Morphological and Molecular Analysis of Intravarietal Variability in Mango (*Mangifera indica* L.) cv. Dashehari in Lucknow region

THESIS

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FOR THE AWARD OF THE DEGREE OF

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IN
HORTICULTURE

Supervisor
Prof. Deepa H. Dwivedi

Submitted by
Sachin Kishor
Enrolment No. 272/13

DEPARTMENT OF APPLIED PLANT SCIENCE (HORTICULTURE)
SCHOOL FOR BIO-SCIENCES AND BIOTECHNOLOGY
BABASAHEB BHIMRAO AMBEDKAR UNIVERSITY
(A CENTRAL UNIVERSITY)
VIDYA VIHAR, RAE BARELI ROAD
LUCKNOW-226025 (U.P.)
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DEDICATED

My Respected Parents

…who sacrificed their today for my tomorrow

Sachin Kishor……

CERTIFICATE

This is to certify that the thesis entitled **"Morphological and Molecular Analysis of Intravarietal Variability in Mango (*Mangifera indica* L.) cv. Dashehari in Lucknow region"** submitted by **Mr. Sachin Kishor, Enrolment No. 272/13** is an original research work and has not been previously submitted in part or full for the award of any other degree or diploma to this or any other University.

The thesis submitted to Babasaheb Bhimrao Ambedkar University Lucknow satisfies all the requirements as stipulated in the Doctor of Philosophy (Ph.D.) Regulations, 1999 as amended in 2008/2010/2013 and it is fit for submission and evaluation for the award of the degree of Doctor of Philosophy of the University.

Deepa 29/11/19

Date:-29/11/19 (Supervisor)

(Prof. Deepa H. Dwivedi)

29/11/19

Place: BBAU, Lucknow Head, Department of Horticulture

DECLARATION

I, Sachin Kishor, Enrolment No. 272/13, hereby declare that, I am a candidate for the Degree of **Doctor of Philosophy in Horticulture,** Department of Applied Plant Science (Horticulture), School for Biosciences and Biotechnology, Babasaheb Bhimrao Ambedkar University (A Central University), Vidya Vihar, Rae Bareli Road, Lucknow-226025 (U.P.), India and have carried out my research work entitled **"Morphological and Molecular Analysis of Intravarietal Variability in Mango (*Mangifera indica* L.) cv. Dashehari in Lucknow region"**. The thesis has been submitted for the award of the degree of Doctor of Philosophy in Horticulture and is my original research work.

I do also hereby undertake that the thesis is essentially free from any kinds of plagiarism.

Sachin

Date: 29-11-2019 **(Sachin Kishor)**

Place: Lucknow **Research Scholar**

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Sachin Kishor

Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

List of Abbreviations

cm	:	Centimeter
CD	:	Critical Difference
C.R.D.	:	Complete Randomized Design
cv.	:	Cultivar
d.f.	:	Degree of Freedom
et al.	:	Et Alii
g	:	Gram
Kg	:	Kilogram
MT	:	Metrication
ha	:	Hectare
i.e.	:	That is
ml	:	Millilitre
µ	:	Micron
pH	:	Puissance de Hydrogen
R H	:	Relative Humidity
SE	:	Standard error of mean
SS	:	Sum of Square
Viz	:	Videlicet
%	:	Percent
PCV	:	Phenotypic coefficient of variatio
GCV	:	Genotypic coefficient of variatio
h^2	:	Heritability
GA	:	Genetic advance
GAM	:	Genetic advance as percent of mean
CV	:	Coefficient of variation
SEM	:	Scanning Electron Microscopy
AEZ	:	Agri-export Zone
ddH_2O	:	Double distilled water
SDS-PAGE	:	Sodium Dodecyl Sulphate Polyacrylamide Gel Electrophoresis
SDS	:	Sodium Dodecyl Sulphate

INTRODUCTON

Mango (*Mangifera indica* L.), commonly known as "King of Fruits" belongs to family Anacardiaceae and has originated from Indo-Burma region. The genus *Mangifera* contains around 70 species, which can be divided into two subgenera, *Limus* and *Mangifera* (Kostermans and Bompard, 1993) with at least 26 species producing edible fruits. Mango genotypes can be divided into two distinct categories: monoembryonic and polyembryonic (Viruel *et al*., 2005) having species which are diploid with 2n= 2x = 40 chromosomes e.g. *Mangifera indica* L., *M. sylvatica* Roxb., *M. caloneura* Kurz. and *M. odorata* Ariff (Mukherjee, 1997). It is highly cross-pollinated and most cultivars have developed through selection of desirable types from natural seedlings (Karihaloo *et al.,* 2003).

Mango has nutritional as well as therapeutic value due to its high vitamin, mineral and fiber content (Lakshminarayana, 1980). Ripe fruits are one of the richest sources of beta carotene (Bose and Mitra, 2001) and are consumed as fresh fruits or prepared as juice, jams, jellies and squash or canned, while unripe fruits are used in pickles, chutneys and other culinary preparations. The different parts of mango tree are used as antihelmintic, diaphoretic and refrigerant agents and in bleeding piles, mannorrhagia, scabies and cutaneous infection, lecorrhoea, diarrhoea and dyssentery (Lakshminarayana, 1980; Mukherjee, 1997). Besides this mango also has religious as well as social importance (Singh, 2015).

The mango tree is erect, generally 10-30 m tall, with a broad, rounded canopy which may, with age, attain a crown of 100 to 125 ft in width. It is successfully grown in deep alluvial soil of Indo-Gangetic plains with pH 5.5 to 7.5. Mango is a tropical as well as semi tropical crop, which grows across India, up to an altitude of 1400 meters above mean see level (MSL) (Bose and Mitra, 2001) but fruiting is not obtained above 1000 meters above MSL. The two important considerations for mango cultivation are a frost-free, dry period at the time of flowering and sufficient heat during the ripening of fruits while optimum growth takes place at 23.^{0}C to 26^{0}C temperature.

Mango is distributed all over the world and major producing countries include China, India, Thailand, Mexico, Pakistan, Philippines, Indonesia, Brazil, Nigeria and Egypt. In India it is commercially cultivated in Andhra Pradesh, West Bengal, Karnataka, Kerala, Bihar, Uttar Pradesh, Uttarakhand, Punjab, Haryana, Maharashtra and Gujarat covering 22.58 M hectare areas with a production of 21822 ′000 MT (Annon, 2018).

India has over 1000 mango cultivars and is the biggest mango gene-pool in the world, of which only 350 species are of commercial importance. Dashehari is one such selection from a chance seedling and is an outstanding mid-season variety of mango with delicate taste. The fruits are elongated, dull yellow; medium-sized with dull yellow fibreless flesh. It is grown commercially on a large scale in Malihabad and Mal Agri-Export Zone of mango located in district Lucknow, Uttar Pradesh in India. Dashehari like almost all commercial cultivars of mango is propagated through vegetative means in order to retain the fruit characters of the mother plant. Despite this, variation in the fruit size, shape and quality has been observed indicating presence of intravarietal variability within the cultivar (Begum *et al.*, 2014) which needs to be characterized to be more efficiently managed and utilized. There are different methods to characterize intra-varietal variability, such as morphological, biochemical and molecular markers (Singh *et al*., 2009; de Souza and Lima, 2004; Rocha *et al*., 2012).

Variability among the population is a pre-requisite for genetic improvement for any breeding programme. The understanding of such variability provides many avenues in genetic amelioration of a crop. In fact, high magnitude of genetic variability, heritability (h^2) and expected genetic advance (GA) and genetic advance as percent of mean (GAM) reveals the possibility of profitable selection. The relative values of phenotypic coefficients of variation (PCV) and genotypic coefficients of variation GCV) give an idea about the extent of variability present in a population (Singh, 2000).

One of the main objectives of any breeding programme is to produce high-yielding and better quality lines for release as commercial cultivars for growers. The prerequisite to achieve this is to find out sufficient variability, which influences yield and yield attributing traits, as well as fruit quality whether due to environment or polygenic effects. Thus, the variability in the collection for these characters is the sum total of hereditary effect of concerned gene and the influence of the environment. Hence, it is very essential to partition the observed variability into heritable and non-heritable components measured as PCV, GCV, h^2, GA and GAM. Heritability of a trait alone may not be indicative of its breeding value, but in conjugation with genetic advance over mean it is more effective and reliable in predicting the resultant effect of selection. Genetic advance is also of considerable importance, since it indicates the magnitude of the expected genetic gain from one cycle of selection (Patil *et al.*, 1996; Ramanjinappa *et al.*, 2011).

Crop diversity in mango is well represented in the form of developed cultivars, landraces or as folk varieties in different eco-geographical regions of India. Allopolyploidy, cross pollination and wide range of agro-climatic conditions prevailing in this country contribute to the enormous genetic diversity of mango. The present day cultivars are mainly seedling selections and are maintained through clonal propagation (Iyer and Degani, 1997). Each is identified by its characteristic combination of properties such as plant architecture, fruit size, color, taste, flavor etc (Anu *et al.*, 2015) which have helped significantly in cultivar identification (Ravisankar *et al.*, 2000; Karihaloo *et al.*, 2003; Pandit *et al.*, 2007).

For any crop improvement programme, germplasm collection and assessment of genetic variability is important. Intra-varietal variability of certain varieties of mango from India and other countries has been characterized based on morphological traits and genetic markers (Bally *et al*., 1996; de Souza and Lima, 2004). Until recently, morphological characterization of tree and its vegetative parts and fruit shape, size, color and quality have been used most commonly for the characterization of intravarietal variability in mango (Singh *et al*. 2009) which may be ascribed to bud mutations. As early as 1956, wide variability in the performance of the trees of same variety in the same orchard has been reported (Oppenheinmer, 1956) through surveys and studies related to fruit size, shape, color and quality (Naik, 1971) which are highly influenced by environment. Gan *et al*. (1981) and Pandey (1998) studied different clones of Alphonso and found that they differ from one another in more than one character. Morphological analysis based on 17 fruit characters detected prominent variation in the landraces Banganapalli, Langra and Dashehri and some variation in the cultivar Mallika (Singh *et al*., 2009). In the above cases, the identification of intra-varietal variability is based on morphological traits, even though the number of these traits is limited, they are unstable and do not always distinguish between closely related accessions or cultivars besides their major drawback of susceptibility to environmental effects which renders this measure relatively insensitive, particularly where differences are very small. It is thus, always advisable to supplement morphological characterization with studies which deal with parameters whose expression is regulated primarily at the genotypic level.

Stomata are minute pores in the epidermis of the leaf or stem of a plant, forming a slit of variable width which allows movement of gases in and out of the intercellular spaces. Generally, stomatal initiation is controlled by both environmental and genetic factors (Casson and Hetherington, 2010). However, stomatal characteristics (i.e., size and density) are highly variable depending on the genetic background of the plants as well as on the growth conditions or the leaf ontogeny (Masarovicova, 1991) as in oak leaves. Stomatal density has been shown to vary significantly within individuals, cultivars or ecotypes of a single species, as well as within a community (Jones, 1992). Within the *Populus* genus, a wide interspecific as well as interclonal variation in stomatal density, dimension and stomatal index has already been observed by Ferris *et al.* (2002). Additionally, molecular markers are still more sensitive markers and are used widely to reveal seed protein and isozymic variation. They operate at the gene product level where the environment has very little influence (Manikandan *et al.,* 2012).

Molecular markers have diverse application in crop improvement, particularly in the areas of genetic diversity and varietal identification studies, gene tagging, disease diagnostic, pedigree analysis, hybrid detection, sex differentiation and marker assisted selection. DNA markers can be used to diagnose the presence of the gene without having to wait for its effect to be seen as reported by Botez *et al*. (2009) in apple**,** Sisko *et al*. (2009) in pears and Thimmapaiah *et al*. (2009) in cashew, besides other crops.

Sodium Dodecyl Sulfate Polyacrylamide Gel Electrophoresis (SDS-PAGE) is an analytical method in biochemistry for the separation of charged molecules in mixtures by their molecular masses in an electric field which helps to identify and isolate protein molecules for further study in genetic variation (Aiswariya and Thomas, 2016).

Plant gene pools are reservoirs of variations, which provide the raw material for crop improvement. Samples represent the spectrum of genetic variation within cultivated species and their wild relatives. Each variety or a group of varieties, exhibits characteristic banding pattern on the basis of which they can be identified. Electrophoretic patterns of the protein fractions are directly related to the genetic background of the proteins and can be used to certify the genetic makeup. SDS-PAGE is increasingly used to describe the genetic structure for crop germplasm identification (Asghar *et al.,* 2004).

Thus, keeping above points in consideration, the proposed investigation entitled, **"Morphological and Molecular Analysis of Intravarietal Variability in Mango (*Mangifera indica* L.) cv. Dashehari in Lucknow region"** was carried out with the following objectives:

1. To survey the possibility of genetic diversity and variability in Dashehari mango in two Blocks of district Lucknow i.e. Malihabad and Mal.
2. To evaluate the intravarietal variability in mango cv. Dashehari on the basis of vegetative characters.
3. To establish intravarietal variability in mango cv. Dashehari on the basis of physico-chemical characters of the fruit.
4. Microscopy studies for exploring intravarietal variability in mango cv. Dashehari.
5. Molecular analysis of intravarietal variability in mango cv. Dashehari.

REVIEW OF LITERATURE

Mango (*Mangifera indica* L.) belongs to family Anacardiaceae. It is commonly known as the 'king of fruits'. It is a diploid fruit tree with 2n=40 chromosomes (Mukherjee, 1997). Mango is a highly cross-pollinated plant and most cultivars have arisen through selection of desirable types among naturally produced seedling (Karihaloo *et. al.,* 2003).

Mango has nutritional as well as therapeutic value due to its high vitamin, mineral and fiber content (Lakshminarayana, 1980). Ripe fruits are freshly eaten or prepared as juice, jams, jellies and squash or canned, while unripe fruits are used in pickles, chutneys and other culinary preparations. The various part of the mango are used as antihelmintic, diaphoretic and refrigerant agents and in bleeding piles, mannorrhagia, scabies and cutaneous infection, lecorrhoea, diarrhea and dysentery (Lakshminarayana, 1980; Mukherjee, 1997).

The mango tree is erect, 30 to 100 ft (roughly 10-30 m) high, with a broad, rounded canopy which may, with age, attain a crown 100 to 125 ft (30-38 m) in width, or a more upright, oval and relatively slender crown. It is successfully grown in deep alluvial soil of Indo-Gangetic plains with pH 5.5 to 7.5. Mango is a tropical as well as semi tropical plant, which grows almost all over India. It grows up to an altitude of 1200 meters above mean see level (MSL) but the fruiting is above 600 meters above MSL. Mango trees are seen growing at altitude of up to 900 meters in India, but of course these do not bear fruit at this height. The two important considerations for mango cultivation are a frost-free, dry period at the time of flowering and sufficient heat during the ripening of fruits while optimum growth takes place at 23.^{0}C to 26^{0}C temperature.

Variability among the population is a pre-requisite for genetic improvement for any breeding programme. The understanding of such variability provides many avenues in genetic amelioration of a crop. In fact, high magnitude of genetic variability, heritability and expected genetic advance and genetic advance as percent of mean reveals the possibility of profitable selection. The relative values of coefficients of variation (PCV and GCV) give an idea about the extent of variability present in a population (Johnson *et al.*, 1955).

Crop diversity in mango is well represented in the form of developed cultivars, landraces or as folk varieties in different eco-geographical regions of India. Allopolyploidy, cross pollination and wide range of agro-climatic conditions prevailing in this country contribute to the enormous genetic diversity of mango. The present day cultivars are mainly seedling selections and are maintained through colonal propagation (Iyer and Degani, 1997). Most cultivars have arisen through selection of desirable type from naturally produced seedling (Karihaloo *et al.,* 2003) and each is identified by its characteristic combination of properties such as plant architecture, fruit size, color, taste, flavor etc (Anu *et al.*, 2015) which have helped significantly in cultivar identification (Ravisankar *et al.*, 2000; Karihaloo *et al.*, 2003; Pandit *et al.*, 2007).

Intravarietal variability of certain varieties of mango from India and other countries has been characterized based on morphological traits and genetic markers (De Souza and Lima, 2004; Diaz-Matallana *et al*., 2009; Singh *et al*., 2009; Rocha *et al*., 2012). Morphological characterization is traditionally the most common method used. Until recently, morphology-based methods have been used for the characterization of intravarietal variability in mango (Gan *et al*., 1981; Pandey, 1998; Singh *et al*., 2009) where significant variation among the trees of the same variety in an orchard was observed with regard to fruit shape, size, color and quality of the fruits which was ascribed to bud mutations. Based on a survey in many mango orchards in India reported wide variability in the performance of the trees of the same variety in the same orchard. Further, there are few reports on variability among the trees of the same variety in an orchard with respect to fruit size, shape, color and quality (Naik, 1971) which are highly influenced by environment. Morphologically, all the six 'clones' of mango studied *viz.,* 'Harummanis', 'Apple', 'Irwin', 'Kent', 'Malgoa' and 'Hj. Bakar' are very distinct with respect to the morphology and the taste of the fruits (Gan *et al*., 1981; Pandey 1998). Pandey (1998) studied different clones of 'Alphonso' and found that they differ from one another in more than one character. Morphological analysis based on 17 fruit characters detected prominent variation in the landraces 'Banganapalli', 'Langra', and 'Dashehri' and some variation in the cultivar 'Mallika' (Singh *et al*., 2009). In the above cases, the identification of intravarietal variability is based on morphological traits. But number of these traits is limited, they are unstable and they do not always enable to distinguish between closely related accessions or cultivars.

Thus, the previous research works carried out by different workers in relation to the present investigation have been reviewed on the basis of following objectives:

2.1 Survey the possibility of genetic diversity and variability in Dashehari mango in two Blocks of district Lucknow

A survey is defined as a research method used for collecting data from a pre-defined group of respondents to gain information and insights on various topics of interest. Surveys have a variety of purposes and can be carried out in many ways depending on the methodology chosen and the objectives to be achieved.

A survey was conducted in West Bengal by Mukherjee (1997) described several clones of important mango varieties. An internationally accepted descriptor list for characterization of mango germplasm was also prepared, which facilitated uniform description at the global level. It contains characterization and evaluation descriptors covering morphological features of leaf, inflorescence, fruit and tolerance to biotic and abiotic stress conditions. Begum *et al.* (2014) exploration surveys covering three eco-geological regions of the state were conducted during summer 2009. Thirty accessions of ‘Cherukurasam’ (CKR Acc-l to CKR Acc-30) were selected and their fruit and leaf samples were collected to study intra-varietal variability through classical and molecular analysis in Cherukurasam cultivar of mango. Beneshan is the choicest table cultivar of mango (*Mangifera indica* L.) that has been under cultivation for more than a century in Andhra Pradesh state, India. Through an eco-geographic survey covering the three regions of the state, 31 accessions of Beneshan (BN Acc-l to BN Acc 31) were selected and their fruit and leaf samples were collected to study intracultivar heterogeneity based on morphological fruit traits and microsatellite markers, respectively. The fruit and leaf samples of 16 trees of Panchadarakalasa’ (PK Acc-l to PK Acc-16) spread over the three eco-geographical regions (Coastal Andhra, Rayalaseema and Telangana) of the state were collected during summer 2009, which were subjected to *in-situ* morphological and *ex-situ* microsatellite analysis, respectively to identify whether there is variability in the plants grown in the state (Begum *et al.,* 2014a; Begum *et al*., 2013).

Suriyagoda *et al.* (2008) and Deb *et al*. (2013) based on a survey in water chestnut germplasm reported wide variability in the performance of plant and fruit morphology in India as also other countries such as Japan, China and Sri Lanka, etc. Variability in germplasm has also been reported in Salparni (Manivel *et al.*, 2019). Conducted a preliminary survey, collection and evaluation of different cultivars of water chestnut for their physical and biochemical parameters was conducted by Babasaheb Bhimrao Ambedkar University, Lucknow from 2005-2008 in order to explore the possibility of genetic variability in water chestnut Dwivedi*et al.* (2011). Suriyagoda *et al.* (2008) conducted survey and collection of water chestnut germplasm on the basis of yield performance of 17 water chestnut lines, eight from China (*Trapa acornis* L., *T. bicornis* L., *T. bispinosa* Roxb, *T. quadrispinosa* Roxb), one from France (*T. natans* L.), one from India (*T. bispinosa* Roxb.), three from Italy (*T. natans* L.), three from Japanese (*T. incisa* L., *T. japonica* Flerov, *T. natans*.L. var. *rubeola* Makino), and one from Korean (*T. japonica* Flerov.) were cultivated in Saga City, Japan during the summer, 2005 and the morphological characters of their fruit were analysed.

Arima (1999) conducted a study where the vegetative growth characters and yield components of water chestnuts distributed in Japan and China were investigated for 12 local lines of 6 species i.e. 5 small and 2 medium fruit lines from Japan, and 5 large fruit lines from China. The materials were transplanted and grown in a flooded field usually used for rice cultivation in Saga City in 1995.

Pandey (1984) compiled an International Check- List of Mango Cultivars, which contained chief characteristic features of 793 cultivars and their synonyms from India, Bangladesh, Israel, South Africa, Florida and Philippines.

2.2 Intravarietal variability in mango cv. Dashehari on the basis of vegetative characters.

Clonal variation

As early as (1948) Naik, observed significant variation among the trees of same clones in an orchard with respect to fruit shape, colour and quality which was discribed to bud mutations As early as (1956) Oppenheimer reported a wide variability in the performance of the trees belonging to same variety in same orchard, after surveying many orchards in India. Mukherjee *et al.* (1983) conducted a survey of mangoes in eastern India and identified some superior clones. Singh and Chadha (1981) in a study of mango orchards of 'Dashehari' located four clones which were superior in performance. Singh and Gangwar (1985) isolated two high yielding clones from the orchards of 'Langra' with improved resistance to bacterial black spot. Anu *et al.* (2015) identified certain strains within 'Kensington' clone, having improved resistance to bacterial black spot disease. Significant variation exists among the clones of Langra mango with respect to fruit shape, size, colour, quality and taste. Several studies have been made on characterization of intra-varietal variability of many different cultivars of mango.

