CLASSIFICATION OF DIFFERENT VARIETIES AND NEW ACCESSIONS OF MANGO (*Mangifera indica* L.) BASED ON QUALITATIVE TRAITS AND ASSESSMENT OF GENETIC DIVERSITY

Thesis

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By

Satyendra Singh Narvariya
M.Sc. (Ag.)

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(Satyendra Singh Narvariya)
Author

C E R T I F I C A T E

This is to certify that the thesis entitled **"Classification of different varieties and new accessions of mango (*Mangifera indica* L.) based on qualitative traits and assessment of genetic diversity"** submitted in partial fulfilment of the requirements for the degree of **Doctor of Philosophy** with major in **Horticulture** and minor in **Plant Physiology** of the College of Post-Graduate Studies, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, is a record of *bona fide* research carried out by **Mr. Satyendra Singh Narvariya, Id. No. 40958** under my supervision and 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.

Pantnagar
October, 2016

(A.K. Singh)
Chairman
Advisory Committee

CERTIFICATE

We, the undersigned, members of the Advisory Committee of **Mr. Satyendra Singh Narvariya, Id. No. 40958,** a candidate for the degree of **Doctor of Philosophy** with major in **Horticulture** and minor in **Plant Physiology**, agree that the thesis entitled **"Classification of different varieties and new accessions of mango (*Mangifera indica* L.) based on qualitative traits and assessment of genetic diversity"** may be submitted in partial fulfilment of the requirements for the degree.

(A.K. Singh)
Chairman
Advisory Committee

(C.P. Singh) Member	**(D.C. Dimri)** Member	**(A.S. Nain)** Member
(P.K. Shrotria) Member		**(S.K. Guru)** Member

Ex-officio member
Head of the Department

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LIST OF SYMBOLS USED

%	Per cent
^0B	Degree brix
^0C	Degree centigrade
AMMI	Additive Main Effect and Multiplicative Interaction
AOAC	Association of officials analytical chemists
CD	Critical Difference
cm	Centimeter
CV	Coefficient of Variation
e.g.	For example
ECV	Environmental coefficient of variation
et.al.	Co-workers and others
Fig.	Figure
g	Gram
GA	Genetic Advance
GCV	Genotypic coefficients of variation
$h^2_{(b)}$	Broad sense heritability
i.e.	That is
kg	Kilo gram
mg	Mili gram
No.	Number
PCA	Principal Component Analysis.
PCV	Phenotypic coefficients of variation
S	Serial
SE	Standard Error
TSS	Total Soluble Solids

Introduction

Mango (*Mangifera indica* L.) is the most important commercial fruit of India. It belongs to the family Anacardiaceae and order Sapindales. It was originated in the South East Asian or Indo-Burma region. The genus *Mangifera* is having 69 recognized species as forest trees with fibrous and resinous fruits. Most of the cultivars of mango belong to single species *Mangifera indica* but few cultivars also belong to the other edible species such as *M. lagenefera* Griff, *M. odorata* Griff, *M. sylvatica* Roxb., *M. altissima* Blanco and *M. macrocarpa* Blume (Kostermans and Bompard, 1993).The mango tree is an arborescent evergreen with simple alternate leaves with high variation in leaf morphology. The mango inflorescence is a terminal panicle with large numbers of hermaphrodite and male flowers. The fruit is a drupe, with yellowish, often red-blushed exocarp, orange-yellow mesocarp and hard stone, fibrous endocarp**.**

Mango is considered as the "King of fruits" because of its high delicacy, flavour and nutritional value, attractive appearance, wide adaptability and popularity. Its fruit can be used at all stages of development; raw fruit is used for the extraction of tannins and other astringents, making curries, cold drink and pickles (Singh and Saxena, 2008). Mango fruit pulp is rich in antioxidants, provitamin A, carotenoids, vitamin C, prebiotic dietary fiber, diverse polyphenols and nutrient like potassium, copper and amino acids are present. There are many health benefits of mango fruit. The abundant bioactive compounds including carotenoids, phenolic compound, reducing sugar and vitamin C in mango are good antioxidants and their daily intake in the diet has been related to prevention of degenerative processes such as cardiovascular diseases and cancer etc. (Berardini *et al.,* 2005).

Mango is cultivated in tropical regions and distributed widely across the countries like Pakistan, Mexico, Brazil, Philippines, Myanmar, Vietnam, South Africa, Venezuela, Bangladesh and India. As many as 111 countries of the world have been growing mango but India continues to be the largest mango producing country in the world. In India, it is grown on an area of 2.21 million hectares with annual production of 18.50 million tonne having productivity of 8.35 metric tonne per hectare (Anonymous, 2015). In India, the major mango growing states are Uttar Pradesh andhra Pradesh, Karnataka, Bihar, Maharashtra, Gujarat, Tamilnadu, West Bengal and Odisha.

Majority of mango cultivars show eco-geographical preferences for growth and yield. Each cultivar is characterized by the combination of properties such as plant architecture, flowering attributes, fruit parameters like size, colour, taste, flavor, etc. The presence of diverse characters with a continuous variation in each one creates extreme complexity in the identification and classification of cultivars. Each mango cultivar is distinct from others in colour and flavor therefore varies in its suitability for specific uses. Proper identification of genetic resources or the parental lines are the basic need for successful crop improvement programme. Therefore, it should be recognized that all the germplasm available is useful one way or other (Knight, 1993). If certain genotype is lacking marketable value, then it may be suitable for some other use such as disease resistance, climatic adaptation, home gardening etc. (Cambell, 1995). Some verities are heavy yielder in respect of fruit number, while the others produce large fruits. But the main problem regarding the identification of exact cultivar is the wide range of variability in physico-chemical characters of fruit and the trees of different cultivars under different agro-climatic conditions. Mango has been reported to have extensive diversity due to alloploidy, out breeding, continuous grafting and phenotypic differences arising from varied agro-climatic conditions in different mango growing regions (Ravishankar *et al.*, 2000). Apart from numerous seedling varieties, more than a thousand vegetatively propagated mango cultivars have been reported. Most of these have originated as chance seedlings selected earlier and further maintained asexually. A large number of mango cultivars are grown in India but qualitative and quantitative traits such as morphological, physiological and quality parameters have not yet been studied in details**.** The physiological traits flowering and fruiting of a variety cannot be ignored because the yield is closely related to these parameters. The success in mango improvement primarily depends on the nature and magnitude of variation present in the population.

It is more important to classify the accessions into their homogeneous groups on the basis of multivariate parameters instead of using univariate method to distinguish the nature and structure of varieties so that it becomes helpful for improvement of population. At present, the vast genetic diversity of mango has not been thoroughly exploited either by using them directly or indirectly in the fruit breeding programmes. In addition, a lot of indigenous germplasm has not been characterized yet and systematic documentation of variability is lacking which needs attention in the light of Intellectual Property Rights issues. Genetic diversity amongst mango offers opportunity to utilize various genomic resources and technologies in efforts to manipulate desirable traits. Hence, systematic characterization, documentation and conservation of the varied gene pool are highly essential for future exploitation. It helps in eliminating duplicate accessions and in maintaining purity of germplasm.

Considering the potentiality of this crop, there is a need for improvement and development of varieties as per specific agro-ecological requirements. A thorough knowledge regarding the amount of genetic variability existing for various characters is essential for initiating the crop improvement programme. The phenotypic expression of the plant is mainly controlled by the genetic makeup and the environment, in which it is growing. Further, the genetic variance of any quantitative trait is composed of additive variance (heritable) and non-additive variance which includes dominance and epistasis (non-allelic interaction). Further, genetic advance can be used to predict the efficiency of selection. It is a known fact that higher variability creates greater chances of selection of desirable genotype. However, it is only the genetic variation which is heritable and hence important. Therefore, it is pertinent to partition the variability into phenotypic, genotypic and environmental components with suitable parameters such as phenotypic and genotypic coefficient of variation, heritability and genetic advance. A study of correlation among different quantitative characters provides an idea of association that could be effectively exploited to formulate selection strategies for improving yield components. For any effective selection programme, it would be desirable to consider the relative magnitude of association of various characters with yield. Moreover, genetic diversity present in the genotypes further play important role in characterizing the genotypes which can be utilized in selection of parents for hybridization programme.

The information on genetic divergence of various traits particularly of those that contribute to yield and quality would be of most useful in planning the breeding programme. The D^2 statistics developed by Mahalnobis (1936) provide a measure of magnitude for divergence between two genotypes under comparison. It considers the variation produced by any character and their consequent effect that it bears on other characters. This technique has been applied in several crops to select genotypes for further breeding programmes directed toward hybridization and recombination breeding. Grouping of genotypes based on D^2 analysis will be useful in choosing suitable parental lines for heterosis breeding. Such studies are also useful in selection of parents for hybridization to recover superior transgressive segregates and it can further result into release of improved open pollinated varieties for commercial cultivation.

Multivariate statistical methods such as Principal Component Analysis (PCA) and cluster analysis are valuable tools for monitoring cultivars, characterizing and classifying plant germplasm (Iezzoni and Pritts, 1991). Principal component analysis involves a mathematical procedure that transforms a number of (possible) correlated variables into number of uncorrelated variables called principal components. The first principal component accounts for as much of the variability in the data as possible and each succeeding component accounts for as much of the remaining variability as possible. The main application of factor analytic technique is to reduce the number of variables and to detect structure in the relationship between variables that is to classify variables. Therefore, factor analysis is applied as a data reduction or structure detection method. The principle component analysis is a multivariate analysis used to study the kind of variation present in the selected population (Wold, 1987).

Keeping in view the above facts, the investigation entitled "Classification of different varieties and new accessions of mango (*Mangifera indica* L.) based on qualitative traits and assessment of genetic diversity" was carried out with following broad objectives:

1. Assessment of the genetic variability present in the experimental material for different traits of economic importance.
2. Characterization and grouping of genotypes based on qualitative traits
3. Assessment of the genetic diversity using Mahalnobis D^2 and Principal Component Analysis.

Review of Literature

Chapter 2 REVIEW OF LITERATURE

Mango (*Mangifera indica* L.) is the most important commercial fruit of India and belongs to the family anacardiaceae. The morphological and physico-chemical traits such as tree, leaf, inflorescence and fruit characteristics are influenced by environmental factors and caused numerous synonyms. It is most important to classify the accessions into their homogeneous groups on the basis of multivariate parameters instead of using univariate method to identify the nature and structure of varieties and to avoid duplicacy of accessions.

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. Therefore, classification and characterization of varieties and new accessions based on qualitative traits and assessment of genetic diversity are essential for better use of varieties/genotypes in crop improvement programme.

The literature pertaining to qualitative traits and assessment of genetic diversity in different fruit crops have been reviewed. The brief account of available information along with supporting evidences in fruit crops have been described under following heads and sub-heads.

2.1 Morphological Qualitative Traits.

2.1.1 Tree traits

2.1.2 Leaf traits

2.1.3 Inflorescence traits

2.1.4 Fruit traits

2.2 Genetic Parameters

2.2.1 Coefficient of variation

2.2.2 Heritability and Genetic advance

2.2.3 Correlation coefficients

2.3 Genetic Divergence

2.3.1 Principal Component Analysis

2.3.2 Mahalnobis' D^2 analysis

2.1 Morphological Qualitative Traits

Genetic diversity is assessed in fruit crops based on differences in morphological qualitative traits. This is probably due to the fact that assessment of qualitative traits does not need any sophisticated equipment; they are generally simple, rapid and inexpensive to score. In many cases, the morphological qualitative traits have been used as a powerful tool in the classification of cultivars. As such morphological traits continue to be the first step in the studies of genetic relationships in most breeding programmes (Cox and Murphy, 1990; Van Beuningen and Busch, 1997). Morphological markers are sensitive to specific environment in which they are growing (Muchugi *et al*., 2008). Morphological information is essential for understanding the ideotype performance relationships and explains the heterosis that may be enhanced if morphological measures of distances are included as an independent variable. Characterization includes use of phenotypic traits that are highly heritable and these can easily be seen and equally expressed in all environments. Phenotypic studies are very important in tree improvement as the best morphological structure influences yield (Mwase, 2007).

2.1.1 Tree traits

Mango tree have different types of canopies such as oblong, broadly pyramidal, semi circular and spherical type. Majumder *et al.* (2011) noticed that 23 genotype showed ellipsoid plant shape and the rest of the genotypes were spheroid. The mango plants under the study showed three types of growth habit i.e., spreading, upright and intermediate. However, most of the genotypes showed spreading and dense type growth habit and rest upright and intermediate in nature.

Joshi *et al*. (2013) identified mango cultivars which had wide range of variability in physico-chemical traits of fruit and the trees under different agro-climatic conditions. As a result, morphological traits like plant growth, bark characters, foliage density, colour and leaf characters were examined. Results showed that the minimum canopy growth was found in Amrapali followed by Dashehari. Bark surface, bark colour, foliage density, foliage colour and different leaf characters also differed from each other. Joshi *et al*. (2013) assessed nine mango cultivars *viz.,* Amrapali, Bombay Green, Chausa, Dashehari, Gaurjit, Gulabkhas, Langra, Mallika and Pant Sindhuri for morphological traits. They found that Bombay Green, Chausa and Dashehari have upright growth habit while Gaurjit, Gulabkhas and Mallika were spreading growth habit as compared to other cultivars. The medium foliage density was observed in Amrapali, Dashehari, Gaurjit and Pant Sindhu, whereas, sparse foliage density in Gaurjit and Mallika and dense foliage density in the rest cultivars. A wide variation was also observed in the colour of the foliage. The Amrapali, Dashehari, Gaurjit, Pant Sindhuri, Gulabkhas and Mallika gave green foliage, while all other genotypes produced dark green foliage.

Singh (2014) studied qualitative traits of tree like growth habit, canopy shape, branch density and foliage density which were varied with each other. The upright growth was found in Amin, Husn-a-ra, Mallika and Safeda Lucknow; intermediate in Amarpali, Bombay Green, whereas spreading type in Bride of Russia, Khasl-ul-Khas and Jafrani Gola. Rajwana *et al.* (2011) evaluated 17 mango varieties for morphological characterization and found that most of the varieties had spreading/compact/erect growing habit except Camal Wala, which had drooping tree shape. Castro *et al.* (2011) evaluated forty six cashew accessions for morphological characterization and found that *A. occidentale* accessions, 60% had a tall canopy and an upright/open tree shape; *A. othonianum* accessions, 66% had a semi-tall canopy, 54% had an upright and compact tree shape while, 41% instead had an upright and open tree shape and A. *humile* accessions, consisted of dwarf trees with a spreading tree shape. The species showed differences for all characters and also a high variability within species. Trees with narrow and high conical-shaped canopy would have a canopy surface consisting of separated cones that would form a much large surface area than the low spreading trees (Ohler, 1979). Ierla *et al.* (2013) evaluated 103 mango accession based on Brazilian descriptors for morphological characterization and found that the growth habit of the trees were predominantly semi-vertical (60.1%), with the vertical present in only 3.7% of the accessions. According to Albuquerque *et al.* (2002), the semi-vertical growth habit can simplify orchard maintenance. Krishnapillai and Wijeratnam (2016) evaluated eighteen mango varieties for characterization and determine genetic diversity among genotypes on the basis of qualitative and quantitative morphological traits. They found that most of the mango varieties showed spreading growth habit. Singh (2014) studied tree traits in 42 mango varieties and observed that upright growth habit was ascertained as in Amin, Husn-a-ra, Mallika, Safeda Lucknow, while, intermediate in Amrapali, Bombay Green, chausa, Dashehari, Langra and spreading in Bride of Russia, Haathijhool, Khas-ul-khas, Zafrani Gola etc. Ellipsoid canopy shape was observed in Amrapali, Husn-a-ra, Mallika, Rumani, Safeda Lucknow etc., while spheroid shape was in Baramasi, Bride of Russia, Bijoragarh, Zafari Gola etc. Branch density was recorded dense in Bara Malda, Baramasi, Langra, Thanking Amadi, etc. medium dense in Bombay Green, chausa, Dashehari and Ratual and spare in Amin, Husn-a-ra, Safeda Lucknow etc. Foliage density varied among studied mango varieties as dense in Ratual, Baramasi, Haathijhool, Mallika etc., medium dense in Amrapali, chausa, Dashehari etc. and spare in Safeda Lucknow, Zafrani Gola, Rehaman Pasand etc.

2.1.2 Leaf traits

The leaf morphology has wide variability particularly for leaf shape, size, young, leaf colour and leaf margin. Differences are due to varietal variation, climate, cultural practices and growth stages. Young leaves from different varieties can present different colour. This can vary from copper-red to purplish in colour. At maturity, the leaf colour changes to dark green and usually smells like turpentine (Fivaz, 2008). Islam and Nasir (1993) carried out an investigation to study vegetative characters of some mango cultivars (Malda, Anwar Rataul, Sindhri and Banganpalli). They reported that colour of newely emerged leaves was light reddish brown in Malda, orange green in Banganpalli, light green with brownish tinge in Anwar Rataul and Sindhi, while colour of mature leaves was Spanish green in all cultivars. The shape of the leaves was lanceolate in Sindhi, oval lanceolate in Malda and Anwar Rataul and oblong in Banganpalli; leaf apex was sub-acuminate in Malda and Banganpalli, acuminate in Anwar Rataul and acute in Sindhi, whereas margin of leaf was flat and entire in Malda and Sindhi respectively and slightly reflexed in remaining cultivars. Sarder *et al.* (1998) reported that the most of mango cultivars had tall tree growth habit except Gopalbhog and Khirsapat, which had medium growth habit.

Rajwana *et al*. (2011) evaluated 17 mango varieties for morphological characterization and found that differences in leaf shape and size were also observed, however, common leaf shape was lanceolate with some variability to ovate lanceolate to oval or elliptic lanceolate. Joshi *et al*. (2013) observed leaf variability among nine mango cultivars *viz.,* Amrapali, Bombay Green, Chausa, Dashehari, Gaurjit, Gulabkhas, Langra, Mallika and Pant Sindhuri. The acuminate type of leaf apex was found in cultivars *viz.,* Mallika and Amrapali, while sub-acuminate was observed in Dashehari, Gulabkhas and Langra, while Bombay Green, Chausa, Gaurjit and Pant Sindhuri had acute apex. The leaf base of Chausa and Pant Sindhuri was found rounded elliptic lanceolate in Mallika and Amrapali, ovate lanceolate in Chausa and Pant Sindhuri while rest of the cultivars had oval lanceolate shape. The leaf margin was found entire in Mallika, Amrapali, Dashehari and Langra, while slightly wavy leaf margin was recorded in Pant Sindhuri and rest of the cultivars had wavy margins. The nature of leaf apex was acuminate and sub-acuminate in all the cultivars except Bombay Green where it was acute. Krishnapillai and Wijeratnam (2016) evaluated eighteen mango varieties for characterization and to determine genetic diversity among genotypes on the basis of qualitative and quantitative morphological traits. They found that most of the mango varieties showed lanceolate leaf shape, acuminate leaf tip and entire leaf margin. Dark green colour mature leaves were observed in 80% of the trees where 82% of the leaves had strong fragrance. Colour of young leaves was selected as one of the important morphological traits for varietal characterization.

Ierla *et al.* (2013) evaluated 103 mango accession based on Brazilian descriptors for morphological characterization and found that the majority of the accessions showed anthocyanin leaf colouration (78.2%) as well as short petioles (77.8%). As to the predominant leaf shape, the lanceolate and oval shape was not found. As to the undulation descriptor, the edge of the leaf blade underwent a similar distribution ranging from the average to the weak with a predominance of the obtuse base shape. Singh (2014) studied leaf traits in 42 mango varieties and observed that new leaf colour varied as fluorescent green in Amrapali; coppery red in chausa, Haathijhool, Sensation, Zardalu; brownish green in Bijoragarh, Gulabkhas Green, Mithu Malda, Tamancha, etc; Light coppery brown in Gurwani; Dark coppery brown in Rahman Pasand; coppery red in Thanking Amadi and also found that ovate lanceolate leaf shape was found in Bada Malda, Bombay Green, chausa, Dashehari etc., oblong lamceolate in Bathui, Zardalu, Safeda Lucknow, Langra etc.while, elliptic lanceolate leaf shape in Duddha Peda, K.O.-07, Mallika and vanraj. Leaf apex shape was noted acute in Bada Malda, Rumani and Vanraj etc. while, attenuate in Amrapali, Dashehari, Ratual, Sensation etc. and acuminate in Bombay Green, Langra, Neelum, Thanking Amadi etc.

2.1.3 Inflorescence traits

Mango inflorescence is mainly pyramidal shape and developed on reproductive shoot called panicle. The mango inflorescence is primarily terminal and its length varies from few inches to two-three feet. The inflorescence colour change from yellow to light green with crimson patches at development stage were reported by Singh (1968). Variation in panicle emergence and flowering behaviour in mango hybrids were also reported by Sharma *et al* (1998). According to Campbell and Malo (1974), the inflorescence of the mango had a pyramidal shape, while Mukherjee (1985) mentioned a conical and pyramidal shape. Majumdar *et al.* (2011) noticed that the inflorescence position varied from terminal axillaries to terminal and colour in most of the varieties varied from light green to light green with red patch. The variation in flowering behaviour may be attributed to the genetic and the environmental conditions.

Rajwana *et al.* (2011) evaluated 17 mango varieties for morphological characterization and found that shape of inflorescence varied from pyramidal (Sufaid Chausa) to broadly pyramidal (Late Ratole no 12) conical (Kala Chausa), semi circular for Faiz Kareem and spreading for Hafeez Pasand. Ierla *et al.* (2013) evaluated 103 mango accession based on Brazilian descriptors for morphological characterization and found that pyramidal shape was the predominant one in most of the accessions. Krishnapillai and Wijeratnam (2016) evaluated eighteen mango varieties for characterization and determine genetic diversity among genotypes on the basis of qualitative and quantitative morphological traits. They found that the terminal position of inflorescence was a dominant morphological trait as compared to the axillary position. Inflorescence and flower colour showed higher variation among the varieties. Inflorescence colour was selected to identify mango varieties.

Singh (2014) studied panicle traits in 42 mango varieties and observed that Conical shape of panicle was exhibited by Amin, Langra Gorakhpur, sensation, Zafrani Gola etc., the varieties Amrapali, Kesar, Khas-ul-Khas, Thanking Amadi etc. were found to have pyramidal panicle shape except Bara Malda and Duddha Peda which exihibited unsymmetrical panicle shape. Colour of primary rachis varied as dark red in Totapuri Red Small; red in Bride of Russia; light red in Bijoragarh and Bombay Green; dark pink in Bara Malda, Baramasi, Rumani and Suvarnrekha; light pink in Banarasi Betali, Haathijhool, Vanraj and sensation; pink in Rataul; pink blush in Dudha Peda and Gulabkhas; green with pink streaks in Neelum; light green in Langra, Pulgoa Darbhanga, Rahman Pasand, Safeda Lucknow and Tamancha; and green in Amrapali, Dashehari, Mithua Malda and Zardalu.

2.1.4 Fruit traits

Mango fruit of the different varieties varies in shape, size, appearance, colour and internal trait. Campbell (1992) reported yellow with red blush fruit skin colour in Afonsa Pair, Fernandinh, Kent and Sensation. Skin colouration of mature fruit may be due to anthocyanins that develop when tissues are exposed to light. Islam *et al.* (1992) observed the fruit shapes of mango varieties as oblong, ovate oblong and roundish. Kamaluddin (1967) described the colour of ripe fruits of Brindaboni and Baromashi as mostly yellow and light yellow. Haque *et al.* (1993) observed the varietals characteristics and colours of ripe fruits. Maximum fruits turned to yellow or greenish yellow during ripening while, Kohitur and summer behest turned to red and reddish yellow. The mature fruit colour of Bombay green was green; Carabao, Manila, Mulgoa and Arumanis were greenish-yellow and Haden, Keitt and Tommy Atkins have a striking red blush as reported by Mukherjee (1997).

Sardar *et al.* (1998) observed wide range of variability in respect of different physico-chemical characteristics of mango fruits. Skin and pulp colour of ripe fruits varied from green to yellow and yellow to orange, respectively. Kumar (2000) reported that pulp colour of the fruit was not influenced by the environment and it was controlled genetically. Anila and Radha (2003) found that oblong fruit shape and beak was absent in most of the cultivars *viz.,* Alphonso, Prior, Muvandan, Neelum, Ratna and H-151. The skin of fruit is smooth and entirely pale green or yellow marked with red patches on skin at the time of ripening (Griesbach, 2003). Much variation in fruit morphology in respect of stalk thickness, base, cavity, shape, sinus, beak, apex, surface, dots and finally fruit colour were observed by Sinha *et al.* (2007).

Bhuyan and Kobra (2007) reported that fruit sinus in most of the varieties was shallow and basal cavity in most of the varieties was absent. They also observed that the apex of fruit varied from round to obtuse. Singh *et al.* (2012) observed yellow fruit colour with red blush on the shoulder in Anami Chhalli, Choe Sindhuri, Ghassipur di Chhalli, Laddu Amb, Mahantan di Laltain, Sindhuri and Chausa. Fruit colour ranged from yellowish to light yellow, deep chrome, greenish, spinach green and dark green in rest of selected mango strains. It was noted that fruit colour ranged from attractive yellow with red blush on the shoulders to fully coloured, yellowish, light yellow, deep chrome and greenish among selected mango strains and these can be used as a donor source for developing coloured mango hybrid cultivars.

Sharma and Majumder (1989) suggested that red skin colour of the fruit is dominant and it has been governed by duplicate gene thereby showed various gradation of pink blush on the fruits in progeny population. Litz (2009) repoted that Willard and Kilichondan had attractive skin colour with excellent fruit quality and were noted as suitable for export markets in Europe where red toned skin colour mangoes with sweet taste are preferred. Ierla *et al.* (2013) evaluated 103 mango accession based on Brazilian descriptors for morphological characterization and found that the predominant shape of the transversal section of the fruit was large and elliptic (61.6%). The Pingo de Ouro showed a large elliptical, while Mastruz had narrow and elliptic shape and found narrow and elliptic for Florignon and large and elliptic for Eldon, respectively. The green colour of the epidermis was most frequent (28.8%) followed by the yellow and pinkish colour (17.3%). The depth of cavity was absent or very low for almost 80% of the evaluated accessions, showing a similar distribution among the accessions with the prominence descriptor at the base of the pedicel. The shape of the predominant dorsal base was the one downwardly inclined (39.4%), while the least frequent shape was one with an abrupt inclination (10.6%), which was found in 11 accessions such as the Itiuba, Espada, Manteiga and Ruby varieties.

According to Iyer and Subramanyam (1979) the presence of pistilar scar deformation is a dominant character. Almost all the available colour categories were found for the fruits in accordance with the descriptors used by Brasil (2002), except for the colours, orange, purple and red and purple. Three colour categories were more frequent; yellow (16.3%), yellow and red (15.4%) and orange and red (15.4%). Costa *et al.* (2004) also analyzed the colour of the fruits and found discrepant results, such as the accession Hilda, the colour of which was classified as reddish, different, however, from what was found in the present study and which was classified as yellow. Another verified discrepancy was the accession like Salitre, the colour of which was classified as green and yellow. Other accessions were given the same colour classifications in the two studies, such as Amrapali (green and yellow), Manzinilllo (red), Uba (yellow and green), Espada (green and yellow), Espada Ouro (yellow), Black Java (yellow and red) and Maca (yellow). According to Chitarra and Chitarra (2005), the colouration is a quality attribute that is more attractive to the consumer, varying intensely among the fruit species and even among cultivars. The distribution of the skin colouration was non-uniform in most of the fruits. As to the flesh colour, a great diversity was observed in the characterized accessions. Iyer (1979) found that the yellow colour dominates the orange colour, while, Chitarra and Chitarra (2005) mentioned that the variation in colouration among the cultivars of the same species is due to the difference in the concentration of pigments.

Rajwana *et al.* (2011) evaluated 17 mango varieties for morphological characterization and found that fruit shape and size differed from variety to variety and varied from ovate (Shahanshah) to ovate oblong (Sufaid Chausa), round ovate (Faiz Kareem), oblong lanceolate (Kala Chausa) and elliptical (Camal Wala). Irregular round shape was also observed in Bubar Wala. Four germplasm (Tube Well Wala, Chun Wala, Camal Wala & Gola) had acute beak, while in others beak was absent or slightly prominent (Sufaid Chausa, Late Ratole No. 12 & Joyan Wala). The selected germplasm expressed yellow to orange skin colour except Camal Wala that had pink blush on the shoulders. Generally, the background colour of fruit is dark green when developing on the tree that turns lighter green to yellow as it ripens. Some varieties develop a red background colour at fruit set that remains until the fruits ripen. The mesocarp is the fleshy, edible part of the fruit that usually has a sweet and slightly turpentine flavor. When ripe, its colour varies from yellow to orange and its texture from smooth to fibrous (Haque *et al.* 1993; Akhter, 2013).

An experiment conducted by Shirin *et al*. (2013) revealed that the different fruit shape were observed for different cultivars such as oblong for Alam shahi, oblong elliptic for Champa, oblong oblique for Danadar and Mirabhog, roundish for

Hayati, ovate oblong for Lugnee, oblong oval for Shantu. Green with yellow skin colour was found in Alam shahi, Champa, Hayati, Lugnee and Mirabhog. Light yellow pulp colour was found in Champa and Lugnee; yellow pulp colour was found in Shantu; light orange pulp colour was found in Mirabhog. The pulp colour of Alam shahi, Hayati and Danadar was found deep yellow. Beak was absent in most of the cultivars except Alam shahi and Lugnee. In Alam shahi beak was pointed, while in Lugnee beak was prominent. The sinus was absent in all the cultivars while basal cavity was present in all the cultivars except Champa. Apex of Alam shahi, Champa, Danadar and Mirabhog was obtuse, while the apex of Hayati, Lugnee and Shantu was round. The flavor of the ripe fruit was found pleasant in all the studied cultivars.

Krishnapillai and Wijeratnam (2016) evaluated eighteen mango varieties for characterization and to determine the genetic diversity among genotypes on the basis of qualitative and quantitative morphological traits and found that skin colour of ripe mango fruit varied from light yellow to orange, while 10 accessions showed pink or red mixed skin colour. Fruits were observed to be oblong in 31 mango accessions and beak was absent in 16 accessions. Stem end cavity was not observed in 46 accessions and round apex was found in 49 mango accessions. Seeds were oblong with elevated forked venation in more than 35 accessions. Fruit traits of skin colour, shape and beak and stem end cavity showed clear variations.

2.2 Genetic Parameters

The nature and extent of variability of the basic population is the raw material on which selection acts to evolve superior genotypes or varieties in plant breeding programme. Genetic diversity is the amount of genetic variability among individuals of varieties, populations or species (Brown, 1993). The variability exploited in breeding programme is derived from the naturally occurring variants and the wild relative of crops as well as artificially developed strains and genetic stocks by human-efforts. Mango has been reported to have extensive variability due to alloploidy, cross pollination, continuous grafting and phenotypic differences arising from varied agro-climatic conditions in different growing regions (Ravishankar *et al.,* 2000).

The long period of domestic cultivation, cross-pollination nature, alloploidy and out-crossing have contributed to the wide genetic diversity in mango (Krishna and

Singh, 2007; Mukherjee, 1972). The phenomenon of allopolyploidy is believed to have originated from amphidiploidy because differentiation of many varieties occurred primarily through gene mutations, selection and preservation of some of them through grafting (Mukherjee, 1953; Mathews and Litz, 1992; Yonemory *et al.,* 2002). In recent times, two spontaneous tetraploid mango seedlings were identified. A tetraploid "Gomera-1" from Canary Island (Galan Sauco *et al.,* 2001) and another one from Katrine in Australia and both are used for rootstock breeding purposes (Bally *et al.,* 2009).The available literatures on the relevant aspect have been reviewed under the following heads:

2.2.1 Coefficient of variation

A measure of variation which is independent of the unit of measurement is provided by the standard deviation, expressed as percentage of mean is known as coefficient of variation. Rathod and Naik (2007) studied analysis of variance in 35 genotypes of mango for characters like fruit weight, fruit volume, fruit length, fruit width, specific gravity, peel percentage, stone%, pulp%, TSS, acidity, ascorbic acid, total sugar, reducing sugar and non reducing sugar and found significant variation among the genotypes for all the traits. However, the higher genotypic and phenotypic coefficient of variation were obtained for ascorbic acid, fruit volume, fruit weight, acidity, peel%, stone%, non reducing sugar, fruit length and reducing sugar. An experiment was carried out with 9 mango cultivars by Bhowmick and Banik (2008) to assess the genetic variability for different fruit characteristics. They found that the lowest range was recorded with acidity and highest for weight. The highest phenotypic coefficient of variation was recorded for all fruit characteristics as compare to genotypic coefficient of variation.

Nayak *et al.* (2013) reported that phenotypic coefficients of variation (PCV) was higher than genotypic coefficients of variation but minimum difference was noticed between them. Comparatively high degree of genotypic coefficients of variation (GCV) along with phenotypic coefficients of variation was observed in quality traits like fruit weight, fruit volume, pulp: stone ratio and total carotenoids of mango. Vasugi *et al. (*2013) conducted an experiment to study the genetic divergence for 19 quantitative traits among 43 indigenous mango accessions. The estimates of phenotypic and genotypic variance were quite high for fruit weight (12909.38, 12661.92) followed by vitamin C (1231.71 and 1221.023). The genotypic coefficient of variation was more than 60 per cent for the characters like fruit weight, vitamin C and sugars.

Adeigbe *et al.* (2016) observed the variation among six group of cashew nut for the nine traits. The nut weight ranged from 2.95 to 23.20 g while, kernel weight ranged from 0.035 to 6.88 g. The nine traits significantly differentiated the six cashew groups. The PCV was higher than the GCV for all the traits. The high proportion of genotypic component in the total phenotypic variation among the six cashew groups for the traits depicts that the role of the environment in the phenotypic expression of the nine nut parameters was minimal; hence, genetic effect was more implicated on the nine traits. Kabir (2001) reported that fruit weight ranged from 169.31 to 706.67 g and maximum fruit weight of Neelumbori, Mallika, Gopalbhog and Amrapali were 273.23, 394.74, 172.33 and 169.31 g respectively. Length, breadth and thickness of fruits in Amrapali were 8.62, 5.91 and 5.46 cm, in Mallika 11.73, 7.88 and 7.01 cm, in Neelumbori 9.26, 7.32 and 7.25 cm and in Gopalbhog 8.15, 6.32 and 6.03 cm, respectively. The percent moisture in pulp was ranged from 77.11 to 86.45 depending upon Germplasm in Amrapali Mallika Neelumbori and Gopalbhog percent moisture in pulp were 78.75, 82.83, 81.31 and 79.09, respectively. Altaf *et al.* (2008) studied fruit variability in Kinnow mandarin and found that the fruit weight ranged from 101 to 287 g, length 4.2 to 7.0 cm, diameter 5.2 to 8.5 cm, volume 110 to 300 ml and TSS 8 to 12.5 ^{0}B indicating the differences in the physiological maturity time of different fruits. Sundouri *et al.* (2009) reported that the coefficient of variance for different traits in pecan varied from minimum (6.74) in nut width to maximum (34.97) in shell thickness and found high genotypic coefficient of variance kernel weight (44.49%), nut weight (43.84%) and moderate for nut length (29.23%) and kernel percentage (24.21%). Phenotypic coefficient of variance was estimated highest for kernel weight (52.74%), nut weight (44.36%) and moderate for nut length (29.45%) and kernel percentage (25.18%). Islam *et al.* (2010) found variability in ber for fruit and yield characters. The highest range of variation was recorded in fruit weight (6.63 to 44.72 g) followed by yield per plant (14.88 to 64.99 kg), stone weight (0.71 to 3.94 g) and pulp: stone ratio (6.31 to 17.89). The highest GCV (55.67%) and PCV (55.67%) were recorded for fruit weight, while both were lowest for stone breadth (16.24% and

17.12%). Karunakaran *et al.* (2010) reported in papaya that phenotypic coefficient of variation for all the traits were higher than the genotypic coefficient of variation. Very little difference was noticed between the values of PCV and GCV in S_4 generation for the quantitative traits such as plant height at the time of first fruiting, stem girth, intermodal length, fruit weight, fruit length and fruit diameter. The medium GCV and PCV were observed in S_2 generation, while low was observed in the S_3 generation as compare to S_2 generation.

Pandey *et al.* (2014) reported that variability in fruit weight ranged from (13.40 to 54.33 g), diameter (2.87 to 4.81 cm), fruit length (2.51 to 4.04 cm), pulp weight (12.43 to 52.80 g), stone weight (0.97 to 2.23 g), stone length (1.21 to 2.02 cm), stone breadth (1.08 to 1.70 cm), pulp stone ratio (8.27 to 34.4), TSS (10.17 to 17.40 B), vitamin C content (347.67 to 632.33 mg/100 g pulp), acidity (2.07 to2.97%) and total sugar (4.98 to 8.85%) in different genotypes of mango. Singh and Kumar (2010) studied phenotypic and genotypic coefficient of variability for growth, yield and yield attributes and showed higher PCV than the GCV for all the characters under consideration, indicating high degree of environmental influence. The PCV ranged from 9.28 for plant girth to 44.0 for fruit yield and GCV ranged from 5.95 for plant girth to 42.26 for fruit yield. The magnitude of differences was little in respect of days to first flowering, fruiting height, fruiting length and fruit weight. Among the various characters, relatively higher PCV were observed for fruit yield, fruit weight, number of fruits and fruiting length indicating that selection based on these characters would be highly effective. Dwivedi *et al.* (1995) also observed that selection based on characters having higher PCV would be more effective in papaya. According to Burton (1952) a character having high value of GCV with high heritability would be more valuable in selection programme. Accordingly fruit yield, fruit weight and fruiting length were having high estimate of GCV and heritability which indicates direct selection for these characters would be effective. Singh *et al.* (1997) have also reported high magnitude of PCV and GCV for fruit yield in papaya.

Majumder *et al.* (2012) estimated genotypic and phenotypic variability among sixty genotypes of mango. There were also considerable differences between the genotypic and the phenotypic coefficients of variation for almost all the characters which indicated the influence of environment on the expression of these traits. Among the studied characters, GCV and PCV were high for weight of harvested fruits per plant, % fruit harvest per inflorescence,% initial fruit set per inflorescence, number of fruits per plant and number of main branches per inflorescence.

2.2.2 Heritability and Genetic advance

The concept of heritability is important to determining whether phenotypic differences observed among various individuals are due to genetic changes or due to the effects of environmental factors. Heritability indicates the possibility and extent on which improvement can be brought about through selection. It is a useful measure for considering the ratio of genetic variance to the total variance and is genetically represented in percentage. Lush (1949) defined the heritability in broad sense that it is a ratio of genetic variance to the total variance expressed in per cent. The genetic gain is the product of heritability and selection differential expressed in terms of phenotypic standard deviation of that character, heritability and genetic advance both are the components of direct selection parameters. It is necessary to utilize heritability estimates in conjunction with selection differential differentia which indicates the expected genetic gain.

Rathod and Naik (2007) found high heritability coupled with genetic advance in mango for the traits like fruit length, fruit weight, sugars, acidity ascorbic acid, peel percentage and stone percentage indicating importance of these traits for crop improvement programme. Bhowmick *et al.* (2008) conducted an experiment to study heritability and genetic advance for different physico-chemical traits among nine mango genotypes. They found high heritability coupled with genetic advance for most of physico-chemical traits. Islam *et al.*(2010) in mango reported high heritability along with high degree of genetic advance (GA) for yield per plant (95.38% and 93.38), number of fruits per plant (89.90% and 49.63), fruit weight (99.35% and 114.31), fruit breadth (90.14% and 49.70), stone weight (99.05% and 90.82), stone length (98.34% and 51.83) and pulp:stone ratio (98.74% and 66.34).

Nayak *et al.* (2013) estimated high heritability for fruit weight (0.82), fruit length (0.70), fruit volume (0.80), stone width (0.71), total carotenoids (0.97) and ascorbic acids (0.83); and moderate heritability for acidity (0.58), fruit width (0.62), stone length (0.68), stone thickness (0.62), peel thickness (0.53) and total soluble solids (0.69). High heritability along with high genetic advance was estimated for fruit weight and fruit volume. Genetic parameters estimated for fruit quality traits of mango may be useful to formulate pre-selection criteria and efficient breeding strategies of mango for development of new hybrids. Adeigbe *et al. (*2016) in Cashew nut reported high heritability for nut weight (99.25%) with high genetic potential. Karunakaran *et al.* (2010) reported that very little difference was noticed in the heritability values between S_3 to S_4 generation. Among the characters, high genetic advance as percent mean was recorded for the characters of fruit length, fruit weight and number of seeds, while other traits exhibit moderate to low. Heritability and genetic advance (GA) as percent mean was obtained high for the characters of fruit weight and fruit length.

Jambhale *et al.* (2014) studied the heritability coupled with high genetic advance (GA) in Papaya for yield contributing traits and found high heritability coupled with genetic advance as percent of mean for traits like yield per plant (83.5, 37.64), fruits per plant (71.8, 24.18), seeds per fruit (98.3, 148.75), pulp to seed ratio (79.70, 91.47), fruit length (84.5, 34.04), distance of first fruiting node from ground level (78.0, 31.66), fruit diameter, fruit cavity and average fruit weight indicating that these characters are predominantly governed by additive gene action. In papaya, Kumar *et al.* (2015) observed that heritability varied from 59.30 to 99.70% and high heritability values were recorded for plant height at flowering (99.70%) followed by fruit weight (97.50%), flowering initiation (94.80%) fruits per plant (96.40%), fruit yield per plant (93.50%), petiole length (93.30%), fruit girth (92.40%), flowering at days (91.70%) and plant height (86.70%). High heritability estimate is mainly due to additive gene effect and high genetic advance thus may be expected upon effective selection.

Singh and Kumar (2010) studied heritability and genetic advance in papaya and found that heritability ranged from 25.62 for leaf length to 96.00 for the characters. High heritability was observed for yield, fruit weight and fruit length and high genetic advance as per cent of mean was observed for fruit yield, fruit weight and fruit length. High genetic advance coupled with high heritability for these characters indicated preponderance of additive gene action. Majumder *et al.* (2012) estimated heritability and genetic advance among sixty genotypes of mango and showed considerably high heritability which ranged from 56.21 to 98.24% and the genetic advance (as% of mean) was high for the maximum traits. High heritability coupled with high genetic advance was observed in weight of harvested fruits per plant,% initial fruit set per inflorescence,% of flowering shoot, number of inflorescences per shoot, percent fruit harvest per inflorescence, number of main branches per inflorescence, number of fruits per plant, number of inflorescences per shoot, plant height (cm) and percent perfect flowers which indicated that these characters were less influenced by environment confirming predominance of additive gene action and therefore, selection in favour of these characters would be feasible for yield improvement of mango. Patel *et al. (*2015) estimated heritability and genetic advance in eleven genotype of guava with respect to plant growth, floral and yield related traits and observed that high phenotypic variation along with high heritability and genetic advance were reported among the genotypes. High heritability estimates associated with high genetic advance as% of mean were obtained for fruit yield which indicated that selection of this character would be more effective. Such association may be attributed to the action of additive genes

2.2.3 Correlation coefficients (character association)

Correlation measures the degree and direction of relationship between two or more variables. The study of character association helps breeder in fixing a selection criteria for fruit yield in parental lines such as selection will be effective in isolation than correlating the correlation of phenotypic values and subjected to change in the environment. Several workers have been studied the correlation coefficient in fruit crop, a brief review of studies on the association of characters in fruit crop is presented below:

Gupta *et al.* (1996) studied correlation in mango indicate that fruit diameter had significant positive correlation with fruit weight, stone weight, stone width, seed weight and seed width, whereas, negative correlation with stone thickness as well as petiole length. The fruit weight was significant positive correlation with stone length, stone width, stone weight and seed width and seed length but negatively correlated with seed weight. Azevedo *et al.* (1998) studied the phenotypic and genotypic correlations among plant height and crown direction. Leaf blade length was highly significantly correlated with leaf blade width; and petiole length significantly correlated with crown north-south direction. Rathod and Naik (2007) studied genotypic and phenotypic correlation among fruit traits of mango and found that the genotypic correlation were higher than their corresponding phenotypic correlations for all the traits and also reported stone weight was highly significantly correlated with seed length, seed width and seed weight. However, it was negatively correlated with leaf blade width and TSS: acidity ratio. Wright *et al.* (2007) noticed that genotypic correlation coefficient was higher than that of phenotypic correlation coefficient for most of fruit traits. Islam *et al.* (2010) reported in mango that yield per plant was strongly and positively correlated with fruit weight (rg=0.965), fruit breadth (rg=0.807), stone weight (rg=0.742), fruit length (rg=0.737) and pulp-stone ratio (rg=0.574). Barhate *et al.* (2012) studied phenotypic and genotypic correlation coefficient between number of fruits per tree and yield and found significant positive correlation of yield with number of fruits per tree, plant height, tree spread and tree girth. Vasugi *et al.* (2013) noticed higher genotypic correlation than phenotypic correlation in mango and found that fruit weight was most closely associated with pulp percent, total sugar, non reducing sugar, reducing sugar and stone weight. Bhowmick *et al.* (2008) studied genotypic and phenotypic correlation among fruit traits of mango and found that genotypic correlation coefficient was higher than phenotypic correlation coefficient for most of characters. There was a significant positive correlation of fruit weight with pulp content, breadth and significant negative correlation with peel and acid content. Total soluble solids (TSS) showed high positive correlation with total sugar and non reducing sugar. Whereas, acidity showed high negative correlation with non reducing sugar, fruit weight, pulp content, TSS, Sugar and reducing sugar content.

Adeigbe *et al. (*2016) reported that nut weight had high positive correlation with kernel length (r = 0.965), nut length (r = 0.957) and kernel weight (r = 0.873) in Cashew nut. The nut length was positively and significantly correlated with kernel length, width and weight and nut girth. Shell thickness was positively and significantly correlated with kernel girth (0.919). Chipojola *et al.* (2009) reported that total number of flowers per panicle had high correlation with male flowers per panicle and perfect flowers per panicle but correlated negatively with flower sex ratio. Nut weight correlated positively with kernel weight and nut thickness and male flowers whereas, nut weight negatively correlated with flower sex ratio in cashew nut. Nut thickness correlated negatively with perfect flowers while, kernel weight correlated positively without turn percent. Perfect flowers are positively correlated with flower sex ratio. The correlation between nut weights and its thickness and kernel weight were recorded by Faluyi (2006) indicating selection for one of these characters affects the other. This means breeders would find their work simple because as one trait is manipulated the others will also be affected favorably. Total flowers per panicle correlates strongly with male flowers but slightly with perfect flowers and negatively with flower sex ratio indicating that as total number of flowers is increasing male flowers increases strongly with perfect flowers increasing slightly hence decreasing the sex ratio. As perfect flowers increases the sex ratio increases indicating increases in the nut and apple yield. Kernel weight greatly affects turn out percent therefore, cashew accessions with high out turn percent will yield more and this is a selection criterion by buyers and manufacturers as reported by Ohler (1979).

Singh *et al.* (2012) reported that fruit weight showed significant positive correlation with fruit size, pulp weight, stone weight, peel weight, pulp content, pulp/stone ratio and stone size. However, it exhibited negative significant correlation with fruit stone content. Significant negative correlations were also recorded for fruit weight, fruit breadth, pulp weight, peel weight, pulp/stone ratio with total sugars content of the fruit. Total soluble solids in juice showed significant positive correlation with total sugars (0.88) and reducing sugars (0.62) and negative correlation with juice acid content (-0.47). Akhter *et al.* (2009) reported that fruit diameter, rind thickness, length of segment and number of segment had positive and highly significant phenotypic association with fruit weight and also genotypic positive association. The percent fruit set had negative genotypic and phenotypic association with fruit weight. Patel *et al. (*2015) estimated the characters association in eleven genotype of guava with respect to plant growth, floral and yield related traits and revealed that fruit yield was significantly and positively correlated with plant height, stem diameter, canopy spread, shoot diameter, number of leaves, days to flowering, fruit set, bud length, bud diameter, petal length, stamen length, number of stamens per flower and pistil length at both genotypic and phenotypic levels while, with flowering duration, fruit drop, number of petals per flower and petal width at genotypic level. Positive direct effect of petal length, bud length, plant height, bud diameter, stamen length, number of leaves per shoot, petal width, pistil length, days to flowering, flowering duration, fruit drop, fruit set, stem diameter, canopy spread along with significant and positive correlation with fruit yield suggested that these traits must be given due importance while selecting a genotype.

Karunakaran *et al.* (2010) studied that plant height was positively correlated with fruit length and TSS in papaya. Fruit weight had a significant positive correlation with plant spread and pulp thickness. Fruit length was correlated with the fruit diameter, number of seeds and hundred seed weight. Singh and Kumar (2010) observed that genotypic correlation values of most of the characters were higher than the phenotypic correlation values and most of yield attributing characters were positively correlated in papaya. Fruit yield per plant had positive correlation with number of fruits, fruit weight, fruiting length and leaf length. Similarly number of nodes to the first fruiting had positive association with plant height and fruiting height. Fruit yield is negatively correlated with fruiting height, nodes at first fruiting, plant height and days to first flowering.

Jambhale *et al.* (2014) reported that genotypic correlation was higher than phenotypic correlation for most of traits in papaya. The yield per plant exhibited highly significant positive correlation with fruit cavity (rg = 0.885), number of fruits per plant (rg = 0.869), average fruit weight (rg = 0.772), pulp thickness (rg = 0.632), â-carotene (rg = 0.572), plant height (rg = 0.522), pulp to seed ratio (rg = 0.503), fruit diameter (rg = 0.483) and length of fruit (rg = 0.294). The yield per plant exhibited significant negative correlation with days to first flower appearance (rg = -0.253) and TSS (rg = - 0.687). Kumar *et al.*(2015) in papaya studied that fruit yield per plant had significant positive correlation with plant height at flowering, petiole length, number of leaves at flowering, fruit length, fruit girth, central cavity, pulp thickness, TSS and number of fruits plant per both at genotypic and phenotypic level respectively.

2.3 Genetic Divergence

Genetic diversity is an essential requirement for increasing crop productivity through plant breeding programme. Present farming systems leads to predominance of few high yielding varieties over large acreage which leads to genetic homogeneity and ultimately genetic vulnerability to biotic and abotic factors. Swaminathan (1991) emphasized that genetic diversity and location specific varieties are essential for achieving sustainable advances in productivity. In any breeding programme, germplasm serves as the most valuable reservoir in providing variability for various traits as evidenced by earlier workers (Arunachalan, 1989). It is also established that degree of hetrosis is related to the magnitude of genetic divergence between parental lines. The evaluation data obtained on any germplasm collections represents many duplicate accessions. Such duplicates and accessions which differ from each other in one or two characters significantly pose a difficult situation for resolving distinct types. Thus, the estimation of variation within the form classification into different homogeneous groups is an important practice. There are several methods for determination of genetic diversity among the genotype out of which two methods were commonly used in the divergence study.

2.3.1 Principal Component Analysis

PCA is useful in defining the number of main factors, thus decreasing the number of efficient parameters to differentiate genotypes. Selection of diverse parent in breeding programme helps in isolation of superior recombination using cluster analysis, such as principle components analysis which has shown to be useful in selecting genetically distant parent. In addition to, associations between characteristics emphasized by this method may correspond to genetic linkage between loci controlling traits with a pleiotropic effect (Iezzoni and Pritts, 1991). The central idea of PCA is to decrease the dimensionality of a data set consisting of a large number of interrelated variables, while PCA does not take into account covariance and correlations, it concentrates on variances. The variation can be explained by the components e.g. 60% of variation and the correlations between principal component and original variables less than 0.25 can also be discarded (Jolliffe, 1986).

Parhi *et al.* (1993) reported maximum percent contribution towards genetic divergence of seed weight followed by number of seeds per fruits and yield per plant. These differences in the contributing factors for genetic divergence could be attributed to differences among the clones under study, which in term might be due to environmental conditions of the locations associated and interacted with the clone of Alphonso. Majumder *et al.* (2013) studied the genetic divergence among sixteen genotypes of mango using principal component analysis. The first nine component of the principal component axes with Eigen-values above unity accounted for 88.3% of the total variation among the fifteen characters. Weight of harvested fruits per plant (0.990 and 0.181), number of fruits per plant (0.101 and 0.607) and individual fruit weight (0.027 and 0.107) for both the vectors were positive across two axes indicating the important components of genetic divergence. Mitra *et al.* (2015) studied genetic diversity in mango germplasm through principal component analysis and found that different clusters were obtained on the basis of physico-chemical traits. All the clusters may be considered as genetically divergent groups. These may be considered as the base population for selecting genetically divergent germplasm in the mango breeding programme.

Singh *et al.* (2015) observed the genetic diversity in 77 local mango seedling trees through principal component analysis and found that the first four component were identified as major based upon their Eigen values and explained 71.72% of the total variation among seven characters. The first component (fruit weight) has 25.11% share in total variation, whereas second component contributes 17.79% for fruit length, third contributes for fruit width to 14.61%. The traits contributed the maximum to the divergence should be given greater emphasis for selection of desirable genotypes. Krishnapillai and Wijeratnam (2016) evaluated eighteen mango varieties for characterization and determine genetic divergence using principal component analysis and found that the first four principle components explained 75.6 percent of total variation observed in the eighteen mango cultivars. Principal component one explained 34.2 percent variations while, principal component two explained 21.8 percent variations. Principal component one loadings included fruit length, fruit breadth and fruit weight respectively. Variations of the parameters of leaf length, leaf breadth and inflorescence length were explained by principal component two. Singh *et al.* (2016) studied genetic diversity in mango genotypes on the basis of principal component analysis and showed that first nine components had Eigen-values greater than one and all together accounted for over 99% of the total variability. The first PCA (fruit colour) accounted for 87.14% of the total variation, while the second

PCA (fruit weight) accounted for 6.78% of the total variation. The cumulative percent of variance varied from 87.14% to 99.99% for the PCA which had Eigen-value more than one. The relative discriminating capacity of the PCA is shown by their Eigen-values. The PCA1 had the highest discriminating power as revealed by its highest Eigen-value of 17315.20 followed by PCA2 with Eigen-value of 1347.62. The characters contributed the maximum to the divergence should be given greater emphasis for selection in breeding. Adeigbe *et al. (*2016) evaluated six group of Cashew nut for assessment genetic diversity using principal component analysis for nine traits. The first three components showed maximum variability of the total variability. All the nine characters significantly (Eigenvector ≥ 0.2) distinguished the six cashew nut size in principal component one. In principal component two, seven characters were significant (Eigenvector ≥ 0.2) in discriminating the nut sizes except kernel length and nut length. The principal component analysis of the forty cashew accessions with the aid of the first two principal component axes accounted for 92.1% of the total variation. The first principal component explains 59.75% of the total sample variance with the first three principal components collectively explaining 95.9% of the total sample variance (Chipojola *et al.*, 2009). The first principal component accounted for maximum variance of 59.8% and eigen values of 23.9 while the first three principal components attributed to 95.0% of the total variance.

Johnson and Wichern (2002) reported that twenty eight variable were replaced by the first three principal component without much loss of information. A component associated with an eigenvalue near zero and hence deemed unimportant is well explained with a useful visual aid. In determining an appropriate number of principal components, a scree plot shows the trend of variation across the variables analyzed (Johnson and Wichern, 2002; StatSoft, 2007). The latent roots or eigen values associated with each principal component measures the contribution of each principal component to the total variance. The first three eigen values are above one which greatly expresses the variance of the principal component over all the variables. The analysis indicates that data can be summarized with just three variables and data have confirmed the reduced set of variables. Raychaudhuri *et al.* (2000) reported that PCA does not consider classes and is independent. Johnson and Wichern (2002) found that the principal components to be linear combinations of the original variables therefore, unreasonable to expect them to be nearly normal. The PCA indicated the amount of genetic diversity of the selected cashew accessions based on the evaluated characters. The reduction to three components (total flowers per panicle; male flowers and leaf size) which in this context can be used to characterize the cashew accessions in the four populations. Krishnapillai and Wijeratnam (2016) explained that the PCA biplot was used to classify mango genotypes and visualize the relationship among the varieties. The distribution of mango accessions in the principal component analysis based on the principal component one and two showed the variations among the genotypes. The varieties scattered on the far right corner were characterized by high fruit weight - namely Maththalamthaddy; while on the left side were varieties with low fruit weight such as Willard, Chembaddan, Pulima, Pachchaithinni, Neelam, Peterpasand and Vellaikolumban. The remaining fruits with average weight were scattered in the centre of the PCA biplot. PCA of morphological traits of mango accessions in Nepal also showed greater genetic diversity (Subedi *et al.,* 2005).

Toili *et al.* (2013) evaluated 98 mango accessions to determine the genetic diversity using principal component analysis. Results classified the accessions into two major groups corresponding to indigenous (17.35%) and exotic (82.65%) varieties. The PCA showed the first seven principal components accounting for 82.87% of the total variance. A strong and highly significant correlation was also found between the colours of young leaves, stem circumference, tree height, leaf margin type and fragrance strength. Four leaf descriptor traits namely pulvinus thickness, leaf pubescence, angle of secondary veins to midrib and presence of secondary veins on leaf, were discarded for presenting only one phenotypic class and hence ineffective in distinguishing between mango varieties. Rajwana, *et al.* (2011) evaluated 17 mango varieties for morphological characterization and found that most of the varieties had spreading/compact/erect growing habit except Camal Wala, which had drooping tree shape. Ranpise and Desai (2003) studied genetic diversity in acid lime using principal component analysis and found that fruits per tree, yield per plant and juice percentage were major contributor towards divergence. Daniel *et al.* (2004) analyzed genetic diversity in nine *Fragaria species* on the basis of qualitative and quantitative traits using principal components analysis (PCA) and noted that the significant differences between species were observed for all 23 morphological characters quantified and 3 different groups of species genotypes were observed after the principal components analysis. Rahman (2009) estimated the genetic divergence in forty lime accessions through PCA and found that accessions were grouped into 6 clusters. The distribution pattern indicated that the maximum number of genotypes were included in cluster III and the minimum number in cluster VI. The highest inter cluster distance was observed between cluster II and III (1568.51) followed by cluster II and VI (1223.72), showed wide diversity among the groups. The highest intra-cluster distance was observed for the cluster III and the lowest for the cluster VI.

Santos *et al.* (2010) analyzed genetic diversity in sixty-nine *Psidium* accessions by two non-hierarchical clustering methods and principal components (PC), to provide orientation for breeding programs. The variables ascorbic acid, b-carotene, lycopene, total phenols, total flavonoids, antioxidant activity, titrable acidity, soluble solids, total soluble sugars, moisture content, lateral and transversal fruit diameter, fruit pulp and seed weighs and plant fruit number and weight were analyzed. Specific groups were observed for the aracazeiros accessions, by the Tocher and the k-means methods, as well as by the three-dimensional dispersion of the four PCs. The clustering separated accessions of aracazeiros from the guava. There was no specific grouping in terms of States of origin, indicating the absence of barriers in the guava propagation accessions. Analyses suggested the collection of a greater number of guava germplasm samples from a smaller number of regions and divergent accessions with high nutritional compound levels to develop new cultivars. Carlos *et al.* (2011) analyzed genetic diversity in sixty-nine guava accessions using principal components analysis (PCA). The accumulated variation of the three principal components was 69%, indicating a restricted suitability for a three-dimensional dispersion model of guava accessions. The 10 aracazeiros accessions formed a specific group in the three-dimensional diagrams, suggesting a smaller differentiation among aracazeiros than guava accessions, probably due to the process of artificial selection with the latter, as observed in the analysis of non-hierarchical grouping methods. Hernandez *et al.* (2007) analyzed 52 *Psidium* accessions in Mexico with 50 qualitative and quantitative characters and reported that the analysis of 14 principal components explained less than 30% of the total variation in the characterization of the accessions. Sanabria *et al.* (2005) reported that the first three principal components explained 72% of the total variation in 53 Colombian accessions analyzed with 17 qualitative characters and 9 quantitative traits and also reported the formation of three groups, with 24, 12 and 17 accessions per group and reported no correlation between sampling locations and grouping of accessions.

Raina *et al.* (2015) evaluated thirty pomegranate genotypes on the basis of 14 qualitaive and quantitative traits for assessment genetic divergence using principal component analysis. Results showed that more than 82% of the variability for qualitative and quantitative trait in different germplasm. Fruit yield, fruit length, leaf length, TSS: acid ratio were observed significant variables components and P-26, Mridula, Amlidana and Ganesh were found with maximum values corresponding to these four variables. Marboh *et al.* (2015) analyzed genetic diversity in fifty genotypes of citrus using principal component analysis and found that genotypes were grouped into components based on their dissimilarity values. The first 3 principal components explained 58.72% of variation and identified seeds per fruit, juice content, pH, T.S.S., T.S.S and petal size as important traits that can be used to differentiate genotypes. Ganopoulos (2015) studied genetic diversity in one hundred forty-six sweet cherry genotypes using principal component analysis (PCA) and found that an unsupervised hierarchical cluster analysis was performed the different cultivars using the Euclidean distance matrix and the Ward's agglomeration method. The sweet cherry cultivars were classified in diverse clusters and it could be potential parents for hybridization and new genotypes could be created with a combination of desirable traits.

Singh *et al.* (2006) studied genetic diversity in papaya using principal component analysis and observed that all the 5 principal components qualified the criterion and the first principal component accounted for more than 74% of total variation, the second principal component accounted for more than 13.9%, third 9.0%, fourth 2% and the fifth less than 1% of total variation. On the basis of highest first principal component score (PC1, PC2, PC3) of 21 varieties, the 'Pusa Delicious' (319.99, -45.97 and 39.26), 'Sunset Solo' (291.36. -3.46, 73.07) and 'Ranchi 1-1 ' (391 29, -3.72, 57.07) were found to contribute maximum for total variation. PCA was done for assessment of 21 cultivars of papaya for the physico-chemical characters i.e., fruit yield per plant, fruit weight, fruit length, fruit width, fruit cavity and TSS. Here

PCI, PC2 and PC3 accounted for more than 89, 7 and 1.0% of total variation. Therefore, on the basis of the principal component scores the varieties 'Ranchi 1-1' (57.40, 14.30, 1.59), 'Co 7' (54.09, 21.35, -2.23) and 'Pusa Delicious' (51.49, 25.93, 4.38) were identified as main contributing characters towards the manifestation of diversity. The expression of diversity influenced by component characters, viz leaf length, earliness in fruiting, number of nodes to first flowering, single fruit weight and height of plants reported by Ghosh (1997). Srivastava *et al*. (2010) studied genetic diversity in 41 genotypes of hazelnut using principal component analysis. The first vector shows the highest eigen value (27.83) and accounts for 22.62% of the total variation. The first vector is the combination of kernel thickness, protein content, kernel weigh, nut length and the number of nuts per cluster. The second vector has an eigen value of 19.41 and explains 15.80% of the total variation. The third vector has an eigen value of 12.12 and the total variation of 9.84%. The fourth vector has an eigen value of 10.88 and the total variation of 8.84%, with the maximum contribution of nut weight. The fifth vector has an eigen value of 9.80 and the total variation of 7.95%; it is mainly the combination of kernel length and nut width. Vector sixth has an eigen value of 9.25 and the total variation of 7.51%, with the highest contribution of kernel width. Vector seven has an eigen value of 6.60, with thetotal variation of 5.37% and, the highest contribution of kernel weight and nut size. In this case, canonical root value accounts for 77.92% of the cumulative variance.

2.3.2 Mahalnobis' D^2 statistics

The concept of generalized distance for classification of number of individuals on the basis of their mean in p-dimensional space representing the characters scored on each individual who introduced the idea of a statistical field in which each point represented the center of diversity (Mahalnobis, 1936).

Rathod and Naik (2007) studied thirty five mango genotypes for assessment of genetic divergence. Results showed that these genotypes were grouped into seven clusters based on Mahalnobis's D^2 statistics. The large intra cluster distance within cluster IV suggested the presence of genetic variability within the cluster. The maximum intra cluster distance was recorded between cluster IV and VII followed by cluster IV and VI; cluster IV and VII, cluster I and IV and cluster II and IV as these groups of genotypes were highly divergent from each other. Among different characters studied, fruit length contributed the maximum towards total divergence followed by fruit width, TSS, ascorbic acid, peel% and acidity. Rajan *et al*. (2009) evaluated forty two mango varieties for assessment genetic divergence using D^2 statistics and grouped into three distinct clusters. They found that higher mean of fruit characters were grouped in cluster III; and high pulp weight and percent, TSS, weight, length and width of stone were grouped in cluster II. Highest intra-cluster distance was observed in cluster I, while highest inter-cluster distance was between cluster I and II. Pulp weight contributed maximum towards the genetic divergence (34.03%) followed by peel weight (22.65%), TSS (10.22%) stone weight (7.90%) and width (5.46%). The maximum contribution to the total divergence was from weight of pulp (22.22%) followed by total soluble solids (19.44%), total weight of fruit (16.67%) the stone thickness (13.89%) and shelf life (11.11%). This contribution is important for the purpose of further selection and choice of parents for hybridization. Manchekar *et al.* (2011) estimated the genetic divergence among nine Alphonso clone of mango by using D^2 statistic over physico-chemical parameters of fruits. The clones were grouped into two clusters. Cluster I, which consists of the clones DPL-I, RTN-I, DEV-1, VEN-1, DWR-I, DWD-II, DWD-III and BGM-II had the higher length of fruit (14.37 cm), pulp (71.58%), pulp: stone ratio (4.75:1), and pulp: peel ratio (5.21:1). Cluster-II comprising of the clones BGM-1 recorded significantly higher total fruit weight 260.8 g), diameter of fruit (70.22 cm), weight of peel (40.79 g), stone weight (41.88 g) and weight of pulp (178.46 g). Regarding quality parameters, the higher values were observed for total soluble solids as (16.690 B), ascorbic acid (54.92 mg/100 g) and total sugar (13.42 mg/100 g) in cluster-I, Similarly in cluster-II. The higher values were recorded in titrable acidity (0.56%) and reducing sugar (3.81 mg/100 g). No relationship between geographical origin and genetic diversity was established.

Barhate *et al.* (2012) studied genetic divergence in 12 genotypes of mango and grouped into four clusters. Among the four clusters, cluster I was the biggest one, consisting of six genotypes and cluster II contained four genotypes, while cluster three and four had one genotype each. Majumder *et al.* (2013) estimated the genetic divergence in sixteen mango genotypes through D^2- statistics. The clustering pattern revealed that the maximum inter cluster distance was noticed between cluster II and VIII and the lowest between clusters VII and VIII. From the cluster means, cluster I was high yielding and ranked first in terms of number of secondary branches per inflorescence, percent fruit set per inflorescence and yield per plant. Cluster VIII had only one genotype which produced the highest percentage of flowering shoots, percentage of perfect flowers, number of fruits per plant and TSS. The genotypes of cluster VII produced the biggest sized fruits. Vasugi *et al.* (2013) evaluated the forty three mango accessions for assessment of genetic divergence using D^2statistics and grouped into seven clusters. The cluster I comprised of 20 accessions followed by cluster II with 18 accessions, while the clusters III, IV, V, VI and VII had only one accession in each. The intra cluster distance ranged from 0.00 to 41.79. Cluster II showed the maximum intra cluster distance and it was found to be the lowest in clusters III, IV, V, VI and VII. Maximum inter cluster distance (136.57) was found between clusters V (Aruna Gowda Appe) and VI (Himsagar) which revealed that these genotypes are more diverse. The minimum inter cluster distance (56.11) was observed between cluster II and IV.

Barholia and Yadav (2014) studied forty eight genotypes of mango were studied for different fruit traits and grouped in 5 clusters based on D^2 values. The cluster I comprised 14 mango varieties such as Langra, Amrapli, Dashehari, Chousa, Neelum, Fazli, Alphonso, Totapari, Mallika, SBM 01-10, SBM 01-13, SBM 01- 14, SBM 01-38 and SBM 01-19 and showed real genetic diversity. Fruits per tree, fruit yield per tree, weight per fruit, length and width of fruit and percentage weight of pulp contributed more towards genetic divergence.The forty mango varieties were evaluated on the basis qualitative and quantitative traits for phylogenic analysis. The diversity among cultivars are indicated by the standard deviation and variance in the eleven quantitative characters of mango. Fourteen mango cultivars were categorized in four groups.

Dwivedi and Mitra (1996) studied the genetic diversity in eleven cultivars of litchi on the basis of six quantitative traits using Tocher's method and observed that the cultivars were grouped in four clusters. Cluster I was the largest with five cultivars and all other clusters had two cultivars each. The inter cluster values varied from 213.9 (between clusters II and III) to 1373.4 (between clusters I and IV); the intra cluster values varied from 79.7 (cluster I) to 138.8 (cluster IV). Crossing between cultivars belonging to cluster I with those of cluster IV is expected to give maximum extent heterosis whereas, crosses between the cultivars of clusters III and IV should yield derivatives with better fruit characters. Pandey and Tripathi (2007) analyzed genetic divergence in 103 walnut accessions using D^2 technique and observed that the genotypes were grouped into 7 clusters and maximum intra-cluster distance was observed in cluster I (15.39) comprising 94 genotypes followed by clusters II, IV, V, VI and VII, which were identified as genetically divergent. The inter-cluster values were maximum between cluster II and VI (57.98) and clusters II and VII (55.11). Crossing between genotypes belonging to clusters II and VI as well as II and VII are expected to give maximum heterosis.

Srivastava *et al.* (2007) studied genetic divergence in thirty germplasm of apricot using D^2 statistics and found that the germplasm were grouped into four clusters, out of which four cluster the cluster I was the largest with 22 genotypes followed by cluster II consisting of four genotypes. Inter-cluster D value was maximum between cluster III (1621.03) and cluster II (83.41). Crossing between genotypes having high genetic distance should be used in hybridization. The cluster mean of yield per tree, fruit weight, fruit length, fruit diameter and stone weight were found maximum in cluster III. Srivastava *et al*. (2010) studied genetic divergence in 41 genotypes of hazelnut using Tocher's method and reported that genotypes were grouped into different clusters. The cluster II and cluster VIII had the lowest inter-cluster distance (2.02), which indicates close relationship and similarity of most traits of the genotypes. Hence selection of parents from these clusters should to be avoided. The cluster V has the highest mean values for such traits as nut roundness index (0.91), kernel width (12.61mm), kernel weight (0.55 g), fat content (56.15%) and protein content (20.99%), while cluster IV shows the highest values for nut weight (1.75 g), kernel length (14.27 mm) and kernel thickness (8.21 mm). The highest percentage of kernels (41.17%) was recorded in cluster III. Clusters IV and V are expected to give promising and desirable recombinations in segregating generations, because they comprise desirable features as evident from their cluster means.

Sharma *et al.* (2013) estimated genetic divergence in sixteen genotypes of apple using D^2 statistic and observed that all the genotypes were grouped into four distinct clusters. The maximum numbers of cultivars were accommodated in Cluster IV (Fuji, Gala, Jonadel, Jonagold, Red Fuji, Royal Gala and Spijon). Cluster IV had highest intra cluster value was most divergent and Cluster I having least intra cluster value was least divergent. Highest value for inter cluster distance was recorded between Cluster I and II, while it was lowest between Cluster III and IV. Cluster means were maximum in Cluster II followed by Clusters I, III and IV. Santos *et al.* (2014) analyzed genetic divergence in 138 genotypes of phalsa using multivariate statistical method and showed that genotypes were grouped into three clusters. The group I was composed of 118 hybrid genotypes; group II was composed of the 10 genotypes and group III was composed of the 10 genotypes. The longest distance was found between groups II and III (474.96). The shortest distance was detected between groups I and II (198.78), which indicates that the segregating population is genetically closer to each other.

Sharma *et al.* (2015) studied genetic divergence in 42 new germplasm of apple using Mahalnobis's D^2 statistics and found that genotypes were grouped into three clusters and maximum numbers of genotypes i.e., 28 were accommodated in cluster I, while 10 and 4 genotypes were arranged in cluster II and III respectively. The maximum intra cluster distance was found in cluster II (2.214) and minimum in cluster III (1.212). Inter-cluster distance was maximum between cluster II and III (5.077) indicating that hybridization between genotypes from cluster II and III can be utilized for getting the superior recombinants in segregating generations. Garg *et al.* (2015) studied genetic divergence in forty genotypes of strawberry by employing D^2 analysis and observed that the germplasm were grouped into three diverse clusters. Cluster III consisted of maximum six genotypes followed by cluster I and II both of which consisted of four genotypes. The maximum inter-cluster distance was recorded between cluster II and cluster III. Hence, genotypes belonging to these clusters can be used as parents for hybridization programme. Raina *et al.* (2015) studied genetic divergence in thirty genotypes of pomegranate using Mahalnobis D^2 and found that genotypes were grouped into eight clusters. The maximum (10) genotypes were included in cluster I and minimum in cluster VII and VIII. The maximum (72.74) inter-cluster distance was observed between the cluster V and VII, while minimum (23.85) between the clusters III and IV.

Materials and Methods

Chapter 3 MATERIALS AND METHODS

The experiment on ''Classification of different varieties and new accessions of mango (*Mangifera indica* L.) based on qualitative traits and assessment of genetic diversity'' was conducted at Horticulture Research Centre, Patharchatta, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar. The experimental material comprised of 40 well known varieties and new accessions of mango were selected for study. The experiment was carried out for two years i.e. during 2014 and 2016 for detailed classification of mango varieties and accessions. The 25 morphological qualitative and 27 quantitative traits were considered for present investigation as per the universal format of descriptors for mango that includes the morphological traits of plant, leaves, flowers, seeds and fruits (IBPGR, 1989, IPGRI, 2006) and also followed the mango Distinctiveness, Uniformity and Stability (DUS) descriptors developed by the Protection of Plant Varieties and Farmers Right Authority, Government of India, New Delhi. The present investigation was carried out with the objective of characterization and grouping of mango varieties/accessions by using morphological qualitative traits and assessment of genetic diversity.

3.1 Experimental Site

The experimental site is situated at 29.5° North latitude and 79.3° East longitude. The altitude of the place is 243.84 m above the mean sea level. This site falls under the humid subtropical zone and situated in the Tarai region of Uttarakhand, India, about 30 km southwards of the foot hills of shiwalik range of the Himalaya.

3.2 Soil Conditions

The soil of the experimental site has been classified as series II Patharchatta silty clay loam under the order mollisol (Deshpande *et al.,* 1971). Soil is dark coloured, imperfectly drained with moderately high organic matter content developed in loamy alluvial sediments averaging 0.6 to 1.0 meter thick over loamy sand, sand or gravel. The soil has high cation exchange capacity and water holding capacity and also contains about 90 percent saturation.

3.3 Climatic Conditions

The climate of the region is broadly humid subtropical with cool winter and hot dry summer. High rainfall and wide temperature variations are the salient features of this Tarai region. Generally, monsoon sets in the end of June and continues up to September. Few showers also occur during the winter and occasionally during summer months. The maximum temperature may exceed 35-40°C during the summer months and the minimum night temperature sometimes touches to 0°C during winter. The data on weather conditions that prevailed during the period of investigation are procured from the Meteorological Observatory located at Norman E. Borlaug Crop Research Centre of GBPUA&T Pantnagar. The weekly average of various weather data for the experimental period 2013-14 and 2015-16 are presented in Appendix I and Appendix II, respectively.

