes. Mallika excelled in terms of sugar (20.82), while Amrapali in carotenoids (8.38 mg/100 g). Among them, Mallika (22.41°B) possessed the highest amount of total soluble solids while lowest amount in Langra (16.90 °B). The study showed the potential of Amrapali in terms of its quality, being late can meet the demand for later period when no other cultivar is available.

Syed *et al.* (2017) studied 425 mango accessions from Azad Jammu & Kashmir (AJK) as well as Northern and Southern Punjab to explore the genetic diversity. Total 33 traits (25 qualitative and 8 quantitative) enabled the assessment of morphological and physico-chemical diversity of the studied indigenous mango germplasm. The first three principal components (PCs) contributed 68.06 per cent variability among all mango

accessions. The PCs also successfully grouped mango accessions according to their morphological and physico-chemical characteristics. Trunk height, tree circumference, crown diameter, leaf colour, leaf blade length, petiole length, inflorescence length, inflorescence width, fruit shape, fruit weight, soluble solid contents, titratable acidity, sugar:acid ratio, reducing sugars, non-reducing sugars and total sugars were found highly variable. Many of these characters are of substantial economic significance and could be used as breeding goals to increase the germplasm repository as well as fruit yield and quality. In conclusion, morphological and physico-chemical traits were highly useful for mango germplasm characterization. Several accessions also showed potentially good traits which could be used to develop new mango cultivars through future breeding schemes.

Husen (2019) performed the characterization and evaluation of mango hybrids by morphological characteristics and chemical properties as well as fruit yield. The material was 17 mango plants hybrid (F1), 3 years old, the cultivars from crosses Arumanis-143 (Cg-48) which has a green color on the fruit skin with 6 clones of Cukurgondang red mango. To find fruit diversity, 16 characters quantitative and 23 qualitative characters were observed using Descriptors for Mango of The International Plant Genetic Resources Institute 2006, and the evaluation was done on the characters of fruit weight, fruit pulp thickness, total soluble solids, fruit yield and fruit color. The results showed that the vast diversity only occured on characters of the weight of the fruit, seed and endocarp weight, while others had a narrow diversity. Principal component analysis on 23 qualitative characters of fruit formed 6 major components with the cumulative diversity of 81.9 %, the highest proportion (PC1) of 23.2 per cent which is the character of the shape of fruit apex, skin color of ripe fruit, fiber length in the pulp, and cluster analysis of 13 genotypes formed two clusters. Evaluation of hybrid with high yield occur in F1-15 and F1-87, while high total dissolved solids observed in F1-02, F1-22, F1-49 and red fruit skin was in hybrids F1-31, F1-47, F1-44 and F1-09 successively.

Neguse *et al.* (2019) conducted a study to assess the diversity of 69 mango cultivars of different growing regions of the country based on 44 phenotypic descriptors. The results of both univariate and multivariate analysis of variance computed for quantitative data, and results from descriptive statistics for qualitative characters indicated

the presence of phenotypic variation among the cultivars. Further analysis of Principal Component Analysis (PCA) indicated the first four components explained more than 75% of the total variation in which most fruit, seed and leaf characters contributed much to the observed variation.

Dutta *et al.* (2020) stated that characterization and documentation of indigenous mango varieties is important for identifying potential candidates for improved utilization of the genetic resource. Murshidabad, district of West Bengal, the land of the Nawabs, is famous for its traditional mango varieties. Even after massive genetic erosion there still exists a rich collection of indigenous mango varieties in this district. Therefore they studied characterisation of the mango fruit and fruit pulp using DUS Testing based on PPV and FRA, 2008 among some indigenous mango varieties of Murshidabad district of West Bengal.

2.5 Molecular characterization

Goulao and Cristina (2001) evaluated the potential use of 13 SSR primer sets in fingerprinting and determination of the similarity degree between 41 commercial cultivars of apple. A total of 84 polymorphic alleles were amplified. Except for cultivars obtained from somatic mutations, all cultivars were easily distinguishable. Dendrograms constructed using UPGMA cluster analysis revealed a phenetic classification that emphasizes the existence of a narrow genetic base among the cultivars used and the Portuguese cultivars revealing higher diversity.

Kumar *et al*. (2001) screened 50 commercial mango cultivars using RAPD markers to estimate the genetic diversity and observed a high degree of genetic variation among the cultivars and the variety Mulgoa was found to be very distinct.

Creste *et al*. (2003) used microsatellite markers to characterize 35 banana (*Musa* spp.) genotypes cultivated in Brazil, including triploid cultivars and tetraploid hybrids. A total of 33 *Musa*-specific primers were tested, and 11 produced clear, reproducible and discrete bands. The microsatellite loci were highly informative, with some pair of primers generating an unique fingerprinting for each genomic group and discriminating a genotype of doubtful classification, although somatic mutants from a subgroup were seldom distinguished from their original clone.

Romero *et al.* (2003) studied forty apricot cultivars with different geographic origins by means of SSR markers. The aim of the study was to determine the genetic relationships among genotypes from different eco-geographical groups. Sixteen primer pairs flanking microsatellite sequences in the peach genome were assayed. Eleven of them were polymorphic in the set of cultivars studied and allowed every genotype to be unambiguously distinguished. UPGMA cluster analysis based on Nei's genetic distance grouped genotypes according to their geographic origins and pedigrees. SSR markers have proved to be an efficient tool for fingerprinting cultivars and conducting genetic diversity studies in apricot.

Charcosset and Moreau (2004) studied the use of molecular markers for the development of new cultivars and the evaluation of genetic diversity. Molecular markers bring new information on the determination of trait variation and the organization of genetic diversity within plant species of agricultural interest. Molecular markers now make it possible to analyze the global organization of genetic diversity within species and to evaluate distance or similarity between individuals and population.

Risterucci *et al*. (2005) carried out an experiment in which A (GA)*n* and (GT)*n* microsatellite-enriched library was constructed and twenty three nuclear simple sequence repeat (SSR) loci were characterized in the guava species (*Psidium guajava* L.). All SSR loci were found to be polymorphic after screening for diversity in different cultivars, and across-taxa amplification tests showed the potential transferability of most SSR markers in three other *Psidium* species. This new SSR resource will be a powerful tool for genetic studies of guava, including cultivars identification and linkage mapping, as well as potentially for interspecific genetic studies within the genus *Psidium.*

Sanchez *et al.* (2005) studied simple sequence repeat (SSR) markers in the molecular characterization of 8 apricot (*Prunus armeniaca* L.) cultivars. DNA fingerprints have been developed establishing the genetic relatedness among cultivars, new releases and breeding lines. Amplification of SSR loci was obtained for all 17 primer pairs and 14 of them produced polymorphic amplification.

Golein *et al.* (2005) studied the genetic variability of eight sweet oranges (*Citrus sinensis* L.) and six mandarins (*Citrus reticulata* Blanco) accessions by using simple sequence repeats (SSRs) analysis. Microsatellite markers discriminated variation

within mandarins, but low variation was observed between sweet oranges. A UPGMA phenetic tree was constructed and one main sweet orange group consisting of three sub-groups and four main mandarin groups were identified. The majority of sweet orange accessions showed a narrow genetic base suggesting that the observed morphological polymorphism within the group must be associated with somatic mutations, which were not exactly detected by these molecular markers.

Maghuly *et al.* (2005) studied a collection of 133 apricot cultivars and three related species originating from different geographical regions with 10 polymorphic microsatellite markers developed in apricot. Altogether, 133 alleles were identified in the set of accessions, with an average of 13.30 alleles per locus. The observed heterozygosity for individual loci ranged from 0.8636 to 0.3182, with an average of 0.6281. An unweighted pair group method with arithmetic mean dendrogram based on Nei's genetic distance grouped the accessions according to their eco-geographical origin and/or their pedigree information.

Bao *et al.* (2007) carried out an experiment in which Simple Sequence Repeat (SSR) markers were used to assess genetic diversity and relationship of pear cultivars native mainly to East Asia. A total of 168 putative alleles were generated from six primer-pair (BGA35, KU10, BGT23b, NH004a, NH011b and NH015a). All the SSR markers showed a high level of genetic polymorphism with a mean of 28 putative alleles per locus and the heterozygosity of 0.63. Ten major groups were generated from all the accessions by UPGMA cluster analysis. Chinese sand pears consisted of four groups with Chinese white pears and Japanese pears, of which Chinese sand pears occurred in all four groups, presenting a large genetic diversity, Chinese white pears were included in three groups, and Japanese pears only fell into one group.

Anuradha *et al.* (2007) analyzed twenty-one rootstock accessions with seven grape microsatellite (SSR) primers. SSR primers detected 56 alleles across 21 genotypes and primer heterozygosity varied from 0.617 to 0.856. A combination of three SSR primers was sufficient to distinguish 21 rootstocks. In cluster analysis majority of rootstocks belonging to same species or having common parents grouped together.

Begum *et al.* (2008) studied morpho-physiological characterization and evaluation based on fruit characteristics and revealed that, six landraces *viz*., DM Acc-3, 4, 7, 15, 17 and 18 were elite with respect to fruit characteristics, which were further characterized for their genetic distinctiveness and relationships with the choicest juicy cultivars of mango in Andhra Pradesh (Peddarasam, Chinnarasam, Cherukurasam, Panchadarakalasa and Suvarnarekha) at the molecular level, using 109 mango-specific microsatellite markers (SSRs).

Jannati *et al.* (2009) used fifteen SSR primer pairs to estimate the level of polymorphism among 23 citrus genotypes and four natural hybrids or bud mutations. All fifteen loci assayed in citrus plant possessed a high level of polymorphism with the average number of 8.27 alleles per locus. Cluster analysis with SSR markers resulted in 2 cluster groups: Group A: Yuzo and *Poncirus*. Group B: There are three separate subgroups within Group B; (i) genus *Fortunella* sp. (ii) Mandarin subgroup: *Citrus reticulata (Citrus clemantin), Citrus sinensis* (Pineapple, Washington Navel), Natural types (Siahvaraz*,* Shalmahaleh, Moallemkoh and Kotra 4 hybrids) and (iii) *Citrus limon* (Amol lemon - pear, Eureka, Rough Lemon), *Citrus aurantifolia, Citrus aurantium, Citrus medica* and *Citrus grandis*.

Narayanaswamy *et al.* (2009) analyzed forty two grape (*Vitis vinifera* L.) genotypes using seven simple sequence repeat (SSR) markers. A total of 45 alleles in all 42 genotypes were obtained with 7 primers with an average number of 6.4 alleles per locus. The dissimilarity matrix showed that a maximum of 110 units was obtained between the genotypes 'Convent Large Black' and 'Arka Hans', while a minimum dissimilarity 37 units were obtained between the genotypes 'Anab-e-Shahi' and 'Dilkhush'. In the dendrogram the microsatellite segregated the genotypes into two clusters (A and B) with two subclusters each. The subclusters grouped genotypes predominantly as A1 with seeded fruits, A2 with seedless fruits, B1 with pigmented and seedless fruits, and B2 with colorless and seeded fruits.

Syed *et al.* (2010) studied isolation and characterization of 12 polymorphic microsatellite markers from a repeat-enriched genomic library of *Punica granatum* L and the genetic diversity of these loci in 60 genotypes. All loci were variable, the number of polymorphic alleles per locus ranged from two to five (average 2.9). The polymorphic

information content ranged from 0.26 to 0.61 (average: 0.43). This is the first time that polymorphic microsatellite markers have been reported for *P. granatum* L. These new markers should allow studies of the population structure and genetic diversity of pomegranate to be performed in the future.

Bora *et al.* (2017), studied genetic diversity of 19 genotypes of mango and characterized both by morphological and 20 Simple Sequence Repeat (SSR) markers. Characterisation of mango genotypes based on morphological and molecular basis is a better approach for designing breeding projects. On the basis of present findings it was observed that Sabri and Amrapali showed dwarf stature, while Swarna Jahangir was found to be vigorous in its growth. The unweighted paired method of arithematic average (UPGMA) dendogram based on genetic distance segregated the 19 mango genotypes into two main clusters. The polymorphic information comtent (PIC) values ranged from 0.38 to 0.81 Jaccard's similarity coefficient values ranged from 0.15 to 0.79 with polymorphism of 77.55 per cent. Three unique fingerprints were identified in three genotypes which can help in varietal identification. A total of 49 loci (42 polymorphic and 7 monomorphic) were dectected with amplified size range of 110 to 359 bp. The maximum numbers of loci (i.e 5) were detected by the primer MiSHRS-48. Out of 20 SSR primers 11 were polymorphic. Pusa Surya was found to be the most diverse genotype both morphologically and genetically. The similarity for Pusa Surya was 15 per cent with remaining Indian genotypes. The significant variation exists among the genotypes based on morphological and biochemical characters but with the use of SSR markers, assessment of the genetic diversity can help us to plan a future breeding program using the diverse parent.

According to Nazish *et al*. (2017), understanding the genetic diversity of different Pakistani mango varieties is important for germplasm management and varietal characterization. Microsatellites are efficient and highly polymorphic markers for comparative genome mapping and were used in the present study to determine the genetic relatedness and variability among 15 indigenous mango cultivars (*Mangifera indica* L.). Overall, 181 bands were produced using 12 simple sequence repeat (SSR) primers. Out of the 12 primers used, 10 were polymorphic and two were monomorphic. Genetic relatedness among cultivars was assessed by constructing a dendrogram using the

unweighted pair group method of arithmetic means. The accessions exhibited coefficients of similarity ranging from 75 to 100 per cent, indicating the frequent use of only a few parent cultivars and the presence of inbreeding. The primers used in the present study were found to be valuable for identifying genetic relationships among mango cultivars.

3. MATERIAL AND METHODS

The present investigation entitled “Biosystemic studies in randomly mated hybrid progenies of mango (*Mangifera indica* L.)” was carried out during 2015-2017. For morphological and biochemical characterization, forty-two derivatives were selected from “Instructional-cum-Research Farm”, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri. Six hybrid mango derivatives and six check varieties (Alphonso, Ratna, Kesar, Sai Sugandh, Neelum, Totapuri) were selected for molecular characterization. The details of material used and methods adopted in the present study are mentioned under the following captions.

3.1 Experimental material

3.1.1 Details of derivatives

The germplasm of mango is maintained at Instructional-cum-Research Farm, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri. Forty two hybrid derivatives for morphological characterization and for molecular six promising hybrid derivatives along with six check varieties were selected from above location.

3.1.2 Experimental site

The morphological and biochemical analysis of fruits of all hybrid derivatives was conducted at Department of Horticulture, MPKV, Rahuri, Dist. Ahmednagar (M.S.). The Mahatma Phule Krishi Vidyapeeth, Rahuri is situated between 190 20’ and 190 57’ North latitude and 740 82’ and 740 19’ East longitude. The altitude varies from 511 to 547 m above the mean sea level.

3.1.3 Climatic conditions

3.1.3.1 General

The region falls under semi-arid and tropical zone. The annual rainfall ranges from 307 to 619 mm with an average of 520 mm. About 80 per cent rainfall is received in June to September from south west monsoon. The distribution of rain is erratic and recurrence of dry spells is a common phenomenon.

The annual average maximum temperature of the tract is 37.9^0C which ranges from 33^0C to 43^0C and the average minimum temperature is 17.2^0C with range of

3 ^{0}C to 18 ^{0}C. The mean relative humidity at 7.30 and 14.30 hours is 59 and 35 per cent, respectively. The mean evaporation ranges from 5.3 to 12.1 mm.

3. 2 Experimental Methods

3.2.1 Collection of fruits

Mango fruits of 42 hybrid derivatives were collected from above mentioned location. Fruits were harvested at physiological maturity stage and were analyzed for morphological and biochemical parameters.

3.3 Morphological characterization

All morphological observations were recorded as per IPGRI 2006 Descriptors for Mango (*Mangifera indica* L.), of the International Plant Genetic Resources Institute, Rome, Italy.

3.3.1 Growth characters

3.3.1.1 Tree height (m)

The height of trees of 42 hybrid derivatives was measured using measuring pole and expressed in meters.

3.3.1.2 Tree spread (N-S) and (E-W) (m)

The spread of the experimental trees was measured in the North-South and East-West directions with the help of measuring tape and was expressed in meters

3.3.1.3 Tree volume (m^3)

Tree volume was calculated as suggested by Castle (1983) using the following formula:

Tree volume (m^3) = 1/6 π. h. 2r

h = height of the tree (m), r = canopy radius (m),

r = canopy spread (East-West + North-South),

π = 22/7

3.3.2 Leaf characters

For all leaf characters, average of 10 fully matured and healthy leaves were collected half-way along the shoot from tree and following observations were recorded.

3.3.2.1 Leaf size

a. Leaf length (cm)

The length of randomly selected ten leaves of all 42 hybrid derivatives excluding petiole was taken from tip of the bearing shoot and average was calculated and expressed in centimeters.

b. Leaf breadth (cm)

The leaf breadth of all 42 hybrid derivatives was measured in the widest part of fully developed leaves and average was calculated and expressed in centimeters.

3. 3.2.2 Leaf type

The leaves of all 42 hybrid derivatives were visually observed and recorded for leaf type as simple, oblanceolate and alternate.

3. 3.2.3 Leaf colour

The colour of leaves of all 42 hybrid derivatives was observed and recorded as pale green, Green and Dark green.

3. 3.2.4 Leaf waxiness

The leaf waxiness of all 42 hybrid derivatives was recorded as waxy and non-waxy.

3.3.3 Flowering characters

The observations were recorded on randomly selected twenty-five panicles of each tree of all 42 hybrid derivatives.

3.3.3.1 Days required from bud burst to full bloom (days)

Days required from the loosening of the bud scales and the elongation of the floral axis with appreciable growth which further leads to development of primary and secondary branches of the panicle was recorded and expressed in days.

3.3.3.2 Date of last emergence of panicle

Date of last panicle emergence of all 42 hybrid derivatives was recorded from the trees when no longer panicles emerged.

3.3.3.3 Type of inflorescence

Inflorescence type of all 42 hybrid derivatives was observed and recorded as, conical (narrowly pyramidal), pyramidal and broadly pyramidal.

3.3.3.4 Inflorescence length (cm)

The length of the inflorescence in all 42 hybrid derivatives of five randomly selected inflorescence from each side and center of the tree was measured from the base to the tip of the inflorescence in centimeters at full bloom stage.

3. 3.3.5 Inflorescence breadth (cm)

The breadth of the inflorescence in all 42 hybrid derivatives of five randomly selected inflorescence from each side and center of the tree was measured in centimeters at the widest portion of the inflorescence at full bloom stage.

3. 3.3.6 Number of flushes

The flushes were visually observed by visiting the orchard regularly.

3. 3.3.7 Colour of panicle

The colour of the inflorescence was observed and recorded as green, light green, yellow, reddish yellow, reddish green and reddish.

3. 3.3.8 Colour of flower

The colour of flower in panicle was visually observed and recorded as yellow and light yellow.

3. 3.3.9 Number of hermaphrodite flowers per panicle

Number of hermaphrodite flowers were counted from North, South, East and West directions of plant canopy from randomly tagged panicles and averaged for each direction.

3. 3.3.10 Number of male flowers per panicle

Total numbers of male flowers were counted at full bloom stage from tagged panicles and average was calculated.

3. 3.3.11 Sex ratio

Sex ratio was calculated by dividing number of hermaphrodite flowers with number of male flowers by using following formula.

$$\text{Sex ratio} = \frac{\text{Number of hermaphrodite flowers}}{\text{Number of male flowers}}$$

3.3.3.12 Number of inflorescence per shoot

The number of inflorescence per shoot of randomly selected shoots in all 42 derivatives was observed and recorded from the tagged panicles in all 42 hybrid derivatives of mango.

3.3.3.13 Number of rachis per panicle

Number of rachis per panicle was recorded by counting the rachis from each tagged panicle and an average was calculated.

3.3.3.14 Duration of flowering (days)

The duration of flowering was calculated from the first day of flower opening to the end of the flowering and expressed in days.

3.3.4 Fruit morphology

All observations were recorded when fruits were fully ripened, unless otherwise specified. Measurements were made on 10 well developed representative fruits of 42 hybrid derivatives of mango at the time of harvest.

3.3.4.1 Days required from fruit setting to mustard stage (days)

Date of fruit set and mustard stage was recorded when tagged panicles of each hybrid derivative started fruit setting upto mustard stage. The date of fruit set and mustard stage was noted by the visual observation. The period from fruit setting to mustard stage was calculated and expressed in days.

3. 3.4.2 Number of fruits per panicle (at mustard stage)

Number of fruits was computed by counting the number of fruit set at mustard stage from five randomly tagged panicles from each side and center of tree was recorded and an average was calculated as number of fruits per panicle.

3.3.4.3 Days required from mustard stage to pea stage (days)

Date of mustard stage and pea stage was recorded when tagged panicles of each hybrid derivative showed mustard stage upto pea stage. The date of mustard stage and pea stage was noted by the visual observation. The period from mustard stage to pea stage was calculated and expressed in days.

3.3.4.4 Days required from pea stage to marble stage (days)

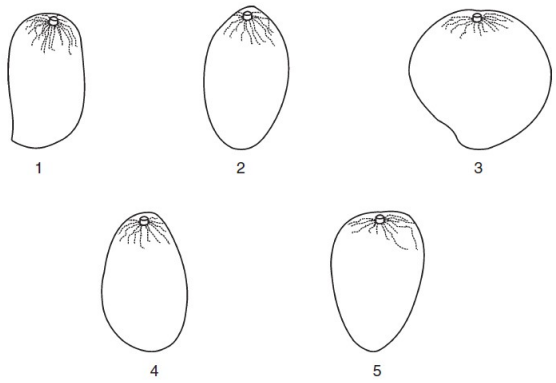
Date was recorded when marble sized fruits were observed from pea stage on tagged inflorescences and expressed in days.

3.3.4.5 Fruit retension per cent at harvest (%)

The number of fruits at mustard stage of tagged panicles and fruits on the same panicle at harvest was counted and recorded and per cent fruit retension was calculated and expressed in percentage.

3.3.4.6 Fruit shape

The fruit shape of 42 hybrid derivatives was observed and recorded as oblong, elliptic, roundish, ovoid and obovoid.



(1. Oblong 2. Elliptic 3. Roundish 4. Ovoid 5. Obovoid)

Fig.1. Fruit shape

3.3.4.7 Fruit length (cm)

The length of ten randomly selected fruits of each hybrid derivative was measured from the base to apex of the fruit with a vernier calliper and an average was calculated and expressed in centimeters.

3.3.4.8 Fruit breadth (cm)

The fruits which were used for recording the length of the fruit were also used for recording the fruit breadth and was measured at the widest portion of the fruit with a vernier calliper and expressed in centimeters.

3.3.4.9 Fruit weight (g)

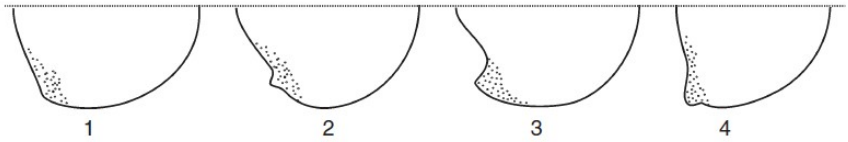
Ten fruits of each hybrid derivative were weighed with an electronic balance and average was calculated and expressed in grams.

3.3.4.10 Fruit volume (cm^3)

The volume of the fruit of each hybrid derivative of randomly selected ten fruits was measured by the conventional water displacement method and average was calculated and expressed in cubic centimeters.

3.3.4.11 Fruit beak

Fruit beak was observed in all hybrid derivatives and recorded as perceptible, pointed, prominent and mammiform.

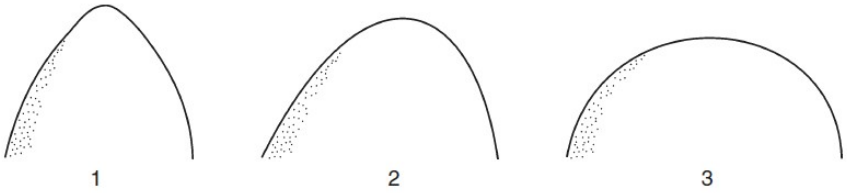


(1. Perceptible 2. Pointed 3. Prominent 4. Mammiform)

Fig. 2. Fruit beak

3.3.4.12 Fruit apex

Fruit apex was observed in all hybrid derivatives and recorded as acute, obtuse and round.



(1. Acute 2. Obtuse 3. Round)

Fig. 3. Fruit apex

3.3.4.13 Fruit base

Fruit base in all hybrid derivatives was recorded as round to obliquely round, slightly flattened and extended, flattened, obliquely flattened, obliquely round.

3.3.4.14 Colour of fruit (Unripe)

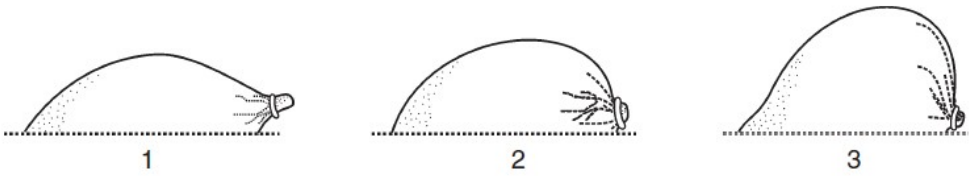
Fruit colour in all hybrid derivatives was recorded by visual observations as green, yellow, orange, purple and red at harvesting time.

3.3.4.15 Stalk insertion

Fruit stalk insertion was observed and recorded as vertical and oblique.

3.3.4.16 Fruit shoulder (slope of fruit ventral shoulder)

Fruit shoulder was recorded as sloping abruptly, rising and then rounded, ending in a long curve.



(1. Sloping abruptly 2. Rising and then rounded 3. Ending in a long curve)

Fig. 4. Fruit shoulder

3.3.4.17 Fruit skin colour (Ripe)

Fruit skin colour of 42 hybrid derivatives was observed after ripening as green, greenish yellow, yellow, green with red blush and green with purple patches.

3.3.4.18 Fruit skin thickness (mm)

To measure the thickness of rind, the fruits were equally divided into two by cutting and length between rind and segments was measured with the help of Vernier calipers in milimeters.

3.3.4.19 Skin percentage (%)

Skin percentage was calculated by dividing average skin weight by average fruit weight and expressed in percentage.

3.3.4.20 Fruit waxiness

Fruit waxiness was recorded as waxy and non-waxy.

3.3.5 Pulp

3.3.5.1 Pulp colour

Pulp colour was observed and recorded as light yellow, golden yellow, yellowish orange, orange, greenish yellow, yellow, light orange and dark orange.

3.3.5.2 Pulp texture

Pulp texture was recorded on fully riped fruits as soft, intermediate and firm.

3.3.5.3 Pulp fibrousness

Pulp fibrousness was recorded as absent, low, intermediate and high.

3.3.5.4 Pulp percentage (%)

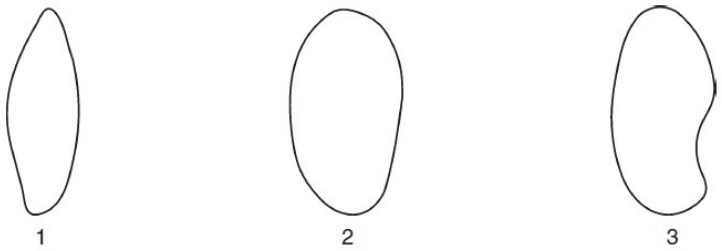
The fruit pulp was separated from the fruit peel and stone. The pulp was weighed and pulp percentage was calculated using the following formula and expressed in percentage.

$$\text{Pulp percentage} = \frac{\text{Pulp weight (g)}}{\text{Fruit weight (g)}} \times 100$$

3.3.6 Stone

3.3.6.1 Stone shape

Stone shape was visually observed and recorded as ellipsoid, oblong and reniform.



(1. Ellipsoid 2. Oblong 3. Reniform)

Fig 5. Stone shape

3.3.6.2 Stone length (cm)

The length of ten stones of each hybrid derivative was measured and an average was calculated and expressed in centimeters.

3.3.6.3 Stone width (cm)

The width of ten stones of each hybrid derivative was measured and an average was calculated and expressed in centimeters.

3.3.6.4 Stone weight (g)

The fruit was peeled and stone was separated from the pulp and after proper cleaning of pulp portion of the fruit, weight of the stone was taken with the aid of an electronic balance and expressed in grams.

3.3.6.5 Stone volume (cm^3)

Stone volume of each hybrid derivative was calculated by water displacement method and expressed in cubic centimeters.

3.4 Biochemical characters

3.4.1 Total soluble solids (°Brix)

Total soluble solids (TSS) of pulp was estimated with the help of a hand refractometer calibrated in °Brix at 20°C. The prism of refractometer was washed with

distilled water and wiped by muslin cloth after recording each observation (A.O.A.C., 1984).

3.4.2 Reducing sugars (%)

The reducing sugars were estimated by using Lane and Eynon (1923) method with modification suggested by Ranganna (1977). A known weight (5 g) of sample was blended with distilled water using lead acetate (45%) for precipitation of extraneous material and potassium oxalate (22 %) to delead the solution. This lead-free extract was used to estimate reducing sugars by titrating against standard Fehling's mixture (Fehling's A and B) using methylene blue as an indicator to a brick red end point.

3.4.3 Non-reducing sugars (%)

The non-reducing sugar content was determined by subtracting the value of reducing sugar from that of the total sugar and multiplying the values with 0.95 (as 0.95 g of sucrose on hydrolysis gives 1 g of monosaccharides i.e. glucose and fructose) and expressed as percentage (%).

3.4.4 Total sugars (%)

The total sugars were estimated by the same procedure of reducing sugars after acid hydrolysis of an aliquot of deleaded sample with 35 per cent hydrochloric acid, followed by neutralization with sodium hydroxide (40 %). This filtrate was used for titration against standard Fehling's mixture (Fehling's A and B) using methylene blue as an indicator to brick red end point (Ranganna, 1977).

3.4.5 Titratable acidity (%)

The titratable acidity was determined by titrating against standard alkali (N/10 NaOH) using phenolphthalein as an indicator and expressed as percentage (%) in terms of citric acid (A.O.A.C., 1984).

3.4.6 pH of pulp

pH of the pulp was recorded using pH meter.

3.4.7 β- carotene (µg/100g)

Total carotenoid pigments (expressed as β–carotene) were determined as per the method described by Roy and Susantha (1973). The results were expressed in terms of β-carotene as µg/100g sample.

3.4.8 Ascorbic acid content (mg/100g)

Determination of ascorbic acid was done by 2, 6-dichlorophen-olindophenol dye method of Johnson (1948) as described by Ranganna (1977). A known quantity of sample was blended with 3 per cent metaphosphoric acid (HPO3) to make the final volume of 100 ml and then filtered. A known quantity of aliquot was titrated against 0.025 per cent 2, 6 - dichlorophenol indophenol dye to a pink colour end point. The ascorbic acid content of the sample was calculated taking into consideration the dye factor and expressed as mg ascorbic acid per 100g fruit pulp (Anon., 1966).

3.4.9 TSS:Acidity ratio

The ratio was calculated by dividing total soluble solids (TSS) by titratable acidity content of fruit.

3.4.10 Sugar : Acid ratio

The ratio was calculated by dividing total sugars by titratable acidity content of fruit.

3.4.11 Fibre (%)

The fibre content was determined from the fat free sample available in filter paper from fat extraction method (Ranganna, 1986). About 2-5 ml of moisture and fat free sample was weighed into 500 ml beaker and 200 ml of boiling 0.255 N sulphuric acid was added. The mixture was boiled for 30 mins. Keeping the volume constant by the addition of water at frequent intervals. At the end of this period, the mixture was filtered through a muslin cloth and the residue was washed with hot water till free from acid. The material was then transferred to the same beaker and 200 ml of boiling 0.313 N (1.25 % NaOH) was added. Then sample was boiled for 30 mins. the mixture was filtered through muslin cloth. The residue was washed with hot water till free from from alkali followed by washing with some alcohol and ether. It was then transferred to a crucible, dried overnight at 30 to 100^0C and weighed. The crucible was heated in a muffle furnace at 600^0C for 2-3 hours. Cooled, weighed again. The difference in the weight represents the weight of crude fibre. The results were expressed in percentage.

3.5 Qualitative characters (Sensory-evaluation)

The ripe fruits were examined for their sensory qualities for accessing the aroma, flavour and texture when they were ripe. It was carried out by panel of 5 judges with 9 point Hedonic scale score (Amerine *et al*., 1965) as given below.

Sensory Score	Rating
9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like nor dislike
4	Dislike slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

(Source: Amerine *et al*. 1965)

The overall rating was obtained by averaging score of evaluation. The fruits with score of 5.5 and above were rated as acceptable.

3.6 Yield characters

3.6.1 Days required for harvesting

Number of days required for harvesting was counted and recorded from the first emergence of panicle to the harvesting of fruits.

3.6.2 Number of fruits per tree

The number of fruits per tree at harvest were counted and recorded.

3.6.3 Yield (kg/tree)

Yield per tree was calculated by multiplying the average weight of the fruits with total number of fruits per tree at harvest and expressed in kilogram (kg).

3.7 Shelf life

The fruit after ripening were kept at room temperature. The shelf life was taken for post ripening period of fruits and expressed in days. The optimum shelf-life of the fruit is considered when the fruit exhibit the symptoms of over ripening by shrivelling and over softening.

3.8 Reaction to physiological disorders

3.8.1 Incidence of malformation (%)

Per cent severity was recorded quantifying number of affected panicles. Disease index was calculated by multiplying incidence and severity values. On the basis of calculated Disease Index (DI), a disease rating scale (1-9) was used for grading of different cultivars: Grade 1= Free from disease (Resistant); Grade 3= 0.1-1.0 % DI (Moderately resistant); Grade 5= 1.0-10.0 % DI (Tolerant); Grade 7= 10.1-20 % DI (Moderately susceptible); Grade 9= >20 % DI (Susceptible) (Kumar and Beniwal, 1992).

Rating	Reaction
1	Resistant
3	Moderately resistant
5	Tolerant
7	Moderately susceptible
9	Susceptible

3.8.2 Incidence of black tip (%)

Fruits were observed for the incidence of black tip and expressed in percentage.

3.8.3 Incidence of spongy tissue (%)

The fruits after ripening were observed for the incidence of spongy tissue and were expressed in percentage.

3.8.4 Incidence of water tissue (%)

The fruits after ripening were observed for the incidence of water tissue and were expressed in percentage.

3.9 Reaction to diseases

3.9.1 Incidence of powdery mildew (%)

The trees were observed for the incidence of powdery mildew on the basis of symptoms present in the inflorescence. Thereafter, disease incidence was calculated as the number of infested panicles showing symptoms out of total number of panicles observed. The per cent disease intensity (PDI) was calculated using the formula developed by McKinney (1923) is given below.

$$\text{PDI (\%)} = \frac{\text{Sum of all disease ratings}}{\text{Number of panicles observed x Maximum disease grade}} \times 100$$

The assessment carried out using the self designed 0 to 5 grades disease rating scale on the basis of area of mango inflorescence affected by powdery mildew from the given disease rating on powdery mildew by Akhtar and Alam, (2002); Raheel *et al*. (2008); Galli *et al*. (2008) and Thind *et al*. (2005).

Rating Scale	Area of Inflorescence Covered (%)
0	Inflorescence free from infection
1	1-10 % Inflorescence covered by powdery mildew
2	11-25 % Inflorescence covered by powdery mildew
3	26-50 % Inflorescence covered by powdery mildew
4	51-75 % Inflorescence covered by powdery mildew
5	>75 % Inflorescence covered by powdery mildew

3.9.2 Incidence of anthracnose

The trees were observed for the incidence of anthracnose and expressed in percentage.

3.10 Statistical analysis

The data collected on individual characters were tabulated and subjected to statistical analysis through mean analysis as described by Panse and Sukhatme (1985).

3.11 Molecular characterization

3.11.1 Experimental material

The leaf sample at young leaf stage of following derivatives was used for the extraction of genomic DNA.

Table 1. List of mango derivatives used for molecular characterization

Sr. No.	Genotype	Sr. No.	Check varieties
1	Hybrid-4	1	Ratna
2	Hybrid-6	2	Kesar
3	Hybrid-7	3	Sai Sugandh
4	Hybrid-10	4	Alphonso
5	Hybrid-12	5	Neelum
6	Hybrid-52	6	Totapuri

3.11.2 Experimental site

The molecular analysis of six hybrid derivatives and six check varieties was carried out by using SSR markers at State Level Biotechnology Centre, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar.