Morphology

In many situations, the most easily obtained assessment of genetic variation is that of measuring morphological or phenotypic variation. The sharing of phenotypic characters is interpreted as an indication of relatedness. Morphological traits are, however, often influenced by environmental conditions (Jasienski, 1997; Kercher and Sytsma, 2000), which in turn may influence the estimation of genetic variation and relatedness. Consequently, to be really useful, morphological measurements should be accomplished on plant material that is grown in comparative trials. This may be both expensive and time consuming, and moreover, almost impossible to accomplish for some species that are very difficult to grow. However, if morphological characters are shown to be heritable, they will nevertheless reflect the genetic structure within the plant material (Person, 2001).

Intra-varietal variability of certain varieties of mango from India and other countries has been characterized based on morphological traits and genetic markers (De Souza and Lima, 2004; Diaz-Matallana *et al*., 2009; Singh *et al*., 2009; Rocha *et al*., 2012). Morphological characterization is traditionally the most common method used. Until recently, morphology-based methods have been used for the characterisation of intravarietal variability in mango (Pandey, 1998 and Singh *et al*., 2009) where significant variation among the trees of the same variety in an orchard was observed with regard to fruit shape, size, color and quality of the fruits which was ascribed to bud mutations. As early as 1956, Oppenheinmer based on a survey in many mango orchards in India reported wide variability in the performance of the trees of the same variety in the same orchard. Further, there are few reports on variability among the trees of the same variety in an orchard with respect to fruit size, shape, color and quality as early as 1971, by Naik which are highly influenced by environment. Morphologically, all the six ‘clones’ of mango studied *viz.,* ‘Harummanis’, ‘Apple’, ‘Irwin’, ‘Kent’, ‘Malgoa’ and ‘Hj. Bakar’ are very distinct with respect to the morphology and the taste of the fruits (Gan *et al*., 1981; Pandey, 1998) studied different clones of ‘Alphonso’ and found that they differ from one another in more than one character. Morphological analysis based on 17 fruit characters detected prominent variation in the landraces ‘Banganapalli’, ‘Langra’, and ‘Dashehri’ and some variation in the cultivar ‘Mallika’ (Singh *et al*., 2009). In the above cases, the identification of intra-varietal variability is based on morphological traits. But number of these traits is limited, they are unstable and they do not always enable to distinguish between closely related accessions or cultivars.

Iyer and Subramanyam (1986) screened the mango varieties at Indian Institute of Horticultural Research, Bengaluru and classified them on the basis of flowering time, sex ratio, fruit retention, harvesting time, fruit weight, TSS, acidity, total sugars and TSS: acid ratio.

The growth and development of a variety having a definite genetic character in particular set of environmental conditions shows positive relation. The variation in vegetative growth characters among mango varieties might be due to variation in genetic makeup. High variability in vegetative growth amongst the mango varieties have also been reported that Singh *et al.* (1997). Until recently, morphology-based methods have been used for the characterization of intra-varietal variability in mango where significant variation among the trees of the same variety in an orchard with regard to fruit shape, size, color and quality of the fruits has been observed which was ascribed to bud mutations (Gan *et al.*, 1981 and Pandey, 1998).

The variations observed in fruiting behaviours may be attributed to the genetic nature of varieties and weather parameter. Fruit drop in mango during initial stages is reported to vary with growth of fruit lets. It is more on number basis at mustard stage and on weight basis at marble stage (active fruiting growth phase). This reveals that the drop of larger fruit lets (those at marble stage) is more associated to ethylene evolution than those of smaller fruit lets (Muhmmad *et al*., 2002; Kumar and Jaiswal, 2004).

Mango is a highly cross-pollinated and heterozygous plant, performance of which varies with the climate resulting in a high level of genetic diversity. Most cultivars have arisen through selection of desirable types from naturally produced seedlings (Karihaloo *et al.*, 2003) where each cultivar is identified by the characteristic combination of properties such as plant architecture, fruit size, color, taste, flavor etc. (Anu *et al.*, 2015). Intra-varietal variability of certain varieties of mango from India and other countries has been characterized based on morphological traits and genetic markers (De Souza and Lima, 2004; Diaz-Matallana *et al*., 2009; Singh *et al*., 2009; Rocha *et al*., 2012). Morphological characterization is traditionally the most common method used. Until recently, morphology-based methods have been used for the characterisation of intravarietal variability in mango (Pandey, 1998 and Singh *et al*., 2009) observed significant variation among the trees of the same variety in an orchard with regard to fruit shape, size, color and quality of the fruits which was ascribed to bud mutations.

A wide range of variation was observed in growth and floral parameters of mango which indicated the presence of genetic divergence of the crop. The higher estimates of genotypic and phenotypic coefficient of variation and medium difference between GCV and PCV were obtained for percent initial fruit set (33.24% and 34.06%), fruit harvest per inflorescence (34.89% and 37.43%), number of fruits per plant (31.72% and 33.68%), number of main branches per inflorescence (30.51% and 30.81%), percent flowering shoots (27.87% and 28.99%), number of inflorescence per shoot (26.41% and 27.57%) and plant height (24.51% and 26.24%) which indicated the presence of environmental effect on these characters and wide scope of improvement through selection. The medium estimates of genotypic and phenotypic coefficient of variation were obtained by days to flowering, fruit weight, fruit breadth, fruit thickness, and percent edible portion suggesting a hopeful scope for improvement of these traits through selection (Majumder *et al.*, 2012).

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.

The heritability were high for most of the characters *viz.*, plant height (87.28 %), duration of flowering (74.61%), percent of flowering shoot (92.44 %), number of inflorescence per shoot (91.76 %), number of main branches per inflorescence (98.24%), percent perfect flower (75.94 %), percent initial fruit set per inflorescence (95.26 %), fruit weight (85.20%), fruit breadth (92.22 %), fruit thickness (83.12 %), percent TSS (82.29%), percent edible portion (95.91%), percent non-edible potion (95.91 %), percent fruit harvest per inflorescence (86.69 %), number of fruits per plant (88.69%), and weight of harvested fruits per plant (94.41%) and moderate estimates for remaining characters. Higher values of heritability indicates that either these were simply inherited characters governed by a few major genes or additive gene effects even if, they were under polygenic control and therefore, selection of these characters would be more effective for improvement. The genetic advance expressed in percent mean was very high for some of the characters, such as weight of harvested fruits per plant (81.07 %)), number of main branches per inflorescence (62.35 %), percent flowering shoot (55.20%), number of inflorescences per shoot (52.12 %), initial fruit set per inflorescence (66.84 %) number of fruits per plant (61.53%), and percent fruit harvested per inflorescence (67.02 %). It might be due to high range of variation among the genotypes (Majumder *et al.*, 2012).

The qualitative traits of tree like growth habit, canopy shape, branch density and foliage density which were varied with each other (Singh, 2014). 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.

Sridhar *et al.* (2018) estimated highest genotypic variance for petiole length, inflorescence width, fruit weight, pulp content, stone weight, seed width, seed weight, reducing sugars, nonreducing sugars, titratable acidity, TSS: acid ratio, ascorbic acid and yield. Highest estimates of phenotypic variance was observed for petiole length, inflorescence width, fruit length, fruit diameter, fruit weight, pulp content, stone weight, seed width, seed weight, reducing sugars, non-reducing sugars, titratable acidity, TSS: acid ratio, ascorbic acid and yield/plant characters. The differences between values of PCV and GCV were less for tree height, pulp content, stone length and stone weight, indicating that these characters were largely under genetic control and environment had least influence on the expression of these traits.

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.

The broad sense heritability is the relative magnitude of genotypic and phenotypic variances for the traits and it is used as a predictive role in selection procedures. High heritability was recorded for majority of the characters viz., tree height (99.51), inflorescence length (95.36), inflorescence width (95.32), fruit diameter (94.53), fruit weight (91.81), fruit skin thickness (93.16), pulp content (99.07), stone length (97.31), stone weight (96.72), seed width (95.46), seed weight (97.52), TSS (94.06), reducing sugars (93.61), ascorbic acid (94.88) and yield/plant (96.59).High heritability generally indicate that the environment effect was very low and enables the breeder to select plants on the basis of the phenotypic expression (Sridhar *et al.,* 2018).

2.3 Intravarietal variability in mango cv. Dashehari on the basis of physico-chemical characters of the fruit

Intra-varietal variability of certain varieties of mango from India and other countries has been characterized based on morphological traits and genetic markers (De Souza and Lima, 2004; Diaz-Matallana *et al*., 2009; Singh *et al*., 2009; Rocha *et al*., 2012). Morphological characterization is traditionally the most common method used. Until recently, morphology-based methods have been used for the characterization of intravarietal variability in mango, Pandey, (1998) and Singh *et al*. (2009) observed significant variation among the trees of the same variety in an orchard with regard to fruit shape, size, color and quality of the fruits which was ascribed to bud mutations. As early as 1956, Oppenheinmer based on a survey in many mango orchards in India reported wide variability in the performance of the trees of the same variety in the same orchard. Further, there are few reports on variability among the trees of the same variety in an orchard with respect to fruit size, shape, color and quality as early as 1971, Naik which are highly influenced by environment. Morphologically, all the six 'clones' of mango studied *viz.*, 'Harummanis', 'Apple', 'Irwin', 'Kent', 'Malgoa' and 'Hj. Bakar' are very distinct with respect to the morphology and the taste of the fruits (Gan *et al*., 1981; Pandey, 1998) studied different clones of 'Alphonso' and found that they differ from one another in more than one character. Morphological analysis based on 17 fruit characters detected prominent variation in the landraces 'Banganapalli', 'Langra', and 'Dashehri' and some variation in the cultivar 'Mallika' (Singh *et al*., 2009). In the above cases, the identification of intra-varietal variability is based on morphological traits. But number of these traits is limited, they are unstable and they do not always enable to distinguish between closely related accessions or cultivars.

Karibasappa *et al.* (1999) conducted an interesting study on characterization of 67 genotypes of mango germ plasm in Dharwad, Karnataka and recorded high PCV and GCV for morphological characters; hermaphrodite flowers (70.3-62.7), panicle per tree (56.0- 51.0), fruit yield (62.8-55.9), tree volume (58.0- 57.2) followed by initial fruit set and bearing panicles, whereas among fruit characters; acidity (93.0-89.1), ascorbic acid content (79.0-75.7) followed by reducing sugars, pulp weight, total sugars and physiological loss of weight. They measured low variability for leaf length, secondary rachis per panicle, number of leaves, the maximum leaf width, thickness of primary rachis, flowering duration, panicle emergence, panicle length, fruit width, total soluble solids, ripe fruit firmness, juiciness of the pulp and pulp colour. Furthermore, they noticed high heritability and high expected genetic gain among morphological characters such as total flowers (0.704-949.2), panicles per tree (0.831-417.2), fruit yield (0.79- 220.4) followed by bearing panicles, hermaphrodite flowers and tree volume, whereas among the fruit characters; for fruit volume (0.985-309.5), fruit weight (0.981-304.0), ripe fruit weight (0.981-278.3) and pulp weight.

Zaied *et al*. (2007) evaluated some mango species by fruit characters and fingerprint. Eight local mango genotypes were evaluated on the basis of physical (fruit weight, fruit length, fruit volume, fruit diameter, fiber percentage and juice weight) and chemical characteristics (TSS, titratable acidity, TSS/acid ratio, total sugar).

The genetic diversity analysis among five commercially important mango cultivars of India (Banganapalli, Dashehri, Langra, Amrapali and Mallika) using morphological markers. Morphological analysis based on 17 fruit characters detected prominent variation in the landraces 'Banganapalli', 'Langra', and 'Dashehari' and some variation in the cultivar 'Mallika' (Singh *et al*., 2009).

A significant variation exists among the clones of 'Langra' mango with respect to fruit shape, size, colour, quality and taste. In this present investigation, an a attempt was undertaken to study the clonal variability which exit in some 'Langra' mango have been studied using morphological, biochemical and Molecular Markers. A significant level of genetic variation exits among 10 clones of 'Langra' mango which can be used for mass multiplication of superior clone(s) and can be further utilized in breeding programs Annu *et al.* (2015).

Majumder *et al.* (2012) found that medium estimates of genotypic and phenotypic coefficient variation were obtained by days to flowering, fruit weight, fruit breadth, fruit thickness, and percent edible portion suggesting a hopeful scope for improvement of these traits through selection. Heritability estimated was high for most of the characters viz. fruit weight (85.20%), fruit breadth (92.22 %) and fruit thickness (83.12 %). Higher values of heritability indicates that either these were simply inherited characters governed by a few major genes or additive gene effects even if, they were under polygenic control and therefore, selection of these characters would be more effective for improvement.

Genetic advance as per cent of mean was recorded highest for all the characters. Among the characters fruit weight (98.90), titratable acidity (160.44), TSS: acid ratio (130.67) and yield/plant (116.54) characters were recorded highest comparing to all characters. It also revealed high degree of variation among the cultivars Sridhar *et al.* (2018).

Begum *et al.* (2013) evaluated of fruit samples based on 9 quantitative and 7 qualitative traits revealed phenotypic variations among accessions under study. Twenty out of 109 mango-specific microsatellite markers validated, were amplified. The pair-wise genetic dissimilarities ranged from 0.00-0.10 with a mean value of 0.05. Microsatellite analysis revealed smaller intracultivar variability of 10% in *in-situ* conditions and a genetic divergence between trees attesting that

‘Panchadarakalasa’ whatsoever cultivated throughout the state is not pure clone. The traditional nursery practices are likely to be responsible for the intracultivar polymorphism since the Panchadarakalasa’ not propagated exclusively vegetatively. Highly polymorphic microsatellites like SSR-83, MngSSR-24 and MngSSR-26 were more useful in differentiating the ‘Panchadarakalasa’ accessions. The results generated with microsatellite markers will be helpful in intracultivar improvement as well as in the application of breeder rights in the country.

Begum *et al.* (2013) showed intracultivar genetic diversity (up to 46%) indicates that ‘Chinnarasam’ whatsoever cultivated throughout the State of Andhra Pradesh is not a pure clone, which allows the genetic breeding of this cultivar by means of mass selection. Microsatellite markers have proven useful in assessing intracultivar genetic diversity and identifying accessions of ‘Chinnarasam’ cultivar.

Thirty accessions of ‘Cherukurasam’ (CKR Acc-l to CKR Acc-30) were selected and their fruit and leaf samples were collected to study intravarietal variability through classical and molecular analysis, respectively. Morphological characterization revealed variations in fruit morphology among 30 accessions. Out of the 109 simple sequence repeats (SSRs) validated with the total sample, 25 were highly polymorphic. Dendrogram based on weightless pair group of arithmetic means indicated that the accessions were not grouped as per geographic separation. Jaccard’s similarity coefficient ranged from 0.75 to 1.00 attesting that ‘Cherukurasam’ whatsoever cultivated throughout Andhra Pradesh state is not pure clone. SSRs constitute the current marker system of choice for characterizing intravarietal variability in ‘Cherukurasam’ mango Begum *et al.* (2014c).

Begum *et al.* (2014a) were selected 31 accessions of 'Beneshan' (BN Acc-l to BN Acc-31) and collected their fruit and leaf samples to study intracultivar heterogeneity based on morphological fruit traits and microsatellite markers, respectively. *In-situ* characterization and evaluation of fruit samples revealed phenotypic variations among 'Beneshan' accessions. Highly polymorphic microsatellites like SSR-80, SSR-87, SSR-28, and SSR-89 were more useful in differentiating the 'Beneshan' accessions. Microsatellites SSR-91 and MngSSR-26 produced unique alleles of 280 and 140 bp in BNAcc-8 and BNAcc-9 accessions, respectively. Jaccard’s similarity coefficient varied from 0.50 to 1.00. There was a wide range of intravarietal heterogeneity (up to 50%) indicating that 'Beneshan' whatsoever cultivated throughout the state is not pure clone, which allows the genetic breeding of this cultivar by means of mass selection.

Ibanez *et al.* (2016) collection of 991 accessions have been studied with nine microsatellite markers and pair wise compared, and the highest intravariety distance and the lowest intervariety distance determined. The collection included 489 different genotypes, and synonyms and sports. Average values for number of alleles per locus (19), Polymorphic Information Content (0.764) and heterozygosities observed (0.773) and expected (0.785) indicated the high level of polymorphism existing in grapevine. The maximum intravariety variability found was one allele between two accessions of the same variety, of a total of 3,171 pair wise comparisons. The minimum intervariety variability found was two alleles between two pairs of varieties, of a total of 119,316 pair wise comparisons. In base to these results, the minimum distance required to set distinctness in grapevine with the nine microsatellite markers used could be established in two alleles. General rules for the use of the system as a support for establishing distinctness in vegetatively propagated crops are discussed.

Luo *et al.* (2011) Observed that cultivars of Xiang Ya Mango type and their progeny have high genetic similarity with each other. The 23 cultivars were clustered into two major groups based on the SCoT analysis and three major groups based on the ISSR analysis with UPGMA. These clusters are in accordance with their known origins and main phenotypic characteristics. Our results indicated that the SCoT analysis better represents the actual relationships than ISSR analysis, although both analyses give similar results. The results also demonstrate that the SCoT marker system is useful for identification and genetic diversity analysis of mango cultivars.

Majumder *et al.* (2012) appeared that in most of the cases, the genotypic correlation values were higher than their corresponding phenotypic values. This suggests that there were strong inherent relationship between the traits. Percent flowering shoot had significant positive correlation with inflorescence per shoot, percent perfect flower, percent initial fruit set, number of fruits per plant and fruit weight both at phenotypic and genotypic levels. Fruit yield is determined by some components. The residual effects of genetic and phenotypic path analysis were 0.209 and 0.385, respectively, revealed higher genetic variability and also proved lower percent of environmental influence on the selected ten characters. In genotypic path analysis, number of fruits per plant had the highest positive direct effect (0.899) on yield. Higher positive direct effects were also observed for the characters inflorescence per shoot (0.539), percent perfect flower (0.816), and percent initial fruit set (0.292), and fruit weight (0.324). Leaf area, percent flowering shoot, number of fruits per plant, and fruit length showed negative direct effects towards yield. In phenotypic path analysis, except percent flowering, shoot per plant and fruit length and other characters also exhibited similar trend on yield as genotypic path coefficient. In combination with correlation coefficient and path analysis, it was found that number of fruits per plant and percent perfect flower gave significant positive correlation coefficients with yield and also produce the high positive direct effect. Thus, it was clear that plant height, inflorescence per shoot, percent perfect flower, percent initial fruit set per inflorescence, and fruit weight are the major component of fruit yield in mango.

Yadav *et al.* (1995) studied the variability in 20 cultivars of mango for 12 physico-chemical traits. They observed moderate to high estimate of genotypic variability for fruit weight, length of fruit, reducing sugar and peel percentage. High heritability coupled with high genetic advance was recorded for all the 12 physico-chemical traits.

The 36 clones of mango, and reported remarkable variability among clones for all the characters viz., fruit weight, length and breadth of fruit, TSS, acidity, stone and pulp weight. All these characters exhibited high heritability and low to moderate genetic advance. While, studying variability in 40 genotypes of mango, Attari *et al.*(1999) reported high genotypic and phenotypic coefficient of variation for fruit weight, fruit length and width, fruit volume acidity, ascorbic acid and carotenoids. All the 15 fruit characters studied showed high heritability; whereas, genetic advance was exhibited to be very high for carotenoids, fruit weight, fruit volume and ascorbic acid (Singh *et al.*, 1997).

Samanta *et al.* (1999a) studied variability in 25 genotypes of mango for various morphology characters. The genotypes showed significant difference for all the characters studied. A broad range of variation was observed for leaf length, average number of leaves/ twig, number of tertiary branches and chlorophyll ‘a’ and chlorophyll ‘b’ content. A great degree of different was observed between phenotypic and genotypic coefficients of variation for number of tertiary branches and number of scaffold branches, indicating the influence of the environment for this trait.

Samanta *et al*. (1999b) studied genetic variability for fruit characters of mango in West Bangal. They reported that differences between the phenotypic coefficient of variation and genotypic coefficient variation were low for fruit volume, fruit weight and pulp weight; indicating a small influence of environment.

Fifteen mango varieties evaluated for vegetative growth characters, flowering and fruiting behavior and physico-chemical composition of fruits in central India (Shrivastava *et al.,* 1987). Langra, Samar Behist, Chausa, Mallika and Baneshan were high volume producers, whereas Bangalora, Swarnarekha, Yanraj, Mulgoa, Alphonso, Fazli, Fernandin and Mankurad appeared as low volume producers. Flowering behaviour showed that Swarnarekha, Vanraj, Langra, Kesar and Fernandin were early, while Neelum, Fazli, Bangalora and Mulgoa were among late cultivars.

Under south Gujarat conditions, Katrodia *et al.* (1988) evaluated sixty mango cultivars for yield and quality. The average fruit yield was observed the maximum in Bangalora (153 kg/tree) followed by Banarasi Langra and Kesar. Whereas, total sugars were estimated the highest in cultivar Pachhatio (15.3%) followed by Jamadar and Alphonso. From a large number of F1 mango hybrid progenies, Rao and Reddy (1989) studied ten promising hybrids for their precocity, bearing potential and fruit quality and found that KO *18/16* was a regular bearer with excellent fruit quality. Singh and Singh (1989) evaluated performance of nearly hundred varieties collected from eastern, western and southern India in central Gangetic plains. They observed that Krishnabhog, Safdar Pasand and Sukul were most promising among the introductions from eastern India. Among the south Indian cultivars, Ambalavi, Neelum and Vellaikolumban excelled the local cultivars in yield and equalled for quality, whereas none of the West Indian collections performed well.

Iyer and Subramanyam (1986) screened the mango varieties at Indian Institute of Horticultural Research, Bengaluru and classified them on the basis of flowering time, sex ratio, fruit retention, harvesting time, fruit weight, TSS, acidity, total sugars and TSS: acid ratio.

The heritability determines the relative importance of genetical and environmental factors in expression of phenotypic differences observed among various plants. It is the portion of phenotypic expression which is transmitted from parents to progeny. Genetic variability largely depends upon heritable variations. Higher the heritable variation greater will be the possibility of fixing the characters by selection methods. So heritability studies are of foremost important to judge whether the observed variations for a particular character is heritable or due to environment. Heritability in broad sense is the ratio of genotypic variance to phenotypic variance (Lush, 1949 and Wright, 1921).