3.4 Experimental Materials

The experimental materials for present investigation were comprised of 40 mango varieties including new accessions, which are being maintained at Horticulture Research Centre, Patharchatta, Pantnagar. The list of varieties including new accessions considered for present investigation during the years 2014 and 2016 has been given in Table 3.1.

3.5 Experimental Design

The experiments were carried out for two years i.e., during 2014 and 2016 under Randomized Block Design (RBD) with three replications at Horticulture Research Centre, Patharchatta, Pantnagar. Three healthy fruit bearing trees of uniform vigour and size under each treatment/variety receiving uniform cultural practices were selected for experimentation. At the start of experiment the age of varieties/accessions was 8 years.

3.6 Method of Observations

The observations related to morphological qualitative and quantitative traits in different mango varieties/accessions were recorded as per following methods.

Table 3.1: List of varieties including new accessions of mango considered for experiment

S. No.	Varieties/accessions	S. No.	Varieties/accessions
1	Dashehari	21	Swarna Jehangir
2	Dashehari 35	22	Ratna
3	Dashehari 51	23	Sabri
4	Langra	24	Bangalora
5	Chausa	25	Totapuri Red Small
6	Bombay Green	26	Angoor Lata
7	Pant Sinduri	27	Saurabh
8	Pant Chandra	28	Rajiv
9	PMSS-1 (Pant Mango-1)	29	Gourav
10	Amrapali	30	Himanshu
11	Mallika	31	Sukul
12	Pusa Arunima	32	Van Raj
13	Pusa Surya	33	Dilpasand
14	Arka Neelkiran	34	Himsagar
15	Ambika	35	Tilka Bhadainya
16	Arunika	36	Chandrakaran
17	Neeluddin	37	Surkha Khal
18	Neeleshan	38	Burma Surkh
19	Neelgoa	39	Sensation
20	A.U. Rumani	40	Tommy Atkins

3.6.1 Morphological Qualitative Traits

The 25 qualitative traits were recorded for the purpose of characterization and grouping of the different varieties/accessions of mango. The methods adopted for recording the different parameters are given under the following heads and subheads:

3.6.1.1. Tree traits: The observations in respect of tree traits have been recorded and described below.

(i) **Tree growth habit:** Growth habit of tree was observed visually and characterized as upright, medium and spreading.

(ii) **Canopy shape**: Visual observations were made for canopy shape and trees were characterized to have ellipsoid and spheroid shape.

(iii) **Branch density:** Branch density was recorded visually and trees were characterized to have dense, medium dense and sparse branch density

(iv) **Foliage density:** Foliage density was observed visually and trees were characterized as dense, medium dense and sparse.

3.6.1.2 Leaf traits: Ten leaves were collected from mature shoot in all the direction of the tree for study.

(i) **Young leaf colour:** Leaf colour was measured with the help of The Royal Horticultural Society Colour Chart (1969) for colour of new emerging leaf.

(ii) **Leaf shape of apex:** Leaf shape of apex was recorded visually, where apexes of leaf shapes were categorized as acuminate, attenuate and acute.

(iii) **Leaf shape of base:** Leaf shape of base was observed visually, where base of leaf shape was of three type i.e., obtuse, rounded and acute

(iv) **Leaf twisting:** Leaf blade twisting was observed visually, where leaf twisting was either absent or present.

(v) **Leaf margin:** Leaf blade margin was recorded visually, where leaf margin varied as wavy, slightly wavy and entire.

3.6.1.3 Inflorescence traits: The observations in respect of inflorescence and flowering have been observed as described below:

(i) **Inflorescence shape:** The inflorescence shape was recorded visually, where inflorescence shapes was either conical or pyramidal.

(ii) **Inflorescence position**: Inflorescence position was observed visually, where inflorescence position was either terminal or terminal & axillary both.

(iii) **Inflorescence colour:** Colours of primary rachis was recognized visually, where inflorescence colour was either present or absent

(iv) **Inflorescence presence of bracts**: Presence of bracts was recorded visually, where it was either present or absent.

3.6.1.4 Mature fruit traits: The methods to record the mature fruit characters of the mango such as colour of skin, shape in cross section, presence of cavity at stalk, presence of neck, shape of ventral shoulder, shape of dorsal shoulder, presence of sinus and point at stylar scar have been described below.

(i) **Colour of skin:** Colour of skin was recognized visually, where it was seven types i.e., yellow, green, green & yellow, green & orange, green & pink, green & red and green & purple.

(ii) **Shape in cross section:** Shape in cross section was recorded visually, where it was three types i.e., medium elliptic, broad elliptic and circular.

(iii) **Presence of cavity at stalk and presence of neck**: Presence of cavity at stalk and presence of neck were recorded visually, where these were of two types either absent or present.

(iv) **Shape of ventral and dorsal shoulder:** Shape of ventral and dorsal shoulder were observed visually, where they were five types i.e., rounded upward, rounded outward, rounded downward, sloping downward and falling abruptly.

(v) **Presence of sinus and point at stylar scar**: Presence of sinus and point at stylar scar were recorded visually, where presence of sinus was two types i.e., either absent or present and point at stylar scar was three types small, medium and large.

3.6.1.5 Ripe fruit traits: Ripe fruit characters of mango such as predominant colour of skin, colour of flesh, surface of stone and lateral view of seed kernel were recorded as per following procedure.

(i) Predominant colour of skin and colour of flesh: Predominant colour of skin was observed visually, where predominant colour of skin was on the basis of 13 types of colour i.e., green, yellow green, green & yellow, yellow, yellow & orange, yellow orange, orange yellow & red, orange & red, red, orange & purple and purple. Colour of flesh was observed on the basis of six type i.e., greenish yellow, light yellow, medium yellow, light orange, medium orange and dark orange.

(ii) Surface of stone and lateral view of seed kernel: Surface of stone and lateral view of seed kernel were recorded visually, where surface of stone was observed on the basis of three types i.e., grooved, smooth and ridged and lateral view of seed kernel was two types reniform and oblong.

3.6.2 Quantitative traits

The 27 morphological and physico-chemical quantitative traits were considered for recording the observations for assessment of genetic variability and analysis of genetic diversity. These traits are described under following heads and subheads:

3.6.2.1 Leaf traits: The observations in respect of leaf have been recorded and described under following heads:

(i) Leaf length: Ten (10) leaves of mango from different replication under each treatment were randomly selected and the length was measured with the help of measuring scale and the average length was expressed in centimetre (cm).

(ii) Leaf width: Ten (10) leaves of mango from different replication under each treatment were randomly selected and the width was measured with the help of measuring scale and the average width was expressed in centimetre (cm).

(iii) Leaf area: The leaf samples taken for measurement of length and width of leaf were used for the measurement of leaf area. The leaf area was measured with help of LI-COR portable leaf area meter LI-3000, attached with LI-3050 a transparent belt conveyor and area was expressed in centimetre square (cm^2).

3.6.2.2 Inflorescence and flowering traits: Ten inflorescence of each replicate for each varieties and accessions were chosen at random at the full bloom to record the following observations.

(i) **Duration of panicle emergence:** Date of start of panicle emergence and end of panicle emergence were recorded by visual observations of each tree by regular visit during panicle emergence. The duration of panicle emergence was calculated by subtracting date of start of panicle emergence from date of end of panicle emergence.

(ii) **Number of secondary rachis per panicle**: Number of secondary rachis was counted in ten panicles of each replication and the average was expressed as number of secondary rachis per panicle.

(iii) **Inflorescence size (length and width)**: Inflorescence size (length and width) were measured with the help of measuring scale and the average was expressed in centimetre (cm).

(iv) **Duration of flowering:** Date of start of flowering and end of flowering were recorded by visual observations of each tree by regular visit during flowering time. The duration of flowering was calculated by subtracting date of start of flowering from date of end of flowering.

3.6.2.3 Yield traits: The observations in respect of yield were recorded as described below.

(i) **Duration of fruit maturity**: Date of full bloom and date of harvesting were recorded by visual observations of each tree by regular visit during flowering and fruiting time. The duration of fruit maturity was calculated by subtracting date of full bloom from date of harvesting.

(ii) **Number of fruits per tree at harvesting:** Total number of fruits per tree in each variety/genotype was counted at the time of harvesting.

(iii) **Yield per tree:** The observations on yield per tree of each variety/genotype were recorded and the average yield was expressed in kilogram (kg).

3.6.2.4 Fruit traits: Quantitative traits of mango fruit such as fruit weight, length, fruit width, stone weight, stone size, pulp weight, peel weight and pulp: stone ratio were recorded as per the following procedure.

(i) **Fruit weight:** Ten (10) fruits of mango from different replication under each treatment were randomly selected and weighed by using electronic weighing balance. The average fruit weight was expressed in gram (g).

(ii) **Fruit size**: Fruit length of 10 fruits was measured with the help of digital Vernier Calipers and the average length was expressed in millimetre (mm). The width of 10 fruits was taken from shoulder side as well as flat side with the help of digital Vernier calipers. The average width was calculated by adding width from shoulder side and flat side values and dividing by two and expressed in millimetre (mm).

(iii) **Stone weight:** Ten (10) stone of mango from different replication under each treatment were randomly selected and weighed by electronic weighing balance and the average was expressed in gram (g).

(iv) **Stone size:** Stone length of 10 stones was measured with the help of digital Vernier Calipers and average length was expressed in millimeter (mm). The width of stone was taken with the help of digital Vernier calipers. The average width was calculated by adding width from shoulder side and flat side values and dividing by two and the average was expressed in millimeter (mm).

(v) **Pulp weight:** Pulp weight of ten (10) fruits was taken with the help of electronic balance and their average weight was expressed in gram (g).

(vi) **Peel weight:** Peel weight of ten (10) fruits was taken with the help of electronic weighing balance and their average weight was expressed in gram (g).

(vii) **Pulp: Stone ratio:** Pulp to stone ratio is the ratio of pulp weight and stone weight. Pulp to stone ratio of 10 fruits was calculated by dividing weight of pulp with weight of stone.

3.6.2.5 Fruit quality traits: The observations in respect of fruit quality were recorded as described under following heads:

(i) **Total soluble solids (TSS):** The juice of mango pulp was squeezed by hand and the total soluble solid of fruit was determined with help of hand refractometer by putting the one drop of juice on its prism and it was expressed in degree Brix (°B).

(ii) **Titratable acidity:** The titratable acidity was determined by titrating 10 ml aliquot (juice) against 0.1N sodium hydroxide solution using phenolphthalein indicator by method as suggested by AOAC (1980). It was expressed in per cent.

(iii) Total sugar: Total sugar was estimated by the standard method of AOAC (1980). The sugar extract was hydrolyzed with concentrated hydrochloric acid and titrated against 10 ml of mixed Fehling's solution (5 ml Fehling's solution A + 5 ml Fehling's solution B) using methylene blue as indicator. Results were expressed as percentage of total sugar.

(iv) Reducing sugar: The reducing sugar was estimated by the method of AOAC (1980). The extract was taken and titrated against 10 ml of mixed Fehling's A and B solution using methylene blue as indicator. The results were expressed as percentage of reducing sugar.

(v) Non-reducing sugar: The amount of non reducing sugar was calculated by subtracting reducing sugar from total sugar and multiplying the difference by factor 0.95 as suggested by AOAC (1980) and expressed as percentage of non-reducing sugar.

(vi) Ascorbic acid: Ascorbic acid content present in fruit juice was determined by diluting the known volume of juice with 3% meta-phosphoric acid and titrating with 2, 6-dichlorophenol indo-phenol visual titration method (AOAC., 1960). Standardization of the dye 2, 6-dichorophenol indo-phenol dye solution was done by titrating it against standard ascorbic acid solution. For the purpose, 100 mg of pure ascorbic acid was dissolved in 3 per cent meta-phosphoric acid and the volume made to 100 ml. From this, 10 ml ascorbic acid solution was used for titration. The results were expressed as Vitamin-C in mg/100 g of edible portion or fresh weight.

$$\text{Ascorbic Acid (mg 100 g}^{-1}) = \frac{\text{Titre Reading x Dye factor x Dilution x 100}}{\text{Weight of the sample x Volume of sample}}$$

(vii) Total carotenoids content: Five gram sample was weighed and grinded with acetone using acid and alkali washed sand in a pestle and mortar. The extract is decanted into a conical flask. The extraction is continued till the residue is colourless. The acetone extract was transferred to a separating funnel containing10-15 ml of petroleum ether and mixed gently. After addition of 25 ml of 5% Sodium sulphate, the solution was shaked and kept for sometimes. The separated yellow colour pigment is transferred into the petroleum ether later. The layer was collected in a volumetric flask and acetone layer containing

5% sodium sulphate was separated until the colour gets transferred into petroleum ether. The colour intensity was measured at 452 nm in a spectrometer and the total carotenoid content was calculated using the formula:

$$\text{Total carotenoids content (mg 100 g}^{-1}\text{)} = \frac{3.857 \text{ x O.D.x Volume made up x } 100}{\text{Weight of the sample x } 100}$$

3.7 Analysis of Genetic Variability

The mean values of measurable characters were used for appropriate statistical analysis. The following methods were used for analysis of different genetic parameters.

3.7.1 Analysis of Variance

The data were analyzed to test the significance of differences between the genotypic means for various characteristics through analysis of variance following the procedure suggested by Panse and Sukhatme (1978).

Table 3.2 Analysis of variance for Randomized Block Design (RBD)

Source of variation	**df**	**Sum of square (SS)**	**Mean square (MSS)**	**F value**
Treatment	t-1	SSt	MSt=SSt/t-1	MSr/ MSe
Replication	r-1	SSr	MSr=SSr/r-1	MSt/ MSe
Error	(t-1) (r-1)	SSe	MSe=TSS-SSt-SSr	
Total	tr-1	TSS	-	-

Where, t = treatment, r = replication, df = Degree of freedom, SSt = Treatment sum of square, SSr = Replication sum of Square, SSe = Error sum of square, TSS = Total sum of square, MSt =Treatment mean square, MSr=Replication mean square, MSe = Error mean square

The significance of differences among genotypic means was tested by 'F' test.

If, F cal ≥ F tab, then the difference between means is significant.

Wherever the F test was found to be significant, Critical Difference (C.D) was calculated for particular character by following formula C.D. (0.05) = SEd ×'t'

Where, 't' = table value of 't' at error degree of freedom at 5% level of probability, SEd = Standard error of difference between two treatment means.

$$\text{Standard error of difference: SEd} = \sqrt{2 \times \text{EMS/r}}$$

Where, EMS = error mean square

$$\text{Coefficient of variance:- C.V.(\%)} = \frac{\text{S.D.}}{\bar{x}} \times 100$$

Where, $\bar{x}$ = General mean

3.7.2 Estimation of coefficient of variation

Variability of different characters was estimated as suggested by Burton and de Vane (1953). Genotypic coefficient of variability (GCV), phenotypic coefficient of variability (PCV) and environmental coefficient of variability (ECV) were computed as follows:

$$\text{GCV (\%)} = \frac{\text{Genotypic standard deviation}}{\text{mean}} \times 100$$

$$\text{PCV (\%)} = \frac{\text{Phenotypic standard deviation}}{\text{mean}} \times 100$$

$$\text{ECV (\%)} = \frac{\text{Environmental standard deviation}}{\text{mean}} \times 100$$

3.7.3 Estimation of heritability

Heritability ($h^2_{(b)}$) in broad sense was calculated by using the following formula suggested by Hanson *et al.* (1956) and it was categorized as low (< 50%), Moderate (50-75%) and High (> 75%)

$$h^2_{(b)} = \frac{\sigma^2 g}{\sigma^2 g + \sigma^2 e} \text{ or } h^2_{(b)} = \frac{\sigma^2 g}{\sigma^2 g + \sigma^2 e} \times 100$$

$$h^2_{(b)} = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

Where, $\sigma^2 g$ = Genotypic variance, $\sigma^2 e$ = Environmental variance, $\sigma^2 p$ = Phenotypic variance

3.7.4 Genetic advance (GA)

Expected genetic advance was estimated by the proposed method of Johnson *et al.* (1955).

$GA = h^2_{(b)}. K.\sigma p$

Where, h^2 = Heritability in broad sense, σp = phenotypic standard deviation of given character, K = Selection differential at 5% selection intensity (2.06).

3.7.4.1 Genetic advance as per cent of mean (GA%)

Genetic advance as per cent of mean was categorized as low (0-10%), moderate (10-20%) and high (20% and above) as suggested by Johnson *et al.* (1955).

$$G.A.(\%) = \frac{\text{genetic advance}}{\text{mean}} \times 100$$

3.7.5 Correlation coefficients (character association) analysis

The estimation of correlation coefficient is based on the variance and covariance of x and y variables. Correlation is ranged between +1 to –1. The intensity of relationship was measured by correlation coefficients (r). The following formulas were used to formula estimate the correlation coefficients as given by Searle's (1961).

(a) Phenotypic correlation coefficient between character X and Y

$$r\ pxy = \frac{Cov.XY\ (p)}{\sqrt{Var.\ X\ (p).\ Var.\ Y\ (p)}}$$

(b) Genotypic correlation coefficient between character X and Y

$$r\ gxy = \frac{Cov.XY\ (g)}{\sqrt{Var.\ X\ (g).\ Var.\ Y\ (g)}}$$

(c) Environment correlation coefficient between characters x and y

$$r\ exy = \frac{Cov.XY\ (e)}{\sqrt{Var.\ X\ (e).\ Var.\ Y\ (e)}}$$

Where, r_{xy} = Correlation coefficient between characters X and Y, Cov. XY = Covariance between characters X and Y, Var. X = Variance for X character, Var. Y= Variance for Y character

3.7.5.1 Test of significance of correlation coefficient

The test of significance of correlation coefficient was calculated by the following formula: $t = \frac{r}{\sqrt{1-r^2}} \times \sqrt{n-2}$

Where, r = Correlation coefficient, n = Number of observations

The calculated value of ‘t’ was tested against tabulated value of ‘t’ at 5% and 1% level of significance with n-2 degree of freedom for phenotypic correlation and error d.f.-1 for environmental correlation.

3.8 Statistical Procedure for Genetic Divergence Studies

The genetic divergence among 40 mango varieties /genotypes was estimated by using the Principal Component Analysis as well as Mahalnobis D^2 Statistics (generalised distance as suggested by Rao, 1952). The details of these two methods are as follows.

3.8.1 Principal Component Analysis (PCA)

The concept of principal component analysis, which is a multivariate technique, was developed by Hotelling (1933) after its original concept given by Pearson (1901). For the principal component analysis each genotype was identified as a single point in a standardized multi dimensional space on the basis of correlation matrix. The axes of this space were principal components obtained from the original data as orthogonal transformation of the original variety. In this way each principal component becomes a linear combination of the varietal scores corresponding to the original variables. The Euclidean distance between any two points represents the degree of similarity or dissimilarly between the two varieties whose score on the principal axes determines their respective position in the hyperspace. The Euclidean distance is a Pythagorean distance extended to multiple axes and consists of difference in scores of any two varieties on each of the principal axes retained. If two varieties are genetically closely related, they are expected to occupy the same region in the hyperspace. The distance between them is small, if they are more distantly related or genetically diverse. For calculating Euclidean distances, the first few components in reduced dimension were used that accounted for sufficient variation. The statistical procedure used for principal component analysis has been described as follows:

(I) Principal component are no scale invariant and the results depends on the units of measurements. To avoid such drawback of principal components, raw data was standardized in the following way:

$$x_{ij} = \frac{(X_{ij} - X_j)}{\sqrt{\sum_{i=1}^{n} (X_{ij} - X_j)^2}}$$

X_{ij} is the observation on i^{th} genotypes for character 'j'.

Taking unit scatter and mean as zero the correlation matrix. $R = (r_{ij})$ was computed.

(II) The next requirement was to see if variation can be accounted for these scores by a smaller subset of independent basic dimensions, i.e., principal components. The number of non-zero principal component is equal to the rank of the correlation matrix. However, our aim of solution was to explain most of the variation of these variables by principal components.

(a) The first step in the procedure was to compute successive powers of the correlation matrix. Starting with R, the values of $RR = R^2$, $R^2R^2 = R^4$, $R^4R^4 = R^8$ and so on, were computed until the element of the vector a' R^i and a' R^{2i} become proportional to each other. The vector a' can be any arbitrary vector and when a' R^i is proportional to a' R^{2i} is proportional to the largest latent vector of eigen vector. For more rapid convergence, it was best to have the elements by a' proportional to the row total of the correlation matrix.

$$R = (r_{ij})$$

$$R^2 = (r_{ij})\,(r_{ij})$$

$$a'\,R^2 = (a')(R^2) \text{ or } (a_1, a_2 \ldots\ldots\ldots\ldots a_p)$$

Where, p = number of elements in the vector = number of variables

(b) Now this vector can be standardized by dividing each element by the largest elements of the vector, say, a_1:

$$\left[\frac{a_1}{a1}\ \frac{a_2}{a_2} - - - - - - - - - - - - - \frac{a_p}{a_1}\right]$$

$$= [a_1s', a_2s', \text{--------------------} a_ps]$$

Where, subscript s in all the elements represents standardization. Next step was to compute $R^4 = R^2R^2$

$$a'R^4 = (a')\,(R^4)$$

$$= (b_l, b_2 \ldots\ldots\ldots b_p)$$

$$\text{Standardized vector} = \left[\frac{b_1}{b1}\ \frac{b_2}{b_2} - - - - - - - - - - - - - \frac{b_p}{b_1}\right]$$

$b = [b_1s', b_2s' \ldots\ldots\ldots b_ps]$

Where, a and b = Vector of coefficient

(c) Next step was to compare this vector with the previous one for their agreement with each other. If they agree with each other upto third decimal place, next order of power is not computed, otherwise, next and successive order of power is computed until two successive vectors showed close agreement with each other.

The last vector, which was in close agreement with previous one, was converted into a latent vector (eigen vector) by dividing each element by square root of sum of squares of the p elements.

$$\sqrt{\left[(d_{1s})^2 + (d_{2s})^2 + \ldots\ldots\ldots\ldots \ldots\ldots\ldots\ldots \ldots\ldots (d_{ps})^2\right]}$$

$$\sqrt{\sum_{i=1}^{p} (d_{is})^2}$$

Where, d = standardized value thus latent vector (eigen vector) will be

$$\frac{d_{1s}}{\sqrt{\sum_{i=1}^{p} (d_{is})^2}} \quad \frac{d_{2s}}{\sqrt{\sum_{i=1}^{p} (d_{is})^2}} \quad - \quad - \quad - \quad \frac{d_{ps}}{\sqrt{\sum_{i=1}^{p} (d_{is})^2}}$$

$= (t_{11}, t_{12} \ldots\ldots\ldots\ldots\ldots\ldots t_{p1})$ with restriction of unit length that is t^0

Since $Rt = \lambda t$

or

$$\left[r_{11}, r_{12} \ldots\ldots\ldots\ldots \ldots\ldots\ldots\ldots r_{1p}\right] \begin{bmatrix} t_{11} \\ t_{21} \\ - \\ t_{p1} \end{bmatrix} = \left[t_{11}\right]\lambda$$

Thus,

$$\lambda = \left[r_{11}, r_{12} \ldots\ldots\ldots\ldots \ldots\ldots\ldots\ldots .r_{1p}\right] \begin{bmatrix} t_{11} \\ t_{21} \\ - \\ t_{p1} \end{bmatrix} = \left[t_{11}^{-1}\right]\lambda$$

Where, t = eigen vector of latent vector, A = eigen value of eigen root or latent root

This λ holds equally for all rows of R and is the largest latent root (eigen root or eigen value) of matrix (R- λ I) = 0 where, I = identity matrix. So those, the associated latent vector become (t_{11}, t_{21}...t_{p1}). This latent vector is also the heightening vector for the largest principal component and its associated λ is equal to the variance of the largest first 0 principal component.

(d) Next step is to derive a second principal component that is orthogonal to the first and the variance of which is maximized. The first step in doing this is to calculate a residual correlation matrix Ii which reflects what is left of the variance and covariance terms of the original correlation matrix after the influence of the first principal component is subtracted out. Thus, these can be subtracted by RS = T-tt'.

Where, RS = Residual correlation matrix, R = Original correlation matrix, A = latent root (eigen root or eigen value) corresponding to the largest first principal component), t = latent (eigen) vector and't' = transponse of t

To obtained second and then successive principal component, the same procedure was repeated which was used for first principal correlation matrix. As a result the successive principal components were getting closer and closer to a null matrix. Thus the principal component analysis can be summarized as follows:

Variables	**Tl**	**t2**	**Eigen vector**	**Tp**
X1	t_{11}	t_{12}	-----------------	t_{1p}
X2	t_{21}	t_{22}	----------------	t_{2p}
-	-	-	---------------	-
-	-	-	---------------	-
X_p	t_{pl}	t_{p2}	-----------------	t_{pp}
Total				

- Eigen value $\hat{\lambda}_1 \hat{\lambda}_2$ ------ $\hat{\lambda}_{p1}$ = sum of $\hat{\lambda}_1$------ $\hat{\lambda}_2$ =G
- Percentage of sum $\frac{100\,\hat{\lambda}_1}{G}$ $\frac{100\,\hat{\lambda}_2}{G}$ ------- $\frac{100\,\hat{\lambda}_{p1}}{G}$
- Cumulative Percent $\frac{100\,\hat{\lambda}_1}{G}$ $\frac{100\,\hat{\lambda}_1+\hat{\lambda}_2}{G}$ ------- $\frac{100\,\hat{\lambda}_1 + \hat{\lambda}_2 ---- \hat{\lambda}_p}{G}$

Now principal component of R may be described as follows. Let be a new variable then j^{th} principal component can be defined as:

$y_j = t_j\ [x\text{-}x]$

$= t_{1j}\ [x_{11}\text{-}x_1] + t_{2j}\ [x_{12}\text{-}x_2] +$ ----------------- $t_{pj}[x_{1p}\text{-}\ x_p]$

$= t_{1j}\ [x_{21}\text{-}x_1] + t_{2j}\ [x_{22}\text{-}x_2] +$ ------------------ $t_{pj}[x_{2p}\text{-}x_p]$

$= t_{1j}\ [x_{n1}\text{-}x_1] + t_{2j}\ [x_{n2}\text{-}x_2] +$ ------------------ $t_{pj}[x_{np}\text{-}x_p]$

Where, n = number of objects, p = number of variables, y_j = jth principal component of R, t_j = Eigen vector value of the jth principal component,

$X - \overline{X}$ = matrix of centred or mean deviated scores

$$\sum_{j=1}^{p} \overline{X} = \sum_{i=1}^{n} X_{ij} \Big/ n$$

Since these are 'p' non-zero Eigen values of r, their, still remains to choose the appropriate solution. The variance of 'y' may be made arbitrarily large by suitable choice of the element t, therefore, it is conventional to norm t to unit length t't = 1.

Maximum t'Rt, subject to t't-1

Joining the constraint to the objective function with a long range multiplier μ and differentiating the solution, t must satisfy the following

$$\frac{\delta}{\delta t}\left[t' RT + \mu\left(t - t' t\right)\right] = 2Rt - 2\mu t = 0 \text{ or } [R\text{-}\mu t] = 0$$

Where, t = one of the Eigen vector of R, μ= associated Eigen value

As found above Rt = μt, multiplying *from* the left by't' then

T'Rt = μt't= μ = var (Y)

Since t't = 1 therefore, the vector of coefficients for Y is the Eigen vector of R corresponding to the largest Eigen value and this Eigen value is itself equal to the variance of Y. The linear composite Y is called the first principal component and the linear composite formed by using the Eigen vector corresponding to the jth largest Eigen value is called the jth principal component.

The first principal has the largest variance of any linear combination of the variables represented in the data matrix, the second principal component has the largest variance of any linear combination orthogonal to the first principal component and the third has the largest variance of any linear combination to the first two and so forth.

In particular, if A (L) is an P x L matrix whose columns are L Eigen vector values, the L x n matrix of principal component, scores is Y (L) = A(L)' X.

Where, P = Row vector = Number of variables, L = Column vector = Eigen vector of largest Eigen values in reduced dimension, X = Original matrix

These scores on principal components axis were used in Euclidean D^2 statistics for computation of genetic distance in the principal component space.

$$d^2_{ij} = \sum_{i=1}^{1} \left(X_{ij} - X_{ik}\right)^2$$

The corresponding individual genetic distance between each variety becomes a basis for clustering of variety with relative similarity within a cluster or relative dissimilarly between clusters. The basic aim to be finding out numerical discontinuity in data set by means of appropriate clustering method the non hierarchical clustering approach was followed.

Non-hierarchical Euclidean cluster analysis

Beale (1969) describe non-hierarchical Euclidean cluster analysis, later Spark (1973) elaborated and used it to study the genetic divergence among the genotypes. The principal component scores obtained from original variables were utilized for this analysis. According to Beale (1969) initially each observation was located to the closest cluster center. The means of the cluster are then calculated and are taken to the new cluster centers. At the same time, the sum of squared deviation of the observations from their respective cluster center was computed. The observations were then checked whether with a decrease in the total sum of squares, a shift to a different cluster center results. This assumes that $d_j^2 < d_k^2$, where, d_j is the distance from the center of cluster i.e., however, a more effective criterion involves reassigning the observation if of cluster i, is less than that from center of cluster k, even when the cluster center are simultaneously reposition that is when:

$$\frac{n_i}{n_i + 1} d_i^{\,2} < \frac{n_k}{n_k + 1} d_k^{\,2}$$

Where, n_i is the number of observation in cluster 'i' and n_k is the number of observation in cluster k.

In delimiting cluster usually average among a subset of 'm' point is considered, not the individual 1/m (m-1) deviances. If the i^{th} variable on the j^{th} member is X_{ij} average of the means deviance of set of 'm' is as follows:

$$\frac{1}{m(m-1)}\sum_{i=1}^{D}\sum_{j=1}^{m}\sum_{k=1}^{m}\left(X_{ij}-X_{kj}\right)^{2}$$

$$\frac{1}{m(m-1)}\sum_{i=1}^{D}\sum_{j=1}^{m}\sum_{k=1}^{m}\left(X_{ij}-X_{kj}\right)^{2}\left(X_{ik}-X_{i}\right)]^{2}$$

Where, x_i is the mean of x_i over m members.

$$\frac{1}{m(m-1)}\sum_{i=1}^{p}\left[\sum_{j}\sum_{k}\left(X_{ij}-X_{ij}\right)^{2}\sum_{j}\sum_{k}\left(X_{ik}-X_{i}\right)^{2}-\sum_{j}\sum_{k}\left(X_{ij}-X_{i}\right)\left(X_{ik}-X_{i}\right)\right]$$

The cross product term vanishes and other two are equal:

$$=\frac{2}{m-1}\sum_{i=1}^{m}\sum_{j=1}^{p}\left(X_{kj}-X_{i}\right)^{2}$$

Now, instead of calculating 1/m (m-1) deviance, ‘m’ deviance from the center of gravity is calculated. Thus assumption in this method are that the Euclidean distances ‘D’ separating ‘n’ point in a ‘p’ dimensional space are proportional to the dissimilarities between the objects, and secondary, that no object belongs simultaneously to two clusters.

Initially, a given number of vector D of cluster centre are located in the ‘p’ space. The position of three centres can be chosen arbitrary of randomly, however, a good choice of initial cluster centres reduces the amount of computation to a considerable extent. To start with, ‘n’ cases are allocated to a predator-mixed maximum number of clusters (c. maximum) according to the procedure suggested by Beale (1969). The residual sum of sequences RSS (c) for the solution involving ‘c’ clusters is calculated. Then the number of cluster ‘c’ is reduced by 1 (unless c = minimum) and this procedure is repeated till ‘c’ maximum was reached i.e., further reduction is negligibly small. For each step RSS (c) is calculated when RSS (c) values for ‘c’ maximum., c minimum are available, these are used in a sequential ratio test of the null hypothesis that the solution for ‘c’ cluster provides no better fit than the solution for the c_2 with $c_1 > c_2$. This F ratio is calculated as:

$$F = \frac{RSS\ (c_2) - RRS\ (c_1)}{RRS\ (c_1)} \Bigg/ \left\{ \left(\frac{n - c2}{n - c1} \right) \left(\frac{c1}{c2} \right)^{2/p} - 1 \right\}$$

With p (c_1-c_2) and p (n-c_1) df. The null hypothesis is rejected if this F exceeds the Table value of F.

To calculate the number of clusters by 1 till c min is reduced, Beale (1969) has suggested certain procedure instead of using Belays procedure for merging two clusters. Doshi *et al.* (1981) have adopted a simple procedure. When a solution is found for ‘c’ clusters “c” of new cluster are calculated. From this set of new cluster centre vectors, last vector is dropped and (c-l) vector are used as initial vector of cluster centres for arriving at (c-l) cluster. For determining the appropriate number of cluster F -test gives rough guide is exploratory analysis.

The classificatory analysis gave clusters of genotypes where similar types occur in one cluster. The solution provides classified genotypes. The cluster mean were graphically depicted in the form of bar diagram.

3.8.2 Mahalnobis D^2 Statistics

The Mahalnobis distance is a measure of the distance between a point P and a distribution D, introduced by P. C. Mahalnobis in 1936. It is a multi-dimensional generalization of the idea of measuring how many standard deviations away P is from the mean of D. This distance is zero if P is at the mean of D and grows as P moves away from the mean: Along each principal component axis, it measures the number of standard deviations from P to the mean of D. If each of these axes is rescaled to have unit variance, then Mahalnobis distance corresponds to standard Euclidean distance in the transformed space. Mahalnobis distance is thus unit less and scale-invariant and takes into account the correlations of the data set. The D^2 values were arranged in increasing order of magnitude. Grouping of strains into various clusters was done by using Tocher's method (Rao, 1952). Following the analysis of variance and co-variance, the data were subjected to multivariate analysis. The original inter-related variables (X'_S) were first transformed into a set of mutually uncorrelated variables (Y’s as linear function of X’s) and then D^2 values were worked out.

Pivotal condensation method was used to compute inverse matrix of the error dispersion matrix (Rao, 1952). The generalized distance function (D^2) between two genotypes is simply the sum of square of differences in Y's i.e.,

$$D^2_{1.2} = \sum_{i=1}^{P} (Y_{1i} - Y_{2i})^2$$

The value between the variables on the basis of P characters is:

$$D^2_p = \sum_{i=1}^{P} \sum_{j=1}^{P} (Wij)didj$$

Where, D^2_p=is the D2 value between the variables on the basis of P characters, Wij = is the inverse matrix of the pooled common dispersion obtained from error matrix, 'd' = is the difference in mean value for the characters of respective genotypes as indicated by i and j.

$D^2 = \sum ijdidj$

Where, ij = Matrices reciprocal to the common dispersion matrices, di and dj = difference between mean value of the population for the i^{th} and j^{th} characters respectively.

The D^2 was calculated by following the steps as given below:

3.8.2.1 Transformation of correlated variables

The original means were subjected to get uncorrelated variables with the standard deviation unity. First the transformation of correlated variables to uncorrelated ones (Yis) and then works out the D^2 values**.**

Transformation is done using pivotal condensation method (Rao, 1952).

$$Y'_s = \frac{X's}{\sqrt{VarYj}}$$

So as to make variance of Yj=1

3.8.2.2 Calculation of mean values of the transformed characters

Mean value of the transformed characters were obtained by substituting the original characters into the uncorrelated transformation variables. The values were obtained separately for each strain.

3.8.2.3 Calculation of D^2 values

D^2 between any two populations were calculated as the sum of square of differences in the value between pairs of corresponding mean value of transformed characters.

3.8.2.4 Test of significance $\sum (Y^1i\text{-}Y^2j)^2$

The D^2 obtained of a pair of population was taken as the calculated value of X^2 (chi square) and tested against the tabulated value of X^2 for P degree of freedom. Where P is the number of characters considered. When calculated value was more than table value at 5% probability of P d.f. then the D^2 value was considered to be significant one. From the data, variances and covariance's was calculated using D^2 model. From these estimates a dispersion table was prepared. Using 'V' statistics which, in turn, utilizes Wilk's criteria, a simultaneous test of differences between mean values of a number of correlated variables was done (Rao, 1952).

3.8.2.5 Contribution of individual characters towards total divergence

In all the combinations (630 in this case) each character is ranked on the basis of di = Xi-Xj values.

Rank 1 was given to the highest mean differences and rank P to the lowest mean difference, where P is the total number of characters (10) finally, another table was prepared and the percent contribution of each character to total divergence was given assuming all possible combinations (630) equal to 100 percent.

3.8.2.6 Grouping of varieties into various clusters

The D^2 values were arranged in increasing order of magnitude. Grouping of strains into various clusters was done by using Tocher's method (Rao 1952). The two populations having smallest distance with each other were considered first to which a third population having smallest average D^2 values from the first two populations were added. Similarly fourth average D^2 value between any two populations in the first row of the table was fixed to decide that what extent to average D^2 value was permissible for including a strain in cluster.

3.8.2.7 Intra and inter –cluster distance

The intra-cluster D^2 was calculated as the sum of n (n-1)/2 genotypes within a cluster divided by total number of combinations. All possible D^2 values between the groups of two clusters were added and then divided by n1 $\times$ n2 for computing inter-cluster distance.

Where, n1 and n 2 = the number of genotypes in two clusters

3.8.2.8 Intra and inter-cluster 'D' value

The square root of average values was worked out to calculate the average intra and inter cluster D values.

3.8.2.9 Cluster mean

The cluster mean for the particular character is the summation of mean values of the strains included in a cluster divided by number of strains in the cluster.

3.8.2.10 Cluster diagram

With the help of D^2 values between and within the cluster, Cluster diagram has been drawn which showed the relationship between different populations.

Results and Discussion

The experimental results obtained from the investigation entitled "Classification of different varieties and new accessions of mango (*Mangifera indica* L.) based on qualitative traits and assessment of genetic diversity'' conducted at the Horticulture Research Centre (HRC), Patharchatta and Department of Horticulture of G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, are described under following heads and subheads:

4.1 Morphological Qualitative Traits

4.1.1 Tree traits

4.1.2 Leaf traits

4.1.3 Inflorescence traits

4.1.4 Mature fruit traits

4.1.5 Ripe fruit and stone traits

4.2 Analysis of Genetic Parameter

4.2.1 Analysis of variance

4.2.2 Mean performances

4.2.3 Coefficient of variability

4.2.4 Heritability and genetic advance

4.2.5 Correlation coefficients (character association)

4.3 Assessment of Genetic Divergence

4.3.1 Principal Component Analysis (PCA)

4.3.1.1 Eigen values (Eigen root) and Eigen vectors

4.3.1.2 Grouping of varieties based on principal component analysis (PCA)

4.3.1.3 Interaction PCA-BiPlot (AMMI 2) between genotypes and environments

4.3.2 Mahalnobis' D^2 statistics

4.3.2.1 Group constellation

4.3.2.2 Intra and inter-cluster average D^2 values

4.3.2.3 Cluster mean

4.3.2.4 Per cent contribution of different characters towards genetic divergence

4.1 Morphological Qualitative Traits

The 25 visual morphological qualitative traits were selected as per mango descriptors for the classification and grouping of varieties including new accessions of mango. These traits are described under following heads and subheads:

4.1.1 Tree traits

The qualitative traits of tree such as tree growth habit, canopy shape, branch density and foliage density showed variations among the mango varieties including new accessions, which are presented as under.

4.1.1.1 Tree growth habit, canopy shape, branch density and foliage density

The observations recorded for the tree growth habit (Table 4.1 and Fig. 4.1) revealed the variation among the mango varieties and new accessions. The spreading growth habit was observed in different mango varieties like Langra, Chausa, Arunika, Van Raj, Burma Surkh, Pant Sinduri, Bombay Green, Amrapali, Pusa Arunima, Pusa Surya, Arka Neelkiran, Ambika, Neeluddin, Neeleshan, Neelgoa, Ratna, Bangalora, Totapuri Red Small, Saurabh, Rajiv, Himanshu, Dilpasand, Chandrakaran, Sensation, Tommy Atkins, Dashehari, Dashehari 35, Dashehari 51, A.U. Rumani, Gourav, Sukul and Himsagar, whereas, erect growth habit was observed in Mallika, Angoor Lata, Tilka Bhadainya, Swarna Jehangir, PMSS-1, Sabri, Pant Chandra and Surkha Khal.

The canopy shape of different mango varieties presented in Table 4.1 and Fig. 4.1, revealed that the oblong canopy was observed in the varieties such as Bombay Green, Pant Chandra, Pusa Arunima, Swarna Jehangir, Totapuri Red Small, Sabri, Angoor Lata, Sukul, Himsagar, Surkha Khal and Sensation, while, Semi-circular shape was observed in Arka Neelkiran, Ambika, Neeluddin, A.U. Rumani, Rajiv, Himanshu, Tilka Bhadainya, Burma Surkh, Chausa, Langra, Pant Sinduri, PMSS-1, Ambika, Neeleshan, Neelgoa, Ratna, Bangalora, Saurabh, Gourav, Van Raj, Dilpasand, Chandrakaran, Tommy Atkins, Dashehari, Dashehari 35, Dashehari 51, Amrapali, Mallika and Pusa Surya. The dense branch density was recorded in the varieties such as Pant Sinduri, Mallika, Pusa Arunima, Pusa Surya, PMSS-1 and Sensation and medium was recorded in Dilpasand, Langra, Chausa, Bombay Green, Chandrakaran, Himanshu, Tommy Atkins, Dashehari, Dashehari 35, Dashehari 51, Pant Chandra, Arka Neelkiran, Arunika, Neeluddin, Neeleshan, Neelgoa, A.U. Rumani, Bangalora, Sukul and Burma Surkh. The sparse branch density was observed in Amrapali, Ambika, Swarna Jehangir, Sabri, Totapuri Red Small, Himsagar, Tilka Bhadainya, Ratna, Saurabh, Van Raj, Angoor Lata, Rajiv, Gourav and Surkha Khal.

The foliage density of different mango varieties has been presented in Table 4.1 and Fig. 4.1. The dense foliage density was observed in Dashehari, Amrapali, Pusa Arunima, Ambika, A.U. Rumani, Pant Sinduri, PMSS-1, Dashehari 35, Dashehari 51, Saurabh, Arka Neelkiran, Sukul and Sensation, while, intermediate foliage density was recorded in Bombay Green, Pant Chandra, Mallika, Neeluddin, Himanshu, Burma Surkh, Neelgoa, Bangalora, Neeleshan, Dilpasand, Tommy Atkins, Chandrakaran and Langra. The sparse foliage density was observed in Ratna, Totapuri Red Small, Rajiv, Swarna Jehangir, Sabri, Pusa Surya, Gourav, Van Raj, Tilka Bhadainya, Himsagar, Angoor Lata and Surkha Khal.

Results obtained during 2014 and 2016 revealed that the mango tree growth habit was of two types i.e., spreading and erect; canopy shape varied from oblong to semi-circular; branch density varied as dense, medium and sparse; and foliage density varied as dense, intermediate and sparse. The variation in tree growth habit, canopy shape, branch density and foliage density amongst the mango varieties could be due to the variation in genetic makeup under the present set of environmental conditions and edaphic condition (Kanpure *et al.,* 2009). Singh (2014) reported that qualitative traits of tree like growth habit, canopy shape, branch density, foliage density varied with each other. The upright growth was found in Amin, Husn-a-ra, Mallika and Safeda Lucknow: intermediate in Amarpali, Bombay Green, whereas, spreading type in Bride of Russia, Khasl-ul-Khas, Jafrani Gola. Similar results were determined by Joshi *et al.* (2013) and Majumder *et al*. (2011), in mango.

4.1.2 Leaf traits

The qualitative traits of leaf such as young leaf colour (intensity of anthocyanin), leaf base shape, leaf apex shape, leaf twisting and margin showed variations among the mango varieties including new accessions, which are described as below:

Table 4.1: Visual assessment of morphological qualitative traits of tree and leaf in different varieties including new accessions of mango (on the basis of 2 years evaluation in 2014 and 2016)

S. No.	Varieties/accessions	Tree characteristics				Leaf characteristics	
		Tree growth habit	Canopy shape	Branch density	Foliage density	Young leaf: (intensity of anthocyanin)	Apex shape
1	Dashehari	Spreading	Semi-circular	Medium	Dense	Weak	Attenuate
2	Dashehari 35	Spreading	Semi-circular	Medium	Dense	Weak	Attenuate
3	Dashehari 51	Spreading	Semi-circular	Medium	Dense	Weak	Attenuate
4	Langra	Spreading	Semi-circular	Medium	Dense	Medium	Acuminate
5	Chausa	Spreading	Semi-circular	Medium	Intermediate	Medium	Acuminate
6	Bombay Green	Spreading	Oblong	Medium	Intermediate	Strong	Acuminate
7	Pant Sinduri	Spreading	Semi-circular	Dense	Dense	Medium	Acuminate
8	Pant Chandra	Erect	Oblong	Medium	Intermediate	Weak	Attenuate
9	PMSS-1	Erect	Semi-circular	Dense	Dense	Medium	Attenuate
10	Amrapali	Spreading	Semi-circular	Sparse	Dense	Strong	Attenuate
11	Mallika	Erect	Semi-circular	Dense	Intermediate	Strong	Acuminate
12	Pusa Arunima	Spreading	Oblong	Dense	Dense	Strong	Acuminate
13	Pusa Surya	Spreading	Semi-circular	Dense	Sparse	Strong	Acuminate
14	Arka Neelkiran	Spreading	Semi-circular	Medium	Dense	Strong	Attenuate
15	Ambika	Spreading	Semi-circular	Medium	Dense	Strong	Acuminate
16	Arunika	Spreading	Semi-circular	Sparse	Sparse	Medium	Attenuate
17	Neeluddin	Spreading	Semi-circular	Medium	Intermediate	Strong	Attenuate
18	Neeleshan	Spreading	Semi-circular	Medium	Intermediate	Strong	Attenuate

19	Neelgoa	Spreading	Semi-circular	Medium	Intermediate	Strong	Attenuate
20	A.U. Rumani	Spreading	Semi-circular	Medium	Dense	Weak	Attenuate
21	Swarna Jehangir	Erect	Oblong	Sparse	Sparse	Medium	Acute
22	Ratna	Spreading	Semi-circular	Sparse	Sparse	Strong	Acuminate
23	Sabri	Erect	Oblong	Sparse	Sparse	Medium	Acute
24	Bangalora	Spreading	Semi-circular	Medium	Intermediate	Strong	Attenuate
25	Totapuri Red Small	Spreading	Oblong	Sparse	Sparse	Strong	Acute
26	Angoor Lata	Erect	Oblong	Sparse	Sparse	Strong	Attenuate
27	Saurabh	Spreading	Semi-circular	Sparse	Dense	Strong	Acuminate
28	Rajiv	Spreading	Semi-circular	Sparse	Sparse	Strong	Attenuate
29	Gourav	Spreading	Semi-circular	Sparse	Sparse	Weak	Attenuate
30	Himanshu	Spreading	Semi-circular	Medium	Intermediate	Strong	Acuminate
31	Sukul	Spreading	Oblong	Medium	Dense	Weak	Attenuate
32	Van Raj	Spreading	Semi-circular	Sparse	Sparse	Medium	Attenuate
33	Dilpasand	Spreading	Semi-circular	Medium	Intermediate	Strong	Acute
34	Himsagar	Spreading	Oblong	Sparse	Sparse	Weak	Acute
35	Tilka Bhadainya	Erect	Semi-circular	Sparse	Sparse	Medium	Acute
36	Chandrakaran	Spreading	Semi-circular	Medium	Intermediate	Strong	Acute
37	Surkha Khal	Erect	Oblong	Sparse	Sparse	Strong	Attenuate
38	Burma Surkh	Spreading	Semi-circular	Medium	Intermediate	Medium	Attenuate
39	Sensation	Spreading	Oblong	Dense	Dense	Strong	Attenuate
40	Tommy Atkins	Spreading	Semi-circular	Medium	Intermediate	Strong	Acuminate

4.1.2.1 Young leaf (intensity of anthocyanin), leaf apex shape and base shape

The observations in relation to leaf traits (Table 4.1, Fig. 4.1 and Plate 1 - 40) indicated that young leaf colour (intensity of anthocyanin) varied among the mango varieties. The weak intensity of anthocyanin in young leaf was observed in the varieties such as Dashehari, Dashehari 35, Dashehari 51, Pant Chandra, A.U. Rumani, Gourav, Sukul and Himsagar, while, medium was recorded in Langra, Chausa, PMSS-1, Arunika, Swarna Jehangir, Sabri, Van Raj, Tilka Bhadainya, Burma Surkh and Pant Sinduri, However, strong intensity of anthocyanin in young leaf was recorded in mango varieties such as Bombay Green, Amrapali, Mallika, Pusa Arunima, Pusa Surya, Arka Neelkiran, Ambika, Neeluddin, Neeleshan, Neelgoa, Ratna, Bangalora, Totapuri Red Small, Angoor Lata, Saurabh, Rajiv, Himanshu, Dilpasand, Chandrakaran, Surkha Khal, Sensation and Tommy Atkins.

Mango varieties showed variations for leaf apex shape as tabulated in Table 4.1 and presented in Fig. 4.2. The acute leaf apex shape was noted in the varieties such as Swarna Jehangir, Sabri, Totapuri Red Small, Dilpasand, Himsagar, Tilka Bhadainya and Chandrakaran; attenuate shape of leaf apex in Dashehari, Dashehari 35, Dashehari 51, Pant Chandra, PMSS-1, Amrapali, Arka Neelkiran, Arunika, Neeluddin, Neeleshan, Neelgoa A.U. Rumani, Ratna, Bangalora, Angoor Lata, Saurabh, Gourav, Sukul, Van Raj, Surkha Khal, Burma Surkh and Sensation and acuminate leaf apex shape in rest of the varieties including new accessions.

The leaf base shape was found to vary among the mango varieties under present investigation as it is also revealed by Table 4.2 and presented in Fig. 4.2. indicate the acute base shape was observed in Dashehari, Dashehari 35, Dashehari 51, Bombay Green, Pant Chandra, Amrapali, Mallika, Pusa Arunima, Pusa Surya, Arka Neelkiran, Ambika, Neeluddin, A.U. Rumani, Totapuri Red Small, Angoor Lata, Rajiv, Himanshu, Himsagar, Tilka Bhadainya and Burma Surkh, while, obtuse leaf base shape in Langra, Chausa, Pant Sinduri, PMSS-1, Ambika Neeleshan, Neelgoa, Swarna Jehangir, Ratna, Bangalora, Saurabh, Gourav, Sukul, Van Raj, Dilpasand, Chandrakaran, Surkha Khal, Sensation and Tommy Atkins.

The observations in relation to intensity of anthocyanin in young leaf, leaf base shape and leaf apex shape showed variation among the mango varieties during

Fig. 4.1: Grouping of different mango varieties including new accessions based on qualitative traits of tree

Tree characters

- **Growth habit**
  - **Erect**: Mallika, Angoor Lata, Swarna Jehangir, PMSS-1, Sabri, Pant Chandra, Surkha Khal, Tilka Bhadainya
  - **Spreading**: Langra, Chausa, Arunika, Van Raj, Burma Surkh, Pant Sinduri, Bombay Green, Amrapali, Pusa Arunima, Pusa Surya, Arka Neelkiran, Ambika, Neeluddin, Neeleshan, Neelgoa, Ratna, Bangalora, Totapuri Red Small, Saurabh, Rajiv, Himanshu, Dilpasand, Chandrakaran, Sensation, TommyAtkins, Dashehari, Dashehari-35, Dashehari 51, A.U.Rumani, Gourav, Sukul, Himsagar
- **Canopy shape**
  - **Oblong**: Bombay Green, Pant Chandra, Pusa Arunima, Swarna Jehangir, Totapuri Red Small, Sabri, Angoor Lata, Sukul, Himsagar, Surkha Khal, Sensation
  - **Semi-circular**: Langra, Chausa, Pant Sinduri, PMSS-1, Ambika, Neeleshan, Neelgoa, Ratna, Bangalora, Saurabh, Gourav, Van Raj, Dilpasand, Chandrakaran, Tommy Atkins, Dashehari, Dashehari 35, Dashehari 51, Amrapali, Mallika, PusaSurya, Arka Neelkiran, Ambika, Neeluddin, A.U. Rumani, Rajiv, Himanshu, Tilka Bhadainya, Burma Surkh
- **Branch density**
  - **Sparse**: Amrapali, Ambika, Swarna Jehangir, Sabri, Totapuri Red Small, Himsagar, Tilka Bhadainya, Ratna, Saurabh, Van Raj, Angoor Lata, Rajiv, Gourav, Surkha Khal
  - **Medium**: Dilpasand, Langra, Chausa, Bombay Green, Chandrakaran, Himanshu, Tommy Atkins, Dashehari, Dashehari 35, Dashehari 51, Pant Chandra, Arka Neelkiran, Arunika, Neeluddin, Neeleshan, Neelgoa, A.U.Rumani, Bangalora, Sukul, Burma Surkh
  - **Dense**: Pant Sinduri, Mallika, Pusa Arunima, Pusa Surya, PMSS-1, Sensation
- **Foliage density**
  - **Sparse**: Ratna, Totapuri Red Small, Rajiv, Swarna Jehangir, Sabri, Pusa Surya, Gourav, Van Raj, Tilka Bhadainya, Himsagar, Angoor Lata, Surkha Khal
  - **Intermediate**: Bombay Green, Pant Chandra, Mallika, Neeluddin, Himanshu, Burma Surkh, Neelgoa, Bangalora, Neeleshan, Dilpasand, Tommy Atkins, Chandrakaran, Langra
  - **Dense**: Dashehari, Amrapali, Pusa Arunima, Ambika, A.U. Rumani, Pant Sinduri, PMSS-1 Dashehari35, Dashehari 51, Saurabh, Arka Neelkiran, Sukul, Sensation

Fig. 4.2: Grouping of different mango varieties including new accessions based on qualitative traits of leaf

Leaf characters

- **Young leaf: intensity of anthocyanin**
  - **Weak**: Dashehari, Dashehari 35, Dashehari 51, Pant Chandra, A.U. Rumani, Gourav, Sukul, Himsagar
  - **Strong**: Bombay Green, Amrapali, Mallika, Pusa Arunima, Pusa Surya, Arka Neelkiran, Ambika, Neeluddin, Neeleshan, Neelgoa, Ratna, Bangalora, Totapuri Red Small, Angoor Lata, Saurabh, Rajiv, Himanshu, Dilpasand, Chandrakaran, Surkha Khal, Sensation, Tommy Atkins
  - **Medium**: Langra, Chausa, PMSS-1, Arunika, Swarna Jehangir, Sabri, Van Raj, Tilka Bhadainya, Burma Surkh, Pant Sinduri
- **Shape of base**
  - **Acute**: Dashehari, Dashehari 35, Dashehari 51, Bombay Green, Pant Chandra, Amrapali, Mallika, Pusa Arunima, Pusa Surya, Arka Neelkiran, Ambika, Neeluddin, A.U. Rumani, Totapuri, Red Small, Angoor Lata, Rajiv, Himanshu, Himsagar, Tilka Bhadainya, Burma Surkh
  - **Obtuse**: Langra, Chausa, Pant Sinduri, PMSS-1, Ambika, Neeleshan, Neelgoa, Swarna Jehangir, Ratna, Bangalora, Saurabh, Gourav, Sukul, Van Raj, Dilpasand, Chandrakaran, Surkha Khal, Sensation, Tommy Atkins
- **Shape of apex**
  - **Attenuate**: Dashehari, Dashehari 35, Dashehari 51, Pant Chandra, PMSS-1, Amrapali, Arka Neelkiran, Arunika, Neeluddin, Neeleshan, Neelgoa, A.U. Rumani, Ratna, Bangalora, Angoor Lata, Saurabh, Gourav, Sukul, Van Raj, Surkha Khal, Burma Surkh, Sensation
  - **Acute**: Swarna Jehangir, Sabri, Totapuri, Red Small, Dilpasand, Himsagar, Tilka Bhadainya, Chandrakaran
  - **Acuminate**: Langra, Chausa, Bombay Green, Pant Sinduri, Mallika, Pusa Arunima, Pusa Surya, Ambika, Ratna, Saurabh, Himanshu, Tommy Atkins
- **Leaf twisting**
  - **Present**: Chausa, Ratna, Totapuri Red Small, Sukul, Sensation
  - **Absent**: Dashehari, Dashehari 35, Dashehari 51, Bombay Green, Pant Chandra, Amrapali, Mallika, Pusa Arunima, Pusa Surya, Arka Neelkiran, Ambika, Neeluddin, A.U. Rumani, Angoor Lata, Rajiv, Himanshu, Himsagar, Tilka Bhadainya, Burma Surkh, Langra, Pant Sinduri, PMSS-1, Ambika, Neeleshan, Neelgoa, Swarna Jehangir, Bangalora, Saurabh, Gourav, Van Raj, Sabri, Dilpasand, Chandrakaran, Surkha Khal, Tommy Atkins
- **Leaf margin**
  - **Wavy**: Dashehari 35, Dashehari 51, Dashehari, Bombay Green Pant Chandra, Mallika, Pusa Surya, Arka Neelkiran, Neeluddin, Angoor Lata, Rajiv Himanshu, Tilka Bhadainya, Burma Surkh Langra, Pant Sinduri, PMSS-1, Ambika Neelgoa, Bangalora, Saurabh, Gourav, Van Raj, Surkha Khal
  - **Entire**: Amrapali, Pusa Arunima, Ambika, Neeleshan, A.U. Rumani, Rajiv, Swarna Jehangir, Ratna, Sabri, Dilpasand, Tommy Atkins, Himsagar, Chandrakaran


1: Dashehari


2: Dashehari 35


3: Dashehari 51


4: Langra


5: Chausa


6: Bombay Green


7: Pant Sinduri


8: Pant Chandra


9:PMSS-1(Pant Mango-1)


10: Amrapali


11: Mallika


12: Pusa Arunima


13: Pusa Surya


14: Arka Neelkiran


15: Ambika

Plate 1-15: Glimpses showing the variations in young leaf of different mango varieties

16: Arunika

17: Neeluddin

18: Neeleshan

19: Neelgoa

20: A.U. Rumani

21: Swarna Jehangir

22: Ratna

23: Sabri

24: Bangalora

25: Totapuri Red Small

26: Angoor Lata

27: Saurabh

28: Rajiv

29: Gourav

30: Himanshu

Plate 16-30: Glimpses showing the variations in young leaf of different mango varieties

31: Sukul

32: Van Raj

33: Dilpasand

34: Himsagar

35: Tilka Bhadainya

36: Chandrakaran

37: Surkha Khal

38: Burma Surkh

39: Sensation

40: Tommy Atkins

Plate 31-40: Glimpses showing the variations in young leaf of different mango varieties

both the years 2014 and 2016. The weak, medium and strong intensity of anthocyanin in young leaf were found in different mango varieties; acute and obtuse leaf base shape and acute, acuminate and attenuate leaf apex shape were found in dissimilar varieties of mango. These variations might be due to the variation in genotypes and environment (Islam and Nasir, 1993; Joshi *et al.*, 2013).

4.1.2.2 Leaf twisting and margin

Leaf twisting was found to vary among the different mango varieties including new accessions (Table 4.2 and Fig. 4.2). The leaf twisting was absent in Dashehari, Dashehari 35, Dashehari 51, Bombay Green, Pant Chandra, Amrapali, Mallika, Pusa Arunima, Pusa Surya, Arka Neelkiran, Ambika, Neeluddin, A.U. Rumani, Angoor Lata, Rajiv, Himanshu, Himsagar, Tilka Bhadainya, Burma Surkh, Langra, Pant Sinduri, PMSS-1, Ambika, Neeleshan, Neelgoa, Swarna Jehangir, Bangalora, Saurabh, Gourav, Van Raj, Sabri, Dilpasand, Chandrakaran, Surkha Khal and Tommy Atkins, whereas it was present in rest of the mango varieties.

The variation in different mango varieties with respect to leaf margin was noticed (Table 4.2 and Fig. 4.2). The entire leaf margin was observed in Amrapali, Pusa Arunima Ambika, Neeleshan, A.U. Rumani, Rajiv, Swarna Jehangir, Ratna, Sabri, Dilpasand, Tommy Atkins, Himsagar and Chandrakaran. The wavy leaf margin was observed in Dashehari 35, Dashehari 51, Dashehari, Bombay Green, Pant Chandra, Mallika, Pusa Surya, Arka Neelkiran, Neeluddin, Angoor Lata, Rajiv, Himanshu, Tilka Bhadainya, Burma Surkh, Langra, Pant Sinduri, PMSS-1, Ambika, Neelgoa, Bangalora, Saurabh, Gourav, Van Raj and Surkha Khal.

The variations were observed during both the years 2014 and 2016 among the mango varieties for leaf twisting which was either absent or present. The leaf margin was found as entire and wavy. These variations might be due to the genetic constitution of varieties and their interaction with environment. The similar findings have also been recorded by Joshi *et al.* (2013) and Singh *et al.* (2014), in mango.

4.1.3 Inflorescence traits

The qualitative traits of inflorescence such as inflorescence anthocyanin colouration on main rachis, shape, position and presence of bracts on main rachis showed variations in different mango varieties which are presented as under:

Table 4.2: Visual assessment of morphological qualitative traits of leaf and inflorescence in different varieties including new accessions of mango (on the basis of 2 years evaluation in 2014 and 2016)

S. No.	Varieties/accessions	Leaf characteristics			Inflorescence characteristics			
		Base shape	Twisting	Margin	Colour: intensity of anthocyanin	Shape	Position	Bract
1	Dashehari	Acute	Absent	Entire	Weak	Pyramidal	Terminal	Present
2	Dashehari 35	Acute	Absent	Wavy	Weak	Pyramidal	Terminal	Present
3	Dashehari 51	Acute	Absent	Wavy	Weak	Conical	Terminal	Present
4	Langra	Obtuse	Absent	Wavy	Weak	Pyramidal	Terminal	Present
5	Chausa	Obtuse	Present	Wavy	Weak	Conical	Terminal	Present
6	Bombay Green	Acute	Absent	Wavy	Medium	Conical	Terminal	Present
7	Pant Sinduri	Obtuse	Absent	Wavy	Strong	Pyramidal	Terminal	Present
8	Pant Chandra	Acute	Absent	Wavy	Weak	Pyramidal	Terminal	Present
9	PMSS-1	Obtuse	Absent	Wavy	Medium	Pyramidal	Terminal	Present
10	Amrapali	Acute	Absent	Entire	Medium	Pyramidal	Terminal	Present
11	Mallika	Acute	Absent	Wavy	Weak	Pyramidal	Terminal	Present
12	Pusa Arunima	Acute	Absent	Entire	Medium	Pyramidal	Terminal	Present
13	Pusa Surya	Acute	Absent	Wavy	Strong	Conical	Terminal	Present
14	Arka Neelkiran	Acute	Absent	Wavy	Medium	Conical	Terminal	Present
15	Ambika	Obtuse	Absent	Entire	Strong	Pyramidal	Terminal	Present
16	Arunika	Acute	Absent	Wavy	Strong	Pyramidal	Terminal	Present
17	Neeluddin	Acute	Absent	Wavy	Medium	Pyramidal	Terminal	Present
18	Neeleshan	Obtuse	Absent	Entire	Medium	Pyramidal	Terminal	Present
19	Neelgoa	Obtuse	Absent	Wavy	Strong	Pyramidal	Terminal	Present

20	A.U. Rumani	Acute	Absent	Entire	Weak	Pyramidal	Terminal	Present
21	Swarna Jehangir	Obtuse	Absent	Entire	Strong	Conical	Terminal	Present
22	Ratna	Obtuse	Present	Entire	Strong	Pyramidal	Terminal	Present
23	Sabri	Acute	Absent	Entire	Strong	Conical	Terminal	Present
24	Bangalora	Obtuse	Absent	Wavy	Medium	Pyramidal	Terminal	Present
25	Totapuri Red Small	Acute	Present	Wavy	Strong	Conical	Terminal	Present
26	Angoor Lata	Acute	Absent	Wavy	Weak	Conical	Terminal	Present
27	Saurabh	Obtuse	Absent	Wavy	Weak	Pyramidal	Terminal	Absent
28	Rajiv	Acute	Absent	Entire	Medium	Pyramidal	Terminal & Axillaries	Present
29	Gourav	Obtuse	Absent	Entire	Medium	Pyramidal	Terminal	Absent
30	Himanshu	Acute	Absent	Wavy	Medium	Pyramidal	Terminal	Present
31	Sukul	Obtuse	Present	wavy	Weak	Pyramidal	Terminal	Present
32	Van Raj	Obtuse	Absent	Wavy	Strong	Conical	Terminal & Axillaries	Present
33	Dilpasand	Obtuse	Absent	Entire	Strong	Pyramidal	Terminal	Present
34	Himsagar	Acute	Absent	Entire	Medium	Pyramidal	Terminal	Present
35	Tilka Bhadainya	Acute	Absent	Wavy	Medium	Conical	Terminal	Absent
36	Chandrakaran	Obtuse	Absent	Entire	Strong	Pyramidal	Terminal	Present
37	Surkha Khal	Obtuse	Absent	Wavy	Strong	Pyramidal	Terminal	Present
38	Burma Surkh	Acute	Absent	Wavy	Medium	Conical	Terminal	Absent
39	Sensation	Obtuse	Present	Wavy	Strong	Conical	Terminal & Axillaries	Present
40	Tommy Atkins	Obtuse	Absent	Entire	Strong	Conical	Terminal	Present

4.1.3.1 Inflorescence anthocyanin colouration on main rachis and shape

The observations recorded in respect to inflorescence anthocyanin colouration on main rachis and shape (Table 4.2, Fig. 4.3 and Plate 41-80) revealed variations among the different varieties. The weak anthocyanin colouration on main rachis of inflorescence was observed in Dashehari, Dashehari 35, Dashehari 51, Pant Chandra, A.U. Rumani, Sukul, Chausa, Angoor Lata, Saurabh, Langra and Mallika, while, medium was found in Tilka Bhadainya, Burma Surkh, Rajiv, Bombay Green, Amrapali, Himsagar, Pusa Arunima, Arka Neelkiran, Gourav, Neeluddin, Neeleshan, Himanshu, PMSS-1 and Bangalora. However, strong anthocynin was found in the varieties of mango like Pusa Surya, Ambika, Neelgoa, Ratna, Totapuri Red Small, Dilpasand, Chandrakaran, Surkha Khal, Sabri, Van Raj, Sensation, Tommy Atkins, Pant Sinduri, Arunika and Swarna Jehangir.

The shape of inflorescence varied in different mango varieties including new accessions as indicated in Table 4.2 and Fig. 4.3. The Pyramidal shape was recorded in Dashehari, Dashehari 35, Pant Chandra, Ambika, Amrapali, Mallika, Pusa Arunima, Neeluddin, A.U. Rumani, Rajiv, Himanshu, Himsagar, Langra, Pant Sinduri, PMSS-1, Ambika, Neeleshan, Neelgoa, Bangalora, Saurabh, Gourav, Sukul, Dilpasand, Chandrakaran and Surkha Khal, while, conical shape was found in Dashehari 51, Bombay Green, Chausa, Pusa Surya, Arka Neelkiran, Swarna Jehangir, Totapuri Red Small, Ratna, Angoor Lata, Van Raj, Tilka Bhadainya, Burma Surkh, Sensation and Tommy Atkins.

Results obtained during 2014 and 2016 for inflorescence anthocyanin colouration on main rachis and shape displayed variations in the different varieties. Varieties were noted to have weak, medium and strong anthocyanin colouration on main rachis of inflorescence and shape of panicle varied as conical and pyramidal. The variations in relations to inflorescence anthocyanin colouration on main rachis and shape might be due to genetic constitution of particular varieties and maturity of the shoots. Similar results were also obtained by Singh *et al.* (2014); Joshi *et al.* (2013) and Majumder *et al*. (2011) in mango.

Fig. 4.3: Grouping of different mango varieties including new accessions based on qualitative traits of inflorescence

Inflorescence characters

- **Anthocyanin colouration of axis and branches**
  - **Weak**: Dashehari, Dashehari 35, Dashehari 51, Pant Chandra, A.U. Rumani, Sukul, Chausa, Angoor Lata, Saurabh,Langra, Mallika
  - **Strong**: Pusa Surya, Ambika, Neelgoa, Ratna, Totapuri Red Small, Dilpasand, Chandrakaran, Surkha Khal, Sabri, Van Raj, Sensation, Tommy Atkins, Pant Sinduri, Arunika, Swarna Jehangir
  - **Medium**: Tilka Bhadainya, Burma Surkh, Rajiv, Bombay Green, Amrapali, Himsagar, Pusa Arunima, Arka Neelkiran, Gourav, Neeluddin, Neeleshan, Himanshu, PMSS-1, Bangalora
- **Inflorescence Shape**
  - **Pyramidal**: Dashehari, Dashehari 35, Pant Chandra, Ambika, Amrapali, Mallika, Pusa Arunima Neeluddin, A.U. Rumani, Rajiv, Himanshu, Himsagar, Langra, Pant Sinduri, PMSS-1, Ambika, Neeleshan, Neelgoa, Bangalora, Saurabh, Gourav, Sukul, Dilpasand Chandrakaran, Surkha Khal
  - **Conical**: Dashehari 51, Bombay Green, Chausa, Pusa Surya, Arka Neelkiran Swarna Jehangir, Totapuri Red Small, Ratna, Angoor Lata, Van Raj, Tilka Bhadainya, Burma Surkh, Sensation, Tommy Atkins
- **Inflorescence Position**
  - **Terminal**: Dashehari, Dashehari 35, Dashehari 51, Pant Chandra, PMSS-1, Amrapali, Arka Neelkiran, Arunika, Neeluddin, Neeleshan Neelgoa, A.U. Rumani, Ratna, Bangalora Angoor Lata, Saurabh, Gourav, Sukul Surkha Khal, Burma Surkh, Swarna Jehangir Sabri, Totapuri Red Small, Dilpasand Himsagar, Tilka Bhadainya, Chandrakaran Pant Sinduri, Mallika, Pusa Arunima Langra, Chausa, Bombay Green, Pusa Surya Ambika, Ratna, Saurabh, Himanshu, Tommy Atkins
  - **Terminal & Axillaries**: Van Raj, Sensation, Rajiv
- **Inflorescence Bracts**
  - **Absent**: Saurabh, Gourav, Tilka Bhadainya, Burma Surkh
  - **Present**: Dashehari, Dashehari 35, Dashehari 51, Bombay Green, Pant Chandra, Amrapali, Mallika, Pusa Arunima, Pusa Surya, Arka Neelkiran, Ambika Neeluddin, A.U. Rumani, Angoor Lata, Rajiv, Himanshu, Himsagar,Langra, Pant Sinduri, PMSS-1, Ambika, Neeleshan, Neelgoa, Swarna Jehangir, Bangalora,Van Raj, Dilpasand, Chandrakaran, Surkha Khal, Tommy Atkins, Sabri, Chausa, Ratna Totapuri Red Small, Sukul ,Sensation

41: Dashehari

42: Dashehari 35

43: Dashehari 51

44: Langra

45: Chausa

46: Bombay Green

47: Pant Sinduri

48: Pant Chandra

49: PMSS-1 (Pant Mango-1)

50: Amrapali

Plate 41-50: Glimpses showing the variations in panicle of mango varieties

71: Sukul

72: Van Raj

73: Dilpasand

74: Himsagar

75: Tilka Bhadainya

76: Chandrakaran

77: Surkha Khal

78: Burma Surkh

79: Sensation

80: Tommy Atkins

Plate 71-80: Glimpses showing the variations in panicle of mango varieties

51: Mallika

52: Pusa Arunima

53: Pusa Surya

54: Arka Neelkiran

55: Ambika

56: Arunika

57: Neeluddin

58: Neeleshan

59: Neelgoa

60: A.U. Rumani

Plate 51-60: Glimpses showing the variations in panicle of mango varieties

61: Swarna Jehangir

62: Ratna

63: Sabri

64: Bangalora

65: Totapuri Red Small

66: Angoor Lata

67: Saurabh

68: Rajiv

69: Gourav

70: Himanshu

Plate 61-70: Glimpses showing the variations in panicle of mango varieties

4.1.3.2 Inflorescence position and bracts

The observations recorded in relation to inflorescence position and bracts (Table 4.2 and Fig. 4.3), revealed variation among the mango varieties. The terminal position was observed in Dashehari, Dashehari 35, Dashehari 51, Pant Chandra, PMSS-1, Amrapali, Arka Neelkiran, Arunika, Neeluddin, Neeleshan Neelgoa, A.U. Rumani, Ratna, Bangalora, Angoor Lata, Saurabh, Gourav, Sukul, Surkha Khal, Burma Surkh, Swarna Jehangir, Sabri, Totapuri Red Small, Dilpasand, Himsagar, Tilka Bhadainya, Chandrakaran, Pant Sinduri, Mallika, Pusa Arunima, Langra, Chausa, Bombay Green, Pusa Surya, Ambika, Ratna, Saurabh, Himanshu and Tommy Atkins, whereas, terminal and axillaries position of inflorescence was observed in Van Raj, Sensation and Rajiv.

The inflorescence bracts varied in the different mango varieties as indicated in Table 4.2 and Fig. 4.3. The inflorescence bracts were present in most of the varieties such as Dashehari, Dashehari 35, Dashehari 51, Bombay Green, Pant Chandra, Amrapali, Mallika, Pusa Arunima, Pusa Surya, Arka Neelkiran, Ambika, Neeluddin, A.U. Rumani, Angoor Lata, Rajiv, Himanshu, Himsagar, Tilka Bhadainya, Burma Surkh, Langra, Pant Sinduri, PMSS-1, Ambika Neeleshan, Neelgoa, Swarna Jehangir, Bangalora, Saurabh, Gourav, Van Raj, Dilpasand, Chandrakaran, Surkha Khal, Tommy Atkins and Sabri, while, inflorescence bracts were absent in some varieties like Chausa, Ratna, Totapuri Red Small, Sukul and Sensation.

The variations were observed during 2014 and 2016 among the mango varieties for inflorescence bracts, which was either absent or present and position which varied as terminal and terminal & axillaries. These variations might be due to the genetic constitution of varieties and their interaction with environment. The findings were similar to those obtained by Singh *et al.* (2014); Joshi *et al.* (2013) and Majumder *et al*. (2011), in mango.