3.11.3 Experimental Methods

3.11.3.1 Isolation of genomic DNA from young leaves

The isolation of genomic DNA from fresh young leaves of the derivatives were carried out as per procedure given by Uddin *et al.* (2014).

Reagents

Two solutions were used to extract DNA. Solution 1 consisted of 0.4 M glucose (Beijing Chemical Works, Beijing, China), 20 mM ethylenediamine tetraacetic acid (EDTA; Amresco, Solon, USA; pH 8.0), 3 % (w/v) polyvinylpyrolidone (PVP)-40 (molecular weight 40,000) (Amresco) and 0.2 % (v/v) β mercaptoethanol. Solution 2 consisted of 2% cetyl trimethyl ammonium bromide (CTAB) (w/v) (Amresco), 100 mM Tris (pH 8.0) (Amresco), 20 mM EDTA (pH 8.0) (Amresco), 1.4 M NaCl, and 0.15% (v/v) β-mercaptoethanol. In both cases, β-mercaptoethanol was added just prior to use. In addition, chloroform:isoamyl alcohol (24:1), 70% alcohol, 100% alcohol, 3 M sodium acetate (pH 5.2) (Sinopharm Chemical Reagents Co., Ltd., Shanghai, China) and Tris-EDTA (TE) buffer consisting of 10 mM Tris (pH 8.0), 1 mM EDTA (pH 8.0) and 0.01 µg/µL RNase A (Promega Corp., Madison, USA) were also used.

Procedure

1. About 0.2–0.3 g of frozen mango leaves were weighed after removing midribs and secondary veins and homogenized with a pre-chilled mortar and pestle in liquid nitrogen.
2. Leaves were ground to a fine powder and transferred into a 2 mL tube (Axygen, Union City, USA) to which 800 µL of solution 1 was added followed by 0.2% β-mercaptoethanol.
3. The mixture was vortexed, then centrifuged at 12,000 rpm for 10 min at 4^0C.
4. The supernatant was discarded. The same procedure was repeated with 700 µL of solution 1.

5. To the pellet, 700 µL of preheated (65^0C) solution 2 was added as extraction buffer, 0.15% (v/v) β-mercaptoethanol was added and the mixture was mixed gently.
6. The tubes, each containing a different leaf sample were incubated at 65◦C in a water bath for 1 h with intermittent shaking.
7. Centrifuge tubes were cooled to room temperature and an equal volume of chloroform:isoamyl alcohol (24:1) was added.
8. The contents were mixed well by vortexing or shaken manually for 5 min, then centrifuged at 12,500 rpm for 10 min at room temperature.
9. The supernatant was transferred to a fresh 1.5-mL tube (Axygen) and this clean-up step was repeated three-times or until a clear supernatant was obtained.
10. The upper aqueous phase was transferred into a new Eppendorf tube (1.5 mL) containing twice the volume of 100 % ethanol and 1/10 (v/v) of sodium acetate, mixed gently and kept at -20^0C for 1 h.
11. The tubes were centrifuged at 12,000 rpm for 15 min and the supernatant was discarded.
12. The DNA pellet was washed twice with 70 % ethanol and dried at room temperature.
13. The dried pellet was re-suspended in 200 µL 0.1XTE and incubated at 37◦C for 30 min.
14. An equal volume of chloroform was added, mixed and tubes were centrifuged at 12,000 rpm for 5 min.
15. The upper aqueous phase was carefully collected and transferred into a new sterile 1.5-mL Eppendorf tube containing twice the volume of 100% ethanol, mixed gently and kept at -20^0C for 1 h.
16. Tubes were centrifuged at 12,000 rpm for 15 min, the liquid was discarded, and tubes were dried at room temperature.
17. The final pellet was dissolved in 20-40 µL TE buffer and kept at -20^0C indefinitely.

3.11.3.2 Casting of Agarose Gel

1. To 5 µl of the DNA sample, 2.5 µl of Bromo-phenol dye was added and spun at top speed for few seconds. Later this solution was used for gel electrophoresis separation.
2. 0.8 per cent agarose solution was prepared in 1x TBE buffer. It was cooled to 40^0C, ethidium bromide solution (0.5µg/ml) was added and poured into the cast with combs.
3. When the gel was set, the comb was removed and kept in the gel electrophoresis unit.

3.11.3.3 Running the Gel

1. The gel was placed in an electrophoresis tank filled with 0.5X TBE buffer. 5µl of the DNA was pipette out, mixed with 2.5 µl of Bromo phenol blue loading dye and loaded into the well.
2. The gel was run at 50 volts current for 2 hours and viewed under UV light.
3. A zigzag pattern of a single band indicated DNA.

3.11.3.4 DNA quantification

The concentration and quality of DNA was estimated using spectrophotometer at 260 nm and 280 nm wavelength.

3.11.3.5 Microsatellite marker (SSR) profiling

3.11.3.5.1 PCR reaction mixture

The total reaction volume for PCR was 25 µL, containing 3 µL template DNA (15 ng), 2.5 µL $MgCl_2$, 2.5 µL 10X PCR buffer, 2.5 µL dNTPs, 3 µL each forward and reverse primer, 1 U Taq polymerase and 9.9 µL PCR water. PCR was performed using Gene Amp® system.

3.11.3.5.2 Amplification conditions for SSR primers

The selected SSR makers (Table1) amplification was carried out on a MJ Research PTC 100 Thermal cycler. The different amplification profiles (Eiadithong *et al.,* 1999; Viruel *et al.,* 2005 and Duval *et al.,* 2005) were tried and the best amplification obtained with the profile given by Viruel *et al.* (2005). The amplification profile for all primers was as follows:

Initial denaturation temperature	: 94^0C - 1 min.
Denaturation	: 94^0C - 30 sec.
Primer annealing	: Tm - 30 sec.

Primer extension : 72^0C - 1 min.

Later three stages were repeated 35 times

Complete primer extension : 72^0C - 5 min.

Soak temperature : 4^0C - Until removed

3.11.3.5.3 Gel electrophoresis

Agarose gel (3%) was prepared using electrophoresis grade agarose (Sigma, USA) in a volume of electrophoresis buffer (1X TBE) sufficient for constructing a gel (300 ml for 18 x 30 cm gel). Ethidium bromide was added at concentration of 0.5 g / ml of gel. The gel was allowed to set fully before removing the comb and loading the sample. Five l of loading dye was added to 25 ml of PCR products and mixed well before loading into the wells. Care was taken to prevent mixing of samples between the wells. Electrophoresis was carried out at 70 volts for a time period of three hours for separation of PCR fragments. After the run, the gel was viewed under UV transilluminator and documented using gel documentation system.

3.11.3.5.4 Molecular Data Analysis

The clearly resolved PCR amplified SSR bands of mango derivatives with 12 different primers, were scored manually for their presence (1) and absence (0) in the data sheet. Data were analyzed and similarity matrix was constructed from binary data with Dice similarity coefficients which are calculated as per model suggested by Nei and Li (1979). Unweighted Pair Group Method Using Arithmetic Averages (UPGMA) was employed for cluster analysis. The analyses were carried out using the computer package NTSYSpc 2.02i (Rohalf, 1998). The polymorphism information content (PIC) value was calculated as PIC=1- $\Sigma P^2 ij$ where *Pij* is the frequency of the jth allele for the ith marker locus and summation extends over n alleles.

3.11.3.5.5 Cluster analysis

The binary data scored was used to construct a dendrogram. The genetic associations between varieties were evaluated by calculating the Jaccard's similarity coefficient for pair wise comparisons based on the proportions of shared bands produced by primers (Jaccard, 1908). Similarity matrix was generated by using the NTSYSpc 2.02i (Rohalf, 1998). The similarity coefficients were used for cluster analysis and dendrogram was constructed by the Unweighted Pair Group Method Using Arithmetic Averages (UPGMA).

4. RESULTS AND DISCUSSION

The present investigation entitled "Biosystemic studies in randomly mated hybrid progenies of mango (*Mangifera indica* L.)" was carried out during 2015-2017. Forty two hybrid derivatives from Research-cum-Instructional Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri were screened for morphological and biochemical characters. Among forty-two hybrid derivatives, six promising hybrid derivatives along with six check varieties (Ratna, Kesar, Neelum, Sai Sugandh, Totapuri) were selected on the basis of quality parameters and analysed at molecular level. The observations for morphological and biochemical characters were recorded for two years in respect of all forty-two hybrid derivatives. The results of present experiment are discussed below.

4.1 Morphological characterization

In present study 42 hybrid derivatives of mango were studied for growth characters. The observations in respect of growth, leaf, flower and fruit characters are recorded and presented below under suitable headings.

4.1.1 Growth characters

4.1.1.1 Height of tree (m)

The data regarding the tree height has been presented in Table 2. Tree height varied from 6.37 to 12.07 m, 6.56 to 12.30 m and 6.47 to 12.19 m during the investigation years (2015-16, 2016-17) and pooled data. Total 22 hybrid derivatives were grouped in a range of 6.0-8.50 m, 15 hybrid derivatives were in a range of 8.51-10.50 m whereas five hybrid derivatives were above 10.51 m. The maximum tree height was recorded in hybrid-33 (12.07 m, 12.30 m and 12.19 m) whereas minimum was recorded in hybrid-52 (6.37 m, 6.56 m and 6.47 m) in 2015-16, 2016-17 and pooled data.

The variation in height of the tree amongst the mango genotypes could be due to variation in genetic makeup under the present set of environmental conditions, edaphic and eco-geographical conditions (Shrivastava *et al.,* 1987 and Sharma *et al.,* 1998).

Grouping of hybrid derivatives according to height of tree (m)

No.	Range (m)	Number of hybrid derivatives
1.	6.0-8.50	22
2.	8.51-10.50	15
3.	Above 10.51	05

Table 2. Morphological characterization in mango progenies for growth characters

Sr. No	Hybrid derivatives	Height of tree (m)			Tree volume (m^3)		
		2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
1	Hybrid -1	7.22	7.25	7.24	158.85	160.11	159.48
2	Hybrid-2	6.61	6.68	6.65	108.76	111.66	110.21
3	Hybrid -3	10.61	10.80	10.71	205.22	210.82	208.02
4	Hybrid -4	7.26	7.29	7.28	157.75	160.08	158.92
5	Hybrid -5	8.57	8.55	8.56	184.51	184.98	184.74
6	Hybrid -6	7.56	7.56	7.56	156.91	158.49	157.70
7	Hybrid -7	6.61	6.81	6.71	107.37	109.20	108.29
8	Hybrid -8	8.72	8.85	8.79	193.49	197.39	195.44
9	Hybrid -9	8.17	8.18	8.18	120.83	123.55	122.19
10	Hybrid -10	7.15	7.24	7.20	110.53	112.99	111.76
11	Hybrid -11	8.72	8.70	8.71	157.35	158.44	157.90
12	Hybrid -12	7.43	6.90	7.17	112.53	102.99	107.76
13	Hybrid -13	9.02	9.20	9.11	174.00	178.72	176.36
14	Hybrid -14	9.83	9.01	9.42	241.68	222.75	232.21
15	Hybrid -15	10.70	10.77	10.74	228.02	230.41	229.22
16	Hybrid -16	7.16	7.18	7.17	128.30	129.63	128.97
17	Hybrid -17	8.60	8.61	8.61	132.68	132.92	132.80
18	Hybrid -18	8.84	8.88	8.86	180.61	183.10	181.85
19	Hybrid -19	8.23	8.80	8.52	120.17	129.23	124.70
20	Hybrid -20	10.82	11.03	10.93	180.86	185.29	183.08
21	Hybrid -21	9.94	9.99	9.97	194.03	196.05	195.04
22	Hybrid -22	10.00	10.02	10.01	185.26	186.99	186.13
23	Hybrid -23	9.30	9.35	9.33	253.28	255.42	254.35
24	Hybrid -24	10.27	10.29	10.28	172.53	174.05	173.29
25	Hybrid -25	7.86	8.09	7.98	118.47	123.37	120.92
26	Hybrid -26	9.54	9.80	9.67	183.13	189.86	186.50
27	Hybrid -27	6.95	7.00	6.98	144.76	147.27	146.01
28	Hybrid -28	7.50	7.50	7.50	126.78	127.72	127.25
29	Hybrid -29	7.83	7.90	7.87	100.15	101.04	100.60
30	Hybrid -30	8.72	8.80	8.76	195.77	199.13	197.45
31	Hybrid -31	8.17	8.30	8.24	145.63	148.21	146.92
32	Hybrid -32	10.74	10.93	10.84	187.28	190.82	189.05
33	Hybrid -33	12.07	12.30	12.19	253.93	259.15	256.54
34	Hybrid -34	7.68	7.65	7.67	107.63	106.73	107.18
35	Hybrid -35	7.38	7.38	7.38	125.21	125.83	125.52
36	Hybrid -36	9.48	9.88	9.68	148.44	155.32	151.88
37	Hybrid -46	7.56	8.09	7.83	179.07	192.38	185.72
38	Hybrid -52	6.37	6.56	6.47	115.14	119.68	117.41
39	Hybrid -55	7.73	7.78	7.76	112.46	112.62	112.54
40	Hybrid -56	7.30	7.41	7.36	101.01	101.99	101.50
41	Hybrid -57	7.89	7.98	7.94	100.58	101.57	101.08
42	Hybrid -68	7.25	7.28	7.27	100.62	102.71	101.67
	Range	6.37 – 12.07	6.56 – 12.3	6.47 -12.19	100.15-253.93	101.04-259.15	100.6-256.54
	Mean	8.46	8.54	8.50	155.04	157.16	156.10
	std	1.37	1.39	1.38	43.68	43.81	43.68
	S.E. ±	0.21	0.22	0.21	6.74	6.76	6.74
	CV (%)	16.16	16.33	16.25	28.17	27.88	27.99

Radha and Manjula (2000) reported that in a study conducted in the central part of Kerala, in Thrissur and Palakkad districts, the age of the trees ranged from 10 to 80 years and the approximate height of the trees from 10 to 35 m.

Kher and Sharma (2002) evaluated five mango cultivars, *viz.* 'Dashehari, Bombay Green, Langra, Chausa and Mallika for their performance under subtropical rainfed regions of Jammu and found the maximum tree height (565 cm) and tree spread (475 cm east-west and 525 cm north-south) in Chausa followed by Mallika.

Chanana *et al.* (2005) evaluated for vegetative characters of some mango cultivars under North Indian conditions and reported that Langra had the maximum tree height and spread.

4.1.1.1.a Tree spread (N-S) and (E-W) (m)

The data pertaining to the tree spread has been presented in Table 2a. Tree spread (E-W) ranged from 5.57 to 12.77 m, 5.48 to 12.82 m and 5.53 to 12.80 m during the experimental years 2015-16, 2016-17 and pooled data respectively. Total 17 hybrid derivatives were grouped in a range of 5.50-8.00 m, 18 hybrid derivatives 8.1-10.50 m, whereas seven hybrid derivatives were above 10.50 m. Hybrid-14 recorded maximum tree spread (E-W) (12.77 m, 12.82 m and 12.80 m) in 2015-16, 2016-17 and pooled data respectively and lowest was recorded by hybrid-29 (5.57 m, 5.48 m and 5.53 m) in 2015-16, 2016-17 and pooled data respectively. Tree spread (N-S) ranged from 5.94 to 14.08 m, 6.20 to 14.12 m and 6.07 to 14.10 m during the experimental years 2015-16, 2016-17 and pooled data respectively. Total 24 hybrid derivatives were grouped in a range of 6.00-9.00 m, 15 hybrid derivatives 9.1-12.00 m, whereas three hybrid derivatives were above 12.00 m. Hybrid-23 recorded maximum tree spread (N-S) (14.08 m, 14.12 m and 14.10 m) in 2015-16, 2016-17 and lowest was recorded by hybrid-9 (5.94 m, 6.20 m and 6.07 m).

Grouping of hybrid derivatives according to tree spread (m)

No.	Range (m)	Number of hybrid derivatives
	E-W spread	
1.	5.50-8.00	17
2.	8.1-10.50	18
3.	Above 10.5	07
	N-S spread	
4.	6.0-9.0	24
5.	9.1-12.0	15
6.	Above 12.0	03

Table 2a. Morphological characterization in mango progenies for growth characters

Sr. No	Hybrid derivatives	Spread East-West (m)			Spread North-South (m)		
		2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
1	Hybrid -1	10.05	10.11	10.08	10.97	10.99	10.98
2	Hybrid-2	7.43	7.65	7.54	8.29	8.32	8.31
3	Hybrid -3	8.23	8.32	8.28	10.25	10.33	10.29
4	Hybrid -4	9.66	9.86	9.76	11.10	11.12	11.11
5	Hybrid -5	7.71	7.75	7.73	12.86	12.92	12.89
6	Hybrid -6	6.61	6.69	6.65	13.22	13.34	13.28
7	Hybrid -7	7.89	7.81	7.85	7.63	7.51	7.57
8	Hybrid -8	11.15	11.21	11.18	10.05	10.10	10.08
9	Hybrid -9	8.19	8.23	8.21	5.94	6.20	6.07
10	Hybrid -10	8.55	8.61	8.58	6.22	6.30	6.26
11	Hybrid -11	9.29	9.45	9.37	7.95	7.95	7.95
12	Hybrid -12	7.32	7.25	7.29	7.15	7.01	7.08
13	Hybrid -13	8.59	8.61	8.60	9.84	9.95	9.90
14	Hybrid -14	12.77	12.82	12.80	10.72	10.80	10.76
15	Hybrid -15	10.82	10.85	10.84	9.54	9.59	9.57
16	Hybrid -16	7.04	7.15	7.10	10.08	10.10	10.09
17	Hybrid -17	6.85	6.85	6.85	7.89	7.90	7.90
18	Hybrid -18	9.50	9.59	9.55	10.02	10.11	10.07
19	Hybrid -19	6.61	6.62	6.62	7.34	7.41	7.38
20	Hybrid -20	8.93	8.96	8.95	7.04	7.09	7.07
21	Hybrid -21	7.16	7.20	7.18	11.49	11.55	11.52
22	Hybrid -22	7.83	7.91	7.87	9.87	9.92	9.90
23	Hybrid -23	11.94	11.98	11.96	14.08	14.12	14.10
24	Hybrid -24	8.62	8.65	8.64	7.43	7.51	7.47
25	Hybrid -25	6.24	6.36	6.30	8.16	8.21	8.19
26	Hybrid -26	9.17	9.26	9.22	9.17	9.25	9.21
27	Hybrid -27	8.47	8.55	8.51	11.43	11.55	11.49
28	Hybrid -28	8.44	8.49	8.47	7.71	7.78	7.75
29	Hybrid -29	5.57	5.48	5.53	6.65	6.74	6.70
30	Hybrid -30	11.82	11.96	11.89	9.63	9.66	9.65
31	Hybrid -31	9.78	9.78	9.78	7.25	7.28	7.27
32	Hybrid -32	9.29	9.29	9.29	7.37	7.39	7.38
33	Hybrid -33	11.36	11.38	11.37	8.74	8.75	8.75
34	Hybrid -34	6.63	6.53	6.58	6.76	6.80	6.78
35	Hybrid -35	8.87	8.87	8.87	7.34	7.42	7.38
36	Hybrid -36	8.59	8.63	8.61	6.37	6.39	6.38
37	Hybrid -46	12.00	12.03	12.02	10.63	10.69	10.66
38	Hybrid -52	9.11	9.15	9.13	8.16	8.28	8.22
39	Hybrid -55	6.99	6.86	6.93	6.91	6.97	6.94
40	Hybrid -56	6.98	6.85	6.92	6.24	6.30	6.27
41	Hybrid -57	5.75	5.68	5.72	6.43	6.48	6.46
42	Hybrid -68	6.91	6.98	6.95	6.35	6.50	6.43
	Range	5.57-12.77	5.48-12.82	5.53-12.8	5.94-14.08	6.2-14.12	6.07-14.1
	Mean	8.59	8.63	8.61	8.77	8.82	8.80
	std	1.80	1.82	1.81	2.09	2.09	2.09
	S.E. ±	0.28	0.28	0.28	0.32	0.32	0.32
	CV (%)	20.91	21.12	21.01	23.78	23.66	23.72

4.1.1.2 Tree volume (m^3)

The data pertaining to the tree volume has been presented in Table 2. Tree volume varied from 100.15 to 253.93 m^3, 101.04 to 259.15 m^3 and 100.6 to 256.54 m^3 in 2015-16, 2016-17 and pooled data respectively. Total 21 hybrid derivatives were grouped in a range of 100.0-155.0 m^3, 16 hybrid derivatives in 155.1-205.0 m^3, whereas five hybrid derivatives were above 205 m^3. The maximum volume of tree was noted in hybrid-33 (253.93 m^3, 259.15 m^3 and 256.54 m^3) whereas minimum volume of tree was noted in hybrid-29 (100.15 m^3, 101.04 m^3 and 100.60 m^3) during the experimental years 2015-16, 2016-17 and pooled data.

The variation in tree canopy volume is expected under a particular micro-climate of a particular cultivar. However, low canopy volume might be seen in the regular bearing cultivars in the sub-tropical and lower hill conditions due to distinct drop in temperature during winter months. Similar observations were made by Kher and Sharma (2002) while evaluating mango cultivars, *viz.* 'Dashehari, Bombay Green, Langra, Chausa and Mallika under subtropical rainfed regions of Jammu, J and K.

Chanana *et al.* (2005) evaluated for vegetative characters of some mango cultivars under North Indian conditions and reported that maximum tree volume was recorded in Langra (311.38 m^3/ tree), while minimum was in Alphonso (58.49 m^3/ tree).

Grouping of hybrid derivatives according to tree volume (m^3)

No.	Range (m^3)	Number of hybrid derivatives
1.	100.0-155.0	21
2.	155.1-205.0	16
3.	Above 205.0	05

4.1.2 Leaf characters

The data pertaining to leaf characters such as leaf size, leaf type, leaf colour and leaf waxiness has been presented in Table 3 and 4.

4.1.2.1 Leaf size

4.1.2.1.1 Leaf length and breadth (cm)

The leaf length (Table 3) varied from 15.10 to 35.50 cm, 15.90 to 34.8 cm, 15.50 to 35.15 cm during the investigation years 2015-16, 2016-17 and the pooled data. Total 14 hybrid derivatives were grouped in a range of 15.0-22.50 cm, 20 hybrid derivatives in 22.51-30.00 cm range, whereas eight hybrid derivatives were above 30 cm.

The highest leaf length was recorded in hybrid-10 (35.50 cm, 34.80 cm and 35.15 cm) in 2015-16, 2016-17 and pooled data and the lowest was recorded in hybrid-57 (15.10 cm, 15.90 cm and 15.50 cm) in 2015-16, 2016-17 and pooled data respectively.

The leaf breadth (Table 3) ranged from 3.20 to 8.70 cm, 3.32 to 8.90 cm and 3.26 to 8.80 cm during the years of investigation 2015-16, 2016-17 and pooled data respectively. Total 20 hybrid derivatives were grouped in a range of 3.00-5.50 cm, 15 hybrid derivatives in 5.51-7.00 cm, whereas seven hybrid derivatives were above 7.00 cm. Hybrid-10 recorded maximum leaf breadth in the year 2015-16, 2016-17 and pooled data (8.70, 8.90 and 8.80 cm) and minimum was recorded in hybrid-57 (3.20, 3.32 and 3.26 cm) in 2015-16, 2016-17 and pooled data respectively.

Usually length and breadth of leaf varies based on derivatives, variations in the length and breadth of leaves may also be due to cultural practices, climatic conditions, genetic variations and growth stages. Rymbai *et al*. (2014) showed considerable variations in leaf morphological characters among the eight mango cultivars and found that maximum leaf length and leaf ratio was observed in Alphonso and minimum in Langra and Fazli. They also found that maximum and minimum leaf width was observed in Totapuri and Dashehari respectively.

Sinha *et al.* (2018), studied the hybrid derivatives in which results showed that the maximum leaf length was recorded in Fazli (29.04 cm) and maximum leaf width (9.38 cm), while the minimum leaf length (16.84 cm), width (4.06 cm) was found in cv. Gulabkhas.

Grouping of hybrid derivatives according to leaf length and breadth (cm)

No.	Range (cm)	Number of hybrid derivatives
	Leaf length	
1.	15.00-22.50	14
2.	22.51-30.00	20
3.	Above 30	08
	Leaf breadth	
1.	3.00-5.50	20
2.	5.51-7.00	15
3.	Above 7.00	07

Table 3. Morphological characterization in mango progenies for leaf characters

Sr. No.	Hybrid derivatives	Leaf size					
		Length (cm)			Breadth (cm)		
		2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
1	Hybrid -1	26.5	25.6	26.05	5.2	5.1	5.15
2	Hybrid-2	22.7	21.04	21.87	4.8	4.6	4.70
3	Hybrid -3	20.6	21.7	21.15	5.6	5.5	5.55
4	Hybrid -4	30.3	29.8	30.05	5.8	5.6	5.70
5	Hybrid -5	15.9	16.5	16.20	3.8	4	3.90
6	Hybrid -6	26.0	25.6	25.80	6.1	5.9	6.00
7	Hybrid -7	26.4	25.5	25.95	4.5	4.2	4.35
8	Hybrid -8	26.3	25	25.65	5.4	5.2	5.30
9	Hybrid -9	25.9	24.6	25.25	6.2	6.0	6.10
10	Hybrid -10	35.5	34.8	35.15	8.7	8.9	8.80
11	Hybrid -11	28.4	26.8	27.60	7.1	6.9	7.00
12	Hybrid -12	24.6	23.5	24.05	4.9	4.8	4.85
13	Hybrid -13	24.2	23.8	24.00	5.1	4.9	5.00
14	Hybrid -14	32.2	31.5	31.85	6.2	6.4	6.30
15	Hybrid -15	26.0	25.3	25.65	7.4	7.2	7.30
16	Hybrid -16	35.0	34.5	34.75	5.3	5.1	5.20
17	Hybrid -17	27.2	26.4	26.80	5.6	5.6	5.60
18	Hybrid -18	32.5	31.5	32.00	7.5	7.3	7.40
19	Hybrid -19	26.9	25.9	26.40	5.5	5.6	5.55
20	Hybrid -20	20.5	21.4	20.95	6.0	5.7	5.85
21	Hybrid -21	23.5	24.2	23.85	5.2	5.0	5.10
22	Hybrid -22	21.3	22.6	21.95	4.8	5.1	4.95
23	Hybrid -23	28.4	27.4	27.90	5.6	5.5	5.55
24	Hybrid -24	22.3	21.5	21.90	7.2	6.9	7.05
25	Hybrid -25	20.5	19.8	20.15	5.5	5.3	5.40
26	Hybrid -26	27.6	28.6	28.10	6.1	5.9	6.00
27	Hybrid -27	32.0	31.5	31.75	8.0	7.8	7.90
28	Hybrid -28	22.2	23.4	22.80	6	5.9	5.95
29	Hybrid -29	20.4	21.5	20.95	4.0	4.2	4.10
30	Hybrid -30	31.5	32.5	32.00	7.2	7.4	7.30
31	Hybrid -31	30.3	31.6	30.95	8.5	8.7	8.60
32	Hybrid -32	22.6	23.5	23.05	6.3	6.3	6.30
33	Hybrid -33	22.5	23.6	23.05	6.4	6.5	6.45
34	Hybrid -34	17.4	18.8	18.10	4.4	4.3	4.35
35	Hybrid -35	21.7	22.5	22.10	4.4	4.6	4.50
36	Hybrid -36	20.1	20.5	20.30	5.0	5.2	5.10
37	Hybrid -46	27.5	28.4	27.95	5.8	5.7	5.75
38	Hybrid -52	22.9	21.9	22.40	4.8	4.6	4.70
39	Hybrid -55	27.1	25.2	26.15	5.4	5.2	5.30
40	Hybrid -56	19.1	20.6	19.85	4.3	4.1	4.20
41	Hybrid -57	15.1	15.9	15.50	3.2	3.3	3.26
42	Hybrid -68	23.6	24.5	24.05	5.1	5.3	5.20
	Range	15.1 - 35.5	15.9- 34.8	15.5 -35.15	3.2 - 8.7	3.32 - 8.9	3.26 - 8.8
	Mean	25.08	25.02	25.05	5.71	5.65	5.68
	std	4.86	4.50	4.66	1.22	1.22	1.22
	S.E. ±	0.75	0.69	0.72	0.19	0.19	0.19
	CV (%)	19.38	17.99	18.59	21.41	21.63	21.46

4.1.2.2 Leaf type

All the forty two hybrid derivatives recorded simple leaf type (Table 4). Simple, alternate and oblanceolate leaves have also been reported in mango (Singh, 1960; Litz, 2003).

4.1.2.3 Leaf colour

Leaf colour showed some variation among the hybrid derivatives however 24 hybrid derivatives showed dark green coloured leaves whereas 17 hybrid derivatives showed green coloured leaves while hybrid-30 showed light green coloured leaves (Table 4).

Fivaz (2008) revealed that the immature or young leaves are initially net importers of carbon and only begin to contribute to the carbon economy of the shoot as they expand. Likewise, the mature leaf colour was found dark green in Mulgoa, light green in Peri Poona while green in rest varieties.

According to Ibrahim (1952), mango has peculiar characteristic intermittent periodic flushes of growth with variety of leaf colours at emergence. Therefore, young leaves have characteristic colour and can successfully be used as a reliable trait for the identification and evaluation of different mango varieties.

Ali (2013) reported that young leaves are specific in nature based on cultivar and can be used for the identification of different mango varieties.

According to Singh (1960), mature leaf colour may be light to dark green.

Grouping of hybrid derivatives according to leaf colour

No.	Character	Number of hybrid derivatives
1.	Dark green	24
2.	Green	17
3.	Light green	01

4.1.2.4 Leaf waxiness

The leaves of all hybrid derivatives showed non-waxy appearance.

Table 4. Morphological characterization in mango progenies for leaf characters

Sr. No.	Hybrid derivatives	Leaf type	Leaf colour	Leaf waxiness
1	Hybrid -1	Simple	Dark Green	Nonwaxy
2	Hybrid-2	Simple	Green	Nonwaxy
3	Hybrid -3	Simple	Green	Nonwaxy
4	Hybrid -4	Simple	Green	Nonwaxy
5	Hybrid -5	Simple	Dark Green	Nonwaxy
6	Hybrid -6	Simple	Dark Green	Nonwaxy
7	Hybrid -7	Simple	Dark Green	Nonwaxy
8	Hybrid -8	Simple	Green	Nonwaxy
9	Hybrid -9	Simple	Dark Green	Nonwaxy
10	Hybrid -10	Simple	Dark Green	Nonwaxy
11	Hybrid -11	Simple	Dark Green	Nonwaxy
12	Hybrid -12	Simple	Dark Green	Nonwaxy
13	Hybrid -13	Simple	Green	Nonwaxy
14	Hybrid -14	Simple	Dark Green	Nonwaxy
15	Hybrid -15	Simple	Green	Nonwaxy
16	Hybrid -16	Simple	Green	Nonwaxy
17	Hybrid -17	Simple	Dark Green	Nonwaxy
18	Hybrid -18	Simple	Green	Nonwaxy
19	Hybrid -19	Simple	Green	Nonwaxy
20	Hybrid -20	Simple	Dark Green	Nonwaxy
21	Hybrid -21	Simple	Dark Green	Nonwaxy
22	Hybrid -22	Simple	Green	Nonwaxy
23	Hybrid -23	Simple	Green	Nonwaxy
24	Hybrid -24	Simple	Green	Nonwaxy
25	Hybrid -25	Simple	Dark Green	Nonwaxy
26	Hybrid -26	Simple	Dark Green	Nonwaxy
27	Hybrid -27	Simple	Dark Green	Nonwaxy
28	Hybrid -28	Simple	Green	Nonwaxy
29	Hybrid -29	Simple	Green	Nonwaxy
30	Hybrid -30	Simple	Dark Green	Nonwaxy
31	Hybrid -31	Simple	Dark Green	Nonwaxy
32	Hybrid -32	Simple	Dark Green	Nonwaxy
33	Hybrid -33	Simple	Light Green	Nonwaxy
34	Hybrid -34	Simple	Green	Nonwaxy
35	Hybrid -35	Simple	Dark Green	Nonwaxy
36	Hybrid -36	Simple	Dark Green	Nonwaxy
37	Hybrid -46	Simple	Green	Nonwaxy
38	Hybrid -52	Simple	Dark Green	Nonwaxy
39	Hybrid -55	Simple	Dark Green	Nonwaxy
40	Hybrid -56	Simple	Dark Green	Nonwaxy
41	Hybrid -57	Simple	Dark Green	Nonwaxy
42	Hybrid -68	Simple	Green	Nonwaxy

4.1.3 Flowering characters

The data regarding flowering characters has been presented under following sub-headings.

4.1.3.1 Days from bud bursting to full bloom (days)

The data regarding days required from bud burst to full bloom has been revealed in Table 5. Total 24 hybrid derivatives were grouped in a range of 50.0-55.0 days, 16 hybrid derivatives in 55.1-60.00 days, whereas two hybrid derivatives were above 60.00 days. The highest number of days from bud burst to full bloom was recorded by hybrid-6 (61.0, 64.0 and 62.5 days) and lowest was recorded by hybrid-52 (50.0, 53.0 and 51.5 days) in 2015-16, 2016-17 and pooled data, respectively.

The seasonal cyclic variation of bud break is dependent on environmental factors and might be due to the differences in the genetic composition of parental mango derivatives. Phenology pattern is strongly under environmental control in mango. The vegetative cycle ceases with the advent of winter and maturation of the leaves takes place along with the dormancy of the apical and axillary buds.

The variation observed in terms of panicle initiation might be due to the differences in genetic composition of mango cultivars. The plant remains visually dormant for about three months during winter. Flowering is commonly related with stoppage or dormancy of the terminal growth which is low temperature controlled in subtropics (Chacko and Randhwa, 1971).

Grouping of hybrid derivatives according to days from bud bursting to full bloom (days)

No.	Range (days)	Number of hybrid derivatives
1.	50.0-55.0	24
2.	55.1-60.00	16
3.	Above 60.00	02

Initiation of flowering in the mango, however is also a varietal character (Naik and Rao, 1943). Some varieties develop all their flowers within ten days after the first bud opens, whereas others may take several weeks or even months (Popenoe, 1927).

Table 5. Morphological characterization in mango progenies for inflorescence characters

Sr. No	Hybrid derivatives	Days from bud bursting to full bloom			Date of last emergence of panicle	
		2015-16	2016-17	Pooled	2015-16	2016-17
1	Hybrid -1	57	55	56.0	19th March	15th February
2	Hybrid-2	55	54	54.5	20th March	16th February
3	Hybrid -3	60	63	61.5	22nd March	7th February
4	Hybrid -4	56	63	59.5	8th March	15th February
5	Hybrid -5	52	56	54.0	22nd March	7th January
6	Hybrid -6	61	64	62.5	25th March	19th February
7	Hybrid -7	56	62	59.0	3rd March	23rd February
8	Hybrid -8	58	60	59.0	7th March	24th February
9	Hybrid -9	54	55	54.5	1st March	3rd February
10	Hybrid -10	51	55	53.0	25th March	22nd February
11	Hybrid -11	55	57	56.0	24th March	26th February
12	Hybrid -12	55	54	54.5	11th March	19th February
13	Hybrid -13	56	59	57.5	1st March	9th February
14	Hybrid -14	51	54	52.5	20th March	4th February
15	Hybrid -15	57	55	56.0	19th March	13th February
16	Hybrid -16	52	55	53.5	21st March	11th February
17	Hybrid -17	58	56	57.0	24th March	4th February
18	Hybrid -18	56	54	55.0	16th March	21st February
19	Hybrid -19	51	54	52.5	11th March	4th February
20	Hybrid -20	56	54	55.0	12th March	9th February
21	Hybrid -21	57	60	58.5	5th February	2nd February
22	Hybrid -22	58	61	59.5	13th March	29th February
23	Hybrid -23	59	55	57.0	14th March	17th February
24	Hybrid -24	55	0	55.0	16th March	-
25	Hybrid -25	53	53	53.0	2nd March	15th February
26	Hybrid -26	53	54	53.5	19th February	8th February
27	Hybrid -27	52	57	54.5	1st March	3rd February
28	Hybrid -28	52	58	55.0	2nd March	17th February
29	Hybrid -29	54	59	56.5	13th March	28th February
30	Hybrid -30	53	54	53.5	5th March	17th February
31	Hybrid -31	53	54	53.5	25th March	15th February
32	Hybrid -32	52	55	53.5	16th March	27th February
33	Hybrid -33	55	60	57.5	21st March	26th February
34	Hybrid -34	59	56	57.5	21st March	10th February
35	Hybrid -35	53	54	53.5	10th March	9th February
36	Hybrid -36	55	0	55.0	7th March	-
37	Hybrid -46	56	54	55.0	1st February	3rd February
38	Hybrid -52	50	53	51.5	9th March	14th February
39	Hybrid -55	54	55	54.5	2nd February	5th February
40	Hybrid -56	54	59	56.5	13th February	3rd February
41	Hybrid -57	59	56	57.5	2nd March	20th February
42	Hybrid -68	52	56	54.0	9th February	17th February
	Range	50 - 61	53 - 64	51.5 - 62.5		
	Mean	54.88	56.55	55.68		
	std	2.72	3.05	2.49		
	S.E. ±	0.42	0.48	0.38		
	CV (%)	4.96	5.39	4.47		

The variability found in the present study is in agreement with the findings of Valmayor (1962) who reported that the variation of blooming period is dependent upon the combination of environmental factors and the condition of plant.