Genetic advance (GA) is the improvement over the base population that can potentially be made from the selection for the characters. It is the function of heritability of traits, amount of phenotypic standard deviation and selection intensity. Heritability with high expected genetic gain shows the most effective contribution of selection. (Johnson *et al.*, 1955).

Kumar and Kumar (2000) studied fruit weight components in mango. An experiment was conducted for 2 consecutive years in 12 genetically diverse strains or varieties of mango to determine their inter-relationship among different characteristics and their effects on fruit weight. The genotypic and phenotypic correlation coefficient values revealed that genotypic correlation coefficients were higher than their corresponding phenotypic correlation coefficients, suggesting a strong inherent relationship among the different genotypes. Fruit weight had highly significant and positive correlation with fruit length, fruit diameter, fruit volume and seed stone length during both years. It also exhibited positive but non-significant correlation with shoot length, leaf width, petiole length, panicle diameter, seed stone weight and seed stone diameter during both the years. Shoot diameter, leaf length and reducing sugar also exhibited positive but non-significant association with fruit weight.

Prasad (1987) studied correlation for 40 divergent varieties of mango. He found positive and significant correlation of total soluble solids with number of fruits, fruit length and breath of fruit. While characters like ascorbic acid, pH value, fruit weight and fruit volume were positively correlated with fruit yield.

Patel (2002) studied the correlation of 17 different characters in Mango for 18 genotypes at Anand. He observed that genotypic correlations were higher than the phenotypic correlations in all the trait pairs indicating inherent association between different characters. The fruit yield per tree exhibited significant and positive correlation with number of fruit per tree, tree height, plant spread (N-S), plant spread (E-W), non-reducing sugar and ascorbic acid at both genotypic and phenotypic level, whereas, it was significantly and negatively correlated with stone peel: pulp ratio and stone: pulp ratio at both the levels.

Yadav *et al*. (2003) studied correlation of fruit characteristics of 69 types of mango cv. Langra. Results revealed that correlation at the genotypic level was higher than at the phenotypic level, indicating a strong genetic correlation of characters and the lowering of effect of environmental interaction at the phenotypic level. Fruit length, fruit diameter, stone weight, peel weight, pulp weight and pulp percentage showed highly positive and significant genotypic and phenotypic correlation with fruit weight. Stone weight showed a strong and positive correlation with peel weight. Fruit length was negatively and significantly correlated with total soluble sugar and total sugar sontent, but was positively correlated with fruit acidity, pulp weight and peel weight.

Jintanawongse *et al.* (1987) characterized eighty local and eight introduced mango cultivars in Thailand based on leaf and fruit shape and reported that both the characters were heritable, easy to see and expressed in all environments. High genotypic coefficient of variation was found for fruit weight, fruit volume and content~ of ascorbic acid and reducing sugars in forty mango varieties.

Heritability was high for contents of ascorbic acid and reducing sugars, pH, fruit , weight and volume. Yadav *et al.* (1995) observed moderate to high estimates of variability, heritability and genetic advance for fruit weight, fruit length, reducing sugars, acidity and peel per cent in mango at Rewa, Madhya Pradesh. Lavi *et al.* (1998) estimated phenotypic and genetic variance for thirteen traits in 745 mango progeny derived from both controlled crosses and open pollination in Israel. In all thirteen traits analyzed, the additive genetic variance components were not statistically significant, while in eight of the traits, viz. fruit weight, harvest duration, softening time, firmness, taste, appearance, quality and final assessment, the dominant genetiC variance was significant. A significant difference was recorded in nineteen genotypes of mango collected from south Andman for different physicochemical characters (Attri *et al.,* 1999). The highest range of variation was shown by fruit weight, volume, pulp and carotenoids, whereas the lowest by acidity. They reported that all the characters under study including fruit length, breadth, weight, volume, specific gravity, peel, stone and pulp per cent, TSS, acidity, sugars, ascorbic acid and carotenoids had shown high estimates of broad sense heritability ranging from 85.3% for specific gravity of fruits to 99.9% for ascorbic acid and carotenoids. Moreover, they mentioned that the genetic advance could be 324.95, 269.03, 266.23 and 77.36% for carotenoids, fruit weight, its volume and ascorbic acid, respectively, with the 5% selection intensity. They concluded that the fruit weight, its length, breadth, pulp per cent and overall quality were found to be effective selection indices and three collections, viz. CP1, CP3 and DBK2 could be further improved for their excellent horticultural characters.

Rai *et al.* (2001) conducted experiment to estimate genetic variance and its relationship with yield components in thirty-three mango varieties under East Indian conditions and reported high GCV for pulp weight (35.06%), stone weight (32.2%) and skin weight (31.42%). The PCV was generally higher than GCV for all the characters and it was high for yield/plant, pulp weight, fruit volume and skin weight. They observed high heritability estimates for yield/plant, tree height, fruit weight, fruit volume, tree girth and pulp weight.

Singh (2002) reported significant variability along with high broad sense heritabilty and low to moderate genetic advance for various characters in thirty-six early and regular bearing clones of mango in Andmans. They observed the highest estimates of broad sense of heritability and expected genetic advance for length and breadth of fruit, fruit weight and pulp per cent. They reported that fruit weight, its length and breadth might be effective selection indices for these clones.

Patel *et al.* (2016) estimated genotypic and phenotypic coefficient of variation were high for all the characters except fruit width, TSS, non-reducing sugar and total sugar which indicated sufficient variability among selected genotypes for different characters.

Sridhar *et al.* (2018) Genetic advance as per cent of mean was recorded highest for all the characters. Among the characters fruit weight (98.90), titratable acidity (160.44), TSS: acid ratio (130.67) and yield/plant (116.54) characters were recorded highest comparing to all characters. It also revealed high degree of variation among the cultivars.

2.4 Microscopy studies for exploring intravarietal variability in mango cv. Dashehari

Scanning Electron Microscopy (SEM) is an ideal technique for examining plant surface, germplasm identification and morphological characterization at high resolution along with other research tools such as molecular markers (Pathan et al., 2010). Stomatal traits are highly variable depending on the genetic background of the plants as well as on the growth conditions or the leaf ontogeny (Masarovicova, 1991 and Jones, 1992).

Stomata are any of the minute pores in the epidermis of the leaf or stem of a plant, forming a slit of variable width which allows movement of gases in and out of the intercellular spaces which is measured by Scanning Electron Microscopy (SEM). Generally, stomatal initiation is controlled by both environmental and genetic factors (Casson and Hetherington 2010).

Sakhanokhono et al. (2014) reported that no significant differences were found among the 12 accessions for quantitative descriptors related to seedlings (petiole length, cotyledons length and width) and stomates, even though more stomates were consistently found on the abaxial surface of leaves for all 12 accessions. An increase in stomatal dimension, which results in reduced stomatal density, is often indicative of increased ploidy level in a species; therefore, the lack of variability among the accessions for stomatal density and size is not surprising since all 12 accessions were found to be diploid with a chromosome number of 2n=2x=24.

Afas et al. (2006) studied stomatal characteristics, as stomatal density and stomatal length, for fully expanded leaves from all clones and at two canopy positions (upper and lower canopy). Above-ground biomass production was assessed by destructive harvesting and varied significantly among clones. Leaves of all clones were amphistomatous except for clones belonging to the Populus trichocarpa parentage. Abaxial stomatal density was higher than adaxial stomatal density for all clones and for both canopy positions. Significant clonal variations in stomatal density and length were observed. Significant differences were also found between the two canopy positions for both stomatal density and length. Upper canopy leaves had higher stomatal density than lower canopy leaves. Variations in stomatal characteristics were related to the parentage of the clones and to the canopy position within each clone. Biomass was positively and significantly correlated with abaxial stomatal density, i.e., clones with high density showed high biomass production. It was conclude that stomatal density of different poplar clones affected biomass production.

Masarovicova, (1991) studied stomatal characteristics (i.e., size and density) which are highly variable depending on the genetic background of the plants as well as on the growth conditions or the leaf ontogeny Stomatal density has been shown to vary significantly within individuals, cultivars or ecotypes of a single species, as well as within a community (Jones, 1992). Within the Populus genus, a wide interspecific as well as interclonal variation in stomatal density, dimension and stomatal index has already been observed (Ferris et al., 2002). Stomatal traits have already been suggested as criteria for clonal discrimination in the genus (Ceulemans et al., 1988). Such an eventual use of stomatal features requires a detailed knowledge of the stomatal characteristics of the most frequently used poplar species and hybrids.

Orlovic et al. (1998) a strong correlation was observed between adaxial stomatal density and biomass in Populus hybrids and this correlation was proposed to be used in the selection of nursery stock for biomass production.

Some species have been reported as possessing generally high heritability (i.e., less sensitive to environmental change) in their stomatal characteristics (Sharma and Dunn 1969; Orlovic et al., 1998), while others have been reported as being more sensitive to environmental factors (Schoch et al., 1980).

Several studies have been performed to understand the genetic basis for stomatal-related traits. In Arabidopsis, natural variation in stomatal responses to environmental changes has been reported (Aliniaeifard and van Meeteren, 2014; Takahashi et al., 2015), as well as for stomatal density (Delgado et al., 2011).

Delgado et al., (2011) studied genetic variation for stomatal development was observed, as well as an indication of relationships among stomatal traits and extreme or uncommon accessions as resources for the genetic dissection of stomatal development.

Using a subset of a population of Solanum pennellii introgression lines, Fanourakis et al. (2015) assessed variation in stomatal responsiveness to desiccation and gs-related anatomical traits under well-watered conditions. Considerable differences with respect to stomatal size, density, distribution between the leaf adaxial and abaxial sides, as well as pore area per stomatal area were observed.

In sugarcane, a broad number of gs measurements obtained across varying moisture regimes, locations, and crop cycles. with several genotypes indicated that there is genetic variation for gs, with moderate heritability (Basnayake et al., 2015).

Marron (2006) postulated that stomatal traits could be used as early indicators of growth potential in poplar as well as criteria for clonal discrimination in the genus and stomatal density is reported to differ significantly even among clones belonging to different parentages, between different canopy positions and on leaf surfaces besides varying within leaves, plants, and individuals of a single species (Afas et al., 2006). Stomatal length has also been reported to correlate with genome size (Xu and Zhou 2008). Therefore, the genetic and developmental basis for high stomatal density and stomatal conductance and its application in germplasm studies is a research priority in plant physiology, agriculture, and paleo-biology (Wang et al. 2015).

Riaz and Chaudhary (2003) who observed genotypic and phenotypic coefficient of variation (7.43 and 7.29%) for stomatal size indicated that all of the variation for the trait was due to genetic causes. The maximum value of heritability (97.50) and genetic advance (20.86) were found for stomatal density.

Examination of variations in stomatal traits: stomatal density (SD), stomatal length (SL), stomatal width (SW) and stomatal surface (SS) based on changes in the plant growth parameters in different growing media in corn. All growth parameters studied was found significant differences between combination rates in both of growing media. The stomatal parameters were changed related to the growing parameters. The increase in leaf growing parameters led to increase in SW, SL and SS values but decrease in SD. It can be said that the SS of corn plant leaf set by changing both of the SW and SL sizes, acting positively on growth conditions. It can be suggested to combine the results obtained from maize with other uninvestigated plant and growth condition to clarify mechanisms of stomatal which are under control of genetic and environmental factors (Orcen, et al. 2013).

Xu and Zhou (2008) reported that SL correlates with both of genome size and water conditions. Besides, SD is genetically determined as a quantitative trait (Gailing et al. 2008). The relative importance of gene versus environment in determining SD or SL and its interspecific variation have not yet been estimated under a unified framework. A wider diversity of models for the genetic and environmental control of stoma should be considered (Zhang, *et al.* 1999).

Camargo and Marenco (2011) reported that large variation in both stomatal density (S_D) and stomatal size (S_S) among species. S_D ranged from 110 mm2 in Neea altissima to 846 mm^{-2} in Qualea acuminata. However, in most species S_D ranges between 271 and 543 mm^{-2}, with a negative relationship between S_D and S_S. We also found a positive relationship between S_D and tree height ($r2 = 0.14$, $p < 0.01$), but no correlation was found between S_D and leaf thickness. The most common stomatal type was anomocytic (37%), followed by paracytic (26%) and anisocytic (11%). We conclude that in Amazonian tree species, stomatal distribution on the leaf surface is a response most likely dependent on the genetic background of every species, rather than a reaction to environmental changes, and that somehow S_D is influenced by environmental factors dependent on tree height.

Afas et al. (2006) found significant clonal variations in stomatal density and length were observed. Significant differences were also found between the two canopy positions for both stomatal density and length. Upper canopy leaves had higher stomatal density than lower canopy leaves. Variations in stomatal characteristics were related to the parentage of the clones and to the canopy position within each clone. Biomass was positively and significantly correlated with abaxial stomatal density, i.e., clones with high density showed high biomass production. We conclude that stomatal density of different poplar clones affected biomass production.

Stomatal density has been shown to vary significantly within individuals, cultivars or ecotypes of a single species, as well as within a community (Jones, 1992). Within thePopulus genus, a wide interspecific as well as interclonal variation in stomatal density, dimension and stomatal index has already been observed (Ferris et al., 2002). Stomatal traits have already been suggested as criteria for clonal discrimination in the genus (Pallardy and Kozlowski, 1979; Ceulemans et al., 1988).

2.5 Molecular analysis of intravarietal variability in mango cv. Dashehari

Sodium Dodecyl Sulfate Ployacrylamide Gel Electrophoresis (SDS-PAGE)

SDS-PAGE (sodium dodecyl sulfate–polyacrylamide gel electrophoresis) is a variant of polyacrylamide gel electrophoresis, an analytical method in biochemistry for the separation of charged molecules in mixtures by their molecular masses in an electric field. It uses Sodium Dodecyl Sulfate (SDS) molecules to help identify and isolate protein molecules. SDS-PAGE is a discontinuous electrophoretic system developed by Ulrich K. Laemmli which is commonly used as a method to separate proteins with molecular masses between 5 and 250 KDa *(*Laemmli, 1970). SDS-PAGE is an electrophoresis method that allows protein separation by mass. The medium (also referred to as ′matrix′) is a polyacrylamide-based discontinuous gel. In addition, SDS (Sodium Dodecyl Sulfate) is used. About 1.4 grams of SDS bind to a gram of protein, corresponding to one SDS molecule per two amino acids. SDS acts as a surfactant, covering the proteins' intrinsic charge and conferring them very similar charge-to-mass ratios. The intrinsic charges of the proteins are negligible in comparison to the SDS loading, and the positive charges are also greatly reduced in the basic pH range of a separating gel. Upon application of a constant electric field, the protein migrates towards the anode, each with a different speed, depending on its mass. This simple procedure allows precise protein separation by mass (Reynolds and Tanford, 1970; Smith, 1984 and Georgios and Anastasios, 2009).

A total of twenty accessions of rice (*Oryza sativa* L.) germplasm were analyzed for total seed protein through SDS-PAGE, to ascertain the extent of genetic variation and its geographical distribution. A considerable variation in protein banding pattern was observed which was distributed to various geographical regions. Inter-specific variation was more as compared to intra-specific variation. *Inter and Intra-Specific Variation in SDS-PAGE of Total Seed Protein in Rice (Oryza sativa L.) Germplasm* (Asghar, *et al.*, 2004).

Singh *et al.* (2017) analyzed variability through seed protein by using SDS-PAGE. Extracting the total seed proteins from 12 cultivars of pea and performed SDS-Polyacrylamide gel electrophoresis. On the basis of banding patterns through SDS-PAGE, indicated that the number of bands found in cultivars ranged from 12 to 19 with Rm value 0.12 to 0.9. Among all the cultivars, the cultivar KPMR-400 had recorded highest number of bands (19) whereas, the minimum number of bands (12) observed in three cultivars viz., KPMR-921, KPMR-902 and KPMR-913. The total seed protein variation were also analyzed using Un-weighted Pair Group Method with Arithmetic Mean (UPGMA) and resultant cluster analysis based on the data of protein profiling, classified twelve cultivars into six major groups. Finally the study concluded that, the protein variability analysis clearly showed that there was sufficient genetic divergence among these cultivars of pea with respect to seed storage protein. Among all the cultivars, the KPMR-906 in cluster IV having wider genetic diversity and suggested to utilize in future crop improvement program.

Grain protein content and protein profiles of six arid grain legumes belonging to three different tribes were studied by Jukanti *et al.* (2016). Average grain protein (per cent) of horse gram, cowpea, moth bean, guar, chickpea and green gram was 20.29, 22.8, 22.6, 20.6, 21.82, and 20.40 respectively. All the six arid legumes were clearly differentiated based on the protein banding patterns generated through SDS-PAGE. The molecular weight range of proteins in different legumes was observed to be ~16 to ~250kD. Interestingly, in chickpea, moth bean and horse gram proteins >100kD were not mostly observed. Further, distinct proteins were observed indicating inter-varietal differences in horse gram (CRHG-19), cowpea (RC-101) and guar (HG-2- 20), which could be useful in varietal identification. The different legumes were broadly clustered in to four clusters. Further, chickpea (Cicereae), green gram and cowpea (Phaseoleae) were clustered together. The similarity indexes of varieties and individual crops ranged from 0.667 to 0.950 and 0.425 to 0.821 respectively. Though the six legumes belong to Leguminosae they have distinct protein profiles which could be useful in species/varietal identification.

Asghar *et al.* (2004) reported that electrophoretic patterns of the protein fractions are directly related to the genetic background of the proteins and can be used to certify the genetic makeup. SDS-PAGE is increasingly used to describe the genetic structure of crop germplasm identification. A total of twenty accessions of rice (*Oryza sativa* L.) germplasm were analyzed for total seed protein through SDS-PAGE, to ascertain the extent of genetic variation and its geographical distribution. A considerable variation in protein banding pattern was observed which was distributed to various geographical regions. Inter-specific variation was more as compared to intra-specific variation.

Aiswariya and Thomas (2016) recorded the genetic variability and relatedness among five cultivars of Oryza sativa viz. Jaya and Uma (improved) and Odachen, Chennellu and Vetteri Black (traditional) cultivated in Kerala using seed protein profiling and morphological characteristics. SDS PAGE of grain protein of five edible rice varieties showed about 50% polymorphism.

Cluster analysis and dendrogram studies

Karibasappa *et al.* (1999) used numerical taxonomic approach of unweighted pair group method using arithmetic average (UPGMA) method for 37 quantitative and 6 qualitative characters in sixty-seven genotypes of mango and identified eleven clusters. They reported that clusters 2, 4, 3 and 10 were most homogenous, whereas cluster 9, 7 and 11 were highly heterogenpus. Cluster 7 (Neelum, Baramasi, Kalepad) and cluster 11 (Batlimavu and Cowasji Patel) were the most divergent followed by cluster 10 (Dophasla, nl.him-46, Neeluddin, Local- 4, Ko-11, Creeping) and cluster 11, while the cluster 3 (Dashehari, Pahutan, nl.him-32, nl.him-33, Local-1, csr.nl, Nekkare-2, Nekkare-1) and cluster 10 were the least divergent.

Kumar *et al.* (2001) estimated genetic diversity of fifty mango cultivars using RAPD markers in south Indian conditions and found a moderate degree of genetic diversity based on dendrogram study. The hybrids, which had a parent in common, were placed together, whereas alternate bearers and regular bearers formed separate groups in the cluster.

Karihaloo *et al.* (2003) analysed genetic diversity of twenty-nine Indian mango cultivars using RAPD markers. They reported that unweighted pair-group method with arithmetic means (UPGMA) dendrogram had shown the majority of the cultivars from northern and eastern regions of India clustering together and separate from southern and western cultivars. Differences among regions were significant, however, northern and eastern regions formed one zone and western and southern regions formed another zone of mango diversity in India.

Most of the studies related to dendrogram and clustering patterns of various mango germplasm have been done with the help of molecular markers. Such studies are highly useful for confirming the results obtained by conventional methods. Lopez-Valenzuela *et al.* (1997) examined fifteen mango cultivars collected from four different geographical regions using RAPD markers and produced a dendrogram of the genetic relatedness. They reported that the four major bifurcations in the dendrogram clearly separated the genotypes into 4 groups according to their geographic origin Eiadthong *et al.* (1999) evaluated twenty-two mango cultivars for their genetic variation using simple sequence repeat (SSR). Based on dendrogram study, they stated that two Thai mango cultivars Nang Klangwan and Nong Saeng were very far distant of the genetic relationship from the other cultivars and remaining 11 Thai cultivars were classified into three groups.

Begum *et al.* (2014) constructed a dendrogram and reported that 30 accessions of Cherukurasam mango were divided into four major clusters (cluster-I, II, III and IV). Of these four clusters, cluster-IV was the largest (18 accessions), followed by cluster-I (7 accessions) and cluster-III was the smallest (4 accessions), while cluster-II was solitary (1 accession).

A UPGMA cluster diagram grouped the 31 accessions of Beneshan mango divided into two major clusters (cluster I and II), effectively differentiating the accessions collected from different regions with additional sub-clusters (Figure 2). Cluster-I consisted of 23 accessions, while cluster-II comprised of 8 accessions. Cluster-I was divided into three sub-groups (cluster IA, IB and IC) and cluster II was divided into two sub-groups (cluster IIA and IIB). Of the three sub clusters (cluster-IA, IB, IC) of cluster-I, the sub cluster IA and IC are solitary comprising of single genotype each (Begum *et al.,* 2014a).

Hierarchical cluster analysis using average linkage between genotypes showed that there are four distinct clusters (at a rescaled distance of 5) for the mango genotypes of northern Kerala in mango (Pradeepkumar, 2006).

MATERIALS AND METHODS

The materials used, experimental procedures and techniques adopted during the course of investigation entitled, **"Morphological and Molecular Analysis of Intravarietal Variability in Mango (*Mangifera indica* L.) cv. Dashehari in Lucknow region"** conducted at two blocks (Malihabad and Mal) of district Lucknow and Babasaheb Bhimrao Ambedkar University, Lucknow, Uttar Pradesh, India; during the year 2016-18 have been described in detail in this chapter under appropriate heads and sub-heads. The investigation was carried out in two phases.