4.1.4 Mature fruit traits

The qualitative traits of mature fruit such as colour of skin, shape in cross section, presence of cavity at stalk, presence of neck, shape of ventral and dorsal shoulder, presence of sinus and point at stylar scar showed variation among the mango varieties, which are presented as under:

4.1.4.1 Skin colour of mature fruit and shape in cross section

The observations recorded during 2014 and 2016 for skin colour of mature fruits in different varieties of mango have been presented in Table 4.3 and Fig. 4.4. The green colour was observed in Dashehari, Dashehari 35, Dashehari 51, Pant Chandra, PMSS-1, Amrapali, Neeluddin, Neeleshan, Himsagar, A.U. Rumani, Angoor Lata, Saurabh, Gourav, Sukul, Surkha Khal, Burma Surkh, Langra, Chausa, Mallika, Bombay Green, Ratna, Saurabh, Himanshu, Swarna Jehangir, Sabri, Chandrakaran and Tilka Bhadainya, while, green and red was observed in Totapuri Red Small, Tommy Atkins, Pant Sinduri, Pusa Surya, Arka Neelkiran, Arunika, Neelgoa, Bangalora, Ratna and Van Raj. However, green and purple colour of mature fruit skin was recorded in Pusa Arunima, Ambika and Sensation.

The observations recorded during 2014 and 2016 for variation in shape for cross section of mature fruits of mango have been presented in Table 4.3 and Fig. 4.4. The shape in cross section of mature fruits was found circular in Pusa Arunima, Pusa Surya, Chandrakaran, Surkha Khal, Tilka Bhadainya, Neelgoa, Van Raj, Sukul and Angoor Lata, while, medium elliptic was observed in Dashehari, Dashehari 35, Dashehari 51, Chausa, Rajiv, A.U. Rumani, Himanshu and Burma Surkh, However broad elliptic was recorded in Bombay Green, Amrapali, Mallika, Arka Neelkiran, Ambika, Neeluddin, Neeleshan, Ratna, Bangalora, Totapuri Red Small, Saurabh, Dilpasand, Langra, Pant Chandra, Gourav, Himsagar, PMSS-1, Arunika, Swarna Jehangir, Sabri, Pant Sinduri, Sensation and Tommy Atkins.

The variation was observed during 2014 and 2016 among the mango varieties for mature fruit characters i.e., colour of skin which has been varied as green, green and red; green and purple and shape in cross section was varied as circular, medium elliptic and broad elliptic. The variation recorded might be due to the genetic constitution of varieties and their interaction with environment. The findings were similar to those obtained by Singh *et al.* (2014); Joshi *et al.* (2013) and Majumder *et al*. (2011), in mango.

4.1.4.2 Presence of cavity at stalk and neck

The observations recorded during 2014 and 2016 for presences of cavity at stalk in different varieties of mango have been presented in Table 4.3 and Fig. 4.4.

Table 4.3: Visual assessment of morphological qualitative traits of mature fruit in different varieties including new accessions of mango (on the basis of 2 years evaluation in 2014 and 2016)

S. No.	Varieties/accessions	Mature fruit characteristics					
		Colour of skin	Shape in cross section	Presence of cavity at stalk	Presence of neck	Presence of sinus	Point at stylar scar
1	Dashehari	Green	Medium Elliptic	Absent	Absent	Absent	Small
2	Dashehari 35	Green	Medium Elliptic	Absent	Absent	Absent	Small
3	Dashehari 51	Green	Medium Elliptic	Absent	Absent	Absent	Small
4	Langra	Green	Broad Elliptic	Absent	Absent	Absent	Small
5	Chausa	Green	Medium Elliptic	Absent	Absent	Absent	Small
6	Bombay Green	Green	Broad Elliptic	Absent	Absent	Absent	Small
7	Pant Sinduri	Green and red	Broad Elliptic	Absent	Absent	Present	Medium
8	Pant Chandra	Green	Broad Elliptic	Absent	Absent	Absent	Small
9	PMSS-1	Green	Broad Elliptic	Absent	Absent	Absent	Small
10	Amrapali	Green	Broad Elliptic	Absent	Absent	Present	Small
11	Mallika	Green	Broad Elliptic	Present	Present	Present	Medium
12	Pusa Arunima	Green and purple	Circular	Present	Present	Absent	Small
13	Pusa Surya	Green and red	Circular	Absent	Absent	Present	Medium
14	Arka Neelkiran	Green and red	Broad Elliptic	Absent	Absent	Absent	Small
15	Ambika	Green and purple	Broad Elliptic	Absent	Absent	Present	Medium
16	Arunika	Green and red	Broad Elliptic	Present	Present	Absent	Small
17	Neeluddin	Green	Broad Elliptic	Present	Present	Absent	Small
18	Neeleshan	Green	Broad Elliptic	Absent	Absent	Absent	Small
19	Neelgoa	Green and red	Circular	Absent	Absent	Present	Small

20	A.U. Rumani	Green	Medium Elliptic	Absent	Absent	Absent	Small
21	Swarna Jehangir	Green	Broad Elliptic	Absent	Absent	Absent	Small
22	Ratna	Green and red	Broad Elliptic	Absent	Absent	Absent	Small
23	Sabri	Green	Broad Elliptic	Absent	Absent	Absent	Small
24	Bangalora	Green and red	Broad Elliptic	Absent	Present	Present	Large
25	Totapuri Red Small	Green and red	Broad Elliptic	Present	Present	Present	Large
26	Angoor Lata	Green	Circular	Absent	Absent	Absent	Small
27	Saurabh	Green	Broad Elliptic	Absent	Absent	Present	Medium
28	Rajiv	Green	Medium Elliptic	Absent	Absent	Absent	Small
29	Gourav	Green	Broad Elliptic	Present	Absent	Present	Medium
30	Himanshu	Green	Medium Elliptic	Absent	Absent	Absent	Small
31	Sukul	Green	Circular	Absent	Absent	Present	Medium
32	Van Raj	Green and red	Circular	Absent	Absent	Absent	Small
33	Dilpasand	Green	Broad Elliptic	Absent	Present	Present	Medium
34	Himsagar	Green	Broad Elliptic	Absent	Absent	Absent	Small
35	Tilka Bhadainya	Green	Circular	Absent	Absent	Absent	Small
36	Chandrakaran	Green	Circular	Absent	Absent	Absent	Small
37	Surkha Khal	Green	Circular	Absent	Absent	Absent	Small
38	Burma Surkhh	Green	Medium Elliptic	Absent	Absent	Present	Small
39	Sensation	Green and purple	Broad Elliptic	Present	Present	Absent	Small
40	Tommy Atkins	Green and red	Broad Elliptic	Present	Present	Absent	Small

Fig. 4.4: Grouping of different mango varieties including new accessions based on qualitative traits of mature fruit

Shape in cross section

Circular

Pusa Arunima
PusaSurya
Chandrakaran
Surkha Khal
Tilka Bhadauria
Neelgoa,Van Raj
Sukul, Angoor
Lata

Medium Elliptic

Dashehari
Dashehari 35
Dashehari 51
Chausa, Rajiv
A.U. Rumani
Himanshu
Burma Surkh

Broad Elliptic

Bombay Green, Amrapali, Mallika
Arka Neelkiran, Ambika, Neeluddin
Neeleshan, Ratna, Bangalora
Totapuri Red Small, Saurabh
Dilpasand, Langra, Pant Chandra
Gourav, Himsagar, PMSS-1, Arunika
Swarna Jehangir, Sabri, Pant Sinduri
Sensation, Tommy Atkins

Presence of cavity at stalk

Absent

Dashehari, Dashehari 35
Dashehari 51, Bombay
Green, Pant Chandra
Amrapali, Pusa Surya
Arka Neelkiran, Ambika
A.U. Rumani, Angoor
Lata, Rajiv, Himanshu
Himsagar, Tilka
Bhadauria, Burma Surkh
Langra, Chausa, Pant
Sinduri, PMSS-1, Ambika
Neeleshan, Neelgoa
Swarna Jehangir, Ratna
Bangalora, Saurabh, Sukul
Van Raj, Dilpasand
Chandrakaran,Surkha Khal

Present

Mallika
Pusa Arunima
Arunika
Neeluddin
Totapuri Red
Small
Gourav
Sensation
Tommy Atkins

,

Mature fruit : colour of skin

Only Green

Dashehari, Dashehari
35, Dashehari 51, Pant
Chandra, PMSS-1
Amrapali, Neeluddin
Neeleshan, Himsagar
A.U. Rumani, Angoor
Lata, Saurabh, Gourav
Sukul, Surkha Khal
Burma Surkh, Langra
Chausa, Mallika
Bombay Green, Ratna
Saurabh, Himanshu
Swarna Jehangir, Sabri
Chandrakaran
Tilka Bhadainya

Green and red

Totapuri Red
Small, Tommy
Atkins, Pant
Sinduri,
Pusa Surya
ArkaNeelkiran
Arunika
Neelgoa,
Bangalora
Ratna,Van Raj

Green and purple

Pusa Arunima
Ambika, Sensation

Presence of neck

Present

Totapuri Red Small, Sensation, Tommy Atkins
Dilpasand, Mallika, Pusa Arunima, Arunika,
Neeluddin

Absent

Dashehari, Dashehari 35,Dashehari 51, Bombay Green, Pant Chandra, Amrapali, Pusa Surya, Arka Neelkiran, A.U. Rumani, Angoor Lata, Rajiv, Himanshu, Himsagar, Tilka Bhadainya, Burma Surkh, Langra, Pant Sinduri, PMSS-1 Ambika, Neeleshan, Neelgoa, Swarna Jehangir, Bangalora, Saurabh, Gourav, Van Raj, Chandrakaran, Surkha Khal Sabri, Chausa, Ratna, Sukul

The presence of cavity at stalk was observed in Mallika, Pusa Arunima, Arunika, Neeluddin, Totapuri Red Small, Gourav, Sensation and Tommy Atkins, while, cavity at stalk was absent in Dashehari, Dashehari 35, Dashehari 51, Bombay Green, Pant Chandra, Amrapali, Pusa Surya, Arka Neelkiran, Ambika, A.U. Rumani, Angoor Lata, Rajiv, Himanshu, Himsagar, Tilka Bhadainya, Burma Surkh, Langra, Chausa, Pant Sinduri, PMSS-1, Ambika, Neeleshan, Neelgoa, Swarna Jehangir, Ratna, Bangalora, Saurabh, Sukul, Van Raj, Dilpasand, Chandrakaran and Surkha Khal.

The observations recorded during 2014 and 2016 for presences of neck in the different varieties of mango have been presented in Table 4.3 and Fig. 4.4. The neck was present in Totapuri Red Small, Sensation, Tommy Atkins, Dilpasand, Mallika, Pusa Arunima, Arunika and Neeluddin, whereas, it was absent in Dashehari, Dashehari 35, Dashehari 51, Bombay Green, Pant Chandra, Amrapali, Pusa Surya, Arka Neelkiran, A.U. Rumani, Angoor Lata, Rajiv, Himanshu, Himsagar, Tilka Bhadainya, Burma Surkh, Langra, Pant Sinduri, PMSS-1, Ambika, Neeleshan, Neelgoa, Swarna Jehangir, Bangalora, Saurabh, Gourav, Van Raj, Chandrakaran, Surkha Khal, Sabri, Chausa, Ratna and Sukul.

The variation was observed during 2014 and 2016 in the different mango varieties for presence of cavity at stalk, which was either absent or present and for presence of neck, which was either absent or present. These variations might be due to the genetic makeup of varieties and their interaction with environment. The findings were similar to those obtained by Singh *et al.* (2014); Joshi *et al.* (2013) and Majumder *et al*. (2011), in mango.

4.1.4.3 Shape of ventral and dorsal shoulder

The observations recorded during 2014 and 2016 for shape of ventral shoulder in different mango varieties have been presented in Table 4.4, Fig. 4.5 and Plate 81-120. The rounded upward ventral shoulder shape was found in Saurabh, Gourav, Surkha Khal, Pusa Surya, Chandrakaran, Tilka Bhadainya, Neelgoa, Sukul, Angoor Lata, Chausa, Rajiv, Himanshu, Burma Surkh, Bombay Green, Mallika, Arka Neelkiran, Ambika, Neeluddin, Neeleshan, Ratna, Bangalora, Dilpasand, Himsagar, Arunika, Pant Sinduri and Tommy Atkins, whereas, rounded outward was observed in Dashehari, Dashehari 35, Dashehari 51, Langra, PMSS-1, Pant Chandra, Amrapali, Van Raj, Pusa Arunima, A.U.Rumani, Swarna Jehangir, Totapuri Red Small, Sabri and Sensation.

Table 4.4: Visual assessment of morphological qualitative traits of mature and ripe fruit in different varieties including new accessions of mango (on the basis of 2 years evaluation in 2014 and 2016)

S. No.	Varieties/accessions	Mature fruit characteristics		Ripe fruit characteristics			
		Shape of ventral shoulder	Shape of dorsal shoulder	Predominant colour of skin	Colour of flesh	Surface of stone	Lateral view of seed kernel
1	Dashehari	Rounded Outward	Sloping Downward	Yellow	Light orange	Grooved	Oblong
2	Dashehari 35	Rounded Outward	Sloping Downward	Yellow	Light orange	Grooved	Oblong
3	Dashehari 51	Rounded Outward	Sloping Downward	Yellow	Light orange	Grooved	Oblong
4	Langra	Rounded Outward	Rounded Downward	Yellow green	Light Yellow	Grooved	Oblong
5	Chausa	Rounded Upward	Falling Abruptly	Green and Yellow	Medium yellow	Grooved	Reniform
6	Bombay Green	Rounded Upward	Sloping Downward	Green	Dark orange	Ridged	Oblong
7	Pant Sinduri	Rounded Upward	Sloping Downward	Yellow and red	Light Yellow	Grooved	Oblong
8	Pant Chandra	Rounded Outward	Rounded Downward	Green	Dark orange	Ridged	Oblong
9	PMSS-1	Rounded Outward	Rounded Downward	Yellow	Medium yellow	Grooved	Reniform
10	Amrapali	Rounded Outward	Sloping Downward	Yellow orange	Dark orange	Grooved	Oblong
11	Mallika	Rounded Upward	Falling Abruptly	Yellow orange	Medium yellow	Grooved	Oblong
12	Pusa Arunima	Rounded Outward	Sloping Downward	Red and purple	Medium yellow	Grooved	Reniform
13	Pusa Surya	Rounded Upward	Rounded Downward	Yellow and red	Dark orange	Smooth	Oblong
14	Arka Neelkiran	Rounded Upward	Rounded Downward	Yellow	Medium orange	Smooth	Oblong
15	Ambika	Rounded Upward	Sloping Downward	Purple	Dark orange	Smooth	Reniform
16	Arunika	Rounded Upward	Sloping Downward	Yellow and red	Medium orange	Grooved	Oblong
17	Neeluddin	Rounded Upward	Falling Abruptly	Yellow green	Medium yellow	Ridged	Reniform
18	Neeleshan	Rounded Upward	Falling Abruptly	Yellow green	Medium yellow	Ridged	Reniform
19	Neelgoa	Rounded Upward	Rounded Outward	Yellow and red	Light Yellow	Smooth	Reniform

20	A.U. Rumani	Rounded Outward	Sloping Downward	Yellow	Light orange	Smooth	Oblong
21	Swarna Jehangir	Rounded Outward	Sloping Downward	Red	Dark orange	Grooved	Reniform
22	Ratna	Rounded Upward	Sloping Downward	Yellow	Dark orange	Ridged	Reniform
23	Sabri	Rounded Outward	Sloping Downward	Yellow and red	Medium orange	Smooth	Reniform
24	Bangalora	Rounded Upward	Falling Abruptly	Yellow and red	Medium yellow	Smooth	Reniform
25	Totapuri Red Small	Rounded Outward	Sloping Downward	Red	Medium orange	Smooth	Oblong
26	Angoor Lata	Rounded Upward	Rounded Downward	Yellow green	Medium orange	Smooth	Oblong
27	Saurabh	Rounded Upward	Sloping Downward	Green and Yellow	Medium yellow	Ridged	Reniform
28	Rajiv	Rounded Upward	Rounded Downward	Green and Yellow	Medium yellow	Grooved	Oblong
29	Gourav	Rounded Upward	Sloping Downward	Yellow	Medium orange	Ridged	Reniform
30	Himanshu	Rounded Outward	Falling Abruptly	Yellow green	Medium yellow	Grooved	Oblong
31	Sukul	Rounded Outward	Falling Abruptly	Yellow green	Light Yellow	Smooth	Reniform
32	Van Raj	Rounded Outward	Rounded Outward	Red and purple	Medium orange	Smooth	Oblong
33	Dilpasand	Rounded Upward	Sloping Downward	Yellow green	Medium yellow	Smooth	Reniform
34	Himsagar	Rounded Outward	Rounded Downward	Yellow green	Medium yellow	Smooth	Reniform
35	Tilka Bhadainya	Rounded Outward	Sloping Downward	Green	Dark orange	Smooth	Oblong
36	Chandrakaran	Rounded Upward	Falling Abruptly	Yellow	Light Yellow	Smooth	Oblong
37	Surkha Khal	Rounded Upward	Sloping Downward	Yellow and red	Dark orange	Smooth	Reniform
38	Burma Surkh	Rounded Upward	Falling Abruptly	Yellow and red	Light orange	Smooth	Oblong
39	Sensation	Rounded Outward	Sloping Downward	Red and purple	Medium yellow	Grooved	Reniform
40	Tommy Atkins	Rounded Upward	Sloping Downward	Red and purple	Medium orange	Smooth	Reniform

The observations recorded during 2014 and 2016 for shape of dorsal shoulder in the different varieties of mango have been presented in Table 4.4 and Fig. 4.5. The shape of dorsal shoulder varied, as sloping downward was found in Dashehari, Dashehari 35, Dashehari 51, Amrapali, A.U. Rumani, Saurabh, Gourav, Sukul, Surkha Khal, Bombay Green, Ratna, Saurabh, Sabri, Swarna Jehangir, Tilka Bhadainya, Pusa Arunima, Arunika, Ambika, Sensation, Totapuri Red Small, Tommy Atkins, Pant Sinduri and Ratna, while, rounded downward dorsal shoulder was observed in Angoor Lata, Himsagar, Pusa Surya, Arka Neelkiran, Neelgoa, Van Raj, Pant Chandra, PMSS-1, Dilpasand, Rajiv and Langra, whereas, falling abruptly was recorded in Chausa, Mallika, Neeluddin, Neeleshan, Himanshu, Chandrakaran, Burma Surkh and Bangalora.

Results obtained during 2014 and 2016 for shape of ventral and dorsal shoulder displayed variation among the varieties of mango. Varieties were noted to have shape of ventral shoulder like rounded upward and rounded outward; and shape of dorsal shoulder varied as sloping downward, rounded downward and falling abruptly. The variation in shape of ventral and dorsal shoulder might be due to genetic constitution of particular varieties and maturity of the fruits. The findings were similar to those obtained by Joshi *et al.* (2013) and Singh *et al.* (2014).

4.1.4.4 Presence of sinus and point at stylar scar

The observations recorded during 2014 and 2016 for variations in presence of sinus among the varieties have been presented in Table 4.3 and Fig. 4.5. The sinus was present in Bangalora, Totapuri Red Small, Mallika, Pant Sinduri, Ambika, Amrapali, Pusa Surya, Neelgoa, Gourav, Sukul and Burma Surkh, whereas, sinus was absent in Dashehari, Dashehari 35, Dashehari 51, Bombay Green, Pant Chandra, Arka Neelkiran, A.U. Rumani, Angoor Lata, Rajiv, Himanshu, Himsagar, Tilka Bhadainya, Langra, Chausa, PMSS-1, Neeleshan, Swarna Jehangi, Pusa Arunima, Arunika, Neeluddin, Sensation, Tommy Atkins, Ratna, Saurabh, Van Raj, Dilpasand, Chandrakaran and Surkha Khal.

The variation in relation to point at stylar scar among mango varieties has been presented in Table 4.3 and Fig. 4.5. The large stylar scar was observed in Totapuri Red Small and Bangalora, whereas, medium was recorded in Dilpasand, Mallika, Pusa Surya, Pant Sinduri, Saurabh, Gourav, Sukul and Ambika. The small

Fig. 4.5: Grouping of different mango varieties including new accessions based on qualitative traits of mature fruit

Mature fruit characters

- **Shape of ventral shoulder**
  - **Rounded Upward**: SaurabhGourav SurkhaPusaSurya Chandrakaran Khal TilkaBhadauria Neelgoa, Sukul Angoor Lata, Chausa Rajiv,Himanshu Burma Surkh Bombay Green Mallika, Arka Neelkiran, Ambika Neeluddin, Neeleshan Ratna, Bangalora, Dilpasand,Himsagar Arunika, Pant Sinduri Tommy Atkins
  - **Rounded Outward**: Dashehari Dashehari-35 Dashehari -51 Langra, PMSS-1 Pant Chandra Amrapali, Van Raj,Pusa Arunima A.U.Rumani SwarnaJehangir Totapuri Red Small, Sabri Sensation
- **Presence of sinus**
  - **Absent**: Dashehari, Dashehari 35 Dashehari 51, Bombay Green, Pant Chandra, Arka Neelkiran, A.U. Rumani Angoor Lata, Rajiv Himanshu, Himsagar TilkaBhadauria, Langra Chausa, PMSS-1,Neeleshan SwarnaJehangir,Pusa Arunima,Arunika,Neeluddin Sensation, Tommy Atkins Ratna, Saurabh, Van Raj Dilpasand, Chandrakaran, Surkha Khal
  - **Present**: Bangalora, Totapuri Red Small,Mallika Pant Sinduri Ambika Amrapali Pusa Surya Neelgoa Gourav Sukul, Burma Surkh
- **Shape of dorsal shoulder**
  - **Sloping Downward**: Dashehari,Dashehari35 Dashehari 51,Amrapali A.U. Rumani, Saurabh Gourav, Sukul, Surkha Khal,Bombay Green Ratna, Saurabh, Sabri SwarnaJehangir Tilka Bhadainya Pusa Arunima, Arunika Ambika, Sensation Totapuri Red Small Tommy Atkins, Pant Sinduri, Ratna
  - **Rounded Downward**: Angoor Lata Himsagar Pusa Surya ArkaNeelkiran Neelgoa Van Raj,Pant Chandra PMSS-1 Dilpasand, Rajiv, Langra
  - **Falling Abruptly**: Chausa, Mallika Neeluddin Neeleshan Himanshu Chandrakaran Burma Surkh Bangalora
- **Point at stylar scar**
  - **Large**: Totapuri Red Small Bangalora
  - **Medium**: Dilpasand Mallika, Pusa Surya Pant Sinduri, Saurabh Gourav,Sukul, Ambika
  - **Small**: Dashehari, Dashehari35,Dashehari 51, Bombay Green, Pant Chandra, Amrapali, Arka Neelkiran, A.U. Rumani, Angoor Lata, Rajiv, Himanshu, Himsagar, Tilka Bhadainya Burma Surkh Langra, PMSS-1, Neeleshan, Neelgoa, SwarnaJehangir, , Van Raj Chandrakaran, Surkha Khal, , Sabri Chausa, Ratna, Sensation, Tommy Atkins, Pusa Arunima, Arunika, Neeluddin

point at stylar scar was observed in most of the varieties *viz.,* Dashehari, Dashehari 35, Dashehari 51, Bombay Green, Pant Chandra, Amrapali, Arka Neelkiran, A.U. Rumani, Angoor Lata, Rajiv, Himanshu, Himsagar, Tilka Bhadainya, Burma Surkh, Langra, PMSS-1, Neeleshan, Neelgoa, Swarna Jehangir, Van Raj, Chandrakaran, Surkha Khal, Sabri, Chausa, Ratna, Sensation, Tommy Atkins, Pusa Arunima, Arunika and Neeluddin.

The variation was observed during 2014 and 2016 among the mango varieties including new accessions for presence of sinus which was either absent or present and point at stylar scar varied as large, medium and small. The variation recorded might be due to the genetic constitution of varieties and their interaction with environment. The findings were similar to those obtained by Singh *et al.* (2014); Joshi *et al.* (2013) and Majumder *et al*. (2011).

4.1.5 Ripe fruit and stone traits

The qualitative traits of ripe fruit such as predominant colour of skin, colour of flesh, surface of stone and lateral view of seed kernel showed variations among the mango varieties, which are presented as under:

4.1.5.1 Predominant colour of skin and flesh of ripe fruit

The observations recorded during 2014 and 2016 for predominant colour of skin and flesh in different mango varieties have been presented in Table 4.4, Fig. 4.6 and Plate 81-120. The predominant colour of skin was varied as green colour in Pant Chandra, Bombay Green and Tilka Bhadainya; yellow green colour in Langra, PMSS-1, Angoor Lata, Neeleshan, Neeluddin, Dilpasand, Himanshu, Himsagar and Sukul; green and yellow colour in Chausa, Rajiv and Saurabh; yellow colour in Dashehari, Dashehari 35, Dashehari 51, Gourav, Chandrakaran, Ratna, Arka Neelkiran and A.U. Rumani; yellow orange colour in Amrapali and Mallika; yellow and red colour in Pant Sinduri, Pusa Surya, Neelgoa, Bangalora, Sabri, Burma Surkh and Arunika; red and purple colour in Tommy Atkins, Sensation, Van Raj and Pusa Arunima and red colour was found in Swarna Jehangir, Surkha Khal, Ambika and Totapuri Red Small.

The different colours of flesh in ripe fruit were observed in different mango varieties. It varied as light yellow in Langra, Pant Sinduri, Neelgoa, Sukul and

Chandrakaran; medium yellow in Chausa, PMSS-1, Mallika, Sensation, Pusa Arunima, Neeluddin, Dilpasand, Bangalora, Saurabh, Rajiv and Himanshu; light orange in Dashehari, Dashehari 35, Dashehari 51, A.U. Rumani and Burma Surkh; medium orange in Arka Neelkiran, Totapuri Red Small, Arunika, Sabri, Angoor Lata, Gourav, Tommy Atkins and Van Raj; dark orange in Bombay Green, Pant Chandra, Amrapali, Himsagar, Ratna, Tilka Bhadainya, Neeleshan, Ambika, Swarna Jehangir, Surkha Khal and Pusa Surya.

4.1.5.2 Surface of stone and lateral view of seed kernel

The observations recorded during 2014 and 2016 for surface of stone and lateral view of seed kernel among the varieties including new accessions of mango have been presented in Table 4.4 and Fig. 4.6. The surface of stone was observed as ridged in Bombay Green, Pant Chandra, Neeluddin, Neeleshan, Ratna, Saurabh and Gourav, while, smooth in Pusa Surya, Arka Neelkiran, A.U. Rumani, Ambika, Neelgoa, Sabri, Bangalora, Totapuri Red Small, Angoor Lata, Dilpasand, Sukul, Van Raj, Tilka Bhadainya, Himsagar, Chandrakaran, Tommy Atkins and Surkha Khal, whereas, grooved in Chausa, PMSS-1, Pusa Arunima, Swarna Jehangir, Sensation, Dashehari, Dashehari 35, Dashehari 51, Amrapali, Arunika, Rajiv, Himanshu, Burma Surkh, Langra, Mallika and Pant Sinduri.

The lateral view of seed kernel was observed as reniform in Chausa, PMSS-1, Pusa Arunima, Ambika, Neeluddin, Neeleshan, Neelgoa, Swarna Jehangir, Ratna, Sabri, Bangalora, Himsagar, Saurabh, Gourav, Dilpasand, Sukul, Sensation, Tommy Atkins and Surkha Khal, whereas, oblong type was observed in Dashehari, Dashehari 35, Van Raj, Dashehari 51, Bombay Green, Pant Chandra, Amrapali, Arunika, Pusa Surya, Arka Neelkiran, A.U. Rumani, Angoor Lata, Rajiv, Himanshu, Tilka Bhadainya, Langra, Pant Sinduri, Chandrakaran, Totapuri Red Small, Mallika and Burma Surkh.

4.2 Analysis of Genetic Parameters

The experimental results in respect to 27 quantitative traits were observed on the basis of different morphological and physico-chemical attributes. These are described under following heads and subheads:

Fig. 4.6: Grouping of different mango varieties including new accessions based on qualitative traits of ripe fruit and stone

Ripe fruit and stone characters

Predominant colour of skin

Green
- Pant Chandra
- Bombay Green
- TilkaBhadauria

Yellow green
- Langra,PMSS1
- Angoor Lata
- Neeleshan
- Neeluddin
- Dilpasand
- Himanshu
- Himsagar Sukul

Green and Yellow
- Chausa
- Rajiv
- Saurabh

Yellow
- Dashehari
- Dashehari35
- Dashehari 51
- Gourav
- Chandrakaran
- Ratna
- ArkaNeelkiran
- A.U.Rumani

Yellow orange
- Amrapali
- Mallika

Yellow and red
- Pant Sinduri
- PusaSurya
- Neelgoa
- Bangalora
- Sabri
- Burma Surkh
- Arunika

Red and purple
- Tommy Atkins
- Sensation
- Van Raj
- Pusa Arunima

Red
- Swarna Jehangir
- Surkha Khal
- Ambika
- Totapuri Red
- Small

Colour of flesh

Light yellow
- Langra
- Pant Sinduri
- Neelgoa Sukul
- Chandrakaran

Medium yellow
- Chausa,PMSS-1
- Mallika,Sensation
- Pusa Arunima
- Neeluddin Dilpasand
- Bangalora Saurabh
- Rajiv, Himanshu

Light orange
- Dashehari,
- Dashehari 35
- Dashehari 51
- A.U. Rumani
- Burma Surkh

Medium orange
- Arka Neelkiran
- Totapuri Red
- Small,Arunika
- Sabri Angoor
- Lata,Gourav
- Tommy Atkins
- Van Raj

Dark orange
- Bombay Green
- Pant Chandra
- Amrapali
- Himsagar,Ratna
- Tilka
- Bhadainya
- Neeleshan
- Ambika
- SwarnaJehangir
- Surkha Khal
- Pusa Surya

Lateral view of seed kernel

Reniform

Chausa, PMSS-1 Pusa Arunima Ambika,Neeluddin Neeleshan,Neelgoa SwarnaJehangir Ratna, Sabri Bangalora,Himsagar Saurabh, Gourav Dilpasand Sukul Sensation, Tommy Atkins Surkha Khal

Oblong

Dashehari,Dashehari35 Van Raj Dashehari 51, Bombay Green PantChandra, Amrapali, Arunika Pusa Surya, Arka Neelkiran, A.U. Rumani, Angoor Lata, Rajiv Himanshu, Tilka Bhadainya Burma Langra, Pant Sinduri Chandrakaran,Totapuri Red Small, Mallika, Burma Surkh

Surface of stone

Ridged

Bombay Green, PantChandra, ,Neeleshan, Ratna, Saurabh, Gourav Neeluddin

Smooth

Pusa Surya, Arka Neelkiran A.U. Rumani, Ambika, ,Neelgoa Sabri, Bangalora,Totapuri Red Small, Angoor Lata, Dilpasand Sukul, Van Raj,Tilka Bhadainya,Himsagar, Chandrakaran, Burma,Tommy Atkins, Surkha Khal

Grooved

Chausa,PMSS1,PusaArunima,SwarnaJehangir,Sensation Dashehari,Dashehari35 Dashehari 51, Amrapali, Arunika,Rajiv Himanshu,Burma Surkh, Langra,Mallika,PantSinduri

81: Dashehari

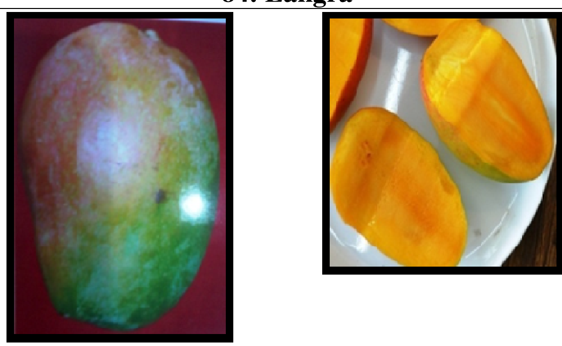
82: Dashehari 35

83: Dashehari 51

84: Langra

85: Chausa

86: Bombay Green



87: Pant Sinduri

88: Pant Chandra

89: PMSS-1 (Pant Mango-1)

Plate 81-89: Glimpses showing the variations in fruits of mango varieties

90: Amrapali

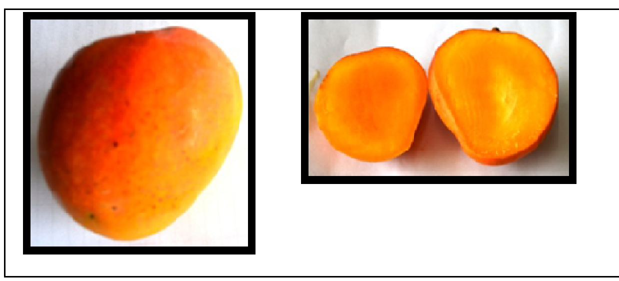
91: Mallika

92: Pusa Arunim

93: Pusa Surya

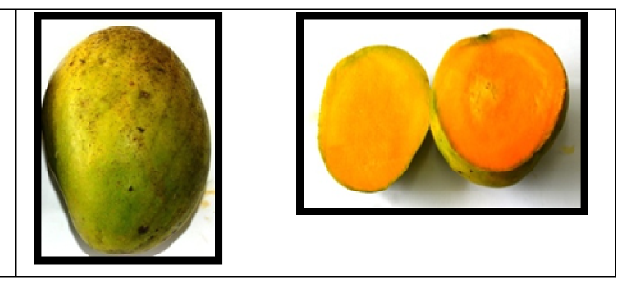
94: Arka Neelkiran

95: Ambika



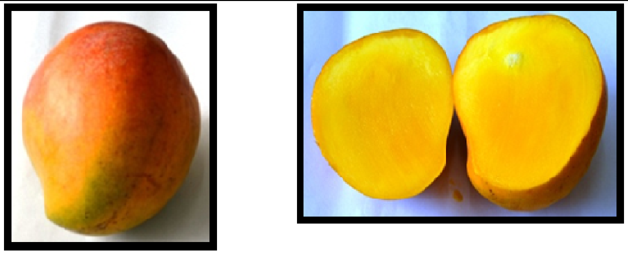
96: Arunika

97: Neeluddin



98: Neeleshan

Plate 90-98: Glimpses showing the variations in fruits of mango varieties



99: Neelgoa

100: A.U. Rumani

101: Swarna Jehangir

102: Ratna

103: Sabri

104: Bangalora

105: Totapuri Red Small

106: Angoor Lata

107: Saurabh

Plate 99-107: Glimpses showing the variations in fruits of mango varieties

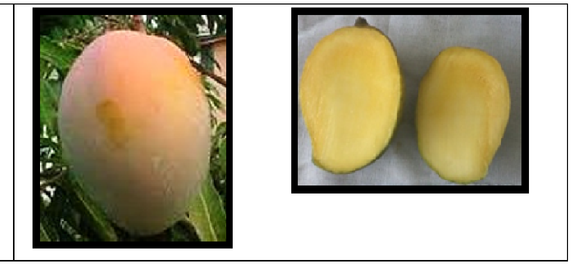
108: Rajiv

109: Gourav

110: Himanshu

111: Sukul

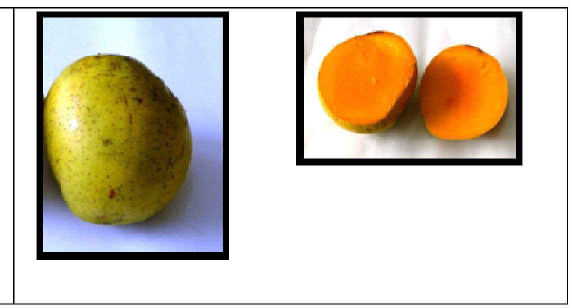
112: Van Raj



113: Dilpasand

114: Himsagar

115: Tilka Bhadainya



116: Chandrakaran

Plate 108-116: Glimpses showing the variations in fruits of mango varieties

117: Surkha Khal

118: Burma Surkh

119: Sensation

120: Tommy Atkins

Plate 117-120: Glimpses showing the variations in fruits of mango varieties

4.2.1 Analysis of variance

The fundamental requirements for any crop improvement programme are the availability of tremendous amount of genetic variability, without which neither the improvement of existing cultivars nor development of new varieties is feasible. The study of variability is of great assistance to a plant breeder for selecting the best genotypes. The natural variability present in the crop species can be exploited and further novel variability could also be created in those crop species which lack it. The nature and magnitude of genetic variability is of paramount importance for a plant breeder to initiating a sound breeding programme.

The results on analysis of variance for 27 quantitative traits *viz.,* leaf length, leaf width, leaf area, duration of panicle emergence, number of secondary rachis per panicle, length of inflorescence, width of inflorescence, duration of flowering, duration of fruit maturity, number of fruits per tree at harvesting, yield per tree, fruit weight, fruit length, fruit width, stone weight, stone length, stone width, pulp weight, peel weight, pulp : stone ratio, TSS, acidity, reducing sugar, non reducing, total sugar, ascorbic acid and total carotenoid have been presented in Table 4.5 (2014), Table 4.6 (2016) and Table 4.7 (pooled data of 2014 and 2016). Perusal of data presented in these Tables revealed that mean square for varieties with respect to all the characters were highly significant in both the years indicating that there is inherent genetic variability present in different varieties for all the characters considered for the study. Analysis of variance combined over the years also showed highly significant differences among the genotypes and environments and highly significant for all the characters except leaf area, stone weight, stone length, stone width and TSS. The interaction (genotype x environments) was not significant for all the characters except ascorbic acid. The presence of polymorphism or variability for different economic traits is one of the basic requirements of any crop improvement programme. The desired variability can be successfully utilized by hybridization programme and in the selection of desired genotypes in the segregations population. Thus, high magnitude of variability for various economic traits in the experimental mango varieties may boost the progress in the crop improvement programmes.

Table 4.5: Analysis of variance for different quantitative traits of mango varieties including new accessions (2014)

S. No.	Characters	Mean of square			C.V. (%)	C.D. at 5%
		Replication	Genotypes	Error		
		Degree of freedom (df)				
		2	39	78		
1	Leaf length (cm)	0.497	12.51**	1.237	5.60	1.808
2	Leaf width (cm)	0.321	1.238**	0.211	9.10	0.747
3	Leaf area (cm^2)	0.661	710.366**	10.088	4.18	5.163
4	Duration of panicle emergence (days)	0.0583	25.8203**	2.5626	7.84	2.602
5	Number of secondary rachis/panicle	0.142	91.936**	4.367	8.47	3.397
6	Length of inflorescence (cm)	1.463	83.664**	2.326	5.20	2.479
7	Width of inflorescence (cm)	0.927	42.123**	2.249	9.19	2.438
8	Duration of flowering (days)	0.075	28.871**	3.528	6.85	3.053
9	Duration of fruit maturity (days)	0.608	510.083**	4.736	2.06	3.538
10	Number of fruits/tree at harvesting	1.733	4871.541**	4871.541	5.67	5.806
11	Yield /tree (kg)	1.060	116.412**	1.589	9.68	2.049
12	Fruit weight (g)	237.187	25651.515**	150.817	5.08	19.963
13	Fruit length (cm)	0.147	9.721**	0.053	2.39	0.375
14	Fruit width (cm)	0.001	4.033**	0.048	3.20	0.340
15	Stone weight (g)	6.868	361.905**	4.345	6.56	3.388
16	Stone length (cm)	0.098	7.216**	0.072	3.50	0.439
17	Stone width (cm)	0.030	1.244**	0.040	5.74	0.328
18	Pulp weight (g)	109.627	17716.728**	144.515	6.63	19.541
19	Peel weight (g)	0.234	343.626**	2.308	5.30	2.470
20	Pulp : stone ratio	0.193	10.876**	0.264	9.00	0.837
21	TSS (^{0}B)	2.396	20.588**	0.921	5.24	1.560
22	Acidity (%)	0.0002	0.0101**	0.0003	9.64	0.027
23	Reducing sugar (%)	0.166	3.844**	0.077	6.47	0.454
24	Non reducing (%)	1.123	8.990**	0.745	5.97	1.542
25	Total sugar (%)	0.782	15.108**	0.899	7.81	1.404
26	Ascorbic acid (mg/100 g flesh)	4.220	204.179**	4.645	5.50	3.504
27	Total carotenoid (mg/100 g flesh)	0.010	7.605**	0.052	6.39	0.371

(* & ** significance at 5% and 1% probability levels, respectively)

Table 4.6: Analysis of variance for different quantitative traits of mango varieties including new accessions (2016)

S. No.	Characters	Mean of square			C.V. (%)	C.D. at 5%
		Replication	Genotypes	Error		
		Degree of freedom (df)				
		2	39	78		
1	Leaf length (cm)	0.617	14.818**	0.499	3.52	1.149
2	Leaf width (cm)	0.111	1.383**	0.071	5.10	0.434
3	Leaf area (cm^2)	54.914	736.108**	29.171	7.17	8.780
4	Duration of panicle emergence (days)	2.445	30.545**	1.634	6.88	2.078
5	Number of secondary rachis/panicle	5.655	113.864**	2.921	5.71	2.778
6	Length of inflorescence (cm)	2.430	85.406**	1.473	3.94	1.973
7	Width of inflorescence (cm)	1.576	45.698**	2.312	8.37	2.472
8	Duration of flowering (days)	2.100	20.435**	1.347	5.25	1.887
9	Duration of fruit maturity (days)	1.825	521.380**	7.981	2.64	4.592
10	Number of fruits/tree at harvesting	4.257	5921.521**	21.745	6.53	7.580
11	Yield /tree (kg)	2.332	148.853**	3.470	12.32	3.028
12	Fruit weight (g)	139.101	27881.416**	702.165	10.66	43.074
13	Fruit length (cm)	0.076	10.052**	0.089	3.05	0.486
14	Fruit width (cm)	0.026	4.161**	0.045	3.16	0.346
15	Stone weight (g)	4.853	361.300**	5.387	7.36	3.773
16	Stone length (cm)	0.048	7.214**	0.231	6.22	0.782
17	Stone width (cm)	0.065	1.113**	0.054	6.66	0.378
18	Pulp weight (g)	227.551	19498.097**	670.374	13.78	42.087
19	Peel weight (g)	7.132	357.804**	11.787	11.62	5.581
20	Pulp : stone ratio	0.025	11.336**	0.786	14.91	1.442
21	TSS (^{0}B)	0.669	16.983**	0.310	3.03	0.906
22	Acidity (%)	0.0002	0.008**	0.0003	9.51	0.028
23	Reducing sugar (%)	0.006	3.626**	0.086	6.58	0.477
24	Non reducing (%)	0.442	9.735**	1.496	7.18	1.904
25	Total sugar (%)	0.402	14.219**	1.371	10.14	1.988
26	Ascorbic acid (mg/100 g flesh)	10.168	192.315**	4.536	5.23	3.462
27	Total carotenoid (mg/100 g flesh)	0.118	8.248**	0.138	9.35	0.604

(* & ** significance at 5% and 1% probability levels, respectively)

Table 4.7: Analysis of variance for different quantitative traits of mango varieties including new accessions (pooled data of 2014 and 2016)

S. No.	Characters	Mean of square					C.V. (%)	C.D. 5%
		Replication	Environments	Interactions	Genotypes	Error		
		Degree of freedom (df)						
		2	1	2	39	195		
1	Leaf length (cm)	0.721	2.559*	0.393	26.143**	0.933	4.84	1.100
2	Leaf width (cm)	0.060	2.119*	0.373	2.003**	0.237	9.45	0.554
3	Leaf area (cm^2)	28.901	22.271	26.675	1402.417**	24.515	6.55	5.638
4	Duration of panicle emergence (days)	1.140	198.326**	1.364	54.552**	2.041	7.33	1.627
5	Number of secondary rachis/ panicle	3.751	255.193**	2.047	186.137**	6.848	7.16	2.980
6	Length of inflorescence (cm)	3.615	125.701**	0.279	166.168**	2.100	4.82	1.650
7	Width of inflorescence (cm)	2.426	205.461**	0.078	82.735**	2.842	9.77	1.920
8	Duration of flowering (days)	1.163	205.350**	1.012	47.479**	2.316	8.30	1.733
9	Duration of fruit maturity (days)	0.206	114.969**	2.229	1021.374**	7.106	2.51	3.035
10	Number of fruits/tree at harvesting	1.86	4342.31**	4.13	10708.87**	30.64	8.24	6.303
11	Yield /tree (kg)	2.121	265.946**	1.272	259.629**	3.151	12.61	2.021
12	Fruit weight (g)	231.96	2737.33**	144.33	53125.29**	422.72	8.38	23.411
13	Fruit length (cm)	0.147	1.857**	0.077	19.603**	0.091	3.10	0.344
14	Fruit width (cm)	0.014	2.278**	0.013	8.009**	0.073	4.06	0.307
15	Stone weight (g)	3.437	3.151	8.285	718.140**	4.906	7.00	2.522
16	Stone length (cm)	0.017	0.011	0.129	14.315**	0.145	4.93	0.433
17	Stone width (cm)	0.065	0.019	0.030	2.317**	0.047	6.17	0.246
18	Pulp weight (g)	155.02	2466.82**	182.16	36812.21**	406.48	10.92	22.957
19	Peel weight (g)	4.964	50.188**	2.403	697.100**	6.505	8.76	2.904
20	Pulp : stone ratio	0.108	3.047**	0.111	21.651**	0.533	12.51	0.831
21	TSS (^{0}B)	2.729*	0.596	0.337	36.615**	0.684	4.50	0.942
22	Acidity (%)	0.0002	0.0030**	0.0002	0.0180**	0.0004	11.16	0.022
23	Reducing sugar (%)	0.061	1.270**	0.112	7.019**	0.156	9.01	0.450
24	Non reducing (%)	1.487	61.277**	0.078	16.957**	1.250	6.93	1.270
25	Total sugar (%)	0.560	11.262**	0.625	27.645**	1.245	9.67	1.273
26	Ascorbic acid (mg/100 g flesh)	0.741	141.005**	13.647*	393.198**	4.332	5.20	2.370
27	Total carotenoid (mg/100 g flesh)	0.050	9.745**	0.080	15.703**	0.106	8.64	0.372

(* & ** significance at 5% and 1% probability levels, respectively)

4.2.2 Mean Performances

Mean performances of 40 mango varieties including new accessions and range of variation among them for 27 quantitative traits have been presented in Table 4.8, 4.9, 4.10 (2014), 4.11 4.12, 4.13 (2016) and 4.14 4.15 and 4.16 (pooled data of 2014 and 2016), respectively. The results regarding mean performances and range of various characters for different varieties are described as follows:

4.2.2.1 Leaf length

Leaf length during the year 2014 ranged from 14.83 to 23.68 cm with an average mean of 19.88 cm. During the year 2016, the leaf length ranged from 13.84 to 24.31 cm with an average of 20.09 cm. However, the pooled data of two years (2014 and 2016) showed the range of 14.34 to 23.99 cm and average mean of 19.98 cm for leaf length. Thus, the significantly higher and lower leaf length were observed in the varieties like Ambika (23.99 cm) and Angoor Lata (14.34 cm), respectively.

4.2.2.2 Leaf width

Leaf width varied from 3.39 to 6.19 cm with an average mean of 5.05 cm during the 2014, while, in 2016 leaf width ranged from 3.53 to 6.90 cm with an average of mean 5.24 cm. In pooled analysis, leaf width ranged from 3.79 to 6.54 cm with an average mean of 5.15 cm. Hence, the significantly maximum and minimum leaf width were observed in the varieties like Ambika (6.54 cm) and Angoor Lata (3.79 cm), respectively.

4.2.2.3 Leaf area

The range of leaf area varied from 36.28 to118.29, 34.65 to119.21 and 35.47-118.75 cm^2 during the years 2014, 2016 and pooled data of 2014 and 2016, respectively. During the year 2014, an average of the leaf area 75.95 cm^2, while in 2016, it was reported 75.34 cm^2.The result drawn by pooled two year data perceived range (35.47 to 118.75 cm^2) in leaf area with the average mean value of 75.64 cm^2. Thus, the significantly higher and lower leaf area were observed in Ambika (118.75 cm^2) and Angoor Lata (35.47 cm^2), respectively.

4.2.2.4 Duration of panicle emergence

In 2014, duration of panicle emergence ranged from 15.33 to 27.00 days with an average mean of 20.41 days. However, in 2016, the average mean of duration of panicle emergence 18.59 days which ranged from 13.00 to 25.00 days. The result drawn by pooled two year data perceived 14.17 to 25.50 days range in duration of panicle emergence with the average mean value of 19.50 days. Thus, the significantly higher and lower duration of panicle emergence were observed in Van Raj (25.50 days) and Angoor Lata (14.17 days), respectively.

4.2.2.5 Duration of flowering

Duration of flowering varied from 15.67 (Mallika) to 28.00 (Van Raj) days with an average mean of 22.17 days during the year 2014, while, in 2016, the duration of flowering ranged from 14.67 (Mallika) to 25.00 (Arka Neelkiran) days with an average of 20.33 days. The result drawn by two years pooled data perceived 15.17 to 26.50 days range in duration of flowering with the average mean value of 21.25 days. Thus, the significantly maximum and minimum duration of flowering were observed in Arka Neelkiran (26.50 days) and Mallika (15.17 days), respectively.

4.2.2.6 Number of secondary rachis per panicle

The significantly higher number of secondary rachis per panicle were recorded in Pant Sinduri, while, lower were recorded in ‘‘Angoor Lata’’ which ranged from 17.21 to 42.13, 19.63 to 44.38 and 18.42 to 43.26 with an average mean of 29.32, 30.77 and 30.05 during the year 2014, 2016 and pooled over the year, respectively.

4.2.2.7 Length of inflorescence

The significantly maximum length of inflorescence was noted for Pant Sinduri in both the year as well as in pooled analysis of two year data, while, minimum length was noted for Pusa Surya in 2014 as well as pooled analysis of two year data, whereas, it was minimum for Dashehari 51 in 2016. During the first year, length of inflorescence ranged from 18.94 to 52.33 cm with an average mean of 30.50 cm. During second year, the length of inflorescence ranged from 20.46 to 52.25 cm with an average of 32.56 cm. The result drawn by on the basis of two year pooled data perceived 22.01 to 52.29 cm range in length of inflorescence with the average mean value of 31.53 cm.

4.2.2.8 Width of inflorescence

The significantly minimum width of inflorescence was noted for Angoor Lata, while, it was maximum for Pant Sinduri in 2014, 2016 and pooled analysis of two year data which ranged from 9.96 to 23.45 cm, 11.92 to 26.84 cm and 10.94 cm to 25.14 with an average mean of 16.33, 18.18 and 17.25 cm, respectively.

4.2.2.9 Duration of fruit maturity

The duration of fruit maturity (during the year 2014) ranged from 80.67 (Bombay Green) to 152.67 (PMSS-1) days with an average mean of 105.51 days. During the year 2016, the duration of fruit maturity ranged from 84.00 (Bombay Green) to 158.00 (PMSS-1) days with an average of 106.89 days. The result drawn by pooled two year data perceived 82.33 to 155.33 days range in duration of fruit maturity with the general mean value of 106.20 days. Thus, the significantly maximum and minimum duration of fruit maturity were observed in PMSS-1 (155.33 days) and Bombay Green (82.33 days), respectively.

4.2.2.10 Number of fruits per tree at harvesting

The number of fruits per tree at harvesting during the year 2014, ranged from 20.00 (Tommy Atkins) to 163.00 (Dashehari 51) with an average mean of 62.96. During the year 2016, the number of fruits per tree at harvesting ranged from 23.20 (Swarna Jehangir) to 189.33 (Dashehari 51) with an average of 71.47. The result drawn by pooled two year data perceived 22.50 to 176.17 ranges in number of fruits per tree at harvesting with the average mean value of 67.21. Thus, the significantly maximum and minimum number of fruits per tree at harvesting were observed in Dashehari (176.17 days) and Tommy Atkins (22.50 days), respectively.

4.2.2.11 Yield per tree

Yield per tree during the year 2014 ranged from 2.73 (Angoor Lata) to 30.00 kg (Himanshu) with an average mean of 13.02 kg, whereas, during the year 2016, it was ranged from 3.24 (Angoor Lata) to 36.40 kg (Pusa Arunima) with an average of 15.13 kg. Pooled analysis of two year data showed that yield per tree ranged from 2.99 to 32.03 kg range in with the average mean value of 14.07 kg. Thus, the significantly higher and lower yields per tree were observed in Pusa Arunima (32.03 kg) and Angoor Lata (2.99 kg), respectively.

Table 4.8: Performance of mango varieties and new accessions in relation to leaf, panicle, flowering and duration of fruit maturity (2014)

S. No.	Varieties/ accessions	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	Duration of panicle emergence (days)	Duration of flowering (days)	Number of secondary rachis/panicle	Length of inflorescence (cm)	Width of inflorescence (cm)	Duration of fruit maturity (days)
1	Dashehari	17.52	4.24	61.46	18.00	18.33	27.66	27.93	15.35	97.00
2	Dashehari 35	17.95	4.59	61.78	18.67	17.67	28.09	33.40	14.05	101.33
3	Dashehari 51	21.67	5.53	68.25	17.00	16.33	28.48	25.20	13.38	94.00
4	Langra	20.87	5.66	85.19	21.00	18.00	28.29	25.47	17.48	90.67
5	Chausa	20.77	5.15	103.03	24.33	26.00	21.02	28.27	17.47	118.00
6	Bombay Green	17.17	5.20	63.50	19.67	24.00	20.45	30.20	11.23	80.67
7	Pant Sinduri	20.83	6.19	75.97	23.33	23.00	42.13	52.33	23.45	90.00
8	Pant Chandra	20.32	5.06	81.99	21.67	18.67	29.70	35.13	17.67	93.33
9	PMSS-1	20.37	6.03	80.97	24.00	20.00	29.07	31.96	15.66	152.67
10	Amrapali	21.28	5.19	86.05	24.67	18.00	30.98	33.53	20.23	115.67
11	Mallika	19.85	4.47	65.56	19.00	15.67	30.11	35.07	20.87	111.00
12	Pusa Arunima	23.22	4.68	86.11	18.00	18.67	31.23	23.14	20.84	125.00
13	Pusa Surya	19.46	4.64	68.81	20.00	25.33	26.19	18.94	14.14	120.00
14	Arka Neelkiran	19.49	4.66	71.66	21.00	28.00	26.71	27.40	14.48	112.00
15	Ambika	23.68	6.17	118.29	23.67	27.00	35.05	35.64	18.81	123.67
16	Arunika	17.11	3.39	58.51	19.00	22.33	29.50	24.07	21.31	111.00
17	Neeluddin	23.14	5.42	80.29	18.00	25.00	29.38	25.74	20.30	112.33
18	Neeleshan	22.11	4.82	83.17	20.00	22.00	30.49	25.54	20.78	111.00
19	Neelgoa	22.06	5.19	87.58	19.33	25.00	29.45	27.47	17.55	108.67
20	A.U. Rumani	19.11	4.49	69.11	18.00	22.00	38.28	32.48	21.17	97.67
21	Swarna Jehangir	18.28	5.63	64.55	24.00	24.00	28.70	33.07	11.21	106.00

22	Ratna	21.27	5.46	83.23	16.00	24.67	34.43	30.34	18.11	110.00
23	Sabri	16.84	4.90	54.98	21.67	22.00	25.15	34.68	14.60	101.00
24	Bangalora	21.98	6.09	104.90	25.00	24.33	29.56	27.33	23.04	95.00
25	Totapuri Red Small	18.32	4.74	65.34	24.00	26.00	26.60	28.14	16.20	112.67
26	Angoor Lata	14.83	4.06	36.28	18.00	21.67	17.21	24.00	9.96	96.00
27	Saurabh	19.35	6.07	89.55	22.00	19.33	40.46	34.81	19.45	110.00
28	Rajiv	20.96	5.13	75.10	20.67	23.00	28.54	34.33	14.27	97.67
29	Gourav	20.91	4.78	64.63	15.67	19.00	23.10	27.48	15.84	100.67
30	Himanshu	20.96	5.98	78.11	19.00	21.67	36.25	31.63	13.02	96.67
31	Sukul	18.35	4.74	64.24	17.33	24.33	30.85	35.11	14.23	106.00
32	Van Raj	17.17	4.16	64.05	27.00	20.33	27.46	34.13	10.91	110.67
33	Dilpasand	17.88	5.27	73.84	18.67	22.00	24.26	25.49	10.85	103.33
34	Himsagar	20.69	4.38	86.25	20.33	24.33	39.48	35.87	21.77	96.00
35	Tilka Bhadainya	17.04	4.61	55.93	17.33	22.00	23.22	25.49	13.39	106.33
36	Chandra Karan	18.84	4.45	73.09	25.00	25.33	24.27	34.02	12.36	92.00
37	Surkha Khal	19.49	5.12	92.75	20.33	21.00	28.89	29.47	11.41	88.33
38	Burma Surkhh	19.83	5.65	72.31	15.33	24.33	28.98	29.67	13.28	94.00
39	Sensation	22.38	5.16	90.59	18.00	20.33	28.92	32.97	15.84	123.00
40	Tommy Atkins	21.80	5.04	90.91	22.67	26.33	34.26	33.00	17.07	109.33
	Mean	**19.88**	**5.05**	**75.95**	**20.41**	**22.17**	**29.32**	**30.50**	**16.33**	**105.51**
	Range	14.83-23.68	3.39-6.19	36.28-118.29	15.33-27.00	15.67-28.00	17.21-42.13	18.94-52.33	9.96-23.45	80.67-152.67
	C.V. (%)	5.60	9.10	4.18	7.84	8.47	5.20	6.85	9.19	2.06
	S.Em±	0.64	0.27	1.83	0.92	1.08	0.88	1.21	0.87	1.26
	C.D. at 5%	1.81	0.75	5.16	2.60	3.05	2.48	3.40	2.44	3.54

Table 4.9: Performance of mango varieties and new accessions in relation to yield and physical characteristics (2014)

S. No.	Varieties/accessions	Number of fruits/tree at harvesting	Yield / tree (kg)	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Stone weight (g)	Stone length (cm)	Stone width (cm)	Pulp weight (g)	Peel weight (g)	Pulp: stone ratio
1	Dashehari	150.00	15.95	106.35	8.76	5.13	18.71	7.40	2.74	70.14	17.50	3.75
2	Dashehari 35	157.33	20.18	128.23	9.11	5.36	17.92	7.79	2.74	93.27	17.03	5.23
3	Dashehari 51	163.00	25.97	159.33	9.16	5.57	19.91	7.95	2.89	124.19	15.22	6.27
4	Langra	64.33	18.63	289.67	9.70	6.98	40.24	8.38	3.82	224.21	25.22	5.58
5	Chausa	49.33	17.67	358.13	10.02	6.48	47.20	10.29	3.91	275.32	35.61	5.85
6	Bombay Green	55.00	10.86	196.95	9.13	6.18	31.47	7.90	3.63	134.34	31.14	4.28
7	Pant Sinduri	90.00	17.30	190.87	9.51	6.06	27.58	7.52	3.44	143.81	19.48	5.19
8	Pant Chandra	64.67	10.07	155.74	8.67	5.17	28.70	6.93	2.68	102.49	24.56	3.57
9	PMSS-1	75.00	18.30	238.49	9.65	7.25	37.79	8.13	3.83	171.30	29.40	4.53
10	Amrapali	85.33	11.36	132.84	8.59	5.31	25.27	7.76	3.63	86.40	21.18	3.40
11	Mallika	39.33	16.18	411.50	12.04	7.37	34.09	10.57	4.48	343.68	33.73	10.15
12	Pusa Arunima	90.00	27.65	307.09	12.51	8.56	35.22	8.96	3.79	238.49	33.39	6.77
13	Pusa Surya	35.67	13.08	366.66	10.60	7.91	36.48	8.16	4.46	291.73	38.46	8.02
14	Arka Neelkiran	32.67	8.25	252.48	8.47	6.71	36.35	7.33	3.48	182.73	33.40	5.03
15	Ambika	37.00	10.92	295.25	11.70	6.85	31.53	9.65	3.82	226.51	37.21	7.19
16	Arunika	52.00	10.41	200.04	7.88	6.57	28.14	5.61	2.92	137.45	34.45	4.88
17	Neeluddin	32.00	7.01	218.94	9.25	6.28	25.47	7.34	3.37	176.66	16.80	7.04
18	Neeleshan	30.33	8.63	284.26	10.08	6.91	25.03	6.78	3.04	238.88	20.35	9.55
19	Neelgoa	34.67	13.06	375.74	10.47	8.52	37.21	7.78	4.54	298.86	39.67	8.04
20	A.U. Rumani	112.33	17.19	153.06	9.49	5.19	19.78	7.97	2.83	109.23	24.05	5.53
21	Swarna Jehangir	23.00	3.60	156.68	8.08	6.31	27.46	6.96	3.72	102.41	26.81	3.73

22	Ratna	23.00	5.89	256.07	9.51	7.37	33.64	6.80	3.05	180.76	41.67	5.39
23	Sabri	46.00	10.55	229.41	8.79	7.44	28.66	6.13	3.01	174.70	26.05	6.10
24	Bangalora	29.67	11.83	398.81	13.09	7.85	64.33	9.55	5.55	290.25	44.23	4.51
25	Totapuri Red Small	91.00	11.49	126.29	8.48	5.16	26.49	6.45	3.55	82.48	17.31	3.12
26	Angoor Lata	140.00	2.73	19.48	3.38	2.68	5.29	2.76	1.89	12.66	1.54	2.44
27	Saurabh	36.00	9.23	256.67	12.50	6.65	41.77	5.52	2.91	185.72	29.18	4.45
28	Rajiv	136.00	20.87	153.47	7.06	5.94	18.26	6.53	3.67	119.33	15.88	6.55
29	Gourav	48.33	11.78	243.85	10.19	5.62	44.56	8.76	3.17	159.86	39.43	3.61
30	Himanshu	94.00	30.00	319.18	11.55	6.72	25.85	9.51	3.83	261.55	31.79	10.17
31	Sukul	31.00	11.99	386.73	11.66	7.12	45.21	8.97	3.79	299.57	41.95	6.67
32	Van Raj	36.00	13.58	376.29	10.71	8.48	52.65	9.81	3.84	289.05	34.59	5.49
33	Dilpasand	31.33	8.68	276.91	11.31	6.94	24.45	9.02	3.39	229.99	22.47	9.42
34	Himsagar	54.33	14.19	261.18	8.54	6.97	30.56	6.62	3.75	208.58	22.04	6.83
35	Tilka Bhadainya	70.00	11.01	157.28	7.80	5.28	25.08	6.74	2.95	100.71	31.49	4.01
36	Chandra Karan	21.00	4.04	192.64	8.23	6.69	28.67	5.92	3.35	144.41	19.57	5.04
37	Surkha Khal	32.00	6.47	202.17	8.46	6.37	27.72	6.69	3.22	145.28	29.16	5.26
38	Burma Surkhh	55.00	11.31	205.32	9.38	5.95	25.37	6.68	3.82	161.71	18.24	6.38
39	Sensation	50.67	17.01	335.99	12.34	7.99	43.06	10.24	4.38	240.96	51.97	5.64
40	Tommy Atkins	20.00	5.95	297.67	9.81	7.57	47.29	8.69	3.49	197.93	52.45	4.19
	Mean	**62.96**	**13.02**	**241.84**	**9.64**	**6.54**	**31.76**	**7.71**	**3.51**	**181.44**	**28.64**	**5.72**
	Range	20.00-163.00	2.73-30.00	19.48-411.50	3.38-13.09	2.68-8.56	5.29-64.33	2.76-10.57	1.89-5.55	12.66-343.68	1.54-52.45	2.44-10.17
	C.V. (%)	5.67	9.68	5.08	2.39	3.20	6.56	3.50	5.74	6.63	5.30	9.00
	S.Em±	2.06	0.73	7.09	0.13	0.12	1.20	0.16	0.12	6.94	0.88	0.30
	C.D. at 5%	5.81	2.05	19.96	0.38	0.34	3.39	0.44	0.33	19.54	2.47	0.84

Table 4.10: Performance of mango varieties and new accessions in relation to quality attributes (2014)

S. No.	Varieties/accessions	TSS (^{0}B)	Acidity (%)	Reducing sugar (%)	Total sugar (%)	Non reducing sugar (%)	Ascorbic acid (mg/100 g flesh)	Total carotenoid (mg/100 g flesh)
1	Dashehari	18.15	0.16	3.94	16.37	11.82	42.59	4.41
2	Dashehari 35	19.54	0.12	3.81	16.52	12.08	42.20	3.78
3	Dashehari 51	17.11	0.11	3.43	16.68	12.59	44.63	4.82
4	Langra	17.52	0.17	4.45	17.54	12.43	56.55	5.40
5	Chausa	21.15	0.14	4.08	18.46	13.66	64.64	3.64
6	Bombay Green	18.77	0.23	3.62	14.71	10.53	47.45	4.02
7	Pant Sinduri	18.82	0.17	4.55	16.52	11.37	29.60	3.21
8	Pant Chandra	17.86	0.18	4.61	15.64	10.48	41.62	1.91
9	PMSS-1	18.12	0.16	4.20	12.47	8.47	40.79	4.59
10	Amrapali	20.72	0.27	5.65	20.85	14.44	33.49	8.68
11	Mallika	21.94	0.20	5.08	19.36	13.56	36.39	7.46
12	Pusa Arunima	17.80	0.19	5.02	18.13	12.46	49.02	5.31
13	Pusa Surya	18.37	0.23	5.81	16.23	9.90	49.00	3.49
14	Arka Neelkiran	20.76	0.20	6.00	14.77	8.33	20.86	2.67
15	Ambika	19.15	0.19	4.63	18.37	13.06	32.54	4.60
16	Arunika	21.62	0.23	5.21	15.11	9.41	28.82	4.11
17	Neeluddin	20.47	0.24	5.31	17.85	11.91	33.71	2.65
18	Neeleshan	18.88	0.18	6.28	15.19	8.47	37.49	3.15
19	Neelgoa	18.11	0.15	4.61	15.38	10.23	34.01	2.82
20	A.U. Rumani	17.78	0.22	6.22	14.44	7.81	32.20	1.80
21	Swarna Jehangir	20.63	0.20	5.71	16.74	10.47	30.13	1.68

22	Ratna	19.17	0.14	5.72	16.12	9.88	42.55	3.35
23	Sabri	21.44	0.15	4.66	17.21	11.93	31.52	1.88
24	Bangalora	18.79	0.20	4.53	18.71	13.47	42.22	5.22
25	Totapuri Red Small	15.63	0.25	3.32	13.22	9.41	48.29	4.52
26	Angoor Lata	18.90	0.10	3.93	17.56	12.95	39.21	3.22
27	Saurabh	22.50	0.08	5.44	18.06	11.99	36.58	2.38
28	Rajiv	12.32	0.24	2.58	11.51	8.48	32.36	1.85
29	Gourav	16.91	0.14	3.47	16.18	12.07	43.32	1.83
30	Himanshu	16.47	0.06	3.45	16.86	12.74	45.44	3.10
31	Sukul	18.20	0.07	2.47	13.27	10.26	48.58	4.07
32	Van Raj	18.44	0.12	5.36	17.86	11.88	27.59	2.22
33	Dilpasand	13.37	0.21	2.39	13.21	10.28	39.93	3.43
34	Himsagar	22.53	0.04	4.52	16.02	10.93	36.69	4.20
35	Tilka Bhadainya	12.03	0.19	2.50	11.19	8.26	42.26	1.61
36	Chandra Karan	12.17	0.19	2.09	11.13	8.59	36.31	1.85
37	Surkha Khal	17.71	0.13	3.56	15.07	10.93	41.61	3.57
38	Burma Surkhh	15.17	0.12	3.86	16.54	12.05	37.58	2.42
39	Sensation	19.27	0.23	3.16	14.88	11.14	32.96	6.16
40	Tommy Atkins	18.21	0.29	3.28	13.49	11.58	36.21	1.89
	Mean	**18.31**	**0.17**	**4.31**	**15.89**	**11.06**	**39.22**	**3.57**
	Range	12.03-22.53	0.04-0.29	2.09-6.28	11.13-20.85	7.81-14.44	20.86-64.64	1.61-8.68
	C.V. (%)	5.24	9.64	6.47	5.97	7.81	5.50	6.39
	S.Em±	0.55	0.01	0.16	0.55	0.50	1.24	0.13
	C.D. at 5%	1.56	0.03	0.45	1.54	1.40	3.50	0.37

Table 4.11: Performance of mango varieties and new accessions in relation to leaf, panicle, flowering and duration of fruit maturity (2016)

S. No.	Varieties/accessions	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	Duration of panicle emergence (days)	Duration of flowering (days)	Number of secondary rachis/ panicle	Length of inflorescence (cm)	Width of inflorescence (cm)	Duration of fruit maturity (days)
1	Dashehari	18.59	4.78	63.11	16.14	18.00	29.58	26.12	15.77	102.04
2	Dashehari 35	18.49	4.83	63.43	16.67	17.00	28.18	26.67	15.80	108.00
3	Dashehari 51	20.15	4.63	66.35	17.67	17.33	27.97	20.46	15.51	101.00
4	Langra	19.97	6.23	88.28	21.00	16.33	29.37	36.33	18.91	95.00
5	Chausa	21.74	6.88	106.22	22.00	24.33	22.81	27.51	18.43	120.33
6	Bombay Green	17.65	5.30	66.42	18.00	21.00	21.20	35.53	12.73	84.00
7	Pant Sinduri	19.77	5.27	74.03	24.00	21.33	44.38	52.25	26.84	92.00
8	Pant Chandra	19.77	5.63	79.17	20.33	16.00	31.71	36.58	19.43	95.00
9	PMSS-1	20.25	5.53	79.54	20.33	18.00	29.13	33.33	15.45	158.00
10	Amrapali	22.44	5.51	88.09	23.13	16.67	33.54	30.58	23.85	116.67
11	Mallika	19.31	4.93	67.59	16.00	14.67	29.20	33.25	21.04	112.00
12	Pusa Arunima	24.13	5.08	87.09	15.00	16.00	31.66	27.58	21.04	124.00
13	Pusa Surya	20.53	4.83	70.40	18.00	22.00	28.22	25.08	13.59	117.33
14	Arka Neelkiran	20.45	4.92	71.18	19.33	25.00	28.23	32.34	18.62	115.00
15	Ambika	24.31	6.90	119.21	21.33	24.33	37.27	44.25	23.11	125.00
16	Arunika	18.88	4.26	57.18	18.00	20.67	31.39	28.58	22.46	110.00
17	Neeluddin	22.54	4.96	79.38	17.67	22.00	32.85	26.00	22.21	109.00
18	Neeleshan	22.55	5.21	83.35	19.00	20.67	31.27	24.00	23.00	110.33
19	Neelgoa	23.74	5.28	89.03	18.33	23.00	31.90	32.00	21.93	111.00
20	A.U. Rumani	18.91	4.83	64.81	16.00	20.00	34.93	39.42	21.97	99.00
21	Swarna Jehangir	17.37	5.11	63.07	22.00	23.00	30.31	36.00	16.42	103.00

22	Ratna	21.93	5.37	83.66	13.67	21.00	35.91	35.58	21.31	113.00
23	Sabri	15.65	5.09	56.51	19.33	21.00	27.77	38.08	14.05	102.00
24	Bangalora	22.15	6.61	104.04	25.00	24.33	31.71	29.78	20.67	99.00
25	Totapuri Red Small	18.30	5.22	67.83	22.33	22.00	28.62	26.25	18.27	114.00
26	Angoor Lata	13.84	3.53	34.65	15.00	20.00	19.63	24.25	11.92	98.00
27	Saurabh	18.29	4.44	57.65	20.67	18.00	41.20	34.50	22.62	109.00
28	Rajiv	21.08	5.01	74.93	18.67	22.33	31.62	33.82	18.02	99.00
29	Gourav	19.75	4.55	63.89	13.00	18.00	23.37	27.33	14.34	103.00
30	Himanshu	20.31	5.39	77.78	17.00	18.33	38.10	34.58	17.04	97.00
31	Sukul	19.22	4.98	67.97	16.67	22.00	33.01	39.50	19.71	108.67
32	Van Raj	18.97	4.57	61.49	24.00	20.00	30.52	34.67	12.79	112.00
33	Dilpasand	17.92	6.01	76.43	14.00	21.00	23.15	28.17	11.99	102.00
34	Himsagar	21.33	5.65	85.53	18.67	21.67	42.31	38.67	23.01	98.67
35	Tilka Bhadainya	17.59	4.65	57.99	15.00	20.67	25.36	30.33	14.07	108.00
36	Chandra Karan	19.63	5.26	73.31	23.33	22.00	27.73	39.33	12.28	94.00
37	Surkha Khal	20.67	6.13	90.06	17.00	19.33	30.00	29.87	16.16	84.00
38	Burma Surkhh	19.99	5.03	71.33	13.00	21.67	30.39	34.42	14.22	91.00
39	Sensation	23.13	5.54	91.01	16.33	19.00	28.53	31.67	16.57	125.67
40	Tommy Atkins	22.17	5.75	90.55	21.00	23.33	36.71	37.75	19.88	110.00
	Mean	**20.09**	**5.24**	**75.34**	**18.59**	**20.33**	**30.77**	**32.56**	**18.18**	**106.89**
	Range	13.84-24.31	3.53-6.90	34.65-119.21	13.00-25.00	14.67-25.00	19.63-44.38	20.46-52.25	11.92-26.84	84.00-158.00
	C.V. (%)	3.52	5.10	7.17	6.88	5.71	3.94	5.25	8.37	2.64
	S.Em±	0.41	0.15	3.12	0.74	0.67	0.70	0.99	0.88	1.63
	C.D. at 5%	1.15	0.43	8.78	2.08	1.89	1.97	2.78	2.47	4.59

Table 4.12: Performance of mango varieties and new accessions in relation to yield and physical characteristics (2016)

S. No.	Varieties/accessions	Number of fruits/tree (harvesting)	Yield / tree (kg)	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Stone weight (g)	Stone length (cm)	Stone width (cm)	Pulp weight (g)	Peel weight (g)	Pulp: stone ratio
1	Dashehari	165.12	17.15	103.87	8.86	5.19	17.05	7.60	2.74	67.98	18.83	4.01
2	Dashehari 35	164.59	19.60	119.17	9.47	5.42	17.87	8.03	2.79	85.30	16.00	4.78
3	Dashehari 51	189.33	27.77	146.83	9.57	5.78	18.70	8.36	2.99	111.55	16.58	6.01
4	Langra	75.33	22.16	294.10	10.03	6.62	38.90	8.18	3.53	232.15	23.06	5.97
5	Chausa	57.91	20.99	361.81	10.39	6.71	45.53	10.18	3.88	283.10	33.18	6.24
6	Bombay Green	60.30	11.49	190.70	9.51	6.43	30.10	7.58	3.60	128.43	32.17	4.36
7	Pant Sinduri	110.00	22.44	203.83	9.76	6.40	25.89	7.96	3.38	158.23	19.71	6.11
8	Pant Chandra	62.01	9.98	161.32	8.77	5.69	27.53	7.31	2.72	106.89	26.90	3.88
9	PMSS-1	85.42	20.49	263.11	9.49	7.40	40.89	7.72	3.65	201.54	34.37	4.93
10	Amrapali	101.42	14.48	142.62	8.98	5.59	24.58	7.52	3.29	95.84	22.20	3.90
11	Mallika	39.66	17.08	429.80	12.59	7.91	34.45	10.71	4.48	359.59	35.76	10.51
12	Pusa Arunima	92.20	36.40	394.78	12.85	8.43	38.46	9.18	3.90	320.66	35.66	8.34
13	Pusa Surya	42.25	15.93	376.69	11.02	8.01	37.13	8.09	4.26	303.55	36.01	8.18
14	Arka Neelkiran	36.45	9.99	275.13	8.54	6.85	32.32	7.15	3.27	210.11	32.69	6.51
15	Ambika	49.00	14.86	303.41	12.33	7.72	32.65	9.13	3.72	231.57	39.19	7.14
16	Arunika	64.65	13.53	208.14	8.03	6.98	26.34	5.36	3.22	147.16	34.64	5.58
17	Neeluddin	39.00	9.16	235.04	9.98	7.49	23.38	7.72	3.42	193.08	18.57	8.26
18	Neeleshan	40.00	11.84	296.90	10.55	7.33	23.31	6.82	3.37	252.50	21.09	10.89
19	Neelgoa	38.33	14.90	388.19	10.46	8.89	35.40	7.77	4.60	311.17	41.62	8.87
20	A.U. Rumani	121.62	19.01	156.35	9.16	5.59	18.29	8.25	2.95	114.28	23.78	6.25
21	Swarna Jehangir	23.20	3.87	165.80	7.89	5.95	25.89	6.51	3.32	112.69	27.22	4.37
22	Ratna	26.20	7.02	267.42	10.05	7.58	34.27	6.97	3.10	189.79	43.37	5.53