Majumder and Sharma (1985) stated that unlike many other fruits, flowering in mango is entirely dependent on climatic conditions prevailing in an area. It is reported that for each 400 feet increase in altitude, flowering is retarded by four days and similarly for each degree of latitude towards south and north of the tropics, flowering is advanced and delayed by four days, respectively.

According to Kulkarni (2004), flowering is generally correlated with local environmental conditions, hereditary characteristics, and nutritious as well as hormonal aspects. Moreover, cultivation practices and cultural operations may also affect flowering time and total number of flowers per panicle (Chadha and Pal, 1986).

4.1.3.2 Date of last emergence of panicle

Among all the derivatives under investigation, it was revealed (Table 5) that the last panicle emergence was observed in hybrid-46 (1st January) in the year 2015-16 whereas in the year 2016-17 it was observed in hybrid-22 (29th December).

4.1.3.3 Type of inflorescence

The data pertaining type of inflorescence is presented in Table 6. Among all the hybrid derivatives studied the inflorescences of 18 derivatives were broadly pyramidal, 14 derivatives had narrowly pyramidal inflorescences while 10 derivatives had pyramidal inflorescences.

Similar variation in the type of inflorescences among different mango genotypes was also reported by Rajwana *et al*. (2011), Kobra *et al*. (2012) and Ali (2013) as they reported that inflorescence shape may be conical, pyramidal or broadly pyramidal.

Grouping of hybrid derivatives according to inflorescence type

No.	Characters	Number of hybrid derivatives
1	Broadly pyramidal	18
2	Narrowly pyramidal	14
3	Pyramidal	10

4.1.3.4 Inflorescence length and breadth (cm)

The inflorescence length in different mango derivatives showed a notable variation in all the experimental years as well as in pooled data (Table 6). The inflorescence length of hybrid derivatives ranged from 14.23 to 29.48 cm, 13.58 to 32.05 cm and 13.91 cm to 30.77 cm in 2015-16, 2016-17 and pooled data respectively. Total 16 hybrid derivatives were grouped in a range of 13.0-20.0 cm, 19 hybrid derivatives in 20.1-26.0 cm, whereas seven hybrid derivatives were above 26.0 cm. The maximum inflorescence length (29.48 cm, 32.05 cm and 30.77 cm) was recorded by hybrid-46 during the years of investigation (2015-16, 2016-17 and pooled data respectively) whereas minimum was recorded in hybrid-25 (14.23, 13.58 and 13.98 cm) in 2015-16, 2016-17 and pooled data.

The data presented in the Table 6 indicated the differences in the inflorescence breadth and it was ranged between 6.20 to 15.90 cm, 6.0 to 16.75 cm and 6.10 to 16.33 cm among different hybrid derivatives during the experimental years (2015-16, 2016-17 and pooled data). Total 30 hybrid derivatives were grouped in a range of 6.00 – 10.0 cm, eight hybrid derivatives in 10.1-13.0 cm, whereas four hybrid derivatives were above 13.00 cm. The highest inflorescence breadth (15.90 cm, 16.75 cm and 16.33 cm) was recorded by hybrid-46 during the years of investigation (2015-16, 2016-17 and pooled data respectively) whereas lowest was recorded in hybrid-25 (6.20, 6.0 and 6.10 cm) in 2015-16, 2016-17 and pooled data.

Similar findings were reported by Chandra *et al.* (2001), Sarkar *et al.* (2001), Singh (2002), Singh *et al.* (2014) and Singh *et al.* (2015). They further reported that the variation in size of panicles in mango cultivars might be due to genetic composition and more specifically the physiological condition of the shoot on which panicle arised and distinct variation may be due to cultivars grown under different agro-climatic conditions.

Grouping of hybrid derivatives according to inflorescence length and breadth (cm)

No.	Range (cm)	Number of hybrid derivatives
	Inflorescence length	
1.	13.0-20.0	16
2.	20.1-26.0	19
3.	Above 26.0	07
	Inflorescence breadth	
1.	6.0-10.0	30
2.	10.10 -13.00	08
3.	Above 13.00	04

Table 6. Morphological characterization in mango progenies for inflorescence characters

Sr. No	Hybrid derivatives	Type of inflorescence	Inflorescence length (cm)			Inflorescence breadth (cm)		
			2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
1	Hybrid -1	Broadly pyramidal	26.51	26.90	26.71	12.90	12.72	12.81
2	Hybrid-2	Narrow	24.22	25.60	24.91	8.23	8.30	8.27
3	Hybrid -3	Broad	18.90	18.70	18.80	12.50	13.55	13.03
4	Hybrid -4	Broad	20.33	22.40	21.37	11.17	12.07	11.62
5	Hybrid -5	Narrow pyramidal	23.21	24.60	23.91	9.22	9.18	9.20
6	Hybrid -6	Pyramidal	27.50	26.10	26.80	11.50	10.15	10.83
7	Hybrid -7	Narrow	21.70	23.17	22.44	6.78	7.07	6.93
8	Hybrid -8	Broadly pyramidal	28.12	27.07	27.60	11.60	10.05	10.83
9	Hybrid -9	Narrow	18.50	17.60	18.05	8.50	7.23	7.87
10	Hybrid -10	Narrow	15.80	17.45	16.63	8.54	8.85	8.70
11	Hybrid -11	Broadly pyramidal	21.32	22.13	21.73	8.20	7.62	7.91
12	Hybrid -12	Narrow	19.25	20.08	19.67	6.85	7.76	7.31
13	Hybrid -13	Broadly pyramidal	25.16	26.55	25.86	10.10	9.07	9.59
14	Hybrid -14	Broadly pyramidal	22.21	23.15	22.68	14.50	15.45	14.98
15	Hybrid -15	Pyramidal	18.90	17.15	18.03	7.50	7.67	7.59
16	Hybrid -16	Narrow	19.22	21.65	20.44	7.22	7.35	7.29
17	Hybrid -17	Narrow	22.26	22.65	22.46	6.20	6.76	6.48
18	Hybrid -18	Narrow	17.46	18.47	17.97	6.30	6.50	6.40
19	Hybrid -19	Broadly pyramidal	24.10	23.21	23.66	8.20	8.10	8.15
20	Hybrid -20	Narrow	17.50	17.89	17.70	6.92	7.01	6.97
21	Hybrid -21	Narrow	21.24	22.56	21.90	7.90	8.08	7.99
22	Hybrid -22	Broadly pyramidal	23.00	24.56	23.78	11.20	11.08	11.14
23	Hybrid -23	Pyramidal	21.50	23.07	22.29	7.20	6.06	6.63
24	Hybrid -24	Narrow	16.00	0.00	16.00	7.60	0.00	7.60
25	Hybrid -25	Narrow	14.23	13.58	13.91	6.20	6.00	6.10
26	Hybrid -26	Broad	26.70	27.98	27.34	15.80	16.68	16.24
27	Hybrid -27	Broadly pyramidal	23.50	25.45	24.48	10.20	9.59	9.90
28	Hybrid -28	Broad	25.00	24.65	24.83	7.90	6.54	7.22
29	Hybrid -29	Narrow	17.00	18.40	17.70	8.20	7.26	7.73
30	Hybrid -30	Broad	25.50	25.69	25.60	6.54	6.92	6.73
31	Hybrid -31	Broadly pyramidal	26.98	27.06	27.02	11.60	11.2	11.40
32	Hybrid -32	Broadly pyramidal	29.32	30.03	29.68	12.9	13.04	12.97
33	Hybrid -33	Broadly pyramidal	22.50	21.90	22.20	7.50	8.8	8.15
34	Hybrid -34	Pyramidal	18.00	19.01	18.51	10.22	10.02	10.12
35	Hybrid -35	Pyramidal	24.00	25.01	24.51	9.70	8.09	8.90
36	Hybrid -36	Pyramidal	18.50	0.00	18.50	9.20	0.00	9.20
37	Hybrid -46	Broadly pyramidal	29.48	32.05	30.77	15.90	16.75	16.33
38	Hybrid -52	Narrow	16.50	15.03	15.77	6.50	6.54	6.52
39	Hybrid -55	Narrow	19.70	20.04	19.87	6.60	6.04	6.32
40	Hybrid -56	Pyramidal	22.50	24.05	23.28	9.20	10.5	9.85
41	Hybrid -57	Pyramidal	18.70	15.60	17.15	6.90	6.22	6.56
42	Hybrid -68	Pyramidal	16.9	17.50	17.2	7.60	7.72	7.66
		Range	14.23-29.48	13.58-32.05	13.91-30.77	6.2-15.9	6.0-16.75	6.1-16.33
		Mean	21.64	22.39	21.89	9.18	9.14	9.14
		std	3.95	4.24	4.08	2.61	2.88	2.69
		S.E. ±	0.61	0.67	0.63	0.40	0.46	0.41
		CV (%)	18.27	18.92	18.63	28.42	31.52	29.41

The variation in size of panicles in mango cultivars might be due to genetic composition and more specifically the physiological condition of the shoot on which panicle arised. In the same line of work, Chandra *et al*. (2001) reported that the breadth of the panicle and number of flowering laterals per square meter had distinct variation in eight mango cultivars and hybrids under agro-climatic conditions of Odisha.

Similarly, Sarkar *et al.* (2001) found that cv. Amrapali produced the highest panicle breadth among the ten mango hybrids evaluated for floral character.

4.1.3.5 Number of flushes

Number of vegetative flushes observed in all derivatives in both years 2015-16 and 2016-17 were two (Table 7).

Growth of mango is not continuous but it occurs as intermittent, short lasting flushes of shoots from apical or lateral buds. The flushing refers to the emergence of new shoots on the terminals of old shoots. Generally a healthy mango shoot completes four to five flushing episodes per year depending upon cultivars and growing condition (Davenport and Elisea, 1997).

Under south Indian conditions, two active flushes occurring from February to June and October to November were reported. Three main growth flushes in February to March, March to April and October to November were reported in western India (Singh, 1958).

4.1.3.6 Colour of panicle

The data regarding colour of panicle has been presented in Table 7 and was documented from colour of rachis as indicated in Mango descriptor revealed remarkable disparity in the colour of inflorescences among all mango derivatives studied. Green coloured panicles were observed in 24 hybrids whereas panicles of six hybrids were yellow, five reddish green, two light green, four reddish and remaining one reddish yellow.

Anila and Radha (2003) while studying six mango derivatives namely Alphonso, Prior, Muvandan, Neelum, Ratna and H-151 found that the colour of rachis of panicle ranged from light green to dark red. Alphonso and Muvandan had light red coloured inflorescence, light green colour was noticed in the case of Prior and H-151.

Neelum had green with red patches and dark red coloured inflorescence was seen in Ratna.

Grouping of hybrid derivatives according to colour of panicle

No.	Characters	Number of hybrid derivatives
1.	Green	24
2.	Light green	02
3.	Reddish green	05
4.	Yellow	06
5.	Reddish	04
6.	Reddish yellow	01

Rajwana *et al.* (2011) and Kobra *et al.* (2012) also reported similar results regarding colour of mango inflorescence among various mango cultivars.

Floral characters are very valuable traits for the classification of mango varieties (Khan *et al*., 2015).

4.1.3.7 Colour of flower

The colour of flower was observed as indicated in descriptors for Mango, 35 hybrid derivatives showed yellow coloured flowers, four light yellow, one yellowish pink, one reddish yellow and one yellowish green coloured flowers (Table 7).

Grouping of hybrid derivatives according to flower colour

No.	Characters	Number of hybrid derivatives
1	Yellow	35
2	Light yellow	04
3	Reddish yellow	01
4	Yellowish pink	01
5	Yellowish green	01

Table 7. Morphological characterization in mango progenies for inflorescence characters

Sr. No.	Hybrid derivatives	Number of flushes	Colour of panicle	Colour of flowers
1	Hybrid -1	2	Green	Yellowish pink
2	Hybrid-2	2	Green	Reddish yellow
3	Hybrid -3	2	Yellow	Yellow
4	Hybrid -4	2	Reddish yellow	Red
5	Hybrid -5	2	Green	Yellow
6	Hybrid -6	2	Reddish green	Yellow
7	Hybrid -7	2	Reddish green	Yellow
8	Hybrid -8	2	Green	Yellow
9	Hybrid -9	2	Green	Light yellow
10	Hybrid -10	2	Green	Yellowish green
11	Hybrid -11	2	Yellow	Yellow
12	Hybrid -12	2	Green	Yellow
13	Hybrid -13	2	Reddish green	Yellow
14	Hybrid -14	2	Green	Yellow
15	Hybrid -15	2	Green	Whitish yellow
16	Hybrid -16	2	Yellow	White
17	Hybrid -17	2	Green	Yellow
18	Hybrid -18	2	Green	Yellow
19	Hybrid -19	2	Light green	Yellow
20	Hybrid -20	2	Light green	White
21	Hybrid -21	2	Yellow	Yellow
22	Hybrid -22	2	Green	Yellow
23	Hybrid -23	2	Green	Creamish
24	Hybrid -24	2	Yellow	Yellow
25	Hybrid -25	2	Green	White
26	Hybrid -26	2	Reddish	Yellow
27	Hybrid -27	2	Green	Yellow
28	Hybrid -28	2	Green	Yellow
29	Hybrid -29	2	Green	Yellow
30	Hybrid -30	2	Green	Yellow
31	Hybrid -31	2	Red	Yellow
32	Hybrid -32	2	Green	Yellow
33	Hybrid -33	2	Green	Yellow
34	Hybrid -34	2	Green	Yellow
35	Hybrid -35	2	Green	Yellow
36	Hybrid -36	2	Yellow	Yellow
37	Hybrid -46	2	Reddish	Yellow
38	Hybrid -52	2	Reddish green	White
39	Hybrid -55	2	Reddish green	White
40	Hybrid -56	2	Reddish	Yellow
41	Hybrid -57	2	Green	Yellow
42	Hybrid -68	2	Green	Yellow

4.1.3.8 Number of hermaphrodite flowers per panicle

It is evident from the data presented in Table 8, that the highest number of hermaphrodite flowers per panicle during the investigation years 2015-16, 2016-17 and pooled data was recorded in hybrid-26 (390.9, 340.2 and 365.55) whereas it was found least in hybrid-15 (108.8, 115.5 and 112.15) in 2015-16, 2016-17 and pooled data. Total 32 hybrid derivatives were grouped in a range of 100.00-200.00, 9 hybrid derivatives in 200.10-300.00, whereas one hybrid derivative was above 300.00.

The total number of flowers in a panicle produced is also controlled by the genetic makeup of the plant. The variation in the total number of flowers per panicle was also reported by earlier workers Thimmapaiah and Suman (1987) and Desai *et al*. (1985).

The total number of flowers per panicle ranged from 294.3 in Neelum to 1092.0 in Amrapali (Rathor *et al.,* 2009).

The number of hermaphrodite flowers per panicle varied from 67.00 in Alphonso to 140.80 in H-151 (Anila and Radha, 2003). Though percentage of hermaphrodite flowers is an inherited character, associated with the productivity of mango varieties and it is the most important factor influencing initial fruit set on the panicle. This parameter is greatly influenced by environment also because mango cultivars exhibit eco-geographical preference for flowering and fruiting (Yadav and Rajan, 1993).

The number of flowers produced in a particular variety is largely influenced by environment. This is the reason that Langra produced 1061.0 flowers per panicle at Saharanpur (Singh, 1954) while it was 598.8 at Faisalabad (Asif *et al.* 2002) and 1690 at Sabour (Kumar and Jaiswal, 2003). The percentage of perfect flowers is affected considerably by the age of tree, climatic factors (Naik and Rao, 1943) and time of panicle emergence (Singh *et al*., 1966).

Grouping of hybrid derivatives according to number of hermaphrodite flowers

No.	Range	Number of hybrid derivatives
1.	100.00-200.00	32
2.	200.10-300.00	09
3.	Above 300.00	01

Table 8. Mean performance of mango progenies for male and hermaphrodite flowers

Sr. No.	Hybrid derivatives	Number of hermaphrodite flowers per panicle			Number of male flowers per panicle		
		2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
1	Hybrid -1	205.2	215.3	210.25	840.4	851.1	845.75
2	Hybrid-2	195.6	189.5	192.55	970.6	968.5	969.55
3	Hybrid -3	165.4	145.6	155.5	840.5	860.3	850.4
4	Hybrid -4	248.9	240.8	244.85	876.2	850.5	863.35
5	Hybrid -5	165.2	172.3	168.75	750.8	775.9	763.35
6	Hybrid -6	282.9	280.6	281.75	600.6	590.7	595.65
7	Hybrid -7	267.4	276.3	271.85	760.4	780.6	770.5
8	Hybrid -8	215.2	230.6	222.90	950.1	920.4	935.25
9	Hybrid -9	195.4	180.4	187.90	765.1	770.2	767.65
10	Hybrid -10	270.9	268.8	269.85	689.5	675.1	682.3
11	Hybrid -11	158.6	156.6	157.60	750.6	769.5	760.05
12	Hybrid -12	290.8	201.1	245.95	725.1	700.6	712.85
13	Hybrid -13	162.1	170.3	166.20	730.8	750.7	740.75
14	Hybrid -14	198.2	188.4	193.30	660.6	680.2	670.4
15	Hybrid -15	108.8	115.5	112.15	740.5	720.1	730.3
16	Hybrid -16	165.3	180.7	173.00	580.4	596.6	588.5
17	Hybrid -17	174.5	161.5	168.00	760.6	780.9	770.75
18	Hybrid -18	160.6	171.9	166.25	850.7	860.1	855.4
19	Hybrid -19	190.7	189.4	190.05	830.5	810.6	820.55
20	Hybrid -20	175.6	190.1	182.85	638.6	620.2	629.4
21	Hybrid -21	196.7	185.3	191.00	955.2	965.3	960.25
22	Hybrid -22	170.1	165.4	167.75	725.3	712.1	718.7
23	Hybrid -23	154.2	145.6	149.90	855.2	825.5	840.35
24	Hybrid -24	140.6	0.0	140.60	740.1	0.0	740.10
25	Hybrid -25	158.8	145.7	152.25	920.5	910.3	915.4
26	Hybrid -26	390.9	340.2	365.55	980.5	1032.5	1006.5
27	Hybrid -27	141.5	155.3	148.4	745.4	760.3	752.85
28	Hybrid -28	180.3	160.2	170.25	650.6	690.5	670.55
29	Hybrid -29	152.5	165.4	158.95	835.8	822.6	829.2
30	Hybrid -30	194.5	188.5	191.50	825.5	840.5	833
31	Hybrid -31	165.4	175.6	170.50	640.3	656.7	648.5
32	Hybrid -32	172.6	185.4	179.00	680.2	710.5	695.35
33	Hybrid -33	186.5	170.8	178.65	820.5	850.6	835.55
34	Hybrid -34	195.3	185.9	190.60	889.4	870.4	879.9
35	Hybrid -35	189.1	190.5	189.80	685.6	679.6	682.6
36	Hybrid -36	180.2	0.0	180.20	830.8	0.0	830.8
37	Hybrid -46	215.1	230.4	222.75	855.8	996.4	926.1
38	Hybrid -52	230.3	226	228.15	740.6	756.3	748.45
39	Hybrid -55	165.5	152.5	159.00	358.2	321.1	339.65
40	Hybrid -56	157.6	158.3	157.95	350.2	349.2	349.7
41	Hybrid -57	149.4	168.9	159.15	496.3	490.5	493.4
42	Hybrid -68	160.6	148.7	154.65	369.1	345.6	357.35
	Range	108.8-390.9	115.5-340.2	112.15-365.55	350.2-980.5	321.1-1032.5	339.65-1006.5
	Mean	191.55	189.26	189.72	744.37	747.98	747.07
	std	50.37	43.98	46.11	152.86	164.86	156.43
	S.E. ±	7.77	6.95	7.11	23.59	26.07	24.14
	CV (%)	26.30	23.24	24.30	20.54	22.04	20.94

4.1.3.9 Number of male flowers per panicle

The data related to the number of male flowers is presented in Table 8 and revealed that the highest number of male flowers per panicle was recorded in hybrid-26 (980.5, 1032.5 and 971.5) whereas least was recorded in hybrid-55 (358.2, 321.2 and 339.65) during the investigation years 2015-16, 2016-17 and pooled data. Total six hybrid derivatives were grouped in a range of 300-600, 19 hybrid derivatives in 601.1-800, whereas 17 hybrid derivatives were above 800.

The total number of male flowers produced is also controlled by the genetic makeup of the plant. The variation in the total number of male flowers per panicle was also reported by earlier workers Thimmapaiah and Suman (1987) and Desai *et al*. (1985). The highest number of male flowers was recorded in Prabhasankar (1328.3) whereas lowest was recorded in Alphonso (475.6), respectively (Ubale and Banik, 2015).

Grouping of hybrid derivatives according to number of male flowers

No.	Range	Number of hybrid derivatives
1.	300-600	06
2.	600.1-800	19
3.	Above 800	17

4.1.3.10 Sex ratio

The data regarding sex ratio has been presented in Table 9, showed remarkable differences in the ratio of hermaphrodite flowers to male flowers among hybrid mango derivatives studied and varied from 0.15 to 0.47, 0.16 to 0.48 and 0.15 to 0.47 during the experimental years i.e 2015-16, 2016-17 and pooled data. Total 33 hybrid derivatives were grouped in a range of 0.10-0.30, five hybrid derivatives in 0.31-0.40, whereas four hybrid derivatives were above 0.40. The highest ratio in 2015-16, 2016-17 and pooled data was observed in hybrid-6 (0.47, 0.48 and 0.47) and lowest was observed in hybrid-15 (0.15, 0.16 and 0.15).

According to Chadha (1963) though better sex ratio may result in better initial fruit set, the final yield in mango need not always be proportionate. This might be due to the subsequent fruit fall occurring due to various climatic and other factors. The sex ratio is a variable component within panicles, trees and among cultivars. This ratio varies with cultivars, but is usually less than 50 % (Davenport and Elisea, 1997). The variability in the perfect and staminate flower ratio may be governed by physiological

and environmental conditions (Davenport and Elisea, 1997). Mukherjee (1997) reported that the ratio of male to perfect flower was strongly influenced by environmental and cultural factors. Another possible reason for variation in sex ratio is genetic characters. The variation in sex ratio of mango hybrids was also reported by Sharma *et al.* (1998) and Kanpure *et al*. (2009).

Grouping of hybrid derivatives according sex ratio

No.	Range	Number of hybrid derivatives
1.	0.10-0.30	33
2.	0.31-0.40	05
3.	Above 0.40	04

4.1.3.11 Number of inflorescence per shoot

Number of inflorescence per shoot in all 42 derivatives observed throughout the investigation years 2015-16 and 2016-17 was one (Table 9).

4.1.3.12 Number of rachis per panicle

The data regarding the number of rachis presented in Table 10 revealed that the number of rachis per panicle ranged from 15.36 to 27.61, 15.60 to 28.70 and 15.48 to 28.16 during the experimental years 2015-16, 2016-17 and pooled data. Total 14 hybrid derivatives were grouped in a range of 15.0-20.0, 18 hybrid derivatives in 20.1-24.0, whereas 10 hybrid derivatives were above 24.0. The highest number of rachis was recorded in hybrid-6 (27.61, 28.70 and 28.16) whereas lowest was recorded in hybrid-23 (15.36, 15.60 and 15.48) in the investigation years 2015-16, 2016-17 and pooled data.

These results are in accordance with the observations noted by Hoda *et al.* (2003). Gill *et al.* (2015), also studied ten grafted mango cultivars namely Alphonso, Mallika, Malda, Kishan Bhog, SB Rampur, Fazli, SB Chausa, Langra, Dashehari and Amrapali and evaluated for their performance in terms of vegetative growth, flowering and fruit physico-chemical characteristics in which highest number of rachis/panicle was noted maximum (20.6) in Amrapali compared to other cultivars under study except 'Fazli'.

This difference is due to cultivar behaviour under different environmental conditions.

Table 9. Morphological characterization in mango progenies for inflorescence characters

Sr. No.	Hybrid derivatives	Sex ratio			Number of inflorescence per shoot		
		2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
1	Hybrid -1	0.24	0.25	0.25	1	1	1.00
2	Hybrid-2	0.20	0.20	0.20	1	1	1.00
3	Hybrid -3	0.20	0.17	0.18	1	1	1.00
4	Hybrid -4	0.28	0.28	0.28	1	1	1.00
5	Hybrid -5	0.22	0.22	0.22	1	1	1.00
6	Hybrid -6	0.47	0.48	0.47	1	1	1.00
7	Hybrid -7	0.35	0.35	0.35	1	1	1.00
8	Hybrid -8	0.23	0.25	0.24	1	1	1.00
9	Hybrid -9	0.26	0.23	0.24	1	1	1.00
10	Hybrid -10	0.39	0.40	0.40	1	1	1.00
11	Hybrid -11	0.21	0.20	0.21	1	1	1.00
12	Hybrid -12	0.40	0.29	0.34	1	1	1.00
13	Hybrid -13	0.22	0.23	0.22	1	1	1.00
14	Hybrid -14	0.30	0.28	0.29	1	1	1.00
15	Hybrid -15	0.15	0.16	0.15	1	1	1.00
16	Hybrid -16	0.28	0.30	0.29	1	1	1.00
17	Hybrid -17	0.23	0.21	0.22	1	1	1.00
18	Hybrid -18	0.19	0.20	0.19	1	1	1.00
19	Hybrid -19	0.23	0.23	0.23	1	1	1.00
20	Hybrid -20	0.27	0.31	0.29	1	1	1.00
21	Hybrid -21	0.21	0.19	0.20	1	1	1.00
22	Hybrid -22	0.23	0.23	0.23	1	1	1.00
23	Hybrid -23	0.18	0.18	0.18	1	1	1.00
24	Hybrid -24	0.19	0.00	0.19	1	0	1.00
25	Hybrid -25	0.17	0.16	0.17	1	1	1.00
26	Hybrid -26	0.40	0.33	0.36	1	1	1.00
27	Hybrid -27	0.19	0.20	0.20	1	1	1.00
28	Hybrid -28	0.28	0.23	0.25	1	1	1.00
29	Hybrid -29	0.18	0.20	0.19	1	1	1.00
30	Hybrid -30	0.24	0.22	0.23	1	1	1.00
31	Hybrid -31	0.26	0.27	0.26	1	1	1.00
32	Hybrid -32	0.25	0.26	0.26	1	1	1.00
33	Hybrid -33	0.23	0.20	0.21	1	1	1.00
34	Hybrid -34	0.22	0.21	0.22	1	1	1.00
35	Hybrid -35	0.28	0.28	0.28	1	1	1.00
36	Hybrid -36	0.22	0.00	0.22	1	0	1.00
37	Hybrid -46	0.25	0.23	0.24	1	1	1.00
38	Hybrid -52	0.31	0.30	0.30	1	1	1.00
39	Hybrid -55	0.46	0.47	0.47	1	1	1.00
40	Hybrid -56	0.45	0.45	0.45	1	1	1.00
41	Hybrid -57	0.30	0.34	0.32	1	1	1.00
42	Hybrid -68	0.44	0.43	0.43	1	1	1.00
	Range	0.15 -0.47	0.16 -0.48	0.15 -0.47	1 - 1	1 - 1	1 - 1
	Mean	0.27	0.27	0.27	1.00	1.00	1.00
	std	0.08	0.08	0.08	0.00	0.00	0.00
	S.E. ±	0.01	0.01	0.01	0.00	0.00	0.00
	CV (%)	31.63	31.73	31.30	0.00	0.00	0.00

Grouping of hybrid derivatives according to rachis per panicle

No.	Range	Number of hybrid derivatives
1.	15.00-20.00	14
2.	20.1-24.00	18
3.	Above 24.00	10

4.1.3.13 Duration of flowering (days)

The data presented in Table 10 showed that there was notable variation in the flowering duration (1st opening of flower to last opening of flower) among all the hybrid derivatives under this experimentation and ranged from 18 to 29 days, 17 to 34 days and 17.5 to 30.50 days in 2015-16, 2016-17 and pooled data. Total 22 hybrid derivatives were grouped in a range of 17.00-22.0 days, 14 hybrid derivatives in 22.1-27.1 days, whereas six hybrid derivatives were above 27.00 days. The longest flowering duration was recorded in hybrid-55 (31 days) in 2015-16, hybrid-22 (34 and 31.50 days) in 2016-17 and pooled data respectively whereas shortest was perceived in hybrid-29 (18 days), hybrid-46 and 13 (18 days) and hybrid-33 (19 days) in 2015-16, 2016-17 and pooled data, respectively.

Grouping of hybrid derivatives according to duration of flowering (days)

No.	Range (days)	Number of hybrid derivatives
1.	17.00-22.0	22
2.	22.1-27.00	14
3.	Above 27.00	06

The duration of flowering in mango is dependent on maturity of shoot and prevailing weather conditions. Mango produces flowers on the shoot terminals. Flowers are also borne on the older flushes of more than two years. The flowers dominate the terminals and if fruit are set, the vegetative growth does not occur from theses terminals until the crop is harvested. If the flowers fail to set fruit or fruit drop occur prematurely, the terminals produces vegetative growth immediately. All the flower buds do not open at the same time. Some buds have been found to open into inflorescences even when the fruits have been set in the majority of the panicles. The present findings are in tune with the findings of Chandra *et al.* (2001) on variation in date of flowering and duration of flowering. Similar results of variation in duration of flowering were also observed by Mallik (1957).

Table 10. Morphological characterization in mango progenies for inflorescence characters

Sr. No.	Hybrid derivatives	Number of rachis per panicle			Duration of flowering		
		2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
1	Hybrid -1	26.50	27.66	27.08	25	29	27.00
2	Hybrid-2	24.21	25.29	24.75	25	27	26.00
3	Hybrid -3	20.52	21.45	20.99	25	34	29.50
4	Hybrid -4	17.04	18.56	17.80	21	31	26.00
5	Hybrid -5	22.62	23.50	23.06	23	20	21.50
6	Hybrid -6	27.61	28.70	28.16	26	33	29.50
7	Hybrid -7	21.08	22.36	21.72	27	34	30.50
8	Hybrid -8	24.51	25.20	24.86	23	31	27.00
9	Hybrid -9	21.20	20.18	20.69	26	25	25.50
10	Hybrid -10	21.62	22.62	22.12	20	23	21.50
11	Hybrid -11	22.58	23.55	23.07	20	29	24.50
12	Hybrid -12	20.19	19.66	19.93	21	20	20.50
13	Hybrid -13	18.36	17.57	17.97	23	18	20.50
14	Hybrid -14	19.27	20.36	19.82	21	19	20.00
15	Hybrid -15	22.40	23.30	22.85	20	27	23.50
16	Hybrid -16	25.42	26.38	25.90	20	20	20.00
17	Hybrid -17	24.38	25.89	25.14	21	25	23.00
18	Hybrid -18	18.05	20.26	19.16	20	21	20.50
19	Hybrid -19	22.00	21.25	21.63	20	29	24.50
20	Hybrid -20	19.15	20.65	19.90	19	26	22.50
21	Hybrid -21	21.50	22.80	22.15	29	31	30.00
22	Hybrid -22	24.26	26.32	25.29	27	34	30.50
23	Hybrid -23	15.36	15.60	15.48	18	28	23.00
24	Hybrid -24	23.80	0.00	23.80	19	0	19.00
25	Hybrid -25	16.25	16.45	16.35	21	29	25.00
26	Hybrid -26	18.90	19.58	19.24	21	19	20.00
27	Hybrid -27	20.27	22.35	21.31	24	31	27.50
28	Hybrid -28	22.16	23.80	22.98	21	20	20.50
29	Hybrid -29	15.50	16.70	16.10	18	17	17.50
30	Hybrid -30	25.50	26.50	26.00	20	21	20.50
31	Hybrid -31	18.72	19.50	19.11	20	19	19.50
32	Hybrid -32	21.53	23.24	22.39	21	22	21.50
33	Hybrid -33	18.29	20.30	19.30	19	19	19.00
34	Hybrid -34	22.32	24.90	23.61	22	20	21.00
35	Hybrid -35	20.15	22.80	21.48	21	21	21.00
36	Hybrid -36	22.32	0.00	22.32	21	0	21.00
37	Hybrid -46	20.28	19.90	20.09	21	18	19.50
38	Hybrid -52	19.05	20.60	19.83	22	22	22.00
39	Hybrid -55	27.50	26.30	26.90	20	21	20.50
40	Hybrid -56	22.50	21.40	21.95	22	21	21.50
41	Hybrid -57	18.95	19.40	19.18	23	22	22.50
42	Hybrid -68	22.33	24.47	23.40	23	31	27.00
	Range	15.36 27.61	15.6 - 28.7	15.48 - 28.16	18 - 29	17 - 34	17.5 - 30.5
	Mean	21.34	22.18	21.78	21.88	24.68	23.17
	std	3.01	3.17	3.02	2.58	5.33	3.56
	S.E. ±	0.46	0.50	0.47	0.40	0.84	0.55
	CV (%)	14.11	14.31	13.86	11.78	21.59	15.37

Kumar *et al*. (2008) also observed a variation in duration of flowering in mango ranging from 23.83 days in Sunder Pasand to 37.50 days in Pairi. The mango varieties exhibit wide variation in flowering time even though when grown under identical conditions indicating the dependence of flowering process on the prevailing climatic conditions in the area of cultivation (Singh, 1960). The time of flowering in different regions is mainly governed by the local weather conditions. To some extent, it may also vary in different varieties grown under the same climatic conditions.

Singh *et al.* (2009) recorded first flower opening on 24 January with 16 days of flowering duration in Fazli under Jharkhand condition.

Bakshi *et al.* (2012) recorded first flower opening in Amrapali (21 February), Dashehari (15 February), Mallika (16 February) and Langra (20 February) with 16.67, 19.67, 18.67 and 19.00 days of flowering duration correspondingly under Jammu conditions. Chandra *et al*. (2001) observed that date of flowering and duration of flowering days varied distinctly in different mango cultivars and hybrids.

4.1.4 Fruit morphology

All observations were recorded when fruit was fully ripened, unless otherwise specified. Measurements were made on 10 well developed representative fruits at harvesting time.

4.1.4.1 Days required from fruit setting to mustard stage (days)

The data presented in Table 11 revealed that the number of days required from fruit setting to mustard stage ranged from 5 to 7 in all hybrid derivatives during the investigation years 2015-16, 2016-17 and pooled data. Total 21 hybrid derivatives were grouped in a range of 5.0-6.0 days, 16 hybrid derivatives in 6.1-6.5 days, whereas five hybrid derivatives were above 6.5 days.

The variation in fruit set could be due to genotypic differences. The ability of cultivars to bear fruit set also depends upon the availability of pollen, its viability, populations of pollinating insects and self and cross compatibility of a cultivar and with other cultivars respectively (Anjum *et al*., 1999). The similar results were also closely supported by Scholefield and Oag, (1986).