In the first survey of mango orchards and collection of samples for study was done in the two blocks as mentioned above while the analytical work (2nd phase) was conducted in the Ph. D Laboratory, Department of Applied Plant Science (Horticulture), School for Biosciences and Biotechnology and University Scientific Instrumentation Center (USIC), Babasaheb Bhimrao Ambedkar University, Lucknow, Uttar Pradesh, India.

Experimental site

A survey of the two blocks viz., Malihabad and Mal of district Lucknow, located within a distance 27.5 km and 40.5 km (www.makemytrip.com), respectively from Lucknow, was conducted in the first phase to explore the presence of any intra-varietal variability which the farmers may have observed in Dashehari trees in their respective orchards with a focus on

i. Age when trees came into bearing
ii. Flowering behaviour
iii. Fruiting behaviour and fruit quality
iv. Fruit weight (g)
v. Yield (quintal per tree)

as per the objective of the study.

Malihabad is situated at 26.9289º N longitude and 80.7148º E latitude and Mal is situated at 27.0236º N longitude and 80.7394º E latitude respectively, at an altitude of 128m and 133m above mean sea level (MSL). Both the blocks are among the

N
Sitapur
Hardoi
Mahona
Itaunja
Mal block
Mal
Rahimabad
Bara Banki
Bhauli
Bakhshi Ka Talab
Malihabad block
Malihabad
Chanhat
Lucknow
Kakori
Juggaur
Alamnagar
Gosainganj
Unnao
Bijnaur
Utrahtia
Banthia
Amethi
Bani
Sikandarpur
Mohanlalganj
Sisendi
Nagram
Nigoha
Rae Bareilly
District Headquarter
District Boundary
Airport
River
Lucknow Map

eight (Bakshi Ka Talab, Chinhat, Gosaiganj, Kakori, Mal, Malihabad, Mohanlalganj and Sarojni Nagar) blocks of district Lucknow and are significant since they are declared as the Agri Export Zone (AEZ) for mango for Dashehari (Anonn, 2008). The two blocks are located at a distance of merely 13 km from each other (http://alldistancebetween.com). The Malihabad and Mal blocks are located 30 km and 45 km from Babasaheb Bhimrao Ambedkar University, Lucknow

Plant samples for the vegetative, flower and fruit studies were collected from 15 selected orchards of Dashehari from the two blocks. Samples for stomatal as well as molecular studies were also collected from the selected orchards.

In the second phase analytical and laboratory work was done in Ph. D Laboratory, Department of Applied Plant Science (Horticulture), School for Biosciences and Biotechnology and University Scientific Instrumentation Center (USIC), Babasaheb Bhimrao Ambedkar University, Lucknow, Uttar Pradesh, India, during the year 2016-18.

The Babasaheb Bhimrao Ambedkar University is located in subtropical tract of central Uttar Pradesh at 26º 46' N latitude, 80 º 55' E longitudes and at an altitude of 129m above MSL.

Climate of the experimental sites

The climate of Malihabad and Mal blocks is subtropical with warm summers and cold winters and an annual precipitation of 305 mm. The average annual temperatures in Mal are 25.5°C while in Mal block it is 24°C (https://en.climate-data.org).

Babasaheb Bhimrao Ambedkar University is located in Lucknow city which has a subtropical climate with maximum temperature ranging from 29.3ºC to 45ºC in summer season and minimum temperature ranging from 3.5ºC to 12ºC in winter. The average annual rainfall is 700mm, most of which is received between July to mid September and is distributed over a period of about 100 days with peak period from July to August. Scattered showers also occur during winter months. The weather data during experimental period (2016-17 and 2017-18) are presented in Appendix I.

The present study was divided into five experiments to explore and establishing presence of intravarietal variability in the sample population of cv. Dashehari from the excising orchards in the two blocks (Malihabad and Mal) in the AEZ for mango in district Lucknow. These are described in details below under each experiment.

3.1 Experiment I

To survey the possibility of genetic diversity and variability of Dashehari mango in Malihabad and Mal block of district Lucknow

Survey for the possibility of existence of intra-varietal variability in mango orchards cv. Dashehari was conducted in two blocks *viz.* Malihabad and Mal of district Lucknow in February-March, 2016 through a questionnaire (Appendix II) (Rosalin and Vinayagamoorthy, 2014) and interview of 100 mango orchardists (Appendix III) of the two blocks.

Experimental details:

Sample size	-	100 mango growers
Method of survey	-	Through questionnaire and interview (Rosalin and Vinayagamoorthy, 2014)

On the basis of the survey, 15 commercial orchards of mango (*Mangifera indica* L.) cv. Dashehari (Appendix IV) were selected for conducting further study for establishing intravarietal variability in two blocks *viz.*, Malihabad and Mal of district Lucknow through planned scientific studies on the basis of morphological analysis, fruit studies etc.

3.2 Experiment II

To evaluate the intravarietal variability in mango cv. Dashehari on the basis of vegetative characters

On the basis of the information collected through the survey, samples of leaf and inflorescence were collected from the selected orchards for evaluation of intravarietal variability in mango cv. Dashehari in the sample orchards as per details below. Tree parameters were recorded at the site of the orchards.

Experimental details:

Treatments	-	45 (Three vegetatively propagated trees each from 15 commercial mango orchards)
Age of plants	-	25-30 years
Replication	-	3
Design	-	Completely Randomized Design (CRD)

Observations recorded

3.2.1 Tree parameters

Three plants each, 25-30 years in age from 15 different orchards of cv. Dashehari (45 trees) in the two adjoining blocks of Lucknow district were selected randomly for recording trunk girth and number of secondary branches per tree.

Trunk girth (cm)

Trunk girth of 45 Dashehari morphotypes were measured 25 cm above ground level with measuring tape and average value was calculated and expressed in cm.

Number of secondary branches per tree

Secondary branches are those branches which originate from primary branches and all such branches were counted manually from each sample tree and computed for recording the average number of secondary branches.

3.2.2 Leaf parameters

Three leaves each of uniform age (5-7 month) and physiological maturity from three directions of each tree were collected, as per leaf sampling technique for mango (Poffley, 2005), in the month of February in both the years 2016 and 2017, from the sample trees from the selected orchards and analyzed for the leaf parameters *viz.*, leaf length (cm), leaf width (cm), leaf thickness (mm) and petiole length (cm). All the analysis was carried out in the Ph. D Laboratory, Department of Applied Plant Science (Horticulture), School for Biosciences and Biotechnology, Babasaheb

Bhimrao Ambedkar University, Vidya Vihar, Raebareli Road, Lucknow using standard methods described in detail below.

Leaf length (cm)

Leaf length was recorded from attachment of petiole with lamina to apex of three leaves from each sample tree with the help of measuring scale and average value was calculated and expressed in cm.

Leaf width (cm)

Leaf width was recorded at the region of maximum expanse of lamina for three leaves of each morphotype with the help of measuring scale and average value was calculated and expressed in cm.

Leaf thickness (mm)

Leaf thickness was recorded for three leaves from each morphotype using digital vernier callipers (Mitutoyo, Japan) and average value was recorded and expressed in mm.

Petiole length (cm)

The petiole length of three leaves from each morphotype was observed by measuring scale from attachment of the leaf petiole with the stem till attachment of petiole with lamina and average value was calculated and expressed in cm.

3.2.3 Inflorescence studies

Three panicles from three directions of each tree were collected in the Ist week of March in both the years 2016 and 2017, from the sample trees from the selected orchards and analyzed for the floral studies *viz.*, panicle length (cm), panicle width (cm), number of florets per panicle, number of flowers per panicle, in Ph. D Laboratory, Department of Applied Plant Science (Horticulture), School for Biosciences and Biotechnology, Babasaheb Bhimrao Ambedkar University, Vidya Vihar, Raebareli Road, Lucknow using standard methods reported described in detail below. The fruit set studies *viz.*, fruit set per panicle at mustard stage, fruit set per panicle at pea stage and final fruit set per panicle were, however, conducted in the selected orchards *in situ.*

Panicle length (cm)

Panicle length was measured with the help of measuring scale from the point of emergence to the apex for three panicles from each tree collected from three directions of the tree and average value was calculated and expressed in cm.

Panicle width (cm)

Panicle width was measured with the help of measuring scale from maximum expanse of panicles for three panicles from each tree collected from three directions of the tree and average value was calculated and expressed in centimeters.

Number of florets per panicle

Number of florets per panicle was also counted manually from three tagged panicles from three directions (east, west and south) of the sample tree and average value was calculated.

Number of flowers per panicle

Number of flowers per panicle was also counted manually from three tagged panicles from three directions (east, west and south) of the sample tree and average value was calculated.

Fruit set studies

The fruits set per panicle were counted manually from three tagged panicles from three directions (east, west and south) of the tree at three different stages (Initial fruit set per panicle, number of fruits per panicle at pea stage and number final fruits per panicle) of each morphotypes and average value was calculated.

3.3 <u>Experiment III</u>

To establish intravarietal variability in mango cv. Dashehari on the basis of physico-chemical characters of the fruit

Three fruit were collected from each tree from three directions of the tree from the orchards selected on the basis of the information collected through the survey, for evaluation of intravarietal variability in mango cv. Dashehari in the sample orchards on the basis of physico-chemical studies of fruit. These were analysed for the various physical as well as biochemical quality parameters of the fruit as per procedures discussed below.

Experimental details:

Treatments	-	45 (Three vegetatively propagated trees each from15 commercial mango orchards)
Age of plants	-	25-30 years
Replication	-	3
Design	-	Completely Randomized Design (CRD)

Observations recorded

3.3.1 Fruit morphology

Three fruits of each morphotype were collected from tagged panicles in accordance with the computational fruit maturity index for mango (Sharma and Singh, 2000) in the month of June-July in both the years, from the sample trees from the selected orchards and analyzed for the fruit morphological character *viz.*, fruit length (cm), fruit width (cm), fruit weight (g) fruit volume (ml), specific gravity of fruit, pulp weight (g), peel weight (g), pulp:peel ratio and peel thickness (mm) in the Ph. D Laboratory, Department of Applied Plant Science (Horticulture), School for Biosciences and Biotechnology, Babasaheb Bhimrao Ambedkar University, Vidya Vihar, Raebareli Road, Lucknow using standard methods which are described in detail below.

Fruit length (cm)

Fruit length was recorded from peduncle to apex of three fruits from three direction of each sample tree with the help of vernier callipers (Mitutoyo, Japan) and average value was calculated and expressed in cm.

Fruit width (cm)

Fruit width was recorded from maximum expansion (cross sectionally) of three fruits from three direction of each sample tree with the help of vernier callipers (Mitutoyo, Japan) and average value was calculated and expressed in cm.

Fruit weight (g)

Fruits of sample population were weighed on a digital weighing balance (International trading company: DD6MM 06/12-W) average value recorded and expressed in grams.

Fruit volume (ml)

Fruit volume of three fruits from three direction of each sample tree was measured by using water displacement method. A wide mouth measuring cylinder was filled with water sufficiently to submerge the fruit. The initial reading of water level was taken and final reading of water level after submerging fruit is also recorded. The difference between final and initial level was computed the volume of fruit.

Specific gravity of fruit

Specific gravity of fruit of three fruits from each sample tree was computed by following formula

$$\text{Fruit specific gravity (g/cc)} = \frac{\text{Weight of Fruit (g)}}{\text{Fruit volume (ml)}}$$

Pulp weight (g)

Pulp was obtained after peeling and removing of three fruits collected from three direction of each sample tree and pulp weight was measured on a digital weighing balance (DD6MM 06/12-W) and value was recorded and expressed in grams (g).

Peel weight (g)

Peel was obtained from after separation from pulp of fruits from each sample tree and peel weight was measured on a digital weighing balance (International trading company: DD6MM 06/12-W) and value was recorded and expressed in grams.

Pulp:peel ratio

Pulp:peel ratio was calculated by dividing pulp weight with peel weight.

$$\text{Pulp:peel ratio} = \frac{\text{Pulp weight (g)}}{\text{Peel weight (g)}}$$

Peel thickness (mm)

Peel was obtained after separating pulp of fruits collected from three direction of each sample tree and peel thickness was recorded using digital vernier callipers (Mitutoyo, Japan) and average value was recorded and expressed in mm.

3.3.2 Stone parameters

Stone of fruits of was obtained after the removing of peel and pulp from ripe fruits and analyzed for the stone parameters *viz.*, stone weight (g), pulp:ston ratio, volume of stone (ml), specific gravity of stone, stone length (cm), stone width (cm) and stone thickness (cm) in the Ph. D Laboratory, Department of Applied Plant Science (Horticulture), School for Biosciences and Biotechnology, Babasaheb Bhimrao Ambedkar University, Vidya Vihar, Raebareli Road, Lucknow using standard methods reported as described below.

Stone weight (g)

Stone weight of three stone obtained from three fruits from three direction of each sample tree was measured on digital weighing balance (International trading company: DD6MM 06/12-W) and average value was calculated and expressed in gram (g)

Pulp:stone ratio

The pulp:stone ratio was calculated by dividing pulp weight with stone weight.

$$\text{Pulp:stone ratio} = \frac{\text{Pulp weight}}{\text{Stone weight}}$$

Volume of stones (ml)

Stone volume of three stone obtained from three fruits from three direction of each sample tree was measured by using water displacement method. A wide mouth measuring cylinder was filled with water sufficiently to submerge the stone. The initial reading of water level was taken and final reading of water level after submerging of stone was also taken. The difference between final and initial level was computed the volume of fruit.

Specific gravity of stones

Specific gravity of stone of three stones obtained from three fruits from three direction of each sample tree was computed by following formula.

$$\text{Stone specific gravity (g/cc)} = \frac{\text{Stone weight (g)}}{\text{Stone volume (ml)}}$$

Stone length (cm)

Stone length of three stones obtained from three fruits from each sample tree was recorded longitudinally with the help of vernier callipers (Mitutoyo, Japan) and average value was calculated and expressed in cm.

Stone width (cm)

Stone width of three stone obtained from three fruits from three direction of each sample tree was measured by digital vernier callipers (Mitutoyo, Japan) from maximum area cross sectionally of the stone and average value was calculated and presented in cm.

Stone thickness (cm)

The stone thickness of three stone obtained from three fruits from three direction of each sample tree was measured by the digital vernier callipers (Mitutoyo, Japan) and average value was expressed in cm.

3.3.3 Kernel parameters

Kernel obtained from splitting of stone of selected fruits from each sample tree in the month of June-July in both the years were analyzed for the kernel parameters *viz.*, kernel length (cm) kernel width (cm) and kernel thickness (cm) in the Ph. D Laboratory, Department of Applied Plant Science (Horticulture), School for Biosciences and Biotechnology, Babasaheb Bhimrao Ambedkar University, Vidya Vihar, Raebareli Road, Lucknow using standard methods described in detail below.

Kernel length (cm)

Kernel length of kernel obtained from splitting of three stone of selected fruits each sample tree was measured with the help of digital vernier callipers (Mitutoyo, Japan) from peduncle to apex and value was recorded and expressed in cm.

Kernel width (cm)

Kernel width of kernel obtained from splitting of three stone of selected fruits from each sample tree was measured with the help of digital vernier callipers (Mitutoyo, Japan) at maximum expansion of kernel and value was recorded and expressed in cm.

Kernel thickness (cm)

Kernel thickness of kernel obtained from splitting of three stone of selected fruits from each sample tree was measured with the help of digital vernier callipers (Mitutoyo, Japan) and value was recorded and expressed in cm.

3.3.4 Bio-chemical parameters of the fruits

Fruits in the month of June-July in both the years were analyzed for the bio-chemical parameters *viz.*, total soluble solids (^{0}Brix), pH of the pulp, Titrable acidity (%), TSS:acid ratio, total sugars (%) reducing sugar (%) and non-reducing sugar (%) at harvest maturity in Ph. D Laboratory, Department of Applied Plant Science (Horticulture), School for Biosciences and Biotechnology, Babasaheb Bhimrao Ambedkar University, Vidya Vihar, Raebareli Road, Lucknow, as per standard procedures.

Total soluble solids (^{0} Brix)

Total soluble solids of the ripe fruit pulp were determined with the help of digital refractometer after calibration with distilled water. The value was recorded and expressed in ^{o}Brix.

pH of the pulp

pH of the juice extracted from pulp was measured with the digital pH meter.

Titratable acidity (%)

The titratable acidity was determined by the method as suggested by Ranganna (2008)**.** 20g of fruit pulp was taken and volume was made up to 100 ml in a volumetric flask by adding distilled water. The content was filtered through Whatman No.1 filter paper. 10 ml of filtered juice was titrated against N/10 NaOH solution, using phenlphthalein as a indicator. Change of the solution colour to light pink indicated the end point. Volume of NaOH used was recorded and the titratable acidity was computed by the following formula.

$$\text{Titratable acidity (\%)} = \frac{\text{Titer value x normality of NaOH x volume made up}}{\text{Alliquot taken x weight of sample x 1000}} \text{ x 100}$$

TSS:acid ratio

TSS:acid ratio was calculated by dividing TSS recorded with the acidity calculated.

Sugars: total sugars, reducing and non-reducing

Sugars were estimated as suggested by Ranganna (1986). The method is briefly explained as follow.

Sample preparation

Twenty five g juice sample was taken from fruit pulp and mixed with 100 ml distilled water and neutralized with 1 N NaOH. Two millilitre of lead acetate solution was added and allowed to stand for 10 minutes. Then 1 to 2 ml of potassium oxalate (%) solution was added to neutralize the lead and volume was made up to 250 ml.

Standardization of the Fehling's solution

Fifty ml each of Fehling's solution A and B were mixed. 10 ml of mixed solution was pipetted into a 250 ml conical flask containing 50 ml of distilled water. Standard invert sugar solution was taken in 50 ml burette and titration was done. Invert sugar solution (18 to 19 ml) was added so that not more than one ml of invert sugar solution was used to complete titration. The flask was heated over a hot plate. Three drops of methylene blue indicator were added and the titration was completed in one minute. The decolorization indicates the end point.

$$\text{Factor of Fehling's solution} = \frac{\text{Titre value}}{1000} \times 2.5$$

Reducing sugar (%)

Ten ml of mixed Fehling's solution was taken into 250 ml conical flask. Burette was filled with the prepared juice sample solution and titration was done. The contents of flask were mixed and boiled for 2 minutes. Then three drops of methylene blue solution were added. Titration was completed within one minute by adding 2 to 3 drops of prepared juice sample solution at 5 to 10 seconds interval until indicator was completely decolorized and ultimately turned into brick red colour. The reducing sugar was computed by the following formula.

$$\text{Reducing sugar (\%)} = \frac{\text{Factor x Dilution x 100}}{\text{Titre value x Weight of sample or volume of sample}}$$

Non-Reducing sugar (%)

Non-reducing sugar was calculated by the following formula

Non-reducing sugar (%) = [Total sugar (%) - Reducing sugar (%)]

Total sugars (%)

Fifty ml of clear juice extract was taken in a 250 ml conical flask. 5 g acid and 50 ml distilled water were added to it. It was boiled gently for 10 minutes to complete the inversion of sucrose into monosachharides. The solution was neutralized with 1.0 N NaOH and volume was made up to 250 ml by adding distilled water. 50 ml of aliquot of clarified and de-leaded solution was taken in a 250 ml flask. 10 ml of Hel was added and allowed to stand at room temperature for 24 hours. It was neutralized with concentrated NaOH solution and volume was made up. An aliquot was taken and total sugar was determined.

$$\text{Total sugars (\%)} = \frac{\text{Factor x dilution x 100}}{\text{Titre value x weight of sample or volume of sample}}$$

3.4 <u>Experiment IV</u>

Microscopy studies for exploring intravarietal variability in mango cv. Dashehari

Stomata in mango are primarily found on the abaxial surface of the leaf (Zaharah and Razi, 2009) and are reported to be under genetic control (Casson and Hetherington, 2010). Hence, the stomatal density and morphology in leaf of mango were studied for further elucidation of the results obtained from morphological analysis of the sample trees. The samples for stomatal studies were prepared at the Ph. D Laboratory, Department of Applied Plant Science (Horticulture), School for

Biosciences and Biotechnology, as per procedure described below (Fig. 3.1). Stomatal density and morphology was studied through the Scanning Electron Microscope (SEM) of *AKTA JEOL*, model JSM 6490 at University Scientific Instrumentation Center, Babasaheb Bhimrao Ambedkar University, Lucknow.

3.4.1 Sample collection

5-7 month old leaves of almost uniform age and physiological maturity were collected as per leaf sampling technique for mango (Poffley, 2005) for studying the variations in the sample trees of mango through stomatal studies. The leaf was chopped (2-4 mm) and fixed in 2.5% Glutaraldehyde Karnovsky's fixative for 2-6 hours at 4°C.

3.4.2 Washing

Sample was washed thrice in 0.1 M phosphate buffer solution at 4°C for 15 minutes for removing unreacted fixative.

3.4.3 Dehydration of sample

Samples were dehydrated using increasing concentrations of acetone to remove water from the leaf samples as described below:

30% Acetone	30 minute
50% Acetone	30 minute
70% Acetone	30 minute
90% Acetone	30 minute
95% Acetone	30 minute
100% (Dry Acetone)	30 minute

(Dry Acetone = 30% $CuSO_4 . 5H_2O$ + 70% absolute acetone)

All steps of dehydration were performed at 4°C. After dehydration, the samples were kept in dry and dust free environment in a desiccator for protection of samples from excessive fluctuation in atmospheric humidity.

3.4.4 Sample mounting

Samples prepared as above, were mounted to on aluminium stubs with carbon tape.

3.4.5 Coating

Samples were coated by using sputter coater to make sample conductive, and were subsequently observed under Scanning Electron Microscope (*AKTA JEOL*, model JSM 6490) at 500x and 5000x.