23	Sabri	53.48	12.90	240.83	9.13	7.23	30.79	6.68	3.12	182.88	27.15	6.13
24	Bangalora	34.86	14.16	407.75	13.47	7.48	65.47	9.93	5.41	295.21	47.08	4.51
25	Totapuri Red Small	110.00	14.93	135.75	8.69	5.39	24.16	6.46	3.23	91.64	19.95	3.85
26	Angoor Lata	156.96	3.24	20.67	3.58	2.93	5.39	2.98	1.95	13.65	1.62	2.55
27	Saurabh	57.00	14.85	260.54	12.12	6.18	40.45	5.57	2.85	191.74	28.36	4.74
28	Rajiv	151.19	23.08	152.93	7.36	6.27	19.05	6.25	3.55	117.12	16.77	6.17
29	Gourav	32.66	8.10	247.84	10.97	6.03	43.11	8.87	3.18	168.37	36.36	3.91
30	Himanshu	104.16	32.51	312.02	11.02	6.20	26.19	9.69	3.61	253.50	32.32	9.81
31	Sukul	35.67	13.82	385.71	11.24	7.56	44.98	8.82	3.87	297.02	43.70	6.61
32	Van Raj	39.16	13.56	346.86	10.20	8.63	51.45	9.42	4.00	259.40	36.02	5.05
33	Dilpasand	39.00	11.09	285.33	11.72	7.26	27.74	9.34	3.54	233.43	24.16	8.35
34	Himsagar	70.00	17.81	252.87	8.72	7.29	32.73	6.67	3.58	195.41	24.72	5.94
35	Tilka Bhadainya	83.78	12.70	150.46	7.39	4.80	27.88	6.89	2.88	91.80	30.78	3.30
36	Chandra Karan	32.99	6.47	195.83	8.14	6.90	28.90	5.60	3.51	145.83	21.10	5.07
37	Surkha Khal	35.20	7.12	201.37	8.61	6.82	28.11	6.52	3.49	144.20	29.06	5.13
38	Burma Surkhh	60.51	12.84	212.17	9.78	6.22	28.49	6.66	3.83	162.86	20.82	5.74
39	Sensation	53.00	18.10	341.75	12.52	8.30	43.39	10.26	4.49	242.71	55.65	5.62
40	Tommy Atkins	25.00	7.65	308.20	9.72	7.80	44.04	8.37	3.45	210.15	54.02	4.77
	Mean	**71.47**	**15.13**	**248.60**	**9.82**	**6.73**	**31.53**	**7.73**	**3.49**	**187.85**	**29.56**	**5.95**
	Range	23.20-189.33	3.24-36.40	20.67-429.80	3.58-13.47	2.93-8.89	5.39-65.47	2.98-10.71	1.95-5.41	13.65-359.59	1.62-55.65	2.55-10.89
	C.V. (%)	6.53	12.32	10.66	3.05	3.16	7.36	6.22	6.66	13.78	11.62	14.91
	S.Em±	2.69	1.08	15.30	0.17	0.12	1.34	0.28	0.13	14.95	1.98	0.51
	C.D. at 5%	7.58	3.03	43.07	0.49	0.35	3.77	0.78	0.38	42.09	5.58	1.44

Table 4.13: Performance of mango varieties and new accessions in relation to quality attributes (2016)

S. No.	Varieties/accessions	TSS (^{0}B)	Acidity (%)	Reducing sugar (%)	Total sugar (%)	Non reducing sugar (%)	Ascorbic acid (mg/100 g flesh)	Total carotenoid (mg/100 g flesh)
1	Dashehari	18.71	0.15	4.25	16.58	12.54	42.05	4.36
2	Dashehari 35	19.22	0.13	4.06	16.59	12.73	40.39	4.13
3	Dashehari 51	18.31	0.10	3.92	17.19	13.47	43.16	4.76
4	Langra	18.43	0.16	4.21	17.81	13.81	55.89	5.74
5	Chausa	21.27	0.13	4.17	17.63	13.67	65.29	4.20
6	Bombay Green	19.45	0.20	3.92	18.60	14.88	48.99	4.42
7	Pant Sinduri	18.10	0.18	4.10	16.43	12.53	32.92	3.68
8	Pant Chandra	17.12	0.22	3.83	15.82	12.18	42.61	2.30
9	PMSS-1	18.00	0.18	4.17	12.77	8.17	41.54	4.41
10	Amrapali	21.28	0.25	6.04	20.54	14.80	36.80	9.77
11	Mallika	21.48	0.19	5.52	19.76	14.52	40.67	7.95
12	Pusa Arunima	18.33	0.15	5.30	17.32	12.28	49.52	6.08
13	Pusa Surya	18.08	0.21	5.93	16.20	10.57	49.52	3.58
14	Arka Neelkiran	19.40	0.19	5.92	14.07	8.45	22.41	3.12
15	Ambika	19.00	0.20	4.75	17.87	13.36	35.58	5.14
16	Arunika	21.98	0.21	6.13	17.36	11.54	31.82	5.30
17	Neeluddin	20.88	0.22	5.67	17.83	12.44	36.25	3.63
18	Neeleshan	19.20	0.19	4.74	15.95	11.45	39.84	3.87
19	Neelgoa	18.16	0.16	4.30	16.16	12.07	36.24	3.25
20	A.U. Rumani	18.90	0.19	6.13	15.82	10.00	34.03	2.36
21	Swarna Jehangir	21.26	0.24	5.87	17.90	12.33	31.64	2.27
22	Ratna	19.77	0.16	5.69	16.40	10.99	48.14	3.70

23	Sabri	20.59	0.17	5.79	17.79	12.29	31.82	2.08
24	Bangalora	16.37	0.24	3.87	17.19	13.51	43.71	4.83
25	Totapuri Red Small	15.30	0.27	3.81	14.66	11.04	50.63	4.38
26	Angoor Lata	19.51	0.12	4.16	18.26	14.30	40.67	3.44
27	Saurabh	21.22	0.10	5.83	18.43	12.89	39.29	2.72
28	Rajiv	13.88	0.27	2.73	11.21	8.61	32.65	1.92
29	Gourav	17.31	0.13	3.78	17.27	13.68	45.37	2.15
30	Himanshu	16.02	0.09	3.62	17.43	13.99	47.03	3.49
31	Sukul	19.00	0.09	2.68	11.72	9.17	52.01	4.60
32	Van Raj	18.00	0.16	4.15	18.89	14.95	28.31	2.70
33	Dilpasand	14.60	0.27	2.58	14.27	11.82	41.50	3.65
34	Himsagar	22.10	0.06	5.94	17.41	11.77	37.35	4.88
35	Tilka Bhadainya	12.08	0.20	2.89	12.68	9.93	43.16	1.95
36	Chandra Karan	12.95	0.20	2.32	11.62	9.41	37.07	2.37
37	Surkha Khal	18.20	0.16	3.99	15.97	12.17	43.99	4.07
38	Burma Surkhh	16.06	0.15	3.94	14.60	10.86	37.35	2.84
39	Sensation	19.10	0.21	4.17	16.45	12.48	34.86	6.78
40	Tommy Atkins	17.87	0.27	3.47	14.35	11.05	38.18	2.23
	Mean	**18.41**	**0.18**	**4.46**	**16.32**	**12.07**	**40.76**	**3.98**
	Range	12.08-22.10	0.06-0.27	2.32-6.13	11.21-20.54	8.17-14.95	22.41-65.29	1.92-9.77
	C.V. (%)	3.03	9.51	6.58	7.18	10.14	5.23	9.35
	S.Em±	0.32	0.01	0.17	0.68	0.71	1.23	0.21
	C.D. at 5%	0.91	0.03	0.48	1.90	1.99	3.46	0.60

Table 4.14: Performance of mango varieties and new accessions in relation to leaf, panicle, flowering and duration of fruit maturity (pooled data of 2014 and 2016)

S. No.	Varieties/accessions	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	Duration of panicle emergence (days)	Duration of flowering (days)	Number of secondary rachis/ panicle	Length of inflorescence (cm)	Width of inflorescence (cm)	Duration of fruit maturity (days)
1	Dashehari	18.06	4.51	62.28	17.07	18.17	28.62	27.03	15.56	99.52
2	Dashehari 35	18.22	4.71	62.60	17.67	17.33	28.14	30.03	14.93	104.67
3	Dashehari 51	20.91	5.08	67.30	17.33	16.83	28.23	22.83	14.44	97.50
4	Langra	20.42	5.94	86.74	21.00	17.17	28.83	30.90	18.20	92.83
5	Chausa	21.26	6.01	104.63	23.17	25.17	21.92	27.89	17.95	119.17
6	Bombay Green	17.41	5.25	64.96	18.83	22.50	20.83	32.86	11.98	82.33
7	Pant Sinduri	20.30	5.73	75.00	23.67	22.17	43.26	52.29	25.14	91.00
8	Pant Chandra	20.05	5.35	80.58	21.00	17.33	30.71	35.86	18.55	94.17
9	PMSS-1	20.31	5.78	80.26	22.17	19.00	29.10	32.65	15.55	155.33
10	Amrapali	21.86	5.35	87.07	23.90	17.33	32.26	32.06	22.04	116.17
11	Mallika	19.58	4.70	66.58	17.50	15.17	29.66	34.16	20.96	111.50
12	Pusa Arunima	23.67	4.88	86.60	16.50	17.33	31.44	25.36	20.94	124.50
13	Pusa Surya	20.00	4.73	69.60	19.00	23.67	27.20	22.01	13.86	118.67
14	Arka Neelkiran	19.97	4.79	71.42	20.17	26.50	27.47	29.87	16.55	113.50
15	Ambika	23.99	6.54	118.75	22.50	25.67	36.16	39.94	20.96	124.33
16	Arunika	18.00	3.83	57.85	18.50	21.50	30.44	26.33	21.89	110.50
17	Neeluddin	22.84	5.19	79.83	17.83	23.50	31.11	25.87	21.25	110.67
18	Neeleshan	22.33	5.01	83.26	19.50	21.33	30.88	24.77	21.89	110.67
19	Neelgoa	22.90	5.24	88.31	18.83	24.00	30.67	29.73	19.74	109.83
20	A.U. Rumani	19.01	4.66	66.96	17.00	21.00	36.61	35.95	21.57	98.33
21	Swarna Jehangir	17.82	5.37	63.81	23.00	23.50	29.50	34.53	13.82	104.50
22	Ratna	21.60	5.41	83.45	14.83	22.83	35.17	32.96	19.71	111.50

23	Sabri	16.25	4.99	55.74	20.50	21.50	26.46	36.38	14.33	101.50
24	Bangalora	22.07	6.35	104.47	25.00	24.33	30.64	28.55	21.85	97.00
25	Totapuri Red Small	18.31	4.98	66.58	23.17	24.00	27.61	27.19	17.23	113.33
26	Angoor Lata	14.34	3.79	35.47	16.50	20.83	18.42	24.13	10.94	97.00
27	Saurabh	18.82	5.25	73.60	21.33	18.67	40.83	34.65	21.03	109.50
28	Rajiv	21.02	5.07	75.01	19.67	22.67	30.08	34.08	16.15	98.33
29	Gourav	20.33	4.67	64.26	14.33	18.50	23.24	27.41	15.09	101.83
30	Himanshu	20.64	5.69	77.95	18.00	20.00	37.17	33.10	15.03	96.83
31	Sukul	18.78	4.86	66.11	17.00	23.17	31.93	37.30	16.97	107.33
32	Van Raj	18.07	4.36	62.77	25.50	20.17	28.99	34.40	11.85	111.33
33	Dilpasand	17.90	5.64	75.13	16.33	21.50	23.70	26.83	11.42	102.67
34	Himsagar	21.01	5.01	85.89	19.50	23.00	40.90	37.27	22.39	97.33
35	Tilka Bhadainya	17.31	4.63	56.96	16.17	21.33	24.29	27.91	13.73	107.17
36	Chandra Karan	19.23	4.85	73.20	24.17	23.67	26.00	36.68	12.32	93.00
37	Surkha Khal	20.08	5.63	91.40	18.67	20.17	29.44	29.67	13.78	86.17
38	Burma Surkhh	19.91	5.34	71.82	14.17	23.00	29.68	32.04	13.75	92.50
39	Sensation	22.76	5.35	90.80	17.17	19.67	28.73	32.32	16.21	124.33
40	Tommy Atkins	21.99	5.39	90.73	21.83	24.83	35.48	35.38	18.48	109.67
	Mean	**19.98**	**5.15**	**75.64**	**19.50**	**21.25**	**30.05**	**31.53**	**17.25**	**106.20**
	Range	14.34-23.99	3.79-6.54	35.47-118.75	14.17-25.50	15.17-26.50	18.42-43.26	22.01-52.29	10.94-25.14	82.33-155.33
	C.V. (%)	4.84	9.45	6.55	7.33	7.16	4.82	8.30	9.77	2.51
	S.Em±	0.39	0.20	2.02	0.58	0.62	0.59	1.07	0.69	1.09
	C.D. at 5%	1.10	0.55	5.64	1.63	1.73	1.65	2.98	1.92	3.04

Table 4.15: Performance of mango varieties and new accessions in relation to yield and physical characteristics (pooled data of 2014 and 2016)

S. No.	Varieties/accessions	Number of fruits/tree at harvesting	Yield / tree (kg)	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Stone weight (g)	Stone length (cm)	Stone width (cm)	Pulp weight (g)	Peel weight (g)	Pulp: stone ratio
1	Dashehari	157.56	16.55	105.11	8.81	5.16	17.88	7.50	2.74	69.06	18.17	3.88
2	Dashehari 35	160.96	19.89	123.70	9.29	5.39	17.90	7.91	2.77	89.29	16.52	5.00
3	Dashehari 51	176.17	26.87	153.08	9.36	5.67	19.31	8.15	2.94	117.87	15.90	6.14
4	Langra	69.83	20.40	291.89	9.86	6.80	39.57	8.28	3.67	228.18	24.14	5.78
5	Chausa	53.62	19.33	359.97	10.21	6.60	46.36	10.24	3.89	279.21	34.40	6.04
6	Bombay Green	57.65	11.17	193.82	9.32	6.30	30.78	7.74	3.61	131.39	31.65	4.32
7	Pant Sinduri	100.00	19.87	197.35	9.63	6.23	26.73	7.74	3.41	151.02	19.59	5.65
8	Pant Chandra	63.34	10.02	158.53	8.72	5.43	28.11	7.12	2.70	104.69	25.73	3.73
9	PMSS-1	80.21	19.40	250.80	9.57	7.33	39.34	7.93	3.74	186.42	31.88	4.73
10	Amrapali	93.38	12.92	137.73	8.78	5.45	24.92	7.64	3.46	91.12	21.69	3.65
11	Mallika	39.50	16.63	420.65	12.31	7.64	34.27	10.64	4.48	351.64	34.74	10.33
12	Pusa Arunima	91.10	32.03	350.94	12.68	8.50	36.84	9.07	3.85	279.58	34.52	7.56
13	Pusa Surya	38.96	14.51	371.68	10.81	7.96	36.81	8.13	4.36	297.64	37.24	8.10
14	Arka Neelkiran	34.56	9.12	263.80	8.51	6.78	34.33	7.24	3.38	196.42	33.04	5.77
15	Ambika	43.00	12.89	299.33	12.02	7.28	32.09	9.39	3.77	229.04	38.20	7.17
16	Arunika	58.33	11.97	204.09	7.95	6.78	27.24	5.49	3.07	142.30	34.54	5.23
17	Neeluddin	35.50	8.08	226.99	9.61	6.89	24.43	7.53	3.40	184.87	17.69	7.65
18	Neeleshan	35.17	10.24	290.58	10.31	7.12	24.17	6.80	3.20	245.69	20.72	10.22
19	Neelgoa	36.50	13.98	381.97	10.47	8.70	36.31	7.78	4.57	305.02	40.65	8.45
20	A.U. Rumani	116.98	18.10	154.71	9.32	5.39	19.03	8.11	2.89	111.76	23.92	5.89
21	Swarna Jehangir	23.10	3.74	161.24	7.98	6.13	26.67	6.74	3.52	107.55	27.02	4.05
22	Ratna	24.60	6.45	261.75	9.78	7.48	33.95	6.89	3.08	185.28	42.52	5.46

23	Sabri	49.74	11.73	235.12	8.96	7.34	29.73	6.41	3.07	178.79	26.60	6.12
24	Bangalora	32.26	12.99	403.28	13.28	7.66	64.90	9.74	5.48	292.73	45.65	4.51
25	Totapuri Red Small	100.50	13.21	131.02	8.59	5.28	25.33	6.45	3.39	87.06	18.63	3.48
26	Angoor Lata	148.48	2.99	20.07	3.48	2.81	5.34	2.87	1.92	13.15	1.58	2.50
27	Saurabh	46.50	12.04	258.60	12.31	6.42	41.11	5.55	2.88	188.73	28.77	4.59
28	Rajiv	143.60	21.98	153.20	7.21	6.11	18.65	6.39	3.61	118.22	16.32	6.36
29	Gourav	40.50	9.94	245.85	10.58	5.83	43.84	8.82	3.18	164.11	37.89	3.76
30	Himanshu	99.08	31.26	315.60	11.28	6.46	26.02	9.60	3.72	257.52	32.05	9.99
31	Sukul	33.33	12.90	386.22	11.45	7.34	45.09	8.89	3.83	298.30	42.83	6.64
32	Van Raj	37.58	13.57	361.57	10.46	8.56	52.05	9.61	3.92	274.22	35.31	5.27
33	Dilpasand	35.17	9.89	281.12	11.51	7.10	26.09	9.18	3.46	231.71	23.32	8.88
34	Himsagar	62.17	16.00	257.02	8.63	7.13	31.65	6.64	3.66	201.99	23.38	6.39
35	Tilka Bhadainya	76.89	11.85	153.87	7.59	5.04	26.48	6.82	2.91	96.25	31.14	3.66
36	Chandra Karan	27.00	5.26	194.24	8.18	6.79	28.78	5.76	3.43	145.12	20.33	5.05
37	Surkha Khal	33.60	6.79	201.77	8.54	6.59	27.92	6.61	3.36	144.74	29.11	5.19
38	Burma Surkhh	57.76	12.07	208.74	9.58	6.08	26.93	6.67	3.82	162.29	19.53	6.06
39	Sensation	51.83	17.56	338.87	12.43	8.15	43.22	10.25	4.44	241.84	53.81	5.63
40	Tommy Atkins	22.50	6.80	302.94	9.76	7.69	45.67	8.53	3.47	204.04	53.23	4.48
	Mean	**67.21**	**14.07**	**245.22**	**9.73**	**6.63**	**31.65**	**7.72**	**3.50**	**184.65**	**29.10**	**5.83**
	Range	22.50-176.17	2.99-32.03	20.07-420.65	3.48-13.28	2.81-8.70	5.34-64.90	2.87-10.64	1.92-5.48	13.15-351.64	1.58-53.81	2.50-10.33
	C.V. (%)	8.24	12.61	8.38	3.10	4.06	7.00	4.93	6.17	10.92	8.76	12.51
	S.Em±	2.26	0.72	8.39	0.12	0.11	0.90	0.16	0.09	8.23	1.04	0.30
	C.D. at 5%	6.30	2.02	23.41	0.34	0.31	2.52	0.43	0.25	22.96	2.90	0.83

Table 4.16: Performance of mango varieties and new accessions in relation to quality attributes (pooled data of 2014 and 2016)

S. No.	Varieties/accessions	TSS (^{0}B)	Acidity (%)	Reducing sugar (%)	Total sugar (%)	Non reducing sugar (%)	Ascorbic acid (mg/100 g flesh)	Total carotenoid (mg/100 g flesh)
1	Dashehari	18.43	0.16	4.10	16.48	12.18	42.32	4.38
2	Dashehari 35	19.38	0.13	3.93	16.56	12.40	41.30	3.96
3	Dashehari 51	17.71	0.11	3.67	16.93	13.03	43.90	4.79
4	Langra	17.97	0.16	4.33	17.67	13.12	56.22	5.57
5	Chausa	21.21	0.14	4.13	18.05	13.66	64.96	3.92
6	Bombay Green	19.11	0.22	3.77	16.66	12.71	48.22	4.22
7	Pant Sinduri	18.46	0.18	4.33	16.47	11.95	31.26	3.45
8	Pant Chandra	17.49	0.20	4.22	15.73	11.33	42.11	2.11
9	PMSS-1	18.06	0.17	4.18	12.62	8.32	41.16	4.50
10	Amrapali	22.32	0.26	5.84	20.69	14.62	35.14	9.23
11	Mallika	21.71	0.20	5.30	19.56	14.04	38.53	7.70
12	Pusa Arunima	18.07	0.17	5.16	17.72	12.37	49.27	5.70
13	Pusa Surya	18.23	0.22	5.87	16.22	10.23	49.26	3.53
14	Arka Neelkiran	20.08	0.20	5.96	14.42	8.39	21.64	2.89
15	Ambika	19.08	0.19	4.69	18.12	13.21	34.06	4.87
16	Arunika	21.80	0.22	5.67	16.24	10.47	30.32	4.71
17	Neeluddin	20.68	0.23	5.49	17.84	12.18	34.98	3.14
18	Neeleshan	19.04	0.19	5.51	15.57	9.96	38.66	3.51
19	Neelgoa	18.14	0.16	4.46	15.77	11.15	35.13	3.04
20	A.U. Rumani	18.34	0.20	6.18	15.13	8.90	33.12	2.08
21	Swarna Jehangir	20.94	0.22	5.79	17.32	11.40	30.88	1.98
22	Ratna	19.47	0.15	5.70	16.26	10.44	45.35	3.52

23	Sabri	21.01	0.16	5.22	17.50	12.11	31.67	1.98
24	Bangalora	17.58	0.22	4.20	17.95	13.49	42.97	5.03
25	Totapuri Red Small	15.47	0.26	3.56	13.94	10.23	49.46	4.45
26	Angoor Lata	19.20	0.11	4.05	17.91	13.63	39.94	3.33
27	Saurabh	21.86	0.09	5.64	18.24	12.44	37.93	2.55
28	Rajiv	13.10	0.26	2.66	11.36	8.55	32.50	1.89
29	Gourav	17.11	0.13	3.63	16.72	12.87	44.35	1.99
30	Himanshu	16.25	0.08	3.54	17.15	13.37	46.24	3.30
31	Sukul	18.60	0.08	2.58	12.50	9.72	50.29	4.33
32	Van Raj	18.22	0.14	4.75	18.37	13.41	27.95	2.46
33	Dilpasand	13.99	0.24	2.48	13.74	11.05	40.71	3.54
34	Himsagar	21.00	0.05	5.23	16.72	11.35	37.02	4.54
35	Tilka Bhadainya	12.06	0.19	2.69	11.93	9.10	42.71	1.78
36	Chandra Karan	12.56	0.19	2.20	11.38	9.00	36.69	2.11
37	Surkha Khal	17.95	0.15	3.78	15.52	11.55	42.80	3.82
38	Burma Surkhh	15.62	0.14	3.90	15.57	11.46	37.46	2.63
39	Sensation	19.18	0.22	3.66	15.66	11.81	33.91	6.47
40	Tommy Atkins	18.04	0.28	3.37	13.92	11.32	37.20	2.06
	Mean	**18.36**	**0.18**	**4.39**	**16.10**	**11.56**	**39.99**	**3.78**
	Range	12.06-22.32	0.05-0.28	2.20-6.18	11.36-0.69	8.32-14.62	21.64-64.96	1.78-9.23
	C.V. (%)	4.50	11.16	9.01	6.93	9.67	5.20	8.64
	S.Em±	0.34	0.01	0.16	0.46	0.46	0.85	0.13
	C.D. at 5%	0.94	0.02	0.45	1.27	1.27	2.37	0.37

4.2.2.12 Fruit weight

Fruit weight was ranged from 19.48 (Angoor Lata) to 411.50 g (Mallika) with an average mean of 241.84 g during the year 2014, whereas, in 2016, it was ranged from 20.67 (Angoor Lata) to 429.80 g (Mallika) with an average of 248.60 g. The pooled analysis of two year data indicated the range of fruit weight 20.07 to 420.65 g with 245.22 g as an average value. Thus, the significantly maximum and minimum fruit weight were observed in Mallika (420.65 g) and Angoor Lata (20.07 g), respectively.

4.2.2.13 Fruit length

The significantly lower fruit length was observed in Angoor Lata, while, higher fruit length was observed in Bangalora which ranged from 3.38 to 13.09 cm with an average mean of 9.64 cm, 3.58 to 13.47 cm with an average of 9.82 cm and 3.48 to 13.28 cm with the average mean value of 9.73 cm during the year 2014, 2016 and pooled data of two years (2014 and 2016), respectively.

4.2.2.14 Fruit width

The range of variation for fruit width during the year 2014 ranged from 2.68 (Angoor Lata) to 8.56 cm Pusa Arunima) with an average mean of 6.54 cm. During the year 2016, the fruit width ranged from 2.93 (Angoor Lata) to 8.89 cm (Neelgoa) with an average of 6.73 cm. Pooled analysis of two year data that showed range of fruit width from 2.81 (Angoor Lata) to 8.70 cm (Neelgoa) with 6.63 cm as an average value. Thus, the significantly higher and lower fruit width were observed in Neelgoa Pusa (8.70 cm) and Angoor Lata (2.81 cm), respectively.

4.2.2.15 Stone weight

The lower stone weight was observed in Angoor Lata, while, higher stone weight was observed in Bangalora during the years 2014, 2016 and pooled data of year (2014 and 2016) which ranged from 5.29 to 64.33g with an average mean of 31.76 g; ranged from 5.39 to 65.47 g with an average of 31.53g and 5.34 to 64.90 g range in stone weight with the average mean value of 31.65 cm, respectively. Thus, the significantly maximum and minimum stone weight were observed in Bangalora (64.90 g) and Angoor Lata (5.34 g), respectively.

4.2.2.16 Stone length

The significantly minimum stone length was observed in Angoor Lata, while, maximum stone weight was observed in Mallika during the years 2014, 2016 and pooled analysis of year data which ranged from 2.76 to 10.57 cm with an average mean of 7.71 cm; ranged from 2.98 to 10.71cm with an average of 7.73 cm and 2.87 to 10.64 cm range in stone length with the average mean value of 7.72 cm, respectively.

4.2.2.17 Stone width

The stone width was ranged from 1.89 cm in Angoor Lata to 5.55 cm in Bangalora with an average mean of 3.51 cm during the year 2014. During the year 2016, the stone width ranged from 1.95 cm of Angoor Lata to 5.41cm Bangalora with an average of 3.49 cm. The result drawn by pooled two year data perceived 1.92 cm to 5.48 cm range in stone width with the general mean value of 3.50 cm. Thus, the significantly maximum and minimum stone width were observed in Bangalora (5.48 cm) and Angoor Lata (1.92 cm), respectively.

4.2.2.18 Pulp weight

During the year 2014, pulp weight ranged from 12.66 to 343.68 g with an average mean of 181.44 g. During year 2016, the pulp weight ranged from 13.65-359.59 g with an average of 187.85 g. The result drawn by pooled two year data perceived 13.15-351.64 g range in pulp weight with the average mean value of 184.65 g. Thus, the significantly higher and lower pulp weight were observed in Mallika (351.64 g) and Angoor Lata (13.15 g), respectively.

4.2.2.19 Peel weight

The peel weight during the year 2014 ranged from 1.54 to 52.45 g with an average mean of 28.64 g. During the year 2016, the peel weight ranged from 1.62 to 55.65 g with an average of 29.56 g. The result drawn by pooled data of two year (2014 and 2016) ranged from 1.58 to 53.81 g range in peel weight with the general mean value of 29.10 g. Thus, the significantly higher and lower peel weight were observed in Sensation (53.81 g) and Angoor Lata (1.58 g), respectively.

4.2.2.20 Pulp: stone ratio

During the year 2014, the pulp: stone ratio ranged from 2.44 (Angoor Lata) to 10.17 (Himanshu) with an average mean of 5.72. During the year 2016, the Pulp: stone ratio ranged from 2.55 (Angoor Lata) to 10.89 (Neeleshan) with an average of 5.95. The result drawn by pooled two year data perceived 2.50 to 10.33 ranges in pulp: stone ratio with the average mean value of 5.83. Thus, the significantly maximum and minimum pulp: stone ratio were observed in Mallika (10.33) and Angoor Lata (2.50), respectively.

4.2.2.21 TSS

The significantly minimum TSS was recorded in Tilka Bhadainya, while, maximum was recorded in Himsagar during the years 2014, 2016 and pooled analysis of two year data. It was ranged from 12.03 22.53 with an average mean of 18.31 in first year, while, in second year, the TSS ranged from 12.08 to 22.10 with an average of 18.41. However, in pooled data of two year, it was ranged from 12.06 to 22.32 with the average mean value of 18.36.

4.2.2.22 Acidity

In 2014, the acidity of varieties ranged from 0.04 to 0.29% with an average mean of 0.17%. In 2016, the acidity ranged from 0.06 to 0.27% with an average of 0.18% days. Pooled analysis of two year indicated that the range of acidity 0.05 to 0.28% with the general mean value of 0.18%. Thus, the significantly higher and lower acidity were observed in Tommy Atkins (0.28%) and Himsagar (0.05%), respectively.

4.2.2.23 Reducing sugar

In first year (2014), reducing sugar was found to vary from 2.09 to 6.28% with an average mean of 4.31%, whereas; in second year (2016) the range of variation for reducing sugar was from 2.32 to 6.13% with an average of 4.46%. Pooled analysis of two year data revealed that reducing sugar of the varieties ranged from 2.20 to 6.18% with an average value of 4.39%. Thus, the significantly maximum and minimum reducing sugar were observed in A.U. Rumani (6.18%) and Chandrakaran (2.20%), respectively.

4.2.2.24 Total sugar

During the year 2014, the total sugar ranged from 11.13 to 20.85% with an average mean of 15.89%, while, in 2016, the average total sugar was found 16.32 per cent which ranged from 11.21 to 20.54 per cent. Total sugar in pooled analysis of two year data was ranged from 11.36 to 20.69 per cent with the general mean value of 16.10%. Thus, the significantly higher and lower total sugar were observed in Amrapali (20.69%) and Rajiv (11.36%), respectively.

4.2.2.25 Non reducing sugar

The range of variation for non reducing sugar ranged from 7.81 to14.44% with an average mean of 11.06% during the year 2014, whereas, in 2016, the non reducing sugar ranged from 8.17 to 14.95% with an average of 12.07%. The perusal of data drawn by pooling two year showed that non reducing sugar value ranged from 8.32 to14.62% with an average value of 11.56%. Thus, the significantly maximum and minimum non reducing sugar were observed in Amrapali, (14.62%) and PMSS-1 (8.32%), respectively.

4.2.2.26 Ascorbic acid

The significantly lower ascorbic acid was recorded in Arka Neelkiran, while higher was recorded in Chausa during the year 2014, 2016 and pooled analysis which ranged from 20.86 to 64.64 mg/100 g of flesh with an average mean of 39.22 mg/100 g of flesh in first year, whereas, During second year, the ascorbic acid ranged from 22.41 to 65.29 mg/100 g of flesh with an average of 40.76 mg/100 g of flesh. Pooled analysis of two year data exhibited that ascorbic acid ranged from 21.64 to 64.96 mg/100 g of flesh with the average mean value of 39.99 mg/100 g of flesh.

4.2.2.27 Total carotenoid

The range of variation for total carotenoid was from 1.61 to 8.68 mg/100 g of flesh with an average mean of 3.57 mg/100 g of flesh during the year 2014, whereas, in 2016, the total carotenoid was ranged from 1.92 to 9.77 mg/100 g of flesh with an average of 3.98 mg/100 g of flesh. The result drawn by pooled two year data perceived 1.78 to 9.23 mg/100 g of flesh ranges in total carotenoid with the average mean value of 3.78 mg/100 g of flesh. Thus, the significantly maximum and minimum non reducing sugar were observed in Amrapali, (9.23 mg/100 g of flesh) and Tilka Bhadainya (1.78 mg/100 g of flesh), respectively

Significant differences among the 40 mango varieties including new accessions were observed for all most all the traits and high range of variation recorded during both the year as well as in pooled analysis indicating high degree of variability for these traits. Therefore, more opportunities for improve the population. The perusal of data in Table 4.8, 4.9, 4.10, 4.11, 4.12, 4.13, 4.14, 4.15 and 4.16 revealed that large amount of variation as shown by mean performance and range were exhibited for leaf area, number of secondary rachis per panicle, length of inflorescence, width of inflorescence, duration of fruit maturity, number of fruits per tree at harvesting, yield per tree, fruit weight, fruit length, fruit width, stone weight, stone length, stone width, pulp weight, peel weight, pulp : stone ratio, TSS, acidity, reducing sugar, non reducing, total sugar, ascorbic acid and total carotenoid. Similar findings have also been reported by Nayak *et al.* (2013) in mango, Nafees *et al.* (2008) in Kinnow mandarin, Sundouri *et al.* (2009) in pecan, Islam *et al.* (2010) in ber, Pandey *et al.* (2014) in aonla, Jambhale *et al.* (2014) and Kumar *et al.* (2015) in papaya.

4.2.3 Coefficient of variability

The assessment of variability parameters revealed that there was tremendous amount of variation among the genotypes for different characters. A comparative study of phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), environmental coefficient of variation (ECV), heritability and genetic advance (as% of mean) have been presented in Table 4.17 and Fig. 4.7 (2014), 4.18 and Fig. 4.8 (2016); and 4.19 and Fig. 4.9 (pooled data of 2014 and 2016), respectively.

During the year 2014, the highest genotypic coefficient of variation was estimated for number of fruits per tree at harvesting (63.92%) followed by yield per tree (47.51%), total carotenoid (44.39%), pulp weight (42.18%), fruit weight (38.12%), peel weight (37.24%), stone weight (34.37%) and pulp: stone ratio (32.87%), while, lowest was estimated for leaf length (9.75%). The highest phenotypic coefficient of variation was estimated for number of fruits per tree at harvesting (64.17%) followed by yield per tree (48.48%), total carotenoid (44.85%), pulp weight (42.69%), fruit weight (38.45%), peel weight (37.61%), stone weight (34.99%) and pulp: stone ratio (34.08%), whereas, lowest was estimated for leaf length (11.24%). The highest environmental coefficient of variation was determined for yield per tree (9.68%) followed by acidity (9.63%), leaf width (9.09%), pulp: stone ratio (8.99%), width of inflorescence (9.18%) and duration of flowering (8.47%), whereas, lowest was estimated for duration of fruit maturity (2.06%).

During the year 2016, the highest genotypic coefficient of variation was estimated for number of fruits per tree at harvesting (62.05%) followed by yield per tree (46.01%), pulp weight (42.17%), total carotenoid (41.35%), fruit weight (38.28%), peel weight (36.33%), stone weight (34.54%) and pulp: stone ratio (31.53%), while, lowest was estimated for leaf length (10.87%). The highest phenotypic coefficient of variation was estimated for number of fruits per tree at harvesting (62.39%) followed by yield per tree (47.63%), pulp weight (44.36%), total carotenoid (42.38%), fruit weight (39.74%), peel weight (38.14%), stone weight (39.74%) and pulp: stone ratio (34.88%), while, lowest was estimated for leaf length (11.43%). The highest environmental coefficient of variation was determined for pulp: stone ratio (14.91%) followed by pulp weight (13.78%), yield per tree (12.31%), peel weight (11.61%), fruit weight (10.65%), total sugar (10.31%), acidity (9.50%) and total carotenoid (9.34%).

In pooled analysis of two year data (2014 and 2016) revealed that the highest genotypic coefficient of variation was estimated for number of fruits per tree at harvesting (62.76%) followed by yield per tree (46.45%), total carotenoid (42.69%), pulp weight (42.18%), fruit weight (38.21%), peel weight (36.86%), stone weight (34.45%) and pulp: stone ratio (32.15%), while, lowest was estimated for leaf length (10.25%). The highest phenotypic coefficient of variation was estimated for number of fruits per tree at harvesting (63.30%) followed by yield per tree (48.13%), pulp weight (43.57%), total carotenoid (43.56%), fruit weight (39.12%), peel weight (37.89%), stone weight (35.15%) and pulp: stone ratio (34.50%), while, lowest was estimated for leaf length (11.34%). The highest environmental coefficient of variation was determined for yield per tree (12.61%) followed by pulp: stone ratio (12.51%), acidity (11.16%), pulp weight (10.91%), width of inflorescence (9.77%), total sugar (9.67%) and leaf width (9.45%).

Table 4.17: Estimate of phenotypic, genotypic, environmental coefficient of variation, heritability and genetic advance of different morphological and physico-chemical quantitative traits of mango varieties including new accessions (2014)

S.No	Characters	PCV (%)	GCV (%)	ECV (%)	h^2 bs (%)	GA (%)	GA (as% of mean)
1	Leaf length (cm)	11.24	9.75	5.59	75.23	3.46	17.43
2	Leaf width (cm)	14.72	11.57	9.09	61.83	0.95	18.75
3	Leaf area (cm^2)	20.54	20.11	4.18	95.86	30.81	40.57
4	Duration of panicle emergence (days)	15.73	13.64	7.84	75.16	4.97	24.36
5	Number of secondary rachis/ panicle	18.99	17.71	6.85	86.99	10.38	34.04
6	Length of inflorescence (cm)	18.50	17.75	5.20	92.10	10.29	35.11
7	Width of inflorescence (cm)	24.14	22.33	9.18	85.53	6.95	42.54
8	Duration of flowering (days)	15.60	13.10	8.47	70.54	5.02	22.68
9	Duration of fruit maturity (days)	12.47	12.30	2.06	97.27	26.37	24.99
10	Number of fruits/tree at harvesting	64.17	63.92	5.67	99.22	82.58	131.16
11	Yield /tree (kg)	48.48	47.51	9.68	96.01	12.49	95.90
12	Fruit weight (g)	38.45	38.12	5.07	98.26	188.26	77.85
13	Fruit length (cm)	18.77	18.62	2.39	98.37	3.67	38.04
14	Fruit width (cm)	17.93	17.64	3.20	96.81	2.34	35.76
15	Stone weight (g)	34.99	34.37	6.56	96.48	22.09	69.55
16	Stone length (cm)	20.30	20.00	3.49	97.03	3.13	40.59
17	Stone width (cm)	18.96	18.07	5.74	90.83	1.25	35.48
18	Pulp weight (g)	42.69	42.18	6.62	97.59	155.75	85.84
19	Peel weight (g)	37.61	37.24	5.30	98.01	21.75	75.95
20	Pulp : stone ratio	34.08	32.87	8.99	93.03	3.74	65.32
21	TSS (^{0}B)	14.93	13.98	5.24	87.68	4.94	26.97
22	Acidity (%)	34.56	33.19	9.63	92.23	0.11	65.66
23	Reducing sugar (%)	26.77	25.97	6.46	94.16	2.24	51.93
24	Non reducing (%)	14.94	13.70	5.97	84.04	4.11	25.87
25	Total sugar (%)	16.90	14.99	7.81	78.66	3.03	27.39
26	Ascorbic acid (mg/100 g flesh)	21.50	20.79	5.49	93.47	16.24	41.41
27	Total carotenoid (mg/100 g flesh)	44.85	44.39	6.38	97.97	3.24	90.52

Table 4.18: Estimate of phenotypic, genotypic, environmental coefficient of variation, heritability and genetic advance of different morphological and physico-chemical quantitative traits of mango varieties including new accessions (2016)

S.No.	Characters	PCV (%)	GCV (%)	ECV (%)	h^2 bs (%)	GA (%)	GA (as% of mean)
1	Leaf length (cm)	11.43	10.87	3.52	90.52	4.28	21.32
2	Leaf width (cm)	13.60	12.61	5.09	85.97	1.26	24.10
3	Leaf area (cm^2)	21.60	20.37	7.16	88.98	29.83	39.59
4	Duration of panicle emergence (days)	18.05	16.69	6.87	85.50	5.91	31.81
5	Number of secondary rachis/ panicle	19.40	18.67	5.24	92.68	12.06	37.04
6	Length of inflorescence (cm)	17.63	17.19	3.94	95.00	10.62	34.52
7	Width of inflorescence (cm)	22.53	20.92	8.36	86.21	7.27	40.02
8	Duration of flowering (days)	13.66	12.41	5.71	82.52	4.72	23.22
9	Duration of fruit maturity (days)	12.52	12.23	2.64	95.54	26.34	24.64
10	Number of fruits/tree at harvesting	62.39	62.05	6.52	98.91	90.85	127.13
11	Yield /tree (kg)	47.63	46.01	12.31	93.32	13.85	91.58
12	Fruit weight (g)	39.74	38.28	10.65	92.81	188.89	75.98
13	Fruit length (cm)	18.81	18.56	3.04	97.38	3.70	37.74
14	Fruit width (cm)	17.68	17.40	3.158	96.81	2.37	35.27
15	Stone weight (g)	35.31	34.54	7.36	95.66	21.94	69.60
16	Stone length (cm)	20.70	19.74	6.22	90.96	3.00	38.79
17	Stone width (cm)	18.27	17.01	6.66	86.71	1.14	32.64
18	Pulp weight (g)	44.36	42.17	13.78	90.35	155.12	82.58
19	Peel weight (g)	38.14	36.33	11.61	90.73	21.07	71.30
20	Pulp : stone ratio	34.88	31.53	14.91	81.72	3.49	58.73
21	TSS (^{0}B)	13.15	12.80	3.02	94.70	4.73	25.67
22	Acidity (%)	30.99	29.50	9.50	90.59	0.10	57.84
23	Reducing sugar (%)	25.24	24.36	6.58	93.20	2.16	48.46
24	Non reducing (%)	14.57	12.68	7.17	75.74	3.71	22.73
25	Total sugar (%)	17.06	13.73	10.13	64.74	2.75	22.76
26	Ascorbic acid (mg/100 g flesh)	20.10	19.41	5.22	93.24	15.74	38.61
27	Total carotenoid (mg/100 g flesh)	42.38	41.34	9.34	95.14	3.30	83.06

Table 4.19: Estimate of phenotypic, genotypic, environmental coefficient of variation, heritability and genetic advance of different morphological and physico-chemical quantitative traits of mango varieties including new accessions (pooled data of 2014 and 2016)

S.No.	Characters	PCV (%)	GCV (%)	ECV (%)	h^2 bs (%)	GA (%)	GA (as% of mean)
1	Leaf length (cm)	11.34	10.25	4.83	81.82	3.82	19.11
2	Leaf width (cm)	14.15	10.54	9.45	55.43	0.83	16.16
3	Leaf area (cm^2)	21.07	20.03	6.54	90.35	29.67	39.23
4	Duration of panicle emergence (days)	16.84	15.17	7.32	81.09	5.49	28.14
5	Number of secondary rachis/ panicle	19.22	17.33	8.30	81.36	4.94	32.21
6	Length of inflorescence (cm)	18.06	17.40	4.82	92.87	10.38	34.55
7	Width of inflorescence (cm)	23.30	21.15	9.77	82.41	6.82	39.56
8	Duration of flowering (days)	14.76	12.91	7.16	76.47	10.16	23.26
9	Duration of fruit maturity (days)	12.49	12.24	2.51	95.97	26.24	24.71
10	Number of fruits/tree at harvesting	63.30	62.76	8.23	98.31	86.17	128.20
11	Yield /tree (kg)	48.13	46.45	12.61	93.13	13.00	92.35
12	Fruit weight (g)	39.12	38.21	8.38	95.41	188.58	76.90
13	Fruit length (cm)	18.79	18.53	3.10	97.27	3.66	37.66
14	Fruit width (cm)	17.80	17.33	4.06	94.79	2.31	34.77
15	Stone weight (g)	35.15	34.45	6.99	96.04	22.01	69.55
16	Stone length (cm)	20.50	19.90	4.92	94.23	3.07	39.80
17	Stone width (cm)	18.62	17.57	6.17	89.03	1.20	34.15
18	Pulp weight (g)	43.57	42.18	10.91	93.72	155.34	84.13
19	Peel weight (g)	37.89	36.86	8.76	94.65	21.50	73.89
20	Pulp : stone ratio	34.50	32.15	12.51	86.85	3.60	61.74
21	TSS (^{0}B)	14.06	13.32	4.50	89.75	4.78	26.01
22	Acidity (%)	32.76	30.80	11.16	88.39	0.10	59.65
23	Reducing sugar (%)	25.99	24.38	9.00	87.99	2.07	47.12
24	Non reducing (%)	14.75	13.02	6.92	77.95	3.82	23.69
25	Total sugar (%)	17.01	13.99	9.67	67.67	2.74	23.71
26	Ascorbic acid (mg/100 g flesh)	20.79	20.13	5.20	93.73	16.06	40.15
27	Total carotenoid (mg/100 g flesh)	43.56	42.69	8.64	96.06	3.26	86.21

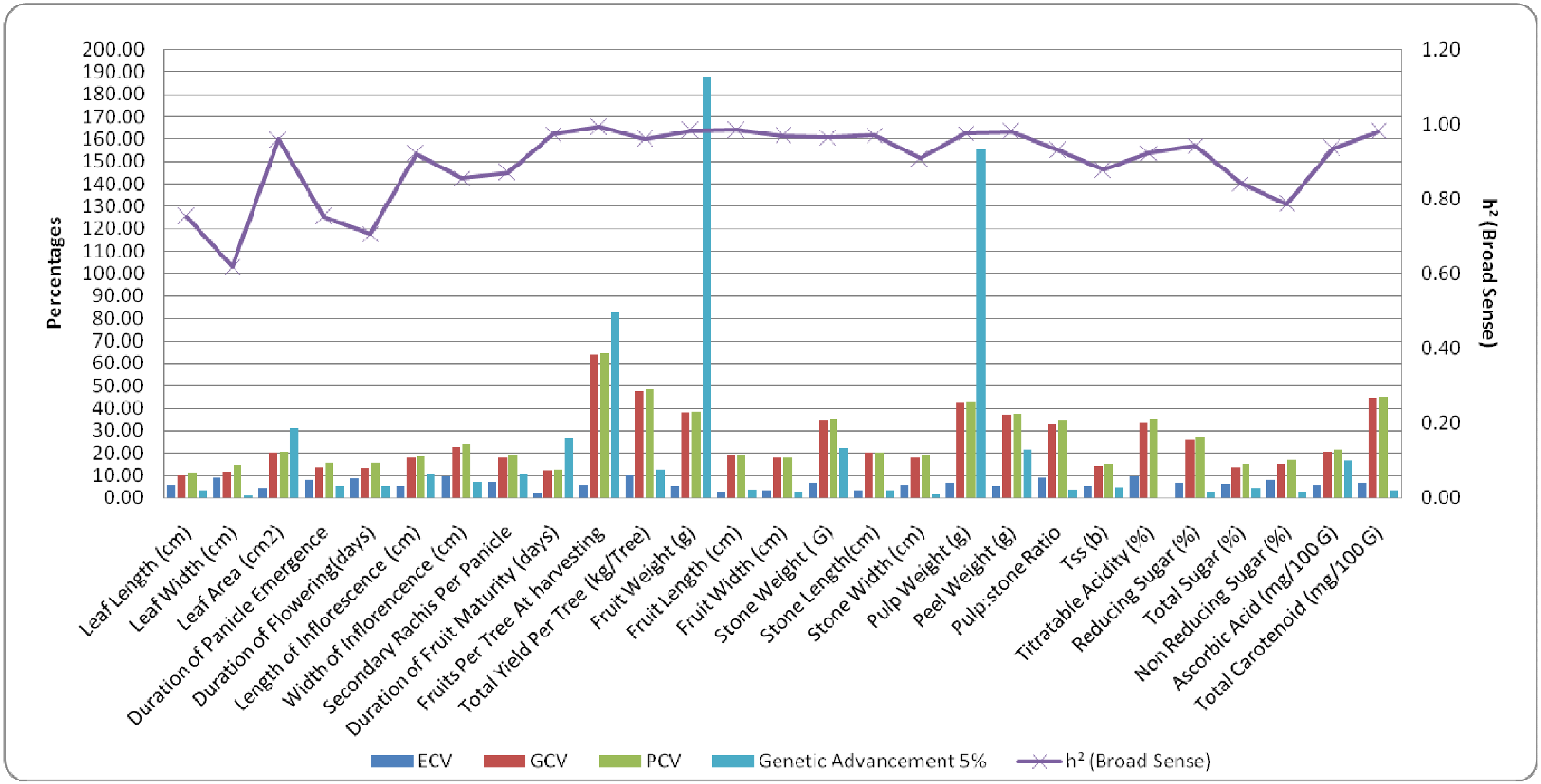


Fig. 4.7: Graph showing genetic variability based on analysis of morphological and physico-chemical characteristics in different mango varieties including new accessions (2014)

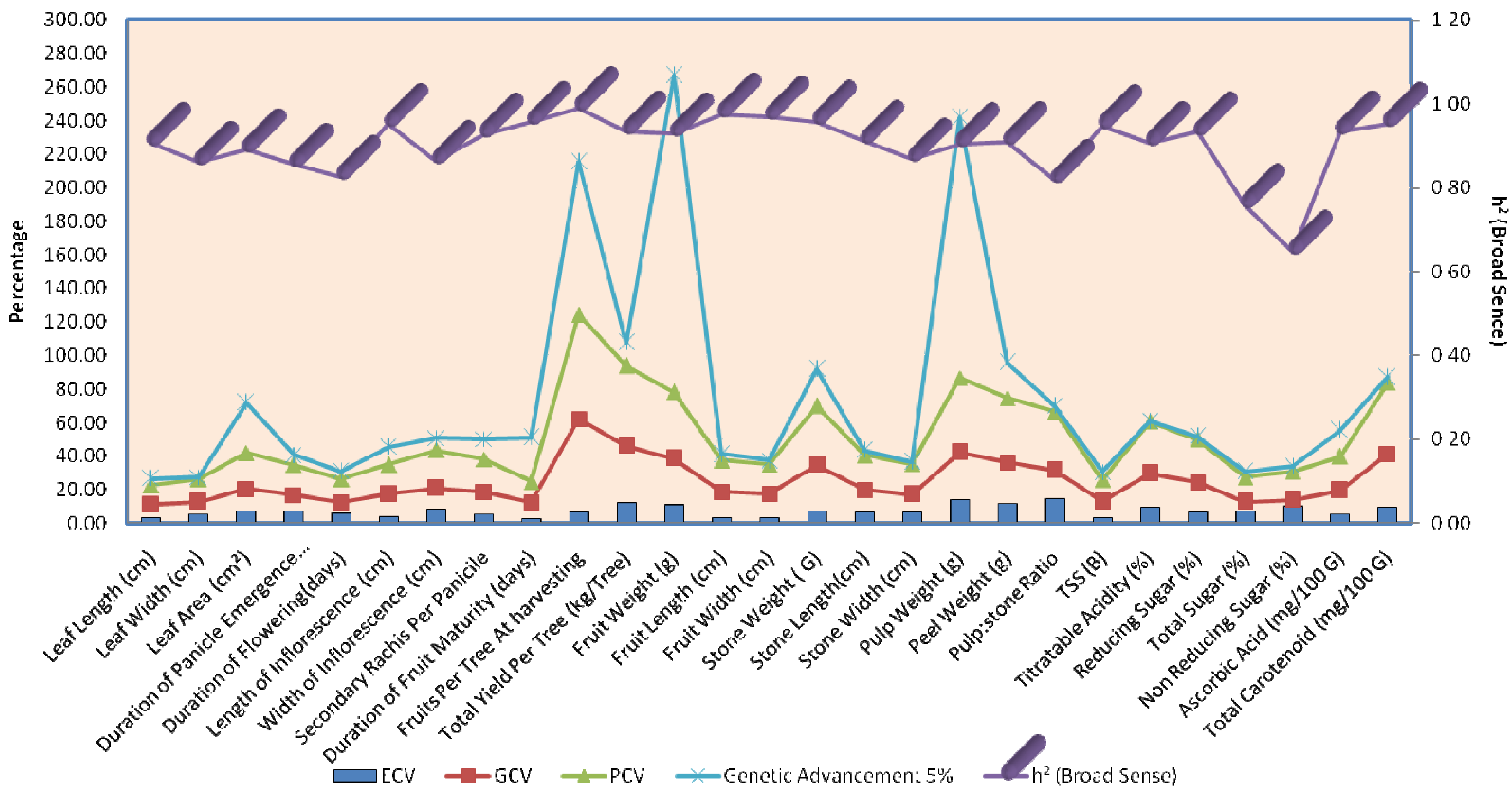


Fig. 4.8: Graph showing genetic variability based on analysis of morphological and physico-chemical characteristics in different mango varieties including new accessions (2016)

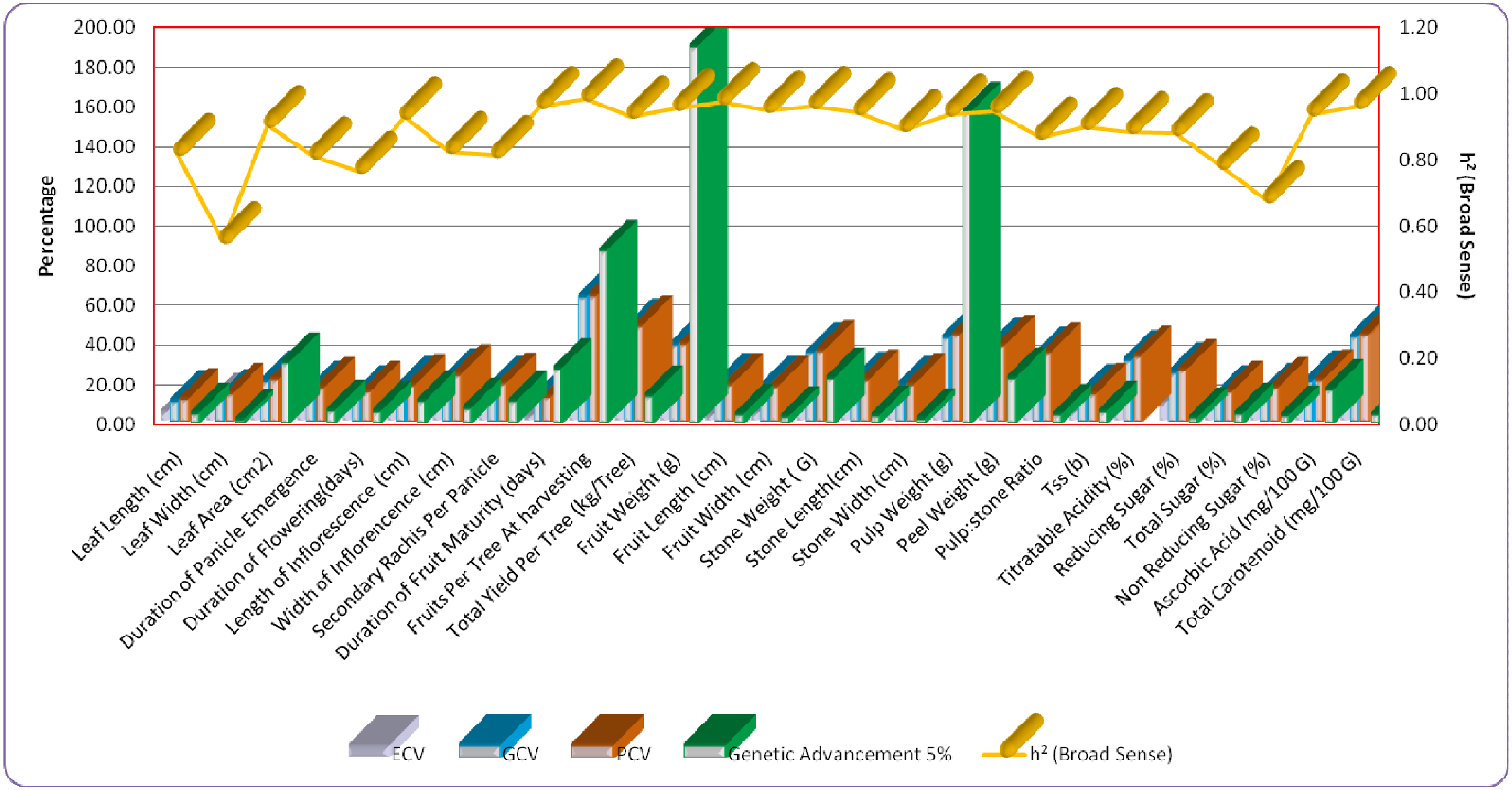


Fig. 4.9: Graph showing genetic variability based on analysis of morphological and physico-chemical characteristics in different mango varieties including new accessions (pooled data of 2014 and 2016)

The twenty seven quantitative traits were subjected to statistical analysis by comparison of respective values of PCV and GCV based on pooled data over the years. Out of twenty seven quantitative traits under study four exhibited almost equivalent magnitude of phenotypic as well as genotypic coefficient of variation which revealed less environmental influence in their expression, while rest of the characteristics showed comparatively greater difference in magnitudes of PCV and GCV which indicates that environmental factors influences the expression of these characters. Hence, these characters were considered relatively less stable as compared to other characters.

In general, the high estimate of PCV and GCV for the characters like number of fruits per tree at harvesting, yield per tree, total carotenoid, pulp weight, fruit weight, peel weight, stone weight and pulp: stone ratio indicated greater variability in these traits, which can be effectively improved through selection. On the other hand, low estimate of PCV and GCV for leaf length, leaf width, fruit size, stone size, duration of panicle emergence and duration of flowering indicated low to moderate variability for these characters for which selection may be restricted to certain degree. Similar results have also been reported by Rathod and Naik (2007), Bhowmick and Banik (2008), Nayak *et al.* (2013), Barhate *et al.* (2012), in mango.

4.2.4 Heritability and Genetic advance

The data regarding heritability and genetic advance have been presented in Table 4.17 and Fig. 4.7 (2014), 4.18 and Fig. 4.8 (2016); and 4.19 and Fig. 4.9 (pooled data of 2014 and 2016), respectively.

4.2.4.1 Heritability

The data regarding heritability has been presented in Table (4.17, 4.18 and 4.19) and Fig. (4.7, 4.8 and 4.9) during the years 2014, 2016 and pooled data of 2014 and 2016, respectively. The estimates of broad sense heritability was high for number of fruits per tree at harvesting (99.22, 98.91 and 98.31%), fruit length (98.37, 97.38 and 97.27%), fruit weight (98.26, 92.81 and 95.41%), peel weight (98.01, 90.73 and 94.65%), total carotenoids (97.97, 95.14 and 96.06%), pulp weight (97.59, 90.35 and 93.72%), duration of fruit maturity (97.27, 95.54 and 95.97%), stone length (97.03, 90.96 and 94.23%), stone weight (96.48, 95.66 and 96.04%), fruit width (96.81, 96.81

and 94.79) yield per tree (96.01, 93.32 and 93.13%), leaf area (95.86, 88.98 and 90.35%), reducing sugar (94.16, 93.20 and 87.99%), ascorbic acid (93.47, 93.24 and 93.73%), pulp: stone ratio (93.03, 81.72 and 86.85%), acidity (92.23, 90.59 and 88.39%), length of inflorescence (92.10, 95.00 and 92.87%), stone width (90.83, 86.71 and 89.03%) during the years 2014, 2016 and pooled analysis of two year data, respectively. The moderate to high heritability was estimated for leaf width (61.83 and 55.43%), duration of flowering (70.54 and 76.47%), duration of panicle emergence (75.16 and 81.09%), leaf length (75.23 and 81.82%) during the year 2014 and pooled analysis, respectively. The moderate heritability was recorded for total sugar (64.75%). It was more fluctuation in relation to heritability for leaf length (90.52%) during the year 2016 as compared to 2016 due to some environmental variation.

The estimate of broad sense heritability includes both additive and non-additive components of genotypic variance. Most of the traits included in the present investigation were having heritability ranging from very high to moderate during both the year as well as pooled analysis. Over all the environments, number of fruits per tree at harvesting, fruit length, fruit weight, peel weight, total carotenoid, pulp weight, duration of fruit maturity, stone length, stone weight, fruit width, yield per tree, leaf area, reducing sugar, ascorbic acid, pulp: stone ratio, acidity, length of inflorescence and stone width were having the moderate to very high heritability with minor fluctuation as per specific environmental conditions. Leaf length interval heritability was highly influenced by environments as indicated by low heritability in 2014 and pooled analysis and high heritability in 2016. This major fluctuation in heritability of leaf length interval was due to environmental fluctuations. This indicated that all characters except leaf length interval were less influenced by the environmental fluctuations and selection for such traits on the basis of phenotype will be effective. Higher estimates of heritability for yield and yield contributing characters as well as physico-chemical traits have also been reported by Rathod and Naik (2007), Bhowmick *et al.* (2008), Islam *et al.* (2010), Nayak *et al.* (2013) and Kumar *et al.* (2015).

4.2.4.2 Genetic advance

Genetic advance was estimated at 5% selection intensity and for comparison among the traits; it was transformed into genetic advance as per cent of mean. The data regarding genetic advance has been presented in Table (4.17, 4.18 and 4.19) and

(Fig. 4.7, 4.8 and 4.9) during the years 2014, 2016 and (pooled data of 2014 and 2016), respectively. The estimate of genetic advance was higher for fruit weight (188.26, 188.89 and 188.58%) and pulp weight (155.75, 155.12 and 155.34%) whereas, it was lower for leaf width (0.95, 1.29 and 0.83%) and acidity (0.11, 0.10 and 0.10%) during the years 2014, 2016 and pooled analysis, respectively. The estimate of genetic advance as per cent of mean was higher for most of the traits such as number of fruits per tree at harvesting (131.16, 127.31 and 128.20%) followed by yield per tree (95.90, 91.58 and 92.35%), total carotenoids (90.52, 83.06 and 86.21%), pulp weight (85.84, 82.58 and84.13%), fruit weight (77.85, 75.98 and 76.90%) during the year 2014, 2016 and pooled analysis, respectively. The moderate genetic advance was estimated for leaf length (17.43 and 19.11%) and leaf width (18.75 and 16.16%) during the year 2014 and pooled analysis, respectively.

Genetic advance as per cent of mean for all the traits were higher in the first year than the second year. This indicated that genetic advance as per cent of mean for all the characters were more responsive in first year than second year. Genetic advance as per cent of mean for particular trait is used to compare the expected gain among the traits. In the present study, high to moderate estimates of genetic advance as per cent mean across during both the year have been found for number fruits per tree at harvesting, yield per tree, total carotenoid, pulp weight, fruit weight, while, moderate genetic advance was reported for leaf length and leaf width. The similar findings have also been reported by Rathod and Naik (2007), Bhowmick *et al.* (2008), Islam *et al.* (2010), Nayak *et al.* (2013) and Kumar *et al.* (2015).

Heritability and genetic advance are two important genetic parameters. The knowledge of both heritability and genetic advance of a trait is necessary for deciding the scope of improvement through selection (Johanson *et al.,* 1955). Since heritability variation cannot be ascertained from the genotypic coefficient of variation alone, hence along with heritability, estimates of genetic advance were the calculated. Expected genetic advance indicates the expected genetic progress for a particular trait under a suitable selection system. GCV and heritability determines the component of heritable variation and the genetic advance measures the extent of its stability under selection pressure. Characters showing high GCV need not to have high heritability. Characters having high GA along with high heritability are useful for easy improvement through selection. As, they are showing additive genetic variance the simple breeding methods even without progeny testing is feasible to improve them. Some additive portion of genetic variance is fixable in nature; so the selection of these traits is expected to be effective (Chakravorty *et al.,* 2013). High genetic advance along with high heritability arises due to additive type of gene action, while high heritability estimates with low genetic advance indicates that heritability of these characters is due to non-additive gene effects, *viz.,* dominance, over dominance and epitasis gene action. High genetic advance as per cent of mean coupled with high heritability for most important economic traits i.e. number fruits per tree at harvesting and yield per tree indicated that genotypic variation present in the genetic material studied may be possibly due to high additive genetic variance in both the year. There may be the chances of exploitation heterosis for these characters but it should be confirmed by further study.

4.2.5 Correlation coefficients (character association)

The genotypic, phenotypic and environmental correlation coefficients for 27 quantitative traits have been estimated during the years 2014, 2016 and in pooled analysis. These correlation coefficients among the characters are described under following heads:

4.2.5.1 Estimates of correlation coefficients during first year

The estimates of genotypic and phenotypic correlation coefficients have been presented in Table 4.20 and 4.21, respectively for the year 2014. The significant positive correlation for leaf length was observed with leaf width (0.574, 0.473), leaf area (0.836, 0.735), length of inflorescence (0.479, 0.435), width of inflorescence (0.590, 0.506), secondary rachis per panicle, duration of fruit maturity (0.310, 0.271), yield per tree (0.32, 0.295), fruit weight (0.440, 0.389), fruit length (0.539, 0.477), fruit width (0.461, 0.376), stone weight (0.34, 0.303), stone length, (0.493, 0.425), stone width (0.495, 0.399), pulp weight (0.432, 0.380), peel weight (0.356, 0.313), pulp: stone ratio (0.372, 0.311), total sugar (0.242, 0.248), non reducing sugar (0.233, 0.196) and total carotenoid (0.282, 0.243). The leaf width showed positive genotypic and phenotypic correlation with leaf area (0.632, 0.519), length of inflorescence (0.400, 0.326), secondary rachis per panicle (0.336, 0.283), fruit length (0.445, 0.342), stone weight (0.256, 0.192), stone length (0.302, 0.205), stone width (0.389, 0.283) and non reducing sugar (0.276, 0.227). The leaf area showed positive correlation with duration of panicle emergence (0.356, 0.328), duration of flowering (0.236, 0.215), length of inflorescence (0.442, 0.422), width of inflorescence (0.482, 0.437), duration of fruit maturity (0.261, 0.259), fruit weight (0.487, 0.471), fruit length (0.563, 0.554), fruit width (0.474, 0.452), stone weight (0.499, 0.487), stone length, (0.472, 0.456), stone width (0.520, 0.484), pulp weight (0.454, 0.436), peel weight (0.444, 0.432), pulp: stone ratio (0.223, 0.202), total sugar (0.243, 0.226), non reducing sugar (0.258, 0.223) and total carotenoid (0.249, 0.246). However, it revealed significant negative correlation with number of fruits per tree (-0.379, -0.368).

The duration of panicle emergence exhibited significant positive correlation with duration of flowering (0.207, 0.236), secondary rachis per panicle (0.367, 0.356), duration of fruit maturity (0.195, 0.186), fruit width (0.217, 0.184), stone weight (0.381, 0.336), stone width (0.318, 0.282) and acidity (0.221, 0.218), while it was significantly negative correlation with number of fruits per tree (-0.264, -0.219) and pulp: stone ratio (-0.247, -0.199). Duration of flowering revealed highly significant negative correlations at both genotypic and phenotypic correlation with number of fruits per tree (-0.517, -0.417), yield per tree (-0.475, -0.388), total sugar (-0.362, -0.218), non reducing sugar (-0.373, -0.290) and total carotenoid (-0.42, -0.344), while, it was showed positive correlation with peel weight (0.248, 0.208), acidity (0.199, 0.181),

Length of inflorescence revealed positive significant correlation with width of inflorescence (0.635, 0.592), secondary rachis per panicle (0.568, 0.531), yield per tree (0.238, 0.232), fruit length (0.399, 0.383), fruit width (0.259, 0.242), pulp: stone ratio (0.233, 0.222), TSS (0.297, 0.269) and reducing sugar (0.353, 0.329), whereas negative showed with ascorbic acid (-0.312, -0.270). The width of inflorescence revealed positive correlation with secondary rachis per panicle (0.232, 0.208), duration of fruit maturity (0.201, 0.190), fruit weight (0.246, 0.231), fruit length (0.362, 0.335), fruit width (0.223, 0.193), stone weight (0.235, 0.224), stone width (0.258, 0.185), pulp weight (0.235, 0.224), TSS (0.475, 0.394), reducing sugar (0.507, 0.456), total sugar (0.369, 0.339) and total carotenoid (0.35, 0.317), while, negative correlation of secondary rachis per panicle with ascorbic acid (-0.387, -0.337).

Table 4.20: Estimate of genotypic correlation coefficients between different morphological and physico-chemical characteristics in different mango varieties including new accessions (2014)

Characters	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	Duration of panicle emergence	Duration of flowering (days)	Length of inflorescence (cm)	Width of inflorescence (cm)	Secondary rachis/ panicle	Duration of fruit maturity (days)	Number of fruits/ tree (harvesting)	Yield /tree (kg)	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)
Leaf length (cm)		0.574	0.836	-0.006	0.044	0.479	0.590	0.060	0.310	-0.197	0.320	0.440	0.539	0.461
Leaf width (cm)			0.632	0.225	0.116	0.400	0.126	0.336	0.076	-0.152	0.175	0.198	0.445	0.197
Leaf area (cm^2)				0.356	0.236	0.442	0.482	0.145	0.261	-0.379	0.102	0.487	0.563	0.474
Duration of panicle emergence					0.207	0.060	0.098	0.367	0.195	-0.264	-0.176	0.132	0.049	0.217
Duration of flowering (days)						-0.037	-0.046	-0.024	0.057	-0.517	-0.475	0.178	-0.100	0.176
Length of inflorescence (cm)							0.635	0.568	0.049	-0.060	0.238	0.179	0.399	0.259
Width of inflorescences (cm)								0.232	0.201	-0.105	0.160	0.246	0.362	0.223
Secondary rachis / panicle									-0.163	-0.008	0.039	-0.033	0.084	0.009
Duration of fruit maturity (days)										-0.192	0.092	0.319	0.302	0.386
No. of fruits /tree at harvesting											0.566	-0.614	-0.390	-0.609
Yield/ tree (kg)												0.183	0.356	0.164
Fruit weight (g)													0.803	0.863
Fruit length (cm)														0.723
Fruit width (cm)														
Stone weight (g)														
Stone length(cm)														
Stone width (cm)														
Pulp weight (g)														
Peel weight (g)														
Pulp: stone ratio														
TSS(^{0}B)														
Acidity (%)														
Reducing sugar (%)														
Total sugar (%)														
Non reducing sugar (%)														
Ascorbic acid (mg/100 g flesh)														
Total carotenoid (mg/100 g flesh)														

Table 4.20: Cont….

Characters	Stone weight (g)	Stone length (cm)	Stone width (cm)	Pulp weight (g)	Peel weight (g)	Pulp: Stone ratio	TSS (^{0}B)	Acidity (%)	Reducing sugar (%)	Total sugar (%)	Non reducing sugar (%)	Ascorbic acid (mg/100 g flesh)	Total carotenoid (mg/100 g flesh)
Leaf length (cm)	0.340	0.493	0.495	0.432	0.356	0.372	0.096	0.141	0.187	0.242	0.233	0.053	0.282
Leaf width (cm)	0.256	0.302	0.389	0.184	0.129	0.127	-0.023	-0.083	-0.028	0.199	0.276	0.119	0.058
Leaf area (cm^2)	0.499	0.472	0.520	0.454	0.444	0.223	0.153	0.077	0.125	0.243	0.258	0.126	0.249
Duration of panicle emergence	0.381	0.121	0.318	0.096	0.055	-0.247	0.141	0.221	0.151	0.104	0.089	-0.162	0.063
Duration of flowering(days)	0.187	-0.114	0.256	0.152	0.248	0.016	-0.067	0.199	-0.015	-0.362	-0.373	-0.167	-0.420
Length of inflorescence (cm)	0.099	0.121	0.108	0.180	0.151	0.233	0.297	-0.171	0.353	0.160	0.004	-0.312	0.058
Width of inflorescence (cm)	0.251	0.166	0.258	0.235	0.181	0.115	0.475	0.174	0.507	0.369	0.143	-0.097	0.350
Secondary rachis per panicle	0.038	0.092	0.018	-0.044	-0.013	-0.075	0.157	-0.149	-0.060	0.011	0.070	-0.387	-0.050
Duration of fruit maturity (days)	0.269	0.291	0.255	0.296	0.352	0.109	0.233	0.220	0.272	0.034	-0.087	-0.047	0.272
No. of fruits /tree at harvesting	-0.619	-0.211	-0.438	-0.567	-0.600	-0.208	-0.195	-0.140	-0.194	0.015	0.118	0.141	0.144
Yield/ tree (kg)	-0.009	0.477	0.223	0.222	-0.002	0.359	-0.098	-0.218	-0.110	0.145	0.230	0.325	0.314
Fruit weight (g)	0.794	0.725	0.774	0.988	0.746	0.597	0.214	-0.089	0.119	0.204	0.190	0.156	0.197
Fruit length (cm)	0.674	0.776	0.648	0.782	0.639	0.500	0.154	-0.048	0.101	0.272	0.280	0.161	0.298
Fruit width (cm)	0.711	0.571	0.708	0.840	0.707	0.507	0.167	0.059	0.180	0.067	0.000	-0.051	0.124
Stone weight (g)		0.602	0.692	0.701	0.805	0.014	0.230	0.007	0.079	0.156	0.198	0.155	0.106
Stone length(cm)			0.675	0.702	0.617	0.435	0.056	0.119	-0.040	0.238	0.348	0.240	0.378
Stone width (cm)				0.753	0.574	0.375	0.054	0.192	0.029	0.176	0.206	0.093	0.378
Pulp weight (g)					0.645	0.699	0.199	-0.131	0.126	0.224	0.198	0.159	0.210
Peel weight (g)						0.126	0.187	0.155	0.044	-0.008	0.028	0.052	0.085
Pulp: stone ratio							-0.024	-0.146	0.068	0.089	0.031	0.029	0.118
TSS(^{0}B)								-0.151	0.693	0.693	0.423	-0.175	0.327
Acidity (%)									0.110	-0.181	-0.226	-0.226	0.145
Reducing sugar (%)										0.584	0.055	-0.318	0.097
Total sugar (%)											0.857	0.057	0.474
Non reducing sugar (%)												0.270	0.506
Ascorbic acid (mg/100 g flesh)													0.211
Total carotenoid (mg/100 g flesh)													

Table 4.21: Estimate of phenotypic correlation coefficients between different morphological and physico-chemical characteristics in different mango varieties including new accessions (2014)

Characters	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	Duration of panicle emergence	Duration of flowering(days)	Length of inflorescence (cm)	Width of inflorescence (cm)	Secondary rachis/ panicle	Duration of fruit maturity (days)	Number of fruits/ tree (harvesting)	Yield /tree (kg)	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)
Leaf length (cm)		0.473***	0.735***	0.067	0.109	0.435***	0.506***	0.073	0.271***	-0.163	0.295**	0.389***	0.477***	0.376***
Leaf width (cm)			0.519***	0.176	0.052	0.326***	0.125	0.283**	0.029	-0.123	0.132	0.159	0.342***	0.136
Leaf area (cm^2)				0.328***	0.215*	0.422***	0.437***	0.145	0.259**	-0.368***	0.109	0.471***	0.554***	0.452***
Duration of panicle emergence					0.236**	0.098	0.082	0.356***	0.186*	-0.219*	-0.120	0.116	0.053	0.184*
Duration of flowering (days)						0.035	-0.012	0.011	0.067	-0.417***	-0.388***	0.137	-0.076	0.160
Length of inflorescence (cm)							0.592***	0.531***	0.053	-0.048	0.232*	0.172	0.383***	0.242***
Width of inflorescences (cm)								0.208*	0.190*	-0.094	0.157	0.231*	0.335***	0.193*
Secondary rachis / panicle									-0.144	0.001	0.047	-0.034	0.082	-0.010
Duration of fruit maturity (days)										-0.187*	0.095	0.311***	0.297***	0.375***
No. of fruits /tree at harvesting											0.559***	-0.606***	-0.384***	-0.600***
Yield/ tree (kg)												0.186*	0.349***	0.154
Fruit weight (g)													0.789***	0.840***
Fruit length (cm)														0.704***
Fruit width (cm)														
Stone weight (g)														
Stone length(cm)														
Stone width (cm)														
Pulp weight (g)														
Peel weight (g)														
Pulp: stone ratio														
TSS(^{0}B)														
Acidity (%)														
Reducing sugar (%)														
Total sugar (%)														
Non reducing sugar (%)														
Ascorbic acid (mg/100 g flesh)														
Total carotenoid (mg/100 g flesh)														

Table 4.21: Cont….