Grouping of hybrid derivatives according to days required from fruit setting to mustard stage (days)

No.	Range (days)	Number of hybrid derivatives
1.	5.00-6.00	21
2.	6.1-6.5	16
3.	Above 6.5	05

4.1.4.2 Number of fruits per panicle (At mustard stage)

It is evident from the data presented in Table 11 that the number of fruits per panicle ranged from 45.9 to 69.7, 45.7 to 69.9 and 46.2 to 69.6 during the investigation years (2015-16, 2016-17 and pooled data). Total 17 hybrid derivatives were grouped in a range of 45.00-55.00, 14 hybrid derivatives in 55.1-62.0, whereas 11 hybrid derivatives were above 62.00. The highest number of fruits per panicle was recorded in hybrid-10 (69.7) in 2015-16, hybrid-7 (69.9) in 2016-17 and hyrid-6 (69.6) in pooled data whereas lowest was recorded in hybrid-31 (45.9) in 2015-16, hybrid-46, 55 (45.7) in 2016-17 and hybrid-30 (46.20) in pooled data.

Sharma and Singh (1970) and Singh *et al.* (1962) had reported fruit set in mango as a genotypic character *i.e*. self and cross incompatibility.

Grouping of hybrid derivatives according to number of fruits per panicle (at mustard stage)

No.	Range	Number of hybrid derivatives
1.	45.00-55.00	17
2.	55.10-62.00	14
3.	Above 62.00	11

Hada and Singh (2017) conducted a field experiment to investigate the flowering, fruiting and yield attributes of some mango cultivars for the years 2014-15 and 2015-16 and reported that the highest number of fruit set per panicle was recorded in Langra (137.75) while, maximum fruit set per cent was noted in Bombai (41.07 %).

Table 11. Morphological characterization in mango progenies for fruit characters

Sr. No.	Hybrid derivatives	Days required from fruit setting to mustard stage			Number of fruits per panicle (at mustard stage)		
		2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
1	Hybrid -1	6	7	6.5	63.5	66.7	65.10
2	Hybrid-2	6	6	6.0	68.5	68.9	68.70
3	Hybrid -3	7	7	7.0	64.7	65.8	65.25
4	Hybrid -4	5	6	5.5	58.7	59.2	58.95
5	Hybrid -5	7	7	7.0	52.7	52.5	52.60
6	Hybrid -6	6	7	6.5	69.6	69.7	69.65
7	Hybrid -7	5	6	5.5	68.5	69.9	69.20
8	Hybrid -8	6	5	5.5	55.8	57.8	56.80
9	Hybrid -9	6	6	6.0	52.6	55.7	54.15
10	Hybrid -10	7	6	6.5	69.7	68.3	69.00
11	Hybrid -11	6	7	6.5	49.7	55.7	52.70
12	Hybrid -12	6	5	5.5	68.5	69.8	69.15
13	Hybrid -13	7	6	6.5	58.6	59.7	59.15
14	Hybrid -14	6	6	6.0	53.5	55.8	54.65
15	Hybrid -15	7	7	7.0	58.6	58.9	58.75
16	Hybrid -16	7	6	6.5	57.6	58.9	58.25
17	Hybrid -17	5	7	6.0	61.7	63.4	62.55
18	Hybrid -18	6	7	6.5	55.8	55.7	55.75
19	Hybrid -19	5	6	5.5	56.8	55.9	56.35
20	Hybrid -20	6	7	6.5	58.5	55.4	56.95
21	Hybrid -21	6	7	6.5	62.8	64.5	63.65
22	Hybrid -22	7	6	6.5	59.7	60.6	60.15
23	Hybrid -23	6	6	6.0	54.5	55.1	54.80
24	Hybrid -24	5	0	5.0	48.9	0.0	48.90
25	Hybrid -25	6	5	5.5	58.8	59.7	59.25
26	Hybrid -26	7	6	6.5	59.8	65.2	62.50
27	Hybrid -27	7	7	7.0	49.8	52.6	51.20
28	Hybrid -28	7	6	6.5	57.8	56.9	57.35
29	Hybrid -29	6	5	5.5	54.8	56.9	55.85
30	Hybrid -30	6	6	6.0	46.5	45.9	46.20
31	Hybrid -31	6	7	6.5	45.9	50.5	48.20
32	Hybrid -32	5	5	5.0	52.4	54.7	53.55
33	Hybrid -33	6	5	5.5	52.1	50.2	51.15
34	Hybrid -34	6	6	6.0	56.7	57.6	57.15
35	Hybrid -35	7	7	7.0	51.4	54.9	53.15
36	Hybrid -36	6	0	6.0	49.9	0.0	49.90
37	Hybrid -46	6	7	6.5	49.9	45.7	47.80
38	Hybrid -52	7	6	6.5	68.9	65.7	67.30
39	Hybrid -55	6	7	6.5	49.5	45.7	47.60
40	Hybrid -56	5	6	5.5	48.9	49.8	49.35
41	Hybrid -57	6	5	5.5	49.8	51.8	50.80
42	Hybrid -68	6	6	6.0	57.4	56.5	56.95
	Range	5 - 7	5 - 7	5 - 7	45.9 - 69.7	45.7 - 69.9	46.2 - 69.65
	Mean	6.12	6.19	6.15	56.90	58.11	57.30
	std	0.67	0.74	0.54	6.74	6.74	6.70
	S.E. ±	0.10	0.11	0.08	1.04	1.07	1.03
	CV (%)	10.95	11.96	8.70	11.85	11.61	11.70

4.1.4.3 Days required from mustard stage to pea stage (days)

The data presented in Table 12 revealed that the number of days from mustard stage to pea stage ranged from 10 to 15 days, 10 to 13 days and 10.50 to 14 days in 2015-16, 2016-17 and pooled data respectively. Total 39 hybrid derivatives were grouped in a range of 10.0-12.00 days, two hybrid derivatives in 12.1-13.0 days, whereas one hybrid derivative was above 13.0. The highest number of days required was recorded by hybrid-32 (15 days, 13 days and 14 days) in 2015-16, 2016-17 and pooled data respectively.

Some varieties develop all their flowers within ten days after the first bud opens, whereas others may take several weeks or even months (Popenoe, 1927). Therefore variation in duration may be observed in fruit setting and further stages.

Grouping of hybrid derivatives according to days required from mustard stage to pea stage (days)

No.	Range (days)	Number of hybrid derivatives
1.	10.00-12.00	39
2.	12.1-13.0	02
3.	Above 13.00	01

4.1.4.4 Days required from pea stage to marble stage (days)

The data presented in Table 12 showed that the number of days from pea stage to marble stage ranged from 13 to 16 days, 14 to 16 days and 13.50 to 15.50 days in 2015-16, 2016-17 and pooled data respectively.

Grouping of hybrid derivatives according to days required from pea stage to marble stage (days)

No.	Range (days)	Number of hybrid derivatives
1.	13.00-14.50	27
2.	14.51-15.00	06
3.	Above15.00	09

Table 12. Morphological characterization in mango progenies for fruit characters

Sr. No.	Hybrid derivatives	Days required from mustard stage to pea stage			Days required from pea stage to marble stage		
		2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
1	Hybrid -1	10	11	10.5	14	15	14.5
2	Hybrid-2	11	12	11.5	15	14	14.5
3	Hybrid -3	12	10	11	13	16	14.5
4	Hybrid -4	12	11	11.5	14	15	14.5
5	Hybrid -5	10	12	11	14	15	14.5
6	Hybrid -6	14	11	12.5	14	14	14
7	Hybrid -7	12	12	12	16	15	15.5
8	Hybrid -8	10	11	10.5	13	14	13.5
9	Hybrid -9	12	10	11	15	14	14.5
10	Hybrid -10	11	11	11	16	15	15.5
11	Hybrid -11	10	12	11	15	14	14.5
12	Hybrid -12	11	12	11.5	14	15	14.5
13	Hybrid -13	13	11	12	15	16	15.5
14	Hybrid -14	12	10	11	16	15	15.5
15	Hybrid -15	11	10	10.5	14	15	14.5
16	Hybrid -16	12	12	12	15	14	14.5
17	Hybrid -17	13	11	12	14	15	14.5
18	Hybrid -18	12	11	11.5	15	15	15
19	Hybrid -19	11	12	11.5	14	16	15
20	Hybrid -20	10	12	11	13	15	14
21	Hybrid -21	13	11	12	14	15	14.5
22	Hybrid -22	11	12	11.5	14	15	14.5
23	Hybrid -23	10	12	11	15	14	14.5
24	Hybrid -24	11	0	11	16	0	16.0
25	Hybrid -25	12	12	12	14	14	14
26	Hybrid -26	10	11	10.5	16	15	15.5
27	Hybrid -27	10	12	11	14	15	14.5
28	Hybrid -28	11	12	11.5	15	15	15
29	Hybrid -29	11	11	11	14	16	15
30	Hybrid -30	12	12	12	15	16	15.5
31	Hybrid -31	13	12	12.5	14	15	14.5
32	Hybrid -32	15	13	14	15	15	15
33	Hybrid -33	12	11	11.5	13	16	14.5
34	Hybrid -34	11	12	11.5	15	15	15
35	Hybrid -35	12	11	11.5	14	14	14
36	Hybrid -36	12	0	12	14	0	14
37	Hybrid -46	10	11	10.5	15	14	14.5
38	Hybrid -52	10	12	11	13	15	14
39	Hybrid -55	11	10	10.5	15	14	14.5
40	Hybrid -56	12	12	12	14	14	14
41	Hybrid -57	11	13	12	16	15	15.5
42	Hybrid -68	12	11	11.5	16	15	15.5
	Range	10 - 15	10 - 13	10.5 -14	13 - 16	14 - 16	13.5 - 15.5
	Mean	11.45	11.38	11.42	14.52	14.86	14.69
	std	1.17	0.79	0.69	0.92	0.65	0.53
	S.E. ±	0.18	0.12	0.11	0.14	0.10	0.08
	CV (%)	10.24	6.98	6.03	6.31	4.35	3.60

4.1.4.5 Fruit retension per cent at harvest (%)

The data presented in Table 13 revealed that the fruit retension per cent ranged from 1.87 to 3.80 per cent, 1.75 to 3.81 per cent and 1.81 to 3.80 per cent during the experimentation period (2015-16, 2016-17 and pooled data). Total 18 hybrid derivatives were grouped in a range of 1.5-2.5 per cent, 21 hybrid derivatives in 2.51 – 3.50 per cent, whereas three hybrid derivatives were above 3.50 per cent. The highest fruit retension per cent was recorded in hybrid-7 (3.80, 3.81 and 3.80) whereas lowest fruit retension per cent was recorded in hybrid-34 (1.87, 1.75 and 1.81) during both the years of investigation (2015-16, 2016-17) and pooled data.

Possible reason for low fruit retention in mango may be attributed to the sex ratio in panicle which may influence fruit set. The fruit loss in mango may be attributed to embryo abortion, resulting in blackened or shriveled embryos (Singh, 1954) and prevailing weather conditions (Chandler, 1958). The present findings indicated that the number of fruit set per panicle and fruit retention percentage at harvest depends on the proportion of hermaphrodite flowers. The similar finding was also reported by Chauhan (1972), while evaluating the mango hybrids.

Grouping of hybrid derivatives according to fruit retension per cent at harvest (%)

No.	Range (%)	Number of hybrid derivatives
1.	1.5-2.5	18
2.	2.51-3.50	21
3.	Above 3.50	03

4.1.4.6 Fruit shape

The data presented in Table 13 showed that fruit shape was elliptic in 17 derivatives, oblong in 11 derivatives, roundish in eight derivatives, obovoid in five derivatives and ovoid in remaining 1 genotype.

Fruit shape is a characteristic feature and it is usually strongly correlated with the genetic make-up of particular cultivar. Beside genetics, to some extent this also vary with production locality, cultural practices and particular environmental conditions (Ali, 2013 and Jamil *et al*., 2015). Similarly, we also found significant variations in fruit shapes. Moreover, fruit shape is very pivotal characters and useful for the identification and characterization of different mango accessions or varieties (Rajwana *et al.,* 2011; Khan *et al*., 2015).

Table 13. Morphological characterization in mango progenies for fruit characters

Sr. No	Hybrid derivatives	Fruit retention per cent at harvest			Fruit shape
		2015-16	2016-17	Pooled	
1	Hybrid -1	2.82	2.87	2.85	Elliptic
2	Hybrid-2	2.67	2.84	2.76	Roundish
3	Hybrid -3	2.85	2.91	2.88	Elliptic
4	Hybrid -4	3.77	3.55	3.66	Elliptic
5	Hybrid -5	2.49	2.29	2.39	Elliptic
6	Hybrid -6	3.74	3.59	3.66	Obovoid
7	Hybrid -7	3.80	3.81	3.80	Obovoid
8	Hybrid -8	2.83	2.32	2.57	Elliptic
9	Hybrid -9	2.44	2.45	2.44	Elliptic
10	Hybrid -10	3.27	3.35	3.31	Elliptic
11	Hybrid -11	2.81	3.19	3.00	Elliptic
12	Hybrid -12	3.77	3.75	3.76	Roundish
13	Hybrid -13	1.87	2.35	2.11	Ovoid
14	Hybrid -14	2.10	3.35	2.72	Elliptic
15	Hybrid -15	2.24	2.53	2.38	Obovoid
16	Hybrid -16	2.59	2.51	2.55	Obovoid
17	Hybrid -17	2.93	2.73	2.83	Elliptic
18	Hybrid -18	2.02	3.04	2.53	Elliptic
19	Hybrid -19	2.94	2.49	2.71	Oblong
20	Hybrid -20	2.99	2.27	2.63	Elliptic
21	Hybrid -21	2.84	2.61	2.73	Roundish
22	Hybrid -22	3.09	2.81	2.95	Roundish
23	Hybrid -23	2.44	2.90	2.67	Elliptic
24	Hybrid -24	2.15	0.00	2.15	Oblong
25	Hybrid -25	2.94	2.24	2.59	Elliptic
26	Hybrid -26	3.38	3.53	3.45	Oblong
27	Hybrid -27	2.37	2.05	2.21	Oblong
28	Hybrid -28	2.08	1.93	2.00	Oblong
29	Hybrid -29	1.87	1.93	1.90	Elliptic
30	Hybrid -30	2.43	2.18	2.30	Oblong
31	Hybrid -31	2.31	2.18	2.24	Roundish
32	Hybrid -32	2.19	2.24	2.22	Roundish
33	Hybrid -33	2.01	2.19	2.10	Roundish
34	Hybrid -34	1.87	1.75	1.81	Roundish
35	Hybrid -35	2.77	3.57	3.17	Elliptic
36	Hybrid -36	2.04	0.00	2.04	Oblong
37	Hybrid -46	2.72	2.33	2.52	Elliptic
38	Hybrid -52	3.34	3.49	3.42	Obovoid
39	Hybrid -55	2.41	2.53	2.47	Oblong
40	Hybrid -56	2.25	2.25	2.25	Oblong
41	Hybrid -57	2.45	2.28	2.36	Oblong
42	Hybrid -68	2.06	2.07	2.07	Oblong
	Range	1.87 - 3.8	1.75 - 3.81	1.81 - 3.8	-
	Mean	2.64	2.68	2.65	-
	std	0.55	0.57	0.53	-
	S.E. ±	0.08	0.09	0.08	-
	CV (%)	20.78	21.29	19.84	-

Grouping of hybrid derivatives according to fruit shape

No.	Character	Number of hybrid derivatives
1	Elliptic	17
2	Roundish	08
3	Obovoid	05
4	Oblong	11
5	Ovoid	01

4.1.4.7 Fruit length and breadth (cm)

The data presented in Table 14 revealed that the fruit length ranged from 6.56 to 14.91 cm, 6.36 to 15.16 cm and 6.46 to 15.04 cm during the experimental period (2015-16 and 2016-17) and pooled data respectively. Total 39 hybrid derivatives were grouped in a range of 6.0-10.0 cm, one hybrid derivative in 10.1-13.0 cm, whereas two hybrid derivatives were above 13.00 cm. The maximum fruit length was recorded in hybrid-46 (14.91 cm, 15.16 cm and 15.04 cm) and minimum length was noted in hybrid-17 (6.56 cm, 6.36 and 6.46 cm) during the experimentation years (2015-16 and 2016-17) and pooled data.

The data pertaining to the fruit breadth of mango derivatives presented in Table 14 varied during the experimental period and ranged from 4.96 to 8.92 cm, 4.56 to 8.90 and 4.86 cm to 8.91 cm during both the years of investigation (2015-16, 2016-17) and pooled data. The data revealed that the maximum fruit breadth (8.92 cm, 8.90 cm and 8.91 cm) was recorded in hybrid-46 whereas minimum was reported in hybrid-17 (4.96 cm), hybrid-2 (4.56 cm) and hybrid-11 (4.86) during 2015-16, 2016-17 and pooled data.

Rathor *et al.* (2009) evaluated twenty mango derivatives and reported that the highest fruit length was observed in Fazli variety whereas Chanana *et al.* (2005) stated that Mallika recorded highest fruit breadth.

Fruit length and breadth of different mango hybrids showed variation and Mallika recorded maximum fruit breadth of fruit (Choudhari and Desai, 1996; Kumar, 1997; Sarkar *et al*. 2001; Reddy *et al.* 2000 and Chakraborti, 2012).

Singh *et al*. (2009) noted the maximum fruit length (11.23 cm) and fruit breadth (7.46 cm).

Table 14 Mean performance of mango progenies for fruit length and breadth

Sr. No.	Hybrid derivatives	Fruit length (cm)			Fruit breadth (cm)		
		2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
1	Hybrid -1	8.68	8.56	8.62	5.65	6.24	5.95
2	Hybrid-2	6.59	6.62	6.61	5.37	4.56	4.97
3	Hybrid -3	6.98	6.61	6.80	5.12	5.13	5.13
4	Hybrid -4	8.16	8.22	8.19	7.13	7.18	7.16
5	Hybrid -5	7.35	7.47	7.41	6.21	6.22	6.22
6	Hybrid -6	8.99	8.96	8.98	6.18	6.42	6.30
7	Hybrid -7	8.96	8.6	8.78	6.26	6.33	6.30
8	Hybrid -8	8.01	8.34	8.18	5.88	5.54	5.71
9	Hybrid -9	8.31	8.33	8.32	6.23	6.13	6.18
10	Hybrid -10	8.62	8.6	8.61	6.26	6.49	6.38
11	Hybrid -11	8.03	7.89	7.96	5.07	4.65	4.86
12	Hybrid -12	11.78	11.46	11.62	8.54	8.85	8.70
13	Hybrid -13	8.9	8.46	8.68	6.01	5.86	5.94
14	Hybrid -14	8.16	8.31	8.24	5.78	6.92	6.35
15	Hybrid -15	7.45	7.4	7.43	6.21	6.6	6.41
16	Hybrid -16	8.81	9.9	9.36	7.52	7.2	7.36
17	Hybrid -17	6.56	6.36	6.46	4.96	5.37	5.17
18	Hybrid -18	7.55	8.13	7.84	5.3	5.74	5.52
19	Hybrid -19	8.86	8.85	8.86	6.07	5.47	5.77
20	Hybrid -20	8.78	7.79	8.29	6.36	5.79	6.08
21	Hybrid -21	7.56	7.95	7.76	5.97	6.53	6.25
22	Hybrid -22	8.16	8.02	8.09	7.19	6.98	7.09
23	Hybrid -23	7.2	7.32	7.26	5.7	5.47	5.59
24	Hybrid -24	7.34	0.00	7.34	5.1	0.00	5.10
25	Hybrid -25	8.26	8.44	8.35	6.2	5.68	5.94
26	Hybrid -26	13.96	14.78	14.37	8.2	8.19	8.20
27	Hybrid -27	7.75	6.84	7.30	6.26	6.22	6.24
28	Hybrid -28	8.65	7.54	8.10	5.16	5.4	5.28
29	Hybrid -29	6.61	7.68	7.15	5.1	5.2	5.15
30	Hybrid -30	8.65	9.59	9.12	6.14	5.94	6.04
31	Hybrid -31	8.31	8.15	8.23	6.1	5.99	6.05
32	Hybrid -32	7.69	7.83	7.76	5.34	5.43	5.39
33	Hybrid -33	7.64	7.6	7.62	5.71	6.19	5.95
34	Hybrid -34	8.19	8.07	8.13	8.59	8.41	8.50
35	Hybrid -35	6.59	7.12	6.86	6.06	6.15	6.11
36	Hybrid -36	8.52	0.00	8.52	5.84	0.00	5.84
37	Hybrid -46	14.91	15.16	15.04	8.92	8.9	8.91
38	Hybrid -52	9.43	10.05	9.74	6.82	7.19	7.01
39	Hybrid -55	7.58	8.26	7.92	4.97	4.89	4.93
40	Hybrid -56	8.17	7.96	8.07	5.83	5.92	5.88
41	Hybrid -57	7.49	6.38	6.94	5.96	5.266	5.61
42	Hybrid -68	7.38	7.65	7.52	5.26	5.15	5.21
	Range	6.56-14.91	6.36-15.16	6.46-15.04	4.96 - 8.92	4.56 - 8.9	4.86 - 8.91
	Mean	8.37	8.43	8.39	6.16	6.19	6.16
	std	1.66	1.82	1.70	0.99	1.05	1.00
	S.E. ±	0.26	0.29	0.26	0.15	0.17	0.15
	CV (%)	19.85	21.55	20.30	16.08	16.94	16.19

Bhuyan and Islam (1986) conducted an experiment on physico-chemical studies of 13 varieties of mangoes at Nawabganj in which the length and breadth of fruit of Gopalbhog was 8.72 × 6.54 cm.

The variation in length (11.50-6.86) and breadth (5.37-10.96 cm) of fruit in mango was also observed by Kher and Sharma (2002) and Abirami *et al.* (2011). The variations in the fruit size depend upon the genetic makeup of an individual variety and are highly influenced by environmental factors.

Grouping of hybrid derivatives according to fruit length and breadth (cm)

No.	Range (cm)	Number of hybrid derivatives
	Fruit length	
1.	6.0-10.0	39
2.	10.1-13.0	01
3.	Above 13.00	02
	Fruit breadth	
1.	4.50-6.50	34
2.	6.51-8.00	04
3.	Above 8.00	04

4.1.4.8 Fruit weight (g)

It is evident from the data presented in Table 15 that the fruit weight ranged from 94.90 to 575.7 g, 97.60 to 598.60 g and 94.90 to 583.45 g. Total 36 hybrid derivatives were grouped in a range of 90.0-260.0 g, three hybrid derivatives in 260.1-425.01 g, whereas three hybrid derivatives were above 425.00 g. The highest weight of fruit was recorded in hybrid-46 (668.30 g, 698.60 g and 683.45 g) and the lowest fruit weight was recorded in hybrid-17 (96.30 g, 97.60 g and 96.95 g) in both the years of investigation (2015-16 and 2016-17) and pooled data.

The higher or lower fruit weight might be due to the varietal or genetic characters. Similar trend in the variation of fruit weight from 365.33 to 219.00 g has also been reported by Majumder *et al.* (2011), while evaluating different mango cultivars. There was a wide variation in fruit weight and size among the mango cultivars and had earlier been reported by Mollah and Siddique (1973), Saha and Hossain (1988), and Uddin *et al*. (2006). In case of hybrids, namely, Amrapali, Mallika, Pusa Pratibha, Pusa Peetambar, Pusa Shresth, and Pusa Arunima, this might be due to transgressive

segregation of genes controlling fruit weight in mango. The present finding corroborates with the reports of Lavi *et al*. (1991) and Kulkarni *et al.* (2002).

Lodh *et al.* (1974) studied the physico - chemical characteristics of mango varieties and found that maximum average fruit weight was registered by Totapuri (622.00 g) followed by Mulgoa and Banganpalli (480.00 and 410.00 g, respectively) and minimum fruit weight was attained by Langra (209.00 g).

Jindal and Sharma (1981) assessed six mango cultivars under semi-arid conditions of Hisar, Haryana and noted that fruits of Sipia Sah Pasand were the heaviest (248 g) followed by Bombay Green and Saroli.

Passam (1982), who compared some local mango cultivars with the introduced ones, observed that the fruits of local cultivars weighed from approximately 100 (Doodooth) to 500 g/fruit (Graham). In contrast, the introduced cultivars (Haden, Sensation and Zill) produced medium to heavy fruits with 250-500 g of weight.

Kulkarni and Rameshwar, (1981) noticed wide variation in the physical characters of the ripe fruits of 22 important mango cultivars at Sangareddy, Andhra Pradesh. The fruits of Alampur Baneshan were the heaviest (400 g/fruit), while Alphonso and Pairi bore the minimum fruit weight (180 g).

Grouping of hybrid derivatives according to fruit weight (g)

No.	Range (g)	Number of hybrid derivatives
1.	90.0-260.0	36
2.	260.1-425.01	03
3.	Above 425.00	03

4.1.4.9 Fruit volume (cm^3)

The data pertaining to the volume of fruit has been presented in Table 15. During the period of investigation years 2015-16, 2016-17 and pooled data, fruit volume ranged from 93.95 to 553.9 cm^3, 95.15 to 571.25 cm^3 and 94.04 to 562.58 cm^3. Total 36 hybrid derivatives were grouped in a range of 90.0-250.0 cm^3, three hybrid derivatives in 250.1-410.0 cm^3, whereas three hybrid derivatives ranged above 410 cm^3. Fruit volume was found maximum in hybrid-46 (553.90 cm^3, 571.25 cm^3 and 562.58 cm^3) in 2015-16, 2016-17 and pooled data whereas lowest fruit volume was recorded in hybrid-17 (93.95 cm^3, 95.15 cm^3, 94.04 cm^3) in 2015-16, 2016-17 and pooled data.

Table 15. Mean performance of mango progenies for fruit weight and fruit volume

Sr. No.	Hybrid derivatives	Fruit weight (g)			Fruit volume (cm^3)		
		2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
1	Hybrid -1	155.2	163.6	159.40	144.84	155.41	150.13
2	Hybrid-2	170.4	167.2	168.80	165.34	160.91	163.13
3	Hybrid -3	98.2	105.4	101.80	95.89	98.41	97.15
4	Hybrid -4	247.6	259.3	253.45	242.95	236.26	239.61
5	Hybrid -5	172.1	168.4	170.25	164.32	159.31	161.82
6	Hybrid -6	267.5	274.8	271.15	277.73	266.06	271.90
7	Hybrid -7	281.7	276.2	278.95	276.51	265.04	270.78
8	Hybrid -8	202.5	202.7	202.60	197.07	196.37	196.72
9	Hybrid -9	178.9	181.6	180.25	163.98	172.75	168.37
10	Hybrid -10	200.2	196.2	198.20	199.58	192.39	195.99
11	Hybrid -11	111.1	102.6	106.85	104.75	100.89	102.82
12	Hybrid -12	575.7	583.1	579.40	530.17	527.29	528.73
13	Hybrid -13	195.4	186.4	190.90	184.59	179.83	182.21
14	Hybrid -14	158.6	147.3	152.95	142.64	139.17	140.91
15	Hybrid -15	170.9	183.7	177.30	159.67	163.37	161.52
16	Hybrid -16	118.8	124.2	121.50	109.22	116.43	112.83
17	Hybrid -17	96.3	97.6	96.95	93.95	95.15	94.55
18	Hybrid -18	147.8	159.5	153.65	132.57	146.84	139.71
19	Hybrid -19	205.8	197.8	201.80	200.1	192.84	196.47
20	Hybrid -20	188.2	173.3	180.75	174.95	169.52	172.24
21	Hybrid -21	136.7	149	142.85	128.11	132.19	130.15
22	Hybrid -22	162.6	151.6	157.10	150.49	143.52	147.01
23	Hybrid -23	140.5	134.41	137.46	133.06	125.12	129.09
24	Hybrid -24	94.9	0.00	94.90	94.04	0.00	94.04
25	Hybrid -25	143.1	130.1	136.60	136.45	129.51	132.98
26	Hybrid -26	537.7	527.8	532.75	525.37	518.33	521.85
27	Hybrid -27	178.4	164.8	171.60	167.59	154.72	161.16
28	Hybrid -28	138.9	149.3	144.10	131.89	134.89	133.39
29	Hybrid -29	100.6	108.3	104.45	97.8	104.7	101.25
30	Hybrid -30	207.8	203.2	205.50	201.75	198.75	200.25
31	Hybrid -31	125.6	122.3	123.95	113.64	118.42	116.03
32	Hybrid -32	110.5	125.2	117.85	104.74	116.81	110.78
33	Hybrid -33	122.6	135.3	128.95	119.05	129.53	124.29
34	Hybrid -34	221.5	238.4	229.95	211.12	233.17	222.15
35	Hybrid -35	122.7	124.7	123.70	119.87	120.48	120.18
36	Hybrid -36	126.8	0.00	126.80	121.21	0.00	121.21
37	Hybrid -46	568.3	598.6	583.45	553.9	571.25	562.58
38	Hybrid -52	363.9	371.2	367.55	355.96	354.27	355.12
39	Hybrid -55	186.2	192.9	189.55	179.49	191.04	185.27
40	Hybrid -56	136.4	142.4	139.40	127.72	138.57	133.15
41	Hybrid -57	145.6	153.2	149.40	139.7	149.6	144.65
42	Hybrid -68	161.8	173.5	167.65	152.8	176.05	164.425
	Range	94.9 - 575.7	97.6 - 598.6	94.9 - 583.45	93.95 - 553.9	95.15 - 571.25	94.04 - 562.58
	Mean	194.67	201.18	195.77	186.35	191.88	187.11
	std	116.09	119.49	117.05	112.38	112.93	111.93
	S.E. ±	17.91	18.89	18.06	17.34	17.86	17.27
	CV (%)	59.64	59.40	59.79	60.30	58.86	59.82

Tripathi (2000) reported that the fruit weight and volume of cultivars viz., Mallika, Nariyal, Fazli and Dadamiyan were more than 400 g and 400 cc per fruit, respectively among the 93 germplasm of mango studied in Tarai conditions which is in close proximity with the present study.

Gowda and Ramanjaneya (1994) observed significant differences in the volume of different varieties under Bangalore conditions. Fruit volume was more than 300 ml in three varieties, *viz*., Totapari, Mulgoa and Swarnarekha, while it was less than 200 ml in Janardan Pasand, Dashehari, Panakalu and Kesar.

Grouping of hybrid derivatives according to fruit volume (cm^3)

No.	Range (cm^3)	Number of hybrid derivatives
1.	90.0-250.0	36
2.	250.1-410.0	03
3.	Above 410.00	03

4.1.4.10 Fruit beak

The data presented in Table 16 revealed that among all the hybrid derivatives studied fruit beak of 25 derivatives was recorded as perceptible, 11 as pointed, four mammiformed and two prominent.

Grouping of hybrid derivatives according to fruit beak

No.	Character	Number of hybrid derivatives
1	Perceptible	25
2	Pointed	11
3	Mammiformed	04
4	Prominent	02

4.1.4.11 Fruit apex

The data presented in Table 16 showed that the apex of the fruit was recorded as obtuse, acute and round however 29 hybrid derivatives showed obtuse fruit apex, 12 derivatives had acute fruit apex and remaining one hybrid derivative had roundish fruit apex.

Qualitative characteristics such as fruit shape, fruit apex and fruit stalk depth are less prone to influences from environmental factors but are considered to be subjective to a certain extent (Morell *et al.* 1995) and is mostly a genetic character. Most cultivars in Shendi, Sudan also reported oblong fruit shape followed by round and obtuse fruit apex (Ahmed and Mohamed, 2015).

Table 16. Morphological characterization of mango progenies for fruit characters

Sr. No.	Hybrid derivatives	Fruit beak	Fruit apex	Fruit base	Colour of fruit
1	Hybrid -1	Perceptible	Obtuse	OR	Green
2	Hybrid-2	Perceptible	Acute	OR	Green
3	Hybrid -3	Mammiform	Acute	OR	Green
4	Hybrid -4	Pointed	Obtuse	SFE	Light green
5	Hybrid -5	Perceptible	Round	OR	Green
6	Hybrid -6	Pointed	Obtuse	F	Green
7	Hybrid -7	Perceptible	Acute	OF	Green
8	Hybrid -8	Perceptible	Acute	OR	Green
9	Hybrid -9	pointed	Acute	SF	Green
10	Hybrid -10	Perceptible	Obtuse	OR	Green
11	Hybrid -11	Perceptible	Obtuse	OR	Green
12	Hybrid -12	Perceptible	Obtuse	OR	Green
13	Hybrid -13	Perceptible	Obtuse	N	Green
14	Hybrid -14	Perceptible	Obtuse	OR	Green
15	Hybrid -15	Perceptible	Obtuse	OR	Green
16	Hybrid -16	Pointed	Obtuse	F	Green
17	Hybrid -17	Perceptible	Obtuse	OR	Green
18	Hybrid -18	Perceptible	Obtuse	OR	Dark green
19	Hybrid -19	Perceptible	Acute	OR	Dark green
20	Hybrid -20	Pointed	Acute	OR	Green
21	Hybrid -21	Pointed	Obtuse	SFE	Green
22	Hybrid -22	Perceptible	Obtuse	OR	Green
23	Hybrid -23	Perceptible	Obtuse	OR	Dark green
24	Hybrid -24	Perceptible	Obtuse	OR	Green
25	Hybrid -25	Mammiform	Obtuse	OR	Green
26	Hybrid -26	Prominent	Obtuse	N	Green
27	Hybrid -27	Pointed	Acute	OR	Green
28	Hybrid -28	Pointed	Acute	N	Green
29	Hybrid -29	Perceptible	Obtuse	OR	Green
30	Hybrid -30	Perceptible	Acute	SFE	Green
31	Hybrid -31	Perceptible	Obtuse	RF	Green
32	Hybrid -32	perceptible	Obtuse	OR	Green
33	Hybrid -33	Perceptible	Obtuse	SFE	Green
34	Hybrid -34	Perceptible	Obtuse	OR	Green
35	Hybrid -35	Pointed	Obtuse	OR	Green
36	Hybrid -36	Perceptible	Acute	OR	Green
37	Hybrid -46	Perceptible	Obtuse	OR	Green
38	Hybrid -52	Prominent	Acute	SOF	Green
39	Hybrid -55	Mammiform	Obtuse	OR	Green
40	Hybrid -56	Pointed	Obtuse	OR	Green
41	Hybrid -57	Pointed	Obtuse	OR	Green
42	Hybrid -68	Mammifom	Obtuse	OR	Green

OR=Obliquely round, SFE=Slightly flattened and extended, N=Necked, F=Flattened, OF=Obliquely flattened, SF=Slightly flattened, RF=Round flattened, SOF=Slightly obliquely flattened

Grouping of hybrid derivatives according to fruit apex

No.	Character	Number of hybrid derivatives
1	Obtuse	29
2	Acute	12
3	Roundish	01

4.1.4.12 Fruit base

The data presented in Table 16 revealed that fruit base of 29 derivatives was recorded as obliquely round, four hybrid derivatives had slightly flattened and extended fruit base, three necked, two flattened, one obliquely flattened, one slightly flattened, one round flattened and one slightly obliquely flattened.

The variation can be seen due to the varietal differences.

Grouping of hybrid derivatives according to fruit base

No.	Character	Number of hybrid derivatives
1	Obliquely round	29
2	Slightly flattened and extended	04
3	Necked	03
4	Flattened	02
5	Obliquely flattened	01
6	Slightly flattened	01
7	Round flattened	01
8	Slightly obliquely flattened	01

4.1.4.13 Colour of fruit

The data regarding colour of unripe fruits has been presented in Table 16. The colour of fruit was observed and recorded as green, dark green and light green, almost all the hybrid derivatives studied produced green coloured fruits when unripe except hybrid-18, 19 and hybrid-23 which showed dark green fruits and hybrid-4 had light green fruits.

Skin colour of mango fruit is considered as genotype dependent trait. It has been reported that fruit of Carabao, Mulgoa and Manila are greenish yellow; while, Bombay Green bears completely green coloured fruits (Lizada, 1991 and Bally, 2006).