Fig. 3.1 Procedure for Scanning Electron Microscopy (SEM) of mango (*Mangifera indica* L.) leaf cv. Dashehari

Chopped leaf (2mm)

↓

Washed with distilled water (dH_2O)

↓

Fixed in Glutaraldehyde Karnovsky's fixative (2.5%)

↓ 4 hours

Washed thrice (0.1 M Phosphate buffer solution)

↓ 4^0C for 15 minutes

Serial dehydration with acetone 30%, 50%, 70%, 90%, 95% and 100%

↓ 30 minutes

Sample mounted on aluminum stubs with carbon tape and coated by using Sputter coater

↓

Observations recorded under the scanning electron microscope at 500x and 5000x magnificence

(Modified from Fischer *et al.,* 2013)

Data generated was subjected to statistical analysis and the sample population was grouped on the basis of cluster analysis depicted through a dendogram.

Observations recorded

Stomatal length (µm)

Stomatal length was measured with the help of Scanning Electron Microscope (SEM) at x 5000 magnificence and data was expressed in micrometer (µm).

Stomatal width (µm)

Stomatal width was measured with the help of Scanning Electron Microscope (SEM) at 5000x magnificence and data was expressed in micrometer (µm).

Stomatal pore length (µm)

Stomatal pore length was measured with the help of Scanning Electron Microscope (SEM) at 5000x magnificence and data was expressed in micrometer meter (µm).

Stomatal pore width (µm)

Stomatal pore width was measured with the help of Scanning Electron Microscope (SEM) at 5000x magnificence and data was expressed in micrometer (µm).

Trichome length (µm)

Trichome length was measured with the help of Scanning Electron Microscope (SEM) at x 500 magnificence and data was expressed in micrometer (µm).

Trichome width (µm)

Trichome width was measured with the help of Scanning Electron Microscope (SEM) at 500x magnificence and data was expressed in micrometer (µm).

Stomata density (μm^{-2})

Stomatal density was measured with the help of Scanning Electron Microscope (SEM) at 500x magnificence and data was expressed in micrometer (μm^{-1}).

3.5 <u>Experiment No. V</u>

Molecular analysis of intravarietal variability in mango cv. Dashehari

Stomatal variability established on the basis of morphological, fruit and stomatal studies was further substantiated through molecular analysis of intravarietal variability in mango cv. Dashehari by protein profiling at Ph. D Laboratory, Department of Applied Plant Science (Horticulture), School for Biosciences and Biotechnology, Babasaheb Bhimrao Ambedkar University, Lucknow, Uttar Pradesh, India

3.5.1 Equipments and chemicals used

- Power supply with adjustable constant voltage/current (100 V, 500 mA)
- SDS-PAGE unit (CAVOY)
- Electronic balance (Instrument limited: CA-224)
- Gel rocker (L1-GR-E-100)
- Multispin Motorless Magnatic Stirrer (Tarsons: CAT. 4060)
- pH meter (Labman Scientific Instruments PVT. Limited: LMPH-10)
- A bench top refrigerated centrifuge (EITEK: 880-2049)
- Transilluminator for gel viewing (GENEI, Bangalore Genei Pvt. Ltd.)
- Refrigerator (Godrej Appliance Limited)
- Water bath (Gupta Scientific Industries)
- Micropipette (10 µl, 20 µl, 30 µl,50 µl,100 µl, 200 µl, 500 µl and 1000µl)

3.5.2 Collection and processing of leaf material

Tender and healthy tagged leaves from each morphotype from the 15 commercial mango orchards of cv. Dashehari, were collected and wrapped in aluminium foil and placed in an icebox. Leaves were washed under tap water followed by distilled water, at Ph. D Laboratory, Department of Applied Plant Science (Horticulture), School for Biosciences and Biotechnology, Babasaheb Bhimrao Ambedkar University, Lucknow, and cleaned with tissue paper. The midribs and thick veins of the leaves were removed and 500 mg leaf lamina sample was weighed on an electronic balance (Instrument limited: CA-224) and again wrapped in aluminium foil and stored at -20˚C temperature overnight. The sample was macerated in a pestle and mortar on the following day in the protein extraction buffer presented as per details below.

Preparation of protein extraction buffer (pH 8.0)

All chemicals used for the protein extraction were of Analytical grade produced by Genetics Private Limited).

0.1 M Tris HCl	1.576 g
0.01 M $MgCl_2$	0.216 g
Sucrose 18% (w/v)	18.0 g
Sodium dodicyl sulfate (SDS) 4% (w/v)	4.0 g
40 M β mercaptoethanol	280 µl
Double distilled water	100 ml

Protein of the leaf sample was extracted as per procedure described below (Fig. 3.1)

Fig. 3.2 Procedure for Protein Extraction

Take 500 mg pre-chilled leaf

↓

Added protein extraction buffer (2ml)

↓

Sample was taken in centrifuge tube

↓

Centrifuge

↓ 8000 rpm for 20 minute at 4˚C temperature

Supernatant was taken

↓

Centrifuge

↓ 8000 rpm for 20 minute at 4˚C temperature

Supernatant was taken for protein profiling

↓

Store at -20˚C temperature

↓

Sample ready for protein profiling through SDS-PAGE

3.5.3 Chemicals and preparation of stock solutions/buffers for Sodium Dodicyl Sulphate Poly Acrylamide Gel Electrophoresis (SDS-PAGE)

All chemicals used for SDS-PAGE were Analytical grade and were produced from Genetics, India. Solutions were prepared as per details given below:

Acrylamide/bis-acrylamide (30%)

Acrylamide (29.2g) and bis-acrylamide (0.8g) was mixed and dissolved in double distilled water (ddH_2O) to make volume up to 100ml.

TEMED solution (1ml)

N,N,N,'N'Tetramethylenthyenedaiamine (84µl) was mixed and dissolved in ddH_2O to make volume up to 1000ml.

Ammonium per sulfate solution (1ml)

Ammonium per sulfate (0.125g) was mixed and dissolved in ddH_2O to make volume up to 1.00ml.

Separating buffer (2X) pH (8.8)

Tris base (9.0g) and Sodium Dodecyl Sulphate (SDS) 0.2 g was mixed and dissolved in ddH_2O and pH was maintained at 8.8. Volume was made up to 100ml.

Staking buffer (2X) pH (6.8)

Tris base (3.3 g) and SDS (0.2 g) was mixed and dissolved in ddH_2O and pH was maintained at 6.8. Volume was made up to 50ml.

Sample buffer (2x) pH (6.8)

Tris base (1.57g), glycine (20.0ml), SDS (4.0g), bromophenol blue (0.002g) and β mercaptoethanol (10.0ml) was mixed and dissolved in ddH_2O and pH was maintained at 6.8. Volume was made up to 10ml.

Commassiae blue staining solution (100 ml)

Methanol (40ml), acetic acid (10ml), commassiae (0.125 g) was mixed and dissolved in ddH_2O and volume was made up to 100ml.

De-stainig solution (100 ml)

Methanol (40 ml) and acetic acid (10 ml) was mixed and dissolved in ddH_2O and volume was made up to 100ml

10x running buffer (pH 8.6)

Glysine (144.0g), Tris base (60.4g) and SDS (20.0g) was was mixed and dissolved in ddH_2O and pH was maintained 8.6 and volume was made up to 1000ml.

3.5.3 Preparation of gel for SDS-PAGE

Various solutions required for the preparation of gel were prepared as per details below:

Separating gel (12%): 10 ml

30% Acrylamide	3.96 ml
Separating gel buffer	6 ml
Double distilled water	40 µl
Ammonium per suphate (APS)	100 µl
N,N,N,'N'Tetramethylenthyenedaiamin (TEMED)	50 µl

Stacking gel (3.6%): 10 ml

30%Acrylamide	1.2 ml
Stacking buffer	5.0 ml
Double distilled water make up to	3.8 ml
Ammonium per suphate (APS)	100 µl
N,N,N,'N'Tetramethylenthyenedaiamine (TEMED)	50 µl

Performing of SDS-PAGE was done as described by Laemmli (1970) (Fig. 3.3) has been presented in following procedure.

Fig. 3.3 Procedure for SDS-PAGE

Poured separating gel solution (12%) in gel casting plate

↓

Added Iso-Propyl Alcohol (300µl) above separating gel

↓ For maintaining equal surface tension

Allowed it to polymerize

↓ 25 to 35 minute

Decant Iso-Propyl Alcohol after polymerization of gel

↓

Washed with double distilled water

↓

Soaked and dried with tissue paper

↓

Poured staking gel solution (3.6%) in gel casting plate above separating gel

↓

Insert the comb

↓

Allowed the gel to polymerize

↓ 25 to 35 minute

Prepared sample (with 2x sample buffer in 1:1 ratio)

↓

Sample allowed boiling in water bath

↓ 100˚C temperature for 10 minute

After polymerization of stacking gel comb was removed very carefully

↓

Loaded sample (30 µl) in a well

↓

Contd...

↓

Gel casting plate put in SDS-PAGE unit

↓

Poured running buffer (1x and pH 8.6)

↓

Run the gel

↓ 60 volts for 6.00 hrs

After the completion of SDS-PAGE

↓

Separate the gel from gel casting plate very carefully

↓

Gel put in staining solution

↓

After the staining of gel kept in de-staining solution till the protein bands visible

↓

Gel put on the illuminator to capture the image of gel

The molecular weight was estimated by comparing with standard four colour Prestained Protein Ladder (Puregene, Genetix Biotech Asia Pvt. Ltd.).

3.6 tatistical Analysis

The experimental data was compiled by taking mean values for the various parameters under study recorded from randomly selected trees. These were recorded in respect to various characters *viz.*, vegetative, floral, fruit physico-chemical and stomatal traits. The following statistical parameters were calculated using ICAR-SPAR (Statistical Package for Agricultural Research).

Range

It is the difference of the least and the highest value.

Mean

Arithmetic mean was calculated for each character by using the following formula

$$\overline{X} = \frac{\sum_i^n X_i}{N}$$

Where,

$\overline{X}$	=	mean
X_i	=	value of i^{th} plant for a character
n	=	number of plants

Variance

It is estimated as mean squared deviation as given below

$$V_X = \frac{\sum X^2 - \frac{(\sum X)^2}{n}}{n-1}$$

Standard deviation

It is square root of variance

$$SD = \sqrt{V_x}$$

Coefficient of variation (CV)

It is percent ratio of SD of a sample to its mean

$$CV = \frac{SD}{\overline{X}} \times 100$$ SD = standard deviation

Standard error

It is the measure of mean difference between sample mean and population mean. It is measure of uncontrolled variation present in sample.

$$\mathrm{SE(m)} \pm = \frac{\mathrm{SD}}{\sqrt{\mathrm{N}}} = \sqrt{\mathrm{V_E}\left(\frac{1}{r_1} + \frac{1}{r_2}\right)}$$

V_E = Error variance

r_1 and r_2 = number of observation on which two means are based

If $r_1 = r_2 = r$

$$\mathrm{SE\,(d)} \pm = \sqrt{\frac{2\,\mathrm{V_E}}{\mathrm{r}}}$$

Critical difference

It is the least significant difference equal to or greater than which all the differences are significant.

$$\mathrm{CD} = \mathrm{SE_{(d)}} \times \text{t value (at error d.f.)} = \left[\sqrt{\frac{2\mathrm{V_E}}{\mathrm{r}}}\right] \times \mathrm{t}$$

Analysis of variance

The mean value of the characters from each morphotype in each replication was used for statistical analysis (Sahu and Das, 2014). Data recorded in both the years and pooled data were analysed separately by using Completely Randomized Design (CRD).

Table 3.1 Analysis of variance (ANOVA)

Source of variation	**Degree of freedom**	**Sum of square**	**Mean sum of square**	**F-ratio**	**Tabulated F (0.05)**	**Tabulated F (0.01)**
Treatment	t-1	TrSS	$\mathrm{TrMS} = \frac{\mathrm{TrSS}}{\mathrm{t-1}}$	$\frac{\mathrm{TrMS}}{\mathrm{ErMS}}$		
Error	n-t	ErSS	$\mathrm{ErMS} = \frac{\mathrm{ErSS}}{\mathrm{n-t}}$			
Total	n-1	TSS				

Biometric Techniques in Plant Breeding

Biometry or biometrics is the science that deals with the application of statistical procedure to the study of biological problems. Similarly, biometrical genetics is that branch of genetics, which attempt to unravel the inheritance of quantitative traits using statistical concept and procedure it is also known as quantitative genetics for obvious reason. The various statistical procedures employed in biometrical genetics are called biometrical techniques which outline the type of genetic information obtained from each biometrical technique, and the manner in which that information is helpful in plant breeding programmes Biometrical techniques are useful to the plant breeders in the assessment of genetic variability present in a population and include the followings *viz.*, range, variance standard deviation, coefficient of variation, PCV, GCV, heritability, genetic advance and genetic advance as percent of mean (Singh, 2000).

In the present study heritability (h^2%) was estimated according to Falconer (1989). Phenotypic coefficient of variation (%) and genotypic coefficient of variation (%) to compare the variations among the traits were computed as per the method suggested by Singh and Chaudhary (1985). Genetic advance (GA %) and genetic advance as percent of mean (GAM %) were calculated as per procedure recommended by Singh and Chaudhary (1985) and Allard (1960).

Cluster analysis was performed (SPSS software) and a dendrogram was prepared on the basis of tree, leaf, stomatal and protein profiling parameters using SPSS software for genetic relationships among the morphotypes.

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EXPERIMENTAL FINDINGS

The present investigation entitled **"Morphological and Molecular Analysis of Intravarietal Variability in Mango (*Mangifera indica* L.) cv. Dashehari in Lucknow region"** was conducted during 2016-18 in Malihabad and Mal block of district Lucknow and Ph. D. Laboratory, Department of Applied Plant Science (Horticulture), School for Biosciences and Biotechnology, Babasaheb Bhimrao Ambedkar University, Vidya Vihar, Raebareli Road, Lucknow.

The study was conducted in two phases. In the first phase survey of the two blocks viz., Malihabad and Mal of district Lucknow was conducted to establish the presence of any intra-varietal variability. In the second phase, analytical and laboratory works were done in the Ph. D. Laboratory, Department of Applied Plant Science (Horticulture), School for Biosciences and Biotechnology and University Scientific Instrumentation Centre (USIC), Babasaheb Bhimrao Ambedkar University, Lucknow, Uttar Pradesh, India, based on five experiments according to objectives. Observations were recorded under experiments for different vegetative parameters, floral parameters, fruit, stone and kernel morphology, fruit biochemical parameters, Scanning Electron Microscopy (SEM), and protein profiling of different Dashehari morphotypes. The mean data were subjected to various statistical analyses. The results have been presented clearly through tables and have been further elucidated through graphical presentations and plates as required.

<u>EXPERIMENT I</u>

4.1 To survey the possibility of genetic diversity and variability in Dashehari mango in two Blocks i.e. Malihabad and Mal of district Lucknow

Survey was conducted in two blocks *viz.* Malihabad and Mal, of district Lucknow through a questionnaire (Appendix III) in February-March, 2016 to explore the possibility of existence of intra-varietal variability in Dashehari mango orchards. Intra-varietal variability was observed during discussion with 100 mango growers on the basis of questionnaire which was filled by mango growers and collected data were analyzed with focus on

i. Age when trees came into bearing
ii. Flowering behaviour
iii. Fruiting behaviour and fruit quality
iv. Fruit weight (g)
v. Yield (quintal per tree)

As per survey the farmers reported variation in age when trees came into bearing, flowering behaviour, fruiting behaviour and fruit quality, fruit weight and fruit yield. Data was recorded for age when trees came into bearing. 37% growers mango growers recorded that trees come into bearing after transplanting in 5 years while, 5, 10, 23 and 25% mango growers reported that trees came into bearing in 4.5 years, 3.5 years, 4 years and 3 years, respectively after transplanting.

65% mango growers reported that 70 percent trees came into flowering at the same time. However, 35% mango growers reported that some trees in their orchards flowered at different time.

Variation was observed in fruit weight since 70% mango growers reported that fruit weight ranged from 200g to 250g while 30% mango growers reported fruit weight ranged from 300-350g. Data was recorded for yield per tree(quintal) and 82% mango growers' reported yield quintal per tree ranged from 1.5 to 2.5q per tree. However, 6% mango growers reported 2.5 q yield per tree in their orchards. Thus, the results of the survey are clearly indicative of some variation which, may be existing in the orchards under study and could elicit detailed study

15 mango orchards belonging to local farmers; six (Balram, Deshraj, Indra Pal, Panna Lal, Ayaz Ahmad, Nawab Nawab Hasan) from Malihabad and eight (Atul Kumar, Virendra Kumar, Vipin Singh, Chetram, Ram Kumar, Rajaram, Saroj Kumar, Ajay Singh and Sunil Kumar) from Mal block of district Lucknow were selected for study (Appendix IV). Thus, leaves, panicle and fruits samples were collected from the selected orchards and morphological and fruit physico-chemical analysis was done in the Ph. D. laboratory of the Department Applied Plant Science (Horticulture) and recorded data were analyzed for existence of intravarietal variability in the sample population.

EXPERIMENT II

4.2 To evaluate the intravarietal variability in mango cv. Dashehari on the basis of vegetative characters

Three trees, 25-30 years in age, from each of the 15 selected orchards (total 45 trees), were recorded for analysis of intra-varietal variability study through tree, leaf characters.

4.2.1 Tree parameters

Trunk girth (cm)

Trunk girth of the mango trees showed wide variation under study and varied between 102.50 to 151.33 cm and its grand mean was recorded 134.84 (Table 4.6). The maximum trunk girth (151.33 cm) was observed for morphotypes DM_{25} (151.33 cm) followed by DM_{13} (150.00 cm) and DM_{26} (149.00 cm), both of which were at par with each other. The minimum trunk girth was found in DM_9 (102.50 cm) which was significantly lower from all other morphotypes under the study (Table 4.1 and Figure 4.1A).

Number of secondary branches per tree

Observation on number of secondary branches revealed significant difference among the morphotypes and trunk girth was ranged from 12.00 to 29.00 with a grand mean of 18.79 (Table 4.6). The data on number of secondary branches per tree are presented in Table 4.1 and Figure 4.1B. The maximum number of secondary branches per tree (29.00) was counted in morphotype DM_{14} and DM_{31} followed by morphotype DM_{19} (26.00) while, minimum number of secondary branches per tree (15.00) was found in morphotype DM_9.

4.2.2 Leaf parameters

Leaf length (cm)

Leaf length of the mango trees under study showed wide variation (17.45 to 22.78 cm) having grand mean of 20.79 cm (Table 4.6). Morphotype DM_{38} showed the significantly maximum (22.78 cm) followed by morphotype DM_{28}

Table 4.1 Average performance of tree parameters in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow

Morphotypes	Trunk girth (cm)			Number of secondary branches per tree		
	2016	2017	Pooled	2016	2017	Pooled
DM_1	132.00	132.00	132.00	12.00	12.00	12.00
DM_2	126.00	126.33	126.17	20.67	20.67	20.67
DM_3	131.67	132.00	131.83	20.00	20.00	20.00
DM_4	136.33	136.33	136.33	17.67	17.67	17.67
DM_5	122.00	122.33	122.17	14.00	14.00	14.00
DM_6	132.00	132.33	132.17	16.00	16.00	16.00
DM_7	112.00	113.00	112.50	18.00	18.00	18.00
DM_8	120.00	120.33	120.17	12.00	12.00	15.00
DM_9	102.33	102.67	102.50	15.00	15.00	12.00
DM_{10}	145.00	145.67	145.33	13.33	13.33	13.33
DM_{11}	147.00	148.33	147.67	21.00	21.00	21.00
DM_{12}	138.00	140.33	139.17	20.00	20.00	20.00
DM_{13}	151.00	149.00	150.00	20.33	20.33	20.33
DM_{14}	148.00	148.67	148.33	29.00	29.00	29.00
DM_{15}	131.67	132.67	132.17	20.00	20.00	20.00
DM_{16}	130.33	131.00	130.67	16.33	16.33	16.33
DM_{17}	125.00	126.00	125.50	15.00	15.00	15.00
DM_{18}	132.33	133.00	132.67	19.00	19.00	19.00
DM_{19}	141.67	142.00	142.83	26.00	26.00	26.00
DM_{20}	116.00	117.00	116.50	15.33	15.33	15.33
DM_{21}	120.33	121.00	120.67	24.67	24.67	24.67
DM_{22}	138.00	139.00	138.50	22.00	22.00	22.00
DM_{23}	141.33	142.00	141.67	24.33	24.33	24.33
DM_{24}	138.00	138.33	138.17	12.00	12.00	12.00
DM_{25}	151.00	151.67	151.33	20.67	20.67	20.67
DM_{26}	148.00	150.00	149.00	20.00	20.00	20.00
DM_{27}	131.67	132.33	132.00	17.67	17.67	17.67
DM_{28}	130.33	131.67	131.00	14.00	14.00	14.00
DM_{29}	125.00	126.00	125.50	16.00	16.00	16.00
DM_{30}	132.33	133.00	132.67	20.33	20.33	20.33
DM_{31}	130.00	131.67	130.83	29.00	29.00	29.00
DM_{32}	132.00	132.33	132.17	20.33	20.33	20.33
DM_{33}	140.33	141.00	140.67	21.33	21.33	21.33
DM_{34}	142.33	142.33	142.33	22.67	22.67	22.67
DM_{35}	139.67	140.67	140.17	20.67	20.67	20.67
DM_{36}	145.00	146.00	145.50	18.00	18.00	18.00

DM_{37}	132.00	132.67	132.33	18.00	18.00	18.00
DM_{38}	144.33	145.00	144.67	14.00	14.00	14.00
DM_{39}	139.00	139.67	139.33	17.33	17.33	17.33
DM_{40}	147.00	148.00	147.50	14.67	14.67	14.67
DM_{41}	138.00	139.67	138.83	17.33	17.33	17.33
DM_{42}	133.00	133.67	133.33	17.00	17.00	17.00
DM_{43}	132.00	132.00	132.00	22.00	22.00	22.00
DM_{44}	145.33	146.00	145.67	20.00	20.00	20.00
DM_{45}	136.33	137.00	136.00	21.00	21.00	21.00
SE(m)±	1.06	1.07	0.89	0.86	0.92	0.71
CD (P=0.05)	**2.11**	**2.13**	**1.76**	**1.71**	**1.83**	**1.41**