Characters	Stone weight (g)	Stone length (cm)	Stone width (cm)	Pulp weight (g)	Peel weight (g)	Pulp: Stone ratio	TSS (^{0}B)	Acidity (%)	Reducing sugar (%)	Total sugar (%)	Non reducing sugar (%)	Ascorbic acid (mg/100 g flesh)	Total carotenoid (mg/100 g flesh)
Leaf length (cm)	0.303***	0.425***	0.399***	0.380***	0.313***	0.311***	0.065	0.147	0.165	0.248**	0.196*	0.056	0.243**
Leaf width (cm)	0.192*	0.205*	0.283***	0.148	0.107	0.102	-0.036	-0.074	0.011	0.179	0.227*	0.092	0.056
Leaf area (cm^2)	0.487***	0.456***	0.484***	0.436***	0.432***	0.202**	0.143	0.081	0.121	0.226*	0.223*	0.137	0.246**
Duration of panicle emergence	0.336***	0.106	0.282**	0.085	0.054	-0.199*	0.146	0.218*	0.126	0.135	0.085	-0.109	0.052
Duration of flowering(days)	0.170	-0.077	0.213	0.114	0.208*	0.011	-0.058	0.181*	0.004	-0.218*	-0.290**	-0.070	-0.344***
Length of inflorescence (cm)	0.095	0.119	0.107	0.172	0.149	0.222*	0.269*	-0.145	0.329***	0.170	0.027	-0.270***	0.060
Width of inflorescence (cm)	0.224*	0.156	0.185*	0.224*	0.156	0.128	0.394***	0.166	0.456***	0.339***	0.139	-0.085	0.317***
Secondary rachis per panicle	0.043	0.081	0.008	-0.044	-0.017	-0.073	0.139	-0.130	-0.048	0.035	0.081	-0.337***	-0.041
Duration of fruit maturity (days)	0.266**	0.285**	0.236**	0.288**	0.346**	0.100	0.215*	0.211*	0.254**	0.043	-0.062	-0.042	0.268**
No. of fruits /tree at harvesting	-0.601***	-0.203*	-0.415***	-0.559***	-0.591***	-0.205*	-0.178	-0.123	-0.187*	0.018	0.100	0.139	0.144
Yield/ tree (kg)	0.001	0.467***	0.204*	0.224*	0.005	0.344***	-0.084	-0.190*	-0.103	0.137	0.198*	0.315***	0.310***
Fruit weight (g)	0.777***	0.706***	0.729***	0.987***	0.731***	0.588***	0.196*	-0.085	0.118	0.186*	0.178	0.149	0.192*
Fruit length (cm)	0.658***	0.757***	0.607***	0.765***	0.632***	0.476***	0.144	-0.038	0.093	0.253**	0.249*	0.159	0.293**
Fruit width (cm)	0.679***	0.548***	0.675***	0.815***	0.692***	0.488***	0.166	0.052	0.169	0.048	-0.012	-0.051	0.123
Stone weight (g)		0.582***	0.648***	0.682***	0.779***	-0.006	0.209*	0.015	0.075	0.160	0.176	0.157	0.105
Stone length(cm)			0.622***	0.682***	0.599***	0.412***	0.047	0.119	-0.046	0.212*	0.293*	0.234*	0.368**
Stone width (cm)				0.706***	0.551***	0.348	0.061	0.180*	0.041	0.162	0.172	0.099	0.367**
Pulp weight (g)					0.626***	0.692***	0.182*	-0.123	0.127	0.203*	0.184*	0.151	0.204*
Peel weight (g)						0.114	0.179	0.148	0.038	-0.007	0.026	0.046	0.086
Pulp: stone ratio							-0.013	-0.131	0.078	0.068	0.023	0.027	0.111
TSS(^{0}B)								-0.122	0.625***	0.598**	0.345**	-0.153	0.302**
Acidity (%)									0.090	-0.151	-0.209*	-0.192*	0.139
Reducing sugar (%)										0.524**	0.028	-0.296**	0.098
Total sugar (%)											0.810**	0.059	0.441**
Non reducing sugar (%)												0.230*	0.450**
Ascorbic acid (mg/100 g flesh)													0.204*
Total carotenoid (mg/100 g flesh)													

Duration of fruit maturity revealed significant positive correlation with fruit weight (0.319, 0.311), fruit length (0.302, 0.297), fruit width (0.386, 0.375), stone weight (0.269, 0.266), stone length (0.291, 0.285), stone width (0.255, 0.236), pulp weight (0.296, 0.288), peel weight (0.352, 0.346), TSS (0.233, 0.215), acidity (0.220, 0.211), reducing sugar (0.272, 0.254) and total carotenoid (0.272, 0.268), while negative correlation with number of fruits per tree (-0.192, 0.187). The number of fruits per tree at harvesting showed highly negative correlation with yield per tree (0.566, 0.559), fruit weight (-0.614, -0.606), fruit length (-0.390, -0.384), fruit width (-0.609, -0.600), stone weight (-0.619, -0.601), stone length (-0.211, -0.203), stone width (-0.438, -0.415), pulp weight (-0.567, -0.559), peel weight (-0.600, -0.591), pulp: stone ratio (-0.208, -0.205) and reducing sugar (-0.194, -0.187), while, yield per tree was revealed highly positive correlation with fruit weight (0.183, 0.186), fruit length (0.356, 0.349), stone length (0.477, 0.467), stone width (0.223, 0.204), pulp weight (0.222, 0.224), pulp: stone ratio (0.359, 0.344), non reducing sugar (0.23, 0.198), ascorbic acid (0.325, 0.315) and total carotenoid (0.314, 0.310), whereas, it found to be negatively correlated with acidity (-0.218, -0.190).

Fruit weight revealed significant positive correlation with fruit length (0.803, 0.789), fruit width (0.863, 0.840), stone weight (0.794, 0.777), stone length (0.725, 0.706), stone width (0.774, 0.729), pulp weight (0.988, 0.987), peel weight (0.746, 0.731), pulp: stone ratio (0.597, 0.588), TSS (0.214, 0.196), total sugar (0.204, 0.186) and total carotenoid (0.197, 0.192). The fruit length exhibited significant positive correlation with fruit width (0.723, 0.704), stone weight (0.674, 0.658), stone length (0.776, 0.757), stone width (0.648, 0.607), pulp weight (0.782, 0.765), peel weight (0.639, 0.632), pulp: stone ratio (0.500, 0.476), total sugar (0.272, 0.253), non reducing sugar (0.280, 0.249) and total carotenoid(0.0.298, 0.293), whereas, fruit width also showed significant positive correlation with stone weight (0.711, 0.679), stone length (0.571, 0.548), stone width (0.708, 0.675), pulp weight (0.840, 0.815), peel weight (0.707, 0.692), pulp: stone ratio (0.507, 0.488). The stone weight showed significant positive correlation with stone length (0.602, 0.582), stone width (0.692, 0.648), pulp weight (0.701, 0.682), peel weight (0.805, 0.779) and TSS (0.230, 0.209). Significant positive correlation of stone length with stone width (0.675, 0.622), pulp weight (0.702, 0.682), peel weight (0.617, 0.599), pulp: stone ratio

(0.435, 0.412), total sugar (0.238, 0.212), non reducing sugar (0.348, 0.293), ascorbic acid (0.240, 0.234) and total carotenoid (0.378, 0.368) was observed. Stone width revealed significant positive correlation with pulp weight (0.753, 0.706), peel weight (0.574, 0.551), acidity (0.192, 0.180) and total carotenoid (0.378, 0.367).

Pulp weight revealed significant positive correlation with peel weight (0.645, 0.626), pulp: stone ratio (0.699, 0.692), TSS (0.199, 0.182), non reducing sugar (0.198, 0.184), total sugar (0.224, 0.203) and total carotenoid (0.210, 0.204). The total soluble solids positive significant with reducing sugar (0.693, 0.625), total sugar (0.693, 0.598), non reducing sugar (0.423, 0.345) and total carotenoid (0.327, 0.302).The acidity of fruit negatively correlated with non reducing sugar (-0.226, -0.209) and ascorbic acid (-0.226, -0.192) and reducing sugar positively correlated with total sugar (0.584, 0.524) but negative with ascorbic acid (-0.318, -0.296). The total sugar revealed positive correlation with non reducing sugar (0.857, 0.810) and total carotenoid (0.474, 0.441). The non reducing sugar significant positively correlated with ascorbic acid (0.270, 0.230) and total carotenoid (0.506, 0.450). The ascorbic acid showed significant positive correlation with total carotenoid (0.211, 0.204).

The estimates of environmental correlation coefficients have been presented in Table 4.22 for the year 2014 indicated that positive significant correlation of leaf length with leaf width (0.264), leaf area (0.248), duration of panicle emergence (0.287), duration of flowering (0.288), length of inflorescence (0.259), yield per tree (0.236), fruit length (0.213) and total sugar (0.277), while negative with fruit width (-0.197). The leaf width revealed positive correlation with leaf area (0.261), reducing sugar (0.218) whereas, it was showed negative correlation with duration of fruit maturity (-0.291), stone length (-0.269). The leaf area revealed positive correlation with duration of panicle emergence (0.256), duration of flowering (0.192), duration of fruit maturity (0.210). The duration of panicle emergence revealed positive correlation with duration of flowering (0.314), length of inflorescence (0.345), secondary rachis per panicle (0.332), duration of fruit maturity (0.235), number of fruits per tree (0.216), yield per tree (0.297), acidity (0.247), total sugar (0.265) and ascorbic acid (0.209). The duration of flowering showed positive correlation with length of inflorescence (0.426), duration of fruit maturity (0.222), number of fruits per tree (0.334), stone length (0.183), total sugar (0.281), ascorbic acid (0.473). Length of

Table 4.22: Estimate of environmental correlation coefficients between different morphological and physico-chemical characteristics in different mango varieties including new accessions (2014)

Characters	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	Duration of panicle emergence	Duration of flowering(days)	Length of inflorescence (cm)	Width of inflorescence (cm)	Secondary rachis/ panicle	Duration of fruit maturity (days)	Number of fruits/ tree (harvesting)	Yield /tree (kg)	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)
Leaf length (cm)		0.264*	0.248**	0.287**	0.288**	0.259**	0.176	0.137	0.077	0.160	0.236*	0.155	0.213*	-0.197*
Leaf width (cm)			0.261**	0.073	-0.073	0.138	0.141	0.166	-0.291**	-0.084	-0.025	0.051	-0.061	-0.147
Leaf area (cm^2)				0.256**	0.192**	0.120	0.011	0.171	0.210*	0.089	0.274	-0.059	0.269	-0.128
Duration of panicle emergence					0.314**	0.345**	0.021	0.332**	0.235**	0.216*	0.297*	0.044	0.176	-0.015
Duration of flowering (days)						0.426**	0.112	0.152	0.222*	0.334***	0.020	-0.148	0.102	0.144
Length of inflorescence (cm)							0.267*	0.225*	0.125	0.353	0.151*	0.031	0.096	-0.052
Width of inflorescences (cm)								0.058	0.106	0.086	0.153	0.106	0.059	-0.149
Secondary rachis / panicle									0.108	0.255**	0.169	-0.063	0.091	-0.286**
Duration of fruit maturity (days)										0.142	0.187*	-0.007	0.058	0.020
No. of fruits /tree at harvesting											0.368*	-0.031	0.144	-0.154
Yield/ tree (kg)												0.336**	0.140	-0.138
Fruit weight (g)													-0.050	-0.090
Fruit length (cm)														-0.048
Fruit width (cm)														
Stone weight (g)														
Stone length(cm)														
Stone width (cm)														
Pulp weight (g)														
Peel weight (g)														
Pulp: stone ratio														
TSS(^{0}B)														
Acidity (%)														
Reducing sugar (%)														
Total sugar (%)														
Non reducing sugar (%)														
Ascorbic acid (mg/100 g flesh)														
Total carotenoid (mg/100 g flesh)														

Table 4.22: Cont….

Characters	Stone weight (g)	Stone length (cm)	Stone width (cm)	Pulp weight (g)	Peel weight (g)	Pulp: Stone ratio	TSS (^{0}B)	Acidity (%)	Reducing sugar (%)	Total sugar (%)	Non reducing sugar (%)	Ascorbic acid (mg/100 g flesh)	Total carotenoid (mg/100 g flesh)
Leaf length (cm)	0.141	0.047	-0.064	0.126	0.109	0.001	-0.073	0.210	0.063	0.277**	0.072	0.088	0.018
Leaf width (cm)	-0.052	-0.269**	-0.048	0.045	0.077	0.032	-0.090	-0.066	0.218*	0.144	0.122	0.010	0.124
Leaf area (cm^2)	0.194	0.019	-0.013	-0.084	0.075	-0.151	0.037	0.148	0.051	0.095	-0.009	0.341	0.156
Duration of panicle emergence	0.122	0.024	0.126	0.035	0.094	0.059	0.179	0.247**	-0.012	0.265**	0.074	0.209*	-0.040
Duration of flowering(days)	0.157	0.183*	0.052	-0.142	0.022	-0.011	-0.029	0.130	0.120	0.281**	-0.049	0.473**	0.072
Length of inflorescence (cm)	0.046	0.099	0.087	0.028	0.126	0.089	0.028**	0.161	0.014	0.261	0.178	0.268**	0.124
Width of inflorescence (cm)	-0.056	0.085	-0.367**	0.154	-0.182*	0.255**	-0.127	0.102	0.017	0.172	0.129	0.011	-0.070
Secondary rachis per panicle	0.126	-0.057	-0.077	-0.053	-0.099	-0.060	0.018	0.029	0.069	0.179	0.142	0.126	0.103
Duration of fruit maturity (days)	0.196*	0.091	-0.076	-0.032	0.093	-0.093	-0.009	0.077	-0.142	0.179	0.182*	0.068	0.094
No. of fruits /tree at harvesting	0.265**	0.239**	0.058	-0.063	0.051	-0.185*	0.123	0.427**	-0.010	0.136	-0.088	0.156	0.166
Yield/ tree (kg)	0.272**	0.190*	-0.073	0.310**	0.052	0.083	0.087	0.272**	0.047	0.089	-0.019	0.131	0.186*
Fruit weight (g)	0.146	-0.091	-0.045	0.980**	-0.088	0.486**	-0.054	0.015	0.107	0.022	0.169	-0.020	-0.078
Fruit length (cm)	0.047	-0.075	-0.147	-0.091**	0.268	-0.067	0.010	0.211*	-0.130	0.123	0.044	0.116	-0.004
Fruit width (cm)	-0.232*	-0.189*	0.197*	-0.071	0.153	0.140	0.199*	-0.080	-0.063	-0.170	-0.153	-0.058	0.102
Stone weight (g)		-0.016	0.002	0.060	-0.170	-0.385*	-0.026	0.166	-0.003	0.257**	0.040	0.201**	0.059
Stone length(cm)			-0.231*	-0.055	-0.114	-0.021	-0.081	0.132	-0.187*	-0.039	-0.149	0.122	-0.026
Stone width (cm)				-0.061	0.229*	0.045	0.120	0.053	0.197*	0.071	-0.015	0.165	0.246**
Pulp weight (g)					-0.210*	0.614**	-0.042	0.018	0.151	0.000	0.144	-0.011	-0.092
Peel weight (g)						-0.173	0.114	0.010	-0.127	0.014	0.021	-0.113	0.133
Pulp: stone ratio							0.095	0.050	0.218**	-0.102	-0.027	-0.005	-0.027
TSS(^{0}B)								0.139	-0.047	0.026	-0.037	0.062	-0.017
Acidity (%)									-0.186*	0.077	-0.123	0.261**	0.038
Reducing sugar (%)										0.047	-0.174	0.034	0.141
Total sugar (%)											0.617**	0.081	0.185*
Non reducing sugar (%)												-0.014	0.096
Ascorbic acid (mg/100 g flesh)													0.043
Total carotenoid (mg/100 g flesh)													

inflorescence showed positive correlation with width of inflorescence (0.267), secondary rachis per panicle (0.225), yield per tree (0.151), TSS (0.028), ascorbic acid (0.268), while, width of inflorescence also showed negative with stone width (-0.367), peel weight (-0.182) and positive with pulp: stone ratio (0.255). Secondary rachis per panicle showed positive correlation with number of fruits per tree at harvesting (0.255) and negative with fruit width (-0.286). Duration of fruit maturity showed positive correlation with yield per tree (0.187), stone weight (0.196), non reducing sugar (0.182). Number of fruits per tree at harvesting showed positive correlation with yield per tree (0.368), stone weight (0.265), stone length (0.239), acidity (0.427) and negatively with pulp: stone ratio (-0.185).Yield per tree showed positive correlation with fruit weight (0.336), stone weight (0.272), stone length (0.190), pulp weight (0.310), acidity (0.272) and total carotenoid (0.186). Fruit weight showed positive correlation with pulp weight (0.980), pulp: stone ratio (0.486) and fruit length with acidity (0.211) and negatively with pulp weight (-0.091). Fruit width showed significant negative correlation with stone weight (-0.232), stone length (-0.189) but positive with stone width (0.197) and TSS (0.199); stone weight with pulp: stone ratio (-0.385) and positive with total sugar (0.257) and ascorbic acid (0.201). Stone length showed negative correlation with stone width (-0.231), reducing sugar (-0.187); Stone width with peel weight (0.229), reducing sugar (0.197) and total carotenoid (0.246). Pulp weight showed negative correlation with peel weight (-0.210) and positive with pulp: stone ratio (0.614). Pulp: stone ratio showed positive correlation with reducing sugar (0.218). The acidity showed negative correlation with reducing sugar negative (-0.186) and positive with ascorbic acid (0.261). Total sugar was exhibited significant positive correlation with non reducing sugar (0.617) and total carotenoid (0.185).

4.2.5.2 Estimates of correlation coefficients during second year

The estimates of genotypic and phenotypic correlation coefficients have been presented in Table 4.23 and 4.24, respectively for the year 2016. The leaf length was positively correlated with leaf width (0.555, 0.515), leaf area (0.852, 0.831), length of inflorescence (0.416, 0.386), width of inflorescence (0.572, 0.506), duration of fruit maturity (0.373, 0.341), yield per tree (0.320, 0.292), fruit weight (0.559, 0.513), fruit length (0.563, 0.535), fruit width (0.645, 0.601), stone weight (0.396, 0.373), stone length (0.483, 0.435), stone width (0.590, 0.503), pulp weight (0.548, 0.497), peel weight (0.510, 0.450), pulp: stone ratio (0.454, 0.392), total carotenoid (0.363, 0.325).It was showed negative correlation with number of fruits per tree at harvesting (-0.270 -0.264). Leaf width showed significant positive correlation with leaf area (0.901, 0.897), duration of panicle emergence (0.405, 0.346), duration of flowering (0.290, 0.246), width of inflorescence (0.264, 0.186), secondary rachis per panicle (0.288, 0.257), fruit weight (0.422, 0.383), fruit length (0.457, 0.422), fruit width (0.387, 0.362), stone weight (0.467, 0.411), stone length (0.508, 0.464), stone width (0.511, 0.449), pulp weight (0.393, 0.353), peel weight (0.385, 0.350), acidity (0.249, 0.199), ascorbic acid (0.301) and total carotenoid (0.240, 0.216). Number of fruits per tree at harvesting (-0.356, -0.327) negatively correlated with leaf width. Leaf area revealed significant positive correlation with duration of panicle emergence (0.328, 0.296), duration of flowering (0.272, 0.234), length of inflorescence (0.307, 0.282), width of inflorescence (0.463, 0.375), duration of fruit maturity (0.257, 0.243), yield per tree (0.219, 0.195), fruit weight (0.534, 0.490), fruit length (0.550, 0.519), fruit width (0.543, 0.510), stone weight (0.484, 0.441), stone length, (0.541, 0.494), stone width (0.603, 0.526), pulp weight (0.510, 0.462), peel weight (0.494, 0.444), pulp: stone ratio (0.305, 0.275), ascorbic acid (0.249, 0.223), total carotenoid (0.345, 0.310), while, negative correlation with number of fruits per tree at harvesting (-0.343, -0.326).

Duration of panicle emergence showed positive correlation with duration of flowering (0.298, 0.259), length of inflorescence (0.305, 0.270), width of inflorescence (0.297, 0.250), secondary rachis per panicle (0.351, 0.321), stone weight (0.330, 0.295), stone width (0.245, 0.212), acidity (0.309, 0.264). Duration of flowering showed positive correlation with secondary rachis per panicle (0.207, 0.200), fruit width (0.208, 0.183), whereas, significant negative correlation with number of fruits per tree at harvesting (-0.389, -0.350), yield per tree (-0.387, -0.329), acidity (0.272, 0.236), reducing sugar (-0.069, -0.067), total sugar (-0.369, -0.276) and total carotenoid (-0.414, -0.373). Length of inflorescence showed positive correlation with width of inflorescence (0.775, 0.711), secondary rachis per panicle (0.589, 0.569), yield per tree (0.263, 0.250), fruit length (0.263, 0.260), fruit width (0.267, 0.258), pulp: stone ratio (0.223, 0.197), TSS (0.200), reducing sugar (0.308, 0.296), while negative correlation with ascorbic acid (-0.277, -0.258). Width of inflorescence

Table 4.23: Estimate of genotypic correlation coefficients between different morphological and physico-chemical characteristics in different mango varieties including new accessions (2016)

Characters	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	Duration of panicle emergence	Duration of flowering(days)	Length of inflorescence (cm)	Width of inflorescence (cm)	Secondary rachis/ panicle	Duration of fruit maturity (days)	Number of fruits/ tree (harvesting)	Yield /tree (kg)	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)
Leaf length (cm)		0.555	0.852	0.136	0.143	0.416	0.572	0.040	0.373	-0.270	0.320	0.559	0.563	0.645
Leaf width (cm)			0.901	0.405	0.290	0.162	0.264	0.288	0.088	-0.356	0.117	0.422	0.457	0.387
Leaf area (cm^2)				0.328	0.272	0.307	0.463	0.196	0.257	-0.343	0.219	0.534	0.550	0.543
Duration of panicle emergence					0.298	0.305	0.297	0.351	0.102	-0.128	-0.007	0.098	0.024	0.141
Duration of flowering (days)						0.038	0.048	0.207	-0.025	-0.389	-0.387	0.145	-0.103	0.208
Length of inflorescence (cm)							0.775	0.589	0.002	-0.056	0.263	0.175	0.263	0.267
Width of inflorescences (cm)								0.346	0.154	-0.079	0.229	0.236	0.296	0.251
Secondary rachis / panicle									-0.161	-0.255	-0.019	0.123	0.076	0.195
Duration of fruit maturity (days)										-0.095	0.206	0.355	0.286	0.372
No. of fruits /tree at harvesting											0.501	-0.631	-0.399	-0.638
Yield/ tree (kg)												0.239	0.381	0.148
Fruit weight (g)													0.815	0.868
Fruit length (cm)														0.681
Fruit width (cm)														
Stone weight (g)														
Stone length(cm)														
Stone width (cm)														
Pulp weight (g)														
Peel weight (g)														
Pulp: stone ratio														
TSS(^{0}B)														
Acidity (%)														
Reducing sugar (%)														
Total sugar (%)														
Non reducing sugar (%)														
Ascorbic acid (mg/100 g flesh)														
Total carotenoid (mg/100 g flesh)														

Table 4.23: Cont….

Characters	Stone weight (g)	Stone length (cm)	Stone width (cm)	Pulp weight (g)	Peel weight (g)	Pulp: Stone ratio	TSS (^{0}B)	Acidity (%)	Reducing sugar (%)	Total sugar (%)	Non reducing sugar (%)	Ascorbic acid (mg/100 g flesh)	Total carotenoid (mg/100 g flesh)
Leaf length (cm)	0.396	0.483	0.590	0.548	0.510	0.454	0.065	0.132	0.100	0.015	-0.045	0.062	0.363
Leaf width (cm)	0.467	0.508	0.511	0.393	0.385	0.157	-0.060	0.249	-0.176	0.003	0.108	0.349	0.240
Leaf area (cm^2)	0.484	0.541	0.603	0.510	0.494	0.305	0.014	0.209	-0.054	0.035	0.075	0.249	0.345
Duration of panicle emergence	0.330	0.033	0.245	0.069	0.054	-0.175	0.070	0.309	0.032	0.119	0.123	-0.151	0.069
Duration of flowering(days)	0.198	-0.127	0.251	0.113	0.226	0.000	-0.119	0.272	-0.069	-0.369	-0.409	-0.187	-0.414
Length of inflorescence (cm)	0.108	0.044	0.091	0.171	0.176	0.223	0.212	-0.150	0.308	0.066	-0.107	-0.277	0.051
Width of inflorescence (cm)	0.084	0.120	0.147	0.246	0.166	0.322	0.450	0.020	0.470	0.242	0.017	-0.125	0.367
Secondary rachis per panicle	0.179	0.055	0.097	0.094	0.217	-0.022	0.001	-0.001	-0.026	-0.133	-0.151	-0.284	-0.154
Duration of fruit maturity (days)	0.308	0.276	0.211	0.349	0.390	0.143	0.190	0.098	0.236	-0.065	-0.267	0.026	0.311
No. of fruits /tree at harvesting	-0.631	-0.202	-0.498	-0.583	-0.638	-0.246	-0.111	-0.207	-0.121	0.004	0.077	0.041	0.101
Yield/ tree (kg)	0.041	0.467	0.222	0.287	-0.011	0.381	-0.052	-0.295	-0.011	0.083	0.103	0.266	0.330
Fruit weight (g)	0.805	0.705	0.841	0.989	0.755	0.618	0.125	-0.059	0.074	0.097	0.074	0.213	0.236
Fruit length (cm)	0.673	0.805	0.708	0.801	0.631	0.540	0.085	-0.032	0.056	0.208	0.227	0.233	0.340
Fruit width (cm)	0.666	0.542	0.780	0.857	0.715	0.599	0.148	0.095	0.140	-0.002	-0.096	-0.076	0.176
Stone weight (g)		0.583	0.747	0.723	0.814	0.066	0.019	-0.002	-0.065	0.029	0.068	0.219	0.101
Stone length(cm)			0.654	0.688	0.579	0.444	0.002	0.022	-0.115	0.192	0.311	0.275	0.353
Stone width (cm)				0.819	0.663	0.452	-0.058	0.185	-0.059	0.000	0.034	0.106	0.323
Pulp weight (g)					0.662	0.711	0.138	-0.087	0.093	0.108	0.076	0.214	0.253
Peel weight (g)						0.147	0.070	0.120	0.019	-0.029	-0.053	0.081	0.135
Pulp: stone ratio							0.122	-0.062	0.182	0.083	-0.004	0.015	0.183
TSS(^{0}B)								-0.304	0.795	0.721	0.407	-0.079	0.422
Acidity (%)									-0.078	-0.218	-0.223	-0.258	0.024
Reducing sugar (%)										0.637	0.175	-0.283	0.279
Total sugar (%)											0.870	0.031	0.497
Non reducing sugar (%)												0.214	0.444
Ascorbic acid (mg/100 g flesh)													0.198
Total carotenoid (mg/100 g flesh)													

Table 4.24: Estimate of phenotypic correlation coefficients between different morphological and physico-chemical characteristics in different mango varieties including new accessions (2016)

Characters	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	Duration of panicle emergence	Duration of flowering(days)	Length of inflorescence (cm)	Width of inflorescence (cm)	Secondary rachis/ panicle	Duration of fruit maturity (days)	Number of fruits/ tree (harvesting)	Yield /tree (kg)	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)
Leaf length (cm)		0.515***	0.831***	0.142	0.126	0.386***	0.506***	0.031	0.341***	-0.264***	0.292**	0.513***	0.535**	0.601**
Leaf width (cm)			0.897***	0.346***	0.246**	0.147	0.186**	0.257**	0.092	-0.327***	0.101	0.383***	0.422**	0.362***
Leaf area (cm^2)				0.296**	0.234*	0.282*	0.375***	0.176	0.243**	-0.326***	0.195*	0.490*	0.519**	0.510***
Duration of panicle emergence					0.259**	0.270**	0.250**	0.321**	0.061	-0.127	-0.026	0.082	0.029	0.137
Duration of flowering (days)						0.051	0.025	0.200*	-0.017	-0.350**	-0.329*	0.139	-0.078	0.183*
Length of inflorescence (cm)							0.711**	0.569**	0.007	-0.051	0.250**	0.169	0.260**	0.258**
Width of inflorescences (cm)								0.311**	0.127	-0.078	0.204**	0.224**	0.272**	0.231**
Secondary rachis / panicle									-0.159	-0.242**	-0.026	0.098	0.076	0.192*
Duration of fruit maturity (days)										-0.083	0.211*	0.347*	0.276*	0.360*
No. of fruits /tree at harvesting											0.497**	-0.604**	-0.393*	-0.624**
Yield/ tree (kg)												0.263**	0.356**	0.136
Fruit weight (g)													0.772**	0.826**
Fruit length (cm)														0.675**
Fruit width (cm)														
Stone weight (g)														
Stone length(cm)														
Stone width (cm)														
Pulp weight (g)														
Peel weight (g)														
Pulp: stone ratio														
TSS(^{0}B)														
Acidity (%)														
Reducing sugar (%)														
Total sugar (%)														
Non reducing sugar (%)														
Ascorbic acid (mg/100 g flesh)														
Total carotenoid (mg/100 g flesh)														

Table 4.24: Cont….

Characters	Stone weight (g)	Stone length (cm)	Stone width (cm)	Pulp weight (g)	Peel weight (g)	Pulp: Stone ratio	TSS (^{0}B)	Acidity (%)	Reducing sugar (%)	Total sugar (%)	Non reducing sugar (%)	Ascorbic acid (mg/100 g flesh)	Total carotenoid (mg/100 g flesh)
Leaf length (cm)	0.373***	0.435***	0.503**	0.497**	0.450***	0.392***	0.043	0.095	0.103	-0.007	-0.062	0.068	0.325***
Leaf width (cm)	0.411***	0.464***	0.449**	0.353**	0.350**	0.154	-0.045	0.199**	-0.150	-0.013	0.060	0.301***	0.216*
Leaf area (cm^2)	0.441***	0.494***	0.526**	0.462**	0.444**	0.275**	0.009	0.161	-0.037	0.011	0.030	0.223*	0.310**
Duration of panicle emergence	0.295**	0.021	0.212**	0.051	0.046	-0.160	0.047	0.264**	0.013	0.100	0.105	-0.113	0.068
Duration of flowering(days)	0.179	-0.092	0.255	0.111	0.178	0.015	-0.092	0.236**	-0.067*	-0.276*	-0.277	-0.167	-0.373*
Length of inflorescence (cm)	0.106	0.053	0.093	0.165	0.143	0.197**	0.200*	-0.143	0.296*	0.072	-0.068	-0.258*	0.050
Width of inflorescence (cm)	0.090	0.088	0.129	0.232	0.147	0.271**	0.409**	0.014	0.428**	0.207**	0.022	-0.089	0.323**
Secondary rachis per panicle	0.164	0.061	0.086	0.067	0.197*	-0.034	-0.007	0.005	-0.010	-0.098	-0.109	-0.260**	-0.139
Duration of fruit maturity (days)	0.296*	0.254*	0.200*	0.338**	0.363**	0.141	0.184**	0.087	0.218*	-0.051	-0.203*	0.003	0.290*
No. of fruits /tree at harvesting	-0.612**	-0.194**	-0.459**	-0.551**	-0.603**	-0.223**	-0.106	-0.198**	-0.119	0.009	0.070	0.037	0.099
Yield/ tree (kg)	0.047**	0.427**	0.211**	0.308**	0.006	0.377***	-0.051	-0.280*	-0.012	0.051	0.060	0.251**	0.301**
Fruit weight (g)	0.764**	0.645**	0.778**	0.988**	0.708**	0.624**	0.119	-0.069	0.066	0.048	0.020	0.200*	0.218*
Fruit length (cm)	0.654**	0.757**	0.652**	0.746**	0.589**	0.476**	0.082	-0.030	0.055	0.192*	0.194*	0.219*	0.324*
Fruit width (cm)	0.637**	0.508**	0.717**	0.804**	0.674**	0.544**	0.140	0.102	0.132	0.002	-0.070	-0.070	0.174
Stone weight (g)		0.531**	0.678**	0.676**	0.744**	0.015**	0.023	-0.009	-0.055	0.038	0.065	0.204*	0.083
Stone length(cm)			0.608**	0.621**	0.543**	0.397**	0.003	0.034	-0.112	0.149	0.230*	0.256**	0.324**
Stone width (cm)				0.752**	0.595**	0.413**	-0.044	0.180**	-0.063	0.054	0.093	0.078	0.294**
Pulp weight (g)					0.607**	0.715**	0.129	-0.095	0.082	0.052	0.016	0.200*	0.232*
Peel weight (g)						0.154	0.069	0.119	0.020	-0.040	-0.061	0.076	0.116
Pulp: stone ratio							0.103	-0.065	0.145	0.020	-0.048	0.025	0.169
TSS(^{0}B)								-0.274**	0.739**	0.615**	0.328**	-0.074	0.401**
Acidity (%)									-0.070	-0.144	-0.130	-0.234*	0.037
Reducing sugar (%)										0.525	0.090	-0.267	0.264
Total sugar (%)											0.894**	0.029	0.406**
Non reducing sugar (%)												0.171	0.329**
Ascorbic acid (mg/100 g flesh)													0.183*
Total carotenoid (mg/100 g flesh)													

showed positive correlation with secondary rachis per panicle (0.346, 0.311), yield per tree (0.229, 0.204), fruit weight (0.236, 0.224), fruit length (0.296, 0.272), fruit width (0.251, 0.231), pulp: stone ratio (0.322, 0.271), TSS (0.450, 0.409), reducing sugar (0.470, 0.428), total sugar (0.242, 0.207), total carotenoid (0.367, 0.323). Secondary rachis per panicle revealed positive correlation with number of fruits per tree at harvesting (-0.255, -0.242), fruit width (0.195, 0.192), peel weight (0.217, 0.197), while negative with ascorbic acid (-0.284, -0.260). Duration of fruit maturity showed positive correlation with yield per tree (0.206, 0.211), fruit weight (0.355, 0.347), fruit length (0.286, 0.276), fruit width (0.372, 0.360), stone weight (0.308, 0.296), stone length (0.276, 0.254), stone width (0.211, 0.200), pulp weight (0.349, 0.338), peel weight (0.390, 0.363), TSS (0.190, 0.184), reducing sugar (0.236, 0.218) and total carotenoid (0.311, 0.290), while negative correlation with non reducing sugar (-0.267, -0.203). Number of fruits per tree at harvesting showed significant negative correlation with fruit weight (-0.631, -0.604), fruit length (-0.399, -0.393), fruit width (-0.638, -0.624), stone weight (-0.631, -0.612), stone length (-0.202, -0.194), stone width (-0.498, -0.459), pulp weight (-0.583, -0.551), peel weight (-0.638, -0.603), pulp: stone ratio (-0.246, -0.223), TSS (-0.111, -0.198) except yield per tree (0.501, 0.497).

Yield per tree showed significant negative correlation with fruit weight (0.239, 0.263), fruit length (0.381, 0.356), stone weight (0.041, 0.047), stone length (0.467, 0.427), stone width (0.222, 0.211), pulp weight (0.287, 0.308), pulp: stone ratio (0.381, 0.377), ascorbic acid (0.266, 0.251) and total carotenoid (0.330, 0.301), while, it was negatively correlated with acidity (-0.295, -0.280). Fruit weight showed positive correlation with fruit length (0.815, 0.772), fruit width (0.868, 0.826), stone weight (0.8050.764), stone length (0.705, 0.645), stone width (0.841, 0.778), pulp weight (0.989, 0.988) and peel weight (0.755, 0.708), pulp: stone ratio (0.618, 0.624), ascorbic acid (0.213, 0.200) and total carotenoid (0.236, 0.218). Fruit length showed significant positive correlation with fruit width (0.681, 0.675), stone weight (0.673, 0.654), stone length (0.805, 0.757), stone width (0.708, 0.652), pulp weight (0.801, 0.746), peel weight (0.631, 0.589), pulp: stone ratio (0.540, 0.476), total sugar (0.208, 0.192), non reducing sugar (0.227, 0.194), ascorbic acid (0.233, 0.219) and total carotenoid (0.340, 0.324). Fruit width showed significant positive correlation with stone weight (0.666, 0.637), stone length (0.542, 0.508), stone width (0.780, 0.717), pulp weight (0.857, 0.804), peel weight (0.715, 0.674) and pulp: stone ratio (0.599, 0.544). Stone weight showed positive correlation with stone length (0.583, 0.531), stone width (0.747, 0.678), pulp weight (0.723, 0.676) and peel weight (0.814, 0.744), pulp: stone ratio (0.066, 0.015), ascorbic acid (0.219, 0.204). Stone length showed significant positive correlation with stone width (0.654, 0.608), pulp weight (0.688, 0.621) and peel weight (0.579, 0.543), pulp: stone ratio (0.444, 0.397), non reducing sugar (0.311, 0.230), ascorbic acid (0.275, 0.256) and total carotenoid (0.353, 0.324). Stone width revealed positive correlation with pulp weight (0.819, 0.752), peel weight (0.663, 0.595), pulp: stone ratio (0.452, 0.413), acidity (0.185, 0.180) and total carotenoid (0.323, 0.294). Pulp weight showed positive correlation with peel weight (0.662, 0.605), pulp: stone ratio (0.711, 0.715), ascorbic acid (0.214, 0.200) and total carotenoid (0.253, 0.232).

The total soluble solids showed negative correlation with acidity (-0.304, -0.274), while, positive correlation with reducing sugar (0.795, 0.739), total sugar (0.721, 0.615), non reducing sugar (0.407, 0.328) and total carotenoid (0.422, 0.401). Acidity showed positive correlation ascorbic acid (-0.258, -0.234).Total sugar showed positive correlation with non reducing sugar (0.870, 0.894) and total carotenoid (0.497, 0.406). Non reducing sugar showed positive correlation total carotenoid (0.444, 0.329). Ascorbic acid showed positive correlation with total carotenoid (0.198, 0.183).

The estimates of environmental correlation coefficients have been presented in Table 4.25 for the year 2016 indicating positive significant correlation of leaf length with leaf width (0.219), leaf area (0.652), duration of panicle emergence (0.186), acidity (0.255), while, negative correlation with number of fruits per tree at harvesting (-0.251), TSS (-0.243) and total carotenoid (-0.180). Leaf width revealed positive correlation with leaf area (0.876) and negative with width of inflorescence (-0.295). Leaf area showed positive correlation with width of inflorescence acidity (0.266), while negative correlation with (-0.247). Duration of panicle emergence revealed negative correlation with duration of fruit maturity (-0.387) number of fruits per tree at harvesting (-0.243), yield per tree (-0.202) and TSS (-0.180). Duration of flowering exhibited positive correlation with length of inflorescence (0.185), fruit length (0.209) and stone width (0.281).

Table 4.25: Estimate of environmental correlation coefficients between different morphological and physico-chemical characteristics in different mango varieties including new accessions (2016)

Characters	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	Duration of panicle emergence	Duration of flowering (days)	Length of inflorescence (cm)	Width of inflorescence (cm)	Secondary rachis/ panicle	Duration of fruit maturity (days)	Number of fruits/ tree (harvesting)	Yield /tree (kg)	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)
Leaf length (cm)		0.219*	0.652**	0.186*	0.015	0.003	0.003	-0.067	-0.084	-0.251*	-0.023	0.017	0.134	-0.056
Leaf width (cm)			0.876**	-0.010	0.010	0.003	-0.295*	-0.001	0.164	0.020	-0.035	0.062	0.063	0.144
Leaf area (cm^2)				0.076	0.008	-0.002	-0.247*	-0.019	0.086	-0.113	-0.051	0.056	0.125	0.107
Duration of panicle emergence					0.054	-0.054	-0.039	0.087	-0.387**	-0.243**	-0.202*	-0.048	0.119	0.133
Duration of flowering (days)						0.185*	-0.100	0.166	0.049	0.020	0.098	0.107	0.209*	-0.034
Length of inflorescence (cm)							0.114	0.265*	0.114	0.157	0.027	0.071	0.174	0.032
Width of inflorescences (cm)								0.016	-0.153	-0.125	-0.016	0.128	0.013	0.026
Secondary rachis / panicle									-0.119	0.093	-0.114	-0.215*	0.086	0.156
Duration of fruit maturity (days)										0.404	0.303	0.221	0.005	0.055
No. of fruits /tree at harvesting											0.583**	0.021	-0.097	0.017
Yield/ tree (kg)												0.583**	-0.171	-0.084
Fruit weight (g)													-0.071	0.061
Fruit length (cm)														0.479**
Fruit width (cm)														
Stone weight (g)														
Stone length(cm)														
Stone width (cm)														
Pulp weight (g)														
Peel weight (g)														
Pulp: stone ratio														
TSS(^{0}B)														
Acidity (%)														
Reducing sugar (%)														
Total sugar (%)														
Non reducing sugar (%)														
Ascorbic acid (mg/100 g flesh)														
Total carotenoid (mg/100 g flesh)														

Table 4.25: Cont….

Characters	Stone weight (g)	Stone length (cm)	Stone width (cm)	Pulp weight (g)	Peel weight (g)	Pulp: Stone ratio	TSS (^{0}B)	Acidity (%)	Reducing sugar (%)	Total sugar (%)	Non reducing sugar (%)	Ascorbic acid (mg/100 g flesh)	Total carotenoid (mg/100 g flesh)
Leaf length (cm)	0.068	-0.039	-0.172	0.017	-0.128	0.011	-0.243*	-0.255**	0.142	-0.127	-0.153	0.141	-0.180*
Leaf width (cm)	-0.161	0.127	0.059	0.059	0.087	0.138	0.101	-0.178	0.078	-0.082	-0.096	-0.119	-0.010
Leaf area (cm^2)	-0.088	0.073	-0.031	0.053	0.002	0.109	-0.044	-0.266**	0.144	-0.106	-0.134	-0.047	-0.099
Duration of panicle emergence	-0.037	-0.068	0.012	-0.087	-0.013	-0.084	-0.180*	-0.072	-0.159	0.023	0.060	0.222*	0.060
Duration of flowering(days)	0.036	0.142	0.281*	0.104	-0.143	0.083	0.131	0.013	-0.061	0.078	0.089	-0.027	-0.066
Length of inflorescence (cm)	0.063	0.170	0.126	0.094	-0.304**	0.002	-0.026	-0.056	0.117	0.153	0.119	0.038	0.032
Width of inflorescence (cm)	0.169	-0.167	0.012	0.130	-0.002	0.003	0.027	-0.032	0.070	0.060	0.040	0.242**	-0.124
Secondary rachis per panicle	-0.070	0.138	-0.010	-0.231*	-0.016	-0.132	-0.138	0.077	0.194*	0.096	0.048	0.061	0.084
Duration of fruit maturity (days)	0.020	-0.059	0.101	0.201	-0.001	0.164	0.081	-0.060	-0.093	0.037	0.057	-0.389	-0.132
No. of fruits /tree at harvesting	0.074	-0.086	0.053	0.010	0.040	-0.034	0.052	-0.053	-0.125	0.112	0.137	-0.079	0.026
Yield/ tree (kg)	0.149	-0.043	0.119	0.557**	0.198*	0.403**	-0.041	-0.109	-0.023	-0.147	-0.134	0.041	-0.171
Fruit weight (g)	0.097	-0.032	0.237*	0.983**	0.177	0.748*	0.020	-0.177	-0.038	-0.254*	-0.234*	0.027	-0.072
Fruit length (cm)	0.149	0.004	0.027	-0.092	-0.072	-0.085	0.005	-0.018	0.038	0.165	0.149	-0.074	-0.094
Fruit width (cm)	-0.088	-0.017	0.047	0.041	0.079	0.146	-0.046	0.231*	-0.023	0.051	0.053	0.040	0.115
Stone weight (g)		-0.212*	-0.030	0.058	-0.238**	-0.486**	0.110	-0.112	0.121	0.125	0.091	-0.062	-0.279**
Stone length(cm)			0.250**	-0.027	0.188*	0.112	0.013	0.153	-0.081	-0.073	-0.052	0.028	-0.067
Stone width (cm)				0.235*	0.063	0.210*	0.104	0.138	-0.102	0.303**	0.313**	-0.187*	0.014
Pulp weight (g)					0.081	0.783**	0.019	-0.171	-0.035	-0.244*	-0.226*	0.042	-0.030
Peel weight (g)						0.212*	0.061	0.115	0.035	-0.107	-0.111	0.026	-0.129
Pulp: stone ratio							-0.042	-0.089	-0.125	-0.216*	-0.178	0.112	0.084
TSS(^{0}B)								0.098	-0.121	0.037	0.062	0.006	0.012
Acidity (%)									0.020	0.241*	0.225*	0.043	0.225*
Reducing sugar (%)										-0.075	-0.301**	-0.045	0.030
Total sugar (%)											0.973**	0.022	-0.145
Non reducing sugar (%)												0.031	-0.146
Ascorbic acid (mg/100 g flesh)													-0.051
Total carotenoid (mg/100 g flesh)													

Length of inflorescence exhibited positive correlation with secondary rachis per panicle (0.265), while negative correlation with peel weight (-0.304). The width of inflorescence showed positive correlation with ascorbic acid (0.242). Secondary rachis per panicle showed negative correlation with fruit weight (-0.215), pulp weight (-0.231) reducing sugar (0.194). Number of fruits per tree at harvesting revealed positive correlation with yield per tree (0.583).Yield per tree showed positive correlation with fruit weight (0.583), pulp weight (0.557) and peel weight (0.198), pulp: stone ratio (0.403). Fruit width showed positive correlation with fruit width (0.479). Stone weight exhibited negative correlation with stone length (-0.212), peel weight (-0.238), pulp: stone ratio (-0.486) total and carotenoid (-0.279). Stone length showed positive correlation with stone width (0.250) peel weight (0.188). Stone width exhibited positive correlation with pulp weight (0.235), pulp: stone ratio (0.210), total sugar (0.303), non reducing sugar (0.313) and negative correlation with ascorbic acid (-0.187). Pulp weight with pulp: stone ratio (0.783), whereas negative correlation with total sugar (-0.244) and non reducing sugar (-0.226). Peel weight revealed positive correlation with pulp: stone ratio (0.212). Pulp: stone ratio showed negative correlation with total sugar (-0.216). The acidity of fruit showed positive correlation with total sugar (0.241), non reducing sugar (0.255) and carotenoid (0.255). Reducing sugar showed negative correlation with non reducing sugar (-0.301). Total sugar exhibited positive correlation with non reducing sugar (0.973).

4.2.5.3 Estimates of correlation coefficients in pooled over two year analysis

The estimates of genotypic and phenotypic correlation coefficients have been presented in Table 4.26 and 4.27, respectively (pooled data of 2014 and 2016) indicating significant positive correlation of leaf length with leaf width (0.578, 0.493), leaf area (0.855, 0.785), length of inflorescence (0.445, 0.410), width of inflorescence (0.593, 0.506), duration of fruit maturity (0.348, 0.307), yield per tree (0.323, 0.293), fruit weight (0.508, 0.454), fruit length (0.562, 0.507), fruit width (0.559, 0.491), stone weight (0.373, 0.338), stone length (0.500, 0.430), stone width (0.533, 0.450), pulp weight (0.499, 0.442), peel weight (0.436, 0.384), pulp: stone ratio (0.418, 0.353), reducing sugar (0.153, 0.134) and total carotenoid (0.319, 0.286), while negative correlation with number of fruits per tree at harvesting (-0.237, -0.216). Leaf width exhibited significant positive correlation with leaf area (0.853, 0.708), duration of panicle emergence (0.404, 0.261), duration of flowering (0.242, 0.136), length of inflorescence (0.310, 0.238), width of inflorescence (0.267, 0.155), secondary rachis per panicle (0.338, 0.269), fruit weight (0.367, 0.272), fruit length (0.510, 0.381), fruit width (0.320, 0.248), stone weight (0.419, 0.299), stone length (0.483, 0.333), stone width (0.499, 0.362), pulp weight (0.343, 0.252), peel weight (0.306, 0.229), pulp: stone ratio (0.175, 0.128), non reducing sugar (0.217, 0.141), ascorbic acid (0.275, 0.193) and total carotenoid (0.167, 0.136), whereas negative correlation with number of fruits per tree at harvesting (-0.292, -0.228). Leaf area revealed significant positive correlation with duration of panicle emergence (0.350, 0.311), duration of flowering (0.260, 0.222), length of inflorescence (0.376, 0.350), width of inflorescence (0.490, 0.405), secondary rachis per panicle (0.174, 0.161), duration of fruit maturity (0.259, 0.251), number of fruits per tree at harvesting (-0.361, -0.346), yield per tree (0.173, 0.156), fruit weight (0.515, 0.481), fruit length (0.559, 0.536), fruit width (0.512, 0.482), stone weight (0.494, 0.463), stone length (0.513, 0.476), stone width (0.566, 0.505), pulp weight (0.486, 0.450), peel weight (0.471, 0.438), pulp: stone ratio (0.269, 0.241), ascorbic acid (0.191, 0.180) and total carotenoid (0.301, 0.279). Duration of panicle emergence showed significant positive correlation with duration of flowering (0.255, 0.244), length of inflorescence (0.187, 0.186), width of inflorescence (0.200, 0.169), secondary rachis per panicle (0.337), fruit width (0.178, 0.160), stone weight (0.362, 0.315), stone width (0.284, 0.247), pulp: stone ratio (-0.220, -0.179) and acidity (0.281, 0.240), while, negative correlation with number of fruits per tree at harvesting (-0.195, -0.169).

Duration of flowering exhibited significant negative correlation with number of fruits per tree at harvesting (-0.449, -0.381), yield per tree (-0.417, -0.354), total sugar(-0.353, -0.242), non reducing sugar (-0.400, -0.280) and total carotenoid (-0.402, -0.354) whereas positive correlation with fruit width (0.199, 0.169), stone weight (0.191, 0.173), stone width (0.250, 0.231), peel weight (0.235, 0.192), acidity (0.228, 0.204). Length of inflorescence revealed significant positive correlation with width of inflorescence (0.719, 0.652), secondary rachis per panicle (0.610, 0.550), yield per tree (0.252, 0.241), fruit weight (0.180, 0.170), fruit length (0.334, 0.321), fruit width (0.266, 0.250), pulp weight (0.179, 0.168), peel weight (0.161, 0.146), pulp: stone ratio (0.230, 0.209), TSS (0.263, 0.236), reducing sugar (0.343, 0.313), while negative for acidity (-0.171, -0.144) and ascorbic acid (-0.293, -0.264). Width of inflorescence exhibited significant positive correlation with secondary rachis per panicle (0.314, 0.263), duration of fruit maturity (0.186, 0.158), yield per tree (0.200, 0.182), fruit weight (0.251, 0.277), fruit length (0.344, 0.303), fruit width (0.237, 0.212), stone weight (0.179, 0.156), stone width (0.208, 0.157), peel weight (0.175, 0.151), pulp: stone ratio (0.223, 0.203), TSS (0.463, 0.400), reducing sugar (0.552, 0.442), total sugar(0.324, 0.272) and total carotenoid (0.357, 0.320). Secondary rachis per panicle showed significant negative correlation with duration of fruit maturity (-0.162, -0.151) number of fruits per tree at harvesting (-0.145, -0.132) and ascorbic acid (-0.351, -0.297).

Duration of fruit maturity showed significant positive correlation with yield per tree (0.159, 0.157), fruit weight (0.341, 0.330), fruit length (0.295, 0.286), fruit width (0.386, 0.367), stone weight (0.291, 0.281), stone length (0.282, 0.269), stone width (0.236, 0.218), pulp weight (0.328, 0.314), peel weight (0.370, 0.355), TSS (0.216, 0.200), acidity (0.166, 0.151), reducing sugar (0.262, 0.236), total carotenoid (0.297, 0.279), while, negative correlation with non reducing sugar (-0.178, -0.136) and number of fruits per tree at harvesting (-0142, -0.132). Number of fruits per tree at harvesting revealed significant negative correlation with fruit weight (-0.622, -0.605), fruit length (-0.395, -0.389), fruit width (-0.630, -0.612), stone weight (-0.626, -0.606), stone length (-0.206, -0.198), stone width (-0.466, -0.437), pulp weight (-0.575, -0.555), peel weight (-0.620, -0.597), pulp: stone ratio (-0.227, -0.215), TSS (-0.154, -0.142), acidity (-0.176, -0.160) and reducing sugar (-0.166, -0.152), whereas positive correlation with yield per tree (0.530, 0.524).Yield per tree showed significant positive correlation with fruit weight (0.211, 0.228), fruit length (0.372, 0.352), fruit width (0.161, 0.144), stone length (0.473, 0.445), stone width (0.226, 0.207), pulp weight (0.254, 0.207), pulp: stone ratio (0.369, 0.362), ascorbic acid (0.295, 0.280) and total carotenoid (0.321, 0.305), while negative for acidity (-0.254, -0.235). Fruit weight exhibited significant positive correlation with fruit length (0.808, 0.780), fruit width (0.874, 0.832), stone weight (0.798, 0.770), stone length (0.712, 0.674), stone width (0.807, 0.753), pulp weight (0.988, 0.987), peel weight (0.748, 0.718), pulp: stone ratio (0.608, 0.607), TSS (0.172, 0.158), ascorbic acid (0.182, 0.175) and total carotenoid (0.215, 0.206).

Table 4.26: Estimate of genotypic correlation coefficients between different morphological and physico-chemical characteristics in different mango varieties including new accessions (pooled data of 2014 and 2016)

Characters	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	Duration of panicle emergence	Duration of flowering (days)	Length of inflorescence (cm)	Width of inflorescence (cm)	Secondary rachis/ panicle	Duration of fruit maturity (days)	Number of fruits/ tree (harvesting)	Yield /tree (kg)	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)
Leaf length (cm)		0.578	0.855	0.094	0.113	0.445	0.593	0.041	0.348	-0.237	0.323	0.508	0.562	0.559
Leaf width (cm)			0.853	0.404	0.242	0.310	0.267	0.338	0.090	-0.292	0.163	0.367	0.510	0.320
Leaf area (cm^2)				0.350	0.260	0.3765	0.490	0.174	0.259	-0.361	0.173	0.515	0.559	0.512
Duration of panicle emergence					0.255	0.187	0.200	0.385	0.137	-0.195	-0.087	0.115	0.036	0.178
Duration of flowering (days)						0.016	0.011	0.139	0.014	-0.449	-0.417	0.166	-0.098	0.199
Length of inflorescence (cm)							0.719	0.610	0.028	-0.059	0.252	0.180	0.334	0.266
Width of inflorescences (cm)								0.314	0.186	-0.098	0.200	0.251	0.344	0.237
Secondary rachis / panicle									-0.162	-0.145	-0.005	0.044	0.091	0.121
Duration of fruit maturity (days)										-0.142	0.159	0.341	0.295	0.386
No. of fruits /tree at harvesting											0.530	-0.622	-0.395	-0.630
Yield/ tree (kg)												0.211	0.372	0.161
Fruit weight (g)													0.808	0.874
Fruit length (cm)														0.704
Fruit width (cm)														
Stone weight (g)														
Stone length(cm)														
Stone width (cm)														
Pulp weight (g)														
Peel weight (g)														
Pulp: stone ratio														
TSS(^{0}B)														
Acidity (%)														
Reducing sugar (%)														
Total sugar (%)														
Non reducing sugar (%)														
Ascorbic acid (mg/100 g flesh)														
Total carotenoid (mg/100 g flesh)														

Table 4.26: Cont...

Characters	Stone weight (g)	Stone length (cm)	Stone width (cm)	Pulp weight (g)	Peel weight (g)	Pulp: Stone ratio	TSS (^{0}B)	Acidity (%)	Reducing sugar (%)	Total sugar (%)	Non reducing sugar (%)	Ascorbic acid (mg/100 g flesh)	Total carotenoid (mg/100 g flesh)
Leaf length (cm)	0.373	0.500	0.533	0.499	0.436	0.418	0.076	0.147	0.153	0.131	0.084	0.057	0.319
Leaf width (cm)	0.419	0.483	0.499	0.343	0.306	0.175	-0.051	0.110	-0.131	0.104	0.217	0.275	0.167
Leaf area (cm^2)	0.494	0.513	0.566	0.486	0.471	0.269	0.077	0.148	0.039	0.144	0.170	0.191	0.301
Duration of panicle emergence	0.362	0.069	0.284	0.082	0.055	-0.220	0.112	0.281	0.097	0.126	0.113	-0.149	0.065
Duration of flowering(days)	0.191	-0.118	0.250	0.139	0.235	0.019	-0.090	0.228	-0.034	-0.353	-0.400	-0.158	-0.402
Length of inflorescence (cm)	0.105	0.087	0.106	0.179	0.161	0.230	0.263	-0.171	0.343	0.128	-0.038	-0.293	0.054
Width of inflorescence (cm)	0.179	0.152	0.208	0.252	0.175	0.223	0.463	0.087	0.522	0.324	0.086	-0.119	0.357
Secondary rachis per panicle	0.113	0.087	0.066	0.022	0.115	-0.055	0.076	-0.069	-0.038	-0.064	-0.045	-0.351	-0.114
Duration of fruit maturity (days)	0.291	0.282	0.236	0.328	0.370	0.130	0.216	0.166	0.262	-0.013	-0.178	-0.009	0.297
No. of fruits /tree at harvesting	-0.626	-0.206	-0.466	-0.575	-0.620	-0.227	-0.154	-0.176	-0.166	0.010	0.102	0.090	0.123
Yield/ tree (kg)	0.016	0.473	0.226	0.254	-0.006	0.369	-0.071	-0.254	-0.063	0.124	0.179	0.295	0.321
Fruit weight (g)	0.798	0.712	0.807	0.988	0.748	0.608	0.172	-0.069	0.098	0.156	0.142	0.182	0.215
Fruit length (cm)	0.675	0.788	0.676	0.790	0.635	0.519	0.119	-0.035	0.078	0.250	0.265	0.196	0.320
Fruit width (cm)	0.697	0.561	0.741	0.857	0.714	0.556	0.153	0.087	0.167	0.033	-0.050	-0.069	0.146
Stone weight (g)		0.589	0.716	0.711	0.803	0.042	0.128	-0.003	0.002	0.104	0.148	0.188	0.104
Stone length(cm)			0.661	0.692	0.597	0.440	0.033	0.075	-0.082	0.219	0.335	0.258	0.366
Stone width (cm)				0.787	0.615	0.417	-0.001	0.196	-0.008	0.094	0.122	0.097	0.347
Pulp weight (g)					0.651	0.705	0.170	-0.102	0.113	0.172	0.147	0.184	0.230
Peel weight (g)						0.140	0.133	0.136	0.031	-0.019	-0.009	0.064	0.110
Pulp: stone ratio							0.050	-0.086	0.141	0.084	0.004	0.018	0.146
TSS(^{0}B)								-0.216	0.760	0.711	0.421	-0.127	0.371
Acidity (%)									0.038	-0.186	-0.227	-0.242	0.098
Reducing sugar (%)										0.616	0.136	-0.308	0.190
Total sugar (%)											0.084	0.044	0.487
Non reducing sugar (%)												0.244	0.478
Ascorbic acid (mg/100 g flesh)													0.200
Total carotenoid (mg/100 g flesh)													

Table 4.27: Estimate of phenotypic correlation coefficients between different morphological and physico-chemical characteristics in different mango varieties including new accessions (pooled data of 2014 and 2016)

Characters	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	Duration of panicle emergence	Duration of flowering (days)	Length of inflorescence (cm)	Width of inflorescence (cm)	Secondary rachis per panicle	Duration of fruit maturity (days)	Number of fruits/ tree (harvesting)	Yield /tree (kg)	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)
Leaf length (cm)		0.493***	0.785***	0.106	0.116	0.410**	0.506***	0.051	0.307**	-0.216**	0.293**	0.454**	0.507***	0.491***
Leaf width (cm)			0.708***	0.261***	0.136*	0.238**	0.155*	0.269***	0.060	-0.228**	0.115	0.272***	0.381***	0.248***
Leaf area (cm2)				0.311**	0.222**	0.350**	0.405**	0.161*	0.251**	-0.346**	0.156*	0.481***	0.536***	0.482***
Duration of panicle emergence					0.244**	0.186*	0.169*	0.337**	0.122	-0.169**	-0.069	0.098	0.041	0.160*
Duration of flowering(days)						0.042	0.005	0.098	0.029	-0.381**	-0.354*	0.137*	-0.076	0.169**
Length of inflorescence (cm)							0.652**	0.550**	0.029	-0.050	0.241**	0.170**	0.321***	0.250***
Width of inflorescence (cm)								0.263**	0.158*	-0.085	0.182*	0.227**	0.303***	0.212***
Secondary rachis per panicle									-0.151*	-0.132*	0.007	0.037	0.079	0.096
Duration of fruit maturity (days)										-0.132*	0.157**	0.330***	0.286***	0.367***
No. of fruits /tree at harvesting											0.524**	-0.605**	-0.389**	-0.612**
Yield/ tree (kg)												0.228***	0.352***	0.144*
Fruit weight (g)													0.780***	0.832***
Fruit length (cm)														0.690***
Fruit width (cm)														
Stone weight (g)														
Stone length(cm)														
Stone width (cm)														
Pulp weight (g)														
Peel weight (g)														
Pulp: stone ratio														
TSS(^{0}B)														
Acidity (%)														
Reducing sugar (%)														
Total sugar (%)														
Non reducing sugar (%)														
Ascorbic acid (mg/100 g flesh)														
Total carotenoid (mg/100 g flesh)														

Table 4.27: Cont...

Characters	Stone weight (g)	Stone length (cm)	Stone width (cm)	Pulp weight (g)	Peel weight (g)	Pulp: stone ratio	TSS (^{0}B)	Acidity (%)	Reducing sugar (%)	Total sugar (%)	Non reducing sugar (%)	Ascorbic acid (mg/100 g flesh)	Total carotenoid (mg/100 g flesh)
Leaf length (cm)	0.338***	0.430***	0.450***	0.442***	0.384***	0.353**	0.054	0.121	0.134*	0.119	0.059	0.062	0.286***
Leaf width (cm)	0.299***	0.333***	0.362***	0.252***	0.229***	0.128*	-0.040	0.055	-0.067	0.085	0.141*	0.193**	0.136*
Leaf area (cm2)	0.463***	0.476***	0.505***	0.450***	0.438***	0.241**	0.079	0.120	0.042	0.116	0.120	0.180**	0.279***
Duration of panicle emergence	0.315***	0.062	0.247***	0.067	0.050	-0.179*	0.098	0.240**	0.069	0.117	0.096	-0.111	0.060
Duration of flowering(days)	0.173**	-0.083	0.231***	0.111	0.192***	0.013	-0.072	0.204**	-0.027	-0.242**	-0.280**	-0.112	-0.354***
Length of inflorescence (cm)	0.101	0.085	0.100	0.168**	0.146*	0.209**	0.236*	-0.144*	0.313**	0.121	-0.023	-0.264**	0.055
Width of inflorescences (cm)	0.156*	0.121	0.157*	0.228	0.151*	0.203**	0.400*	0.091	0.442**	0.272**	0.077	-0.087	0.320***
Secondary rachis per panicle	0.106	0.071	0.048	0.016	0.097	-0.052	0.067	-0.062	-0.028	-0.035	-0.023	-0.297**	-0.093
Duration of fruit maturity (days)	0.281***	0.269***	0.218***	0.314***	0.355**	0.121	0.200**	0.151*	0.236**	-0.005	-0.136*	-0.019	0.279***
No. of fruits /tree at harvesting	-0.606***	-0.198***	-0.437***	-0.555***	-0.597***	-0.215**	-0.142*	-0.160*	-0.152*	0.013	0.084	0.086	0.120
Yield/ tree (kg)	0.025	0.445***	0.207**	0.270***	0.003	0.362***	-0.067	-0.235*	-0.055	0.091	0.121	0.280**	0.305***
Fruit weight (g)	0.770***	0.674***	0.753***	0.987***	0.718***	0.607***	0.158*	-0.076	0.092	0.115	0.093	0.175*	0.206**
Fruit length (cm)	0.656***	0.757***	0.629***	0.755***	0.610***	0.476***	0.114	-0.034	0.074	0.222**	0.220**	0.189	0.309***
Fruit width (cm)	0.658***	0.527***	0.696***	0.809***	0.683***	0.517***	0.153*	0.076	0.151*	0.025	-0.043	-0.060	0.149*
Stone weight (g)		0.556***	0.662***	0.678***	0.761***	0.005	0.122	0.004	0.011	0.099	0.118	0.180*	0.094
Stone length(cm)			0.615***	0.650***	0.570***	0.404***	0.026	0.077	-0.079	0.180*	0.259**	0.245**	0.345***
Stone width (cm)				0.728***	0.573***	0.381***	0.013	0.180**	-0.009	0.109	0.131*	0.089	0.330***
Pulp weight (g)					0.616***	0.704***	0.155*	-0.109	0.104	0.125	0.093	0.176**	0.219***
Peel weight (g)						0.135***	0.126	0.133*	0.029	-0.024	-0.021	0.061	0.102
Pulp: stone ratio							0.043	-0.098	0.112	0.043	-0.015	0.026	0.142*
TSS(^{0}B)								-0.191*	0.677**	0.605**	0.334*	-0.116	0.349**
Acidity (%)									0.014	-0.148*	-0.168*	-0.212**	0.089
Reducing sugar (%)										0.524**	0.060	-0.282**	0.182**
Total sugar (%)											0.853**	0.044	0.423**
Non reducing sugar (%)												0.199**	0.385***
Ascorbic acid (mg/100 g flesh)													0.193**
Total carotenoid (mg/100 g flesh)													

Fruit length revealed significant positive correlation with fruit width (0.704, 0.690), stone weight (0.675, 0.656), stone length (0.788, 0.757), stone width (0.676, 0.629), pulp weight (0.790, 0.755) and peel weight (0.635, 0.610), pulp: stone ratio (0.519, 0.476), total sugar (0.250, 0.222), non reducing sugar (0.265, 0.220) and total carotenoid (0.320, 0.309). Fruit width showed significant positive correlation with stone weight (0.697, 0.658), stone length (0.561, 0.527), stone width (0.741, 0.696), pulp weight (0.857, 0.809), peel weight (0.714, 0.683) and pulp: stone ratio (0.556, 0.517), TSS (0.153, 0.153), reducing sugar (0.167, 0.151), total carotenoid (0.146, 0.149). Stone weight showed significant positive correlation with stone length (0.589, 0.556), stone width (0.716, 0.662), pulp weight (0.711, 0.678), peel weight (0.803, 0.761) and ascorbic acid (0.104, 0.180). Stone length exhibited significant positive correlation with stone width (0.661, 0.615), pulp weight (0.692, 0.650) and peel weight (0.597, 0.570), pulp: stone ratio (0.440, 0.404), total sugar (0.219, 0.180), non reducing sugar (0.335, 0.259), ascorbic acid (0.258, 0.245), total carotenoid (0.366, 0.345). Stone width showed significant positive correlation with pulp weight (0.787, 0.728), peel weight (0.615, 0.573), pulp: stone ratio (0.417, 0.381), acidity (0.196, 0.180), non reducing sugar (0.122, 0.131), total carotenoid (0.347, 0.330). Pulp weight with peel weight (0.651, 0.616), pulp: stone ratio (0.705, 0.704), TSS (0.170, 0.155), ascorbic acid (0.184, 0.176) and total carotenoid (0.230, 0.219). Peel weight showed significant positive correlation with pulp: stone ratio (0.140, 0.135) acidity (0.136, 0.133). The total soluble solids showed significant positive correlation with reducing sugar (0.760, 0.677), total sugar (0.711, 0.605), non reducing sugar (0.421, 0.334) and total carotenoid (0.371, 0.349), while negative for acidity (-0.216, -0.191). Acidity showed significant negative correlation with total sugar (-0.186, -0.148), non reducing sugar (-0.227, -0.168), ascorbic acid (-0.242, -0.212). Reducing sugar exhibited significant positive correlation with total sugar (0.616, 0.524), total carotenoid (0.190, 0.182), while negative correlation with ascorbic acid (-0.308, -0.282). Total sugar revealed significant positive correlation with non reducing sugar (0.084, 0.853), total carotenoid (0.487, 0.423). Non reducing sugar exhibited significant positive correlation with ascorbic acid (0.244, 0.199), total carotenoid (0.478, 0.385). Ascorbic acid showed significant positive correlation with total carotenoid (0.200, 0.193).

The estimates of environmental correlation coefficients have been presented in Table 4.28 (pooled data of 2014 and 2016) indicating positively significant correlation of leaf length with leaf width (0.365), leaf area (0.369), duration of panicle emergence (0.156), duration of flowering (0.128) and length of inflorescence (0.188). Leaf width showed significant positive correlation with leaf area (0.499), secondary rachis per panicle (0.145), whereas negative correlation with number of fruits per tree at harvesting (-0.133). Leaf area exhibited significant positive correlation with duration of fruit maturity (0.147), fruit length (0.224), while, negative correlation with number of fruits per tree at harvesting (-0.133) and width of inflorescence (-0.137). Duration of panicle emergence showed significant positive correlation with duration of flowering (0.202), length of inflorescence (0.199), secondary rachis per panicle (0.132) and ascorbic acid (0.176). Duration of flowering revealed significant positive correlation with length of inflorescence (0.218), duration of fruit maturity (0.169), number of fruits per tree at harvesting (0.147), stone length (0.153), stone width (0.149) and ascorbic acid (0.180). Length of inflorescence s exhibited significant positive correlation with width of inflorescence (0.202), secondary rachis per panicle (0.171), number of fruits per tree at harvesting (0.196) and ascorbic acid (0.136).Width of inflorescence revealed significant positive correlation with ascorbic acid (0.172), whereas, negative correlation with stone length (-0.136) and stone width (-0.154). Duration of fruit maturity showed significant positive correlation with number of fruits per tree at harvesting (0.254) and ascorbic acid (-0.212), while negative correlation with total carotenoid (-0.165). Number of fruits per tree at harvesting showed significant positive correlation with yield per tree (0.503).Yield per tree exhibited significant positive correlation with fruit weight (0.520), stone weight (0.192), pulp weight (0.494), peel weight (0.153) and pulp: stone ratio (0.308). However, negative correlation with fruit width (-0.132) and non reducing sugar (-148). Fruit weight showed significant positive correlation with pulp weight (0.983), peel weight (0.142), pulp: stone ratio (0.678), acidity (-0.177), whereas, negative correlation with total sugar (-0.200) and non reducing sugar (-148). Fruit width revealed significant positive correlation with stone width (0.187), pulp: stone ratio (0.145), TSS (0.167) and total carotenoid (0.204), while, negative correlation with stone weight (-0.159). Stone weight showed significant negative correlation with

Table 4.28: Estimate of environmental correlation coefficients between different morphological and physico-chemical characteristics in different mango varieties including new accessions (pooled data of 2014 and 2016)

Characters	Leaf Length (cm)	Leaf Width (cm)	Leaf Area (cm2)	Duration of Panicle Emergence	Duration of Flowering (days)	Length of Inflorescence (cm)	Width of Inflorescence (cm)	Secondary Rachis Per Panicle	Duration of Fruit Maturity (days)	Fruits /tree at harvesting	Yield /tree (kg)	Fruit Weight (g)	Fruit Length (cm)	Fruit Width (cm)
Leaf length (cm)		0.365**	0.369**	0.156*	0.128*	0.188**	0.104	0.094	-0.017	-0.061	0.096	0.053	0.071	-0.022
Leaf width (cm)			0.499**	-0.037	-0.068	0.085	-0.090	0.145*	-0.041	-0.133*	-0.010	0.032	0.060	0.100
Leaf area (cm2)				0.082	0.036	0.067	-0.137*	0.086	0.147*	-0.133*	-0.047	0.039	0.224**	0.110
Duration of panicle emergence					0.202*	0.199**	0.032	0.132*	-0.001	0.096	0.067	-0.035	0.115	0.034
Duration of flowering(days)						0.218***	-0.021	-0.057	0.169**	0.147*	-0.015	-0.052	0.111	-0.009
Length of inflorescence (cm)							0.202**	0.171**	0.045	0.196*	0.084	0.006	0.072	0.000
Width of inflorescence (cm)								0.028	-0.089	0.059	0.058	0.045	-0.087	0.025
Secondary rachis per panicle									-0.088	-0.031	0.105	-0.022	-0.030	-0.103
Duration of fruit maturity (days)										0.254**	0.117	0.062	0.012	-0.034
No. of fruits /tree at harvesting											0.503**	-0.061	-0.076	-0.101
Yield/ tree (kg)												0.520**	-0.056	-0.132*
Fruit weight (g)													0.027	0.013
Fruit length (cm)														0.343**
Fruit width (cm)														
Stone weight (g)														
Stone length(cm)														
Stone width (cm)														
Pulp weight (g)														
Peel weight (g)														
Pulp: stone ratio														
TSS(^{0}B)														
Acidity (%)														
Reducing sugar (%)														
Total sugar (%)														
Non reducing sugar (%)														
Ascorbic acid (mg/100 g flesh)														
Total carotenoid (mg/100 g flesh)														

Table: 4.28: Cont...