Grouping of hybrid derivatives according to fruit colour

No.	Character	Number of hybrid derivatives
1	Green	38
2	Dark green	03
3	Light green	01

4.1.4.14 Stalk insertion

The data presented in Table 17 revealed that fruit stalk insertion was vertical in 32 hybrid derivatives and in remaining 10 derivatives it was oblique.

Vieccelli *et al.* (2016) performed a study in four-year-old mango plants from cv. Imbú, and found that the fruit stalk insertion was vertical, with minor latex release when detaching it and the bond strength between stalk and fruit was moderate.

Grouping of hybrid derivatives according to stalk insertion

No.	Character	Number of hybrid derivatives
1	Vertical	32
2	Oblique	10

4.1.4.15 Fruit shoulder (fruit ventral slope)

Among the derivatives studied and presented in Table 17, fruit shoulder of 22 derivatives appeared to be ending in long curve, 16 hybrid derivatives had rising and then rounded fruit shoulder and in remaining four derivatives it was sloping abruptly.

Vieccelli *et al.* (2016), performed a study in four-year-old mango plants from cv. Imbú, and found that the slope of the fruits ventral shoulder ended in a long curve and in the apical portion, a beak is barely noticeable, as well as a sinus.

Table 17. Morphological characterization of mango progenies for fruit characters

Sr. No.	Hybrid derivatives	Stalk insertion	Fruit shoulder	Ripe fruit skin colour
1	Hybrid -1	Vertical	SA	Green
2	Hybrid-2	Vertical	RR	Yellow
3	Hybrid -3	Vertical	RR	Yellow
4	Hybrid -4	Vertical	ELC	Yellow
5	Hybrid -5	Oblique	RR	Yellow
6	Hybrid -6	Oblique	SA	Yellow
7	Hybrid -7	Vertical	ELC	Yellow
8	Hybrid -8	Vertical	ELC	Yellow
9	Hybrid -9	Vertical	SA	Yellow
10	Hybrid -10	Oblique	RR	Yellow
11	Hybrid -11	Vertical	RR	Greenish yellow
12	Hybrid -12	Vertical	RR	Yellow
13	Hybrid -13	Vertical	RR	Yellow
14	Hybrid -14	Vertical	ELC	Yellow
15	Hybrid -15	Vertical	ELC	Green
16	Hybrid -16	Oblique	RR	Yellow
17	Hybrid -17	Vertical	ELC	Green
18	Hybrid -18	Oblique	ELC	Green
19	Hybrid -19	Vertical	RR	Yellow
20	Hybrid -20	Vertical	RR	Greenish yellow
21	Hybrid -21	Oblique	ELC	Yellow
22	Hybrid -22	Oblique	ELC	Yellow
23	Hybrid -23	Vertical	ELC	Yellow
24	Hybrid -24	Vertical	RR	Green
25	Hybrid -25	Oblique	ELC	Yellow
26	Hybrid -26	Vertical	ELC	Yellow
27	Hybrid -27	Vertical	ELC	Yellow
28	Hybrid -28	Oblique	ELC	Yellow
29	Hybrid -29	Oblique	ELC	Yellow
30	Hybrid -30	Vertical	ELC	Yellow
31	Hybrid -31	Vertical	ELC	Yellow
32	Hybrid -32	Vertical	ELC	Yellow
33	Hybrid -33	Vertical	ELC	Yellow
34	Hybrid -34	Vertical	RR	Yellow
35	Hybrid -35	Vertical	RR	Greenish yellow
36	Hybrid -36	Vertical	ELC	Yellow
37	Hybrid -46	Vertical	RR	Yellow
38	Hybrid -52	Vertical	RR	Yellow
39	Hybrid -55	Vertical	ELC	Yellow
40	Hybrid -56	Vertical	SA	Yellow
41	Hybrid -57	Vertical	RR	Yellow
42	Hybrid -68	Vertical	ELC	Yellow

ELC=Ending in a long curve, RR=Rising and then rounded, SA=Sloping abruptly

Grouping of hybrid derivatives according to fruit shoulder

No.	Character	Number of hybrid derivatives
1	Ending in long curve	22
2	Rising and then rounded	16
3	Sloping abruptly	04

4.1.4.16 Fruit skin colour

The observations with respect to fruit skin colour of ripe fruits were recorded as per Mango descriptors. The data presented in Table 17 showed that the fruits of 34 derivatives were yellow coloured after ripening, three derivatives were having greenish yellow and remaining five derivatives showed no change in colour after ripening and appeared green.

These could be the sources of fruit colour genes for using in breeding programmes, as the external appearance could get special advantage in fresh fruit market, especially in export market. Fruits generally have a dark green background that becomes light green to yellow in colour as they ripe. Red blush may develop in some fruits at fruit set which may persist until the fruit ripe as in cv. Sensation. Pulp usually has a sweet taste or may have marginal or nominal turpentine flavour in some cases and as soon as fruit ripens the colour of pulp changes from yellow to orange. On the other hand, fruits of Alphonso and Dashehri possessed yellow colour, whereas Tomy Atkins, Keitt and Haden mango fruit contain red blush on yellow background. The red blush in mango skin is also genotype dependent due to a pigment known as anthocyanin (Lizada, 1991 and Bally, 2006).

Grouping of hybrid derivatives according to fruit skin colour

No.	Character	Number of hybrid derivatives
1	Yellow	34
2	Green	05
3	Greenish yellow	03

4.1.4.17 Fruit skin thickness (mm)

The data has been presented in Table 18. The fruit skin thickness ranged from 0.6 to 1.4 mm and remained unchanged during the period of investigation i.e 2015-16 and 2016-17. Total 25 hybrid derivatives were grouped in a range of 0.5-0.9 mm, 15 hybrid derivatives in 0.91-1.20 mm, whereas two hybrid derivatives ranged above 1.20 mm. The highest skin thickness was recorded in hybrid-46 (1.4 mm) and the lowest was recorded in hybrid-18 (0.6 mm).

Similar trends of results were also obtained by Mannan *et al.* (2003), who reported the range of peel thickness varied from 1.48 mm to 2.72 mm in different mango varieties *viz.,* Amrapali, Fazli, Neelambari, Indian Tota and Madrazi Tota. Peel thickness provides a protection against fruit fly and help to reduce post harvest losses, however this fact could increase the difficulty of removing peel before processing.

Grouping of hybrid derivatives according to fruit skin thickness (mm)

No.	Range (mm)	Number of hybrid derivatives
1	0.5-0.9	25
2	0.91-1.20	15
3	Above 1.20	02

4.1.4.18 Skin percentage

It is evident from the data presented in Table 18 that the skin percentage of fruit ranged between 11.90 to 33.86 per cent. Total 20 hybrid derivatives were grouped in a range of 1.50-20.0 per cent, 19 hybrid derivatives in 20.1-27.0 per cent, whereas three hybrid derivatives ranged above 27.0 per cent. The maximum skin per cent was recorded in hybrid-46 (33.86 %) and minimum was recorded in hybrid-35 (11.90 %).

Begum *et al.* (2014) undertook eco-geographic survey covering the three regions of the state and studied 31 accessions of 'Beneshan' (BN Acc-l to BN Acc-31). They found that the peel percentage ranged from 8.80 to 25.80 per cent. The results are also in accordance with Dinesh (2004) in mango.

Grouping of hybrid derivatives according to skin percentage

No.	Range (%)	Number of hybrid derivatives
1	11.50-20.0	20
2	20.1-27.0	19
3	Above 27.0	03

Table 18. Morphological characterization of mango progenies for fruit characters

Sr. No.	Hybrid derivatives	Fruit skin thickness (mm)	Skin percentage	Fruit waxiness
1	Hybrid -1	0.8	16.80	Non-waxy
2	Hybrid-2	0.7	13.87	Non-waxy
3	Hybrid -3	0.8	18.56	Non-waxy
4	Hybrid -4	1.1	22.60	Non-waxy
5	Hybrid -5	0.9	23.85	Waxy
6	Hybrid -6	1	19.95	Non-waxy
7	Hybrid -7	1.2	20.47	Non-waxy
8	Hybrid -8	0.7	25.45	Waxy
9	Hybrid -9	0.8	27.57	Non-waxy
10	Hybrid -10	1.1	27.01	Waxy
11	Hybrid -11	0.9	31.33	Waxy
12	Hybrid -12	1.0	9.89	Waxy
13	Hybrid -13	0.9	12.12	Waxy
14	Hybrid -14	0.9	25.18	Waxy
15	Hybrid -15	0.8	23.04	Waxy
16	Hybrid -16	1.1	47.12	Waxy
17	Hybrid -17	0.9	31.88	Non-waxy
18	Hybrid -18	0.6	22.47	Waxy
19	Hybrid -19	1.01	14.82	Waxy
20	Hybrid -20	0.9	18.12	Waxy
21	Hybrid -21	0.8	17.14	Waxy
22	Hybrid -22	0.8	28.54	Waxy
23	Hybrid -23	1.12	19.96	Waxy
24	Hybrid -24	0.83	22.29	Non-waxy
25	Hybrid -25	0.92	27.16	Waxy
26	Hybrid -26	1.3	18.40	Waxy
27	Hybrid -27	0.79	28.00	Waxy
28	Hybrid -28	0.81	18.20	Non-waxy
29	Hybrid -29	0.93	17.31	Non-waxy
30	Hybrid -30	0.87	16.94	Waxy
31	Hybrid -31	0.79	16.96	Waxy
32	Hybrid -32	1.02	21.03	Non-waxy
33	Hybrid -33	0.98	18.86	Waxy
34	Hybrid -34	0.92	34.59	Non-waxy
35	Hybrid -35	0.89	12.37	Waxy
36	Hybrid -36	1.01	27.73	Waxy
37	Hybrid -46	1.4	19.97	Non-waxy
38	Hybrid -52	0.77	13.71	Waxy
39	Hybrid -55	0.9	27.37	Waxy
40	Hybrid -56	0.9	23.45	Waxy
41	Hybrid -57	0.8	25.57	Waxy
42	Hybrid -68	0.94	13.10	Waxy
	Range	0.6 - 1.4	25.57-13.10	
	Mean	0.92	22.05	
	std	0.16	7.08	
	S.E. ±	0.02	1.12	
	CV (%)	17.13	32.09	

4.1.4.19 Fruit waxiness

The data presented in Table 18 revealed that the fruits of 28 derivatives possessed waxy skin while remaining 14 derivatives had non-waxy fruits.

The skin is leathery or waxy, smooth or rough depending upon genotype (Griesbach, 2003).

Grouping of hybrid derivatives according to fruit waxiness

No.	Character	Number of hybrid derivatives
1	Waxy	28
2	Non-waxy	14

4.1.5 Pulp

4.1.5.1 Pulp colour

The data presented in Table 19 showed that the pulp colour was yellow in 22 derivatives, orange in 12 derivatives, creamish in three derivatives, yellowish orange in three derivatives and creamish yellow in two derivatives.

Degree of intensity of pulp colour could be an indicator for higher content of carotenoids (Desai and Dhandar, 2000). Kalra *et al.* (1994) suggested that total carotenoids could improve the natural appearance of fruit products, particularly in the international market where the addition of synthetic colour would be discouraged. This is specially important in view of the fact that 97.70 per cent of the processed fruit export from India is contributed by mango (Shikhamany and Murti, 2005).

Grouping of hybrid derivatives according to pulp colour

No.	Character	Number of hybrid derivatives
1	Yellow	22
2	Orange	12
3	Creamish	03
4	Yellowish orange	03
5	Creamish yellow	02

Table 19. Morphological characterization of mango progenies for fruit pulp

Sr. No.	Hybrid derivatives	Pulp colour	Pulp texture	Pulp fibrousness
1	Hybrid -1	Orange	Soft	Fibrous
2	Hybrid-2	Orange	Soft	Non-fibrous
3	Hybrid -3	Y-orange	Soft	Fibrous
4	Hybrid -4	Orange	Soft	Less fibrous
5	Hybrid -5	Yellow	Soft	intermediate
6	Hybrid -6	Yellow	Soft	intermediate
7	Hybrid -7	Yellow	Soft	intermediate
8	Hybrid -8	Yellow	Soft	Less fibrous
9	Hybrid -9	Orange	Soft	intermediate
10	Hybrid -10	Orange	Intermediate	Less fibrous
11	Hybrid -11	Orange	Soft	intermediate
12	Hybrid -12	Yellow	Intermediate	Non-fibrous
13	Hybrid -13	Yellow	Soft	intermediate
14	Hybrid -14	C- yellow	Intermediate	intermediate
15	Hybrid -15	Yellow	Soft	Less fibrous
16	Hybrid -16	Yellow	Soft	Less fibrous
17	Hybrid -17	Yellow	Soft	Non-fibrous
18	Hybrid -18	Yellow	Soft	Non-fibrous
19	Hybrid -19	Yellow	Intermediate	High fibre
20	Hybrid -20	Cream	Soft	Less fibrous
21	Hybrid -21	Cream	Soft	High fibre
22	Hybrid -22	Yellow	Soft	High fibre
23	Hybrid -23	Yellow	Soft	High fibre
24	Hybrid -24	Yellow	Soft	Less fibrous
25	Hybrid -25	Yellow	Soft	intermediate
26	Hybrid -26	O- yellow	Firm	Less fibrous
27	Hybrid -27	Y-orange	Soft	intermediate
28	Hybrid -28	Yellow	Soft	intermediate
29	Hybrid -29	Orange	Soft	intermediate
30	Hybrid -30	Orange	Soft	intermediate
31	Hybrid -31	Orange	Intermediate	intermediate
32	Hybrid -32	Yellow	Soft	intermediate
33	Hybrid -33	Cream	Intermediate	High fibre
34	Hybrid -34	Yellow	Intermediate	Less fibrous
35	Hybrid -35	Orange	Soft	Less fibrous
36	Hybrid -36	Yellow	Soft	High fibre
37	Hybrid -46	Creamish yellow	Firm	Less fibrous
38	Hybrid -52	Orange	Intermediate	intermediate
39	Hybrid -55	Yellow	Firm	intermediate
40	Hybrid -56	Yellow	Soft	intermediate
41	Hybrid -57	Yellow	Firm	High fibre
42	Hybrid -68	Orange	Soft	intermediate

4.1.5.2 Pulp texture

From the data presented in Table 19, it was revealed that the pulp texture was recorded as soft, firm and intermediate however 30 derivatives had soft textured pulp, eight derivatives had intermediate pulp texture while four derivatives had firm textured pulp.

The pulp texture seems to be a varietal character. Similar variation in pulp texture was observed by Simi (2006). He reported that twenty four varieties had firm flesh, thirteen varieties each possessed soft and juicy textured flesh.

Grouping of hybrid derivatives according to pulp texture

No.	Hybrid derivatives	Number of hybrid derivatives
1	Soft	30
2	Intermediate	08
3	Firm	04

4.1.5.3 Pulp fibrousness

The data regarding pulp fibrousness has been presented in Table 19. The pulp fibrousness was recorded as absent, low, intermediate and high, pulp of 20 hybrid derivatives had intermediate fibrousness, 11 derivatives recorded low pulp fibrousness, seven derivatives had high pulp fibrousness and pulp fibrousness was absent in four derivatives.

Presence of fine fibres are a necessity to protect the interior of a fruit from bruising and internal collapse during handling and shipping, however, abundance of fibre content is not acceptable to the consumer (Iyer, 1991). Hence, the existing mango genotypes can also be utilized in different mango breeding programme for developing superior varieties.

Grouping of hybrid derivatives according to pulp fibrousness

No.	Character	Number of hybrid derivatives
1	Intermediate	20
2	Low	11
3	High	07
4	Absent	04

4.1.5.4 Pulp percentage

It is evident from the data presented in Table 20 that the pulp percentage ranged from 36.29 to 80.72, 37.94 to 80.94 and 37.11 to 80.83 during the experimental years (2015-16 and 2016-17) and pooled data. Total three hybrid derivatives were grouped in a range of 35.0-52.0 per cent, 22 hybrid derivatives in 52.1-68.0 per cent, whereas 17 hybrid derivatives ranged above 68.0 per cent. The maximum pulp percentage was recorded in hybrid-52 (80.72, 80.94 and 80.83 %) whereas minimum was recorded in hybrid-16 (36.29, 37.94 and 37.11 %) during the year 2015-16, 2016-17 and the pooled data.

Rathor *et al.* (2009) observed maximum pulp per cent in Fazli (80.0) followed by Mallika (75.7). Pulp percentage seems to vary according to the derivatives however it may be influenced by cultural practices to some extent.

Kulkarni and Rameshwar (1981) pointed out that cultivar Vanraj had the maximum pulp (81.0%) followed by Alampur Baneshan and Banganpalli. The cultivar "Chinnarasam" had 62.5 per cent pulp at Sangareddy, Andhra Pradesh.

Sharma and Ray (1985) observed considerable variation amongst different cultivars in respect of pulp percentage in West Bengal. Surajapuri and Mallika had high pulp percentage, which is one of the most desirable characters of the fruit.

Kumar (1998) in an experiment with 101 mango varieties at Sabour in Bihar, noted a great variation in pulp content. A range of 56 per cent (Safeda Malihabadi) to 85 per cent (Puttu) pulp was recorded. Three varieties, *viz.*, Dalma, Mandhappa and Puttu contained more than 80 per cent pulp, while pulp percentage of 24 varieties ranged between 70 to 79.9 %, he therefore, found that only 27 out of 101 varieties had high pulp containing values.

Grouping of hybrid derivatives according to pulp percentage

No.	Range (%)	Number of hybrid derivatives
1.	35.0-52.0	03
2.	52.1-68.0	22
3.	Above 68.00	17

Table 20. Mean performance of mango progenies for fruit pulp percentage

Sr. No.	Hybrid derivatives	Pulp percentage		
		2015-16	2016-17	Pooled
1	Hybrid -1	66.04	67.59	66.82
2	Hybrid-2	68.66	67.31	67.99
3	Hybrid -3	60.69	63.88	62.29
4	Hybrid -4	69.84	70.52	70.18
5	Hybrid -5	66.14	65.81	65.97
6	Hybrid -6	73.55	74.07	73.81
7	Hybrid -7	70.78	69.49	70.13
8	Hybrid -8	65.08	64.04	64.56
9	Hybrid -9	62.90	62.27	62.58
10	Hybrid -10	64.42	63.55	63.98
11	Hybrid -11	57.79	53.45	55.62
12	Hybrid -12	79.75	80.57	80.16
13	Hybrid -13	79.44	79.44	79.44
14	Hybrid -14	66.73	65.41	66.07
15	Hybrid -15	65.26	66.53	65.89
16	Hybrid -16	36.29	37.94	37.11
17	Hybrid -17	50.32	51.99	51.15
18	Hybrid -18	63.78	65.75	64.76
19	Hybrid -19	78.34	76.91	77.62
20	Hybrid -20	72.52	70.28	71.40
21	Hybrid -21	71.41	73.26	72.34
22	Hybrid -22	57.50	54.90	56.20
23	Hybrid -23	69.52	68.43	68.97
24	Hybrid -24	58.31	0.00	58.31
25	Hybrid -25	67.53	64.47	66.00
26	Hybrid -26	77.59	76.97	77.28
27	Hybrid -27	66.38	62.46	64.42
28	Hybrid -28	73.41	75.83	74.62
29	Hybrid -29	64.15	67.22	65.68
30	Hybrid -30	76.38	76.34	76.36
31	Hybrid -31	71.12	69.51	70.32
32	Hybrid -32	60.22	64.19	62.20
33	Hybrid -33	67.36	70.27	68.82
34	Hybrid -34	52.39	54.32	53.36
35	Hybrid -35	75.75	74.21	74.98
36	Hybrid -36	49.33	0.00	49.33
37	Hybrid -46	64.61	66.19	65.40
38	Hybrid -52	80.72	80.94	80.83
39	Hybrid -55	47.71	71.61	59.66
40	Hybrid -56	61.89	64.21	63.05
41	Hybrid -57	61.01	62.58	61.79
42	Hybrid -68	74.75	77.65	76.20
	Range	36.29 - 80.72	37.94 - 80.94	37.11 - 80.83
	Mean	65.89	67.31	66.28
	std	9.47	8.62	8.98
	S.E. ±	1.46	1.36	1.39
	CV (%)	14.37	12.81	13.54

4.1.6 Stone

4.1.6.1 Stone shape

The stone shape was recorded as oblong, ellipsoid and reniform; 30 derivatives recorded oblong shaped stone, nine derivatives had reniform stones and three derivatives had ellipsoidal stones (Table 21).

Similar works were observed by Jilani *et al.* (2010).

Grouping of hybrid derivatives according to stone shape

No.	Character	Number of hybrid derivatives
1	Oblong	30
2	Reniform	09
3	Ellipsoid	03

4.1.6.2 Stone length and width (cm)

The data presented in Table 21 showed great variation. The stone length ranged from 4.68 to 12.77 cm, 4.56 to 12.85 cm and 4.62 to 12.81 cm during the experimental years (2015-16 and 2016-17) and pooled data. Total 36 hybrid derivatives were grouped in a range of 4.50-8.00 cm, five hybrid derivatives in 8.1-11.0 cm, whereas one hybrid derivative ranged above 11.00 cm. The maximum stone length was recorded in hybrid-46 (12.77 cm, 12.85 cm and 12.81 cm) whereas minimum was recorded in hybrid-29 (4.68, 4.56 and 4.62 cm) during the years 2015-16, 2016-17 and the pooled data.

The data regarding stone width has been presented in Table 21. The stone width varied from 2.43 to 6.23 cm, 2.58 to 6.26 cm and 2.51 to 6.25 cm in 2015-16, 2016-17 and pooled data respectively. Total 33 hybrid derivatives were grouped in a range of 2.50-4.00 cm, eight hybrid derivatives in 4.1-5.5 cm, whereas one hybrid derivative ranged above 5.5 cm. The highest breadth was recorded in hybrid-46 (6.23, 6.26 and 6.25 cm) whereas lowest was recorded in hybrid-57 (2.43, 2.58 and 2.51 cm) in the years of experimentation (2015-16, 2016-17 and pooled data).

Variation in stone length and stone width of different mango cultivars was also reported by Kundu and Ghosh (1992) and Abirami *et al.* (2004). This variation in stone characteristics might be due to environmental interaction and genetic composition. They further noted that stone size is an important character of mango varieties as it determines the edible portion in the fruit. Similar variations were also reported by Anila and Radha (2003), Pradeepkumar *et al.* (2006), Maity (2007) and Singh *et al.* (2011).

Table 21. Morphological characterization of mango progenies for stone characters

Sr. No	Hybrid derivatives	Stone shape	Stone length (cm)			Stone width (cm)		
			2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
1	Hybrid -1	Ellipsoid	6.6	6.5	6.55	3.45	3.36	3.41
2	Hybrid-2	Oblong	6.12	5.99	6.06	3.37	3.29	3.33
3	Hybrid -3	Oblong	5.82	5.73	5.78	3.18	3.15	3.17
4	Hybrid -4	Oblong	5.97	5.96	5.97	3.34	3.21	3.28
5	Hybrid -5	Oblong	7.24	7.21	7.23	3.65	3.56	3.61
6	Hybrid -6	Oblong	9.29	9.23	9.26	3.72	3.89	3.81
7	Hybrid -7	Reniform	7.64	7.86	7.75	3.33	3.26	3.30
8	Hybrid -8	Reniform	6.21	6.26	6.24	3.5	3.58	3.54
9	Hybrid -9	Reniform	6.64	6.61	6.63	3.36	3.32	3.34
10	Hybrid -10	Oblong	7.09	7.13	7.11	4.94	4.65	4.80
11	Hybrid -11	Oblong	5.99	6.1	6.05	3.96	3.76	3.86
12	Hybrid -12	Oblong	6.42	6.51	6.47	3.48	3.32	3.40
13	Hybrid -13	Oblong	6.43	6.35	6.39	4.28	4.42	4.35
14	Hybrid -14	Oblong	6.16	6.26	6.21	3.47	3.36	3.42
15	Hybrid -15	Oblong	7.5	7.54	7.52	3.94	3.86	3.90
16	Hybrid -16	Reniform	5.58	5.63	5.61	3.6	3.57	3.59
17	Hybrid -17	Oblong	4.96	5.02	4.99	3.34	3.32	3.33
18	Hybrid -18	Oblong	6.28	6.25	6.27	3.59	3.46	3.53
19	Hybrid -19	Oblong	6.62	6.85	6.74	5.25	4.98	5.12
20	Hybrid -20	Oblong	7.15	7.22	7.19	4.93	4.86	4.90
21	Hybrid -21	Oblong	6.49	6.46	6.48	3.48	3.35	3.42
22	Hybrid -22	Oblong	6.43	6.33	6.38	3.59	3.57	3.58
23	Hybrid -23	Oblong	6.42	6.55	6.49	3.58	3.65	3.62
24	Hybrid -24	Oblong	6.68	0.00	6.68	3.28	0.00	3.28
25	Hybrid -25	Oblong	7.85	7.98	7.92	3.98	3.88	3.93
26	Hybrid -26	Ellipsoid	10.65	10.52	10.59	4.12	3.96	4.04
27	Hybrid -27	Oblong	5.72	5.56	5.64	3.36	3.22	3.29
28	Hybrid -28	Reniform	6.2	6.25	6.23	3.27	3.15	3.21
29	Hybrid -29	Oblong	4.68	4.56	4.62	3.22	3.26	3.24
30	Hybrid -30	Reniform	8.57	8.46	8.52	4.24	4.33	4.29
31	Hybrid -31	Oblong	6.79	6.75	6.77	3.51	3.49	3.50
32	Hybrid -32	oblong	6.62	6.75	6.69	3.41	3.38	3.40
33	Hybrid -33	Oblong	5.16	4.98	5.07	3.58	3.65	3.62
34	Hybrid -34	Oblong	8.46	8.3	8.38	4.39	4.39	4.39
35	Hybrid -35	Oblong	5.98	6.12	6.05	3.29	3.27	3.28
36	Hybrid -36	Reniform	7.57	0.00	7.57	3.45	0.00	3.45
37	Hybrid -46	Oblong	12.77	12.85	12.81	6.23	6.26	6.25
38	Hybrid -52	Reniform	8.75	9.04	8.90	4.21	4.25	4.23
39	Hybrid -55	Oblong	6.32	6.46	6.39	3.38	3.48	3.43
40	Hybrid -56	Oblong	5.34	5.24	5.29	3.28	3.16	3.22
41	Hybrid -57	Ellipsoid	6.13	5.59	5.86	2.43	2.58	2.51
42	Hybrid -68	Reniform	5.83	6.01	5.92	3.54	3.44	3.49
		Range	4.68-12.77	4.56-12.85	4.62-12.81	2.43-6.23	2.58-6.26	2.51-6.25
		Mean	6.84	6.82	6.84	3.73	3.70	3.70
		std	1.50	1.56	1.51	0.66	0.66	0.65
		S.E. ±	0.23	0.25	0.23	0.10	0.10	0.10
		CV (%)	21.94	22.79	22.07	17.66	17.77	17.54

Grouping of hybrid derivatives according to stone length and width (cm)

No.	Range (cm)	Number of hybrid derivatives
	Stone length	
1.	4.50-8.00	36
2.	8.10-11.00	05
3.	Above 11.00	01
	Stone width	
1.	2.50-4.00	33
2.	4.1-5.5	08
3.	Above 5.5	01

4.1.6.3 Stone weight (g)

It is evident from the data presented in Table 22. that the stone weight ranged from 9.37 to 86.12 g, 9.27 to 84.39 g and 9.32 to 85.26 g during the investigation (2015-16, 2016-17 and pooled data). Total 40 hybrid derivatives were grouped in a range of 9.00-35.00 g, one hybrid derivative in 35.1-60.00 g, whereas remaining one hybrid derivative ranged above 60.00 g. The maximum stone weight was recorded in hybrid-46 (86.12 g, 84.39 g and 85.26 g) and minimum weight was recorded in hybrid-25 (9.37 g, 9.27 g and 9.32 g) in both the years of experimentation (2015-16, 2016-17) and pooled data.

The present findings related to stone weight are also in accordance with the results of Jilani *et al.* (2010) and Anila and Radha (2003), who observed that stone weight ranged from 22.99 g to 47.07 g in four varieties and two hybrids *viz.* Alphonso, Prior, Muvandan, Neelum and hybrids Ratna (Neelum x Alphonso) and H-151 (Kalapady x Neelum).

Grouping of hybrid derivatives according to stone weight (g)

No.	Range (g)	Number of hybrid derivatives
1.	9.00-35.00	40
2.	35.1-60.0	01
3.	Above 60.0	01

4.1.6.5 Stone volume (cm^3)

From the data presented in Table 22 large variation was observed in stone volume and the stone volume ranged from 9.20 to 83.60 cm^3, 9.10 to 81.39 cm^3 and 9.15 to 82.50 cm^3 in 2015-16, 2016-17 and pooled data. Total 40 hybrid derivatives were grouped in a range of 9.00-33.00 cm^3, one hybrid derivative in 33.1-60.00 cm^3, whereas

one hybrid derivative ranged above 60.00 cm^3. The maximum stone volume was exhibited in hybrid-46 (83.60 cm^3, 81.39 cm^3 and 82.50 cm^3) and the minimum stone volume was recorded in hybrid-25 (9.20 cm^3, 9.10 cm^3 and 9.15 cm^3) during the investigation period (2015-16, 2016-17) and pooled data.

The maximum volume (41.69 ml) was recorded in stones of rootstock Vellaikolumban. There was a wide variation for stone characters in polyembryonic genotypes than the monoembryonic genotypes (Abirami *et al.* 2011). These results are in accordance with Divekar and Bisen (2016).

Grouping of hybrid derivatives according to stone volume (cm^3)

No.	Range (cm^3)	Number of hybrid derivatives
1.	9.00-33.00	40
2.	33.1-60.0	01
3.	Above 60.0	01

4.2 Biochemical characters

4.2.1 Total soluble solids (°Brix)

The data presented in Table 23 revealed that among different derivatives TSS ranged from 11.9 to 20.70 °B, 12.0 to 21.0 °B and 11.95 to 20.85 °B in the experimental years (2015-16 and 2016-17) and pooled data. Total 18 hybrid derivatives were grouped in a range of 11.5-15.00 ^{0}Brix, 15 hybrid derivatives in 15.1-18.00 ^{0}Brix, whereas nine hybrid derivatives ranged above 18.00 ^{0}Brix. Hybrid-6 had the highest total soluble solids (20.70, 21.0 and 20.85 °B) whereas hybrid-13 recorded minimum TSS (11.90, 12.0 and 11.95 °B) in the experimental years 2015-16, 2016-17 and pooled data.

Grouping of hybrid derivatives according to TSS (^{0}Brix)

No.	Range (^{0}Brix)	Number of hybrid derivatives
1.	11.5-15.00	18
2.	15.1-18.00	15
3.	Above 18.00	09

Table 22. Mean performance of mango progenies for stone weight and stone volume

Sr. No.	Hybrid derivatives	Stone weight (g)			Stone volume (cm^3)		
		2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
1	Hybrid -1	25.89	26.3	26.10	22.3	24.29	23.30
2	Hybrid-2	29.98	31.26	30.62	25.97	29.31	27.64
3	Hybrid -3	19.61	19.32	19.47	17.99	18.28	18.14
4	Hybrid -4	17.48	19.15	18.32	16.66	18.27	17.47
5	Hybrid -5	17.7	16.95	17.33	16.86	15.26	16.06
6	Hybrid -6	16.58	17.26	16.92	15.86	16.28	16.07
7	Hybrid -7	25.1	27.3	26.20	22.22	25.96	24.09
8	Hybrid -8	19.29	21.2	20.25	18.32	19.62	18.97
9	Hybrid -9	17.24	18.25	17.75	16.19	17.91	17.05
10	Hybrid -10	17.31	18.36	17.84	16.29	17.26	16.78
11	Hybrid -11	13.61	14.2	13.91	14.31	13.36	13.84
12	Hybrid -12	58.64	56.63	57.64	54.49	54.23	54.36
13	Hybrid -13	16.82	15.43	16.13	15.21	14.27	14.74
14	Hybrid -14	13.81	12.96	13.39	12.69	12.33	12.51
15	Hybrid -15	18.94	20.29	19.62	17.29	19.27	18.28
16	Hybrid -16	18.09	20.26	19.18	17.26	18.87	18.07
17	Hybrid -17	16.92	15.96	16.44	15.36	14.22	14.79
18	Hybrid -18	18.87	20.37	19.62	17.92	18.43	18.18
19	Hybrid -19	15.36	15.12	15.24	12.18	14.29	13.24
20	Hybrid -20	19.21	18.64	18.93	17.97	17.56	17.77
21	Hybrid -21	14.74	15.29	15.02	14.39	14.31	14.35
22	Hybrid -22	24.29	23.62	23.96	22.26	21.67	21.97
23	Hybrid -23	15.23	15.19	15.21	14.51	14.36	14.44
24	Hybrid -24	18.41	0.00	18.41	15.4	0.00	15.40
25	Hybrid -25	9.37	9.27	9.32	9.2	9.10	9.15
26	Hybrid -26	22.37	23.62	23.00	19.43	22.46	20.95
27	Hybrid -27	12.67	13.29	12.98	12.53	12.49	12.51
28	Hybrid -28	10.43	10.23	10.33	9.89	9.75	9.82
29	Hybrid -29	17.97	17.5	17.74	15.46	15.26	15.36
30	Hybrid -30	14.24	13.28	13.76	13.17	13.39	13.28
31	Hybrid -31	15.23	16.29	15.76	14.41	16.17	15.29
32	Hybrid -32	19.26	20.16	19.71	18.34	19.22	18.78
33	Hybrid -33	15.8	15.92	15.86	14.91	14.96	14.94
34	Hybrid -34	26.13	29.33	27.73	23.26	25.38	24.32
35	Hybrid -35	15.08	16.21	15.65	14.26	15.26	14.76
36	Hybrid -36	29.09	0.00	29.09	24.15	0.00	24.15
37	Hybrid -46	86.12	84.39	85.26	83.6	81.39	82.50
38	Hybrid -52	19.8	20.29	20.05	18.56	19.46	19.01
39	Hybrid -55	18.05	17.26	17.66	17.82	16.29	17.06
40	Hybrid -56	19.37	18.22	18.80	18.39	17.26	17.83
41	Hybrid -57	18.37	19.38	18.88	17.6	18.49	18.05
42	Hybrid -68	18.52	17.29	17.91	17.98	16.36	17.17
	Range	9.37-86.12	9.27-84.39	9.32-85.26	9.2 - 83.6	9.1 - 81.39	9.15 - 82.5
	Mean	20.88	21.03	21.02	19.35	19.81	19.58
	std	12.81	12.78	12.66	12.22	12.29	12.10
	S.E. ±	1.98	2.02	1.95	1.89	1.94	1.87
	CV (%)	61.34	60.75	60.21	63.13	62.07	61.82

These findings partially agreed with the results of Bhuyan and Guha (1995), who also reported TSS from 16.22 to 24.14 °B in 14 mango germplasm under the climatic conditions of Rajshahi. Similar variation was also reported by Teaotia *et al*. (1972) and Samad *et al.* (1975) in mango fruits. Variation in TSS (16.11 °B to 23.00 °B) is also reported by Singh (2002). The variation in TSS may be due to their varietal character.

4.2.2 Total sugars (%)

The data presented in Table 23 showed great variation in total sugars. The total sugar content varied from 8.39 to 17.58 per cent, 8.62 to 17.34 per cent and 8.51 to 17.46 per cent in 2015-16, 2016-17 and pooled data respectively. Total 21 hybrid derivatives were grouped in a range of 8.00-12.00 per cent, 13 hybrid derivatives in 12.1-15.0 per cent, whereas eight hybrid derivatives ranged above 15.00 per cent. The highest total sugar content was recorded in hybrid-26 (17.58, 17.34 and 17.46 %) in 2015-16, and 2016-17 and pooled data, the lowest was recorded in hybrid-2 (8.39, 8.62 and 8.51 %) during the investigation years 2015-16 and 2016-17 and pooled data.

Total sugars have been found variable within the cultivars. Lodh *et al.* (1974) observed 7.35 to 13.20 per cent total sugars in eight varieties of mango. Similarly, Singh (1968) and Uddin *et al.* (2007) recorded the variability for total sugars to the tune of 11.5 to 25 per cent and 12.71 to 20.34 per cent which might be due to genetic differences as well as agro-climatic conditions.