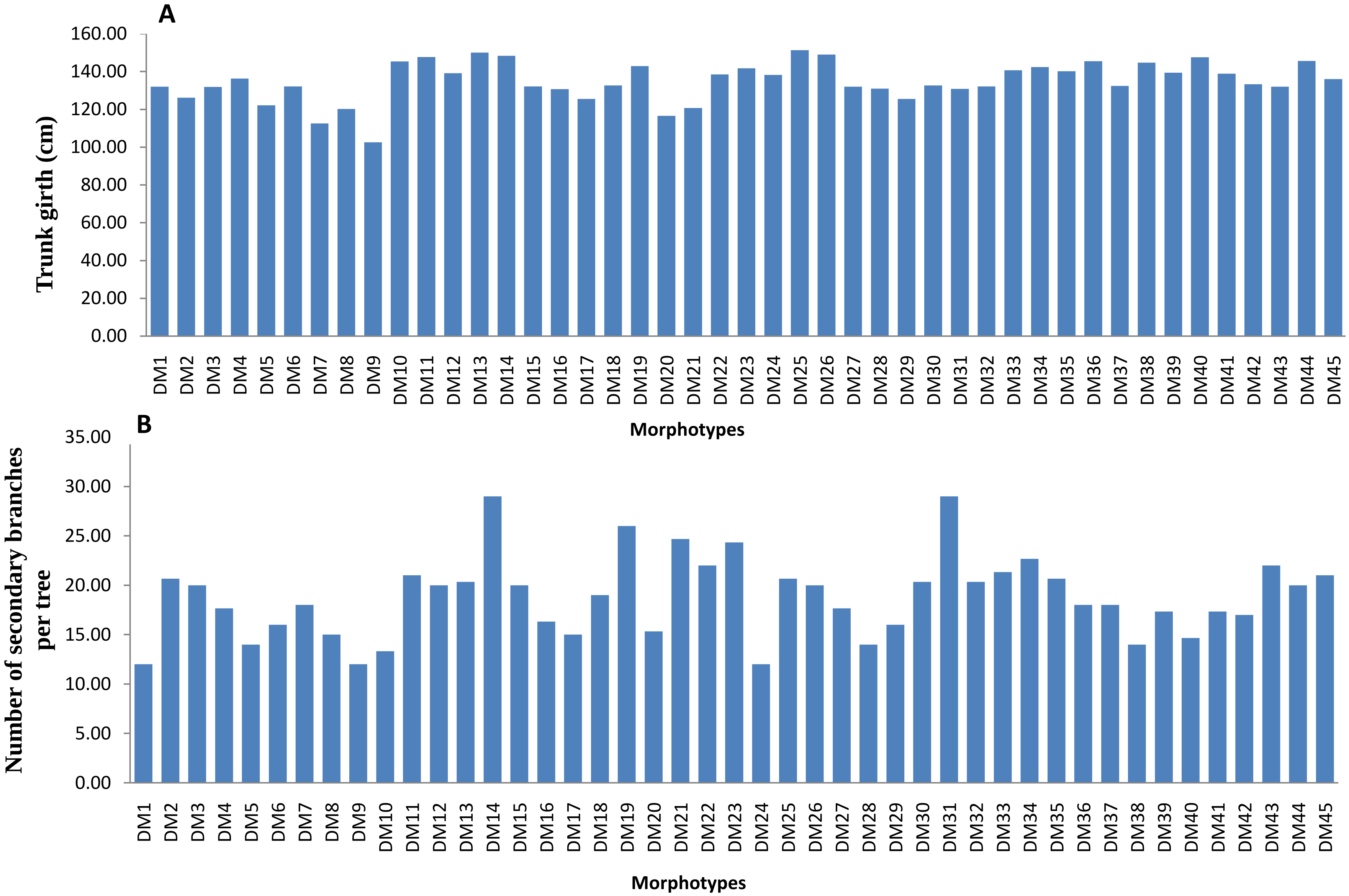


Fig. 4.1 Average performance of (A) trunk girth (cm) and (B) number of secondary branches per tree in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

(22.55 cm) and DM_5 (22.32 cm). The minimum leaf length (17.45 cm) was recorded for morphotypes DM_{16} (Table 4.2 and Figure 4.2A).

Leaf width (cm)

Leaf width was ranged from 3.95 to 5.62 cm with grand mean 4.91 cm (Table 4.6) and data on leaf width are presented in Table 4.2 and Figure 4.2B. The maximum leaf width (5.62 cm) was recorded in morphotype DM_5 followed by morphotypes DM_4 and DM_{18} (5.47 cm). However, the minimum leaf width (3.95 cm) was recorded for morphotype DM_{16}.

Leaf thickness (mm)

In the present investigation showed that leaf thickness of 45 morphotypes ranged from 0.21 to 0.38 mm with a grand mean of 0.26 mm (Table 4.6) and The maximum leaf thickness (0.38 mm) was recorded in morphotypes DM_1 and DM_9 followed by morphotypes DM_{22} (0.30 mm) and minimum leaf thickness (0.21 mm) was recorded for morphotype DM_{44} (Table 4.2 and Figure 4.3A). Thus, leaf thickness was statistically variable between the morphotypes.

Petioles length (cm)

Table 4.6 showed 3.19 cm mean length of petiole, recording maximum (4.33 cm) in morphotype DM_{38} followed by morphotype DM_{12} and DM_{19} (3.93 cm). However, the minimum petiole length (2.42 cm) was recorded in morphotype DM_{16} (Table 4.2 and Figure 4.3B).

4.2.3 Floral parameters

Panicle length (cm)

Morphotypes statistically differed to each other for panicle length. In the present investigation the panicle length of morphotypes was recorded ranged from 27.70 to 37.08 cm with a grand mean of 31.50 cm (Table 4.6). The morphotype DM_{12} produced maximum panicle length (37.08 cm) and

Table 4.2 Average performance of leaf parameters in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow

Morphotypes	Leaf length (cm)			Leaf width (cm)			Leaf thickness (mm)			Petiole length (cm)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
DM_1	20.63	22.60	21.62	4.67	5.77	5.22	0.43	0.33	0.38	4.23	3.20	3.72
DM_2	21.87	17.17	19.52	4.80	4.20	4.50	0.30	0.27	0.29	3.43	1.90	2.67
DM_3	22.47	19.90	21.18	5.37	4.70	5.03	0.29	0.30	0.29	3.13	2.87	3.00
DM_4	18.02	22.40	20.21	5.40	5.53	5.47	0.29	0.29	0.29	3.33	2.80	3.07
DM_5	20.10	24.53	22.32	5.27	5.97	5.62	0.28	0.27	0.27	3.50	3.53	3.52
DM_6	21.33	19.27	20.30	5.37	4.50	4.93	0.27	0.24	0.26	3.50	1.73	2.62
DM_7	20.83	19.43	20.13	4.23	5.23	4.73	0.28	0.21	0.25	3.50	2.17	2.78
DM_8	24.67	19.87	22.27	4.17	5.20	4.68	0.28	0.25	0.26	2.37	3.33	2.85
DM_9	22.40	17.50	19.95	4.47	5.17	4.82	0.49	0.27	0.38	4.07	2.60	3.33
DM_{10}	19.33	23.20	21.27	4.43	5.63	5.03	0.30	0.27	0.29	4.07	3.23	3.65
DM_{11}	19.20	19.80	19.50	4.30	5.20	4.75	0.31	0.25	0.28	2.77	3.03	2.92
DM_{12}	21.47	21.97	21.72	4.03	5.30	4.67	0.30	0.23	0.27	4.53	3.33	3.93
DM_{13}	22.47	19.10	20.78	4.53	4.63	4.58	0.28	0.22	0.25	3.87	2.27	3.07
DM_{14}	19.17	21.50	20.33	4.07	6.40	5.23	0.25	0.28	0.26	3.83	2.60	3.22
DM_{15}	21.53	21.23	21.38	3.77	4.13	4.87	0.29	0.24	0.27	3.83	2.93	3.38
DM_{16}	17.17	17.73	17.45	5.37	4.37	3.95	0.26	0.28	0.27	3.13	2.37	2.42
DM_{17}	20.67	18.47	19.57	4.47	4.57	4.52	0.28	0.23	0.25	3.00	1.83	2.75
DM_{18}	23.63	19.90	21.77	6.13	4.80	5.47	0.30	0.27	0.28	2.70	3.73	3.22
DM_{19}	18.20	22.83	20.52	4.10	6.00	5.05	0.24	0.24	0.24	4.77	3.60	4.18
DM_{20}	18.20	22.73	20.47	3.67	5.63	4.65	0.24	0.24	0.24	3.90	3.97	3.93
DM_{21}	19.70	23.03	21.37	4.93	4.80	4.87	0.33	0.20	0.27	4.50	2.57	3.53

DM_{22}	22.17	20.00	21.08	4.33	5.77	5.05	0.39	0.21	0.30	3.73	2.20	2.97
DM_{23}	21.00	20.67	20.83	3.43	6.03	4.73	0.39	0.16	0.28	3.60	3.97	3.78
DM_{24}	21.06	19.93	20.50	3.97	4.97	4.47	0.26	0.22	0.24	2.23	4.00	3.12
DM_{25}	20.33	17.30	18.82	3.90	5.63	4.77	0.33	0.22	0.27	3.30	3.07	3.18
DM_{26}	18.00	23.40	20.70	5.40	4.77	5.08	0.33	0.18	0.25	2.50	3.07	2.78
DM_{27}	20.67	20.27	20.47	4.13	5.52	4.83	0.39	0.19	0.29	3.60	3.77	3.68
DM_{28}	20.77	24.33	22.55	5.57	5.30	5.43	0.29	0.24	0.26	3.23	2.63	2.93
DM_{29}	20.50	19.53	20.02	5.20	5.57	5.38	0.27	0.26	0.26	2.43	4.00	3.22
DM_{30}	24.27	20.50	22.38	5.03	4.87	4.95	0.30	0.19	0.25	3.83	2.53	3.18
DM_{31}	20.97	20.72	20.84	4.50	5.30	4.90	0.30	0.23	0.27	3.77	2.63	3.20
DM_{32}	22.23	19.93	21.08	4.97	4.87	4.92	0.36	0.22	0.29	4.03	2.10	3.07
DM_{33}	20.00	22.33	21.17	4.60	5.17	4.88	0.27	0.20	0.24	3.63	2.40	3.02
DM_{34}	19.50	18.10	18.80	4.70	4.80	4.75	0.27	0.18	0.22	3.30	3.40	3.35
DM_{35}	17.03	24.00	20.52	3.70	5.90	4.80	0.33	0.18	0.26	3.20	2.17	2.68
DM_{36}	20.50	23.93	22.22	4.67	5.50	5.08	0.28	0.23	0.25	2.90	2.83	2.87
DM_{37}	21.63	22.17	21.90	4.60	5.57	5.08	0.26	0.24	0.25	2.70	2.63	2.67
DM_{38}	20.00	25.57	22.78	3.93	5.83	4.88	0.28	0.20	0.24	4.97	3.73	4.33
DM_{39}	22.30	17.30	19.80	4.40	5.20	4.80	0.26	0.24	0.25	3.30	2.67	2.97
DM_{40}	18.43	24.17	21.30	4.67	5.30	4.98	0.26	0.22	0.24	2.83	3.23	3.03
DM_{41}	21.33	19.17	20.25	4.23	4.87	4.55	0.29	0.21	0.25	4.00	2.27	3.13
DM_{42}	22.90	18.80	20.85	5.27	5.07	5.17	0.25	0.21	0.23	2.33	2.63	2.48
DM_{43}	21.93	22.33	22.13	3.83	5.10	4.47	0.27	0.18	0.23	3.90	3.23	3.73
DM_{44}	20.67	19.40	20.03	5.83	5.00	5.42	0.23	0.18	0.21	4.00	3.07	3.53
DM_{45}	20.67	21.33	21.00	4.67	5.37	5.02	0.29	0.21	0.25	3.97	3.07	3.52
SE(m)±	1.18	1.09	1.14	0.15	0.18	0.34	0.01	0.01	0.02	0.15	0.13	0.39
CD (P=0.05)	**2.35**	**2.17**	**2.25**	**0.30**	**0.36**	**0.67**	**0.01**	**0.01**	**0.04**	**0.30**	**0.26**	**0.78**

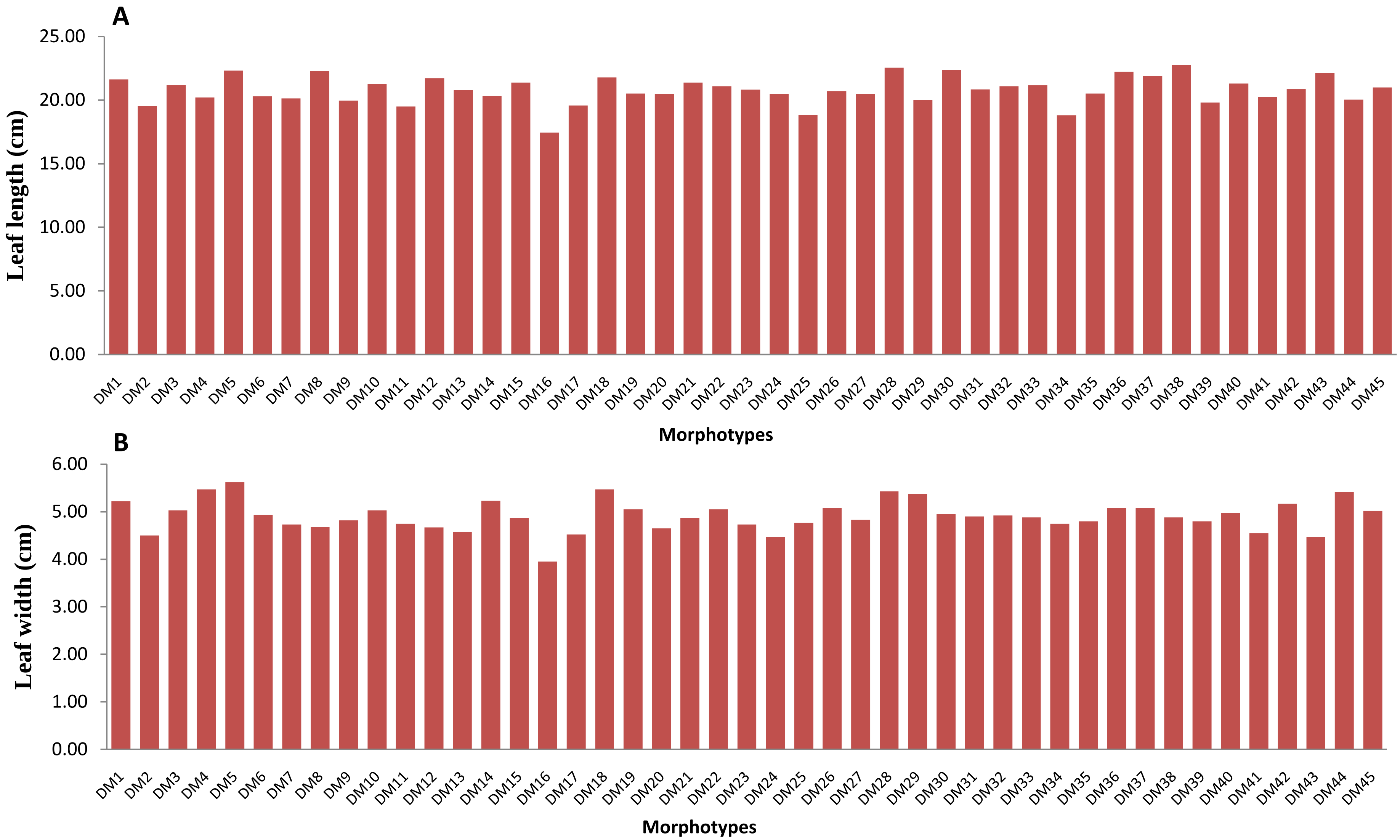


Fig. 4.2 Average performance of (A) leaf length (cm) and (B) leaf width in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

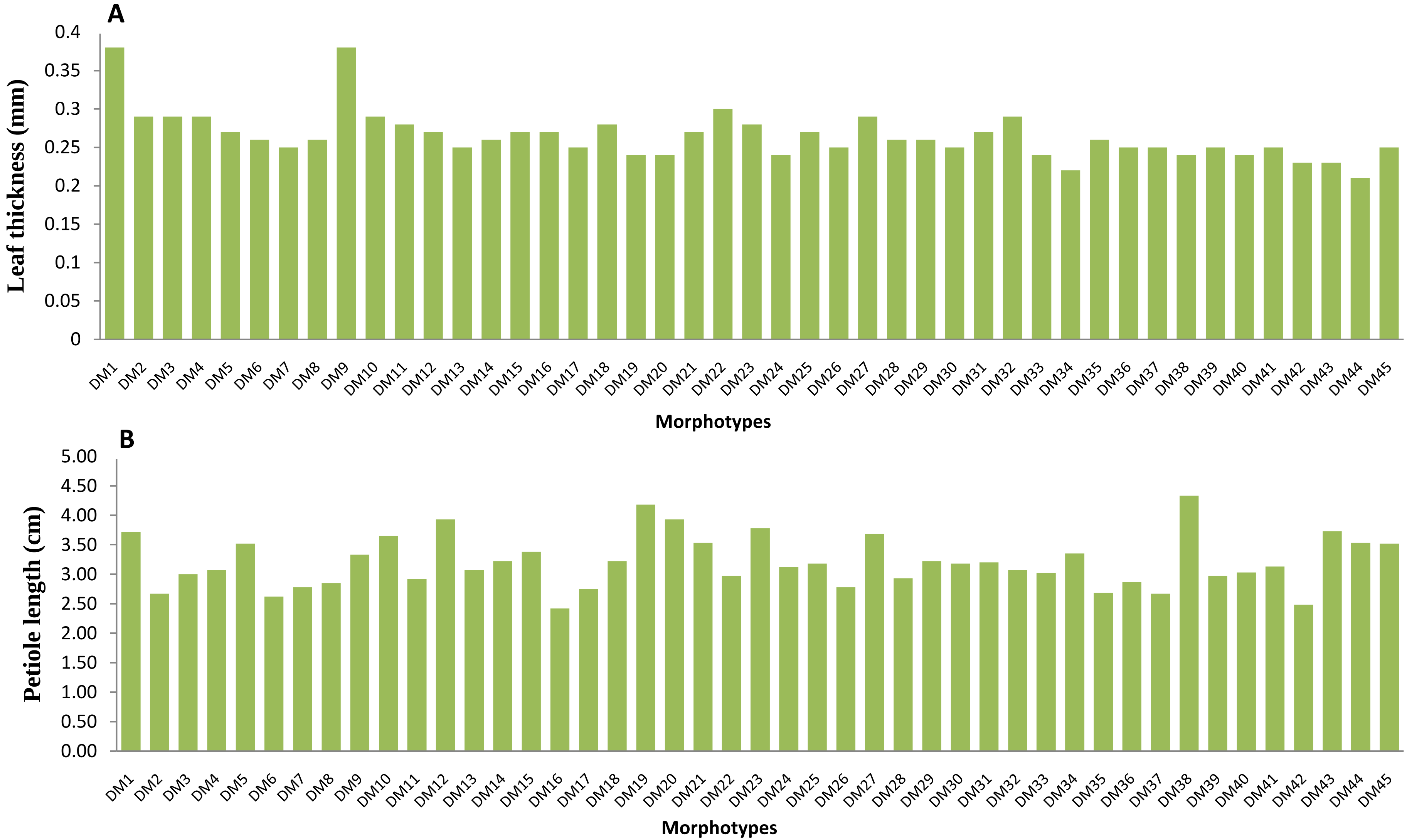


Fig. 4.3 Performance of (A) leaf thickness (mm) and (B) petiole length (cm) in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

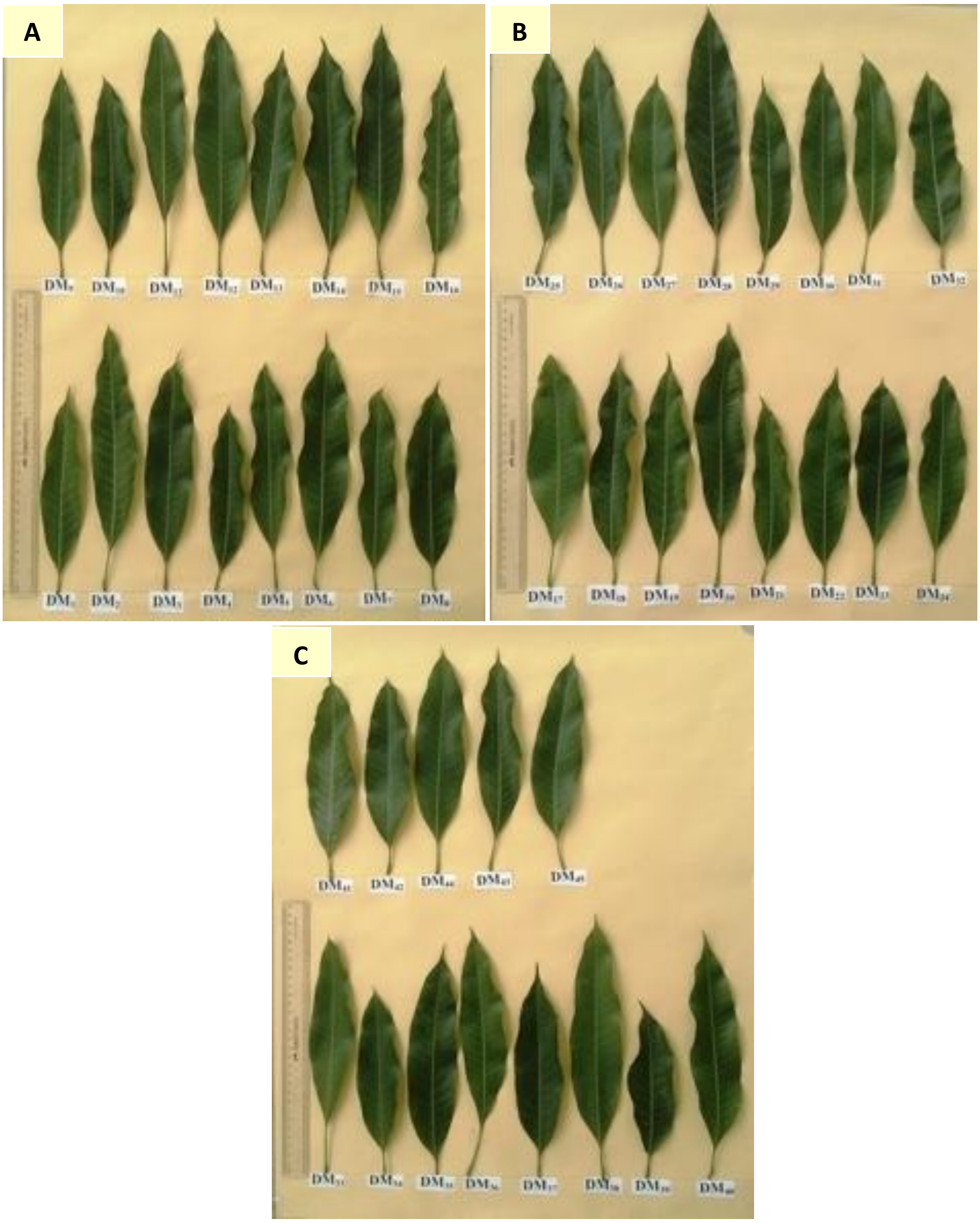


Plate 1: Variation in leaf of 45 morphotypes of mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district

minimum were recorded in DM_{25} (27.70 cm). The panicle length produced by morphotype DM_9 (36.33 cm) and DM_{27} (35.92 cm) were also significant higher after DM_{12} than other morphotypes (Table 4.3 and Figure 4.4A).