Characters	Stone weight (g)	Stone length (cm)	Stone width (cm)	Pulp weight (g)	Peel weight (g)	Pulp: stone ratio	TSS (^{0}B)	Acidity (%)	Reducing sugar (%)	Total sugar (%)	Non reducing sugar (%)	Ascorbic acid (mg/100 g flesh)	Total carotenoid (mg/100 g flesh)
Leaf length (cm)	0.083	-0.092	-0.033	0.041	0.000	0.006	-0.081	-0.027	0.025	0.069	-0.018	0.104	0.029
Leaf width (cm)	-0.051	-0.102	0.053	0.022	0.045	0.025	-0.020	-0.098	0.108	0.053	0.021	-0.032	0.108
Leaf area (cm2)	0.042	0.030	-0.029	0.026	0.038	0.017	0.090	-0.119	0.059	-0.032	-0.075	0.042	-0.016
Duration of panicle emergence	-0.058	0.009	0.035	-0.050	0.008	0.041	0.011	0.013	-0.090	0.081	0.049	0.176**	0.025
Duration of flowering(days)	0.093	0.153*	0.149*	-0.052	-0.067	-0.018	0.017	0.099	0.004	0.136*	0.028	0.180**	-0.043
Length of inflorescence (cm)	0.017	0.053	0.033	0.010	-0.095	0.023	-0.049	0.125	0.023	0.091	0.049	0.136*	0.072
Width of inflorescences (cm)	-0.047	-0.136*	-0.154*	0.060	-0.043	0.094	0.012	0.112	-0.019	0.057	0.050	0.172**	0.027
Secondary rachis per panicle	0.067	-0.060	-0.062	-0.028	-0.043	-0.038	0.012	-0.019	0.027	0.081	0.045	0.095	0.089
Duration of fruit maturity (days)	0.046	0.013	-0.005	0.053	0.035	0.029	-0.009	-0.035	-0.073	0.068	0.067	-0.212**	-0.165*
No. of fruits /tree at harvesting	0.091	0.029	-0.013	-0.073	0.047	-0.088	0.082	0.085	0.067	0.073	0.007	-0.034	-0.014
Yield/ tree (kg)	0.192**	0.024	0.008	0.494**	0.153*	0.308*	-0.015	-0.047	0.032	-0.123	-0.148*	0.071	0.011
Fruit weight (g)	0.127	-0.017	0.118	0.983**	0.142*	0.678*	-0.019	-0.177**	0.013	-0.200*	-0.178*	0.038	-0.015
Fruit length (cm)	0.094	0.042	-0.011	0.004	-0.004	-0.018	0.045	-0.032	0.031	0.058	0.050	0.021	-0.030
Fruit width (cm)	-0.159*	-0.065	0.187*	0.007	0.119	0.145*	0.167**	-0.046	-0.024	-0.029	-0.018	0.090	0.204**
Stone weight (g)		-0.090	0.000	0.065	-0.114	-0.465*	0.045	0.105	0.122	0.091	-0.019	0.021	-0.161*
Stone length(cm)			0.117	-0.016	0.108	0.062	-0.061	0.102	-0.050	-0.073	-0.068	0.036	-0.086
Stone width (cm)				0.106	0.098	0.117	0.134*	0.044	-0.012	0.195**	0.193**	-0.008	0.130*
Pulp weight (g)					0.045	0.737**	-0.018	-0.190**	0.008	-0.195**	-0.173**	0.048	0.006
Peel weight (g)						0.097	0.038	0.105	0.006	-0.068	-0.097	0.006	-0.079
Pulp: stone ratio							-0.015	-0.185**	-0.093	-0.152*	-0.091	0.108	0.117
TSS(^{0}B)								0.021	0.011	0.066	0.034	0.007	0.060
Acidity (%)									-0.168**	0.046	0.041	0.105	-0.030
Reducing sugar (%)										0.085	-0.233**	-0.015	0.094
Total sugar (%)											0.834**	0.054	0.012
Non reducing sugar (%)												0.032	-0.009
Ascorbic acid (mg/100 g flesh)													0.064
Total carotenoid (mg/100 g flesh)													

pulp: stone ratio (-0.465) and total carotenoid (-0.161). Stone width showed significant positive correlation with TSS (0.134), total sugar (0.195), non reducing sugar (0.193) and total carotenoid (0.130). Pulp weight showed significant positive correlation with pulp: stone ratio (0.737), whereas negative correlation with acidity (-0.190), total sugar (-0.195) and non reducing sugar (-0.173). Pulp: stone ratio exhibited significant negative correlation with acidity (-0.185) and total sugar (-0.152). Acidity revealed significant negative correlation with reducing sugar (-0.168). Reducing sugar showed significant negative correlation with non reducing sugar (-0.233). Total sugar exhibited significant positive correlation with non reducing sugar (0.834).

Plant breeding programme basically depend on availability of sufficient variability and its association among different traits which are pre-requisite for executing effective selection for various economically useful desirable traits. Character association (correlation) which provides symmetrical measurements of degree of association between two variables or traits help us in understanding the nature and magnitude of association among yield and yield contributing traits. The association between two variables is termed as simple correlation or total correlation or zero order correlation coefficient. Genotypic correlation coefficients provide a measure of the genetic association among traits and give an indication of traits that could be useful so as to identify more important ones for a particular selection programme. The study of genetic association among the major contributing characters would be helpful in two ways from breeder point of view. Firstly, in selection of important marker characters highly associated with the higher expression of particular traits and secondly, to improve one characters without losing much in the other. Phenotypic correlation coefficients can be explained a correlation between two traits that can be directly observed. A phenotypic correlation is usually a simple correlation; whereas genotypic correlation in its true sense may be interpreted as correlation of breeding value. The environmental correlation includes both dominance and epistatic components of variance. The positive value of correlation coefficient between two traits showed that changes of two variables are associated with high value of other and vice-versa. When association is negative, the movement is in opposite directions, i.e. high value of one variable are associated with low value of others.

In present investigation, it was observed that genotypic correlation coefficients were greater than phenotypic correlation coefficients for most of the characters associations indicate that strong inherent association are reduced at phenotypic level due to environmental effect. This happens when genes governing two traits are similar and environmental conditions pertaining to the expression of these traits have small a similar effect (Swarup and Chaugale, 1962). Certain characters pairs showed significant environmental correlation coefficients. This could be explained as most of the characters studied are quantitative in nature and they are generally influenced by environment and there might be considerable interplay of environmental factors influencing the expression of these characters. A difference in sign between these correlations suggests that perhaps genetic and environmental factors affects the characters through modified physiological means. It should be emphasized that observed correlations apply only to the specific populations under specific environmental conditions. These inter-relationships might be quite different in other plant materials in which different gene association may exist in the genotypes of that population. The correlation obtained for various characters pair may be different when plant material is grown under different environments.

The similar findings have also been reported by Gupta *et al.* (1996), Azevedo *et al.* (1998), Rathod and Naik (2007), Bhowmick *et al.,* (2008), Islam *et al.* (2010), Barhate *et al.* (2012), Singh *et al.* (2012), Vasugi *et al.* (2013), in mango, Chipojola *et al.* (2009), Adeigbe *et al. (*2016) in Cashew nut.

4.3 Assessment of Genetic Divergence

A number of methods are available for analysis of genetic diversity in germlpasm, accessions, breeding lines and populations. Multivariate analysis methods are useful tool to access stability and can be used to identify groups with desirable traits for breeding programme (Lin *et al.,* 1986). Cluster methods are an analysis that used dendrograms to display how various genotypes are differentiated. Diversity of germplasm grouped by cluster analysis and principal component analysis (PCA) explained the variation among genotypes (Hailu *et al.,* 2006). Result of analysis of genetic divergence among the 40 mango varieties including new accessions done by following methods are presented and discussed hereunder:

4.3.1 Principal Component Analysis

As a multivariate statistical technique, the principal component analysis (PCA) has the ability to simplify the complex data by transforming the number of possibly correlated variables into a smaller number of variables called Principal components (Ziegel, 2002), which are linear transformation of the original variables and could be respective of a particular meaning. This approach is very helpful in deciding which agronomic traits of crop contributing most to yield, subsequently; these agronomic traits should be emphasized in the breeding programme (Ahmad *et al.,* 2014).

4.3.1.1 Eigen values (Eigen root) and Eigen vectors

The principal component analysis of 40 mango varieties based on correlation matrix of morphological and physico-chemical traits yielded the 8 to 10 Eigen root (Eigen value), eigen vectors and variance proportion. These values and associated percentage of variation explained by eigen root have been presented in Table 4.29; Fig. 4.10 (2014), Table 4.30; Fig. 4.11 (2016) and Table 4.31; Fig. 4.12 (pooled over years) respectively.

The average data was analyzed by using the principal component analysis. The first principal component accounts for maximum variability in the data with respect to succeeding components (Leilah and Al-khateeb, 2005). Principal component analysis reflects the importance of the largest contributor to the total variation at each axis of differentiation (Sharma, 1996). The sum of the eigen values is usually equal to the number of variables. The eigen values are often used to determine how many factors to retain. Therefore, in the analysis the first factors retains the information contained in value (eigen root) was 9.792 (Table 4.29), 7.238 (Table 4.30) and 7.492 (Table 4.31) of the original variables.

As it has been found that the characters are interrelated, so to have an idea about their independent impact, principal component analysis was undertaken. During the year 2014, the first seven components in the PCA analysis with Eigen values (Eigen root) more than unity contributed 81.13% of the total variability among the varieties evaluated for different morphological and physico-chemical traits and other PC had Eigen value less than one (Table 4.29). The principal component one with Eigen value of 9.792 contributed 36.26% of the total variability, while PC2 with

Table 4.29: Eigenvector, Eigen root, associated and cumulative percentage of variation for different components among the mango varieties including new accessions based on different morphological and physico-chemical characteristics (2014)

Components / Characters	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
Leaf length (cm)	0.177	0.283	0.128	0.091	0.127	0.306	0.224	0.073
Leaf width (cm)	0.050	0.107	-0.241	0.287	0.031	-0.180	0.555	-0.270
Leaf area (cm^2)	0.206	0.166	0.161	0.113	0.194	0.140	0.326	-0.060
Duration of panicle emergence (days)	-0.066	-0.242	0.002	0.111	-0.165	-0.563	0.065	0.322
Number of secondary rachis/ panicle	-0.043	-0.364	-0.253	0.000	0.071	0.221	0.090	-0.125
Length of inflorescence (cm)	0.089	0.253	0.013	0.448	0.072	0.146	-0.334	-0.007
Width of inflorescence (cm)	0.114	0.077	0.484	0.114	0.001	0.056	-0.122	0.123
Duration of flowering (days)	-0.027	0.018	-0.161	0.461	0.160	-0.314	-0.328	-0.005
Duration of fruit maturity (days)	0.091	-0.030	0.044	-0.101	-0.571	0.196	0.083	0.323
Number of fruits/tree at harvesting	-0.248	0.256	0.005	-0.112	-0.077	-0.065	-0.046	0.143
Yield /tree (kg)	0.167	0.175	-0.349	-0.206	-0.136	-0.055	-0.219	-0.066
Fruit weight (g)	0.282	-0.022	-0.045	-0.158	-0.015	-0.049	-0.077	-0.220
Fruit length (cm)	0.266	0.129	-0.132	-0.082	-0.162	-0.089	-0.066	-0.149
Fruit width (cm)	0.244	0.200	-0.073	-0.021	-0.033	-0.049	-0.175	0.121
Stone weight (g)	0.276	-0.123	0.006	-0.051	0.134	-0.179	-0.014	-0.024
Stone length (cm)	0.293	0.079	-0.079	-0.139	-0.019	-0.173	0.003	-0.022
Stone width (cm)	0.295	0.066	-0.017	-0.109	-0.078	-0.131	0.068	-0.095
Pulp weight (g)	-0.269	0.133	0.004	0.144	-0.253	0.088	0.066	-0.044
Peel weight (g)	0.045	-0.255	0.006	-0.259	0.421	0.188	-0.271	-0.025
Pulp : stone ratio	0.146	0.317	-0.216	-0.120	0.130	0.010	0.115	0.315
TSS (^{0}B)	0.253	-0.095	0.186	0.075	-0.111	-0.084	-0.058	-0.152
Acidity (%)	0.171	-0.346	0.107	0.020	0.087	0.053	0.171	0.191
Reducing sugar (%)	0.251	-0.064	0.215	0.059	-0.056	-0.014	-0.083	0.285
Non reducing (%)	-0.178	0.264	0.177	-0.072	0.161	-0.128	-0.090	-0.052
Total sugar (%)	-0.114	0.156	0.157	-0.292	0.365	-0.340	0.202	0.224
Ascorbic acid (mg/100 g flesh)	-0.207	0.171	-0.001	-0.340	-0.083	0.006	-0.083	-0.165
Total carotenoid (mg/100 g flesh)	-0.011	0.002	0.474	-0.090	-0.177	-0.206	0.005	-0.486
Eigenvector (root)	**9.792**	**3.766**	**2.156**	**1.865**	**1.648**	**1.444**	**1.234**	**0.897**
Percent variation	**36.267**	**13.948**	**7.985**	**6.908**	**6.106**	**5.349**	**4.570**	**3.321**
Cum. Var. Exp.	**36.267**	**50.215**	**58.201**	**65.108**	**71.214**	**76.563**	**81.132**	**84.453**

Table 4.30: Eigenvector, Eigen root, associated and cumulative percentage of variation for different components among the mango varieties including new accessions based on different morphological and physico-chemical characteristics (2016)

Characters / Components	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Leaf length (cm)	0.227	0.172	0.080	0.115	0.065	0.177	0.380	0.329	0.034	0.045
Leaf width (cm)	0.169	0.012	-0.076	0.330	0.202	-0.013	-0.343	0.236	0.029	-0.032
Leaf area (cm^2)	-0.204	0.062	-0.031	-0.144	-0.308	0.266	-0.117	-0.113	-0.322	-0.254
Duration of panicle emergence (days)	0.021	0.244	-0.264	0.157	0.004	-0.059	-0.372	-0.177	0.310	-0.279
Number of secondary rachis/ panicle	0.066	-0.054	-0.332	-0.025	-0.235	0.240	-0.093	0.382	0.143	-0.168
Length of inflorescence (cm)	0.107	0.327	-0.143	-0.128	0.327	0.029	0.247	-0.192	-0.231	0.029
Width of inflorescence (cm)	0.100	0.391	-0.091	0.018	0.141	0.328	-0.097	0.226	-0.158	-0.035
Duration of flowering (days)	0.151	-0.042	-0.178	-0.021	0.276	-0.329	-0.135	0.025	-0.412	-0.424
Duration of fruit maturity (days)	0.103	0.317	0.115	0.176	-0.457	-0.137	0.075	0.037	-0.097	-0.035
Number of fruits/tree at harvesting	-0.311	0.089	0.087	0.094	0.182	0.030	0.173	0.021	0.003	-0.167
Yield /tree (kg)	0.344	-0.018	0.027	-0.013	0.092	-0.086	-0.093	-0.106	-0.011	0.076
Fruit weight (g)	-0.231	-0.237	0.125	0.043	0.010	0.162	0.156	-0.042	0.084	-0.524
Fruit length (cm)	0.225	-0.048	0.282	0.180	0.193	0.055	0.089	-0.205	0.020	0.013
Fruit width (cm)	0.261	-0.054	-0.054	-0.211	-0.160	-0.127	0.227	0.258	0.282	-0.102
Stone weight (g)	0.305	-0.111	-0.099	0.088	-0.212	0.011	-0.106	-0.239	0.135	-0.158
Stone length (cm)	0.029	0.087	0.335	0.355	-0.011	0.118	0.116	-0.138	0.105	-0.375
Stone width (cm)	0.277	-0.172	0.044	0.060	0.093	-0.053	0.202	0.069	0.225	-0.121
Pulp weight (g)	-0.142	0.221	0.140	0.144	0.016	-0.431	-0.198	0.231	0.147	0.034
Peel weight (g)	0.264	0.141	-0.205	-0.026	-0.298	0.071	0.151	-0.103	-0.161	-0.044
Pulp : stone ratio	-0.024	0.179	-0.311	0.083	0.084	0.174	0.047	-0.480	0.357	0.165
TSS (^0B)	0.084	0.345	0.213	-0.339	0.040	0.034	-0.171	0.001	-0.003	-0.108
Acidity (%)	-0.208	0.125	-0.113	0.341	0.111	0.134	0.009	0.196	0.051	0.085
Reducing sugar (%)	-0.171	0.296	0.237	-0.214	-0.087	0.050	-0.065	0.024	0.292	0.032
Non reducing (%)	0.138	-0.060	0.338	-0.330	0.029	0.001	-0.285	-0.029	0.126	-0.040
Total sugar (%)	0.078	-0.174	-0.002	-0.211	0.283	0.451	-0.189	0.129	0.115	-0.018
Ascorbic acid (mg/100 g flesh)	0.045	-0.226	0.188	0.293	-0.190	0.220	-0.270	-0.029	-0.227	0.301
Total carotenoid (mg/100 g flesh)	0.251	0.123	0.285	0.119	-0.020	0.189	-0.090	-0.041	-0.100	-0.034
Eigenroot	**7.238**	**3.109**	**3.330**	**2.637**	**1.851**	**1.774**	**1.407**	**1.067**	**0.999**	**0.773**
Percent variation	**26.807**	**11.515**	**12.335**	**9.767**	**6.855**	**6.570**	**5.212**	**3.951**	**3.700**	**2.864**
Cum. Var. Exp.	**26.807**	**38.322**	**50.657**	**60.424**	**67.279**	**73.849**	**79.062**	**83.012**	**86.712**	**89.576**

Table 4.31: Eigenvector, Eigen root, associated and cumulative percentage of variation for different components among the mango varieties including new accessions based on different morphological and physico-chemical characteristics (pooled data of 2014 and 2016)

Components / Characters	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Leaf length (cm)	0.248	0.149	0.081	0.162	0.199	0.301	0.009	0.198	0.114	0.213
Leaf width (cm)	0.024	-0.112	-0.260	0.192	0.241	-0.385	0.112	-0.055	-0.404	0.152
Leaf area (cm^2)	0.262	0.048	-0.011	0.262	0.216	0.018	0.062	0.277	0.003	0.277
Duration of panicle emergence (days)	0.039	-0.207	0.055	0.325	0.077	-0.414	0.083	-0.326	0.021	0.078
Number of secondary rachis/ panicle	0.015	-0.397	-0.048	0.098	-0.084	0.104	0.094	0.351	-0.067	-0.040
Length of inflorescence (cm)	0.093	0.006	0.217	-0.191	0.514	0.086	-0.259	-0.041	0.010	-0.007
Width of inflorescence (cm)	0.188	0.097	0.269	0.191	0.245	-0.033	0.016	0.306	-0.064	-0.211
Duration of flowering (days)	0.003	-0.315	-0.019	-0.034	0.340	-0.209	-0.259	-0.205	0.174	-0.138
Duration of fruit maturity (days)	0.134	0.123	0.196	0.155	-0.314	0.056	-0.444	-0.227	-0.187	0.129
Number of fruits/tree at harvesting	-0.252	0.261	-0.083	0.088	0.147	-0.004	-0.096	0.026	0.273	0.012
Yield /tree (kg)	0.293	0.032	-0.082	-0.121	0.064	0.115	0.082	-0.215	-0.119	0.279
Fruit weight (g)	0.183	0.033	-0.207	-0.124	-0.184	-0.113	0.111	0.024	0.395	-0.344
Fruit length (cm)	0.258	0.231	-0.153	-0.149	0.100	0.067	-0.036	-0.222	-0.154	-0.152
Fruit width (cm)	0.215	-0.159	0.100	-0.031	-0.129	0.233	-0.001	-0.296	0.307	0.359
Stone weight (g)	0.291	-0.163	-0.127	-0.027	-0.154	-0.168	-0.020	-0.043	-0.023	0.020
Stone length (cm)	0.285	0.168	-0.184	0.007	-0.033	-0.051	0.006	-0.213	0.082	-0.050
Stone width (cm)	0.215	0.198	-0.113	0.261	0.160	0.052	0.049	-0.068	0.029	-0.295
Pulp weight (g)	-0.272	0.213	0.093	0.143	0.135	0.032	0.149	-0.243	0.007	0.124
Peel weight (g)	0.278	-0.202	-0.036	-0.127	-0.109	-0.002	-0.251	0.154	-0.117	-0.148
Pulp : stone ratio	0.151	-0.018	-0.209	-0.235	0.113	0.248	0.358	-0.071	-0.320	-0.117
TSS (^{0}B)	0.094	0.060	0.427	-0.267	-0.061	-0.330	0.023	0.106	-0.133	-0.051
Acidity (%)	-0.019	-0.057	0.106	0.476	-0.191	0.212	0.281	-0.160	-0.074	-0.259
Reducing sugar (%)	0.108	0.005	0.526	-0.016	-0.130	0.000	0.188	-0.104	-0.212	-0.061
Non reducing (%)	0.076	0.233	0.118	-0.265	-0.005	-0.314	0.463	0.053	0.215	0.190
Total sugar (%)	0.258	-0.146	0.028	0.190	-0.080	-0.134	0.049	0.170	0.305	0.182
Ascorbic acid (mg/100 g flesh)	-0.049	0.315	-0.263	0.042	-0.228	-0.164	-0.179	0.242	-0.230	0.287
Total carotenoid (mg/100 g flesh)	0.168	0.357	0.042	0.166	-0.097	-0.212	-0.162	0.014	0.057	-0.230
Eigenroot	**7.492**	**3.096**	**2.545**	**2.053**	**1.994**	**1.728**	**1.249**	**1.151**	**1.084**	**0.846**
Percent variation	**27.748**	**11.468**	**9.427**	**7.605**	**7.384**	**6.398**	**4.628**	**4.264**	**4.015**	**3.134**
Cum. Var. Exp.	**27.748**	**39.217**	**48.644**	**56.249**	**63.633**	**70.032**	**74.659**	**78.923**	**82.939**	**86.073**

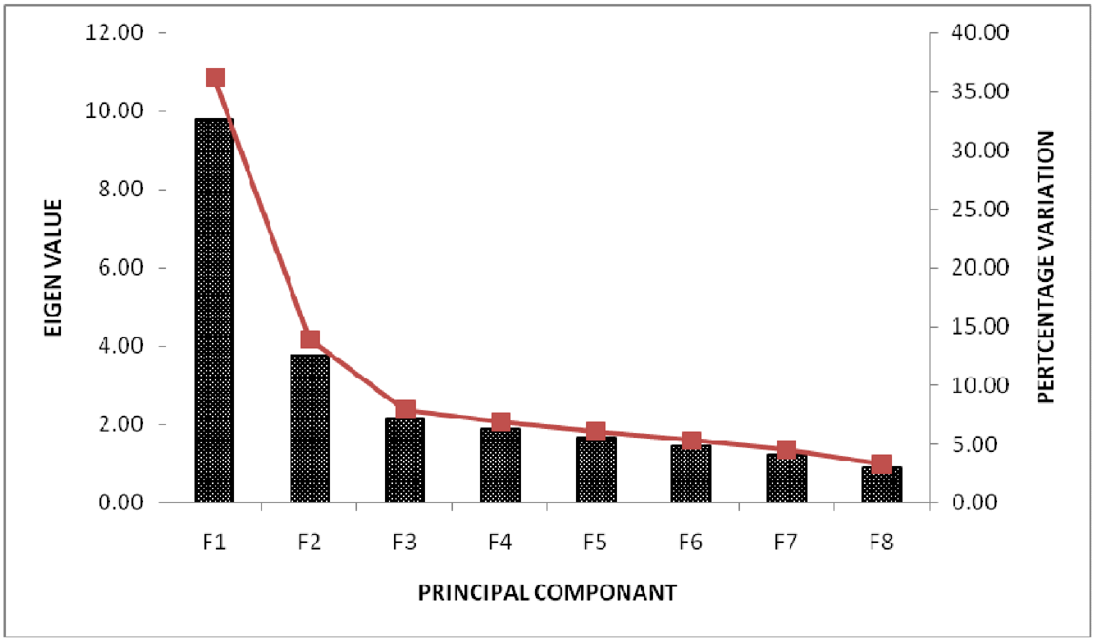


Fig. 4.10: Cattel's scree graph showing eigen value and percentage of variation for principal component based on analysis of morphological and physico-chemical characteristics in different mango varieties including new accessions (2014)

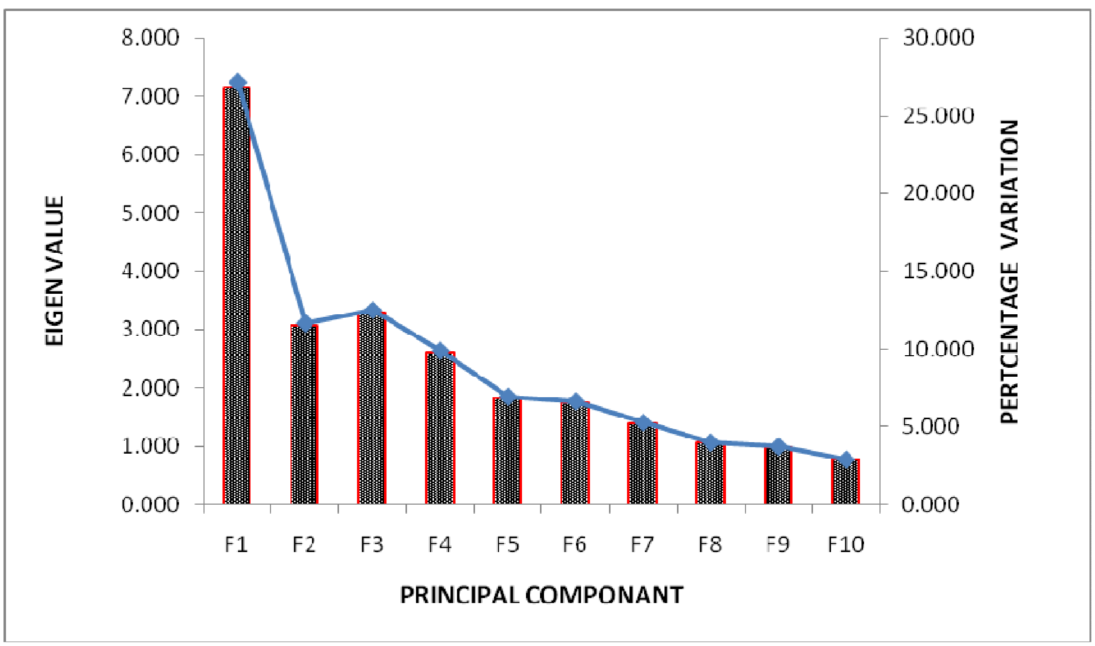


Fig. 4.11: Cattel's scree graph showing Eigen value and percentage of variation for principal component based on analysis of morphological and physico-chemical characteristics in different mango varieties including new accessions (2016)

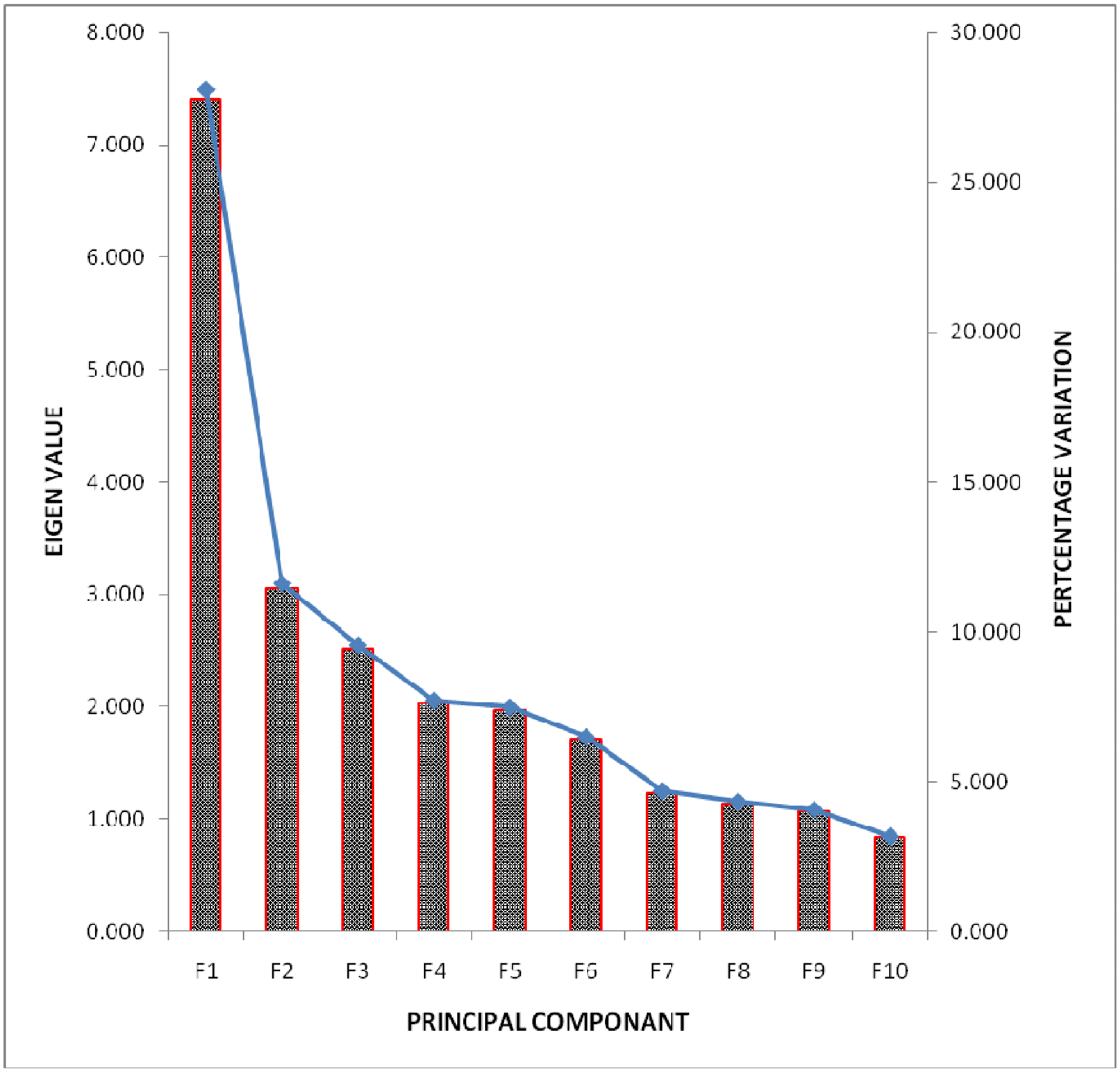


Fig. 4.12: Cattel's scree graph showing eigen value and percentage of variation for principal component based on analysis of morphological and physico-chemical characteristics in different mango varieties including new accessions (pooled data of 2014 and 2016)

Eigen value of 3.766 accounted for 13.94% of the total variability observed among the 40 mango varieties. PC3 had Eigen value of 2.156 and contributed 7.98% to the observed variability. Meanwhile, PC4, PC5, PC6 and PC7 had Eigen value 1.865, 1.648, 1.444, 1.234 and 0.897 and contributed 6.90, 6.10, 5.34, 4.57 and 3.32% of the total variability, respectively.

During the year 2016, the first eight components in the PCA analysis with eigen values (eigen root) more than unity contributed 83.01% of the variability among the varieties evaluated for different morphological and physico-chemical traits and other principal component (PC) had eigen value less than one (Table 4.30). The principal component one with eigen value of 7.238 contributed 26.80% of the total variability, while PC2 with eigen value of 3.109 accounted for 11.51% of the total variability observed among the 40 mango varieties. PC3 had eigen value of 3.330 and contributed 12.33% of the total variability. Meanwhile, PC4, PC5, PC6, PC7, PC8, PC9 and PC10 had eigen value 2.637, 1.851, 1.774, 1.407, 1.067, 0.999 and 0.773 and contributed 9.76, 6.85, 6.57, 5.21, 3.95, 3.70 and 2.86% of the total variability, respectively.

In pooled analysis of two year data, the first ten components in the PCA analysis with eigen values (eigen root) more than unity contributed 86.07% of the total variability among the varieties evaluated for different morphological and physico-chemical traits and other PC had eigen value less than one (Table 4.31). The principal component one with eigen value of 7.492 and contributed 27.74% of the total variability, while, PC2 with eigen value of 3.09 accounted for 11.46% of the total variability observed among the 40 mango varieties. PC3 had eigen value of 2.545 and contributed 9.42% of the total variability observed in different mango varieties. Meanwhile, PC4, PC5, PC6, PC7, PC8, PC9 and PC10 had eigen value 2.053, 1.994, 1.728, 1.249, 1.151, 1.084 and 0.846 and contributed 7.60, 7.38, 6.39, 4.62, 4.26, 4.01 and 3.13% of the total variability, respectively.

In the present investigation, principal component analysis was done on correlation matrix of important morphological and physico-chemical characteristics. Kaiser (1958) suggested to use only first three principal component because these components have eigen root more than unity and responsible for maximum amount of total genetic variance. But in the present investigation, the first three components accounted only 58.20, 50.65 and 48.64 per cent of the total variation during the year 2014, 2016 and in pooled analysis, respectively. Similarly Cattel's (1966) approach of scree graph test which suggests that only those components should be kept which followed a large gap in variances on scree graph as showed in Fig. 4.10, 4.11 and 4.12 for the year 2014, 2016 and pooled analysis, respectively.

The first four components in the present study account for only 65.10, 60.42 and 56.24 per cent of the total variance as per Cattle's criteria during the year 2014, 2016 and pooled analysis, respectively. These above mentioned two approaches of Kaiser (1958) and Cattle (1966) tend to give four components and lost at least one-fourth of the information. Thus, these approaches were thought to be inappropriate for the study.

Rao (1964) approach based on covering 90 per cent of the total variance seems to be more appropriate and, as such or with some modifications have been adopted by most of the earlier workers. Thus, first eight principal components which accounted for 84.45% during the year 2014 (Table 4.29), 89.57% during the year 2016 (Table 4.30) and 86.07% in pooled analysis (Table 4.31) of the total variation. Suggesting these principal components scores might be used to summarize the original 27 variables in any further analysis of the data on 40 mango varieties including new accessions in reduced dimension. Principal component analysis (PCA) has been widely used in plant science for a reduction of variables and grouping of genotypes (Khavari *et al.,* 2011). When dissimilarity between a pair of a variety is defined on a multivariate criterion, it is useful to be able to determine the specific plant characters which cause the dissimilarity and the relative contributions that the various characters make to the total variability in the germplasm (Ariyo, 1993).

Principal component analysis and factor analysis identified some similar characters as the most important for classifying the variation among the genotypes. The important variables are those which have high positive or negative relative weight values. For each principal axis, there are a number of characters contributing to the total variation Table 4.29 (2014), Table 4.30 (2016) and Table 4.31 (pooled analysis).

During the year 2014, first principal component had high positive component loading from stone with (0.295) followed by stone length (0.293) and fruit weight

(0.282) and exhibited high negative loading from pulp weight (-0.269) followed by number of fruits per tree at harvesting (-0.248) and ascorbic acid (-0.207). During the year 2016, highest positive principal component loading was observed from yield per tree (0.344) followed by stone weight (0.305) and stone with (0.277), while it was high negative from number of fruit per tree at harvesting (-0.311) followed by fruit weight (-0.231) and acidity (-0.208). According to pooled analysis, the major contributing characters for the diversity in the principal component one (PC1) was yield per tree (0.293) followed by stone weight (0.291) and stone length (0.285) for high positive loading while, pulp weight (-0.272) followed by number fruits per tree at harvesting (-0.252) and ascorbic acid (-0.049).

During the year 2014, second principal component had high positive component loading from pulp: stone ratio (0.317) followed by leaf length (0.283) and non reducing sugar (0.264) and have high negative loading from number of secondary rachis per panicle (-0.364) followed by acidity (-0.346) and peel weight (-0.255). During the year 2016, highest positive component loading was observed from width of inflorescence (0.391) followed by TSS (0.345) and length of inflorescence (0.327), while it was high negative loading from fruit weight (-0.237) followed by ascorbic acid (-0.226) and total sugar (-0.174). However, in pooled analysis, the second principal component had highest positive loading from total carotenoid (0.357) followed by ascorbic acid (0.315) and number of fruit per tree at harvesting (0.261) and maximum negative loading was due to number of secondary rachis per plant (-0.397) followed by duration of flowering (-0.315) and duration of panicle emergence (-0.207).

During the year 2014, third principal component had high positive component loading from width of inflorescence (0.484) followed by total carotenoid (0.474) and reducing sugar (0.215), while it was high negative loading from yield per tree (-0.349) followed by number of secondary rachis per panicle (-0.253) and pulp: stone ratio (-0.216). In second year (2016), highest positive component loading was observed from non reducing sugar (0.338) followed by stone length (0.335) and total carotenoid (0.285), while, it was high negative loading from number of secondary rachis per panicle (-0.332) followed by pulp: stone ratio (-0.311) and duration of panicle emergence (-0.264). However, in pooled analysis the third principal component had highest positive loading from reducing sugar (0.526) followed by TSS (0.427) and with of inflorescence (0.269), whereas, it was maximum negative loading from ascorbic acid (-0.263) followed by leaf width (-0.260) and pulp: stone ratio (-0.209).

On the basis of principal component analysis, from positive and negative loading value usually it is customary to choose one variable from each principal component (Ahmad *et al.,* 2014). Thus, the prominent characters coming together in different principal components and contributing towards explaining the variability have the tendency to remain together which may be kept into consideration during utilization of these characters in breeding programme. On the basis first three principal components during the year 2014, stone length is the best choice which had largest loading from the principal component one (PC1), pulp: stone ratio for the PC2 and width of inflorescence for PC3. During the year 2016, principal component one (PC1) showed high loading from yield per tree, width of inflorescence by the PC2 and non reducing sugar by PC3 which is further used for improvement programme. In pooled analysis, yield per tree had high component loading for component one, total carotenoid for second (PC2) and reducing sugar for PC3. The above findings suggested that first three principal components influence yield and biochemical traits which are responsible for improvement of yield as well as quality traits.

During the year 2014, fourth principal component had high positive component loading from duration of flowering (0.461) followed by length of inflorescence (0.448) and leaf width (0.287), while highest negative loading was from ascorbic acid (-0.340) followed by total sugar (-0.292) and peel weight (-0.259). During the year 2016, highest positive principal component loading was observed from stone length (0.355) followed by acidity (0.341) and leaf width (0.330), while high negative loading was from TSS (-0.339) followed by non reducing sugar (-0.330) and reducing sugar (-0.214). However, in pooled analysis, the fourth principal component had highest positive loading from acidity (0.476) followed by duration of panicle emergence (0.325) and leaf area (0.262), whereas, highest negative was loading from TSS (-0.267) followed by non reducing sugar (-0.265) and pulp: stone ratio (-0.235).

In the first year, fifth principal component had high positive component loading from peel weight (0.421) followed by total sugar (0.365) and leaf area (0.194), while, maximum negative was observed from duration of fruit maturity

(-0.571) followed by pulp weight (-0.253) and duration of panicle emergence (-0.165). In second year, highest positive principal component loading was observed from length of inflorescence (0.327) followed by total sugar (0.283) and duration of flowering (0.276), whereas, maximum negative loading was observed from duration of fruit maturity (-0.457) followed by leaf area (-0.308) and peel weight (-0.298). However, in pooled analysis, the fifth principal component had highest positive loading from length of inflorescence (0.514) followed by duration of flowering (0.340) and width of inflorescence (0.245), while, high negative loading was from duration of fruit maturity (-0.314) followed by ascorbic acid (-0.228) and fruit weight (-0.184).

During the year 2014, sixth principal component had high positive component loading from leaf length (0.306) followed by number of secondary rachis per panicle (0.221) and duration of fruit maturity (0.196), while, high negative was loading from duration of panicle emergence (-0.563) followed by total sugar (-0.340) and duration of flowering (-0.314). During the year 2016, highest positive principal component loading was observed from total sugar (0.451) followed by width of influences (0.328) and leaf area (0.266), whereas, high negative was observed from pulp weight (-0.431) followed by duration of flowering (-0.329) and duration of fruit maturity (-0.137). However, in pooled analysis, the sixth principal component had highest positive loading from leaf length (0.301) followed by pulp: stone ratio (0.248) and fruit width (0.233), while, high negative loading was observed from duration of panicle emergence (-0.414) followed by TSS (-0.330) and non reducing sugar (-0.314).

Similarly, when choosing one superior variable from the above principal component, during the year 2014, it was found that for fourth principal component duration of flowering was the best variable, which had the highest positive loading, while, fifth (PC5) and sixth (PC6) principal component had the highest loading for peel weight and leaf length, respectively. Therefore, these variables i.e., duration of flowering and peel weight contributing for appreciable diversity and can be used for selection. During the year 2016, fourth principal component stone length was the best variable, which had the highest positive loading, while, fifth (PC5) and sixth (PC6) principal component had the highest loading for length of inflorescence and total sugar, respectively. In pooled analysis, acidity, length of inflorescence and length of leaf had highest positive loading for component fourth, fifth and sixth, respectively.

The above findings indicate the contribution by fourth to sixth principal component suggested that these components weighted by duration of flowering and acidity traits could be responsible for quality improvement of fruit. PCA is the technique which identifies plant traits that contribute most of the observed variation within a group of genotypes. The tool has a practical application in the selection of parent lines for breeding purposes.

In the first year, seventh principal component had high positive component loading from leaf width (0.555) followed by leaf area (0.326), while, high negative from length of influences (-0.334) followed by duration of flowering (-0.328). In second year, highest positive principal component loading was observed from leaf length (0.380) followed by length of influences (0.247), while, maximum negative loading was recorded from duration of panicle emergence (-0.372) followed by leaf width (-0.343). However, the maximum positive loading was observed from non reducing sugar (0.463) followed by pulp stone ratio (0.358), while, highest negative loading was from duration of fruit maturity (-0.444) followed by duration of flowering (-0.259).

During the year 2014, eighth principal component had high positive component loading from duration of fruit maturity (0.323) followed by duration of panicle emergence (0.322), while, high negative from total carotenoid (-0.486) followed by leaf width (-0.270). During the year 2016, highest positive principal component loading was observed from number of secondary rachis per panicle (0.382) followed leaf length (0.329), while, maximum negative loading was recorded from pulp: stone ratio (-0.480) followed by stone weight (-0.239). However, the maximum positive loading was observed from number of secondary rachis per panicle (0.351) followed by width of inflorescence (0.306), while, highest negative loading was from duration of panicle emergence (-0.326) followed by fruit width (-0.296). Pulp: stone ratio (0.357) followed by duration of panicle emergence (0.310) exhibited high positive weight, whereas, high negative weight was noted for duration of flowering (-0.412) followed by leaf area (-0.322) for ninth principal component during the year 2016. High positive component loading exhibited fruit weight (0.395) followed by fruit width (0.307) and maximum negative loading was due to leaf width (-0.404) followed by pulp: stone ratio (-0.320) in pooled analysis of two year data.

Ascorbic acid (0.301) followed by pulp: stone ratio (0.165) exhibited high positive weight, whereas, high negative weight was noted for fruit weight (-0.524) followed by duration of flowering (-0.424) for tenth principal component during the year 2016. High positive component loading exhibited fruit width (0.359) followed by ascorbic acid (0.287) and maximum negative loading was due to fruit weight (-0.344) followed by stone width (-0.295) in pooled analysis of two year data.

The cumulative percentage of variation have been computed in Table 4.29, 4.30 and 4.31 during the year 2014, 2016 and pooled data of two year, respectively which showed that during the year 2014, two components together constituted more than half (50.21%) and first four together constituted approximately two-third (65.10%) of the total variations present in the original data units, while first eight components together explained 84.45% variance of the original data units. During the year 2016, two components together constituted less than half (38.32%), while, first three together constituted more than half (50.65%) and first four together constituted approximately two-third (60.42%) of the total variations present in the original data units, whereas, first ten components together explained 89.57% variance of the original data units. In pooled analysis of two year data, three components together constituted less than half (48.64%), while, first four together constituted more than half (56.24%) and first five together constituted approximately two-third (63.63%) of the total variations present in the original data units, while first ten components together explained 86.07% variance of the original data units.

The similar findings have also been reported by Majumder *et al.* (2013), Singh *et al.* (2015), Krishnapillai and Wilson (2016) and Singh *et al.* (2016), in mango. According to Chahal and Gosal (2002) characters with largest absolute value closer to unity within the first principal component influence the clustering more than those with lower absolute value closer to zero. The principal component had positive and negative loading of factor. It shows the presence of positive and negative correlation trends between the components and variables. Therefore, the above mentioned characters which load positively or negatively contributed more to the diversity and they were the ones that most differentiated the clusters.

As suggested by Rao (1964), the principal components covering 90 per cent of total variation seemed to be sufficient and useful. In the present investigation, 90

Per cent variations are covered by first eight components during the year 2014 and ten during the 2016 as well as pooled analysis. Rest of the components contributed very small amount of per cent variation and they are not much responsible for significant variability among the varieties. Principal component analysis (PCA) is defined as ''a method of data reduction to clarify the relationship between two or more characters and to divide the total variance of the original characters into a limited number of uncorrelated new variables (Wiley, 1981).

PCA is concerned with the variances and covariance of the element of a random vector. The objective of principal component analysis used in this study was to construct new variables and replace the original variables with some as new variables which are index of the original ones. Principal component analysis is optimized in the sense that the information lost during formation of new variables from original is kept to a minimum. With this objective of principal component analysis, the large multidimensional data of present study was condensed into manageable number of new variables, without losing any vital information about the original data. They provide a different angle of viewing the original data and may disclose their nature of variation in a multivariate sense.

4.3.1.2 Grouping of varieties based on principal component analysis

The average data concerning varieties are analyzed by using the principal component analysis (PCA). The first principal component accounts for utmost variability in the data with respect to following components (Leilah and Al-khateeb, 2005). Principal component analysis reflects the amount of the largest contributor of the total variation at every axis of differentiation (Sharma, 1996).

Grouping of 40 mango varieties based on principal component analysis (PCA) into two groups during the first year and pooled analysis of two year data which comprised 39 varieties in the first group and reaming one in second groups. Three groups are formed during the year 2016, which comprised 38 varieties in group one and reaming one variety in second and third groups, respectively. These groups are formed on the basis of correlation matrix of morphological and physco-chemical traits among the varieties which are presented in Fig. 4.13 and 4.14 for the year 2014, Fig. 4.15 and 4.16 for the year 2016 and Fig. 4.17 and 4.18 for pooled data of 2014 and

2016, respectively. The data in relation to grouping of varieties based on PCA are presented in Table 4.32 (2014), Table 4.33 (2016) and Table 4.34 (pooled over years). As it has been found that the varieties are interrelated, so to have an idea about their independent impact, principal component analysis was undertaken.

During the year 2014, the first and second principal components (PC1 and PC2) had positive loading from most the varieties and third principal component had (PC3) negative loading from most of the varieties except Amrapali, Mallika, Arunika and Angoor Lata. The range of variability for different varieties varied from 10.47 to 81% in principal components one (PC1) followed by second principal component ranged from 17.35 to 43.28% of the total variability, respectively. The principal component one (PC1) had highest positive component loading from Bangalora (81.31%) followed by Sensation (74.55%) and Mallika (72.95%), which comprised 39 varieties in first group, while, lowest component loading was recorded from Angoor Lata (10.47%) which comprised in second group.

During the year 2016, the first, second and third principal components (PC1, PC2 and PC3) had positive component loading from most the varieties, whereas, PC3 had few negative component loading from Bombay green, Gourav, Sukul, Dilpasand, Surkha Khal, , Burma Surkh, Chandrakaran and Tilka Bhadainya. The range of variability for different varieties varied from 26.20 to 66.99% in principal components one (PC1) followed by second principal component ranged from 5.84 to 23.45% of the total variability, respectively. The principal component one (PC1) had highest positive component loading from Sensation (66.99%) followed by Sukul (65.97%) and Bangalora (65.00%), which comprised 38 varieties in first group, while, lowest component loading was recorded from Angoor Lata (26.20%) which comprised in second group.

In pooled analysis of two year data, the first, second and third principal components (PC, PC2 and PC3) had shown positive component loading from most the varieties, whereas, third principal component had (PC3) negative loading from Bangalora. The range of variability for different varieties varied from 8.63 to 30.92% in principal components one (PC1) followed by second principal component ranged from 2.81 to 13.16% of the total variability, respectively. The principal component one (PC1) had shown highest positive component loading from Bangalora (30.92%)

Table 4.32: Principal component analysis (PCA) for first three components of mango varieties including new accessions based on different morphological and physico-chemical characteristics (2014)

S.No.	Varieties /accession	PC1	PC2	PC3
1	Dashehari	33.614	35.171	-2.263
2	Dashehari 35	34.575	38.561	-6.246
3	Dashehari 51	33.221	43.287	-6.995
4	Langra	56.710	31.191	-1.978
5	Chausa	65.553	27.214	-3.509
6	Bombay Green	53.251	22.250	-4.288
7	Pant Sinduri	53.236	29.511	-6.233
8	Pant Chandra	48.793	25.779	-2.801
9	PMSS-1	60.304	28.728	-5.837
10	Amrapali	50.268	27.971	9.153
11	Mallika	72.959	27.365	0.081
12	Pusa Arunima	62.124	37.209	-5.070
13	Pusa Surya	66.810	22.317	-5.163
14	Arka Neelkiran	62.592	17.352	-3.417
15	Ambika	70.021	26.535	-2.103
16	Arunika	53.208	19.243	1.371
17	Neeluddin	58.817	23.297	-1.507
18	Neeleshan	59.934	25.421	-1.626
19	Neelgoa	68.419	24.424	-6.748
20	A.U. Rumani	46.995	30.102	-5.786
21	Swarna Jehangir	57.411	17.356	-4.364
22	Ratna	63.368	22.013	-2.795
23	Sabri	54.402	22.562	-6.681
24	Bangalora	81.317	25.362	-1.633
25	Totapuri Red Small	43.181	24.267	-1.196
26	Angoor Lata	10.470	23.707	3.102
27	Saurabh	63.568	26.270	-4.709
28	Rajiv	36.307	33.437	-10.356
29	Gourav	59.940	25.515	-7.413
30	Himanshu	54.541	38.512	-15.280
31	Sukul	68.639	22.799	-8.592
32	Van Raj	71.930	23.788	-8.786
33	Dilpasand	59.980	25.804	-8.199
34	Himsagar	55.367	27.977	-2.551
35	Tilka Bhadainya	44.303	22.372	-7.868
36	Chandrakaran	51.750	18.435	-5.678
37	Surkha Khal	52.550	23.943	-2.467
38	Burma Surkh	50.407	27.096	-8.326
39	Sensation	74.552	26.970	-4.279
40	Tommy Atkins	72.369	18.246	-4.970

Table 4.33: Principal component analysis (PCA) for first three components of mango varieties including new accessions based on different morphological and physico-chemical characteristics (2016)

S. No.	Varieties /accession	PC1	PC2	PC3
1	Dashehari	38.657	5.913	32.173
2	Dashehari 35	39.748	7.054	33.830
3	Dashehari 51	38.332	7.647	35.326
4	Langra	59.146	2.722	32.828
5	Chausa	62.130	4.393	36.020
6	Bombay Green	56.142	-2.855	30.850
7	Pant Sinduri	52.601	10.599	22.640
8	Pant Chandra	53.592	3.074	25.223
9	PMSS-1	54.035	23.451	29.065
10	Amrapali	52.423	15.106	33.818
11	Mallika	64.026	4.348	41.068
12	Pusa Arunima	63.904	5.973	41.139
13	Pusa Surya	61.306	0.370	33.406
14	Arka Neelkiran	58.477	5.471	25.847
15	Ambika	63.627	10.112	28.786
16	Arunika	56.130	8.758	27.701
17	Neeluddin	57.775	7.044	30.050
18	Neeleshan	57.222	6.782	28.986
19	Neelgoa	64.940	1.833	29.061
20	A.U. Rumani	45.250	8.248	27.596
21	Swarna Jehangir	57.382	4.866	23.910
22	Ratna	64.747	2.000	28.752
23	Sabri	57.024	2.491	27.471
24	Bangalora	65.001	1.959	26.715
25	Totapuri Red Small	46.597	5.472	26.351
26	Angoor Lata	26.208	4.742	26.560
27	Saurabh	58.087	8.694	28.058
28	Rajiv	41.591	4.414	20.216
29	Gourav	58.801	-3.431	32.176
30	Himanshu	55.659	3.950	30.807
31	Sukul	65.975	-1.210	29.847
32	Van Raj	64.196	2.383	28.479
33	Dilpasand	57.833	-5.843	30.550
34	Himsagar	61.336	8.000	27.449
35	Tilka Bhadainya	48.644	-1.895	23.166
36	Chandrakaran	57.995	-3.219	19.773
37	Surkha Khal	59.533	-1.755	26.304
38	Burma Surkh	55.312	-3.129	26.570
39	Sensation	66.991	3.329	35.704
40	Tommy Atkins	64.384	2.878	20.771

Table 4.34: Principal component analysis (PCA) for first three components of mango varieties including new accessions based on different morphological and physico-chemical characteristics (pooled data of 2014 and 2016)

S. No.	Varieties /accession	PC1	PC2	PC3
1	Dashehari	16.090	11.596	3.214
2	Dashehari 35	16.482	11.865	3.148
3	Dashehari 51	16.657	13.396	2.001
4	Langra	23.246	10.513	2.350
5	Chausa	26.514	10.283	2.013
6	Bombay Green	20.720	6.968	2.114
7	Pant Sinduri	20.757	6.123	5.458
8	Pant Chandra	20.033	6.757	4.457
9	PMSS-1	24.918	9.200	5.126
10	Amrapali	22.538	12.332	8.348
11	Mallika	28.011	12.262	5.042
12	Pusa Arunima	26.577	13.163	4.536
13	Pusa Surya	25.533	7.974	4.415
14	Arka Neelkiran	23.686	3.472	7.515
15	Ambika	27.498	8.050	5.740
16	Arunika	22.287	5.844	8.680
17	Neeluddin	22.659	7.296	7.900
18	Neeleshan	23.166	7.860	6.775
19	Neelgoa	26.418	5.919	4.350
20	A.U. Rumani	18.833	7.639	6.101
21	Swarna Jehangir	21.208	3.224	7.729
22	Ratna	25.217	5.896	5.845
23	Sabri	21.126	3.994	6.094
24	Bangalora	30.926	8.098	-0.020
25	Totapuri Red Small	18.544	8.984	3.661
26	Angoor Lata	8.636	8.419	5.334
27	Saurabh	24.179	7.174	5.831
28	Rajiv	16.064	6.382	2.902
29	Gourav	23.840	7.970	1.317
30	Himanshu	22.365	10.051	1.517
31	Sukul	26.334	7.468	0.592
32	Van Raj	26.781	4.664	3.860
33	Dilpasand	22.074	8.062	1.325
34	Himsagar	22.895	6.483	6.708
35	Tilka Bhadainya	18.292	6.158	1.828
36	Chandrakaran	19.545	2.913	2.693
37	Surkha Khal	21.236	6.071	3.700
38	Burma Surkh	19.692	6.700	2.883
39	Sensation	29.448	9.856	3.228
40	Tommy Atkins	27.664	2.817	4.001

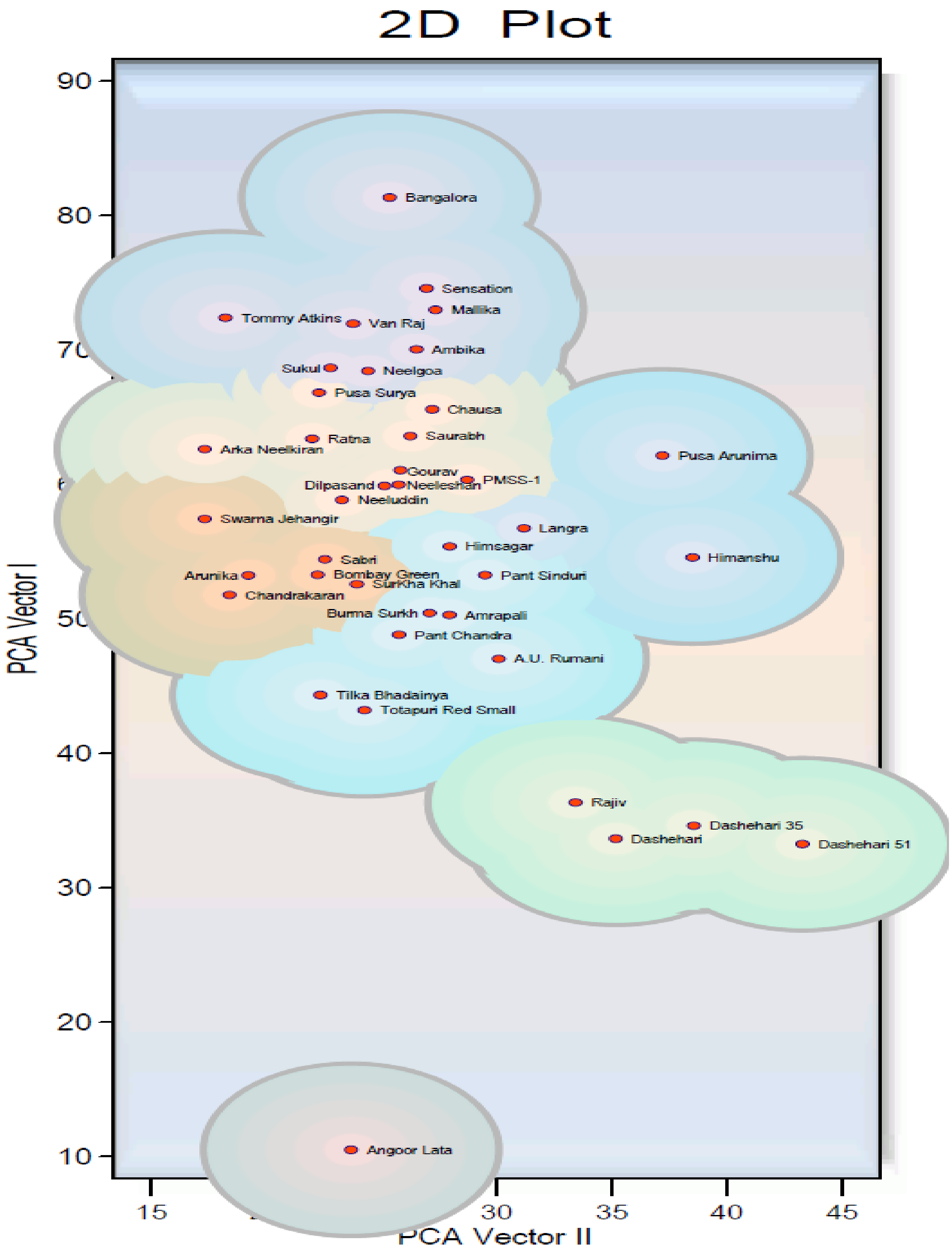


Fig. 4.13: Two dimensional PCA plot based on the first two components of varieties including new accessions of mango (2014)

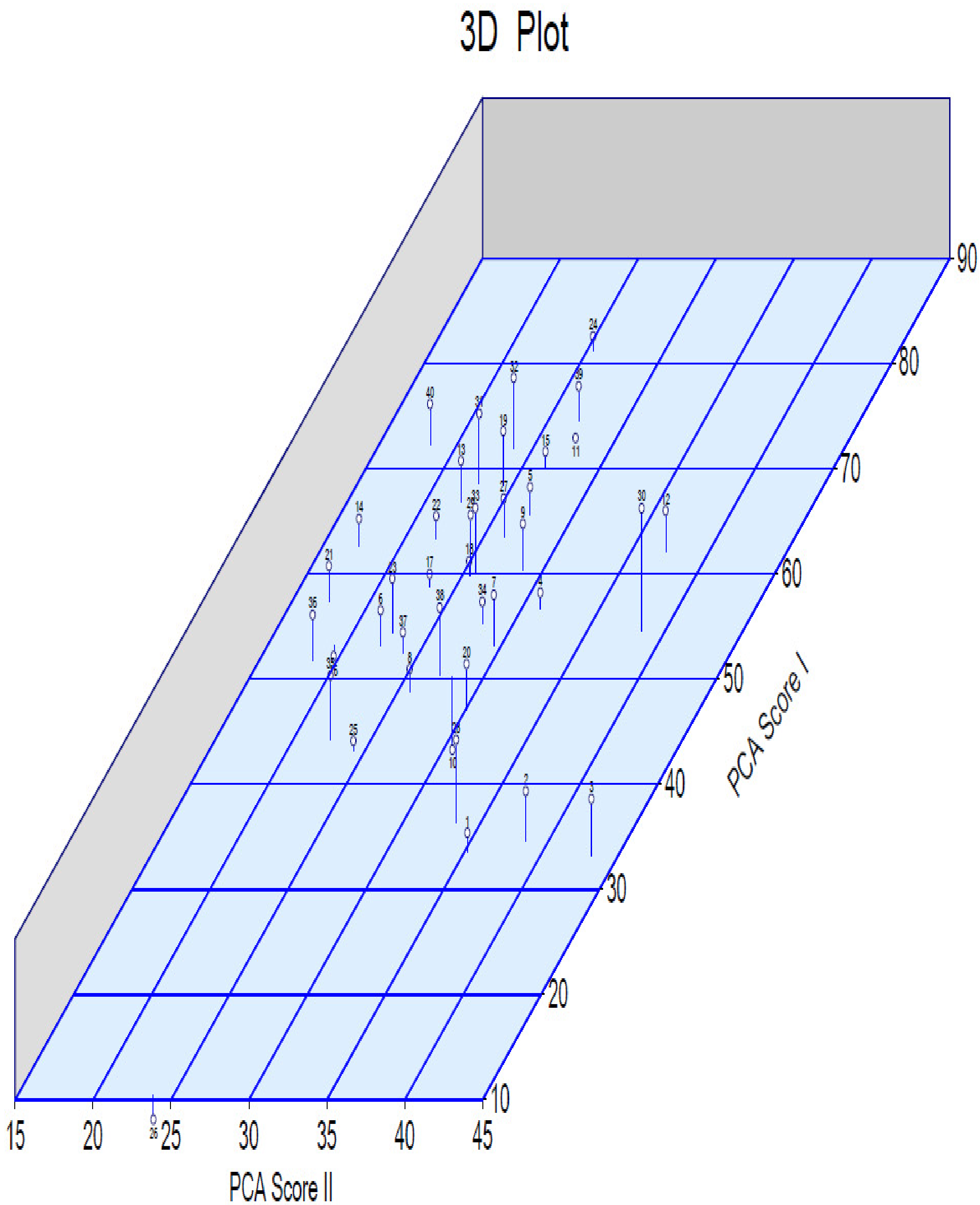


Fig. 4.14: Three dimensional PCA plot based on the first two components of mango varieties (2014)**:** 1. Dashehari, 2. Dashehari, 3. Dashehari 51, 4. Langra, 5. Chausa, 6. Bombay Green, 7. Pant Sinduri, 8. Pant Chandra, 9. PMSS-1, 10. Amrapali, 11. Mallika, 12. Pusa Arunima, 13. Pusa Surya, 14. Arka Neelkiran, 15. Ambika, 16. Arunika, 17. Neeluddin, 18.Neeleshan, 19. Neelgoa, 20. A.U. Rumani, 21. Swarna Jehangir, 22. Ratna, 23. Sabri, 24. Banglora, 25. Totapuri Red Small, 26. Angoor Lata, 27. Saurabh, 28. Rajiv, 29. Gourav, 30. Himanshu, 31. Sukul, 32. Van Raj, 33. Dilpasand, 34. Himsagar, 35. Tilka Bhadainya, 36. Chandrakaran, 37. Surkha Khal, 39. Sensation, 40. Tommy Atkins.

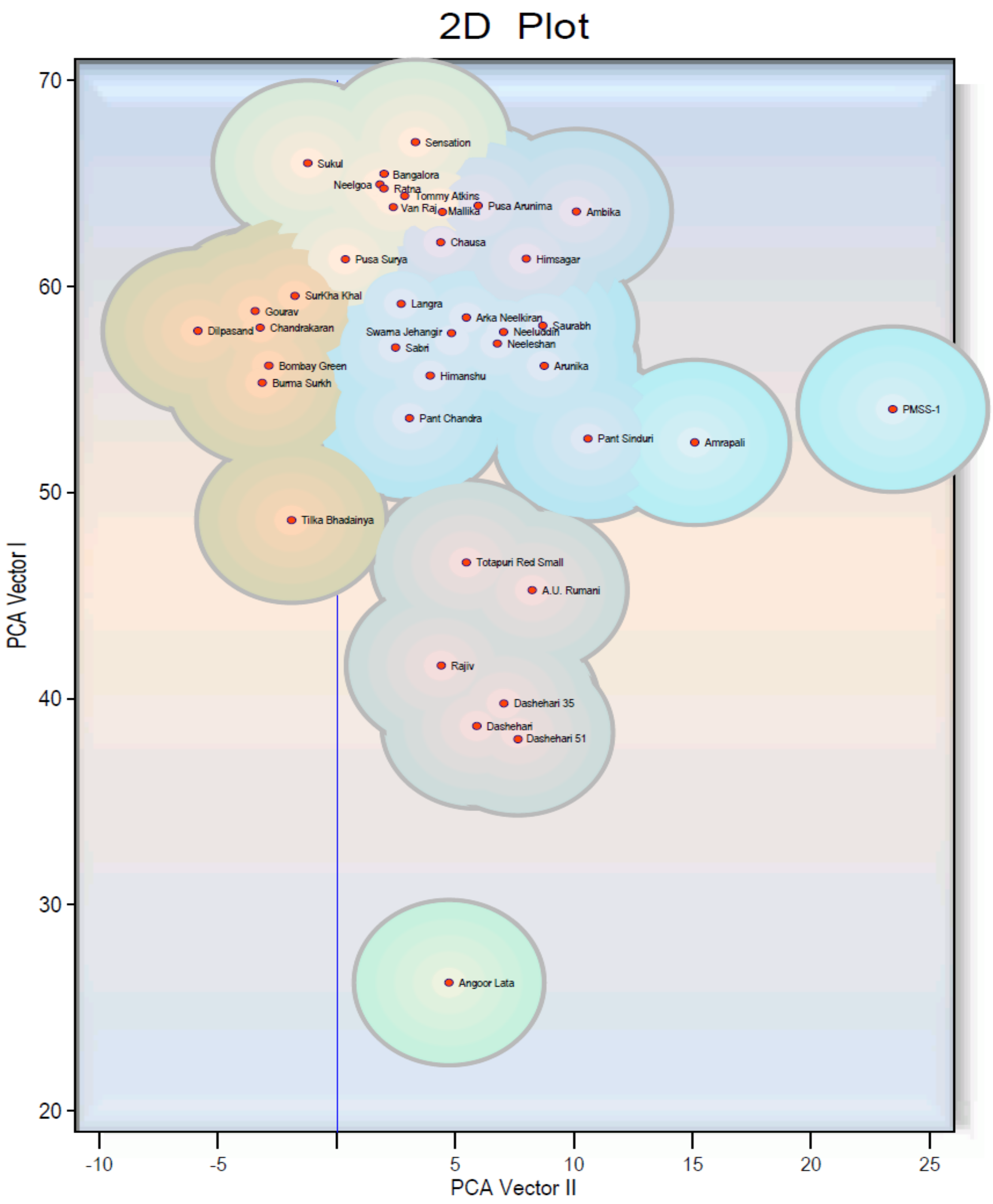


Fig. 4.15: Two dimensional PCA plot based on the first two components of varieties including new accessions of mango (2016)

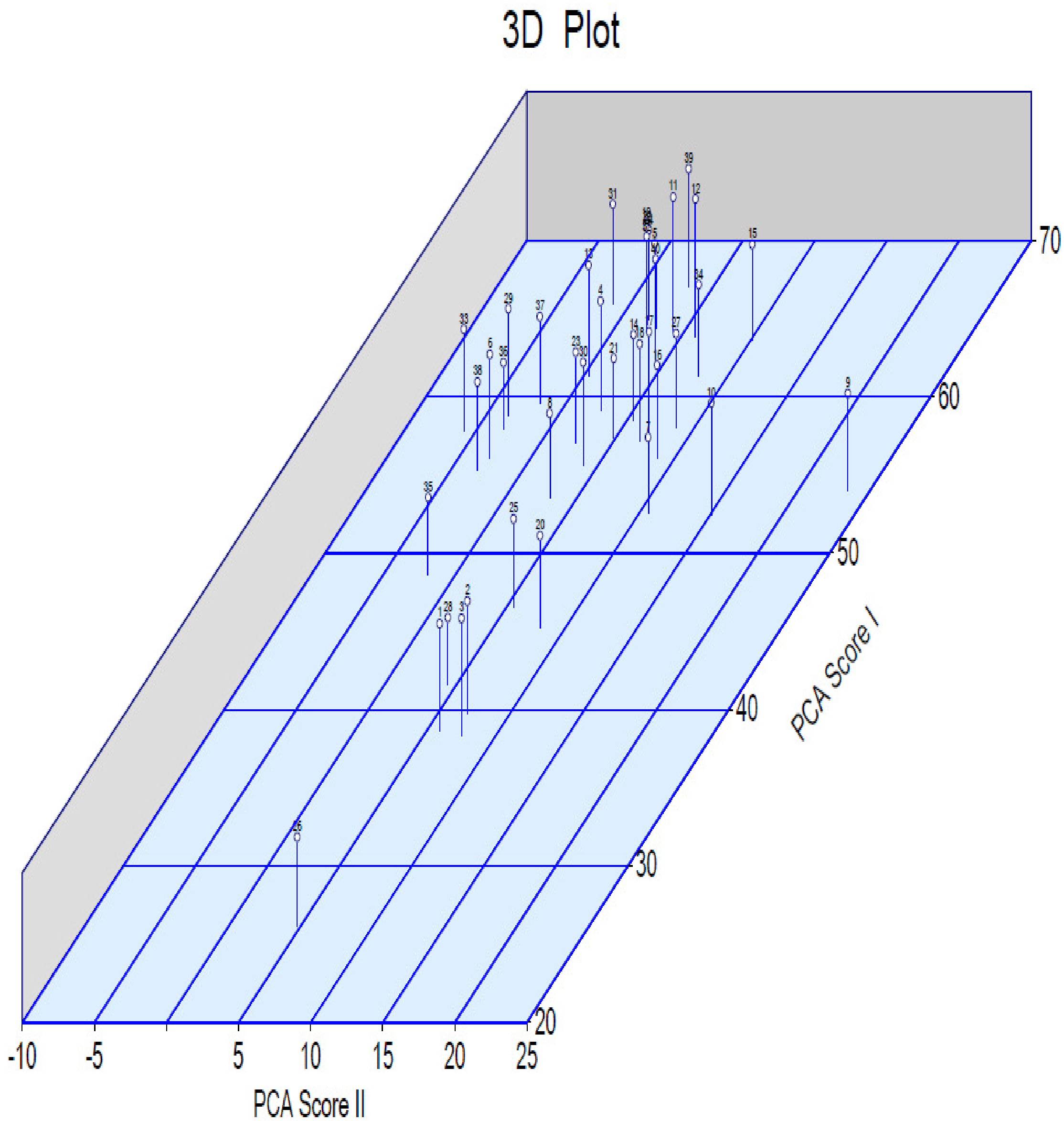


Fig. 4.16: Three dimensional PCA plot based on the first two components of mango varieties (2016)**:** 1. Dashehari, 2. Dashehari, 3. Dashehari 51, 4. Langra, 5. Chausa, 6. Bombay Green, 7. Pant Sinduri, 8. Pant Chandra, 9. PMSS-1, 10. Amrapali, 11. Mallika, 12. Pusa Arunima, 13. Pusa Surya, 14. Arka Neelkiran, 15. Ambika, 16. Arunika, 17. Neeluddin, 18.Neeleshan, 19. Neelgoa, 20. A.U. Rumani, 21. Swarna Jehangir, 22. Ratna, 23. Sabri, 24. Banglora, 25. Totapuri Red Small, 26. Angoor Lata, 27. Saurabh, 28. Rajiv, 29. Gourav, 30. Himanshu, 31. Sukul, 32. Van Raj, 33. Dilpasand, 34. Himsagar, 35. Tilka Bhadainya, 36. Chandrakaran, 37. Surkha Khal, 39. Sensation, 40. Tommy Atkins.