Grouping of hybrid derivatives according to Total sugars (%)

No.	Range (%)	Number of hybrid derivatives
1.	8.00-12.00	21
2.	12.1-15.0	13
3.	Above 15.00	08

4.2.3 Reducing sugars (%)

From the data presented in Table 24 showed notable difference in reducing sugar content of mango derivatives. Total 12 hybrid derivatives were grouped in a range of 1.0-2.50 per cent, 24 hybrid derivatives in 2.51-4.00 per cent, whereas six hybrid derivatives ranged above 4.00 per cent. The 2015-16, 2016-17 and pooled data revealed highest reducing sugar in hybrid-8 (4.71, 4.82 and 4.77 %) and lowest was recorded in hybrid-46 (1.02, 1.03 and 1.03 %).

Table 23. Mean performance of mango progenies for total soluble solids and total sugars

Sr. No.	Hybrid derivatives	Total soluble solids (°B)			Total sugars (%)		
		2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
1	Hybrid -1	18.1	17.0	17.55	13.5	12.60	13.05
2	Hybrid-2	12.1	12.0	12.05	8.39	8.62	8.51
3	Hybrid -3	12.1	12.3	12.20	9.74	9.82	9.78
4	Hybrid -4	18.2	18.1	18.15	14.01	14.62	14.32
5	Hybrid -5	12.3	13.1	12.70	9.81	9.92	9.87
6	Hybrid -6	20.7	21.0	20.85	16.86	16.50	16.68
7	Hybrid -7	19.3	20.9	20.10	16.43	16.28	16.36
8	Hybrid -8	17.6	18.5	18.05	13.15	12.25	12.70
9	Hybrid -9	19.8	19.8	19.80	13.11	13.86	13.49
10	Hybrid -10	18.9	19.6	19.25	17.3	17.10	17.20
11	Hybrid -11	16.7	15.5	16.10	11.61	11.41	11.51
12	Hybrid -12	18.1	18.9	18.50	15.42	15.90	15.66
13	Hybrid -13	11.9	12.0	11.95	9.36	9.41	9.39
14	Hybrid -14	15.6	14.0	14.80	8.89	9.00	8.95
15	Hybrid -15	14.4	13.5	13.95	9.25	9.86	9.56
16	Hybrid -16	16.7	16.5	16.60	12.4	12.34	12.37
17	Hybrid -17	13.9	13.5	13.70	11.81	11.35	11.58
18	Hybrid -18	16.1	17.5	16.80	12.14	12.57	12.36
19	Hybrid -19	12	13.0	12.50	9.94	9.81	9.88
20	Hybrid -20	11.9	12.5	12.20	9.14	9.32	9.23
21	Hybrid -21	17.5	16.5	17.00	14.94	15.11	15.03
22	Hybrid -22	16.5	15.0	15.75	13.58	13.14	13.36
23	Hybrid -23	15.6	14.0	14.80	11.95	11.44	11.70
24	Hybrid -24	16.2	0.0	16.20	12.68	0.00	12.68
25	Hybrid -25	14.8	13.0	13.90	11.43	11.49	11.46
26	Hybrid -26	19.5	18.0	18.75	17.58	17.34	17.46
27	Hybrid -27	12.8	13.5	13.15	10.37	10.57	10.47
28	Hybrid -28	13.2	12.8	13.00	11.87	11.95	11.91
29	Hybrid -29	16.2	15.6	15.90	13.33	13.81	13.57
30	Hybrid -30	15.5	14.2	14.85	13.58	12.14	12.86
31	Hybrid -31	14.9	14.8	14.85	11.63	11.81	11.72
32	Hybrid -32	15.9	14.5	15.20	12.26	11.41	11.84
33	Hybrid -33	14	15.2	14.60	11.23	11.39	11.31
34	Hybrid -34	15.5	15.5	15.50	13.16	13.81	13.49
35	Hybrid -35	15.9	15.5	15.70	12.51	11.44	11.98
36	Hybrid -36	16.6	0.0	16.60	13.26	0.00	13.26
37	Hybrid -46	11.9	12.0	11.95	9.1	9.00	9.05
38	Hybrid -52	18.2	19.2	18.70	17.51	17.29	17.40
39	Hybrid -55	16.5	15.5	16.00	11.77	11.16	11.47
40	Hybrid -56	15.6	15.0	15.30	12.93	12.62	12.78
41	Hybrid -57	14.5	14.0	14.25	12.62	12.34	12.48
42	Hybrid -68	15.2	15.2	15.20	13.36	12.89	13.13
	Range	11.9-20.7	12 - 21	11.95 - 20.85	8.39 - 17.58	8.62 - 17.34	8.51 - 17.46
	Mean	15.69	15.46	15.59	12.50	12.37	12.45
	std	2.40	2.55	2.41	2.41	2.42	2.37
	S.E. ±	0.37	0.40	0.37	0.37	0.38	0.37
	CV (%)	15.27	16.52	15.43	19.25	19.54	19.05

Rathor *et al.* (2009) recorded 3.8 per cent reducing sugar in Dashehri. Uddin *et al.* (2007) also reported lowest results regarding reducing sugars content ranged from 2.82 to 7.35 per cent. Chaudhary *et al.* (1997) reported 2.6 to 7.1 per cent reducing sugar in 19 south Indian mango derivatives. Yadav *et al. (*1982) reported maximum reducing sugars to the tune of 6.86 per cent in Dashehri. The varieties having reducing sugars > 5.0 per cent will be considered suitable for table purposes.

Grouping of hybrid derivatives according to reducing sugars (%)

No.	Range (%)	Number of hybrid derivatives
1.	1.0-2.50	12
2.	2.51-4.00	24
3.	Above 4.00	06

4.2.4 Non-reducing sugars (%)

It is evident from the data presented in Table 24 that the non reducing sugars ranged from 5.45 to 14.49 per cent, 5.87 to 14.15 per cent and 5.66 to 14.32 per cent in the experimental years 2015-16, 2016-17 and pooled data respectively. Total 15 hybrid derivatives were grouped in a range of 5.50-9.00 per cent, 21 hybrid derivatives in 9.1-12.0 per cent, whereas six hybrid derivatives ranged above 12.00 per cent. The highest non reducing sugar content was recorded in hybrid-26 (14.49, 14.15 and 14.32 %) in 2015-16, 2016-17 and pooled data and lowest was recorded in hybrid-2 (5.45, 5.87 and 5.66 %), respectively.

The highest value for non- reducing sugars was reported (Syamal and Mishra, 1989) as 11.5 per cent in Langra. Radha *et al.* (1996) reported that the non-reducing sugar content of Alphonso was 14.2 per cent.

Grouping of hybrid derivatives according to non-reducing sugars (%)

No.	Range (%)	Number of hybrid derivatives
1.	5.50-9.00	15
2.	9.1-12.0	21
3.	Above 12.00	06

Table 24. Mean performance of mango progenies for reducing and non-reducing sugars

Sr. No.	Hybrid derivatives	Reducing sugars (%)			Non-reducing sugars (%)		
		2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
1	Hybrid -1	4.56	4.32	4.44	9.17	8.50	8.83
2	Hybrid-2	3.09	2.90	3.00	5.45	5.87	5.66
3	Hybrid -3	4.13	4.02	4.08	5.82	6.00	5.91
4	Hybrid -4	4.11	4.35	4.23	10.11	10.49	10.30
5	Hybrid -5	4.2	3.70	3.95	5.82	6.41	6.11
6	Hybrid -6	4.57	4.46	4.52	12.52	12.26	12.39
7	Hybrid -7	4.71	4.82	4.77	11.96	11.70	11.83
8	Hybrid -8	3.67	3.76	3.72	9.66	8.68	9.17
9	Hybrid -9	3.98	4.00	3.99	9.33	10.06	9.69
10	Hybrid -10	3.95	3.82	3.89	13.55	13.47	13.51
11	Hybrid -11	3.55	3.38	3.47	8.24	8.20	8.22
12	Hybrid -12	3.38	3.20	3.29	12.21	12.86	12.53
13	Hybrid -13	3.16	3.28	3.22	6.36	6.29	6.33
14	Hybrid -14	3.32	2.92	3.12	5.74	6.23	5.98
15	Hybrid -15	2.43	2.78	2.61	6.94	7.22	7.08
16	Hybrid -16	2.19	2.38	2.29	10.32	10.08	10.20
17	Hybrid -17	2.88	3.02	2.95	9.07	8.48	8.78
18	Hybrid -18	1.98	2.01	2.00	10.26	10.66	10.46
19	Hybrid -19	3.33	2.70	3.02	6.78	7.25	7.01
20	Hybrid -20	1.25	1.28	1.27	7.95	8.10	8.03
21	Hybrid -21	2.38	2.21	2.30	12.68	13.01	12.84
22	Hybrid -22	1.43	1.68	1.56	12.22	11.54	11.88
23	Hybrid -23	1.61	1.53	1.57	10.42	9.99	10.20
24	Hybrid -24	1.43	0.00	1.43	11.32	0.00	11.32
25	Hybrid -25	1.76	1.86	1.81	9.76	9.72	9.74
26	Hybrid -26	3.25	3.36	3.31	14.49	14.15	14.32
27	Hybrid -27	2.94	3.22	3.08	7.58	7.51	7.54
28	Hybrid -28	2.42	3.46	2.94	9.57	8.66	9.12
29	Hybrid -29	2.72	3.01	2.87	10.75	10.95	10.85
30	Hybrid -30	3.14	3.00	3.07	10.60	9.29	9.94
31	Hybrid -31	1.96	2.04	2.00	9.77	9.87	9.82
32	Hybrid -32	2.05	2.23	2.14	10.31	9.29	9.80
33	Hybrid -33	3.56	2.89	3.23	7.85	8.64	8.25
34	Hybrid -34	2.56	2.47	2.52	10.73	11.46	11.10
35	Hybrid -35	2.15	1.69	1.92	10.47	9.83	10.15
36	Hybrid -36	2.66	0.00	2.66	10.73	0.00	10.73
37	Hybrid -46	1.02	1.03	1.03	8.13	8.02	8.08
38	Hybrid -52	3.95	4.03	3.99	13.76	13.46	13.61
39	Hybrid -55	4.13	4.20	4.17	7.85	7.17	7.51
40	Hybrid -56	3.29	3.30	3.30	9.80	9.49	9.64
41	Hybrid -57	2.42	2.97	2.70	10.32	9.52	9.92
42	Hybrid -68	2.86	3.00	2.93	10.64	10.04	10.34
	Range	1.02 - 4.71	1.03 - 4.82	1.03 - 4.77	5.45-14.49	5.87-14.15	5.66-14.32
	Mean	2.96	3.01	2.96	9.69	9.51	9.64
	std	0.97	0.93	0.95	2.26	2.20	2.20
	S.E. ±	0.15	0.15	0.15	0.35	0.35	0.34
	CV (%)	32.98	30.93	31.97	23.36	23.14	22.85

4.2.5 Titratable acidity (%)

From the data presented in Table 25, the acidity of pulp ranged between 0.16 to 0.48 per cent, 0.15 to 0.42 per cent and 0.16 to 0.45 per cent in both the years of investigation (2015-16, 2016-17) and pooled data. Total 33 hybrid derivatives were grouped in a range of 0.15-0.26 per cent, seven hybrid derivatives in 0.27-0.40 per cent, whereas two hybrid derivatives ranged above 0.40 per cent. The maximum acidity of pulp was recorded in hybrid-46 (0.48, 0.42 and 0.45 %) in 2015-16, 2016-17 and pooled data and lowest was recorded in hybrid-35 (0.16, 0.15 and 0.16 %) in 2015-16, 2016-17 and pooled data.

The values of titrable acidity are in accordance with the results of Kumar (1998), who reported the range of 0.17 to 0.33 per cent in different mango cultivars. Its wide range of values from 0.11 to 0.43 per cent was also supported by Bakshi and Bajwa (1959). The variation in the acidity in the different varieties of mango could be due to their varietal characters.

Grouping of hybrid derivatives according to titratable acidity (%)

No.	Range (%)	Number of hybrid derivatives
1.	0.15-0.26	33
2.	0.27-0.40	07
3.	Above 0.40	02

4.2.6 pH of pulp

The data regarding pH presented in Table 25 showed that the pH varied from 2.22 to 4.95, 2.36 to 4.85 and 2.29 to 4.90 in 2015-16, 2016-17 and pooled data respectively. Total 13 hybrid derivatives were grouped in a range of 2.03.50, 23 hybrid derivatives in 3.51-4.50, whereas six hybrid derivatives ranged above 4.50. The pH of pulp was recorded highest in hybrid-68 (4.95, 4.85 and 4.90) and lowest in hybrid-46 (2.22, 2.36 and 2.29) in 2015-16, 2016-17 pooled data.

In mango, generally pH increased and acidity decreased from immature to mature and mature to ripened stages of fruit development. This statement can be better justified with the results of Pleguezuelo *et al*. (2012). They observed higher pH from 4.2 to 5.7 and lower titratable acidity from 0.05 to 0.22 per cent from fruits of different cultivars harvested at maturity stage. Akhtar *et al*. (2010) observed minimum pH lower than 4 and more acidity more than 0.60 in all four varieties including Dusheri, Chaunsa, Ratol and Langra fruits harvested even at maturity stage.

Table 25. Mean performance of mango progenies for titratable acidity and pH of pulp

Sr. No.	Hybrid derivatives	Titratable acidity (%)			pH of pulp		
		2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
1	Hybrid -1	0.35	0.39	0.37	4.58	4.55	4.57
2	Hybrid-2	0.27	0.28	0.28	3.2	3.39	3.30
3	Hybrid -3	0.17	0.18	0.18	4.41	4.15	4.28
4	Hybrid -4	0.24	0.25	0.25	3.48	3.58	3.53
5	Hybrid -5	0.18	0.19	0.19	4.63	4.5	4.57
6	Hybrid -6	0.21	0.22	0.22	3.1	3.79	3.45
7	Hybrid -7	0.23	0.23	0.23	3.86	3.42	3.64
8	Hybrid -8	0.27	0.29	0.28	3.88	3.49	3.69
9	Hybrid -9	0.24	0.26	0.25	3.62	3.21	3.42
10	Hybrid -10	0.27	0.28	0.28	3.4	3.55	3.48
11	Hybrid -11	0.26	0.29	0.28	3.56	3.68	3.62
12	Hybrid -12	0.27	0.29	0.28	3.86	4.1	3.98
13	Hybrid -13	0.26	0.18	0.22	3.68	3.35	3.52
14	Hybrid -14	0.24	0.25	0.25	3.9	3.58	3.74
15	Hybrid -15	0.25	0.26	0.26	3.61	3.32	3.47
16	Hybrid -16	0.22	0.24	0.23	3.32	3.89	3.61
17	Hybrid -17	0.36	0.35	0.36	2.6	2.78	2.69
18	Hybrid -18	0.19	0.18	0.19	4.33	4.45	4.39
19	Hybrid -19	0.17	0.19	0.18	4.93	4.38	4.66
20	Hybrid -20	0.24	0.25	0.25	3.1	3.46	3.28
21	Hybrid -21	0.18	0.18	0.18	4.38	4.33	4.36
22	Hybrid -22	0.18	0.19	0.19	4.22	4.58	4.40
23	Hybrid -23	0.21	0.22	0.22	3.45	3.32	3.39
24	Hybrid -24	0.18	0.00	0.18	3.66	0.00	3.66
25	Hybrid -25	0.23	0.24	0.24	3.38	3.36	3.37
26	Hybrid -26	0.24	0.26	0.25	3.62	3.41	3.52
27	Hybrid -27	0.24	0.26	0.25	3.12	3.24	3.18
28	Hybrid -28	0.23	0.24	0.24	3.34	3.1	3.22
29	Hybrid -29	0.22	0.21	0.22	3.47	3.86	3.67
30	Hybrid -30	0.23	0.21	0.22	3.67	3.69	3.68
31	Hybrid -31	0.22	0.23	0.23	4.5	4.22	4.36
32	Hybrid -32	0.24	0.24	0.24	3.78	3.89	3.84
33	Hybrid -33	0.23	0.24	0.24	3.8	3.5	3.65
34	Hybrid -34	0.18	0.2	0.19	4.15	4.38	4.27
35	Hybrid -35	0.16	0.15	0.16	4.75	4.32	4.54
36	Hybrid -36	0.21	0.00	0.21	4.8	0.00	4.80
37	Hybrid -46	0.48	0.42	0.45	2.22	2.36	2.29
38	Hybrid -52	0.26	0.24	0.25	3.68	3.67	3.68
39	Hybrid -55	0.18	0.18	0.18	4.1	4.09	4.10
40	Hybrid -56	0.21	0.22	0.22	3.9	3.52	3.71
41	Hybrid -57	0.18	0.19	0.19	4.23	4.34	4.29
42	Hybrid -68	0.17	0.16	0.17	4.95	4.85	4.90
	Range	0.16 - 0.48	0.15 - 0.42	0.16 -0.45	2.22 - 4.95	2.36 -4.85	2.29 - 4.9
	Mean	0.23	0.24	0.23	3.81	3.77	3.80
	std	0.06	0.06	0.06	0.60	0.54	0.56
	S.E. ±	0.01	0.01	0.01	0.09	0.09	0.09
	CV (%)	25.22	23.93	24.15	15.83	14.30	14.72

Grouping of hybrid derivatives according to pH of pulp

No.	Range	Number of hybrid derivatives
1.	2.0-3.50	13
2.	3.51-4.50	23
3.	Above 4.50	06

4.2.7 β – carotene (µg/100g)

The data presented in Table 26 showed that the β- carotene content in mango derivatives ranged from 1004 to 2461 µg/100g, 1013 to 2456 µg/100g and 1008.5 to 2458.5 µg/100g in 2015-16, 2016-17 and pooled data. Total 32 hybrid derivatives were grouped in a range of 1000-1500 µg/100g, seven hybrid derivatives in 1500.1 – 2000.0 µg/100g, whereas three hybrid derivatives ranged above 2000 µg/100g. Of all the derivatives in 2015-16, 2016-17 and pooled data hybrid-1 revealed highest β- carotene content (2461 µg/100g, 2456 µg/100g and 2458.5 µg/100g) and lowest was recorded in hybrid-46 (1004 µg/100g, 1013 µg/100g, 1008.5 µg/100g) during the years 2015-16, 2016-17 and pooled data respectively.

These findings are in agreement with observations made by Singh (2002). Variation in total carotenoids contents in the range of 2.33 mg/100 g - 44.95 mg/100 g was also recorded by Hoda *et al.* (2003). Total carotenoids provide an expression of natural appearance to the fruit product and their higher content in fruits offer distinct advantages, particularly in international trade where addition of artificial color is discouraged.

Grouping of hybrid derivatives according to β – carotene (µg/100g)

No.	Range (µg/100g)	Number of hybrid derivatives
1.	1000-1500	32
2.	1500.1-2000	07
3.	Above 2000	03

4.2.8 Ascorbic acid content (mg/100 g)

It has been noticed from the Table 26 that the ascorbic acid content varied among different mango derivatives. The ascorbic acid content in mango fruits during investigation period ranged from 14 to 38 mg/100g, 12 to 36 mg/100g and 13 to 37

Table 26. Mean performance of mango progenies for β-carotene and Ascorbic acid content

Sr. No.	Hybrid derivatives	ß-carotene (µg/100ml pulp)			Ascorbic acid content (mg/100g)		
		2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
1	Hybrid -1	2461	2456	2458.5	34	32	33.0
2	Hybrid-2	1155	1098	1126.5	26	26	26.0
3	Hybrid -3	1867	1926	1896.5	22	23	22.5
4	Hybrid -4	2424	2354	2389.0	24	23	23.5
5	Hybrid -5	1682	1523	1602.5	32	30	31.0
6	Hybrid -6	1873	1825	1849.0	28	26	27.0
7	Hybrid -7	1898	1773	1835.5	36	35	35.5
8	Hybrid -8	1269	1128	1198.5	24	24	24.0
9	Hybrid -9	1065	1058	1061.5	28	26	27.0
10	Hybrid -10	2108	2150	2129.0	20	18	19.0
11	Hybrid -11	1080	1180	1130.0	28	32	30.0
12	Hybrid -12	1765	1768	1766.5	28	28	28.0
13	Hybrid -13	1124	1079	1101.5	26	23	24.5
14	Hybrid -14	1356	1276	1316.0	23	21	22.0
15	Hybrid -15	1278	1255	1266.5	22	19	20.5
16	Hybrid -16	1168	1156	1162.0	20	22	21.0
17	Hybrid -17	1226	1265	1245.5	18	16	17.0
18	Hybrid -18	1396	1288	1342.0	17	18	17.5
19	Hybrid -19	1371	1296	1333.5	14	16	15.0
20	Hybrid -20	1244	1180	1212.0	18	16	17.0
21	Hybrid -21	1194	1179	1186.5	16	14	15.0
22	Hybrid -22	1012	1022	1017.0	26	24	25.0
23	Hybrid -23	1014	1037	1025.5	30	28	29.0
24	Hybrid -24	1255	0	1255.0	25	0	25.0
25	Hybrid -25	1411	1369	1390.0	22	24	23.0
26	Hybrid -26	1396	1694	1545.0	24	23	23.5
27	Hybrid -27	1125	1024	1074.5	15	16	15.5
28	Hybrid -28	1174	1169	1171.5	17	19	18.0
29	Hybrid -29	1377	1262	1319.5	14	12	13.0
30	Hybrid -30	1283	1256	1269.5	15	16	15.5
31	Hybrid -31	1153	1139	1146.0	20	19	19.5
32	Hybrid -32	1402	1388	1395.0	23	20	21.5
33	Hybrid -33	1021	1033	1027.0	19	21	20.0
34	Hybrid -34	1299	1342	1320.5	21	22	21.5
35	Hybrid -35	1305	1278	1291.5	14	15	14.5
36	Hybrid -36	1341	0	1341.0	16	0	16.0
37	Hybrid -46	1004	1013	1008.5	38	36	37.0
38	Hybrid -52	1657	1696	1676.5	15	19	17.0
39	Hybrid -55	1301	1266	1283.5	14	12	13.0
40	Hybrid -56	1134	1145	1139.5	14	15	14.5
41	Hybrid -57	1098	1103	1100.5	22	19	20.5
42	Hybrid -68	1258	1266	1262.0	24	26	25.0
	Range	1004-2461	1013-2456	1008.5-2458.5	14 - 38	12 - 36	13 - 37
	Mean	1381.52	1363.45	1372.49	22.19	21.93	22.06
	std	356.27	356.92	354.63	6.29	5.99	6.05
	S.E. ±	54.97	55.07	54.72	0.97	0.92	0.93
	CV (%)	25.79	26.18	25.84	28.33	27.31	27.43

mg/100g in 2015-16, 2016-17 and pooled data respectively. Total 19 hybrid derivatives were grouped in a range of 13.0-21.0 mg/100g, 19 hybrid derivatives in 21.1-30.0 mg/100g, whereas four hybrid derivatives ranged above 30 mg/100g. In 2015-16, 2016-17 and pooled data, highest ascorbic acid content was recorded in hybrid-46 (38 mg/100g mg/100g, 36 mg/100g and 37 mg/100g) whereas in 2015-16 lowest was recorded in hybrid-19, 29, 35, 55 and 56 (14 mg/100g) during 2016-17 and pooled data hybrid-55 recorded lowest ascorbic acid content (12 and 13 mg/100g) respectively.

A wide variation in ascorbic acid content (2.90 mg/100 g to 136.50 mg/100 g) has been reported by Doreyappa *et al*. (1994). Mitra *et al*. (2001) observed the ascorbic acid content in the range of 21.66 mg/100 g to 125.40 mg/100 g. Such variation in ascorbic acid content could be attributed to the nature and extent of genetic variability present in the experimental material. These differences are supposed to be due to differential genetic makeup of the cultivars and also because of the differences in fruit development period and time of maturity. The variation in ascorbic acid content among mango cultivars is also reported by Rajwana *et al*. (2010).

Grouping of hybrid derivatives according to ascorbic acid content (mg/100g)

No.	Range (mg/100g)	Number of hybrid derivatives
1.	13.00-21.0	19
2.	21.1-30.0	19
3.	Above 30.0	04

4.2.9 TSS : Acidity ratio

The data has been presented in Table 27. TSS to acidity ratio, as calculated by dividing the total soluble solids by titratable acidity elucidated remarkable differences and varied from 24.79 to 99.38, 28.57 to 103.33 and 26.68 to 101.35 among mango derivatives during the period of investigation 2015-16, 2016-17 and pooled data. Total five hybrid derivatives were grouped in a range of 25.0-52.0, 26 hybrid derivatives in 52.1-78.0, whereas 11 hybrid derivatives ranged above 78.00. In 2015-16, 2016-17 and pooled data, it was found highest in hybrid-35 (99.38, 103.33 and 101.35) and lowest was recorded in hybrid-46 (24.79, 28.57 and 26.68).

The results are contrary to the findings of Lodh *et al.* (1974) who recorded TSS/Acidity ratio ranged from 5.50 to 109.20. Moreover, the TSS acidity ratios as reported in present study were similar to those of Palaniswamy *et al*. (1975). The similar

findings have also been reported by Mitra *et al.* (2001), Dhillon *et al*. (2004), Sharma and Josan (1995) and Kher and Sharma (2002) while working on fruit quality characters of different mango varieties under different climatic conditions. Kher and Sharma (2002) and Hoda *et al.* (2003) also reported the similar trend of variation i.e. 39.36 to 152.39 in different mango cultivars. Uddin *et al.* (2007) also showed wide variation in TSS/Acidity ratio which ranged from 24.19 to 81.57.

Grouping of hybrid derivatives according to TSS : Acidity ratio

No.	Range	Number of hybrid derivatives
1.	25.0-52.0	05
2.	52.1-78.0	26
3.	Above 78.00	11

4.2.10 Sugars : Acidity ratio

The data on sugars to acidity ratio, as calculated by dividing the total sugars by titratable acidity presented in Table 27 revealed noteworthy disparity in sugars to acidity ratio of mango derivatives however it ranged from 18.96 to 83.00, 21.43 to 83.94 and 20.19 to 83.47 in 2015-16, 2016-17 and pooled data respectively. Total nine hybrid derivatives were grouped in a range of 19.0-42.0, 22 hybrid derivatives in 42.1-65.0, whereas 11 hybrid derivatives ranged above 65.00. Highest sugars to acidity ratio was recorded in hybrid-21 (83.00, 83.94 and 83.47) in 2015-16, 2016-17 and pooled data whereas lowest was recorded in hybrid-46 (18.96, 21.43 and 20.19) in the experimental years 2015-16 and 2016-17 and pooled data.

The Brix/acidity ratio is a balance between sugars and acids and is an indication of the palatability of the juice (Echeveria, 1990).

Grouping of hybrid derivatives according to Sugars : Acidity ratio

No.	Range	Number of hybrid derivatives
1.	19.00-42.00	09
2.	42.1-65.0	22
3.	Above 65.00	11

Table 27. Mean performance of mango progenies for TSS : Acidity ratio and Sugars : Acidity ratio

Sr. No.	Hybrid derivatives	TSS:Acidity ratio			Sugars:Acidity ratio		
		2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
1	Hybrid -1	51.71	43.59	47.65	38.57	32.31	35.44
2	Hybrid-2	44.81	42.86	43.84	31.07	30.79	30.93
3	Hybrid -3	71.18	68.33	69.75	57.29	54.56	55.92
4	Hybrid -4	75.83	72.40	74.12	58.38	58.48	58.43
5	Hybrid -5	68.33	68.95	68.64	54.50	52.21	53.36
6	Hybrid -6	98.57	95.45	97.01	80.29	75.00	77.64
7	Hybrid -7	83.91	90.87	87.39	71.43	70.78	71.11
8	Hybrid -8	65.19	63.79	64.49	48.70	42.24	45.47
9	Hybrid -9	82.50	76.15	79.33	54.63	53.31	53.97
10	Hybrid -10	70.00	70.00	70.00	64.07	61.07	62.57
11	Hybrid -11	64.23	53.45	58.84	44.65	39.34	42.00
12	Hybrid -12	67.04	65.17	66.10	57.11	54.83	55.97
13	Hybrid -13	45.77	66.67	56.22	36.00	52.28	44.14
14	Hybrid -14	65.00	56.00	60.50	37.04	36.00	36.52
15	Hybrid -15	57.60	51.92	54.76	37.00	37.92	37.46
16	Hybrid -16	75.91	68.75	72.33	56.36	51.42	53.89
17	Hybrid -17	38.61	38.57	38.59	32.81	32.43	32.62
18	Hybrid -18	84.74	97.22	90.98	63.89	69.83	66.86
19	Hybrid -19	70.59	68.42	69.50	58.47	51.63	55.05
20	Hybrid -20	49.58	50.00	49.79	38.08	37.28	37.68
21	Hybrid -21	97.22	91.67	94.44	83.00	83.94	83.47
22	Hybrid -22	91.67	78.95	85.31	75.44	69.16	72.30
23	Hybrid -23	74.29	63.64	68.96	56.90	52.00	54.45
24	Hybrid -24	90.00	0.00	90.00	70.44	0.00	70.44
25	Hybrid -25	64.35	54.17	59.26	49.70	47.88	48.79
26	Hybrid -26	81.25	69.23	75.24	73.25	66.69	69.97
27	Hybrid -27	53.33	51.92	52.63	43.21	40.65	41.93
28	Hybrid -28	57.39	53.33	55.36	51.61	49.79	50.70
29	Hybrid -29	73.64	74.29	73.96	60.59	65.76	63.18
30	Hybrid -30	67.39	67.62	67.51	59.04	57.81	58.43
31	Hybrid -31	67.73	64.35	66.04	52.86	51.35	52.11
32	Hybrid -32	66.25	60.42	63.33	51.08	47.54	49.31
33	Hybrid -33	60.87	63.33	62.10	48.83	47.46	48.14
34	Hybrid -34	86.11	77.50	81.81	73.11	69.05	71.08
35	Hybrid -35	99.38	103.33	101.35	78.19	76.27	77.23
36	Hybrid -36	79.05	0.00	79.05	63.14	0.00	63.14
37	Hybrid -46	24.79	28.57	26.68	18.96	21.43	20.19
38	Hybrid -52	70.00	80.00	75.00	67.35	72.04	69.69
39	Hybrid -55	91.67	86.11	88.89	65.39	62.00	63.69
40	Hybrid -56	74.29	68.18	71.23	61.57	57.36	59.47
41	Hybrid -57	80.56	73.68	77.12	70.11	64.95	67.53
42	Hybrid -68	89.41	95.00	92.21	78.59	80.56	79.58
	Range	24.79 -99.38	28.57-103.33	26.68-101.35	18.96 – 83.00	21.43 - 83.94	20.19 - 83.47
	Mean	70.76	67.85	69.70	56.49	54.44	55.76
	std	16.53	16.72	16.29	14.95	14.78	14.67
	S.E. ±	2.55	2.64	2.51	2.31	2.34	2.26
	CV (%)	23.37	24.65	23.38	26.47	27.16	26.31

4.2.11 Fiber (%)

The data regarding fiber content in the fruit pulp presented in Table 28 ranged from 0.12 to 0.91 per cent, 0.10 to 1.02 per cent and 0.11 to 0.97 per cent in 2015-16, 2016-17 and pooled data respectively. Total 25 hybrid derivatives were grouped in a range of 0.01-0.40 per cent, 10 hybrid derivatives in 0.41-0.70 per cent, whereas seven hybrid derivatives ranged above 0.70 per cent. In 2015-16, 2016-17 and pooled data, the highest fiber content was recorded in hybrid-1 (0.91, 1.02 and 0.97 %) whereas lowest was recorded in hybrid-2 (0.12, 0.10 and 0.11 %) during the investigation years and pooled data.

The fiber content was less in those varieties with high organoleptic acceptance. Consumer preference is for succulence and low fiber. Juicy and fibrous varieties are not suitable for canning (Lal *et al.,* 1960). They are useful for making juice, squash, nectar, chutney and pickles. Fibrous nature of pulp is a wild character. Wild mangoes have fruits which are unacceptably fibrous (Singh, 1976). Fiber content ranged from 0.4 per cent (Nedungolan) to 2.92 (Natumavu Type-3). Fiber content was less (0.6%) in 14 varieties, while it was medium (0.6 to 0.9 %) in 21 and high (0.9 %) in 15 varieties (Simi, 2006).

Grouping of hybrid derivatives according to fiber percentage

No.	Range (%)	Number of hybrid derivatives
1.	0.01-0.40	25
2.	0.41-0.70	10
3.	Above 0.70	07

4.3 Qualitative characters (Sensory-evaluation)

The sensory analysis was done using a ten point hedonic scale score. The major quality attributes included in the score were flavour, aroma and pulp texture. Score for overall acceptability was obtained by determining the average mean scores for each character as presented in Table 29. Total 21 hybrid derivatives were grouped in a range of 5.0-6.1, 12 hybrid derivatives in 6.2-7.1, whereas remaining nine hybrid derivatives ranged above 7.1. The highest score for flavour (8.1) was obtained by hybrids-6 and lowest (5.0) by hybrids-11, 15, 20, 23, 31 and 33 whereas highest score for aroma was obtained by hybrid-4 (8.0) and lowest was obtained by hybrids-3, 18, 30, 32 and 35. The highest score for pulp texture was obtained by hybrid-10 (8.0) and the lowest was recorded in hybrids-5, 13, 15, 17, 18 and 24 (5.0).