Panicle width (cm)

The panicle width showed a wide variation ranging from 15.80 to 20.15 cm with the grand mean 20.12 cm (Table 4.6). The data on panicle width are presented in Table 4.3 and Figure 4.4B The maximum panicle width (25.15 cm) was recorded for morphotypes DM_{12} followed by morphotype DM_{33} (24.87 cm), DM_{31} and DM_{37} (24.33 cm), respectively and minimum panicle width was recorded for morphotype DM_{44} (15.80 cm).

Number of florets per panicle

Number of florets per panicle showed significant variations between different morphotypes under the study with ranged from 39.17 to 66.17 with grand mean of 48.17 (Table 4.6). Morphotype DM_{12} had maximum (66.17) number of florets per panicle followed by morphotype DM_{27} (60.67) and DM_8 (59.00) which were significantly higher to others, whereas morphotype DM_{25} had minimum (39.17) number of florets per panicle as presented in Table 4.3 and Figure 4.5A.

Number of flowers per panicle

The number of flowers per panicle was ranging from 1932.83 to 2979.33 with grand mean 2495.36 (Table 4.6). Data was pertaining to number of flowers per panicle in Table 4.3 and Figure 4.5B and showed wide variation between different morphotype. The morphotype DM_{12} produced maximum (2979.33) number of flowers per panicle followed by morphotype DM_9 (2890.67). However, the minimum (1932.83) number of flowers per panicle was recorded for morphotype DM_{25}.

Table 4.3 Average performance of panicle morphology of mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow

Morphotypes	Panicle length (cm)			Panicle width (cm)			Number of floral lets per panicle			Number of flowers per panicle		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
DM_1	30.00	28.33	29.17	21.00	20.67	20.83	43.33	40.33	41.83	2123.00	2205.67	2164.33
DM_2	31.77	30.67	31.22	17.67	17.50	17.58	42.67	45.67	44.17	21.7500	2250.00	2212.50
DM_3	29.50	30.00	29.75	20.33	17.67	19.00	46.00	43.33	44.67	2237.23	2200.00	2218.67
DM_4	29.47	29.67	29.72	20.00	15.67	17.83	53.67	48.67	51.17	2512.67	2480.67	2496.67
DM_5	28.27	29.43	28.85	20.33	17.00	18.67	44.33	50.67	47.50	2263.33	2362.33	2312.83
DM_6	30.00	29.17	29.58	20.53	19.33	19.93	49.00	46.33	47.67	2324.00	2355.00	2339.50
DM_7	28.00	30.17	29.08	23.00	16.00	19.50	61.33	51.67	56.50	1980.67	2283.67	2132.17
DM_8	29.50	28.17	28.83	22.00	17.67	19.83	57.00	61.00	59.00	1955.33	2180.00	2067.67
DM_9	38.67	34.00	36.33	21.00	23.00	22.00	65.67	66.67	45.33	2895.67	2885.67	2890.67
DM_{10}	32.00	34.00	33.00	21.00	20.00	20.50	53.00	58.67	55.83	1709.33	2172.67	1941.00
DM_{11}	33.17	32.83	33.00	19.00	20.83	19.92	40.67	38.67	39.67	2019.33	1955.00	1987.17
DM_{12}	34.50	39.67	37.08	25.97	24.33	25.15	47.33	43.33	66.17	2116.00	2017.33	2979.33
DM_{13}	30.00	31.17	30.58	16.00	16.67	16.33	49.33	50.33	49.83	2324.33	2290.00	2307.17
DM_{14}	28.00	29.00	28.50	16.77	15.50	16.13	47.00	50.33	48.67	2407.00	2396.00	2401.50
DM_{15}	29.33	28.27	28.80	17.50	18.00	17.75	45.67	43.67	44.67	2478.33	2425.00	2451.67
DM_{16}	32.17	31.50	31.83	18.00	22.50	20.25	53.00	50.67	51.83	2718.33	2784.00	2251.17
DM_{17}	33.17	32.50	32.83	22.33	23.33	22.83	54.67	57.33	56.00	3055.33	2903.33	2066.67
DM_{18}	34.00	36.00	35.00	22.50	18.00	20.25	61.33	51.33	56.33	2628.67	2689.00	2658.83
DM_{19}	34.00	35.00	34.50	17.63	20.33	18.98	55.67	60.00	57.83	2575.67	2504.33	2540.00
DM_{20}	27.00	30.00	28.50	18.00	19.00	18.50	52.67	53.67	53.17	2378.67	2415.33	2397.00
DM_{21}	36.00	35.67	35.83	19.00	17.63	18.32	58.00	50.67	54.33	2460.33	2490.00	2475.17
DM_{22}	29.00	30.33	29.67	16.00	21.10	18.55	46.67	43.00	44.83	2537.33	2431.67	2484.50

DM_{23}	30.40	32.00	31.20	19.00	18.40	18.70	49.00	49.67	49.33	2680.67	2789.00	2734.83
DM_{24}	30.00	31.67	30.83	16.50	19.00	17.75	44.00	51.67	47.83	2880.00	2855.00	2867.50
DM_{25}	28.40	27.00	27.70	16.00	21.00	18.50	40.33	38.00	38.83	1842.67	2023.00	1932.83
DM_{26}	29.47	30.67	30.07	18.00	18.00	18.00	49.67	50.33	50.00	2627.67	2627.67	2627.67
DM_{27}	35.00	36.83	35.92	25.00	23.00	24.00	62.00	59.33	60.67	2670.33	2680.00	2675.17
DM_{28}	33.00	33.90	33.45	19.33	24.33	21.83	36.33	41.33	39.17	2321.33	2434.67	2378.00
DM_{29}	30.50	29.00	29.75	21.33	23.00	22.17	48.00	43.00	45.50	2474.00	2443.00	2458.50
DM_{30}	34.77	35.83	35.30	24.34	22.00	23.17	45.00	51.33	48.17	2423.33	2489.33	2456.33
DM_{31}	33.47	30.67	32.07	24.50	24.17	24.33	44.33	40.00	42.17	2842.00	2794.33	2818.17
DM_{32}	30.40	28.67	29.53	22.77	24.00	23.38	47.67	41.33	44.50	2633.33	2754.67	2694.00
DM_{33}	31.23	30.33	30.78	23.73	26.00	24.87	44.00	39.00	41.50	2776.67	2784.00	2780.33
DM_{34}	36.70	35.80	36.25	22.50	18.00	20.25	40.00	44.33	42.17	2760.33	2852.33	2806.33
DM_{35}	34.17	33.30	33.73	19.83	19.00	19.42	45.67	54.33	50.00	2810.67	2832.67	2821.67
DM_{36}	33.47	32.50	32.98	18.00	21.67	19.83	45.33	42.67	44.00	2557.67	2794.67	2676.17
DM_{37}	33.00	34.00	33.50	25.00	23.67	24.33	45.00	40.33	42.67	2780.67	2724.33	2752.50
DM_{38}	30.00	29.00	29.50	21.50	22.00	21.75	47.00	47.33	47.17	2938.33	2700.00	2819.17
DM_{39}	35.00	36.00	35.50	19.00	21.00	20.00	43.00	42.33	42.67	2715.67	2736.00	2725.83
DM_{40}	30.17	31.00	30.58	20.93	19.00	19.97	42.00	41.33	41.67	2665.67	2784.33	2725.00
DM_{41}	28.53	32.00	30.26	23.00	20.93	21.97	39.00	43.33	41.17	2719.33	2754.67	2737.00
DM_{42}	27.00	30.00	28.50	19.00	23.00	21.00	41.67	42.33	42.00	2880.00	2895.00	2887.50
DM_{43}	27.00	33.00	30.00	17.00	19.00	18.00	53.33	50.00	51.67	2116.00	2170.67	2143.33
DM_{44}	29.47	30.20	29.83	15.13	16.47	15.80	47.67	52.67	49.67	2300.33	2315.00	2307.67
DM_{45}	28.00	30.00	29.00	19.77	16.00	17.88	46.00	50.33	48.17	2123.00	2256.67	2189.83
SE(m)±	0.89	1.86	1.03	0.90	0.97	0.66	0.87	1.32	0.79	2.92	4.00	2.41
CD (P=0.05)	**1.76**	**3.68**	**2.04**	**1.78**	**1.92**	**1.31**	**1.72**	**2.61**	**1.56**	**5.78**	**7.92**	**4.77**

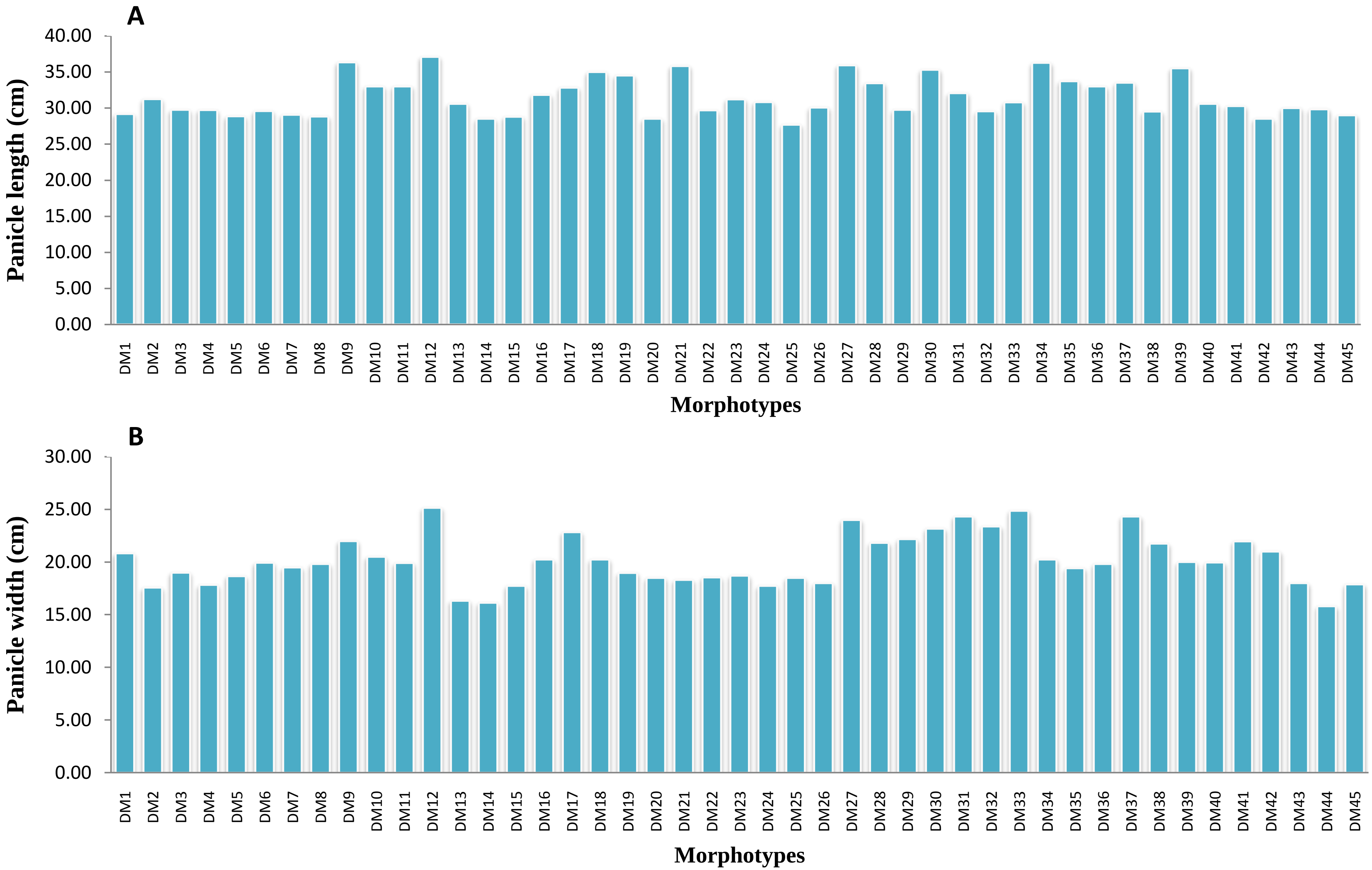


Fig. 4.4 Average performance of (A) panicle length (cm) and (B) panicle width (cm) in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

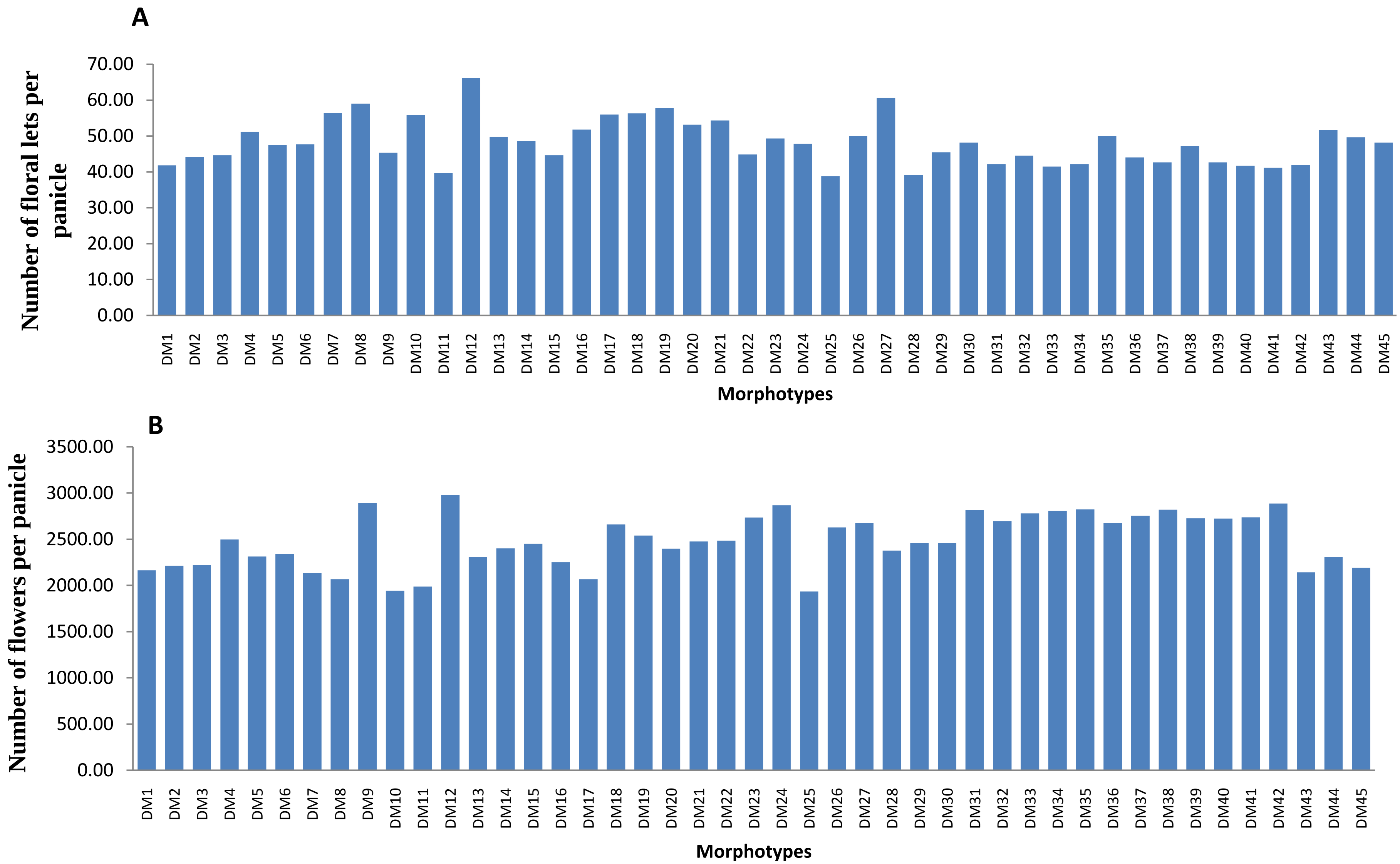
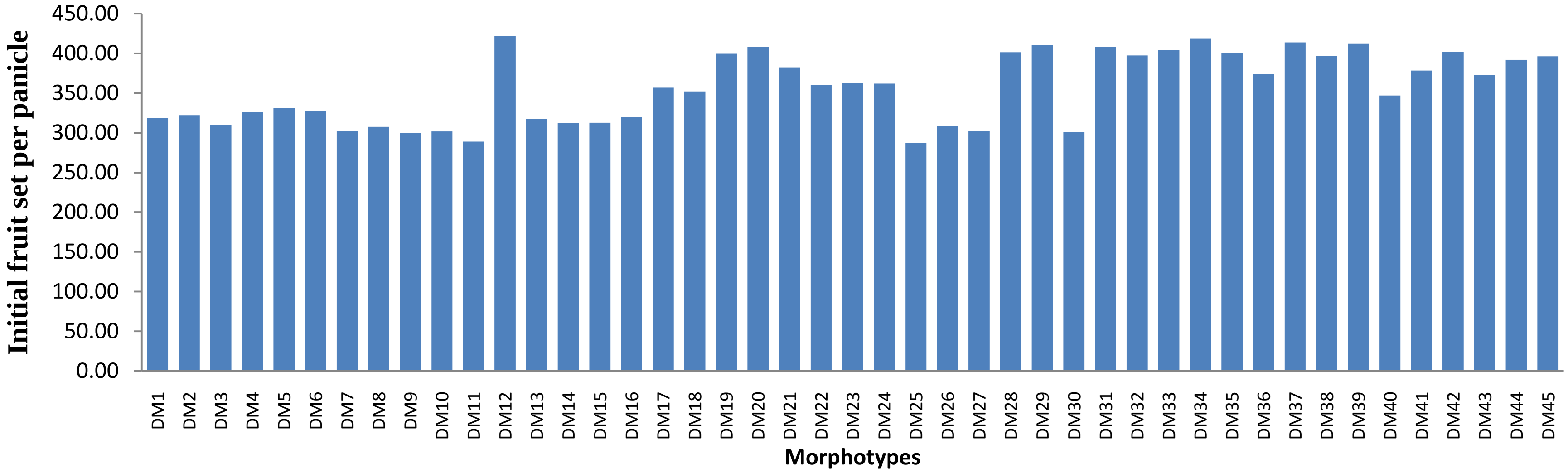


Fig. 4.5 Average performance of (A) number of florets per panicle and (B) number of flowers per panicle in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

Table 4.4 Average performance of fruiting at different stage in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow

Morphotypes	Initial fruit set per panicle			Number of fruits per panicle at pea stage			Number of fruits per panicle at maturity time		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
DM_1	311.67	326.00	318.83	32.67	31.00	31.83	2.33	1.33	1.83
DM_2	320.33	323.67	322.00	33.00	35.67	34.33	1.67	2.33	2.00
DM_3	307.67	312.00	309.83	30.33	26.67	28.50	2.67	2.00	2.33
DM_4	329.67	322.00	325.83	36.67	34.67	35.67	2.00	3.00	2.50
DM_5	330.33	331.67	331.00	31.33	33.33	32.33	2.33	2.33	2.33
DM_6	325.67	329.33	327.50	28.67	25.33	27.00	2.00	3.33	2.67
DM_7	294.00	310.33	302.17	27.67	31.33	29.50	1.33	2.33	1.83
DM_8	305.00	310.33	307.67	31.00	35.00	33.00	2.33	1.33	1.83
DM_9	295.00	305.00	300.00	30.67	36.00	33.33	1.00	2.67	1.83
DM_{10}	303.33	300.33	301.83	33.00	42.00	37.50	1.33	2.00	1.67
DM_{11}	297.67	304.33	289.00	41.67	34.33	38.00	2.33	2.67	2.50
DM_{12}	420.33	433.33	421.83	40.00	36.33	38.17	3.67	3.33	3.50
DM_{13}	321.00	313.67	317.33	27.33	30.33	28.83	2.67	2.00	2.33
DM_{14}	314.67	310.00	312.33	35.33	29.00	32.17	2.67	2.00	2.33
DM_{15}	310.00	315.67	312.83	31.00	33.00	32.00	2.67	2.00	2.33
DM_{16}	322.67	317.33	320.00	28.67	32.00	30.33	1.00	2.33	1.67
DM_{17}	355.00	358.67	356.83	26.67	24.00	25.33	2.33	3.00	2.67
DM_{18}	343.00	361.33	352.17	27.33	24.67	26.00	2.33	2.67	2.50
DM_{19}	403.33	396.00	399.67	35.33	31.33	33.33	2.33	1.33	1.83
DM_{20}	401.67	414.33	408.00	28.00	31.00	29.50	1.67	2.33	2.00
DM_{21}	375.00	390.00	382.50	30.67	33.00	31.83	2.33	3.33	2.83