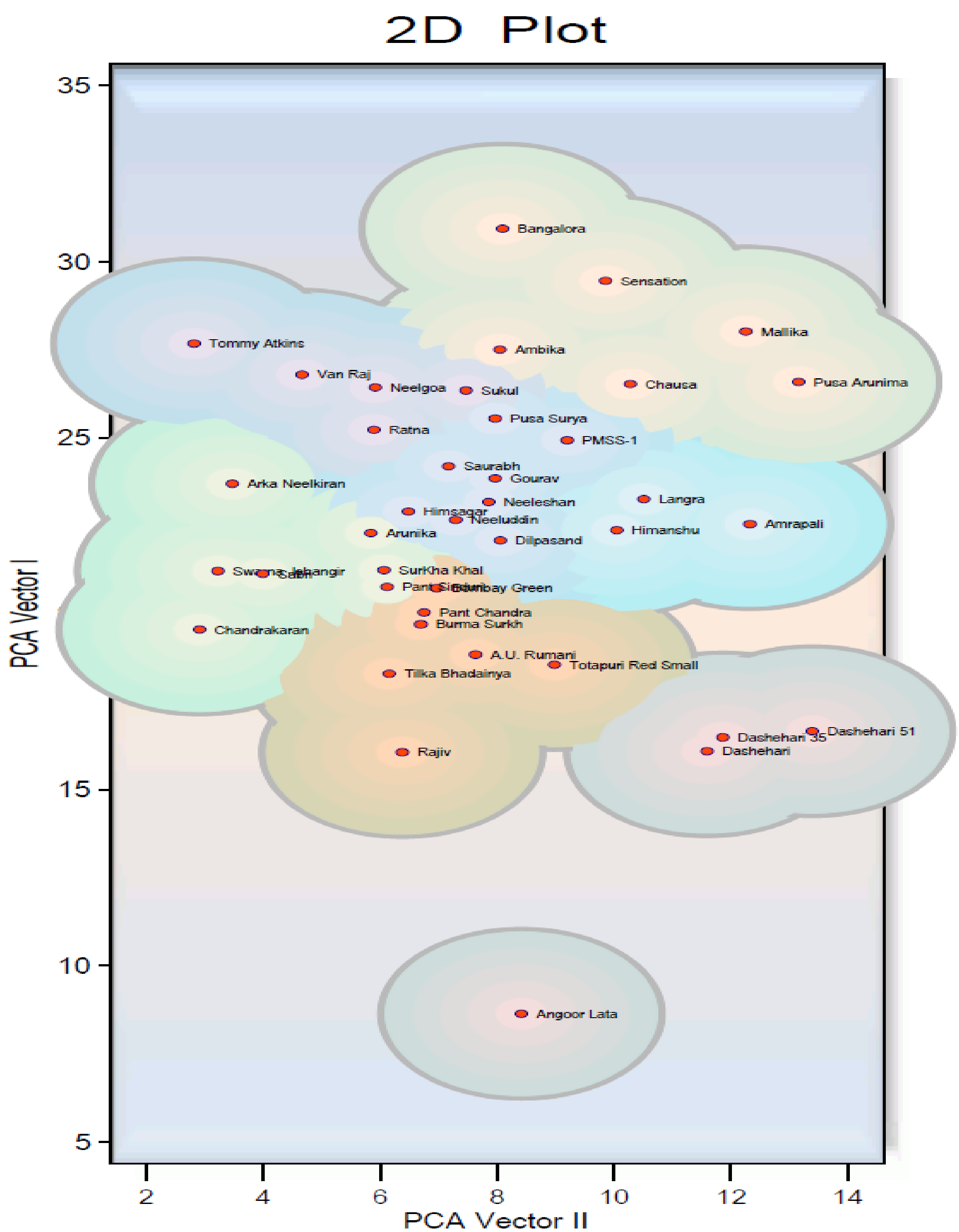


Fig. 4.17: Two dimensional PCA plot based on the first two components of varieties including new accessions of mango (pooled data of 2014 and 2016)

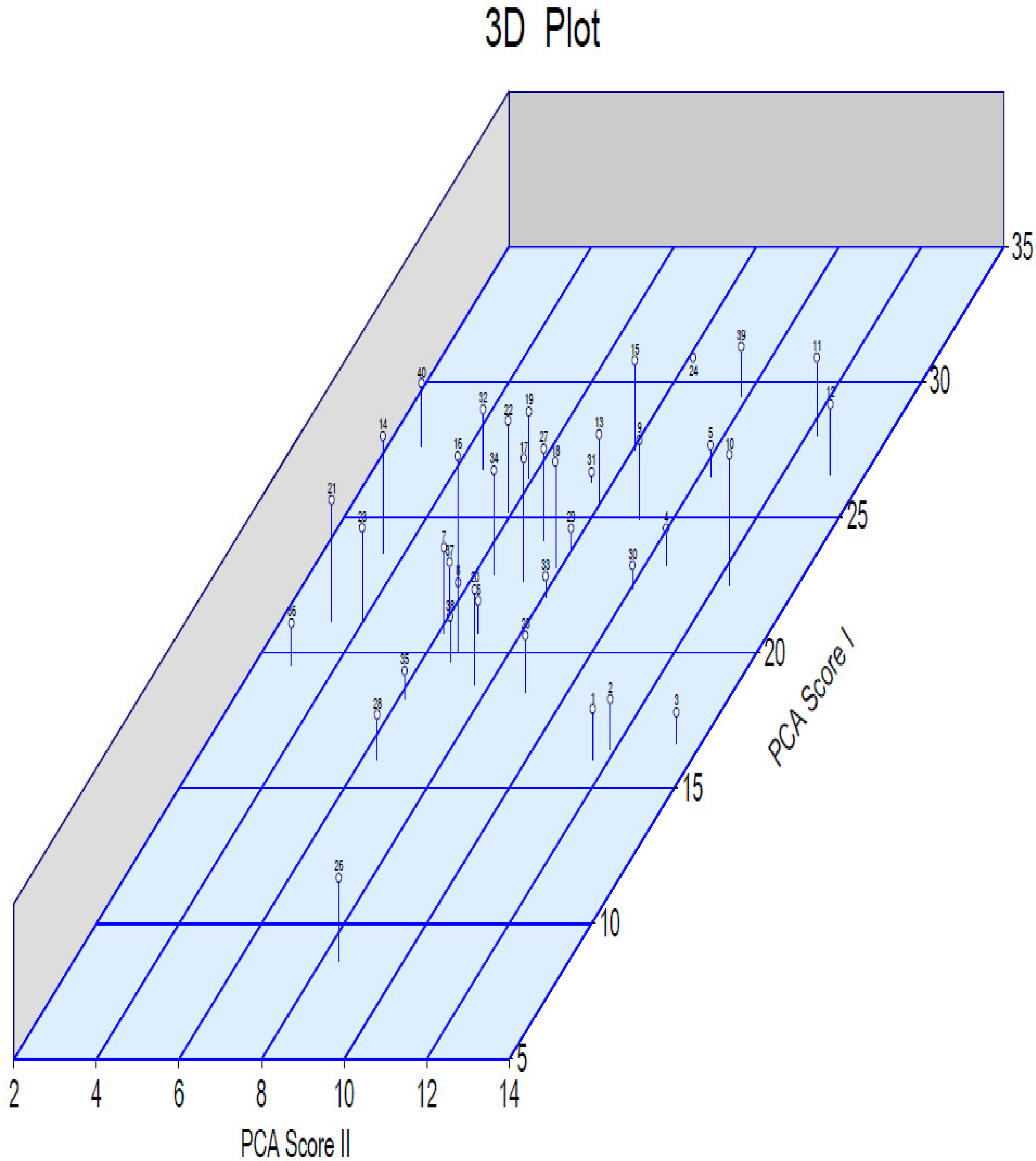


Fig. 4.18: Three dimensional PCA plot based on the first two components of mango varieties (pooled data of 2014 and 2016)**:** 1. Dashehari, 2. Dashehari, 3. Dashehari 51, 4. Langra, 5. Chausa, 6. Bombay Green, 7. Pant Sinduri, 8. Pant Chandra, 9. PMSS-1, 10. Amrapali, 11. Mallika, 12. Pusa Arunima, 13. Pusa Surya, 14. Arka Neelkiran, 15. Ambika, 16. Arunika, 17. Neeluddin, 18.Neeleshan, 19. Neelgoa, 20. A.U. Rumani, 21. Swarna Jehangir, 22. Ratna, 23. Sabri, 24. Banglora, 25. Totapuri Red Small, 26. Angoor Lata, 27. Saurabh, 28. Rajiv, 29. Gourav, 30. Himanshu, 31. Sukul, 32. Van Raj, 33. Dilpasand, 34. Himsagar, 35. Tilka Bhadainya, 36. Chandrakaran, 37. Surkha Khal, 39. Sensation, 40. Tommy Atkins.

followed by Sensation (29.44%) and Mallika (28.01%), which comprised 39 varieties in first group, while, lowest component loading was recorded from Angoor Lata (8.63%) which comprised in second group.

4.3.1.3 Interaction PCA-BiPlot (AMMI 2) between genotypes and environments

To study the genotypic and environmental main effects and their interactions, AMMI 2 biplots are constructed for all genotypes and presented in Fig. 4.19 (2014) and Fig. 4.20 (2016). The IPCA1 versus IPCA2 biplot (AMMI 2), explain the degree of interaction of genotypes and environments. The genotypes and environments furthest from the origin being more responsive fit the worst. Genotypes and environments that fall into the same sector interact positively; negatively if they fall into opposite sectors (Anandan *et al.,* 2009). To know the responsive and stable genotypes, the basic principal is that genotypes and environments that are farthest from the origin being more responsive fit the worst. The closer genotypes score to the center of the biplot are more stable than the score of the genotypes away from the center. The angles between the genotype and environment vectors determine the nature of the interaction if angle is acute, response is positive means responsive; if right angles, negligible response and if there is obtuse angles, response is negative. At the same time, the angle formed by the vectors of two environments provides an estimate of their correlation. The similar result has been reported by Aliyu *et al.* (2014).

4.3.2 Genetic Divergence through Mahalnobis' D^2 Statistics

The genetic divergence analysis was done by following Mahalnobis' D^2 statistics as described by Rao (1952).

4.3.2.1 Group constellation

Based on D^2 value, the constellations of varieties into different clusters are done by following Tocher's method (Rao, 1952). All the 40 mango varieties were grouped in to 7 clusters (Table 4.35). The dendrogram represents different varieties including new accessions into seven clusters on the basis of morphological and physico-chemical characteristics according to Mahalnobis' Euclidean distance during the year 2014 (Fig. 4.24), 2016 (Fig. 4.25) and pooled data of 2014 and 2016 (Fig. 4.26), respectively. Intra-cluster distances showed divergence among the genotypes within a cluster, while, inter-cluster distances exhibited relative divergence between the clusters. Intra and inter-cluster distances are presented in Table 4.36 and 4.37. The cluster wise description of 40 varieties has been below:

Based on group constellation during the year 2014, all the 40 mango varieties including new accessions were grouped in seven clusters. The cluster I comprised 4 varieties namely, Dashehari, Dashehari 35, Dashehari 51, Rajiv, while, cluster II had 25 varieties namely, Neeluddin, Neeleshan, Swarna Jehangir, Arka Neelkiran, Sabri, Ratna, Arunika, Surkha Khal, Pant Chandra, Burma Surkh, Bombay Green, Himsagar, Chandrakaran, Pant Sinduri, Gourav, Langra, Dilpasand, Saurabh, Neelgoa, Pusa Surya, Ambika, Chausa, Tilka Bhadainya, A.U. Rumani, Totapuri Red Small, whereas, cluster III had 7 varieties namely, Mallika, Sensation, Sukul, Van Raj, Bangalora, Tommy Atkins, Pusa Arunima, while cluster IV, V, VI and VII had one varieties each *viz.,* PMSS-1, Himanshu, Amrapali and Angoor Lata, respectively.

The 40 mango varieties including new accessions studied in the year 2016 have been grouped into seven clusters. The cluster I comprised of 4 varieties namely, Dashehari, Dashehari 35, Dashehari 51, A.U. Rumani, while cluster II comprised 23 varieties namely, Neeluddin, Neeleshan, Arunika, Arka Neelkiran, Swarna Jehangir, Sabri, Himsagar, Neelgoa, Surkha Khal, Ratna, Van Raj, Pusa Surya, Burma Surkh, Bombay Green, Pant Chandra, Gourav, Langra, Saurabh, Tommy Atkins, Sukul, Chandrakaran, Dilpasand, Ambika, whereas cluster III had four varieties, Totapuri Red Small, Tilka Bhadainya, Himanshu, Pant Sinduri, while, cluster IV also comprised 6 varieties namely Pusa Arunima, Sensation, Mallika, Chausa, Bangalora, Amrapali. Cluster V, VI and VII had one variety each *viz.,* Rajiv, Angoor Lata and PMSS-1, respectively.

Based on pooled over two year's data analysis, 40 mango varieties including new accessions were grouped into seven clusters. The cluster I comprised of 4 varieties namely, Dashehari, Dashehari 35, Dashehari 51, A.U. Rumani, while, cluster II comprised 24 varieties namely, Neeluddin, Neeleshan, Arka Neelkira, Arunika, Swarna Jehangir, Sabri, Ratna, Neelgoa, Surkha Khal, Pant, Chandra, Burma Surkh, Himsagar, Bombay Green, Chandrakaran, Dilpasand, Pusa Surya, Gourav, Tilka Bhadainya, Langra, Tommy Atkins, Saurabh, Ambika, Pant Sinduri, Totapuri Red Small and cluster III also comprised 8 mango varieties namely, Mallika, Sensation, Pusa Arunima, Sukul, Chausa, PMSS-1, Van Raj, Bangalor. Cluster IV, V, VI and

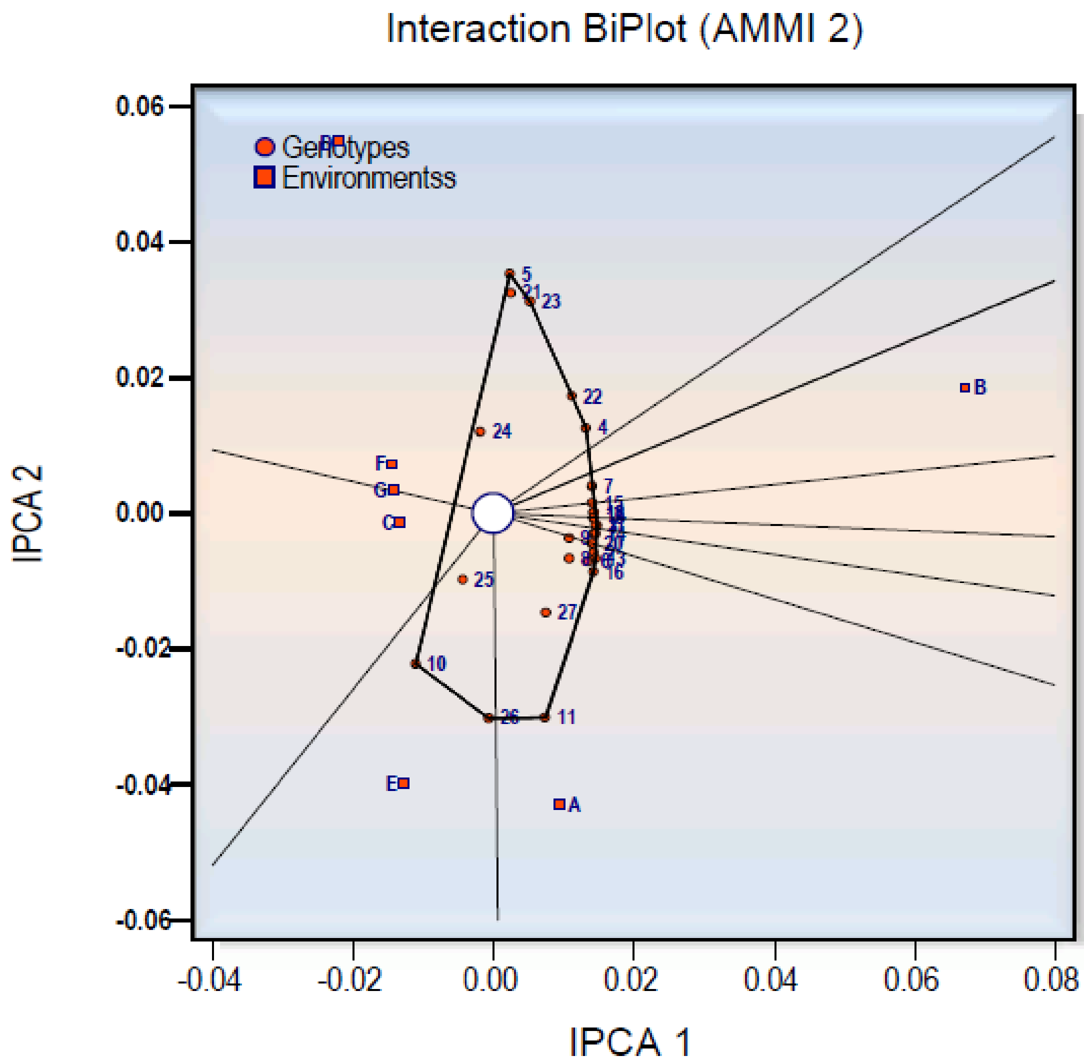


Fig. 4.19: PCA bi-plot showing the relative positions of mango varieties/accessions (during the year 2014) **:** 1. Dashehari, 2. Dashehari, 3. Dashehari 51, 4. Langra, 5. Chausa, 6. Bombay Green, 7. Pant Sinduri, 8. Pant Chandra, 9. PMSS-1, 10. Amrapali, 11. Mallika, 12. Pusa Arunima, 13. Pusa Surya, 14. Arka Neelkiran, 15. Ambika, 16. Arunika, 17. Neeluddin, 18.Neeleshan, 19. Neelgoa, 20. A.U. Rumani, 21. Swarna Jehangir, 22. Ratna, 23. Sabri, 24. Banglora, 25. Totapuri Red Small, 26. Angoor Lata, 27. Saurabh, 28. Rajiv, 29. Gourav, 30. Himanshu, 31. Sukul, 32. Van Raj, 33. Dilpasand, 34. Himsagar, 35. Tilka Bhadainya, 36. Chandrakaran, 37. Surkha Khal, 39. Sensation, 40. Tommy Atkins.

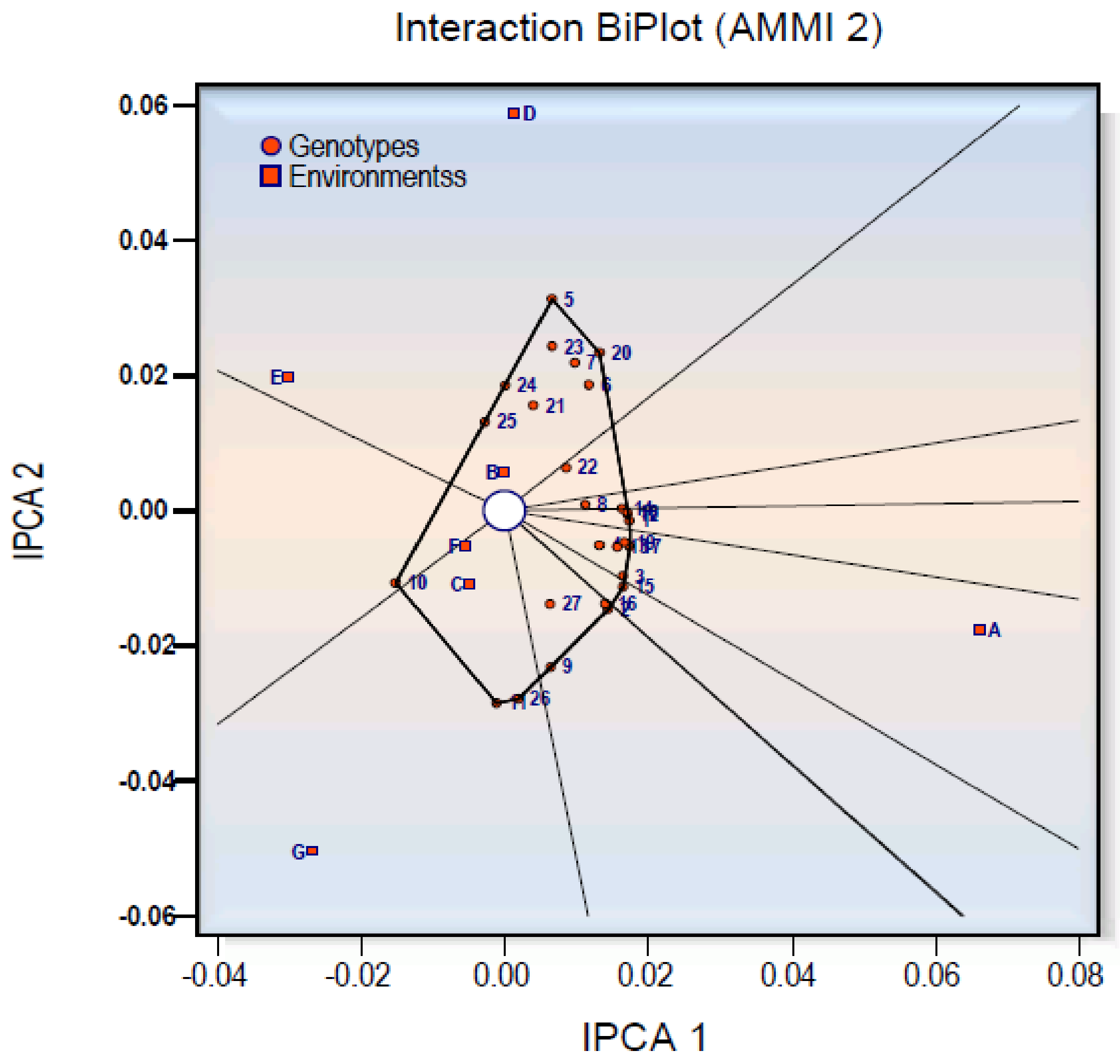


Figure 4.20: PCA bi-plot showing the relative positions of mango varieties/accessions (during the year 2016)**:** 1. Dashehari, 2. Dashehari, 3. Dashehari 51, 4. Langra, 5. Chausa, 6. Bombay Green, 7. Pant Sinduri, 8. Pant Chandra, 9. PMSS-1, 10. Amrapali, 11. Mallika, 12. Pusa Arunima, 13. Pusa Surya, 14. Arka Neelkiran, 15. Ambika, 16. Arunika, 17. Neeluddin, 18.Neeleshan, 19. Neelgoa, 20. A.U. Rumani, 21. Swarna Jehangir, 22. Ratna, 23. Sabri, 24. Banglora, 25. Totapuri Red Small, 26. Angoor Lata, 27. Saurabh, 28. Rajiv, 29. Gourav, 30. Himanshu, 31. Sukul, 32. Van Raj, 33. Dilpasand, 34. Himsagar, 35. Tilka Bhadainya, 36. Chandrakaran, 37. Surkha Khal, 39. Sensation, 40. Tommy Atkins.

Table 4.35: Cluster pattern of different mango varieties including new accessions on the basis of Mahalnobis' D^2 analysis

Cluster number	Year	Varieties/accessions	Number of Varieties/ accession
I	2014	Dashehari , Dashehari 35, Dashehari 51, Rajiv	4
	2016	Dashehari, Dashehari 35, Dashehari 51, A.U. Rumani	4
	Pooled	Dashehari, Dashehari 35, Dashehari 51, A.U. Rumani	4
II	2014	Neeluddin, Neeleshan, Swarna Jehangir, Arka Neelkiran, Sabri, Ratna, Arunika Surkha Khal, Pant Chandra, Burma Surkh, Bombay Green, Himsagar, Chandrakaran, Pant Sinduri, Gourav, Langra, Dilpasand, Saurabh, Neelgoa, Pusa Surya, Ambika, Chausa, Tilka Bhadainya, A.U. Rumani, Totapuri Red Small	25
	2016	Neeluddin, Neeleshan, Arunika, Arka Neelkiran, Swarna Jehangir, Sabri, Himsagar, Neelgoa, Surkha Khal, Ratna, Van Raj, Pusa Surya, Burma Surkh, Bombay Green, Pant Chandra, Gourav, Langra, Saurabh, Tommy Atkins, Sukul, Chandrakaran, Dilpasand, Ambika	23
	Pooled	Neeluddin, Neeleshan, Arka Neelkira, Arunika, Swarna Jehangir, Sabri, Ratna, Neelgoa, Surkha Khal, Pant,Chandra, Burma Surkh, Himsagar, Bombay Green, Chandrakaran, Dilpasand, Pusa Surya, Gourav, Tilka Bhadainya, Langra, Tommy Atkins, Saurabh, Ambika, Pant Sinduri, Totapuri Red Small	24
III	2014	Mallika,Sensation, Sukul, Van Raj, Bangalora, Tommy Atkins, Pusa Arunima	7
	2016	Totapuri Red Small, Tilka Bhadainya, Himanshu, Pant Sinduri	4
	Pooled	Mallika, Sensation, Pusa Arunima, Sukul, Chausa, PMSS-1, Van Raj, Bangalor	8
IV	2014	PMSS-1	1
	2016	Pusa Arunima, Sensation, Mallika, Chausa, Bangalora, Amrapali	6
	Pooled	Himanshu	1
V	2014	Himanshu	1
	2016	Rajiv	1
	Pooled	Rajiv	1
VI	2014	Amrapali	1
	2016	Angoor Lata	1
	Pooled	Amrapali	1
VII	2014	Angoor Lata	1
	2016	PMSS-1	1
	Pooled	Angoor Lata	1

Table 4.36: Average intra and inter-cluster (diagonal) D^2 values in different mango varieties including new accessions based on different morphological and physico-chemical characteristics

Cluster number	Cropping year	Cluster number						
		I	II	III	IV	V	VI	VII
I	2014	**185.191**	1084.499	2038.310	1123.459	691.876	914.148	1142.407
	2016	**120.262**	781.084	410.123	916.720	306.564	499.475	6285.070
	Pooled	**40.259**	150.767	233.519	89.747	81.286	148.243	165.571
II	2014		**363.895**	691.193	532.050	601.665	580.981	2719.402
	2016		**240.439**	417.774	418.978	867.895	1530.049	7207.719
	Pooled		**74.379**	131.495	101.540	161.845	145.709	322.817
III	2014			**448.959**	687.646	860.480	1071.521	4623.738
	2016			**305.747**	593.844	419.812	977.743	6441.368
	Pooled			**104.400**	141.149	299.313	160.028	513.380
IV	2014				**0.000**	598.965	626.846	3093.861
	2016				**349.845**	1236.431	1893.236	7229.675
	Pooled				**0.000**	139.956	177.902	356.772
V	2014					**0.000**	1023.927	2931.605
	2016					**0.000**	620.027	6056.413
	Pooled					**0.000**	231.404	175.606
VI	2014						**0.000**	2068.973
	2016						**0.000**	6517.069
	Pooled						**0.000**	312.129
VII	2014							**0.000**
	2016							**0.000**
	Pooled							**0.000**

Bold values are intra-cluster distance
Normal values are inter-cluster distance

Table 4.37: Average intra and inter-cluster (diagonal) D values in different mango varieties including new accessions based on different morphological and physico-chemical characteristics

Cluster number	Cropping year	Cluster number						
		I	II	III	IV	V	VI	VII
I	2014	**13.61**	32.93	45.15	33.52	26.30	30.23	33.80
	2016	**10.97**	27.95	20.25	30.28	17.51	22.35	79.28
	Pooled	**6.34**	12.28	15.28	9.47	9.02	12.18	12.87
II	2014		**19.076**	26.291	23.066	24.529	24.104	52.148
	2016		**15.51**	20.44	20.47	29.46	39.12	84.90
	Pooled		**8.62**	11.47	10.08	12.72	12.07	17.97
III	2014			**21.19**	26.22	29.33	32.73	68.00
	2016			**17.49**	24.37	20.49	31.27	80.26
	Pooled			**10.22**	11.88	17.30	12.65	22.66
IV	2014				**0.00**	24.47	25.04	55.62
	2016				**18.70**	35.16	43.51	85.03
	Pooled				**0.00**	11.83	13.34	18.89
V	2014					**0.00**	32.00	54.14
	2016					**0.00**	24.90	77.82
	Pooled					**0.00**	15.21	13.25
VI	2014						**0.00**	45.49
	2016						**0.00**	80.73
	Pooled						**0.00**	17.67
VII	2014							**0.00**
	2016							**0.00**
	Pooled							**0.00**

Bold values are intra-cluster distance

Normal values are inter-cluster distance

VII had one variety each *viz.,* Himanshu, Rajiv, Amrapali and Angoor Lata. The similar results have also been reported by Rathod and Naik, (2007), Rajan *et al.* (2009), Manchekar *et al.* (2011), Barhate *et al.* (2012), Majumder *et al.* (2013) and Barholia and Yadav (2014), in mango.

4.3.2.2 Intra and inter-cluster average D^2 values

The intra and inter-cluster average D^2 values have been given in Table 4.36 for the year 2014, 2016 and pooled analysis, respectively.

During the year 2014, the intra-cluster average D^2 ranged from 0.00 to 448.95. It was maximum in cluster III comprising seven varieties followed by cluster II (363.89) and cluster I (185.19) having 25 and 4 varieties, respectively. The clusters IV, V, VI and VII have only one variety; hence intra-cluster D^2 values were zero. The inter-cluster average D^2 value was found maximum (4623.73) between cluster III with seven and VII with one variety followed by D^2 value (3093.86) between cluster IV with one variety and VII with one variety. The minimum inter-cluster D^2 distance (532.05) was observed between cluster II with 25 varieties and cluster IV with one variety followed by inter-cluster D^2 distance (580.98) was observed between cluster II with 25 varieties and VI with a single variety.

During the year 2016, the intra-cluster average D^2 ranged from 0.00 to 349.89. It was maximum in cluster IV comprising six varieties followed by cluster III (305.74), cluster II (240.43) and cluster I (120.26) having 4, 23 and 4 varieties, respectively. The clusters V, VI and VII have only one variety; hence intra-cluster D^2 values were zero.

The inter-cluster average D^2 value was found maximum (7229.67) between cluster IV with six and VII with a single variety followed by D^2 value (7207.71) between cluster II with 23 varieties and VII with a single variety. The minimum inter-cluster D^2 distance (306.56) was observed between cluster I with 4 varieties and cluster V with a single variety followed by inter-cluster D^2 distance (410.12) was observed between cluster I with 4 varieties and III with 4 varieties.

In pooled data analysis, the intra-cluster average D^2 ranged from 0.00 to 104.40. It was maximum in cluster III comprising eight varieties followed by cluster II (74.37) and cluster I (40.25) having 23 and 4 varieties, respectively. The clusters

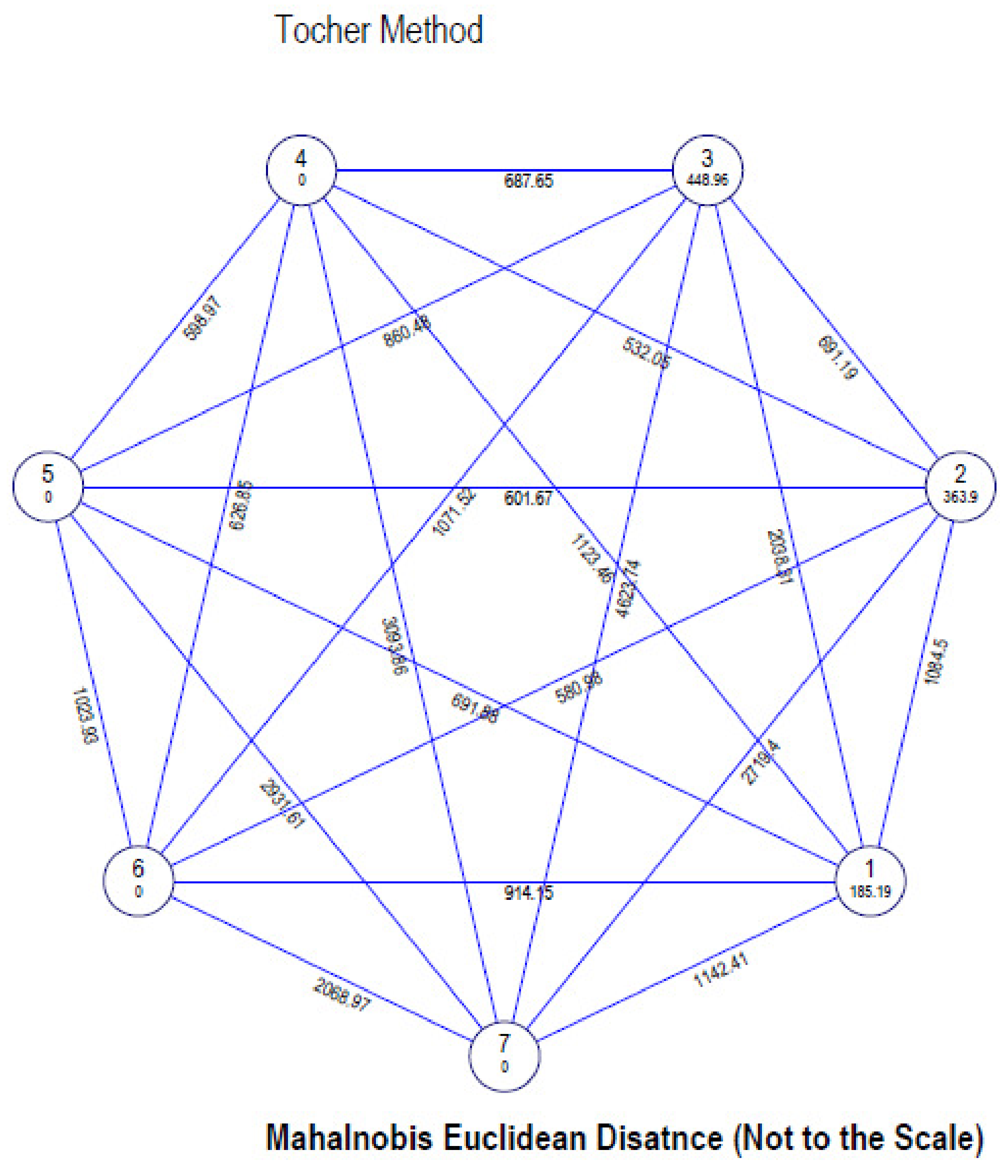


Fig. 4.21: Mahalnobis' Euclidean Distances showing inter-relationship among clusters in different mango varieties including new accessions for different morphological and physico -chemical traits analyzed through D^2 statistics (2014)

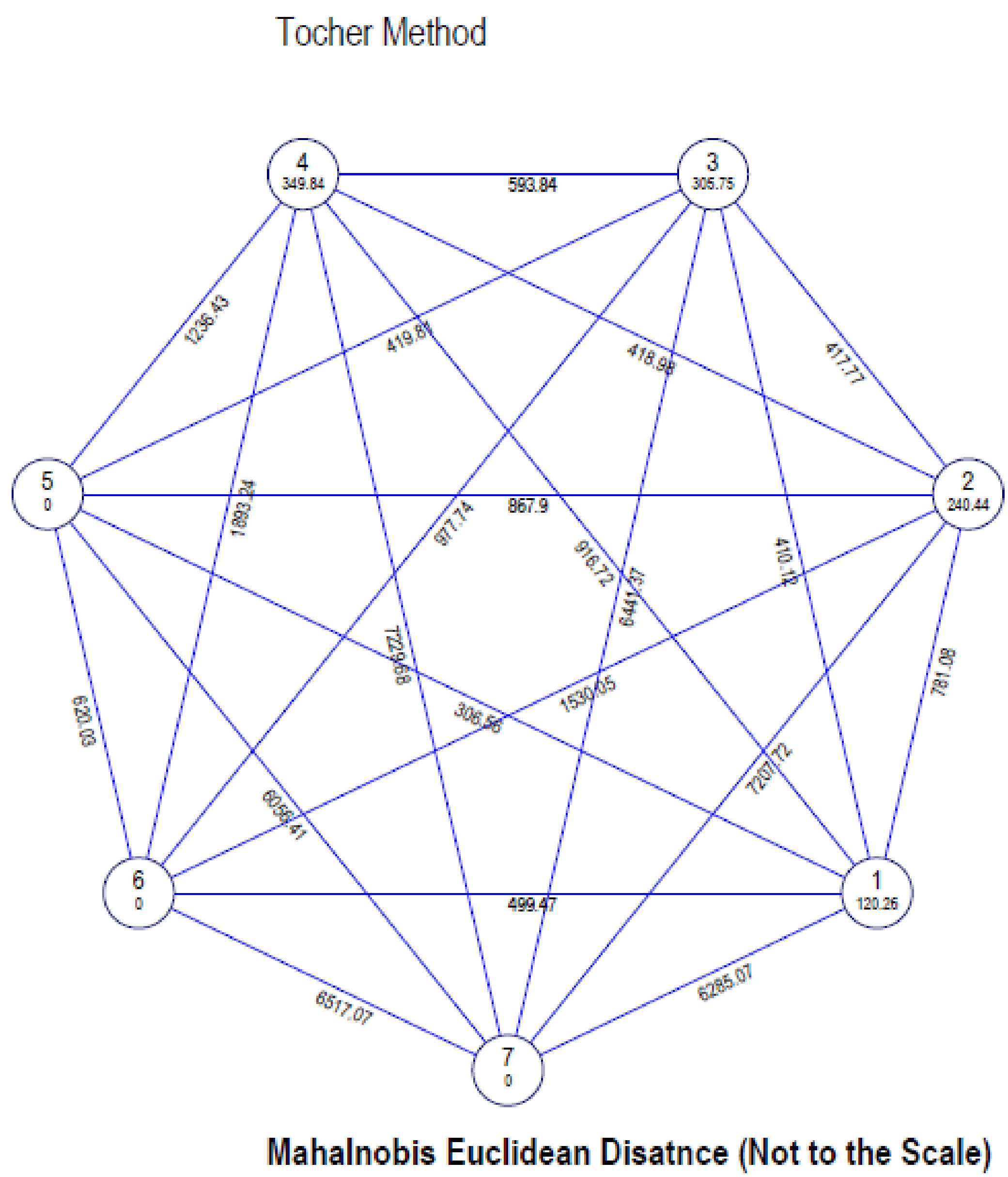


Fig. 4.22: Mahalnobis' Euclidean Distances showing inter-relationship among clusters in different mango varieties including new accessions for different morphological and physico -chemical traits analyzed through D^2 statistics (2016)

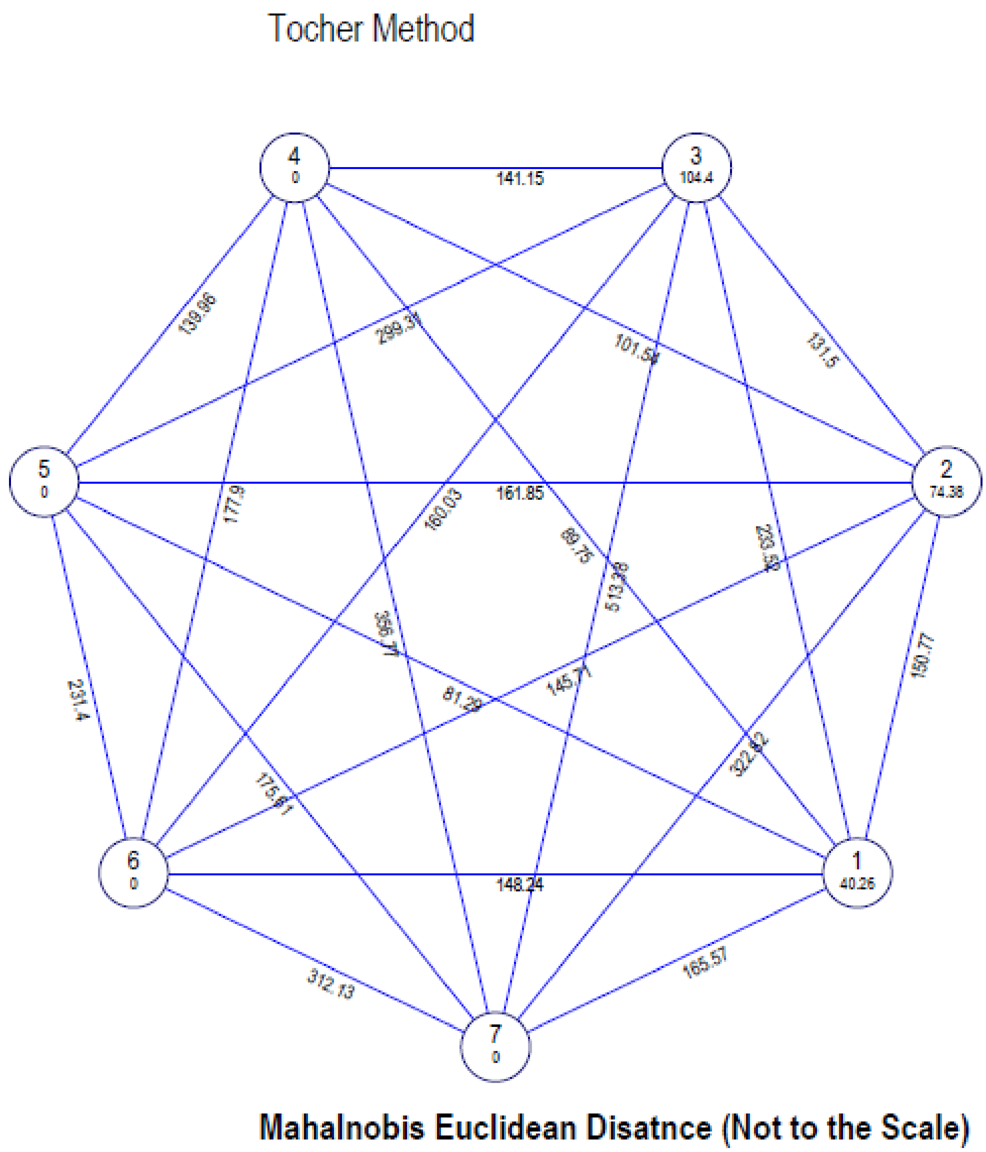


Fig. 4.23: Mahalanobis' Euclidean Distances showing inter-relationship among clusters in different mango varieties including new accessions for different morphological and physico -chemical traits analyzed through D^2 statistics (pooled data of 2014 and 2016)

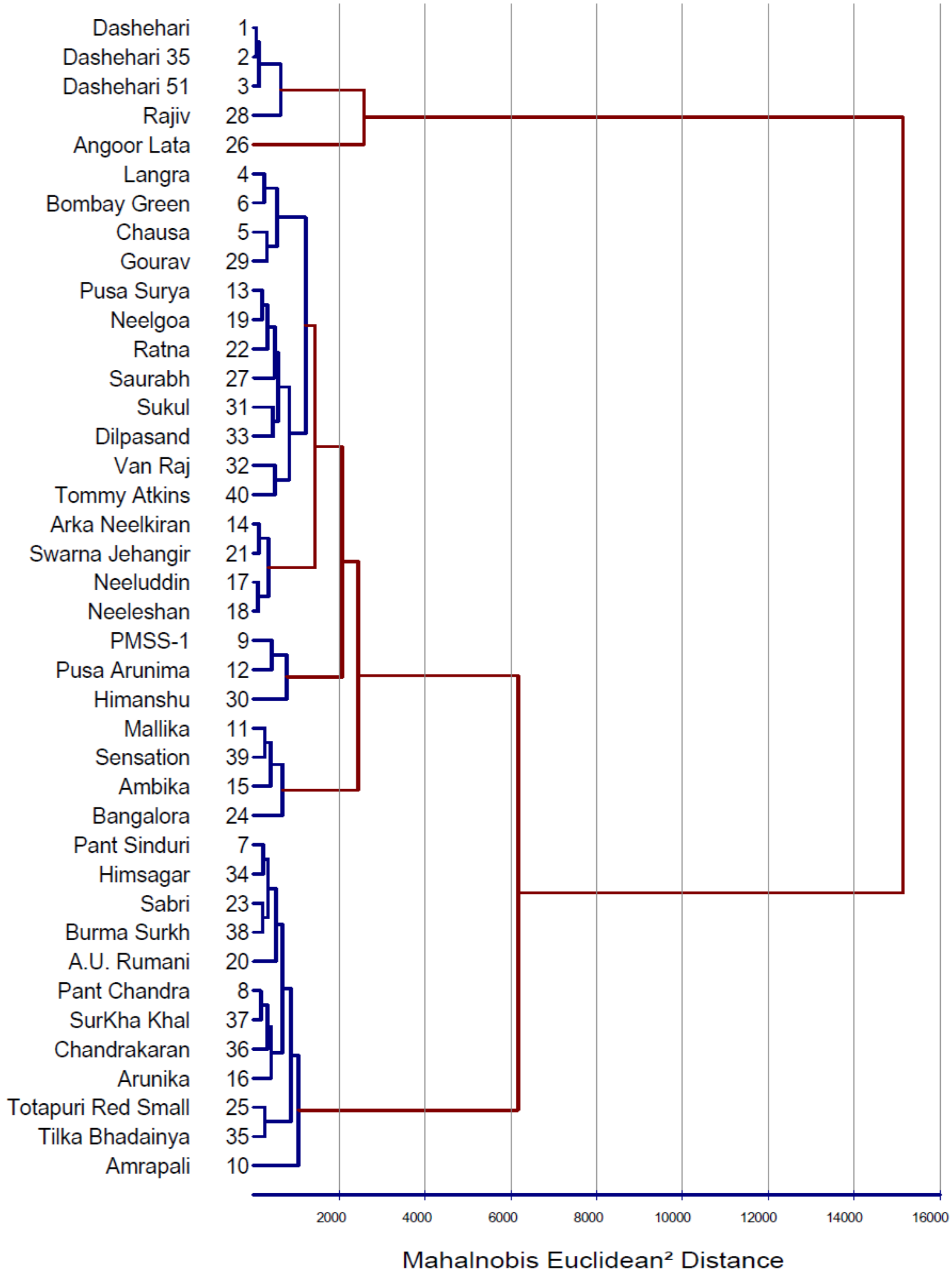


Fig. 4.24: Dendrogram showing the clusters of different mango varieties on the basis of morphological and physico-chemical characteristics according to Mahalnobis' Euclidean distance (2014)

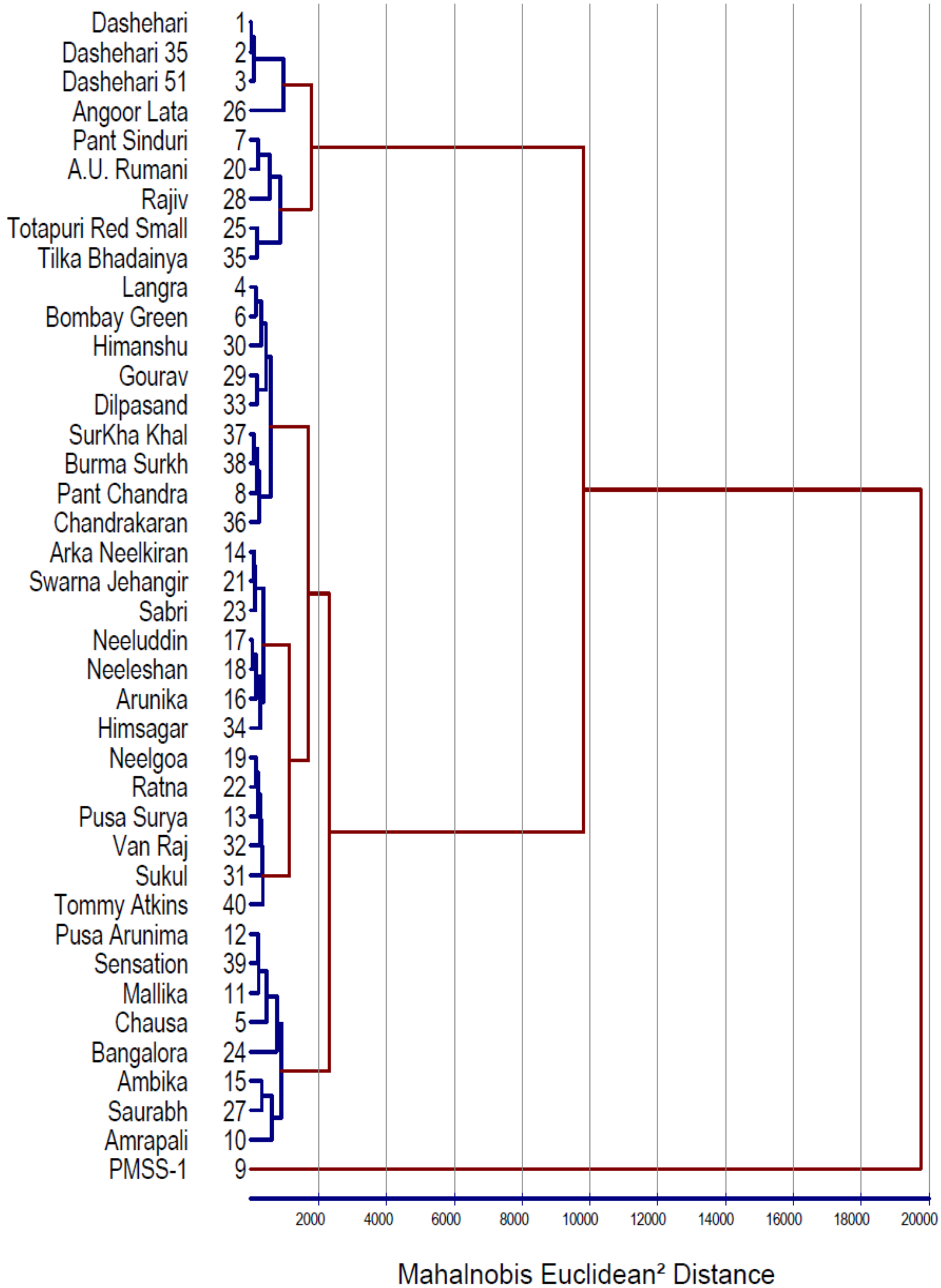


Fig. 4.25: Dendrogram showing the clusters of different mango varieties on the basis of morphological and physico-chemical characteristics according to Mahalnobis' Euclidean distance (2016)

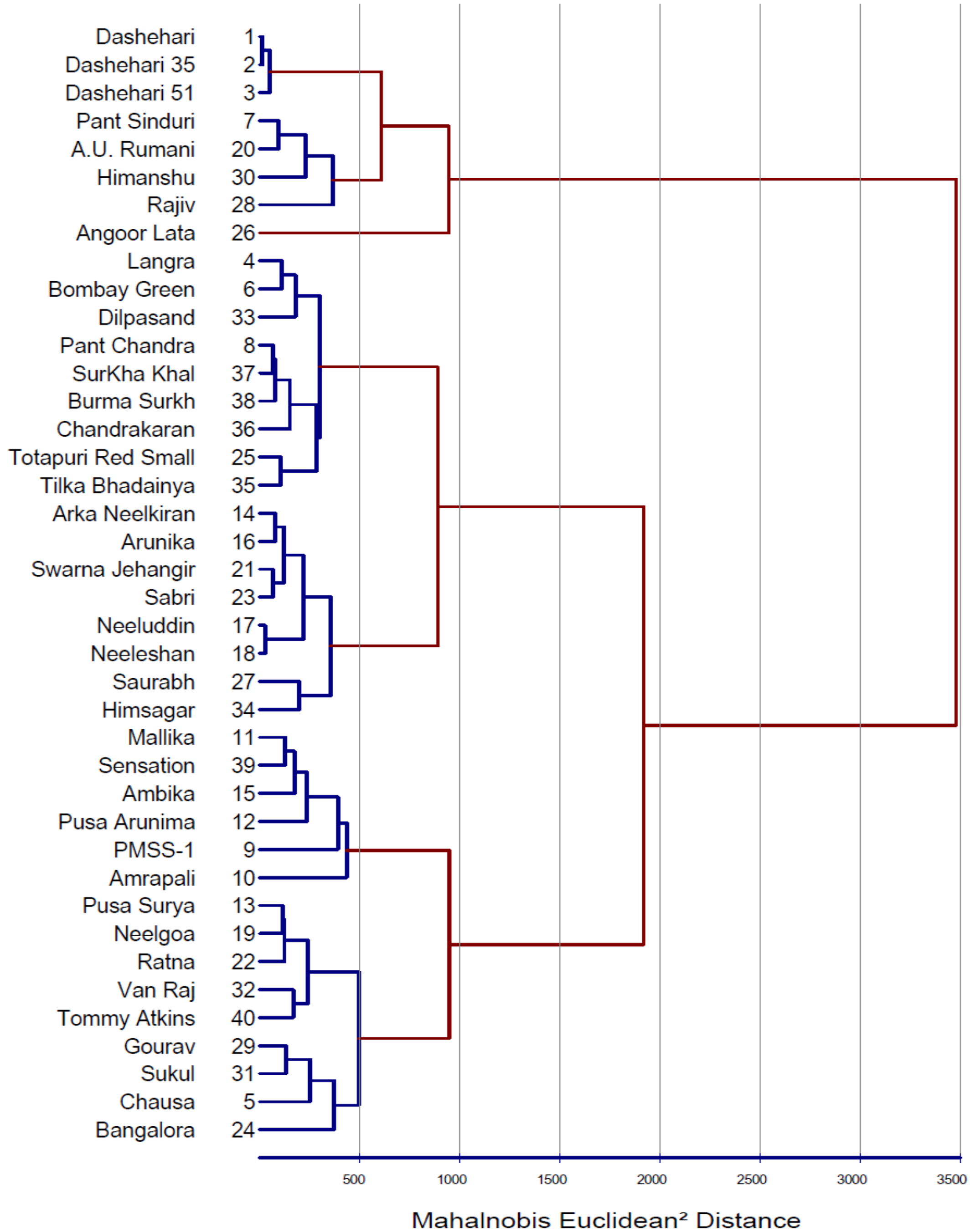


Fig. 4.26: Dendrogram showing the clusters of different mango varieties on the basis of morphological and physico-chemical characteristics according to Mahalnobis' Euclidean distance (pooled data of 2014 and 2016)

VI, V, VI and VII have only one variety; hence intra-cluster D^2 values were zero. The inter-cluster average D^2 value was found maximum (513.38) between cluster III with eight and VII with a single variety followed by D^2 value (356.77) between cluster IV with a single variety and VII with a single variety. The minimum inter-cluster D^2 distance (81.28) was observed between cluster I with 4 varieties and cluster V with a single variety followed by inter-cluster D^2 distance (89.74) was observed between cluster I with 4 varieties and IV with a single variety.

The relative genetic distance (D), as calculated by taking square root of D^2 values, has been presented in the Table 4.37 for the year 2014, 2016 and pooled over year analysis data. During the year 2014, the relative genetic distance (D) was found maximum between cluster III and VII (68.00) followed by between the cluster IV and VII (55.62) indicating that these to be quite genetically diverse. The minimum genetic distance was found between the clusters II and IV (23.06) followed by cluster II and VI (24.10) indicating a close similarity in the varietal composition of these clusters.

During the year 2016, the relative genetic distance (D) was found maximum between cluster IV and VII (85.03) followed by between the cluster II and VII (84.90) indicating that these to be quite genetically diverse. The minimum genetic distance was found between the clusters I and V (17.51) followed by cluster I and III (20.25) indicating a close similarity in the varietal composition of these clusters.

In pooled analysis, the relative genetic distance (D) was found maximum between cluster III and VII (22.66) followed by between the cluster IV and VII (18.89) indicating these to be quite genetically diverse. The minimum genetic distance was found between the clusters I and V (9.02) followed by cluster I and IV (9.47) indicating a close similarity in the varietal composition of these clusters. The similar findings have also been reported by Rathod and Naik, (2007), Rajan *et al.* (2009), Manchekar *et al*. (2011), Barhate *et al.* (2012), Majumder *et al.* (2013) and Barholia and Yadav (2014) in mango.

4.3.2.3 Cluster mean

Cluster mean values for 27 morphological and physico-chemical characteristics are presented in Table 4.38 (2014), Table 4.39 (2016) and pooled (Table 4.40) analysis. In the first year (2014), the cluster mean values for different characters indicated considerable differences between the clusters for studied. Cluster VI with one variety, exhibited the largest cluster mean value (21.28 cm), whereas cluster VII showed lowest cluster mean value (14.83 cm) for leaf length. For leaf width, the highest mean value (6.03 cm) and lowest mean value (4.06 cm) obtained in cluster IV with one genotype and cluster VII with one genotype, respectively. Leaf areas showed the maximum mean value (86.05 cm^2) in cluster VI with one variety and minimum (36.28 cm^2) in cluster VII with one variety. The maximum value of mean for duration of panicle emergence (24.67 days) in cluster VI with a single variety and lowest (18.00 days) in cluster VII with one variety, number of secondary rachis per panicle had the highest mean value (33.53) in cluster VI with one variety and lowest mean value (24.00) in cluster VII with one variety. Length and width of inflorescence had highest mean value (30.98 and 20.23 cm) in cluster VI with one variety and lowest mean value (17.21 and 9.96 cm) in cluster VII with a single variety, respectively. The duration of flowering had maximum mean value (23.21 days) in cluster II with 25 varieties, whereas, minimum mean value was recorded in cluster VI with one variety. The maximum mean value (152.67 days) was found in cluster IV with one genotype and minimum (96 days) was recorded for duration of fruit maturity, whereas, number of fruits per tree at harvesting have highest mean value (151.58) in cluster I with four genotype and lowest mean value (42.38) in cluster III with seven varieties.

The yield per tree showed maximum mean value (30.00 kg) in cluster V and minimum mean value (2.73 kg) in cluster VII with one variety. The fruit weight was recorded maximum mean value (359.15 g) in cluster III with seven genotypes, while minimum mean value (19.48 g)were recorded in cluster VII with one variety, respectively.

The fruit length and width were recorded maximum mean value (11.74 and 7.85 cm) in cluster III with seven genotypes, while minimum mean value (3.38 and 2.68 cm) were recorded in cluster VII with one variety, respectively. The stone weight was recorded maximum mean value (45.98 g) in cluster III with seven genotypes, while minimum mean value (5.29 g) was recorded in cluster VII with one variety, respectively. The stone length and width were recorded maximum mean value (9.51 and 4.19 cm) in cluster III with seven genotypes, while minimum mean value (2.76 and 1.89 cm) were recorded in cluster VII with one variety, respectively. Pulp and

Table 4.38: Cluster mean values for different morphological and physico-chemical characteristics on the basis of Mahalnobis' D^2 analysis (2014)

S. No.	Characteristics	Cluster mean						
		I	II	III	IV	V	VI	VII
1	Leaf length (cm)	19.52	19.79	20.67	20.37	20.96	21.28	14.83
2	Leaf width (cm)	4.87	5.08	4.90	6.03	5.98	5.19	4.06
3	Leaf area (cm^2)	66.65	76.94	80.91	80.97	78.11	86.05	36.28
4	Duration of panicle emergence (days)	18.58	20.37	21.00	24.00	19.00	24.67	18.00
5	Number of secondary rachis/ panicle	30.22	30.29	31.54	31.96	31.63	33.53	24.00
6	Length of inflorescence (cm)	28.19	29.37	30.34	29.07	36.25	30.98	17.21
7	Width of inflorescence (cm)	14.26	16.57	17.54	15.66	13.02	20.23	9.96
8	Duration of flowering (days)	18.83	23.21	21.43	20.00	21.67	18.00	21.67
9	Duration of fruit maturity (days)	97.50	103.57	111.43	152.67	96.67	115.67	96.00
10	Number of fruits/tree at harvesting	151.58	48.84	42.38	75.00	94.00	85.33	140.00
11	Yield per tree (kg)	20.75	10.85	14.88	18.30	30.00	11.36	2.73
12	Fruit weight (g)	136.84	236.09	359.15	238.49	319.18	132.84	19.48
13	Fruit length (cm)	8.52	9.45	11.74	9.65	11.55	8.59	3.38
14	Fruit width (cm)	5.50	6.50	7.85	7.25	6.72	5.31	2.68
15	Stone weight (g)	18.70	31.18	45.98	37.79	25.85	25.27	5.29
16	Stone length (cm)	7.42	7.36	9.54	8.13	9.51	7.76	2.76
17	Stone width (cm)	3.01	3.43	4.19	3.83	3.83	3.63	1.89
18	Pulp weight (g)	101.73	176.75	271.42	171.30	261.55	86.40	12.66
19	Peel weight (g)	16.41	28.15	41.76	29.40	31.79	21.18	1.54
20	Pulp : stone ratio	5.45	5.72	6.20	4.53	10.17	3.40	2.44
21	TSS (^{0}B)	16.78	18.34	18.95	18.12	16.47	20.72	18.90
22	Acidity (%)	0.16	0.17	0.19	0.16	0.06	0.27	0.10
23	Reducing sugar (%)	3.44	4.51	4.13	4.20	3.45	5.65	3.93
24	Non reducing (%)	11.24	10.58	12.05	8.47	12.74	14.44	12.95
25	Total sugar (%)	15.27	15.64	16.53	12.47	16.86	20.85	17.56
26	Ascorbic acid (mg/100 g flesh)	40.45	39.01	39.00	40.79	45.44	33.49	39.21
27	Total Carotenoid (mg/100g flesh)	3.71	3.05	4.62	4.59	3.10	8.68	3.22

Table 4.39: Cluster mean values for different morphological and physico-chemical characteristics on the basis of Mahalnobis' D^2 analysis (2016)

S. No.	Characteristics	Cluster mean						
		I	II	III	IV	V	VI	VII
1	Leaf length (cm)	19.03	20.14	18.99	22.15	21.08	13.84	20.25
2	Leaf width (cm)	4.77	5.28	5.13	5.76	5.01	3.53	5.53
3	Leaf area (cm^2)	64.42	75.87	69.41	90.68	74.93	34.65	79.54
4	Duration of panicle emergence (days)	16.62	18.58	19.58	19.58	18.67	15.00	20.33
5	Number of secondary rachis/ panicle	28.17	33.68	35.85	30.06	33.82	24.25	33.33
6	Length of inflorescence (cm)	30.17	31.12	34.11	29.58	31.62	19.63	29.13
7	Width of inflorescence (cm)	17.26	18.03	19.05	20.27	18.02	11.92	15.45
8	Duration of flowering (days)	18.08	21.00	20.58	19.17	22.33	20.00	18.00
9	Duration of fruit maturity (days)	102.51	104.43	102.75	116.28	99.00	98.00	158.00
10	Number of fruits/tree at harvesting	160.17	45.10	101.99	63.18	151.19	156.96	85.42
11	Yield tree $^{-1}$ (kg)	20.88	11.78	20.65	20.20	23.08	3.24	20.49
12	Fruit weight (g)	131.55	265.23	200.52	346.42	152.93	20.67	263.11
13	Fruit length (cm)	9.26	9.89	9.21	11.80	7.36	3.58	9.49
14	Fruit width (cm)	5.49	7.11	5.70	7.40	6.27	2.93	7.40
15	Stone weight (g)	17.98	33.39	26.03	41.98	19.05	5.39	40.89
16	Stone length (cm)	8.06	7.44	7.75	9.63	6.25	2.98	7.72
17	Stone width (cm)	2.87	3.50	3.27	4.24	3.55	1.95	3.65
18	Pulp weight (g)	94.78	200.45	148.80	266.19	117.12	13.65	201.54
19	Peel weight (g)	18.80	31.39	25.69	38.25	16.77	1.62	34.37
20	Pulp : stone ratio	5.26	6.13	5.77	6.52	6.17	2.55	4.93
21	TSS (^{0}B)	18.79	18.72	15.38	19.64	13.88	19.51	18.00
22	Acidity (%)	0.14	0.18	0.18	0.20	0.27	0.12	0.18
23	Reducing sugar (%)	4.59	4.58	3.61	4.84	2.73	4.16	4.17
24	Non reducing (%)	12.18	11.92	11.88	13.54	8.61	14.30	8.17
25	Total sugar (%)	16.54	16.27	15.30	18.15	11.21	18.26	12.77
26	Ascorbic acid (mg/100 g flesh)	39.91	39.62	43.44	45.14	32.65	40.67	41.54
27	Total Carotenoid (mg/100g flesh)	3.91	3.50	3.38	6.60	1.92	3.44	4.41

Table 4.40: Cluster mean values for different morphological and physico-chemical characteristics on the basis of Mahalnobis' D^2 analysis of pooled data (2014 and 2016)

S. No	Characteristics	Cluster mean						
		I	II	III	IV	V	VI	VII
1	Leaf length (cm)	19.04	19.94	20.81	20.63	21.01	21.86	14.33
2	Leaf width (cm)	4.73	5.19	5.28	5.68	5.06	5.35	3.79
3	Leaf area (cm^2)	64.78	76.20	82.77	77.94	75.01	87.06	35.46
4	Duration of panicle emergence days)	17.26	19.55	20.50	18.00	19.66	23.90	16.50
5	Number of secondary rachis/ panicle	28.95	32.05	31.57	33.10	34.07	32.05	24.12
6	Length of inflorescence (cm)	30.39	30.41	29.05	37.17	30.07	32.26	18.42
7	Width of inflorescence (cm)	16.62	17.37	17.78	15.03	16.14	22.04	10.94
8	Duration of flowering (days)	18.33	22.16	20.50	20.00	22.66	17.33	20.83
9	Duration of fruit maturity (days)	100.00	103.75	118.81	96.83	98.33	116.16	97.00
10	Number of fruits/tree at harvesting	152.92	48.87	52.43	99.08	143.60	93.38	148.48
11	Yield per tree (kg)	20.35	11.17	18.05	31.26	21.98	12.92	2.99
12	Fruit weight (g)	134.15	240.55	359.04	315.60	153.20	137.73	20.07
13	Fruit length (cm)	9.20	9.55	11.55	11.28	7.21	8.78	3.48
14	Fruit width (cm)	5.40	6.72	7.72	6.46	6.11	5.45	2.81
15	Stone weight (g)	18.53	31.45	45.26	26.02	18.65	24.92	5.34
16	Stone length (cm)	7.92	7.26	9.55	9.60	6.39	7.64	2.87
17	Stone width (cm)	2.83	3.43	4.20	3.72	3.61	3.46	1.92
18	Pulp weight (g)	96.99	179.75	275.49	257.52	118.22	91.12	13.16
19	Peel weight (g)	18.63	29.36	39.14	32.05	16.32	21.69	1.58
20	Pulp : stone ratio	5.23	5.80	6.34	9.99	6.36	3.65	2.50
21	TSS (^{0}B)	18.47	18.27	19.08	16.25	13.10	21.00	19.20
22	Acidity (%)	0.15	0.18	0.17	0.08	0.26	0.26	0.11
23	Reducing sugar (%)	4.47	4.48	4.25	3.54	2.66	5.84	4.05
24	Non reducing (%)	11.63	11.21	12.10	13.37	8.55	14.62	13.63
25	Total sugar (%)	16.27	15.81	16.55	17.15	11.36	20.69	17.91
26	Ascorbic acid (mg/100 g flesh)	40.16	39.00	43.63	46.24	32.50	35.14	39.94
27	Total Carotenoid (mg/100g flesh)	3.80	3.25	5.01	3.30	1.89	9.23	3.33

peel weight had highest mean value (271.42 and 41.76 g) in cluster III with seven genotypes and lowest mean value (12.66 and 1.54 g)) in cluster VII with a single variety, respectively, while, pulp: stone ratio had shown maximum mean (10.17) value was recorded in cluster V with a single variety and minimum (2.44) was found in cluster VII with one variety. The TSS, acidity and reducing sugar were recorded maximum mean value (20.72^{0}B; 0.27 and 5.65%) in cluster VI with one genotype, while minimum mean value (16.47^{0}B; 0.06 and 3.44%) were recorded in cluster V with one variety, respectively. Cluster VI with one variety, exhibited the largest cluster mean value (14.44 and 20.85%), whereas cluster IV showed lowest cluster mean value (8.47 and 12.47%) with one variety for non reducing sugar and total sugar, respectively. The ascorbic acid had maximum mean value (45.44 mg/100 g) in cluster V and minimum mean value (33.49 mg/100 g) in cluster VI with one variety, while, maximum mean value (8.68 mg/100 g) was recorded in cluster VI with one variety and minimum (3.05 mg/100 g) was found in cluster II with 25 varieties for total carotenoid.

In the second year (2016), the cluster mean values for different characters indicated considerable differences between the clusters for studied. Cluster IV with six varieties, exhibited the largest cluster mean value (22.15 cm), whereas cluster VI showed lowest cluster mean value (13.84 cm) for leaf length. For leaf width, the highest mean value (5.76 cm) and lowest mean value (3.53 cm) obtained in cluster IV with six genotypes and cluster VI with one genotype. Leaf area had maximum mean value (90.68 cm^2) in cluster IV with six variety and minimum (34.65 cm^2) in cluster VI with one variety. The maximum value of mean for duration of panicle emergence 19.58 days in cluster IV with six variety and lowest (15.00 days) in cluster VI with one variety, number of secondary rachis per panicle had the highest mean value 35.85 in cluster III with four varieties and lowest mean value (24.25) in cluster VI with one variety. Length and width of inflorescence had highest mean value (34.11and 20.27 cm) in cluster III with four varieties and IV with six varieties and lowest mean value (19.63 and 11.92 cm) in cluster VI with a single variety, respectively. The duration of flowering had maximum mean value (22.33 days) in cluster V with single variety, whereas, minimum mean (18 days) value was recorded in cluster VII with one variety. The maximum mean value (158.00 days) was found in cluster VII with one genotype and minimum (98 days) was recorded in cluster VI with one variety for duration of fruit maturity, whereas, number of fruits per tree at harvesting have highest mean value (160.17) in cluster I with four genotypes and lowest mean value (45.10) in cluster II with 23 varieties.

The yield per tree had maximum mean value (23.08 kg) in cluster V and minimum mean value (3.24 kg) in cluster VI with one variety. The fruit weight was recorded maximum mean value (346.42 g) in cluster IV with six genotypes, while minimum mean value (20.67 g) were recorded in cluster VI with one variety, respectively. The fruit length and width were recorded maximum mean value (11.80 and 7.40 cm) in cluster IV with six genotypes, while minimum mean value (3.58 and 2.93 cm) recorded in cluster VI with one variety, respectively. The stone weight was recorded maximum mean value (41.98 g) in cluster IV with six genotypes, while minimum mean value (5.39 g) was recorded in cluster VI with one variety, respectively. The stone length and width were recorded maximum mean value (9.63 and 4.24 cm) in cluster IV with six genotypes, while minimum mean value (2.98 and 1.95 cm) was recorded in cluster VI with one variety, respectively. Pulp and peel weight had highest mean value (266.19 and 38.25 g) in cluster IV with six genotypes and lowest mean value (13.65 and 1.62 g)) in cluster VI with a single variety, respectively, while pulp: stone ratio maximum mean (6.52) value was recorded in cluster IV with six varieties and minimum (2.55) was found in cluster VI with one variety. The TSS was recorded maximum mean value (19.64^{0}B) in cluster IV with six genotypes, while minimum mean value (13.88^{0}B) was recorded in cluster V with one variety. The acidity was recorded maximum mean value (0.27%) in cluster V with one genotype, while minimum mean value (0.12%) was recorded in cluster VI with one variety. The reducing sugar was recorded maximum mean value (4.84%) in cluster IV with six genotypes, while minimum mean value (2.73%) was recorded in cluster V with one variety. The non reducing sugar was recorded maximum mean value (14.30%) in cluster VI with one genotype, while minimum mean value (8.17%) was recorded in cluster VII with one variety. The total sugar was recorded maximum mean value (18.26%) in cluster VI with one genotype, while minimum mean value (11.21%) was recorded in cluster V with one variety. The ascorbic acid had maximum mean value (45.14 mg/100 g) in cluster IV with six genotypes and minimum mean value (32.65 mg/100 g) in cluster V with one variety, while, maximum mean value (6.60 mg/100 g) was recorded in cluster IV with six genotypes and minimum (1.92 mg/100 g) was found in cluster V with one variety for total carotenoid.

In pooled analysis of two year data, the cluster mean values for different characters indicated considerable differences between the clusters for studied. Cluster VI with one variety exhibited the largest cluster mean value (21.86 cm), whereas cluster VII showed lowest cluster mean value (14.33 cm) for leaf length. For leaf width, the highest mean value (5.68 cm) and lowest mean value (3.79 cm) obtained in cluster IV with one genotype and cluster VII with one genotype. Leaf area had maximum mean value (87.06 cm^2) in cluster VI with one variety and minimum (35.46 cm^2) in cluster VII with one variety. The maximum value of mean for duration of panicle emergence (23.90 days) in cluster VI with a single variety and lowest (16.50 days) in cluster VII with one variety, number of secondary rachis per panicle had highest mean value 34.07 in cluster V with one variety and lowest mean value (24.12) in cluster VII with one variety. Length and width of inflorescence had highest mean value (37.17 and 22.04 cm) in cluster IV with one variety and cluster VI with one variety and lowest mean value (18.42 and 10.94 cm) in cluster VII with a single variety, respectively. The duration of flowering had maximum mean value (22.66 days) in cluster V with a single variety, whereas, minimum mean value (17.33 days) was recorded in cluster VI with one variety. The maximum mean value (118.81 days) was found in cluster III with eight genotypes and minimum (96.83 days) was recorded for duration of fruit maturity, whereas, number of fruits per tree at harvesting had highest mean value (152.92) in cluster I with four genotypes and lowest mean value (48.87) in cluster II with 24 varieties.

The yield per tree had maximum mean value (33.26 kg) in cluster IV and minimum mean value (2.99 kg) in cluster VII with one variety each. The fruit weight was recorded maximum mean value (359.04 g) in cluster III with eight genotypes, while minimum mean value (20.07 g) were recorded in cluster VII with one variety, respectively.

The fruit length and width were recorded maximum mean value (11.55 and 7.72 cm) in cluster III with eight genotypes, while minimum mean value (3.48 and 2.81 cm) were recorded in cluster VII with one variety, respectively. The stone weight was recorded maximum mean value (45.26 g) in cluster III with eight genotypes, while minimum mean value (5.34 g) was recorded in cluster VII with one variety, respectively. The stone length and width were recorded maximum mean value (9.60 and 4.20 cm) in cluster III with eight genotypes, while minimum mean value (2.87 and 1.92 cm) was recorded in cluster VII with one variety, respectively. Pulp and peel weight had highest mean value (275.49 and 39.14 g) in cluster III with eight genotypes and lowest mean value (13.16 and 1.58 g)) in cluster VII with a single variety, respectively, while, pulp: stone ratio maximum mean (9.99) value was recorded in cluster IV with a single variety and minimum (2.50) was found in cluster VII with one variety. The TSS was recorded maximum mean value (21.0^0B) in cluster VI with one genotype, while minimum mean value (13.10^0B) was recorded in cluster V with one variety. The acidity was recorded maximum mean value (0.26%) in cluster V with one genotype, while minimum mean value (0.08%) was recorded cluster IV with one genotype. The reducing sugar was recorded maximum mean value (5.84%) in cluster VI with one genotype, while minimum mean value (2.66%) was recorded in cluster V with one variety. The non reducing sugar was recorded maximum mean value (14.62%) in cluster VI with one genotype, while minimum mean value (8.55%) was recorded in cluster V with one variety. The total sugar was recorded maximum mean value (20.69%) in cluster VI with one genotype, while minimum mean value (11.36%) was recorded in cluster V with one variety. The ascorbic acid have maximum mean value (46.24 mg/100 g) in cluster IV with one genotype and minimum mean value (32.50 mg) in cluster V with one variety. While, maximum mean value (9.23 mg/100 g) was recorded in cluster VI with one genotype and minimum (1.89 mg/100 g) was found in cluster V with one variety for total carotenoid.

Selection of diverse parents belonging to distant groups leads to wide spectrum of gene combination for the quantitative traits. For classificatory analysis in crop plants, many methods have been described but D^2 statistics, based on multivariate analysis are the best procedure used for the classificatory analysis and has taken an important and unique place in plant breeding for measuring genetic diversity amongst varieties and selection of parents for the purpose of breeding programme. The present investigation was carried out involving 40 mango varieties subjected to Mahalnobis' D^2 analysis with 27 morphological and physico-chemical characters. Statistics has been used extensively by several workers as a statistical tool for estimating genetic divergence in different crops and many similar reported have appeared in mango by (Rathod and Naik, 2007; Rajan *et al.*, 2009; Manchekar *et al.*, 2011; Barhate, *et al.*, 2012; Majumder *et al.*, 2013; Barholia and Yadav, 2014).

Many workers have discussed the importance of genetic diversity in plant breeding programme. They usually assume that geographical diversity also reflects in form of genetic diversity. However**,** Murty and Arunachalam (1966) and Martinov (1983) could not find any direct relationship between geographical diversity and genetic diversity. The critical perusal of the results obtained in the present investigation also supported this finding i.e., distribution of varieties were not according to their ecogeographical pattern. It means that lines belonging to the same ecogeographical area occupied more than one clusters conversely, the genotypes belong to different ecogeographical areas tend to occur in the same cluster as well as in different clusters.