Table 28. Mean performance of mango progenies for fibre percentage

Sr. No.	Hybrid derivatives	Fibre (%)		
		2015-16	2016-17	Pooled
1	Hybrid -1	0.91	1.02	0.97
2	Hybrid-2	0.12	0.10	0.11
3	Hybrid -3	0.63	0.62	0.63
4	Hybrid -4	0.24	0.22	0.23
5	Hybrid -5	0.31	0.29	0.30
6	Hybrid -6	0.32	0.30	0.31
7	Hybrid -7	0.38	0.34	0.36
8	Hybrid -8	0.22	0.23	0.23
9	Hybrid -9	0.24	0.24	0.24
10	Hybrid -10	0.33	0.36	0.35
11	Hybrid -11	0.26	0.27	0.27
12	Hybrid -12	0.46	0.47	0.47
13	Hybrid -13	0.57	0.58	0.58
14	Hybrid -14	0.4	0.31	0.36
15	Hybrid -15	0.41	0.46	0.44
16	Hybrid -16	0.5	0.49	0.50
17	Hybrid -17	0.23	0.25	0.24
18	Hybrid -18	0.6	0.70	0.65
19	Hybrid -19	0.78	0.64	0.71
20	Hybrid -20	0.41	0.45	0.43
21	Hybrid -21	0.34	0.38	0.36
22	Hybrid -22	0.52	0.44	0.48
23	Hybrid -23	0.48	0.43	0.46
24	Hybrid -24	0.39	0.00	0.39
25	Hybrid -25	0.27	0.29	0.28
26	Hybrid -26	0.82	0.88	0.85
27	Hybrid -27	0.26	0.21	0.24
28	Hybrid -28	0.38	0.35	0.37
29	Hybrid -29	0.42	0.46	0.44
30	Hybrid -30	0.22	0.21	0.22
31	Hybrid -31	0.25	0.28	0.27
32	Hybrid -32	0.7	0.90	0.80
33	Hybrid -33	0.82	0.93	0.88
34	Hybrid -34	0.21	0.18	0.20
35	Hybrid -35	0.19	0.15	0.17
36	Hybrid -36	0.74	0.00	0.74
37	Hybrid -46	0.14	0.12	0.13
38	Hybrid -52	0.17	0.15	0.16
39	Hybrid -55	0.26	0.29	0.28
40	Hybrid -56	0.36	0.39	0.38
41	Hybrid -57	0.69	0.58	0.64
42	Hybrid -68	0.26	0.24	0.25
	Range	0.12 - 0.91	0.1 - 1.02	0.11 - 0.97
	Mean	0.41	0.41	0.41
	std	0.21	0.23	0.22
	S.E. ±	0.03	0.04	0.03
	CV (%)	50.66	55.73	52.69

Table 29. Characterization of mango progenies for quality characters

Sr. No.	Hybrid derivatives	Taste and flavour	Aroma	Pulp texture	Overall acceptability
1	Hybrid -1	7.5	6.3	6.2	6.7
2	Hybrid-2	6.0	6.5	6.0	6.2
3	Hybrid -3	5.5	5.0	5.2	5.2
4	Hybrid -4	8.0	8.0	7.8	7.9
5	Hybrid -5	5.5	6.0	5.0	5.5
6	Hybrid -6	8.1	7.9	7.8	7.9
7	Hybrid -7	8.0	7.9	7.8	7.9
8	Hybrid -8	7.5	7.5	7.6	7.5
9	Hybrid -9	6.0	6.6	6.5	6.4
10	Hybrid -10	7.9	7.9	8.0	7.9
11	Hybrid -11	5.0	5.5	5.8	5.4
12	Hybrid -12	8.0	7.9	7.9	7.9
13	Hybrid -13	5.6	5.5	5.0	5.4
14	Hybrid -14	6.0	6.2	6.0	6.1
15	Hybrid -15	5.0	5.2	5.0	5.1
16	Hybrid -16	6.8	6.5	6.2	6.5
17	Hybrid -17	5.8	5.5	5.0	5.4
18	Hybrid -18	5.5	5.0	5.0	5.2
19	Hybrid -19	5.9	5.6	5.5	5.7
20	Hybrid -20	5.0	6.1	6.0	5.7
21	Hybrid -21	6.1	6.0	6.0	6.0
22	Hybrid -22	5.8	5.9	5.5	5.7
23	Hybrid -23	5.0	5.2	5.5	5.2
24	Hybrid -24	5.6	5.3	5.0	5.3
25	Hybrid -25	5.8	5.5	5.5	5.6
26	Hybrid -26	7.8	7.5	7.6	7.6
27	Hybrid -27	6.0	6.2	6.5	6.2
28	Hybrid -28	6.2	6.1	6.6	6.3
29	Hybrid -29	6.5	6.0	6.2	6.2
30	Hybrid -30	5.5	5.0	5.1	5.2
31	Hybrid -31	5.0	5.2	5.5	5.2
32	Hybrid -32	5.8	5.0	5.3	5.4
33	Hybrid -33	5.0	5.5	5.6	5.4
34	Hybrid -34	7.0	7.2	7.5	7.2
35	Hybrid -35	5.5	5.0	5.2	5.2
36	Hybrid -36	6.3	6.2	6.0	6.2
37	Hybrid -46	6.9	6.8	6.5	6.7
38	Hybrid -52	8.0	7.9	7.9	7.9
39	Hybrid -55	6.3	6.9	6.0	6.4
40	Hybrid -56	6.5	6.0	6.3	6.3
41	Hybrid -57	6.8	6.5	6.5	6.6
42	Hybrid -68	6.4	5.8	5.5	5.9
	Range	5 - 8.1	5 - 8	5 - 8	5.1 - 7.97
	Mean	6.30	6.22	6.16	6.23
	std	0.99	0.96	0.98	0.95
	S.E. ±	0.15	0.15	0.15	0.15
	CV (%)	15.71	15.39	15.87	15.18

The highest score for overall acceptability was obtained for hybrid-4, 6, 7, 10, 12 and 52 (7.9) and the least score was obtained for hybrid-15 (5.1).

The changes in organoleptic qualities can be attributed to the alteration in chemical composition among the different varieties (Nanjundaswamy *et al.,* 1976). The overall fruit quality depends on nutritional and other hidden attributes and sensory quality as assessed by means of human sensory organs (Manay and Shadaksharaswamy, 1995).

Grouping of hybrid derivatives according to Qualitative characters

No.	Range	Number of hybrid derivatives
1.	5.0-6.1	21
2.	6.2-7.1	12
3.	Above 7.1	09

The present results are in accordance with the findings of Uddin *et al.* (2007) who mentioned the variable score in different mango derivatives. Wide variability was recorded in fruits for the presence of flavour, taste and aroma at the time of ripening; this can be exploited for identifying sucking, pickle and table purposes mango strains. Several workers also described the promising local mango seedlings with respect to physico-chemical attributes under different agro-climatic conditions of India (Teaotia and Singh, 1963; Rabbani and Singh, 1989; Parida and Rao, 1989; Navprem and Sharma, 2005).

4.4 Yield characters

4.4.1 Days required for harvesting (days)

The data presented in Table 30 revealed that the days required for harvesting ranged from 103 to 202 days, 111 to 160 days and 107 to 181 days in 2015-16, 2016-17 and pooled data respectively. Total 26 hybrid derivatives were grouped in a range of 105.0-132.0 days, 15 hybrid derivatives in 132.1-157.0 days, whereas one hybrid derivative ranged above 157.0. Maximum number of days required for harvesting in 2015-16, 2016-17 and pooled data was recorded by hybrid-26 (202 days, 160 days and 181 days) whereas minimum number of days was recorded in hybrid-10 (103 days, 111 days and 107 days) in both the years of investigation.

The variation in days for harvesting might be due to the locations having different environmental conditions, management practices and year of production. Bhuyan and Islam (1989) recorded the harvesting time of Gopalbhog, Khirsapat, Langra,

Table 30. Mean performance of mango progenies for days required for harvesting

Sr. No.	Hybrid derivatives	Days required for harvesting		
		2015-16	2016-17	Pooled
1	Hybrid -1	129	121	125.0
2	Hybrid-2	115	119	117.0
3	Hybrid -3	110	135	122.5
4	Hybrid -4	121	136	128.5
5	Hybrid -5	120	132	126.0
6	Hybrid -6	109	119	114.0
7	Hybrid -7	118	121	119.5
8	Hybrid -8	124	142	133.0
9	Hybrid -9	119	112	115.5
10	Hybrid -10	103	111	107.0
11	Hybrid -11	113	114	113.5
12	Hybrid -12	117	145	131.0
13	Hybrid -13	115	136	125.5
14	Hybrid -14	124	129	126.5
15	Hybrid -15	121	141	131.0
16	Hybrid -16	122	132	127.0
17	Hybrid -17	118	135	126.5
18	Hybrid -18	126	120	123.0
19	Hybrid -19	132	137	134.5
20	Hybrid -20	131	135	133.0
21	Hybrid -21	145	126	135.5
22	Hybrid -22	127	141	134.0
23	Hybrid -23	127	149	138.0
24	Hybrid -24	125	0	125.0
25	Hybrid -25	140	143	141.5
26	Hybrid -26	202	160	181.0
27	Hybrid -27	117	124	120.5
28	Hybrid -28	144	139	141.5
29	Hybrid -29	135	132	133.5
30	Hybrid -30	144	140	142.0
31	Hybrid -31	122	131	126.5
32	Hybrid -32	132	135	133.5
33	Hybrid -33	126	118	122.0
34	Hybrid -34	121	143	132.0
35	Hybrid -35	123	144	133.5
36	Hybrid -36	125	0	125.0
37	Hybrid -46	123	133	128.0
38	Hybrid -52	111	135	123.0
39	Hybrid -55	132	139	135.5
40	Hybrid -56	132	135	133.5
41	Hybrid -57	114	124	119.0
42	Hybrid -68	159	128	143.5
	Range	103 - 202	111 - 160	107 - 181
	Mean	126.50	132.28	129.21
	std	16.14	10.67	11.62
	S.E. ±	2.49	1.69	1.79
	CV (%)	12.76	8.06	9.00

Fazli and Ashwina as 31 May, 2 June, 17 June, 10 July, and 21 July, respectively, under the climatic condition of Chapai Nawabgonj. Valmayor (1962) stated that harvesting time of mango may vary depending on the time of flowering and climatic factors during the growing season.

The difference in maturity of fruits of different cultivars might be due to the difference in date of panicle emergence and prevailing environmental conditions, besides their genetic makeup (Kundu *et al.,* 2009). Variation in fruit maturity in different varieties might be due to change in location or inherent genetic variation (Singh, 2002 and Hoda *et al.,* 2003). Similar findings had also reported by Sardar *et al.* (1998) and Majumder *et al.* (2011). Kishore *et al.* (2015) observed Arka Neelachal Kesari had the shortest maturity period followed by Himsagar and Prabhashankar; on the other hand Totapuri took more than 140 days. Thus it is evident that early variety had short maturity period.

Kumar and Singh (2005) evaluated the mango varieties for flowering, fruiting and fruit quality attributes and observed that Bombai has been found earliest (5th June) in maturity period. Bangalora matured at the last (5th July) followed by Mallika and Dadamian 29th and 27th June, respectively.

Grouping of hybrid derivatives according to days required for harvesting (days)

No.	Range (days)	Number of hybrid derivatives
1.	105.0-132.0	26
2.	132.1-157.0	15
3.	Above 157.0	01

4.4.2 Number of fruits per tree

There was notable variation with respect to the number of fruits harvested per tree during the experimental period (Table 31). The number of fruits harvested per tree ranged from 64 to 315, 67 to 324 and 65.5 to 319.5 during both the years (2015-16 and 2016-17) and pooled data. Total 24 hybrid derivatives were grouped in a range of 65-150, 15 hybrid derivatives in 150.1-235.0, whereas three hybrid derivatives ranged above 235. The maximum number of fruits harvested per tree was noticed in hybrid-7 (315.0, 324.0 and 319.5) while least was observed in hybrid-34 (64, 67 and 65.5) in 2015-16, 2016-17 and pooled data.

The variation in number of fruits per tree might be due to tree size, fruit size, leaf area and absorption and translocation of photosynthates (Dhillon *et al.,* 2004 and Singh *et al.,* 1986).

Sharma and Jason (1995) assessed five cultivars, *viz.,* Dashehari, Langra, Mallika, Amrapali and Alphonso introduced from the main mango growing regions of country at arid-irrigated region of Punjab and found that the number of fruits per tree in these five cultivars was 215, 129, 142, 176 and 123 respectively.

Grouping of hybrid derivatives according to number of fruit per tree

No.	Range	Number of hybrid derivatives
1.	65-150	24
2.	150.1-235	15
3.	Above 235	03

4.4.3 Yield (kg/tree)

It is evident from the data presented in Table 31 that the yield per tree varied from 8.55 to 133.89 kg, 9.69 to 123.51 kg and 9.12 kg to 128.70 kg in 2015-16, 2016-17 and pooled data respectively. Total 36 hybrid derivatives were grouped in a range of 9.0-50.0 kg/tree, four hybrid derivatives in 50.1-90.0 kg/tree, whereas two hybrid derivatives ranged above 90 kg/tree. During the investigation, highest yield per tree was recorded by hybrid-26 (133.89 kg, 123.51 kg and 128.70 kg) in 2015-16, 2016-17 and pooled data, whereas hybrid-16 recorded lowest yield (8.55 kg, 9.69 kg and 9.12 kg).

The variation in fruit yield in different cultivars might be due to the inherent variation in the absorption and translocation of photosynthates and plant hormones, fruit set, fruit retension, tree size and leaf area of an individual cultivar (Hoda *et al.,* 2003 and Singh, 2002).The variations in fruit yield attributes have also been reported due to change in inherent genetic factors (Singh and Chadha, 1981; Srivastava *et al.,* 1987; Chanana *et al.,* 2005). The biological yield of a fruit orchard is a function of the amount of light intercepted by orchard canopy. Thus optimizing, biological yield is based upon maximizing the percentage of solar radiation intercepted by orchard canopy and portioning of higher amounts of assimilates towards fruit yield (Dinesh and Reddy, 2012). A single mango tree can produce 200 to 300 kg of fruit in heavy cropping year and as low as 5 kg in low cropping year (Bally, 2006).

Table 31. Characterization of mango progenies for yield characters

Sr. No.	Hybrid derivatives	Number of fruits per tree			Yield (kg/tree)		
		2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
1	Hybrid -1	154	155	154.5	23.90	25.36	24.63
2	Hybrid-2	162	157	159.5	27.60	26.25	26.93
3	Hybrid -3	178	182	180.0	17.48	19.18	18.33
4	Hybrid -4	238	249	243.5	58.93	64.57	61.75
5	Hybrid -5	164	148	156.0	28.22	24.92	26.57
6	Hybrid -6	292	262	277.0	78.11	72.00	75.05
7	Hybrid -7	315	324	319.5	88.74	89.49	89.11
8	Hybrid -8	164	169	166.5	33.21	34.26	33.73
9	Hybrid -9	130	142	136.0	23.26	25.79	24.52
10	Hybrid -10	226	216	221.0	45.25	42.38	43.81
11	Hybrid -11	137	140	138.5	15.22	14.36	14.79
12	Hybrid -12	186	192	189.0	107.08	111.96	109.52
13	Hybrid -13	132	142	137.0	25.79	26.47	26.13
14	Hybrid -14	96	112	104.0	15.23	16.50	15.86
15	Hybrid -15	88	102	95.0	15.04	18.74	16.89
16	Hybrid -16	72	78	75.0	8.55	9.69	9.12
17	Hybrid -17	138	149	143.5	13.29	14.54	13.92
18	Hybrid -18	178	165	171.5	26.31	26.32	26.31
19	Hybrid -19	82	102	92.0	16.88	20.18	18.53
20	Hybrid -20	102	118	110.0	19.20	20.45	19.82
21	Hybrid -21	159	143	151.0	21.74	21.31	21.52
22	Hybrid -22	81	111	96.0	13.17	16.83	15.00
23	Hybrid -23	112	136	124.0	15.74	18.28	17.01
24	Hybrid -24	97	0	97.0	9.21	0	9.21
25	Hybrid -25	119	129	124.0	17.03	16.78	16.91
26	Hybrid -26	249	234	241.5	133.89	123.51	128.70
27	Hybrid -27	98	124	111.0	17.48	20.44	18.96
28	Hybrid -28	148	156	152.0	20.56	23.29	21.92
29	Hybrid -29	106	99	102.5	10.66	10.72	10.69
30	Hybrid -30	119	109	114.0	24.73	22.15	23.44
31	Hybrid -31	126	116	121.0	15.83	14.19	15.01
32	Hybrid -32	158	144	151.0	17.46	18.03	17.74
33	Hybrid -33	126	116	121.0	15.45	15.69	15.57
34	Hybrid -34	64	67	65.5	14.18	15.97	15.07
35	Hybrid -35	139	144	141.5	17.06	17.96	17.51
36	Hybrid -36	142	0	142.0	18.01	0	18.01
37	Hybrid -46	98	83	90.5	55.69	49.68	52.69
38	Hybrid -52	198	183	190.5	72.05	67.93	69.99
39	Hybrid -55	179	208	193.5	19.01	40.12	29.57
40	Hybrid -56	189	184	186.5	25.78	26.20	25.99
41	Hybrid -57	196	186	191.0	28.54	28.50	28.52
42	Hybrid -68	138	126	132.0	22.33	21.86	22.09
	Range	64 - 315	67 - 324	65.5-319.5	8.55-133.89	9.69-123.51	9.12-128.7
	Mean	149.40	152.55	150.19	30.78	32.32	31.11
	std	56.09	52.66	53.67	27.53	26.61	26.82
	S.E. ±	8.66	8.33	8.28	4.25	4.21	4.14
	CV (%)	37.55	34.52	35.74	89.45	82.32	86.24

Chanana *et al.* (2005) evaluated some mango cultivars under north Indian conditions and found that fruit yield was maximum (73.00 kg/ tree) in cultivar Mallika followed by Dashehari (66.33 kg/ tree), while, other cultivars Langra and Amrapali recorded the fruit yield of 62.00 kg/ tree and 45.67 kg/tree, respectively. On the other hand minimum fruit yield (15.67 kg/ tree) was recorded in Alphonso. In another study, Amrapali and Mallika produced significantly higher number of fruits (338.8 and 214.1 kg/ tree) and fruits yield (69.78 and 64.68 / tree) over the control cultivar Langra i.e. 127.2 numbers of fruits and 35.05 kg / tree.

Kumar and Singh (2005) evaluated the mango varieties for flowering, fruiting and fruit quality attributes and observed that Mallika recorded maximum fruit yield (171.00 kg) followed by Bangalora and Langra i.e. 130.00 and 120.00 kg per plant respectively, while least fruit yield (11.00 kg per plant) was found in Alphonso.

Sharma and Josan (1995) assessed five cultivars, *viz.,* Dashehari, Langra, Mallika, Amrapali and Alphonso introduced from the main mango growing regions of country at arid-irrigated region of Punjab. They found the maximum yield in Mallika (60 kg/tree) followed by Dashehari (50 kg/tree) and Langra (38.0 kg/tree). However, the minimum yield was noted in Alphonso (21 kg/tree).

Grouping of hybrid derivatives according to Yield (kg/tree)

No.	Range (kg/tree)	Number of hybrid derivatives
1.	9.0-50.0	36
2.	50.1-90.0	04
3.	Above 90	02

4.5 Shelf life (days)

The data presented in Table 32 revealed that the differences in the shelf life of mango hybrid derivatives under study ranged from 5.7 to 9.1 days, 4.9 to 10.2 days and 5.4 days to 9.65 days in 2015-16, 2016-17 and pooled data. Total 23 hybrid derivatives were grouped in a range of 5.0-7.0 days, 11 hybrid derivatives in 7.1-8.0 days, whereas eight hybrid derivatives ranged above 8.0 days. It is clearly understood from the data that the longest shelf life at ambient condition was documented in hybrid-6 (9.1 days, 10.2 days and 9.65 days) in the experimental years 2015-16, 2016-17 and pooled data and shortest was recorded in hybrid-68 (5.6, 4.9 and 5.4 days).

Table 32. Shelf life

Sr. No.	Hybrid derivatives	Shelf life (Days)		
		2015-16	2016-17	Pooled
1	Hybrid -1	7.2	6.8	7.0
2	Hybrid-2	6.4	6.2	6.3
3	Hybrid -3	7.2	8.4	7.8
4	Hybrid -4	7.4	7.2	7.3
5	Hybrid -5	6.1	6.6	6.4
6	Hybrid -6	9.1	10.2	9.7
7	Hybrid -7	8.8	8.9	8.9
8	Hybrid -8	7.9	8.2	8.1
9	Hybrid -9	6.8	6.1	6.5
10	Hybrid -10	8.2	8.5	8.4
11	Hybrid -11	7.5	7.2	7.4
12	Hybrid -12	8.5	8.8	8.7
13	Hybrid -13	6.5	7.3	6.9
14	Hybrid -14	6.2	6.5	6.4
15	Hybrid -15	7.2	7.5	7.4
16	Hybrid -16	8.2	7.1	7.7
17	Hybrid -17	5.7	6.8	6.3
18	Hybrid -18	6.1	7.4	6.8
19	Hybrid -19	7.8	6.9	7.4
20	Hybrid -20	7.5	6.4	7.0
21	Hybrid -21	7.3	6.8	7.1
22	Hybrid -22	6.9	6.2	6.6
23	Hybrid -23	7.5	7.9	7.7
24	Hybrid -24	7.1	0.0	7.1
25	Hybrid -25	6.2	6.8	6.5
26	Hybrid -26	7.9	8.1	8.0
27	Hybrid -27	7.6	6.1	6.9
28	Hybrid -28	6.2	6.5	6.4
29	Hybrid -29	7.5	6.2	6.9
30	Hybrid -30	6.2	7.3	6.8
31	Hybrid -31	6.5	7.5	7.0
32	Hybrid -32	7.8	6.2	7.0
33	Hybrid -33	6.4	6.6	6.5
34	Hybrid -34	6.2	7.5	6.9
35	Hybrid -35	6.3	6.8	6.6
36	Hybrid -36	7.8	0.0	7.8
37	Hybrid -46	8.2	8.5	8.4
38	Hybrid -52	8.6	8.9	8.8
39	Hybrid -55	7.3	7.2	7.3
40	Hybrid -56	6.9	5.8	6.4
41	Hybrid -57	5.8	6.8	6.3
42	Hybrid -68	5.9	4.9	5.4
	Range	5.7 - 9.1	4.9 - 10.2	5.4 - 9.65
	Mean	7.15	7.19	7.18
	std	0.88	1.04	0.86
	S.E. ±	0.14	0.16	0.13
	CV (%)	12.37	14.41	12.03

The difference in shelf-life might be due to difference in peel thickness composition of peel and fruit firmness. Present result is in corroboration with the findings of Rajwana *et al.* (2010), and Sethi *et al*. (2011). The findings are in tune with Chakraborti (2012) who studied ten hybrids on various aspects and reported shelf life in hybrids namely Ratna (9.50 days), Mallika (12.20 days), Prabhasankar (8.40 days) and Amrapali (11.50 days). The shelf life is associated with loss of firmness, hydration of cell wall, changes in cell wall thickness, decrease in the structural integrity and increase in the intracellular spaces (Tucker and Grierson, 1987).

Grouping of hybrid derivatives according to shelf life (days)

No.	Range (days)	Number of hybrid derivatives
1.	5.0-7.0	23
2.	7.1-8.0	11
3.	Above 8.0	08

4.6 Reaction to physiological disorders

4.6.1 Incidence of malformation (%)

From the data presented in Table 33, the incidence of malformation was observed in few hybrid derivatives however, hybrid-14 showed maximum percentage of incidence (35.0 %) with a rating of grade 9 and was found to be susceptible and minimum was observed in hybrid-34 (8.0 %) with a rating of grade-5 and was found to be tolerant in 2015-16. In 2016-17, maximum percentage was recorded in hybrid-25 (30.0 %) with a rating of grade 9 and was found to be susceptible while minimum was recorded in hybrid-34 (13.0 %) with a rating of grade-7 and was found to be moderately susceptible whereas pooled data revealed maximum percentage in hybrid-14 and 24 (26.5 %) with a rating of grade 9 and was found to be susceptible and minimum percentage of incidence was in hybrid-22 (10.0 %) with a rating of grade-5 and was found to be tolerant. Total 34 hybrid derivatives were grouped in a range of 0-11.0 %, four hybrid derivatives in 11.1-22.01 %, whereas remaining four hybrid derivatives ranged above 22.0 %.

Reports have indicated that early emerging flower buds were severely infected; whereas later buds escaped the disease; the relatively high temperature during panicle development was said to be the cause of the difference (Kumar *et al.,* 1993). In

Table 33. Incidence of disorders in mango progenies

Sr. No.	Hybrid derivatives	Incidence of malformation			Incidence of black tip	Incidence of spongy tissue	Incidence of water tissue
		2015-16	2016-17	Pooled			
1	Hybrid -1	0.0	0.0	0.0	0.0	0.0	0.0
2	Hybrid-2	0.0	0.0	0.0	0.0	0.0	0.0
3	Hybrid -3	0.0	0.0	0.0	0.0	0.0	0.0
4	Hybrid -4	0.0	0.0	0.0	0.0	0.0	0.0
5	Hybrid -5	0.0	0.0	0.0	0.0	0.0	0.0
6	Hybrid -6	0.0	0.0	0.0	0.0	0.0	0.0
7	Hybrid -7	0.0	0.0	0.0	0.0	0.0	0.0
8	Hybrid -8	0.0	0.0	0.0	0.0	0.0	0.0
9	Hybrid -9	0.0	0.0	0.0	0.0	0.0	0.0
10	Hybrid -10	0.0	0.0	0.0	0.0	0.0	0.0
11	Hybrid -11	0.0	0.0	0.0	0.0	0.0	0.0
12	Hybrid -12	0.0	0.0	0.0	0.0	0.0	0.0
13	Hybrid -13	0.0	0.0	0.0	0.0	0.0	0.0
14	Hybrid -14	35.0	18.0	26.5	0.0	0.0	0.0
15	Hybrid -15	29.0	21.0	25.0	0.0	0.0	0.0
16	Hybrid -16	15.0	17.0	16.0	0.0	0.0	0.0
17	Hybrid -17	0.0	0.0	0.0	0.0	0.0	0.0
18	Hybrid -18	16.0	23.0	19.5	0.0	0.0	0.0
19	Hybrid -19	0.0	0.0	0.0	0.0	0.0	0.0
20	Hybrid -20	0.0	0.0	0.0	0.0	0.0	0.0
21	Hybrid -21	0.0	0.0	0.0	0.0	0.0	0.0
22	Hybrid -22	20.0	0.0	10.0	0.0	0.0	0.0
23	Hybrid -23	24.0	20.0	22.0	0.0	0.0	0.0
24	Hybrid -24	28.0	0.0	14.0	0.0	0.0	0.0
25	Hybrid -25	20.0	30.0	25.0	0.0	0.0	0.0
26	Hybrid -26	0.0	0.0	0.0	0.0	0.0	0.0
27	Hybrid -27	0.0	0.0	0.0	0.0	0.0	0.0
28	Hybrid -28	0.0	0.0	0.0	0.0	0.0	0.0
29	Hybrid -29	0.0	0.0	0.0	0.0	0.0	0.0
30	Hybrid -30	0.0	0.0	0.0	0.0	0.0	0.0
31	Hybrid -31	0.0	0.0	0.0	0.0	0.0	0.0
32	Hybrid -32	0.0	0.0	0.0	0.0	0.0	0.0
33	Hybrid -33	0.0	0.0	0.0	0.0	0.0	0.0
34	Hybrid -34	8.0	13.0	10.5	0.0	0.0	0.0
35	Hybrid -35	12.0	22.0	17.0	0.0	0.0	0.0
36	Hybrid -36	12.0	0.0	6.0	0.0	0.0	0.0
37	Hybrid -46	0.0	0.0	0.0	0.0	0.0	0.0
38	Hybrid -52	0.0	0.0	0.0	0.0	0.0	0.0
39	Hybrid -55	0.0	0.0	0.0	0.0	0.0	0.0
40	Hybrid -56	0.0	0.0	0.0	0.0	0.0	0.0
41	Hybrid -57	0.0	0.0	0.0	0.0	0.0	0.0
42	Hybrid -68	0.0	0.0	0.0	0.0	0.0	0.0
	Range	0 - 35	0 - 30	0 - 32.5	-	-	-
	Mean	19.91	14.91	17.4	-	-	-
	std	8.36	10.44	9.4	-	-	-
	S.E. ±	2.52	3.15	2.83	-	-	-
	CV (%)	41.99	70.06	56.0	-	-	-

India, the disease is present in all mango producing areas; however, the incidence is lower in the southern and eastern than in the northern region. Temperatures in those regions are warmer than in the north, where cold conditions precede flowering. Singh, *et al*. (1998) also stated that elevating the temperature of the orchard during flower genesis can minimize the occurrence of floral malformation. Besides this, presence of a natural defensive metabolite i.e. Mangiferin, is also reported in some cultivars, which acts against mango malformation and reduces the incidence of the disease (Chakrabarti *et al*., 1997). Susceptible cultivars were found to have higher rate of transpiration with a concomitant increase in relative humidity and increased moisture holding capacity by malformed tissues. Higher rate of transpiration which was recorded in susceptible cultivar was attributed to presence of higher number of stomata as has been reported in other crop (Singh, 2006). Lower leaf temperature and higher relative humidity in susceptible cultivars were also demonstrated by Varma *et al*. (1971), where it was observed that the fungus *Fusarium mangiferae* (Pv. *moniliforme* var. *subglutinans*), the casual organism of mango malformation, grows well at lower temperature and higher relative humidity.

Grouping of hybrid derivatives according to Malformation disorder (%)

No.	Range (%)	Number of hybrid derivatives
1.	0-11.0	34
2.	11.1-22.00	04
3.	Above 22.0	04

4.6.2 Incidence of black tip

Incidence of black tip was not observed during the period of investigation.

4.6.3 Incidence of spongy tissue

Incidence of spongy tissue was not observed during the period of investigation.

4.6.4 Incidence of water tissue

Incidence of water tissue was not observed during the period of investigation.

4.7 Reaction to diseases

4.7.1 Incidence of powdery mildew

The data presented in Table 34 showed that the incidence of powdery mildew was observed in few hybrid derivatives however, hybrid-11 showed maximum percentage disease incidence (5.6) and minimum was observed in hybrid-16 (1.6) in 2015-16. In 2016-17, maximum percentage was recorded in hybrid-30 (6.4) and minimum was recorded in hybrid-16 (2.1) whereas pooled data revealed maximum percentage in hybrid-30 (6.40) and minimum percentage of incidence was observed in hybrid-16 (1.90). Total 28 hybrid derivatives were grouped in a range of 0-2.20, six hybrid derivatives in 2.21-4.50, whereas eight hybrid derivatives ranged above 4.50.

Misra and Prakash (1988) stated that predominance of susceptible cultivar 'Dashehari', high wind velocity for 3-4 days with maximum temperature around 30^0C, minimum temperature around 15^0C, relative humidity of minimum 23.4-25.5 per cent and maximum 73.3 - 83.9 per cent are conducive for the rapid spread of mildew pathogen in Kakori and Malihabad mango belt of U.P. Recent findings further revealed that maximum temperature of 35^0C play crucial role in the epidemic of powdery mildew. If max. temperature does not reach to 35^0C during the later half of March in northern plains, the epidemic of powdery mildew does not assume (Misra and Prakash, 1997). Misra and Prakash (1998) also found that powdery mildew (floral) start disappearing from panicle during April-May when minimum maximum temperature and RH starts increasing.

Grouping of hybrid derivatives according to powdery mildew disease

No.	Range	Number of hybrid derivatives
1.	0-2.20	28
2.	2.21-4.50	06
3.	Above 4.50	08

4.7.2 Incidence of anthracnose

Incidence of anthracnose was not observed during the period of investigation.

Table 34. Incidence of disease in mango progenies

Sr. No.	Hybrid derivatives	Incidence of powdery mildew			Incidence of anthracnose	
		2015-16	2016-17	Pooled	2015-16	2016-17
1	Hybrid -1	2.4	0.0	2.4	0.0	0.0
2	Hybrid-2	0.0	0.0	0.0	0.0	0.0
3	Hybrid -3	0.0	0.0	0.0	0.0	0.0
4	Hybrid -4	0.0	0.0	0.0	0.0	0.0
5	Hybrid -5	0.0	4.8	4.8	0.0	0.0
6	Hybrid -6	0.0	0.0	0.0	0.0	0.0
7	Hybrid -7	0.0	0.0	0.0	0.0	0.0
8	Hybrid -8	0.0	0.0	0.0	0.0	0.0
9	Hybrid -9	0.0	0.0	0.0	0.0	0.0
10	Hybrid -10	0.0	0.0	0.0	0.0	0.0
11	Hybrid -11	5.6	4.2	4.9	0.0	0.0
12	Hybrid -12	0.0	0.0	0.0	0.0	0.0
13	Hybrid -13	0.0	0.0	0.0	0.0	0.0
14	Hybrid -14	3.2	0.0	3.2	0.0	0.0
15	Hybrid -15	3.2	2.4	2.8	0.0	0.0
16	Hybrid -16	1.6	2.1	1.9	0.0	0.0
17	Hybrid -17	2.4	0.0	0.0	0.0	0.0
18	Hybrid -18	0.0	5.6	5.6	0.0	0.0
19	Hybrid -19	0.0	0.0	0.0	0.0	0.0
20	Hybrid -20	0.0	0.0	0.0	0.0	0.0
21	Hybrid -21	0.0	0.0	0.0	0.0	0.0
22	Hybrid -22	0.0	4.0	4.0	0.0	0.0
23	Hybrid -23	0.0	4.8	4.8	0.0	0.0
24	Hybrid -24	0.0	0.0	0.0	0.0	0.0
25	Hybrid -25	0.0	0.0	0.0	0.0	0.0
26	Hybrid -26	0.0	0.0	0.0	0.0	0.0
27	Hybrid -27	0.0	0.0	0.0	0.0	0.0
28	Hybrid -28	0.0	0.0	0.0	0.0	0.0
29	Hybrid -29	0.0	4.8	4.8	0.0	0.0
30	Hybrid -30	0.0	6.4	6.4	0.0	0.0
31	Hybrid -31	0.0	3.2	3.2	0.0	0.0
32	Hybrid -32	0.0	4.8	4.8	0.0	0.0
33	Hybrid -33	0.0	0.0	0.0	0.0	0.0
34	Hybrid -34	2.4	0.0	2.4	0.0	0.0
35	Hybrid -35	0.0	5.6	5.6	0.0	0.0
36	Hybrid -36	0.0	0.0	0.0	0.0	0.0
37	Hybrid -46	0.0	0.0	0.0	0.0	0.0
38	Hybrid -52	0.0	0.0	0.0	0.0	0.0
39	Hybrid -55	0.0	0.0	0.0	0.0	0.0
40	Hybrid -56	0.0	0.0	0.0	0.0	0.0
41	Hybrid -57	0.0	0.0	0.0	0.0	0.0
42	Hybrid -68	0.0	0.0	0.0	0.0	0.0
	Range	1.6 - 5.6	2.1 - 6.4	1.90 - 6.4	-	-
	Mean	2.97	4.39	4.10	-	-
	std	1.28	1.30	1.38	-	-
	S.E. ±	0.48	0.37	0.36	-	-
	CV (%)	43.17	29.49	33.56	-	-

Table 35. Desirable characters of six promising hybrid derivatives

Sr. No	Characters	Promising hybrid derivatives					
		Hybrid-4	Hybrid-6	Hybrid-7	Hybrid-10	Hybrid-12	Hybrid-52
1	Fruit colour	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
2	Fruit length (cm)	8.19	8.98	8.78	8.61	11.62	9.74
3	Pulp colour	Orange	Yellow	Yellow	Orange	Yellow	Orange
4	Fruit weight (g)	253.45	271.15	278.95	198.20	579.40	367.55
5	Number of hermaphrodite flowers	244.85	281.75	271.85	269.85	245.95	228.15
6	Sex ratio	0.28	0.47	0.35	0.40	0.34	0.30
7	Fruit retension percent	3.66	3.66	3.80	3.31	3.76	3.42
8	TSS °B	18.15	20.85	20.10	19.25	18.50	18.70
9	Acidity (%)	0.25	0.22	0.23	0.28	0.28	0.25
10	Yield (kg/tree)	61.75	75.05	89.11	43.81	109.52	69.99
11	Overall acceptability	7.9	7.9	7.9	7.9	7.9	7.9

4.8 Molecular characterization

The genomic DNAs of the following derivatives of mango derivatives were subjected to PCR amplification using SSR primers.

Table 36. List of mango derivatives

Sr. No.	Varieties	Sr. No.	Derivatives
1	Alphonso	7	H-4
2	Sai Sugandh	8	H-6
3	Ratna	9	H-7
4	Kesar	10	H-10
5	Totapuri	11	H-12
6	Neelum	12	H-52

4.8.1 Molecular characterization by SSR primers

4.8.1.1 SSR analysis of genomic DNAs of six derivatives and six check varieties of mango

The genomic DNAs of the above six derivatives (Table 36) of mango and six check varieties were subjected to PCR amplification using 12 simple sequence repeat primers (SSR). Among 12 primers employed in the present investigation, 09 primers

amplified the genomic DNAs of the mango leaves (Table 37). SSR primers used for molecular analysis in mango which were found polymorphic are listed in Table 37.

SSR analysis in between selected mango derivatives

The SSR profiles of the six mango derivatives and six check varieties were individually computed for each of the 9 primers and were then used for further analysis. The twelve derivatives were namely Alphonso, Sai Sugandh, Ratna, Kesar, Totapuri, Neelum, H-4, H-6, H-7, H-10, H-12 and H-52. These were taken to assess the genetic similarity and distinctiveness. Analysis of the SSR pattern of the genomic DNA of these varieties under study was done with respect to the fragments, efficiency of the markers and polymorphism for molecular profiling of the six mango derivatives and six check varieties.

The SSR markers are polymorphic, co-dominant, highly abundant, widely distributed throughout the genome, readily transferable and analytically simple in nature. SSRs are found to be highly variable as compared to RAPD or RFLP and have been reported to be utilized extensively in various genomic studies by Viruel *et al*. (2005) and Brown *et al*. (1996), In comparison to other markers they may be felt more successfull, when these will be used to trace most anticipated characters on large scale in mango improvement programmes as anchored point map based system for cloning strategies of desirable traits.

4.8.1.2 Per cent polymorphism in mango derivatives

The primer wise amplification detail of the genomic DNA of twelve derivatives and per cent polymorphism across the 9 SSR primers is mentioned in the Table. A total of 100 scorable DNA fragments were produced. Out of these 100, all the fragments were found to be polymorphic. The minimum number of bands (10) were produced by primer MiIIHR24, while the maximum number of bands (12) were produced by primers MiIIHR 12 and MiIIHR 34. The average per cent polymorphism across the 9 SSR primers between twelve derivatives was found to be 100 per cent. All the 9 SSR primers showed 100 per cent polymorphism. The size of amplified primer MiIIHR12 ranged from 150 to 170, MiIIHR13 ranged from 170 to 190, MiIIHR17 ranged from 180 to 190, MiIIHR19 ranged from 170 to 190, MiIIHR24 ranged from 270 to 290,

MiIIHR30 ranged from 180 to 200, MiIIHR31 ranged from 190 to 200, MiIIHR32 ranged from 170 to 180, MiIIHR34 ranged from 220 to 250.

4.8.1.3 Genetic distance between mango derivatives

The genetic distance was computed considering all the six mango derivatives and six check varieties from the pooled data and construction of the dendrogram was done. The distance similarity matrix is based on Jaccard's similarity coefficient and is presented in Table 38 . The overall range of the similarity between twelve mango derivatives was 0.778 to 0.059. The maximum similarity coefficient (0.778) was observed between Ratna and Totapuri, while lowest similarity coefficient (0.059) was observed between Alphonso and H-7 and also between H-4 and H-12 (Table 38).

Table 37. Primer-wise amplification and the per cent polymorphism of mango genotype

Sr. No.	Primer Name	Total number of bands	Total number of Polymorphic bands	Polymorphism (%)	Allele size (bp)
1.	MiIIHR12	12	12	100	150-170
2.	MiIIHR13	11	11	100	170-190
3.	MiIIHR17	11	11	100	180-190
4.	MiIIHR19	11	11	100	170-190
5.	MiIIHR24	10	10	100	270-290
6.	MiIIHR30	11	11	100	180-200
7.	MiIIHR31	11	11	100	190-200
8.	MiIIHR32	11	11	100	170-180
9.	MiIIHR34	12	12	100	220-250
	Total	**100**	**100**	**-**	150-170
	Average	**11.11**	**11.11**	**100**	

Kumar *et al*. (2001) also reported Jaccard`s similarity in the range of 61 to 95 per cent in 50 Indian cultivars and Fitmawati *et al*. (2010) observed 69 to 98 per cent similarity in 82 cultivars of mango from Indonesia, where as similarity in present material was 40 to 69 per cent. Obviously, the present material was genetically more diverse than that used by the above researchers. Jaccard's similarity coefficient uses only the presence of bands among derivatives as similarity and not the absence of bands (Jaccard, 1908), as the absence of bands could be due to several reasons like duplication, deletion, point mutation, inverse etc., resulting in abolition of the site. The molecular analysis of 11 mango derivatives suggested that diversity is moderate to high and has

shown differences, if the similarity matrices were used, which indicated that the reasons for absence of bands are not the same and hence they are more diverse. Autopolyploidy, out breeding, wide range of agro-climatic conditions prevailing in different mango growing regions, wide spread hybridization and recombination of characters have contributed immensely to the existing variability in mango (Ravishankar *et al*., 2000). Moreover, the high genetic diversity within populations is explained by the breeding system since mango is an allogamous species (Ward *et al*., 2005). Shamili *et al.* (2012) found 35-100 per cent genetic similarity among 41 mango cultivars using 16 SSR markers. Similarly, Kumar *et al.* (2013) used 20 SSR markers to study genetic relationships among 10 mango cultivars and reported similarity coefficients of 59-100 per cent, revealing valuable levels of genetic diversity.

4.8.1.4 Cluster analysis of mango derivatives

The construction of dendrogram (Fig. 9) based on Jaccard's similarity coefficient was done using UPGMA after analysis of banding patterns generated by six mango derivatives and six check varieties using 9 SSR primers. Grouping of the genotypes in different clusters is helpful to identify parental lines for breeding or further development of varieties through selection (Karanjalker and Begane, 2016; Majumder *et al.,* 2013). Hence, the resulted cultivar clusters with distinguished characters can be used in mango improvement programs of the country. Likewise, several findings reported on clustering of mango cultivars with their distinguishing traits (Ahmed and Mohamed, 2015; Gitahi *et al.,* 2016; Kheshin *et al.,* 2016; Mohamed and Ahmed, 2015; Sennhenn *et al.,* 2013). The dendrogram grouped the six mango derivatives and six check varieties into two main clusters, *viz*; I and II. Cluster I was divided into two sub-clusters *viz*; IA and IB. IA consisted of two derivatives namely, H-52 and H-12 while IB consisted of two derivatives namely, H-10 and H-7. Cluster II was divided into two sub clusters, *viz*; IIA and IIB. IIA contained only one derivative i.e. H-6. However, IIB was sub-grouped into IIBa and IIBb. IIBa consisted of six derivatives and check varieties namely, Kesar, H-4, Neelum, Totapuri, Ratna and Sai Sugandh. IIBb consisted of only one check variety i.e. Alphonso (Table 39).

Table 38. Genetic similarity coefficient based on SSRs pooled over the 9 primers in 12 derivatives of Mango

	Alphonso	**Sai sugandh**	**Ratna**	**Keshar**	**Totapuri**	**Neelam**	**H-4**	**H-6**	**H-7**	**H-10**	**H-12**	**H-52**
Alphonso	1											
Sai sugandh	0.417	1										
Ratna	0.417	0.6	1									
Keshar	0.364	0.273	0.4	1								
Totapuri	0.308	0.455	0.778	0.4	1							
Neelam	0.286	0.308	0.545	0.5	0.545	1						
H-4	0.286	0.545	0.545	0.364	0.545	0.636	1					
H-6	0.125	0.214	0.214	0.25	0.308	0.5	0.5	1				
H-7	0.059	0	0.133	0.25	0.214	0.286	0.125	0.385	1			
H-10	0.133	0	0.143	0.273	0.231	0.308	0.133	0.308	0.7	1		
H-12	0.059	0	0.063	0.071	0.133	0.125	0.059	0.2	0.5	0.545	1	
H-52	0.063	0	0	0	0	0	0	0.133	0.308	0.333	0.7	1
	Alphonso	**Sai sugandh**	**Ratna**	**Keshar**	**Totapuri**	**Neelam**	**H-4**	**H-6**	**H-7**	**H-10**	**H-12**	**H-52**

Cluster I

It comprised of four derivatives viz. H-52, H-12, H-10 and H-7. A higher level of genetic relationship was observed among these derivatives. Cluster I was divided into two sub clusters viz. IA and IB.

Sub-cluster IA

It consisted of two hybrid derivatives H-52 and H-12 and showed high level of genetic relation.

Sub-cluster IB

It consisted of two hybrid derivatives H-10 and H-7 and showed high level of genetic relation.

Cluster II

This cluster was the largest cluster showing high similarity between the derivatives comprising 8 derivatives and was further bifurcated into two sub-clusters IIA and IIB. IIA consisted of only one genotype H-6 and sub-cluster IIB was further sub grouped into IIBa and IIBb. IIBa contained one hybrid genotype H-4 and five check varieties Kesar, Neelum, Totapuri, Sai Sugandh and Ratna and IIBa consisted of only one parent Alphonso separating itself from other check varieties and hybrid derivatives.

Table 39. SSR clustering pattern of twelve mango derivatives

Clusters			Number of derivatives	Name of genotype
I	**IA**		2	H-52, H-12
	IB		2	H-10, H-7
II	**IIA**		1	H-6
	IIB	**IIBa**	6	Kesar, H-4, Neelum, Totapuri, Ratna, Sai Sugandh
		IIBb	1	Alphonso

4.8.1.5 Polymorphic information content

The PIC values act as evidence that SSR markers were highly informative and polymorphic. It was observed that, for all tested SSR loci, there was the great variation in PIC value of each marker, which can be calculated based on its alleles. The efficiency of the SSR primers in differentiating the mango derivatives was found out by

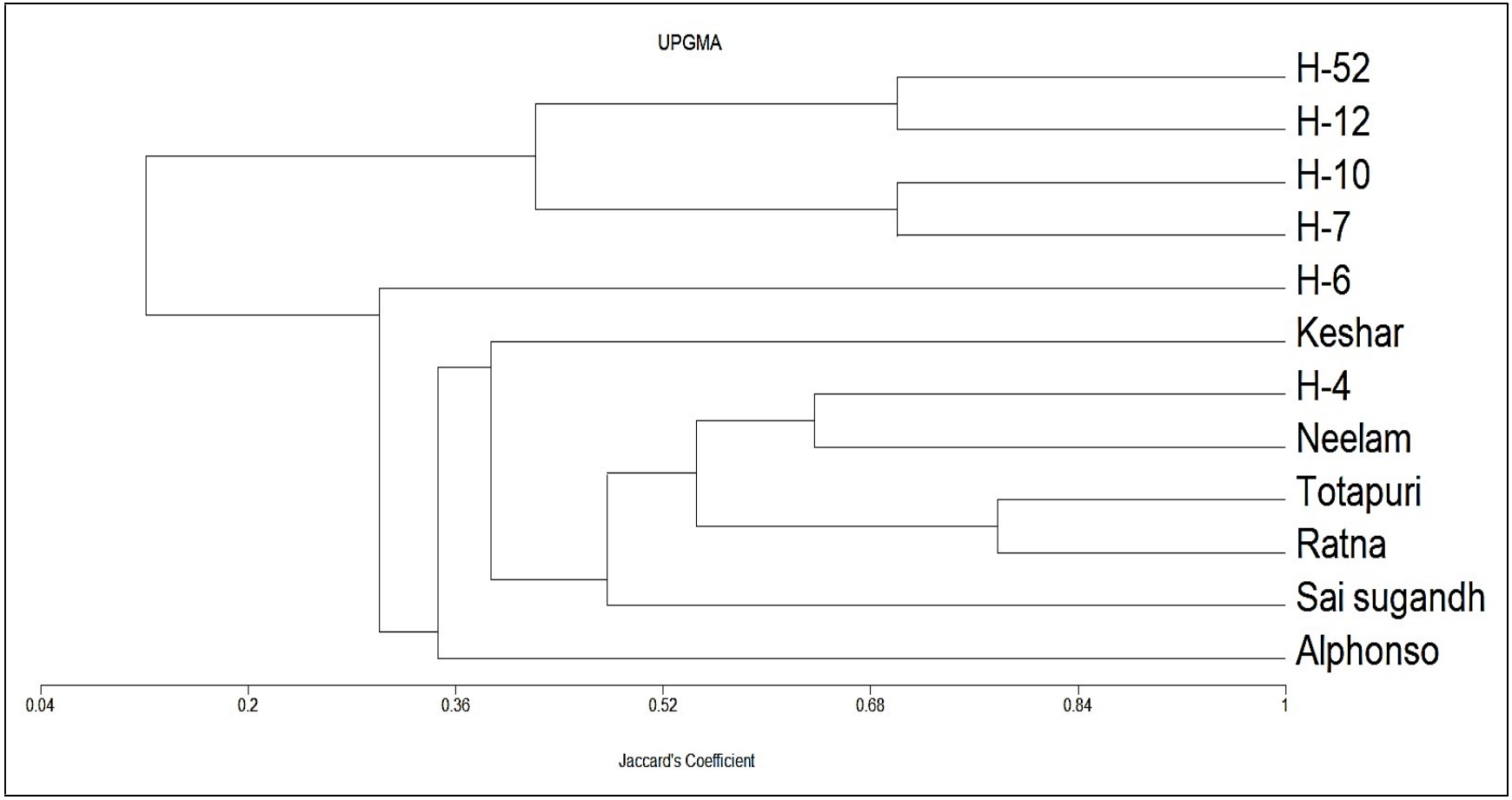


Fig. 6. Dendrogram depicting twelve derivatives of mango based on the genetic distance by 9 SSR primers

calculating the PIC values. The PIC values of 9 SSR markers are given in Table 40. Analysis of the SSR profile generated by each primer was done using standard DNA marker (1 kb) and then compared with their respective banding pattern.

The primer MiIIHR12 showed the highest PIC value (0.680), followed by the primer MiIIHR34 (0.650). The lowest PIC value was 0.300 which was shown by the primer MiIIHR17. Average polymorphic information content among all the Mango derivatives under study was 0.508.

The PIC value predicts the potential utility of DNA markers for germplasm assessment, molecular breeding, and gene mapping. Markers that exhibit higher PIC values have a greater potential of disclosing allelic variation (Spandana *et al.,* 2012).

Table 40. Average PIC values 9 SSR markers

Sr. No.	Primer	PIC value
1.	MiIIHR12	0.680
2.	MiIIHR13	0.560
3.	MiIIHR17	0.300
4.	MiIIHR19	0.430
5.	MiIIHR24	0.540
6.	MiIIHR30	0.500
7.	MiIIHR31	0.460
8.	MiIIHR32	0.460
9.	MiIIHR34	0.650
	Average PIC Value	**0.508**

5. SUMMARY AND CONCLUSION

Mango is the most important fruit crop in India having socio-economic significance. It is known as 'King of fruits' owing to delicious quality of fruit rich in vitamins and minerals. It has commercial importance not only as desert purpose fruit but also due to its medicinal importance. Mango exhibits large diversity in terms of quality and yield due to the presence of high heterozygosity, seed propagation and indiscriminate selection. The diversity in mango comprise native landraces, local selections and elite cultivars of mango. Systematic characterization of physico-chemical characters of available germplasm provides the extent of genetic diversity in the fruit species and facilitate in identifying the superior genotype with desired characters. Use of morphological and molecular markers in fruit crop improvement has been reported by many scientists in recent years. With the availability of recent technologies, the genotypes were screened for morphological and biochemical traits and those found superior were further studied for molecular characterization. The results obtained during the course of investigations are summarized below.

SUMMARY

5.1 Morphological characterisation

5.1.1 Tree characters

A great variation was noticed with respect to the tree height. It varied from 6.47 to 12.19 m. The maximum tree height was recorded in hybrid-33 (12.19 m) whereas minimum was recorded in hybrid-52 (6.47 m). Tree volume varied from 100.6 to 256.54 m^3. The maximum volume of tree was noted in hybrid-33 (256.54 m^3) whereas minimum volume of tree was noted in hybrid-29 (100.60 m^3).

5.1.2 Leaf characters

The pooled data revealed that the leaf length varied from 15.50 to 35.15 cm. The highest leaf length was recorded in hybrid-10 (35.15 cm) and the lowest was recorded in hybrid-57 (15.50 cm). The pooled data of both seasons revealed that the leaf breadth ranged from 3.26 to 8.80 cm. The maximum leaf breadth was recorded in hybrid-10 (8.80 cm) and minimum was recorded in hybrid-57 (3.26 cm).

All hybrid progenies had simple leaves.

Leaf colour showed variation among the hybrid genotypes however twenty-four hybrid genotypes showed dark green coloured leaves whereas seventeen hybrid genotypes showed green coloured leaves while one hybrid-30 showed light green coloured leaves.

The leaves of hybrids were observed for their waxy nature, however all the hybrid progenies showed non-waxy leaves.

5.1.3 Flowering characters

The highest number of days from bud burst to full bloom was recorded by hybrid-6 (62.5 days) and lowest was recorded by hybrid-52 (51.5 days).

Among all the genotypes under investigation, it was revealed that the last panicle emergence was observed in hybrid-46 (1st January) in the year 2015-16 whereas in the year 2016-17 it was observed in hybrid-22 (29th December). Among all the hybrid genotypes studied the inflorescence of eighteen genotypes were broadly pyramidal, fourteen genotypes had narrowly pyramidal inflorescences while ten genotypes had pyramidal inflorescences.

The inflorescence length of hybrid genotypes ranged from and 13.98 cm to 30.77 cm. The longest inflorescence length (30.77 cm) was recorded by hybrid-46 whereas lowest was recorded in hybrid-25 (13.98 cm).

The inflorescence breadth ranged between 6.10 to 16.33 cm among different genotypes. The larger inflorescence breadth (16.33 cm) was recorded by hybrid-46, whereas lowest was recorded in hybrid-25 (6.10 cm). Number of vegetative flushes observed in all genotypes in both years 2015-16 and 2016-17 were two.

Colour of panicle it revealed remarkable disparity in the colour of inflorescence among mango genotypes studied. Green coloured panicles were observed in twenty-four hybrids whereas six panicles appeared to be yellow, one reddish yellow, five reddish green, two light green and four reddish. Among all hybrid progenies, thirty progenies showed yellow coloured flowers, one yellowish pink, one reddish yellow, one light yellow, one red coloured and one yellowish green.

The highest number of hermaphrodite flowers per panicle was recorded in hybrid-26 (365.5) whereas it was found least in hybrid-15 (112.15). The highest number of male flowers per panicle was recorded in hybrid-26 (971.5) whereas least was

recorded in hybrid-55 (339.65). Remarkable differences in the hermaphrodite flower to male ratio has been observed among mango genotypes studied and it varied from 0.15 to 0.47. The highest ratio was observed in hybrid-6 (0.47) and lowest was observed in hybrid-15 (0.15).

Number of inflorescence per shoot in all forty-two genotypes observed throughout the investigation years 2015-16 and 2016-17 was one. The pooled analysis revealed that the number of rachis per panicle ranged from 15.48 to 28.16. The highest number of rachis was recorded in hybrid-6 (28.16) whereas lowest was recorded in hybrid-23 (15.48).

There was notable variation recorded in the flowering duration, among all the genotypes under this experimentation ranged from 19 to 31.50 days. The longest flowering duration was recorded in hybrid-22 (31.50 days), whereas shortest was perceived in hybrid-33 (19 days).

5.1.4 Fruit morphology

The pooled data revealed that the number of days from fruit setting to mustard stage recorded was from 5 to 7 days for all the hybrid progenies.

The present investigation revealed that the number of fruits per panicle ranged from 46.20 to 69.6. The highest number of fruits per panicle was recorded in hyrid-6 (69.65) in pooled data whereas lowest was recorded in hybrid-30 (46.20). The pooled data revealed that the number of days from mustard stage to pea stage ranged from 10.50 to 14 days. The highest number of days required was recorded by hybrid-32 (14 days) while the number of days from pea stage to marble stage ranged from 13.50 to 15.50 days.

Fruit retension per cent ranged from 1.81 to 3.80 %. The highest fruit retension per cent was recorded in hybrid-7 (3.80) whereas, lowest fruit retension per cent was recorded in hybrid-34 (1.81).

Fruit shape was elliptic in seventeen genotypes, oblong in eleven genotypes, roundish in eight genotypes, obovoid in five genotypes and ovoid in remaining one genotype.

The fruit length ranged from 6.46 to 15.04 cm. The maximum fruit length was recorded in hybrid-46 (15.04 cm) and minimum length was noted in hybrid-17 (6.46

cm). Fruit breadth of mango progenies ranged from 4.86 cm to 8.91 cm. The data revealed that the maximum fruit breadth (8.91 cm) was recorded in hybrid-46 whereas minimum was reported in hybrid- 55 (4.90 cm).

The fruit weight ranged from 94.95 to 583.45 g. The highest weight of fruit was recorded in hybrid-46 (583.45 g) and the lowest fruit weight was recorded in hybrid-17 (94.95 g). The volume of the fruit ranged from 94.04 to 562.58 cm^3 and was found maximum in hybrid-46 (562.58 cm^3) whereas lowest fruit volume was recorded in hybrid-17 (94.04 cm^3).

Among all the hybrid genotypes studied fruit beak of twenty-five progenies was recorded as perceptible, eleven as pointed, four mammiformed and two prominent. The apex of the fruit was recorded as obtuse, acute and round however, twenty-nine hybrid genotypes showed obtuse fruit apex, twelve genotypes had acute fruit apex and remaining one genotype had roundish fruit apex.

Fruit base of twenty-nine genotypes were recorded as obliquely round, four were recorded as slightly flattened and extended, three necked, two flattened, one obliquely flattened, one slightly flattened, one round flattened and one slightly obliquely flattened. The colour of fruit was observed and recorded as green, dark green and light green, almost all the hybrid genotypes studied produced green coloured fruits when unripe except hybrid-18, 19 and hybrid-23 which showed dark green fruits and hybrid-4 had light green fruits. Fruit stalk insertion was vertical in thirty-two hybrid genotypes and in remaining ten genotypes it was oblique.

Fruit shoulder of twenty-two genotypes appeared to be ending in long curve, sixteen hybrid genotypes had rising and then rounded fruit shoulder and in remaining four genotypes it was sloping abruptly. The skin colour of ripe fruit was yellow in thirty-four progenies, three genotypes were having greenish yellow and remaining five genotypes showed no change in colour after ripening and appeared green. Fruit skin thickness ranged from 0.6 to 1.4 mm. The highest skin thickness was recorded in hybrid-46 (1.4 mm) and the lowest was recorded in hybrid-18 (0.6 mm).

The skin percentage of fruit ranged between 11.90 to 33.86 per cent. The maximum skin per cent was recorded in hybrid-46 (33.86 %) and minimum was recorded

in hybrid-35 (11.90 %). The fruit skin was waxy in twenty-eight progenies and non-waxy in fourteen progenies.

5.1.5 Pulp

The pulp colour was yellow in twenty-two genotypes, orange in twelve genotypes, creamish in three genotypes, yellowish orange in three genotypes and creamish yellow in two genotypes. The pulp texture was recorded as soft, firm and intermediate however 30 genotypes had soft textured pulp, 8 genotypes had intermediate pulp texture while 4 genotypes had firm textured pulp. The pulp of twenty hybrid genotypes had intermediate fibrousness, eleven genotypes recorded low pulp fibrousness, seven genotypes had high pulp fibrousness and pulp fibrousness was absent in four genotypes.

The pulp percentage ranged from 37.11 to 80.83 per cent. The maximum pulp percentage was recorded in hybrid-52 (80.83 %) whereas minimum was recorded in hybrid-16 (37.11 %).

5.1.6 Stone

The stone shape was recorded oblong in thirty genotypes, nine genotypes had reniform stones and three genotypes had ellipsoidal stones.

The stone length ranged from 4.62 to 12.81 cm. The maximum stone length was recorded in hybrid-46 (12.81 cm) whereas minimum was recorded in hybrid-29 (4.62 cm). The stone width varied from 2.51 to 6.25 cm. The highest breadth was recorded in hybrid-46 (6.25 cm) whereas lowest was recorded in hybrid-57 (2.51 cm).

The stone weight ranged from 9.32 to 85.26 g. The maximum weight was recorded in hybrid-46 (85.26 g) and the minimum weight was recorded in hybrid-25 (9.32 g). The stone volume ranged from 9.15 to 82.50 cm^3. The maximum stone volume exhibited in hybrid-46 (82.50 cm^3) and the minimum stone volume was recorded in hybrid-25 (9.15 cm^3).

5.2 Biochemical characters

Among different cultivars TSS ranged from 11.95 to 20.85 ^{0}B. Hybrid-6 had the highest total soluble solids (20.85 ^{0}B) whereas hybrid-13 recorded minimum TSS (11.95 ^{0}B). The total sugar content varied from 8.51 to 17.46 per cent. The highest total sugar content was recorded in hybrid-26 (17.46 %), the lowest was recorded in hybrid-2

(8.51 %). Notable difference in reducing sugar content of mango genotypes has been observed, highest reducing sugar was recorded in hybrid-8 (4.77 %) and lowest was recorded in hybrid-46 (1.03 %). The non reducing sugar ranged from 5.66 to 14.32 per cent. The highest non reducing sugar content was recorded in hybrid-26 (14.32 %) and lowest was recorded in hybrid-2 (5.66 %).

The acidity of pulp ranged between 0.16 to 0.45 per cent. The maximum acidity of pulp was recorded in hybrid-46 (0.45 %) and lowest was recorded in hybrid-35 (0.16 %) while, pH varied from 2.29 to 4.90. The highest pH of pulp was recorded in hybrid-68 (4.90) and lowest in hybrid-46 (2.29).

The β- carotene content in mango genotypes ranged from 1008.5 to 2458.5 µg/100g. Of all the genotypes hybrid-1 revealed highest β- carotene content (2458.5 µg/100g) and lowest was recorded in hybrid-46 (1008.5 µg/100g) while, the ascorbic acid content in mango pulp ranged from 13 to 37 mg/100g. Highest ascorbic acid content was recorded in hybrid-46 (37 mg/100g) whereas hybrid-55 recorded lowest ascorbic acid content (13 mg/100g).

There was remarkable difference in TSS to acidity ratio and it varied from 26.68 to 101.35. It was found highest in hybrid-35 (101.35) and lowest was recorded in hybrid-46 (26.68). Noteworthy disparity in sugar to acid ratio of mango progenies was observed however, 20.19 to 83.47. Highest sugars to acidity ratio was recorded in hybrid-21 (83.47) whereas lowest was recorded in hybrid-46 (20.19). The fiber content in fruit pulp ranged from 0.11 to 0.97 per cent. The highest content was recorded in hybrid-1 (0.97 %) whereas lowest was recorded in hybrid-2 (0.11 %).

5.3 Qualitative characters (Sensory evaluation)

The highest score for overall acceptability was obtained for hybrid-4, 6, 7, 10, 12 and 52 (7.9) and the least score was obtained for hybrid-15 (5.1).

5.4 Yield characters

Days required for harvesting ranged from 107 to 181 days. Maximum number of days required for harvesting hybrid-26 (181 days) whereas minimum number of days was recorded in hybrid-10 (107 days).

Notable variation was observed on the number of fruits harvested per tree and it ranged from 65.5 to 319.5. The maximum number of fruits harvested per tree was noticed in hybrid-7 (319.5) while, least was observed in hybrid-34 (65.5).

The yield per tree varied from 9.12 kg to 128.70 kg. The highest yield per tree was recorded by hybrid-26 (128.70 Kg), whereas hybrid-16 recorded lowest yield (9.12 kg).

5.5 Shelf life

The shelf life of mango hybrid genotypes ranged from 5.4 days to 9.65 days. The longest shelf life during storage at ambient condition was documented in hybrid-6 (9.65 days) and shortest was recorded in hybrid-68 (5.4 days).

5.6 Reaction to physiological disorders

The pooled data revealed the maximum percentage in hybrid-14 and 24 (26.5 %) with a rating of grade 9 and was found to be susceptible and minimum percentage of incidence was in hybrid-22 (10.0 %) with a rating of grade-5 and was found to be tolerant. There was no incidence of black tip, spongy tissue and water tissue observed during the period of investigation.

5.7 Reaction to diseases

The pooled data revealed maximum percentage in hybrid-30 (6.40) and minimum percentage of incidence was observed in hybrid-16 (1.90). Incidence of anthracnose was not observed during the period of investigation.

5.8 Molecular characterization

A study on molecular characterization in the hybrid mango genotypes was one of the objectives of the present study. Out of forty-two genotypes, six promising types and six check varieties were selected on the basis of quality parameters and those were screened for molecular characterization from SSR markers. The genomic DNAs of the six genotypes of mango and six check varieties were subjected to PCR amplification using 12 simple sequence repeat primers (SSR). Among 12 primers employed in the present investigation, 09 primers amplified the genomic DNAs of the mango leaves.

A total of 100 scorable DNA fragments were produced. Out of these 100, all the fragments were found polymorphic.

The minimum number of bands (10) was produced by primer MiIIHR24, while the maximum number of bands (12) were produced by primers MiIIHR12 and MiIIHR34.

The average per cent polymorphism across the 9 SSR primers between twelve genotypes was found to be 100 per cent. All the 9 SSR primers showed 100 per cent polymorphism.

The size of amplified primer MiIIHR12 ranged from 150 to 170, MiIIHR13 ranged from 170 to 190, MiIIHR17 ranged from 180 to 190, MiIIHR19 ranged from 170 to 190, MiIIHR24 ranged from 270 to 290, MiIIHR30 ranged from 180 to 200, MiIIHR31 ranged from 190 to 200, MiIIHR32 ranged from 170 to 180, MiIIHR34 ranged from 220 to 250.

The distance similarity matrix based on Jaccard's similarity coefficient showed the overall range of the similarity between six mango genotypes and six parents was 0.778 to 0.059. The maximum similarity coefficient (0.778) was observed between Ratna and Totapuri, while lowest similarity coefficient (0.059) was observed between Alphonso and H-7 and also between H-4 and H-12. The dendrogram grouped the twelve genotypes into two main clusters, *viz*., I and II. Cluster I was divided into two sub-clusters *viz*., IA and IB. Cluster II was divided into two sub clusters, *viz*., IIA and IIB.

CONCLUSION

Based on the results obtained from the present investigation, the following conclusions emerged.

The study on physio-morphological, floral biological and fruit characteristics of mango genotypes showed that there are variations among the genotypes. This gives the opportunity to select genotype on the basis of desirable characters. The improved variety of mango may be developed using the variability of collected genotypes.

The mango genotype diversity data generated will be valuable to communities, scientists and policy managers to formulate and implement conservation strategies of *in situ, on-farm* as well as *ex situ* conservation and management of these genetic resources.

Out of forty six hybrid derivatives studied during the investigation six hybrid derivatives were found promising with desirable characters.

As regards to TSS and Total sugars, Hybrid-6 had the highest total soluble solids (20.85 ^{0}B). The highest total sugar content was recorded in hybrid-26 17.46 %) in pooled data.

The highest score for overall acceptability was obtained by hybrids-4, 6, 7, 10, 12 and 52 (7.9) through sensory evaluation.

The maximum number of fruits harvested per tree was noticed in hybrid-7 (315.0, 324.0 and 319.5). During the investigation, highest yield per tree was recorded by hybrid-26 (133.89 kg, 123.51 kg and 128.70 kg) in 2015-16, 2016-17 and pooled data.

Longest shelf life during storage at ambient condition was documented in hybrid-6 (9.65 days).

The hybrids viz., Hybrid-4, 6, 7 10, 12 and 52 were observed to be early, regular bearer, free from diseases and physiological disorders. As they possessed the quality attributes they were further studied for molecular analysis using SSR markers.

Among 12 SSR primers, 9 primers showed polymorphism and produced total 100 bands out of which all bands were polymorphic and yielded 100 per cent average polymorphism.

The overall range of the similarity between twelve mango genotypes was 0.778 to 0.059. The maximum similarity coefficient (0.778) was observed between Ratna and Totapuri, while lowest similarity coefficient (0.059) was observed between Alphonso and H-7 and also between H-4 and H-12.

The UPGMA cluster analysis based on SSR analysis showed that one of the parent formed independent cluster.

A mango breeding programme based on morpho-physiological characterization of fruits and molecular analysis of genotypes may help in developing new improved cultivars for mango growers.

The results of the investigation shows the efficacy of SSR markers for assessment of genetic relationship and diversity.

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7. APPENDICES

Appendix- Ia

Climatological data during 2015-16 (Nov 2015 to June 2016)

Met. Week	Temperature (^{O}C)		Relative humidity (%)		Sunshine (hrs.)	Rainfall (mm)	Rainy days
	Max.	Min.	Morn.	Even.			
November 2015							
45	32.9	17.2	58	36	8.2	26.0	2
46	32.4	14.5	50	30	9.5	0.0	0
47	30.1	17.9	71	59	5.1	0.0	0
48	31.6	17.8	70	44	7.6	0.0	0
December 2015							
49	31.6	13.9	57	32	9.4	0.0	0
50	32.3	16.0	49	33	9.0	0.0	0
51	31.1	13.7	64	35	8.6	0.0	0
52	28.3	7.8	37	22	9.7	0.0	0
January 2016							
1	31.4	11.6	47	26	9.5	0.0	0
2	30.3	11.8	47	27	8.4	0.0	0
3	28.7	11.8	59	30	9.1	0.0	0
4	29.4	9.3	46	22	9.9	0.0	0
5	29.5	12.0	47	25	10.3	0.0	0
February 2016							
6	32.4	13.4	53	24	9.7	0.0	0
7	32.3	14.9	64	27	8.3	0.0	0
8	35.0	17.5	52	23	9.4	0.0	0
9	35.3	18.6	56	28	7.8	10.2	2
March 2016							
10	34.5	17.1	51	22	8.1	-	
11	35.8	17.3	40	20	9.2	0.0	-
12	37.1	18.7	35	17	9.1	0.0	-
13	39.0	19.3	34	18	8.6	0.0	-
April 2016							
14	39.0	21.5	40	22	8.2	0.0	-
15	39.0	20.6	37	20	9.8	0.0	-
16	39.9	22.7	38	22	9.0	0.0	-
17	39.0	20.6	41	19	10.6	0.0	-
18	39.9	22.7	30	17	10.4	0.0	-
May 2016							
19	39.0	24.2	47	27	9.3	1.4	-
20	41.2	25.3	44	25	8.5	5.8	1
21	38.6	24.2	55	24	10.6	46.0	1
22	37.9	25.7	58	30	10.0	1.8	-

Contd….

Met. Week	Temperature (^{O}C)		Relative humidity (%)		Sunshine (hrs.)	Rainfall (mm)	Rainy days
	Max.	Min.	Morn.	Even.			
June 2016							
23	37.1	24.1	66.6	39.6	5.5	36.4	1
24	35.5	24.8	55.9	41.7	7.4	0.0	0
25	32.7	23.7	70.4	58.4	4.2	108.2	4
26	31.5	23.3	72.7	62.1	3.2	16.8	2

Appendix- Ib

Climatological data during 2016-17 (Oct 2016 to April 2017)

Met. Week	Temperature (^{O}C)		Relative humidity (%)		Sunshine (hrs.)	Rainfall (mm)	Rainy days
	Max.	Min.	Morn.	Even.			
October 2016							
40	28.6	21.5	87.3	71.4	3.9	110.6	2
41	31.6	20.6	80.4	53.3	7.1	0.0	0
42	31.8	17.2	66.6	39.0	8.1	0.0	0
43	31.3	16.4	65.9	35.6	9.1	0.0	0
44	30.1	13.4	51.4	40.6	9.5	0.0	0
November 2016							
45	29.6	11.7	52.0	25.3	9.5	0.0	0
46	29.5	12.6	64.4	40.7	7.5	0.0	0
47	29.1	10.1	56.0	26.7	9.3	0.0	0
48	30.9	10.5	62.0	26.0	9.5	0.0	0
December 2016							
49	28.9	11.2	63.7	34.4	8.6	0.0	0
50	28.7	11.7	51.7	36.9	7.8	0.0	0
51	29.2	10.2	54.0	34.4	9.3	0.0	0
52	29.4	8.7	56.5	28.5	9.5	0.0	0
January 2017							
1	29.3	9.3	57.3	34.0	9.6	0.0	0
2	26.5	8.9	60.6	34.0	9.4	0.0	0
3	28.8	13.5	68.1	39.3	6.7	0.0	0
4	31.0	13.0	61.9	30.0	9.4	0.0	0
5	31.3	12.8	59.4	27.9	9.9	0.0	0
February 2017							
6	31.7	13.6	59.4	32.0	9.5	0.0	0
7	32.3	13.9	52.6	26.1	9.7	0.0	0
8	34.6	13.8	45.3	20.6	10.7	0.0	0
9	34.6	14.0	41.3	14.9	9.8	0.0	0
March 2017							
10	32.8	13.9	47.1	22.6	9.1	0.0	0
11	33.0	13.6	32.9	16.6	9.2	0.0	0
12	36.1	17.2	38.0	14.9	9.1	0.0	0
13	39.9	21.0	40.6	14.6	9.1	0.0	0
April 2017							
14	38.5	17.4	37.9	14.6	9.3	0.0	0
15	39.5	18.0	30.7	11.1	10.1	0.0	0
16	41.3	20.6	35.7	11.6	10.7	0.0	0
17	38.6	18.5	44.4	13.6	10.6	0.0	0
18	39.8	22.3	40.7	15.7	10.2	0.0	0

Contd….

Met. Week	Temperature (^{O}C)		Relative humidity (%)		Sunshine (hrs.)	Rainfall (mm)	Rainy days
	Max.	Min.	Morn.	Even.			
May 2017							
19	40.5	22.9	50	19	9.9	2.8	0
20	39.6	23.4	58	22	8.5	0.0	0
21	40.1	22.9	53	23	23.2	7.4	1
22	38.5	24.7	62	34	10.2	27.4	1
June 2017							
23	35.5	23.6	75	39	6.2	9.8	2
24	32.6	22.83	82	53	5.1	93.8	5
25	35.1	24	72	46	8.9	2.4	0
26	32.5	23.5	73	56	3.3	8.2	1
27	29.6	23.6	79	70	0.5	11.2	1

8. VITAE

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IN

FRUIT SCIENCE

2022

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