Inter-cluster statistical distances among 7 clusters were computed. The values are presented in Table 4.36 and 4.37 and the statistical distances among different clusters are presented diagrammatically in Fig. 4.21 (2014), Fig. 4.22 (2016) and Fig. 4.23 (Pooled data of 2014 and 2016). It is worth considering to understand the practical significance of grouping of genotypes into different cluster and computing the statistical distance between them. Varieties grouped into same cluster may presumably be diverse very little genetically from one another with regards to aggregate of the 27 characters studied. The crossing between genotype belongs to same cluster will not likely to give desirable heterotic segregates for the character under consideration. Consequently a crossing programme should be formulated in such a way that the parents should belong to different clusters which will likely to yield transgressive/heterotic/desirable segregants. The parental genotype should be chosen according to inter-cluster distance given in Table 4.36 and 4.37 which represents the index of genetic diversity among clusters. Varieties fall in same cluster showing overall similarity among them. However, it would appear logical to affect crosses between genotypes belonging to the clusters separated by high estimated statistical distance. In the present study during the year 2014, the inter-cluster average D^2 value was found maximum (4623.73) between cluster III and VII followed by D^2

value (3093.86) between cluster IV and VII. In second year 2016, the inter-cluster average D^2 value was found maximum (7229.67) between cluster IV and VII followed by D^2 value (7207.71) between cluster II and VII, whereas, the inter-cluster average D^2 value was found maximum (513.38) between cluster III and VII followed by D^2 value (356.77) between cluster IV and VII.

The importance of different characters in the inter-cluster divergence can be studied further by comparing cluster means for different characters. The cluster mean values for different characters were more or less similar during both the years. Any variation in the cluster mean values for characters under study over the two years may be due to the effect of environment on due to occupation of different genotypes in the cluster over the years. As per pooled analysis, the donor for different characters can be selected from clusters on the basis of their cluster mean values as for leaf length (cluster VI and VII), leaf width (cluster VI and VII), leaf areas (cluster VI and VII), duration of panicle emergence (cluster VI and VII), number of secondary rachis per panicle (cluster V and VII), Length and width of inflorescence (cluster IV and VI), duration of flowering (cluster V and VI), duration of fruit maturity (cluster III and VI), number of fruits per tree at harvesting (cluster I and II), yield per tree (cluster IV and VII), fruit weight, fruit length and width cluster (III and VII), stone weight, stone length and width (cluster III and VII), Pulp and peel weight (cluster III and VII), pulp: stone ratio (cluster IV and VII), TSS (cluster VI and V), Acidity (cluster V and IV), reducing sugar (cluster VI and V), non reducing sugar (cluster VI and V), total sugar (cluster VI and V), ascorbic acid (cluster IV and V) and total carotenoid (cluster VI and V). The genotype belonging to distant clusters with high cluster mean may be identified to be utilized in the hybridization programme with high breeding value can be selected. This information will facilitate the selection of genotypes/lines with desirable attributes.

Comparatively less inter-cluster D^2 Values observed between any cluster pairs indicate close relation of genotypes of different clusters for various characters. Based on the D^2 analysis it is reasonable to assume that the genetic material under study would form groups and clusters of genotypes in which measurement for various characters are normally distributed. The genotypes belonging to distant cluster with high cluster mean may be identified to be utilized further in the hybridization programme. The characters showing substantial contribution towards divergence may be emphasized while practicing stringent selection programme. Though it is reasonable to predict genetic divergence to be associated with geographical diversity, however this may be applicable to land races but when deal with various genotype/ cultivars whose origin is not known, the selection of parent only on the basis of geographical diversity is not always fruitful.

Certain varieties in cluster showed difference in cluster pattern in both the year. As varieties grouped into same cluster in first year were found in different cluster in next year. This could be explained as most of the characters are quantitative in nature and they are generally influenced by environment and there might be a considerable interplay of environmental factors influencing the expression of these characters. A difference in cluster pattern among the cluster in two consecutive years suggests that perhaps genetic and environmental factors affect the characters through modified physiological means. It should be emphasized that observed character apply only to the specific populations under specific environmental conditions. So, this change in grouping pattern of cluster instead of similar varieties with similar experiments is due to environmental condition. The correlation obtained for various character pairs may be different when plant material is grown under different environments.

4.3.2.4 Per cent contribution of different characters towards genetic divergence

Based on the Mahalnobis' D^2 statistics, the estimate of per cent contribution of different characters towards genetic divergence are presented in Table 4.41 and Fig. 4.27, 4.28 and 4.29 for the year 2014, 2016 and pooled analysis respectively.

In the first year (2014), it is evident from D^2 analysis that number of fruit per tree at harvesting contributed maximum towards genetic divergence (24.74%) followed by stone length (21.03%) and total carotenoid (10.00%). Similarly, in the year 2016, number of fruit per tree at harvesting contributed maximum towards genetic divergence (29.10%) followed by total carotenoid (18.72%) and ascorbic acid (8.08%). In pooled analysis of two year data, the maximum percentage of genetic divergence contributed by number of fruit per tree at harvesting (28.97%) followed by total carotenoid (14.23%) and ascorbic acid (10.90%).

Table 4.41: Per cent contribution of different morphological and physico-chemical characteristics towards genetic divergence in mango varieties including new accessions on the basis of Mahalnobis' D^2 analysis

S. No.	Characteristics	Per cent contribution to genetic divergence		
		2014	**2016**	**Pooled**
1	Leaf length (cm)	0.00	0.64	0.38
2	Leaf width (cm)	0.00	0.00	0.00
3	Leaf area (cm^2)	1.79	0.13	0.38
4	Duration of panicle emergence (days)	0.00	0.13	0.13
5	Number of secondary rachis/ panicle	0.00	0.00	0.13
6	Length of inflorescence (cm)	0.77	2.95	3.97
7	Width of inflorescence (cm)	0.00	0.13	0.00
8	Duration of flowering (days)	0.13	0.26	0.00
9	Duration of fruit maturity (days)	7.82	3.46	10.38
10	Number of fruits/tree at harvesting	24.74	29.10	28.97
11	Yield per tree (kg)	0.38	1.67	1.41
12	Fruit weight (g)	1.92	0.00	0.38
13	Fruit length (cm)	3.72	6.54	11.15
14	Fruit width (cm)	1.67	4.74	1.41
15	Stone weight (g)	0.77	3.08	5.00
16	Stone length (cm)	21.03	0.38	2.56
17	Stone width (cm)	2.69	0.00	0.00
18	Pulp weight (g)	5.64	0.00	1.67
19	Peel weight (g)	0.64	1.15	0.13
20	Pulp : stone ratio	0.13	0.26	0.13
21	TSS (^{0}B)	0.00	3.59	2.95
22	Acidity (%)	3.46	3.72	1.67
23	Reducing sugar (%)	6.15	5.26	2.05
24	Non reducing (%)	0.13	1.03	0.00
25	Total sugar (%)	0.00	5.00	0.00
26	Ascorbic acid (mg/100 g flesh)	6.41	8.08	10.90
27	Total Carotenoid (mg/100g flesh)	10.00	18.72	14.23
	Total	**100.00**	**100.00**	**100.00**

It is also observed that in 2014, zero per cent (0.00%) contribution towards genetic divergence was estimated for leaf length, leaf width, duration of panicle emergence, number of secondary rachis per panicle, with of inflorescence, TSS and total sugar, whereas, in the year 2016, Per cent contribution towards genetic divergence was determined zero (0.00%) for leaf width, number of secondary rachis per panicle, fruit weight, stone width and pulp weight. Similarly, in pooled zero Per cent of genetic divergence was contributed by leaf width, with of inflorescence, stone width, non reducing and total sugar.

In addition to, a general feature of variation and divergence, this study also provides information on the characters that contributed maximum to the total divergence. During the year 2014, 2016 and pooled analysis of two year data, number of fruit per tree at harvesting contributed maximum towards divergence followed by stone length, ascorbic acid and total carotenoid, whereas, zero Per cent contribution towards genetic divergence was estimated for leaf width. Similar results have also been reported by Rathod and Naik (2007), Rajan *et al.* (2009), Vasugi *et al*. (2013), Barholia and Yadav (2014) in mango.

The results suggested that, the mango varieties including new accessions taken under investigation having a most diverse range for number of fruit per tree at harvesting followed by stone length, ascorbic acid and total carotenoid. These characters are considered to be most important for the genetic diversity. Genetic diversity play an important role because hybrids between parental lines of diversified group, generally display a greater heterosis rather than between closely related parents and to create further variability for these characters diversified genotypes can be used in breeding programme as donor of these characters. The heterotic effects may be further utilized for yield enhancement through selection.

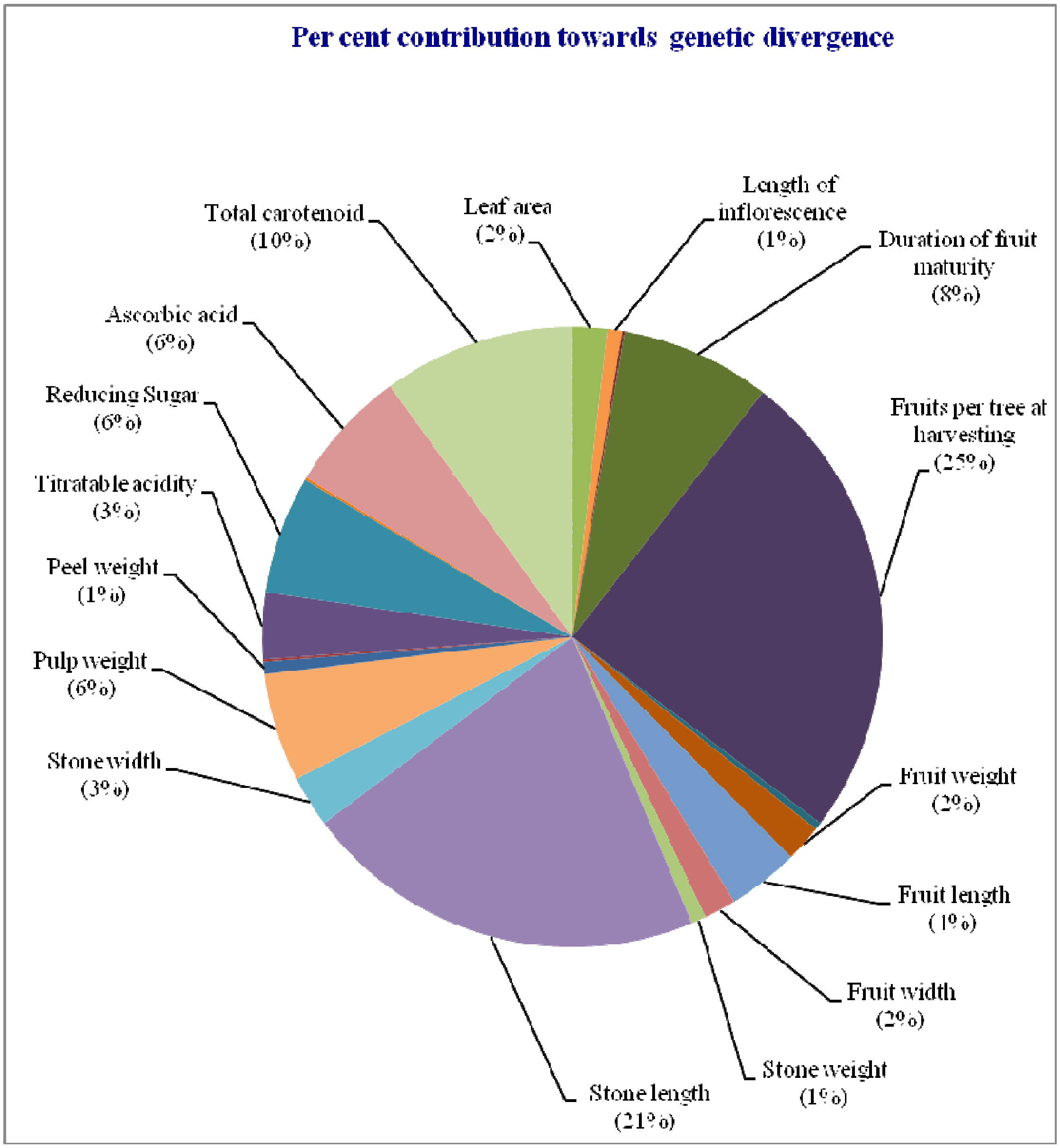


Fig. 4.27: Graph showing per cent contribution towards genetic divergence by different morphological and physico-chemical characteristics on the basis of D^2 analysis (2014)

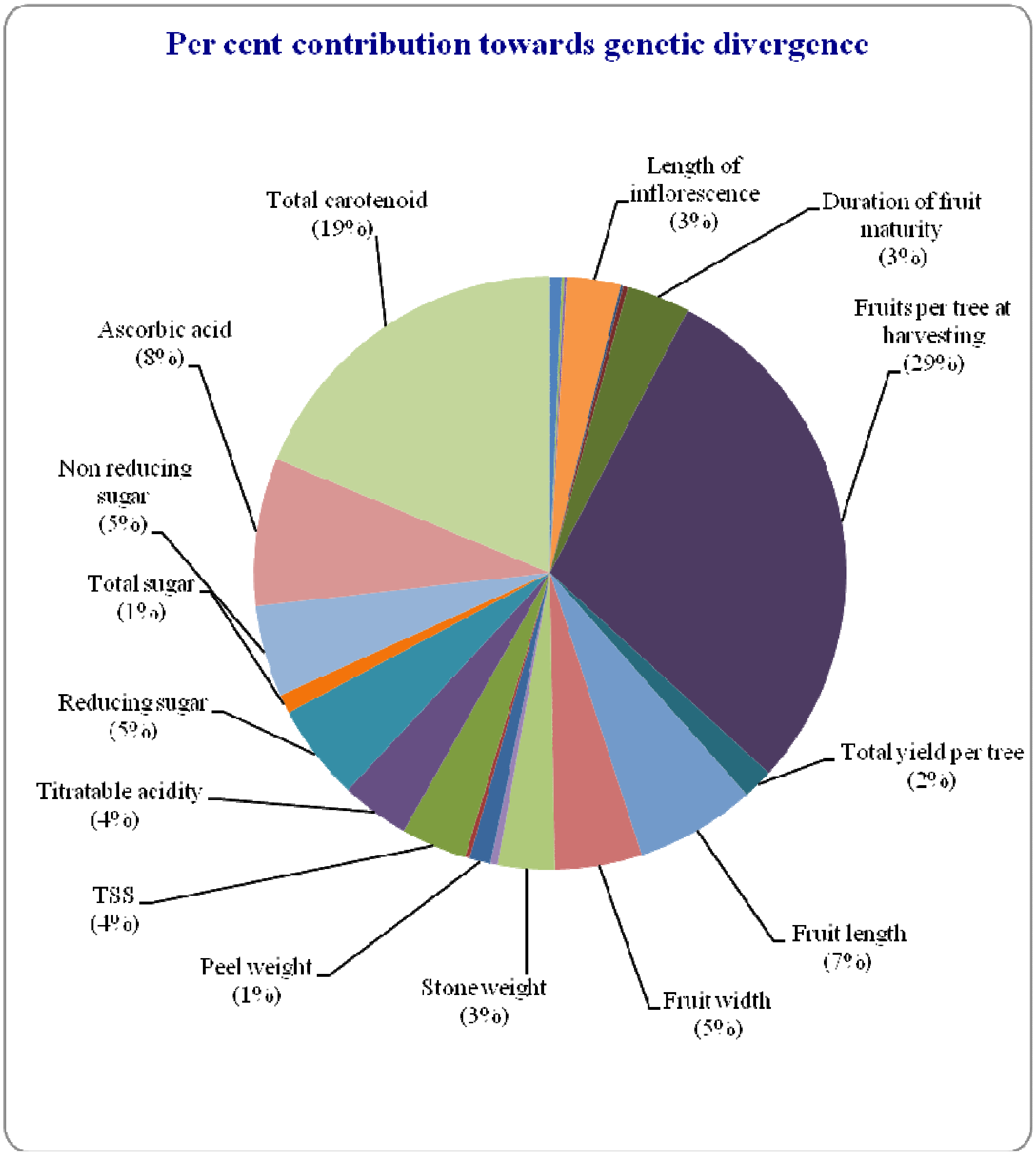


Fig. 4.28: Graph showing per cent contribution towards genetic divergence by different morphological and physico-chemical characteristics on the basis of D^2 analysis (2016)

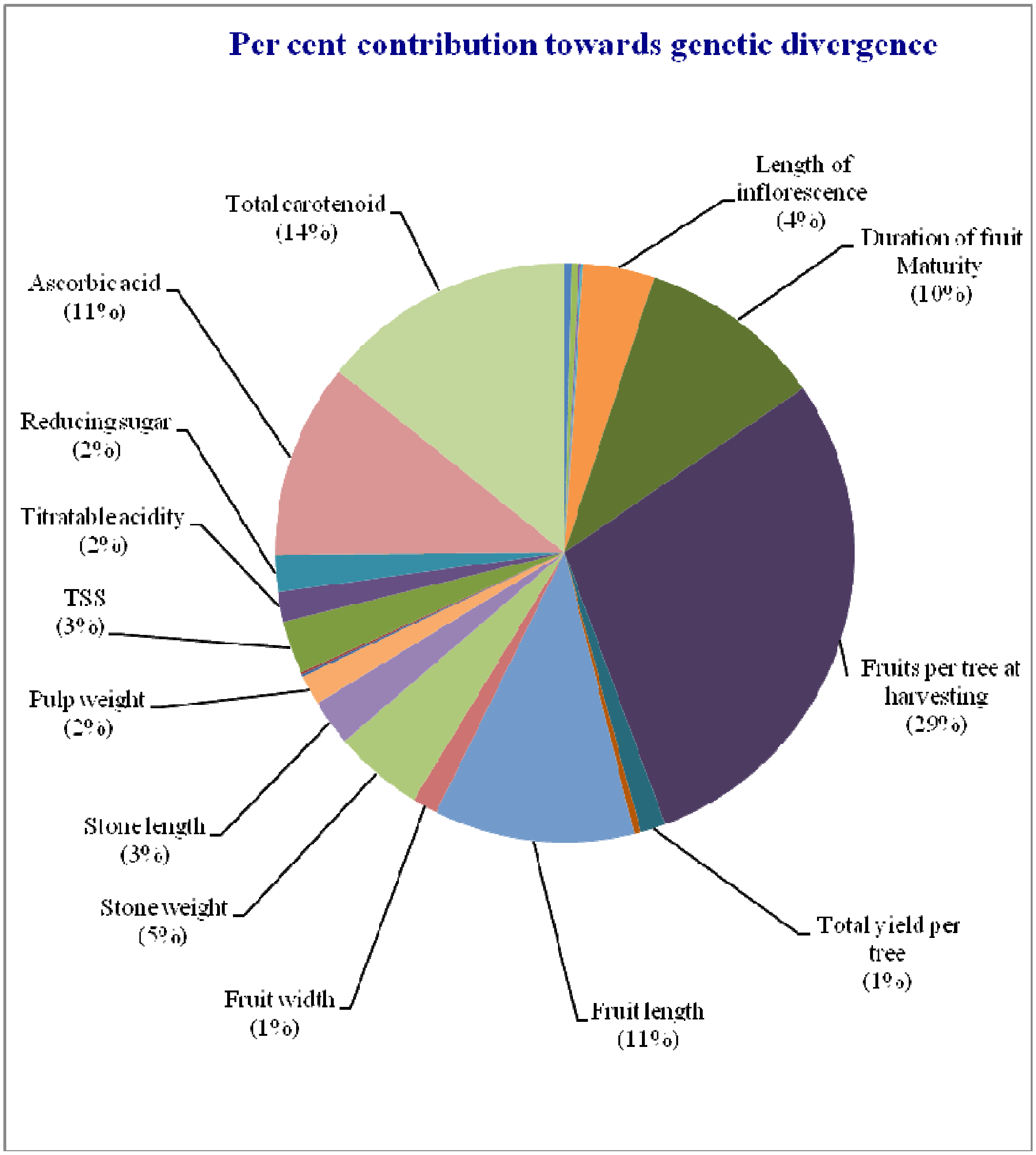


Fig. 4.29: Graph showing per cent contribution towards genetic divergence by different morphological and physico-chemical characteristics on the basis of D^2 analysis (pooled data of 2014 and 2016)

Summary and Conclusions

Chapter 5 SUMMARY AND CONCLUSION

The present investigation entitled "Classification of different varieties and new accessions of mango (*Mangifera indica* L.) based on qualitative traits and assessment of genetic diversity'' was undertaken at GBPUA&T, Pantnagar with the objectives of characterization and grouping of genotypes based on qualitative traits and to assess the genetic variability and diversity among these mango varieties and new accessions through principal component analysis (PCA) and D^2 statistics.

The experiment was carried out for two years i.e., during 2014 and 2016 under Randomized Block Design (RBD) with three replications at Horticulture Research Centre, Patharchatta of GBPUA&T, Pantnagar. Three healthy fruit bearing trees of uniform vigour and size under each treatment/variety, receiving uniform cultural practices were selected for experimentation. At the start of experiment the age of varieties/accessions was 8 years. The 25 morphological qualitative and 27 quantitative traits were considered for present investigation as per the universal format of descriptors for mango that includes the morphological traits of plant, leaves, flowers, seeds and fruits (IBPGR, 1989, IPGRI, 2006) and also followed the mango Distinctiveness, Uniformity and Stability (DUS) descriptors developed by the Protection of Plant Varieties and Farmers Right Authority, Government of India, New Delhi. The twenty five morphological qualitative traits were visually assessed for characterization and grouping of mango varieties and twenty seven quantitative traits were statistically analyzed to estimate the different genetic parameters as well as to assess the genetic divergence among the forty mango varieties including new accessions.

The data were subjected to appropriate statistical analysis and the results obtained through pooled analysis are summarized as follows:

- The spreading growth habit was observed in the mango varieties like Langra, Chausa, Arunika, Van Raj, Burma Surkh, Pant Sinduri, Bombay Green, Amrapali, Pusa Arunima, Pusa Surya, Arka Neelkiran, Ambika, Neeluddin, Neeleshan, Neelgoa, Ratna, Bangalora, Totapuri Red Small, Saurabh, Rajiv, Himanshu, Dilpasand, Chandrakaran, Sensation, Tommy Atkins, Dashehari,

Dashehari 35, Dashehari 51, A.U. Rumani, Gourav, Sukul and Himsagar, whereas, erect growth habit was observed in Mallika, Angoor Lata, Tilka Bhadainya, Swarna Jehangir, PMSS-1, Sabri, Pant Chandra and Surkha Khal.

- The oblong canopy was observed in the varieties such as Bombay Green, Pant Chandra, Pusa Arunima, Swarna Jehangir, Totapuri Red Small, Sabri, Angoor Lata, Sukul, Himsagar, Surkha Khal and Sensation, while Semi-circular shape was observed in Arka Neelkiran, Ambika, Neeluddin, A.U. Rumani, Rajiv, Himanshu, Tilka Bhadainya, Burma Surkh, Chausa, Langra, Pant Sinduri, PMSS-1, Ambika, Neeleshan, Neelgoa, Ratna, Bangalora, Saurabh, Gourav, Van Raj, Dilpasand, Chandrakaran, Tommy Atkins, Dashehari, Dashehari 35, Dashehari 51, Amrapali, Mallika and Pusa Surya.
- The dense branch density was recorded in the varieties such as Pant Sinduri, Mallika, Pusa Arunima, Pusa Surya, PMSS-1 and Sensation and medium was recorded in Dilpasand, Langra, Chausa, Bombay Green, Chandrakaran, Himanshu, Tommy Atkins, Dashehari, Dashehari 35, Dashehari 51, Pant Chandra, Arka Neelkiran, Arunika, Neeluddin, Neeleshan, Neelgoa, A.U. Rumani, Bangalora, Sukul and Burma Surkh. The sparse branch density was observed in Amrapali, Ambika, Swarna Jehangir, Sabri, Totapuri Red Small, Himsagar, Tilka Bhadainya, Ratna, Saurabh, Van Raj, Angoor Lata, Rajiv, Gourav and Surkha Khal.
- The dense foliage density was observed in the varieties like Dashehari, Amrapali, Pusa Arunima, Ambika, A.U. Rumani, Pant Sinduri, PMSS-1, Dashehari 35, Dashehari 51, Saurabh, Arka Neelkiran, Sukul and Sensation, while, intermediate foliage density was recorded in Bombay Green, Pant Chandra, Mallika, Neeluddin, Himanshu, Burma Surkh, Neelgoa, Bangalora, Neeleshan, Dilpasand, Tommy Atkins, Chandrakaran and Langra. The sparse foliage density was observed in Ratna, Totapuri Red Small, Rajiv, Swarna Jehangir, Sabri, Pusa Surya, Gourav, Van Raj, Tilka Bhadainya, Himsagar, Angoor Lata and Surkha Khal.
- The weak intensity of anthocyanin in young leaf was observed in the varieties like Dashehari, Dashehari 35, Dashehari 51, Pant Chandra, A.U. Rumani,

Gourav, Sukul and Himsagar, while, medium was recorded in Langra, Chausa, PMSS-1, Arunika, Swarna Jehangir, Sabri, Van Raj, Tilka Bhadainya, Burma Surkh and Pant Sinduri, however, strong intensity of anthocyanin in young leaf was recorded in mango varieties such as Bombay Green, Amrapali, Mallika, Pusa Arunima, Pusa Surya, Arka Neelkiran, Ambika, Neeluddin, Neeleshan, Neelgoa, Ratna, Bangalora, Totapuri Red Small, Angoor Lata, Saurabh, Rajiv, Himanshu, Dilpasand, Chandrakaran, Surkha Khal, Sensation and Tommy Atkins.

- The acute leaf apex shape was noted in the varieties such as Swarna Jehangir, Sabri, Totapuri Red Small, Dilpasand, Himsagar, Tilka Bhadainya and Chandrakaran; attenuate shape of leaf apex in Dashehari, Dashehari 35, Dashehari 51, Pant Chandra, PMSS-1, Amrapali, Arka Neelkiran, Arunika, Neeluddin, Neeleshan, Neelgoa, A.U. Rumani, Ratna, Bangalora, Angoor Lata, Saurabh, Gourav, Sukul, Van Raj, Surkha Khal, Burma Surkh and Sensation. The acuminate leaf apex shape was found in rest of the varieties including new accessions.
- The acute leaf base shape was observed in the varieties like Dashehari, Dashehari 35, Dashehari 51, Bombay Green, Pant Chandra, Amrapali, Mallika, Pusa Arunima, Pusa Surya, Arka Neelkiran, Ambika, Neeluddin, A.U. Rumani, Totapuri Red Small, Angoor Lata, Rajiv, Himanshu, Himsagar, Tilka Bhadainya and Burma Surkh, while, obtuse leaf base shape in Langra, Chausa, Pant Sinduri, PMSS-1, Ambika, Neeleshan, Neelgoa, Swarna Jehangir, Ratna, Bangalora, Saurabh, Gourav, Sukul, Van Raj, Dilpasand, Chandrakaran, Surkha Khal, Sensation and Tommy Atkins.
- The twisting of leaf was absent in the varieties like Dashehari, Dashehari 35, Dashehari 51, Bombay Green, Pant Chandra, Amrapali, Mallika, Pusa Arunima, Pusa Surya, Arka Neelkiran, Ambika, Neeluddin, A.U. Rumani, Angoor Lata, Rajiv, Himanshu, Himsagar, Tilka Bhadainya, Burma Surkh, Langra, Pant Sinduri, PMSS-1, Ambika, Neeleshan, Neelgoa, Swarna Jehangir, Bangalora, Saurabh, Gourav, Van Raj, Sabri, Dilpasand, Chandrakaran, Surkha Khal and Tommy Atkin, whereas it was present in rest of the mango varieties.

- The entire leaf margin was observed in the varieties such as Amrapali, Pusa Arunima, Ambika, Neeleshan, A.U. Rumani, Rajiv, Swarna Jehangir, Ratna, Sabri, Dilpasand, Tommy Atkins, Himsagar and Chandrakaran and wavy leaf margin was observed in Dashehari 35, Dashehari 51, Dashehari, Bombay Green, Pant Chandra, Mallika, Pusa Surya, Arka Neelkiran, Neeluddin, Angoor Lata, Rajiv, Himanshu, Tilka Bhadainya, Burma Surkh, Langra, Pant Sinduri, PMSS-1, Ambika, Neelgoa, Bangalora, Saurabh, Gourav, Van Raj and Surkha Khal.

- The weak anthocyanin colouration on main rachis of inflorescence was observed in the varieties such as Dashehari, Dashehari 35, Dashehari 51, Pant Chandra, A.U. Rumani, Sukul, Chausa, Angoor Lata, Saurabh, Langra and Mallika, while, medium was found in Tilka Bhadainya, Burma Surkh, Rajiv, Bombay Green, Amrapali, Himsagar, Pusa Arunima, Arka Neelkiran, Gourav, Neeluddin, Neeleshan, Himanshu, PMSS-1 and Bangalora. However, strong anthocynin was found in varieties of mango like Pusa Surya, Ambika, Neelgoa, Ratna, Totapuri Red Small, Dilpasand, Chandrakaran, Surkha Khal, Sabri, Van Raj, Sensation, Tommy Atkins, Pant Sinduri, Arunika and Swarna Jehangir.

- The Pyramidal shape of panicle was recorded in the varieties like Dashehari, Dashehari 35, Pant Chandra, Ambika, Amrapali, Mallika, Pusa Arunima, Neeluddin, A.U. Rumani, Rajiv, Himanshu, Himsagar, Langra, Pant Sinduri, PMSS-1, Ambika, Neeleshan, Neelgoa, Bangalora, Saurabh, Gourav, Sukul, Dilpasand, Chandrakaran and Surkha Khal, while, conical shape of panicle was observed in Dashehari 51, Bombay Green, Chausa, Pusa Surya, Arka Neelkiran, Swarna Jehangir, Totapuri Red Small, Ratna, Angoor Lata, Van Raj, Tilka Bhadainya, Burma Surkh, Sensation and Tommy Atkins.

- The terminal position of inflorescence was observed in the varieties such as Dashehari, Dashehari 35, Dashehari 51, Pant Chandra, PMSS-1, Amrapali, Arka Neelkiran, Arunika, Neeluddin, Neeleshan, Neelgoa, A.U. Rumani, Ratna, Bangalora, Angoor Lata, Saurabh, Gourav, Sukul, Surkha Khal, Burma Surkh, Swarna Jehangir, Sabri, Totapuri Red Small, Dilpasand, Himsagar, Tilka Bhadainya, Chandrakaran, Pant Sinduri, Mallika, Pusa Arunima, Langra, Chausa, Bombay Green, Pusa Surya, Ambika, Ratna, Saurabh, Himanshu and Tommy Atkins, whereas, terminal and axillaries position of inflorescence was observed in Van Raj, Sensation and Rajiv.

- The inflorescence bracts were present in most of the varieties such as Dashehari, Dashehari 35, Dashehari 51, Bombay Green, Pant Chandra, Amrapali, Mallika, Pusa Arunima, Pusa Surya, Arka Neelkiran, Ambika, Neeluddin, A.U. Rumani, Angoor Lata, Rajiv, Himanshu, Himsagar, Tilka Bhadainya, Burma Surkh, Langra, Pant Sinduri, PMSS-1, Ambika Neeleshan, Neelgoa, Swarna Jehangir, Bangalora, Saurabh, Gourav, Van Raj, Dilpasand, Chandrakaran, Surkha Khal, Tommy Atkins and Sabri, while, inflorescence bracts were absent in some varieties like Chausa, Ratna, Totapuri Red Small, Sukul and Sensation.

- The green colour of mature fruit skin was observed in the varieties like Dashehari, Dashehari 35, Dashehari 51, Pant Chandra, PMSS-1, Amrapali, Neeluddin, Neeleshan, Himsagar, A.U. Rumani, Angoor Lata, Saurabh, Gourav, Sukul, Surkha Khal, Burma Surkh, Langra, Chausa, Mallika, Bombay Green, Ratna, Saurabh, Himanshu, Swarna Jehangir, Sabri, Chandrakaran and Tilka Bhadainya, while, green and red colour was observed in Totapuri Red Small, Tommy Atkins, Pant Sinduri, Pusa Surya, Arka Neelkiran, Arunika, Neelgoa, Bangalora, Ratna and Van Raj, however green and purple colour of mature fruit skin was found in Pusa Arunima, Ambika and Sensation.

- The shape in cross section of mature fruits was found circular in the varieties such as Pusa Arunima, Pusa Surya, Chandrakaran, Surkha Khal, Tilka Bhadainya, Neelgoa, Van Raj, Sukul and Angoor Lata, while, medium elliptic was observed in Dashehari, Dashehari 35, Dashehari 51, Chausa, Rajiv, A.U. Rumani, Himanshu and Burma Surkh, However broad elliptic was recorded in Bombay Green, Amrapali, Mallika Arka Neelkiran, Ambika, Neeluddin, Neeleshan, Ratna, Bangalora, Totapuri Red Small, Saurabh, Dilpasand, Langra, Pant Chandra, Gourav, Himsagar, PMSS-1, Arunika, Swarna Jehangir, Sabri, Pant Sinduri, Sensation and Tommy Atkins.

- The cavity at stalk of fruits was present in the varieties like Mallika, Pusa Arunima, Arunika, Neeluddin, Totapuri Red Small, Gourav, Sensation and

Tommy Atkins, while, cavity at stalk was absent in Dashehari, Dashehari 35, Dashehari 51, Bombay Green, Pant Chandra, Amrapali, Pusa Surya, Arka Neelkiran, Ambika, A.U. Rumani, Angoor Lata, Rajiv, Himanshu, Himsagar, Tilka Bhadainya, Burma Surkh, Langra, Chausa, Pant Sinduri, PMSS-1, Ambika, Neeleshan, Neelgoa, Swarna Jehangir, Ratna, Bangalora, Saurabh, Sukul, Van Raj, Dilpasand, Chandrakaran and Surkha Khal.

- The neck of fruit was present in the varieties such as Totapuri Red Small, Sensation, Tommy Atkins, Dilpasand, Mallika, Pusa Arunima, Arunika and Neeluddin, whereas, it was absent in Dashehari, Dashehari 35, Dashehari 51, Bombay Green, Pant Chandra, Amrapali, Pusa Surya, Arka Neelkiran, A.U. Rumani, Angoor Lata, Rajiv, Himanshu, Himsagar, Tilka Bhadainya, Burma Surkh, Langra, Pant Sinduri, PMSS-1, Ambika, Neeleshan, Neelgoa, Swarna Jehangir, Bangalora, Saurabh, Gourav, Van Raj, Chandrakaran, Surkha Khal, Sabri, Chausa, Ratna and Sukul.
- The rounded upward ventral shoulder shape of fruit was found in the varieties like Saurabh, Gourav, Surkha Khal, Pusa Surya, Chandrakaran, Tilka Bhadainya, Neelgoa, Sukul, Angoor Lata, Chausa, Rajiv, Himanshu, Burma Surkh, Bombay Green, Mallika, Arka Neelkiran, Ambika, Neeluddin, Neeleshan, Ratna, Bangalora, Dilpasand, Himsagar, Arunika, Pant Sinduri and Tommy Atkins, whereas, rounded outward was observed in Dashehari, Dashehari 35, Dashehari 51, Langra, PMSS-1, Pant Chandra, Amrapali, Van Raj, Pusa Arunima, A.U.Rumani, Swarna Jehangir, Totapuri Red Small, Sabri and Sensation.
- The sloping downward dorsal shoulder shape of fruit was found in the varieties such as Dashehari, Dashehari 35, Dashehari 51, Amrapali, A.U. Rumani, Saurabh, Gourav, Sukul, Surkha Khal, Bombay Green, Ratna, Saurabh, Sabri, Swarna Jehangir, Tilka Bhadainya, Pusa Arunima, Arunika, Ambika, Sensation, Totapuri Red Small, Tommy Atkins, Pant Sinduri and Ratna, while, rounded downward dorsal shoulder was observed in Angoor Lata, Himsagar, Pusa Surya, Arka Neelkiran, Neelgoa, Van Raj, Pant Chandra, PMSS-1, Dilpasand, Rajiv and Langra, whereas, falling abruptly was found in Chausa, Mallika, Neeluddin, Neeleshan, Himanshu, Chandrakaran, Burma Surkh and Bangalora.

- The sinus of fruit was present in the varieties such as Bangalora, Totapuri Red Small, Mallika, Pant Sinduri, Ambika, Amrapali, Pusa Surya, Neelgoa, Gourav, Sukul and Burma Surkh, whereas, sinus was absent in Dashehari, Dashehari 35, Dashehari 51, Bombay Green, Pant Chandra, Arka Neelkiran, A.U. Rumani, Angoor Lata, Rajiv, Himanshu, Himsagar, Tilka Bhadainya, Langra, Chausa, PMSS-1, Neeleshan, Swarna Jehangi, Pusa Arunima, Arunika, Neeluddin, Sensation, Tommy Atkins, Ratna, Saurabh, Van Raj, Dilpasand, Chandrakaran and Surkha Khal.
- The large point at stylar scar of fruit was observed in the varieties like Totapuri Red Small and Bangalora, whereas, medium was found in Dilpasand, Mallika, Pusa Surya, Pant Sinduri, Saurabh, Gourav, Sukul and Ambika. The small point at stylar scar was observed in most of the varieties *viz.,* Dashehari, Dashehari 35, Dashehari 51, Bombay Green, Pant Chandra, Amrapali, Arka Neelkiran, A.U. Rumani, Angoor Lata, Rajiv, Himanshu, Himsagar, Tilka Bhadainya, Burma Surkh, Langra, PMSS-1, Neeleshan, Neelgoa, Swarna Jehangir, Van Raj, Chandrakaran, Surkha Khal, Sabri, Chausa, Ratna, Sensation, Tommy Atkins, Pusa Arunima, Arunika and Neeluddin.
- The predominant colour of ripe fruit skin was varied as green colour in the varieties such as Pant Chandra, Bombay Green and Tilka Bhadainya; yellow green colour in Langra, PMSS-1, Angoor Lata, Neeleshan, Neeluddin, Dilpasand, Himanshu, Himsagar and Sukul; green and yellow colour in Chausa, Rajiv and Saurabh; yellow colour in Dashehari, Dashehari 35, Dashehari 51, Gourav, Chandrakaran, Ratna, Arka Neelkiran and A.U. Rumani; yellow orange colour in Amrapali and Mallika; yellow and red colour in Pant Sinduri, Pusa Surya, Neelgoa, Bangalora, Sabri, Burma Surkh and Arunika; red and purple colour in Tommy Atkins, Sensation, Van Raj and Pusa Arunima and red colour was found in Swarna Jehangir, Surkha Khal, Ambika and Totapuri Red Small.
- Flesh colour of ripe fruit was varied as light yellow in the varieties such as Langra, Pant Sinduri, Neelgoa, Sukul and Chandrakaran; medium yellow in Chausa, PMSS-1, Mallika, Sensation, Pusa Arunima, Neeluddin, Dilpasand, Bangalora, Saurabh, Rajiv and Himanshu; light orange in Dashehari,

Dashehari 35, Dashehari 51, A.U. Rumani and Burma Surkh, medium orange in Arka Neelkiran, Totapuri Red Small, Arunika, Sabri, Angoor Lata, Gourav, Tommy Atkins and Van Raj; dark orange in Bombay Green, Pant Chandra, Amrapali, Himsagar, Ratna, Tilka Bhadainya, Neeleshan, Ambika, Swarna Jehangir, Surkha Khal and Pusa Surya.

- The ridged surface of stone was observed in the varieties like Bombay Green, Pant Chandra, Neeluddin, Neeleshan, Ratna, Saurabh and Gourav, while, smooth in Pusa Surya, Arka Neelkiran, A.U. Rumani, Ambika, Neelgoa, Sabri, Bangalora, Totapuri, Red Small, Angoor Lata, Dilpasand, Sukul, Van Raj, Tilka Bhadainya, Himsagar, Chandrakaran, Tommy Atkins and Surkha Khal, whereas, grooved in Chausa, PMSS-1, Pusa Arunima, Swarna Jehangir, Sensation, Dashehari, Dashehari 35, Dashehari 51, Amrapali, Arunika, Rajiv, Himanshu, Burma Surkh, Langra, Mallika and Pant Sinduri.
- The reniform lateral view of seed kernel was observed in the varieties like Chausa, PMSS-1, Pusa Arunima, Ambika, Neeluddin, Neeleshan, Neelgoa, Swarna Jehangir, Ratna, Sabri, Bangalora, Himsagar, Saurabh, Gourav, Dilpasand, Sukul, Sensation, Tommy Atkins and Surkha Khal, whereas, oblong lateral view of seed kernel was observed in Dashehari, Dashehari 35, Van Raj, Dashehari 51, Bombay Green, Pant Chandra, Amrapali, Arunika, Pusa Surya, Arka Neelkiran, A.U. Rumani, Angoor Lata, Rajiv, Himanshu, Tilka Bhadainya, Langra, Pant Sinduri, Chandrakaran, Totapuri Red Small, Mallika and Burma Surkh.
- Analysis of variance showed significant variation for most of the characteristics. The interaction (genotype x environments) was not significant for all the characters except ascorbic acid under study. Thus, it signifies the wider genetic base of the experimental material for their use in further breeding programme.
- The large amount of variation (as shown by mean performance and wide range) were exhibited for leaf area, number of secondary rachis per plant, length of inflorescence, width of inflorescence, duration of fruit maturity, number of fruits per tree at harvesting, yield per tree, fruit weight, fruit length,

fruit width, stone weight, stone length, stone width, pulp weight, peel weight, pulp: stone ratio, TSS, acidity, reducing sugar, non reducing, total sugar, ascorbic acid and total carotenoids.

- High estimates of PCV and GCV for the characters *viz.* number of fruits per tree at harvesting, yield per tree, total carotenoids, pulp weight, fruit weight, peel weight, stone weight and pulp: stone ratio indicated greater variability in these traits, which can be effectively improved through selection. On the other hand, low estimates of PCV and GCV for leaf length, leaf width, fruit size, stone size, duration of panicle emergence, duration of flowering indicated low to moderated variability for these characteristics for which selection may be restricted to certain degree.
- High estimates of broad sense heritability was observed for most of characters and moderate for number of fruits per tree at harvesting, fruit length, fruit weight, peel weight, total carotenoids, pulp weight, duration of fruit maturity, stone length, stone weight, fruit width, yield per tree, leaf area, reducing sugar, ascorbic acid, pulp: stone ratio, acidity.
- High estimate of genetic advance (as per cent of mean at 5% selection intensity) was observed for most of traits and moderate for leaf length and leaf width under study.
- Significant positive correlations were observed for yield per tree with fruit weight, fruit length, fruit width, stone length, stone width, pulp weight, pulp: stone ratio, ascorbic acid and total carotenoids. The total soluble solids showed significant positive correlation with reducing sugar, total sugar, non reducing sugar and total carotenoids. Total sugar showed significant positive correlation with non reducing sugar, total carotenoids.
- Principal component analysis formed twenty seven principal axises and the first nine components explained 82.93 per cent of the total variability among the varieties. The principal component one with Eigen value of 7.492 and contributed 27.74 % of the total variability, while, PC2 with Eigen value of 3.09 accounted for 11.46 % of the total variability observed among the 40 mango varieties. PC3 had Eigen value of 2.545 and contributed 9.42 % of the

total variability observed in different mango varieties. Meanwhile, PC4, PC5, PC6, PC7, PC8, PC9 and PC10 had Eigen value 2.053, 1.994, 1.728, 1.249, 1.151, 1.084 and 0.846 and contributed 7.60, 7.38, 6.39, 4.62, 4.26, 4.01 and 3.13 % of the total variability, respectively.

- On basis of PCA, the first, second and third principal components (PC1, PC2 and PC3) had shown positive component loading for most the varieties, whereas, third principal component had shown (PC3) negative loading for Bangalora.
- The range of variability for different mango varieties varied from 8.63 to 30.92 % in principal components one (PC1) followed by second principal component ranged from 2.81 to 13.16 % of the total variability, respectively. The principal component one (PC1) had shown highest positive component loading from Bangalora (30.92 %) followed by Sensation (29.44 %) and Mallika (28.01 %), which comprised 39 varieties in first group, while, lowest component loading was recorded from Angoor Lata (8.63%) which comprised in second group. The closer genotypes score to the center of the biplot are more stable than the score of the genotypes away from the center.
- The forty mango varieties and new accessions were grouped into seven clusters on the basis of D^2 statistics. The cluster I comprised of four varieties namely, Dashehari, Dashehari 35, Dashehari 51 and A.U. Rumani, while, cluster II comprised 24 varieties and cluster III also comprised 8 varieties namely, Mallika, Sensation, Pusa Arunima, Sukul, Chausa, PMSS-1, Van Raj and Bangalor. Cluster IV, V, VI and VII had one variety each *viz.,* Himanshu, Rajiv, Amrapali and Angoor Lata, respectively.
- On the basis D^2 statistics, the Intra-cluster average D^2 ranged from 0.00 to 104.40. It was maximum in cluster III comprising eight varieties followed by cluster II (74.37) and cluster I (40.25) having 24 and 4 varieties, respectively. The clusters VI, V, VI and VII have only one variety; hence intra-cluster D^2 values were zero.
- On the basis D^2 statistics, the inter-cluster average D^2 value was found maximum (513.38) between cluster III with eight and VII with a single variety

followed by D^2 value (356.77) between cluster IV with a single variety and VII with a single variety. The minimum inter-cluster D^2 distance (81.28) was observed between cluster I with 4 varieties and cluster V with a single variety followed by inter-cluster D^2 distance (89.74) was observed between cluster I with 4 varieties and IV with a single variety.

- On the basis of D value, the maximum relative genetic distance was observed between cluster III & VII (22.66) and cluster IV & VII (18.89) which shown the diverse genetics. The minimum genetic distance was found between the clusters I and V (9.02) followed by cluster I and IV (9.47) which indicates the close similarity in the varietal composition of these clusters.
- The donor for different characters can be selected from clusters on the basis of their cluster mean values as for leaf length (cluster VI and VII), leaf width (cluster VI and VII), leaf areas (cluster VI and VII), duration of panicle emergence (cluster VI and VII), number of secondary rachis per panicle (cluster V and VII), Length and width of inflorescence (cluster IV and VI), duration of flowering (cluster V and VI), duration of fruit maturity (cluster III and VI), number of fruits per tree at harvesting (cluster I and II), yield per tree (cluster IV and VII), fruit weight, fruit length and width cluster (III and VII), stone weight, stone length and width (cluster III and VII), Pulp and peel weight (cluster III and VII), pulp: stone ratio (cluster IV and VII), TSS (cluster VI and V), Acidity (cluster V and IV), reducing sugar (cluster VI and V), non reducing sugar (cluster VI and V), total sugar (cluster VI and V), ascorbic acid (cluster IV and V) and total carotenoids (cluster VI and V).
- The genotype belonging to distant clusters with high cluster mean may be identified and it can be utilized in the hybridization programme.
- On the basis of D^2 analysis, the maximum per cent of genetic divergence was contributed by number of fruit per tree at harvesting (28.97 %) followed by total carotenoids (14.23 %) and ascorbic acid (10.90 %) and minimum or zero per cent genetic divergence was contributed by leaf width, with of inflorescence, stone width, non reducing and total sugar.

Conclusion

On the basis of results, it may be concluded that morphological qualitative traits can be used for proper characterization, grouping of genotypes and varietal identification. Analysis of variance indicated that significant wide variations were observed among the mango varieties for most of the characters such as leaf length, width, area, duration of panicle emergence, duration of flowering and number of secondary rachis per panicle (ranged from 14.34-23.99 cm, 3.79-6.54 cm, 35.47-118.75 cm^2, 14.17-25.50 days, 15.17-26.50 days, 18.42-43.26, respectively). The inflorescence length, width, duration of fruit maturity, number of fruits per tree at harvesting and yield per tree varied from 22.01-52.29 cm, 10.94-25.14 cm, 82.33-155.33 days, 22.50-176.17 and 2.99-32.03 kg, respectively. The fruit traits such as fruit weight, length, width, pulp weight and pulp: stone ratio varied from 20.07-420.65 g, 3.48-13.28 cm, 2.81-8.70 cm, 13.15-351.64 g and 2.50-10.33, respectively. However, stone weight, length and width ranged from 5.34-64.90 g, 2.87-10.64 cm and 1.92-5.48 cm, respectively The TSS, total sugar, non reducing sugar and total carotenoids varied from 12.06-22.32 ^{0}B, 11.36-20.69 %, 8.32-14.62 % and 1.78-9.23 mg/100 g, respectively.

The phenotypic and genotypic coefficient of variation were found higher for number of fruits per tree at harvesting, yield per tree, total carotenoid, pulp weight, fruit weight, peel weight, stone weight and pulp: stone ratio, while these were moderate to low for remaining traits. High heritability coupled with moderate to high genetic advance was found for most of the characters, while lower genetic advance recorded for leaf length and leaf width. The genotypic correlation coefficient was higher than phenotypic correlation coefficient for most of the characters and yield per tree showed significant positive correlation with fruit weight, fruit length, fruit width, stone length, stone width, pulp weight, pulp: stone ratio, ascorbic acid, number of fruits per tree and total carotenoids, while negative with acidity. The assessment of genetic divergence revealed sufficient variability among the different varieties of mango. Principal component analysis indicated that first ten components accounted for more than 86.07 % of the total genetic variation. The characters contributing more positively with PC1 and exhibited maximum variability among the varieties for leaf area, leaf length, yield per tree, fruit weight, size, stone weight, stone size, peel weight and total sugar. Cluster analysis using D^2 statistics grouped different mango varieties into seven clusters during both the years as well as on the basis of pooled data of two years. Therefore, it would appear logical to attempt crosses between varieties belonging to the clusters separated by high estimated statistical distance. In pooled analysis, the inter-cluster average D^2 value was found maximum (513.38) between cluster III with eight varieties and VII with a single variety. The promising clusters were identified on the basis of cluster mean value of pooled analysis for desirable traits *viz.,* cluster III for maximum duration of fruit maturity, fruit weight, fruit size, stone weight, stone size, pulp and peel weight; cluster IV for higher yield per tree, length and width of inflorescence and cluster VI for TSS, reducing sugar, non reducing sugar, total sugar and total carotenoids. Results of PCA and D^2 analysis indicated substantial variation among the varieties and new accessions of mango with respect to different morphological and physico-chemical quantitative traits, which may help the mango breeders for future breeding programme.

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Appendices

APPENDIX I

Weekly Standard Meteorological average weather data during course of experimentation (2014)

Month	Standard week no.	Date	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	Sun-Shine Hrs.	Wind Velocity (km/hr.)	Evap. (mm)
			Max.	Min.	0712 am	1412 pm				
Jan-Feb	5	29-04	16.2	9.4	96	72	000.0	02.2	3.1	0.8
Feb	6	05-11	22.5	8.9	92	60	002.0	05.6	6.2	2.1
Feb	7	12-18	20.0	7.0	95	58	093.2	06.7	6.5	2.2
Feb	8	19-25	22.2	10.2	91	55	000.0	06.3	3.9	2.0
Feb-Mar	9	26-04	23.4	11.2	90	48	081.4	06.2	6.1	3.5
Mar	10	05-11	24.9	10.3	88	46	000.0	07.6	3.7	2.6
Mar	11	12-18	27.8	14.1	87	46	012.8	09.1	4.8	3.2
Mar	12	19-25	28.7	14.2	83	39	000.0	07.9	4.4	2.9
Mar-Apr	13	26-01	31.2	14.8	87	32	000.0	07.6	7.8	4.6
Apr	14	02-08	32.5	15.1	82	31	002.2	10.4	6.3	5.4
Apr	15	09-15	33.3	15.4	72	22	000.6	09.4	6.2	6.9
Apr	16	16-22	32.5	15.4	75	29	010.2	07.4	5.4	5.6
Apr	17	23-29	37.5	17.7	67	19	000.0	11.6	7.7	9.7
Apr-May	18	30-06	37.0	20.5	62	30	014.4	09.5	7.4	7.8
May	19	07-13	37.0	20.7	63	26	003.4	09.1	8.0	9.0
May	20	14-20	36.6	20.5	67	23	000.0	10.6	12.6	10.8
May	21	21-27	38.6	22.9	59	28	000.0	10.7	9.6	10.3
May-Jun	22	28-03	37.4	25.4	68	38	021.2	09.5	8.1	8.5
Jun	23	04-10	41.0	26.6	65	34	000.0	11.4	6.9	8.1
Jun	24	11-17	38.3	25.7	71	45	023.6	06.5	9.4	9.6
Jun	25	18-24	35.0	25.7	83	55	067.0	05.9	9.0	5.5
Jun-Jul	26	25-01	36.9	26.6	78	53	002.8	07.2	5.4	6.9
Jul	27	02-08	32.3	25.4	88	67	050.8	02.4	5.2	4.5
Jul	28	09-15	33.5	26.9	88	71	050.6	03.1	6.1	5.2
Jul	29	16-22	30.5	25.6	92	80	265.6	02.1	7.6	4.5
Jul	30	23-29	32.5	26.2	88	67	015.8	04.7	6.6	4.0
Jul-Aug	31	30-05	33.5	25.8	90	67	072.0	06.1	5.3	4.0
Aug	32	06-12	33.3	26.3	88	68	034.4	07.9	6.7	4.8
Aug	33	13-19	32.3	25.6	89	71	027.0	04.8	6.5	3.9
Aug	34	20-26	34.2	25.9	90	64	000.0	07.1	4.5	6.6
Aug-Sep	35	27-02	33.9	25.7	86	62	001.2	07.5	5.3	5.8
Sep	36	03-09	33.2	25.1	85	63	001.2	08.7	7.3	5.4
Sep	37	10-16	32.0	23.5	92	67	005.4	05.4	4.6	3.9
Sep	38	17-23	33.2	23.3	89	63	029.4	08.3	4.0	5.5
Sep	39	24-30	32.7	21.3	89	58	001.0	08.3	5.2	4.7
Oct	40	01-07	31.8	21.4	92	63	0.00	06.4	02.7	02.8
Oct	41	08-14	32.9	19.4	90	57	0.00	07.9	01.8	03.0
Oct	42	15-21	31.7	15.9	90	58	0.00	08.9	02.3	03.2
Oct	43	22-28	30.6	14.4	89	48	0.00	08.4	02.0	02.8
Oct	44	29-04	28.1	14.1	88	47	0.00	04.5	01.9	02.3
Nov	45	05-11	27.5	13.9	88	54	0.00	04.4	01.6	01.6
Nov	46	12-18	26.1	14.1	90	57	0.00	01.3	02.8	01.6
Nov	47	19-25	27.6	11.9	91	49	0.00	05.8	01.8	01.9
Nov-Dec	48	26-02	26.2	8.7	92	41	000.0	07.9	2.3	2.3
Dec	49	03-09	24.3	9.9	94	49	000.0	04.9	2.0	1.8
Dec	50	10-16	20.8	8.2	91	57	040.1	04.3	5.3	2.1
Dec	51	17-23	16.8	7.4	96	78	000.0	04.1	3.9	1.2
Dec	52	24-31	18.5	4.9	95	57	000.0	05.2	3.4	1.1

Weekly Standard Meteorological average weather data during course of experimentation (2015)

Month	Standard week no.	Date	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	Sun-Shine Hrs.	Wind Velocity (km/hr.)	Evap. (mm)
			Max.	Min.	0712 am	1412 pm				
Jan	1	01-07	13.6	07.1	92	81	00.0	00.9	05.2	00.9
Jan	2	08-14	14.0	04.5	95	77	00.0	00.6	04.7	00.6
Jan	3	15-21	17.5	05.6	92	55	02.4	01.3	05.7	01.3
Jan	4	22-28	21.9	05.3	89	48	00.0	02.2	04.7	02.2
Jan-Feb	5	29-4	22.4	7.4	94	54	000.0	03.9	7.0	2.1
Feb	6	05-11	23.2	9.7	88	51	000.0	03.9	5.7	2.0
Feb	7	12-18	27.1	13.4	90	55	000.2	03.3	5.5	2.1
Feb	8	19-25	23.3	13.0	92	61	067.9	04.9	5.9	2.8
Feb-Mar	9	26-04	25.2	10.2	89	45	000.0	08.8	5.8	2.9
Mar	10	05-11	26.9	12.7	90	51	001.2	06.6	5.0	2.9
Mar	11	12-18	29.3	13.7	88	45	000.0	09.5	4.6	3.5
Mar	12	19-25	31.3	17.7	86	44	026.2	07.7	5.1	4.2
Mar-Apr	13	26-01	29.2	15.8	86	45	018.9	06.4	5.0	4.3
Apr	14	02-08	31.9	16.6	82	36	000.0	08.3	5.2	4.9
Apr	15	09-15	34.5	18.5	74	35	000.0	08.2	5.4	6.1
Apr	16	16-22	34.1	19.2	65	34	001.2	09.5	8.6	7.3
Apr	17	23-29	35.4	18.3	70	29	018.4	10.4	5.7	7.4
Apr-May	18	30-06	37.9	24.5	69	39	009.0	08.7	6.7	7.5
May	19	07-13	36.8	22.5	70	37	001.8	10.7	6.5	7.6
May	20	14-20	41.1	22.5	67	31	000.9	09.4	6.7	9.8
May	21	21-27	39.6	22.2	63	31	000.0	08.3	6.3	9.3
May-Jun	22	28-03	40.9	24.5	62	30	000.0	09.7	7.8	10.6
Jun	23	04-10	38.0	25.5	62	38	000.8	07.4	8.8	10.7
Jun	24	11-17	35.1	26.5	73	53	072.2	06.2	7.2	6.4
Jun	25	18-24	32.0	23.8	90	76	324.8	05.0	8.5	5.5
Jun-Jul	26	25-01	32.4	25.7	87	72	100.0	03.1	6.7	3.6
Jul	27	02-08	31.7	25.4	88	72	114.8	04.9	7.0	5.5
Jul	28	09-15	32.7	26.1	84	72	089.8	04.2	5.8	4.0
Jul	29	16-22	33.6	25.9	83	63	006.4	08.5	7.5	5.7
Jul	30	23-29	31.5	25.7	87	74	079.8	05.0	5.3	4.3
Jul-Aug	31	30-05	30.2	25.4	91	76	158.9	02.3	5.5	3.8
Aug	32	06-12	32.7	26.1	90	67	037.8	04.8	3.7	3.9
Aug	33	13-19	32.4	24.9	89	69	039.0	05.2	6.5	3.8
Aug	34	20-26	33.4	25.4	92	65	024.4	06.7	5.6	4.7
Aug-Sep	35	27-02	33.6	23.8	91	60	000.0	07.5	4.9	7.0
Sep	36	03-09	34.1	25.0	87	61	000.0	08.4	3.1	4.7
Sep	37	10-16	34.0	24.9	84	62	112.0	06.6	3.8	4.2
Sep	38	17-23	31.7	21.4	90	61	000.0	08.1	5.0	4.0
Sep	39	24-30	32.9	20.2	83	51	000.0	09.5	2.1	4.7
Oct	40	01-07	32.5	20.3	83	52	000.0	07.5	2.4	4.6
Oct	41	08-14	31.5	19.3	86	51	000.0	05.1	3.1	3.5
Oct	42	15-21	31.2	13.9	88	48	000.0	08.7	3.0	4.0
Oct	43	22-28	29.0	13.7	90	43	005.0	06.2	2.9	3.0
Oct-Nov	44	29-04	28.1	14.1	88	47	0.00	04.5	01.9	02.3
Nov	45	05-11	27.5	13.9	88	54	0.00	04.4	01.6	01.6
Nov	46	12-18	26.1	14.1	90	57	0.00	01.3	02.8	01.6
Nov	47	19-25	27.6	11.9	91	49	0.00	05.8	01.8	01.9
Nov	48	26-02	26.7	12.6	91	46	000.0	03.7	2.7	2.1
Nov-Dec	49	03-09	24.6	10.2	96	49	000.0	01.8	2.3	1.6
Dec	50	10-16	21.1	10.3	94	64	000.0	02.1	4.3	1.3
Dec	51	17-23	20.5	4.6	96	50	000.0	05.3	2.5	1.5
Dec	52	24-31	21.0	5.0	95	46	000.0	06.1	3.0	1.5

Weekly Standard Meteorological average weather data during course of experimentation (2016)

Month	Standard week no.	Date	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	Sun-Shine Hrs.	Wind Velocity (km/hr.)	Evap. (mm)
			Max.	Min.	0712 am	1412 pm				
Jan	1	01-07	23.6	6.9	92	39	000.0	06.0	2.7	1.5
Jan	2	08-14	22.3	7.0	94	49	000.0	04.3	3.3	1.7
Jan	3	15-21	17.4	6.6	94	64	000.0	02.3	4.6	1.4
Jan	4	22-28	17.9	4.1	94	53	000.0	03.3	3.2	1.3
Jan-Feb	5	29-04	22.2	6.8	96	48	000.0	04.8	5.3	1.9
Feb	6	05-11	23.3	8.3	93	46	000.0	05.4	3.7	2.4
Feb	7	12-18	26.4	9.4	82	32	000.0	06.8	5.5	3.1
Feb	8	19-25	26.4	11.8	87	44	002.5	04.6	6.3	2.9
Feb-Mar	9	26-04	29.1	12.1	88	37	000.0	07.6	3.3	3.1
Mar	10	05-11	30.3	13.6	86	37	000.0	08.3	6.3	4.2
Mar	11	12-18	29.0	13.8	81	36	000.9	06.6	7.3	4.6
Mar	12	19-25	31.9	14.2	78	28	000.0	09.3	6.4	4.8
Mar-Apr	13	26-01	33.7	16.0	78	32	000.0	07.0	5.1	4.8
Apr	14	02-08	35.6	20.4	65	32	000.0	06.9	6.0	6.7
Apr	15	09-15	37.3	17.2	64	29	000.0	10.4	8.8	9.0
Apr	16	16-22	38.7	21.5	70	32	020.0	07.5	7.2	9.5
Apr	17	23-29	38.9	16.9	71	27	000.0	11.1	9.2	12.5
Apr-May	18	30-06	33.5	25.2	71	55	14.80	1.9	8.4	9.6
May	19	07-13	35.0	26.6	77	55	0.00	9.7	8.3	6.0
May	20	14-20	36.0	25.3	66	59	0.00	7.1	6.8	4.8
May	21	21-27	36.5	25.2	67	58	0.00	10.6	5.6	7.4
May- June	22	28-03	38.0	26.8	74	42	0.00	10.6	7.6	7.8
June	23	04-10	37.8	26.9	70	44	0.00	8.3	5.6	7.8
June	24	11-17	39.0	25.5	77	34	0.00	6.6	9.3	6.4
June	25	18-24	36.2	26.4	79	44	1.20	7.4	8.9	6.0
June-July	26	25-01	30.4	23.4	93	75	32.80	0.0	6.4	5.8
Jul	27	02-08	31.7	25.4	88	72	114.8	04.9	7.0	5.5
Jul	28	09-15	32.7	26.1	84	72	089.8	04.2	5.8	4.0
Jul	29	16-22	33.6	25.9	83	63	006.4	08.5	7.5	5.7
Jul	30	23-29	32.5	26.02	87	74	079.8	05.0	5.3	4.3
Jul-Aug	31	30-5	33.1	26.34	91	76	158.9	02.3	5.5	3.8
Aug	32	6-12	32.78	25.9	90	67	037.8	04.8	3.7	3.9
Aug	33	13-19	33.28	26.20	89	69	039.0	05.2	6.5	3.8
Aug	34	20-26	35.54	25.60	92	65	024.4	06.7	5.6	4.7

VITA

The author of this manuscript Mr. Satyendra Singh Narvariya was born on 06 Dec. 1986 at Mahapur,-Post Bhind, District-Bhind (Madhya Pradesh.). He passed high school and intermediate from M.P. Board Bhopal in 2002 and 2004 respectively. He completed his graduation in Horticulture from Dr. Punjab Rao Desmukh Krishi Vidhyapeeth,. Akola (M.H.) in the year 2010 with Indian Council of Agricultural Research-National Talent Scholarship. He joined post graduate studies in G.B. Pant university of Agriculture and Technology, Pantnagar, for M.Sc. (Ag.) degree with major in Horticulture in 2010 and completed all the requirements for the same in May 2012. He has awarded with Junior Research Fellowship granted by Indian Council of Agricultural Research, New Delhi during his Master's degree programme. Further he joined Ph.D. with major in Horticulture and minor in Plant Physiology in July 2012 at G.B. Pant University of Agriculture and Technology, Pantnagar. He completed his degree requirement in October, 2016. He qualified ARS-NET in 2012. He has awarded with University fellowship during her Ph.D. programme.

Permanent Address

Satyendra Singh Narvariya
S/o Shri Surendra Singh Narvariya
Vill.-Mahapur
P.O.-Bhind
Distt.-Bhind, M.P., INDIA
Pin- 477001
Mobile No. 8435903423
E-mail- sattuhorti@gmail.com

ABSTRACT

Name : Satyendra Singh Narvariya **Id. No.** : 40958

Sem. & Year of admission: 1st Sem., 2012-13 **Degree** : Ph.D.

Major : Horticulture **Department** : Horticulture

Minor : Plant Physiology

Thesis title : **"Classification of different varieties and new accessions of mango (*Mangifera indica* L.) based on qualitative traits and assessment of genetic diversity".**

Advisor : Dr. A.K. Singh

The present investigation was carried out in different varieties of mango during the years 2014 and 2016 at GBPUA&T, Pantnagar with objectives of characterization and grouping of genotypes based on qualitative traits and to assess the genetic variability and diversity in different varieties using principal component analysis (PCA) and D^2 statistics. The experimental materials were evaluated under Randomized Block Design with three replications. The observations were recorded on morphological and physico-chemical characters covering 25 qualitative & 27 quantitative traits and the data were analyzed by appropriate statistical and Biometrical tools.

The morphological qualitative traits showed wide variations among different mango varieties. Analysis of variance showed adequate amount of genetic variability among different varieties for most of the characters. The fruit characters namely fruit weight, length, width, pulp weight and pulp: stone ratio varied from 20.07-420.65 g, 3.48-13.28 cm, 2.81-8.70 cm, 13.15-351.64 g and 2.50-10.33, respectively. The TSS, total sugar, non reducing sugar and total carotenoids varied from 12.06-22.32^{0}B, 11.36-20.69 %, 8.32-14.62 % and 1.78-9.23 mg/100 g, respectively. The phenotypic and genotypic coefficient of variation were found higher for number of fruits per tree at harvesting, yield per tree, total carotenoid, pulp weight, fruit weight, peel weight, stone weight and pulp: stone ratio, while these were moderate to low for remaining traits. High heritability coupled with moderate to high genetic advance was found for most of the characters, while lower genetic advance recorded for leaf length and leaf width. The genotypic correlation coefficient was higher than phenotypic correlation coefficient for most of the characters and yield per tree showed significant positive correlation with fruit weight, fruit length, fruit width, stone length, stone width, pulp weight, pulp: stone ratio, ascorbic acid, number of fruits per tree and total carotenoids, while negative with acidity. The assessment of genetic divergence revealed sufficient variability among the different varieties of mango. Principal component analysis indicated that first ten components accounted for more than 86.07 % of the total genetic variation. The characters contributing more positively with PC1 and exhibited maximum variability among the varieties for leaf area, leaf length, yield per tree, fruit weight, size, stone weight, stone size, peel weight and total sugar. Cluster analysis using D^2 statistics grouped different mango varieties into seven clusters during both the years as well as on the basis of pooled data of two years. Therefore, it would appear logical to affect crosses between varieties belonging to the clusters separated by high estimated statistical distance. In pooled analysis, the inter-cluster average D^2 value was found maximum (513.38) between cluster III with eight varieties and VII with a single variety. The promising clusters were identified on the basis of cluster mean value of pooled analysis for desirable traits *viz.,* cluster III for maximum duration of fruit maturity, fruit weight, fruit size, stone weight, stone size, pulp and peel weight; cluster IV for higher yield per tree, length and width of inflorescence and cluster VI for TSS, reducing sugar, non reducing sugar, total sugar and total carotenoids.

Therefore, it may be concluded that morphological qualitative traits can be used for proper characterization, grouping of genotypes and varietal identification. Results of PCA and D^2 analysis indicated substantial variation among the varieties and new accessions of mango with respect to different morphological and physico-chemical quantitative traits, which may help the mango breeders for future breeding programme.

(A.K. Singh)
Advisor

(Satyendra Singh Narvariya)
Author

सारांश

नाम	:	सत्येन्द्र सिंह नरवरिया	परिचायाक	:	40958
सत्र एवं वर्ष	:	प्रथम षटमास, 2012–13	उपाधि	:	पीएच.डी.
मुख्य विषय	:	उद्यानिकी	विभाग	:	उद्यान विज्ञान
गौण विषय	:	पादप कार्यकी			
शोध ग्रंथ शीर्षक	:	''आनुवांशिक विविधता के आंकलन एवं गुणात्मक लक्षण के आधार पर आम (मैंजीफेरा इण्डिका एल.) की विभिन्न किस्मों एवं नये एक्सेशन्स का वर्गीकरण''			
सलाहकार	:	डॉ0 अशोक कुमार सिंह			

प्रस्तुत अध्ययन गो0ब0 पन्त कृषि एवं प्रौद्योगिकी विश्वविद्यालय, पन्तनगर में वर्ष 2014 और 2016 के दौरान आम की 40 विभिन्न किस्मों सहित नए एक्सेशन्स का गुणात्मक लक्षण पर आधारित जीनोटाइप के चरित्रीकरण एवं समूहीकरण और आनुवंशिक परिवर्तनशीलता एवं विविधता का आंकलन प्रमुख घटक विश्लेषण (पीसीए) और डी वर्ग आंकड़ों के उपयोग के उद्देश्यों से किया गया। प्रयोगात्मक सामग्री का मूल्यांकन यादृच्छिक ब्लॉक खण्ड अभिकल्पना में तीन अनुकरणों के साथ किया गया। रूपतामक और भौतिक–रासायनिक में सम्मिलित 25 गुणात्मक और 27 मात्रात्मक लक्षणों तथा आंकड़ों का विषलेशण उचित सांख्यिकीय और जीव सांख्यिकीय उपकरणों के साथ किया गया। व्यापक भिन्नता आम की विभिन्न किस्मों में रूपत्मक गुणात्मक लक्षण के कारण दर्ज की गयी। विचरण के विश्लेषण से अधिकांश लक्षण के लिए किस्मों के बीच आनुवांशिक परिवर्तनशीलता की पर्याप्त मात्रा प्राप्त की गयी, जैसे की फल का वजन, फल की लम्बाई एवं चौड़ाई, गुदे का वजन तथा गुदे : गुठली के वजन का अनुपात क्रमशः 20.07–420.56 ग्राम, 3.48–13.28 सेमी0, 2.81–8.70 सेमी0, 13.15–351.64 ग्राम और 2.50–10.30 के लिए विविधता प्रदर्शीत की गयी, इसके साथ–साथ टीएसएस, कुल शर्करा, गैर कम शर्करा और कुल कैरोटिनॉएडस क्रमशः 12.06–22.32 °ब्रिक्स, 11.36–20.69 प्रतिशत, 8.32–14.62 प्रतिशत और 1.78–9.23 मिग्रा0 प्रति 100 ग्राम के लिए भी विविधता प्रदर्शीत हुई। फल की तुड़ाई के समय फलो की संख्या प्रति पेड़, उपज प्रति पेड़, कुल कैरोटीनॉयड, गूदे का वजन, फल का वजन, छिलके का वजन, गुठली का वजन और गुठली : गूदे के वजन का अनुपात के लिए अधिक फेनोटिपिक एवं जनोटिपिक कोफ्फेसिएंट ऑफ वरिएन्स प्राप्त हुये जबकि यह शेष लक्षणों के लिए कम दर्ज किये गये। अधिकांश लक्षणों के लिए अधिक आनुवांशिकता सहित अधिक आनुवांशिक अग्रिम प्राप्त हुये। जबकि पत्ती की लंबाई एवम् चौड़ाई के लिए कम आनुवांशिक आग्रिम दर्ज किए गये। अधिकांश लक्षणों के लिए प्ररूपी सहसंबंध गुणांक की तुलना में जीनोटिपिक सहसंबंध गुणांक अधिक मिले थे। उपज प्रति पेड़ के साथ फल का वजन, फल की लंबाई, फल की चौड़ाई, संख्या प्रति पेड़ ने महत्वपूर्ण सकारात्क सहसंबंध दिखाया। जबकि अम्लता के साथ नकारात्मक सहसंबंध दिखाया। आम की विभिन्न किस्मों के बीच में पर्याप्त परिवर्तनशीलता का आंकलन आनुवांशिक विचलन से प्राप्त हुआ। मुख्य घटक विशलेशण के अनुसार प्रथम दस घटको में कुल आनुवांशिक भिन्नता का 86.07 अंश पाया गया। पत्ती क्षेत्र, लंबाई व उपज प्रति पेड़, फल का वजन एवं आकार गुढली का वजन एवं आकार छिलके का वजन और कुल शर्करा का प्रथम मुख्य घटक के साथ ज्यादा धनात्मक योगदान पाया गया, जोकि भिन्नता के लिए अधिक भागीदारी अदा करते है। डी वर्ग सांख्यिकी के माध्यम से समूह विश्लेषण में दोनो वर्षो के साथ–साथ जमा विश्लेषण के दौरान 40 किस्मों एवं नये एक्सेसन को सात समूह में वर्गीकृत किया गया। उच्च अनुमान सांख्यिकी दूरी वाले दो समूहो से संबंधित किस्मों के मध्य संकरण का प्रभाव उपयुक्त है। जमा विश्लेषण के अनुसार अधिकतम अंतर समूह दूरी (513.38) समूह तीन में आठ प्रजातियां एवं समूह सात में एक प्रजाति में पाई गयी। जमा विशलेषण के समूह की औसत मूल्य के आधार पर वांछनीय लक्षण हेतु उचित समूह का चयन किया जा सकता है जोकि फल परिपक्वता, फल का वजन, फल का आकार, गुठली का वजन एवं आकार, गूदे एवं छिलके का वजन हेतु, समूह III, उपज प्रति पेड़, गुच्छे की लम्बाई एव चौड़ाई हेतु, समूह IV, टी.एस.एस., कम चीनी, कुल चीनी एवं कुल कैरोटीनॉयड हेतु, समूह VI में से प्रजातियों का चयन किया जाना चाहिये। इस प्रकार से यह निष्कर्ष निकाला जा सकता है कि रूपतामक गुणात्मक लक्षण का उपयोग जीनोटाइप के चरित्रीकरण, समूहीकरण और किस्मो की पहचान के लिये किया जा सकता है। रूपतामक और भौतिक–रासायनिक लक्षण के लिए किस्मों के बीच पर्याप्त बदलाव पीसीए और डी वर्ग विश्लेषण के परिणाम के कारण मिले, जो कि भविष्य प्रजनन कार्यक्रम में आम प्रजनक को सहायता दे सकते है।

(अशोक कुमार सिंह)
सलाहकार

(सत्येन्द्र सिंह नरवरिया)
लेखक