DM_{22}	369.00	351.00	360.00	33.67	31.33	32.50	3.67	3.33	1.67
DM_{23}	381.33	344.33	362.83	27.33	32.67	30.00	2.67	2.33	2.50
DM_{24}	359.00	364.67	361.83	30.33	34.00	32.17	2.67	3.33	3.00
DM_{25}	286.00	288.67	287.33	23.33	26.00	24.67	1.33	1.33	1.33
DM_{26}	312.00	304.67	308.33	32.67	28.67	30.67	2.33	3.00	2.67
DM_{27}	299.33	305.00	302.17	37.33	32.33	34.83	3.00	1.67	2.33
DM_{28}	403.67	399.00	401.33	30.67	36.00	33.33	3.33	3.00	3.17
DM_{29}	412.67	408.00	410.33	27.00	32.33	29.67	2.67	3.33	3.00
DM_{30}	420.33	433.33	301.00	32.33	29.00	30.67	3.00	3.00	3.00
DM_{31}	411.00	405.67	408.33	28.00	33.00	30.50	2.67	1.33	2.00
DM_{32}	394.33	400.67	397.50	34.67	31.33	33.00	4.00	3.00	3.50
DM_{33}	405.00	404.00	404.50	32.00	35.67	33.83	3.00	4.00	3.50
DM_{34}	416.00	421.67	418.83	27.00	34.67	30.83	3.00	2.33	2.67
DM_{35}	406.67	395.67	400.83	31.00	33.33	32.17	1.33	3.00	2.17
DM_{36}	393.33	355.00	374.17	31.00	27.00	29.00	3.00	3.33	3.17
DM_{37}	409.67	418.33	414.00	32.33	28.67	30.50	2.67	1.67	2.17
DM_{38}	390.00	403.67	396.83	29.00	33.33	31.17	2.33	2.00	2.17
DM_{39}	408.33	416.00	412.17	36.33	40.00	38.17	1.33	2.67	2.00
DM_{40}	359.33	335.00	347.17	27.00	31.67	29.33	2.00	2.67	2.33
DM_{41}	396.67	360.00	378.33	32.67	26.67	29.67	2.00	4.33	3.17
DM_{42}	408.00	395.67	401.83	28.33	33.00	30.67	3.00	3.00	3.00
DM_{43}	368.00	377.67	372.83	33.00	42.00	32.83	1.33	3.67	2.50
DM_{44}	386.00	397.67	391.83	27.00	36.67	31.83	2.00	1.67	1.83
DM_{45}	390.33	402.33	396.33	31.00	35.00	33.00	1.67	3.33	2.50
SE(m)±	3.49	3.16	2.34	1.62	1.60	1.14	0.55	0.59	0.40
CD (P=0.05)	**6.91**	**6.25**	**4.63**	**3.20**	**3.16**	**2.26**	**1.08**	**1.16**	**0.80**



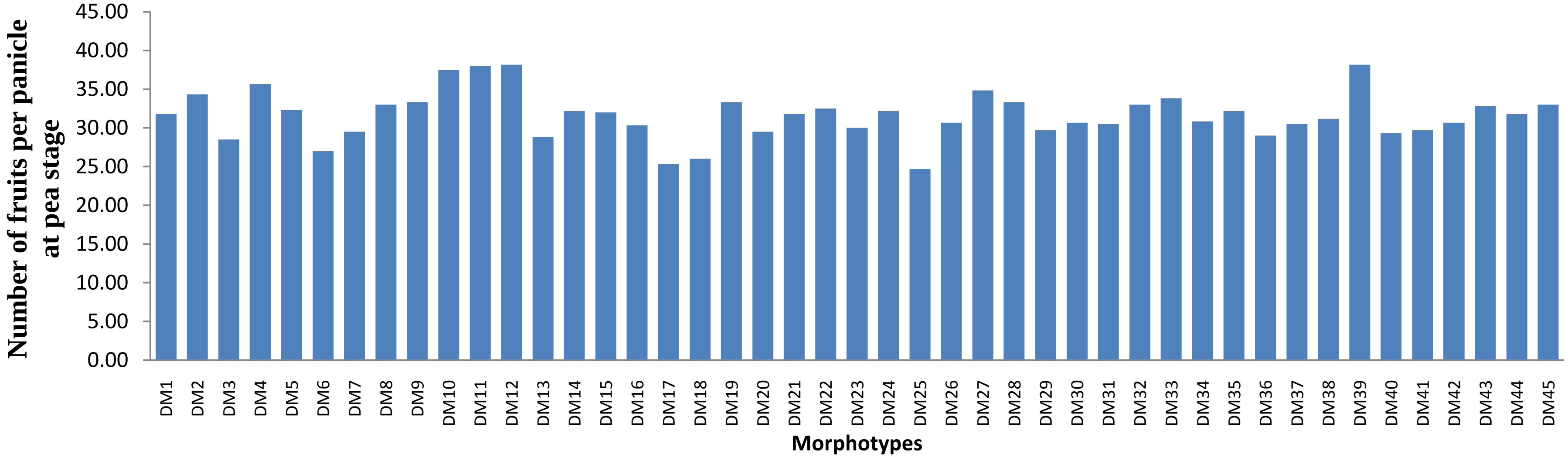


Fig. 4.6 Average performance of (A) initial fruit set per panicle and (B) number of fruits per panicle at pea stage in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

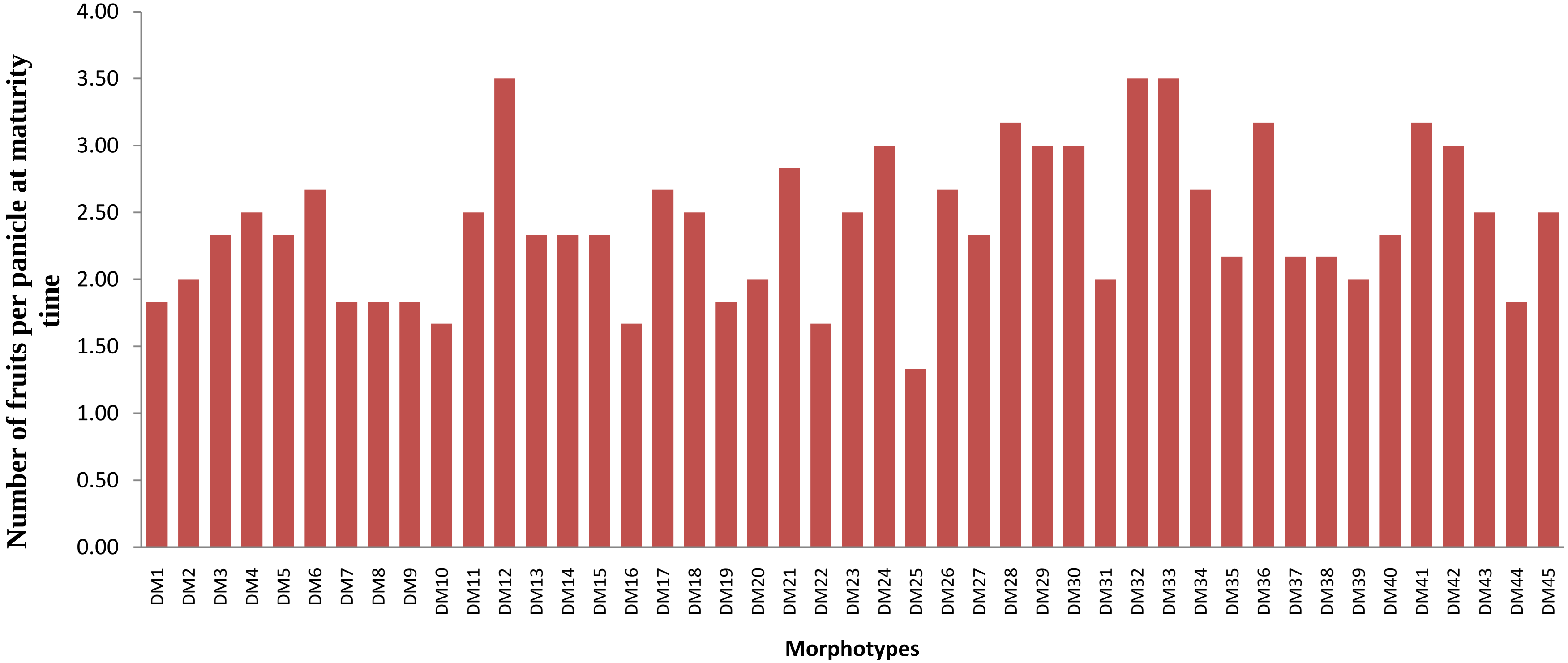


Fig. 4.7 Average performance of number of fruits per panicle at maturity time in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

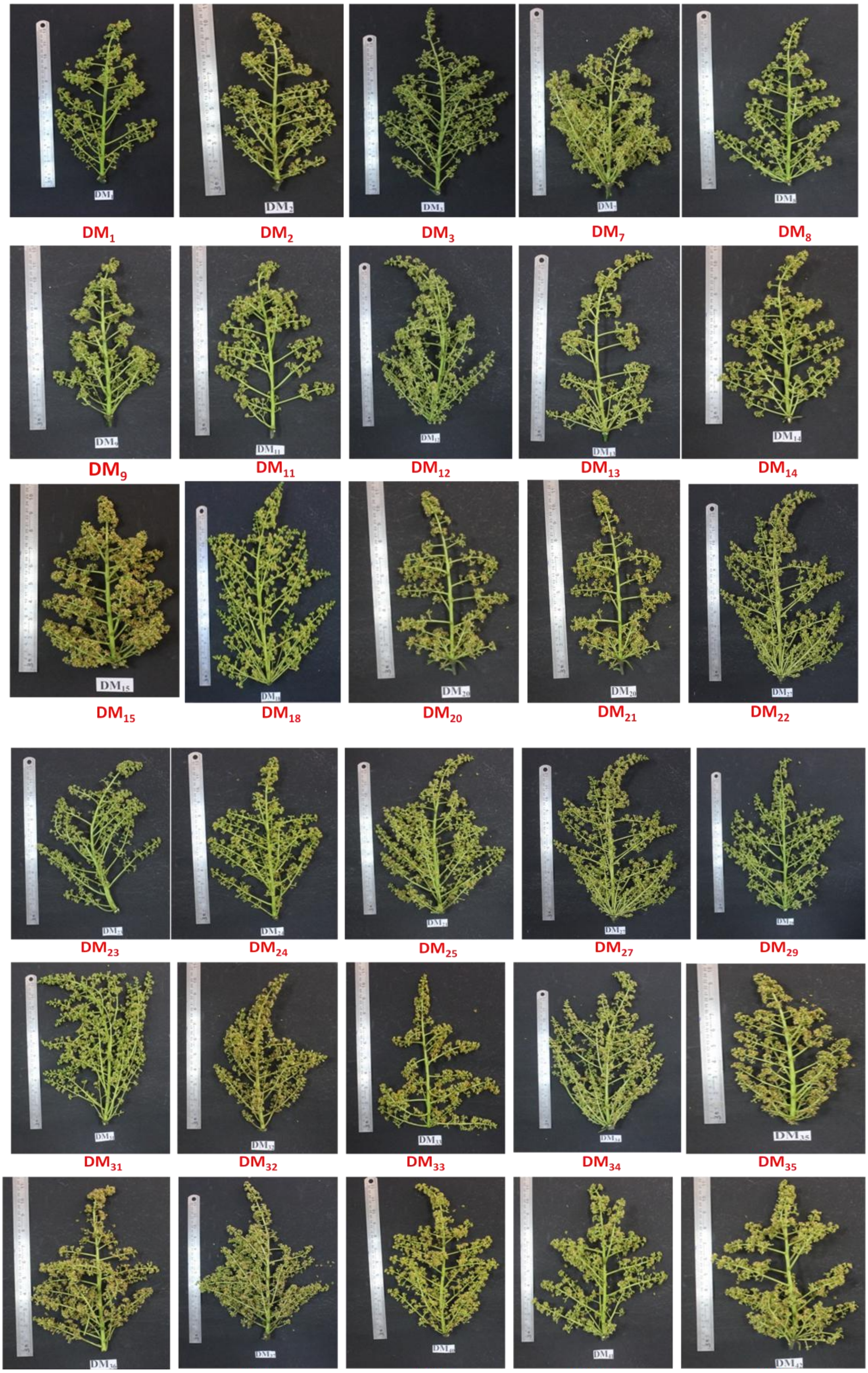


Plate 2: Variation in panicle morphology of 45 morphotypes of mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow.

4.2.4 Fruit set study

Initial fruit set per panicle

Fruit set per panicle at mustard stage revealed significant differences between various morphotypes. The fruit set at mustard stage varied from (287.33 to 421.83 and grand mean 356.21) presented in Table 4.6. The data on fruit set per panicle at mustard stage are presented (Table 4.4 and Figure 4.6A). The highest (421.83) number of fruit per panicle at mustard stage was counted in morphotype DM_{12} followed by DM_{34} (418.83) and DM_{37} (414.00). Number of fruit set per panicle at mustard stage at DM_{25} was found as the lowest (287.33).

Number of fruits per panicle at pea stage

The data pertaining to fruit set per panicle at mustard stage of various morphotypes revealed significant differences among the morphotypes. The fruit set at pea stage ranged from 24.67 to 37.50 and grand mean for the character was 31.63 (Table 4.6). The morphotype DM_{12} produced higher (38.17) fruit set per panicle at pea stage followed by morphotype DM_{10} (37.50) and DM_{11} (38.00). The morphotype DM_{25} had lowest (24.67) fruit set per panicle at pea stage (Table 4.4 and Figure 4.6B).

Number of fruits per panicle at maturity time

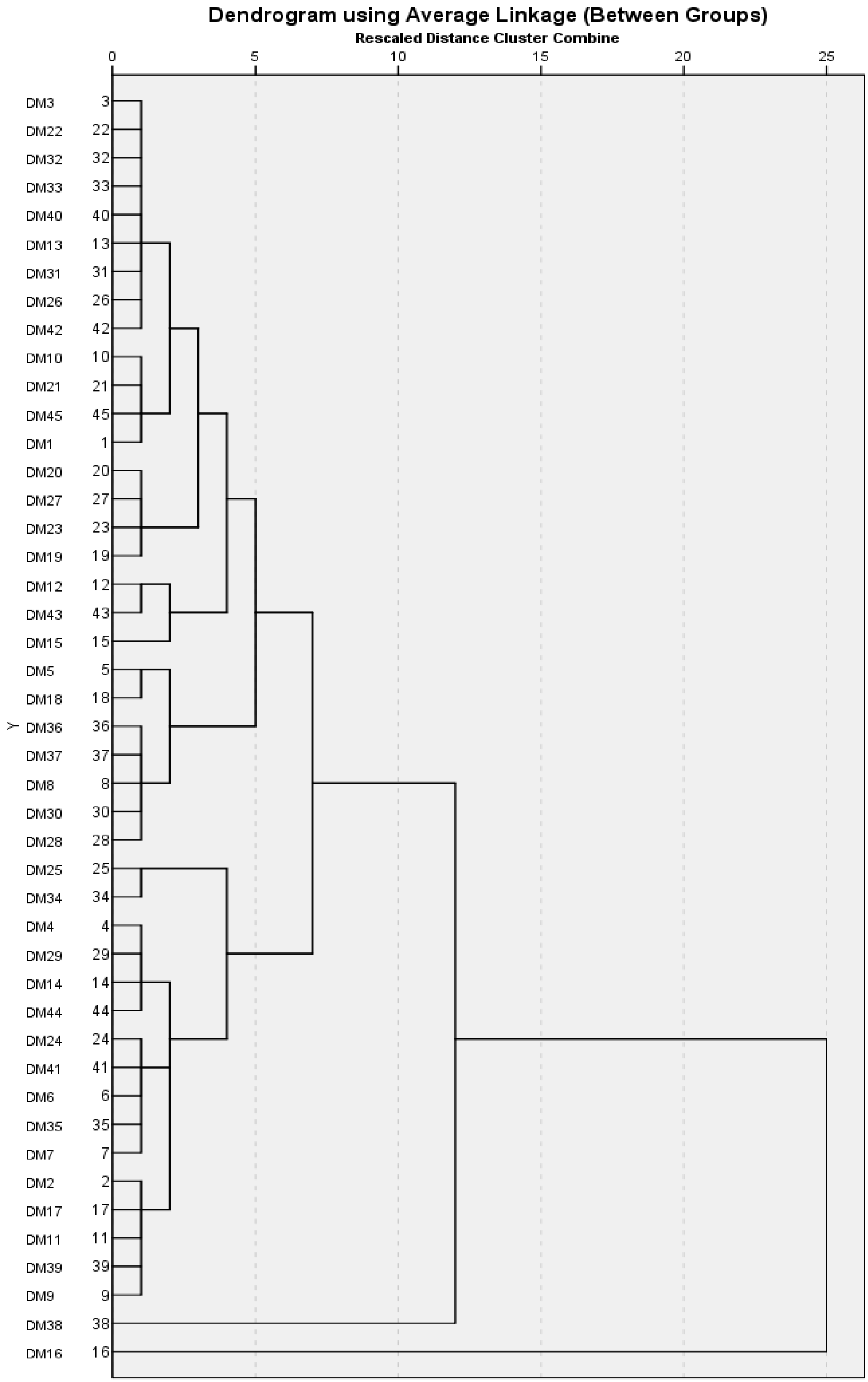
The significant differences were observed for fruit set per panicle at final stage among different morphotypes. In the present investigation the final fruit set per panicle of 45 Dashehari morphotypes ranged from 1.33 to 3.50 with a grand mean of 2.41 (Table 4.6). The maximum (3.50) fruit set per panicle at final stage was observed for morphotype DM_{12}, DM_{32} and DM_{33}, respectively followed by DM_{41} (3.17) and minimum (1.67) fruit set per panicle at final stage was recorded for morphotype DM_{10}, DM_{16} and DM_{22} (Table 4.4 and Figure 4.7).

Biometrical techniques for assessment of intravarietal variability for tree, leaf and floral parameters of 45 Dashehari morphotypes:

UPGMA dendrogram was prepared on the basis of tree and leaf data of 45 Dashehari morphotypes in order to establish their relatedness to each other. Samples were found to be very closely related and grouped into three major clusters (cluster I, II and III) (Table 4.5) with additional sub-clusters, differentiating the morphotypes

Table 4.5 Non-hierarchical Euclidean cluster analysis in 45 morphotypes of Dashehari mango (*Mangifera indica* L.) on the basis of vegetative parameters

Clusters	Morphotypes
Cluster I	DM_1, DM_2, DM_3, DM_4, DM_5, DM_6, DM_7, DM_8, DM_9, DM_{10}, DM_{11}, DM_{12}, DM_{13}, DM_{14}, DM_{15}, DM_{16}, DM_{17}, DM_{18}, DM_{19}, DM_{20}, DM_{21}, DM_{22}, DM_{23}, DM_{24}, DM_{25}, DM_{26}, DM_{27}, DM_{28}, DM_{29}, DM_{30}, DM_{31}, DM_{32}, DM33, DM_{34}, DM_{35}, DM_{36}, DM_{37}, DM_{39}, DM_{40}, DM_{42}, DM_{43}, DM_{44}, DM_{45}
Cluster II	DM_{16}
Cluster III	DM_{38}



Dendrogram using Average Linkage (Between Groups)
Rescaled Distance Cluster Combine
0
5
10
15
20
25
Y
DM3 3
DM22 22
DM32 32
DM33 33
DM40 40
DM13 13
DM31 31
DM26 26
DM42 42
DM10 10
DM21 21
DM45 45
DM1 1
DM20 20
DM27 27
DM23 23
DM19 19
DM12 12
DM43 43
DM15 15
DM5 5
DM18 18
DM36 36
DM37 37
DM8 8
DM30 30
DM28 28
DM25 25
DM34 34
DM4 4
DM29 29
DM14 14
DM44 44
DM24 24
DM41 41
DM6 6
DM35 35
DM7 7
DM2 2
DM17 17
DM11 11
DM39 39
DM9 9
DM38 38
DM16 16

collected from different areas. Cluster-I consisted of 43 morphotypes which further divided into five sub-groups (cluster IA, IB, IC, ID and IE) while cluster-II and cluster-III comprised only one morphotypes DM_{16} and DM_{38} (Plate 2).

The morphological data recorded was subjected to biometrical techniques for assessment which was computed through simple measures of variability viz., range, grand mean and coefficient of variation (CV), genetic variability (PCV % and GCV %), heritability (h^2), genetic advance (GA) and genetic advanceas percent of mean (GAM%) for further elucidation of the data recorded. The highest CV (5.84), PCV (22.46%) and GCV (21.69%) were recorded for number of secondary branches. However, the highest heritability (98.40%) and genetic advance (43.83%) were observed for trunk girth while, the maximum genetic advance as percent of mean (88.87%) was recorded for number of secondary branches (Table 4.6). In case of leaf parameters the maximum CV (6.73) was recorded for leaf length. Among leaf parameters the highest PCV (6.28%), GCV (4.50%), heritability (14.50%) and genetic advance as percent of mean (7.69%) were recorded for petiole length (Table 4.6). Floral parameters showed narrow difference between PCV and GCV (Table 4.6). The panicle width showed highest coefficient of variation (5.70). Highest PCV (12.52%) and GCV (12.19%) were recorded for number of florets per panicle followed by number of flowers per panicle. However, highest heritability (99.40%) and genetic advance (80.78%) was recorded for number of flowers per panicle while genetic advance as percent of mean (50.36%) was recorded for number of florets per panicle followed by number of flowers per panicle. Fruit set study also showed a wide variation between morphotypes (Table 4.6). The maximum coefficient of variation (19.23) was observed for final fruit set per panicle. Fruit set at mustard stage per panicle showed narrow difference between PCV (12.19%) and GCV (12.13%) but fruit set at pea stage per panicle and final fruit set per panicle showed wide difference between PCV and GCV. The highest heritability (99.10%), genetic advance (182.61%) and genetic advance as percent of mean (51.17%) were recorded for fruit set at mustard stage per panicle.

Table 4.6 Range (minimum and maximum), grand mean, coefficient of variation, phenotypic coefficient of variation (PCV %), genotypic coefficient of variation (GCV %), heritability (%), genetic advance (%) and genetic advance as percent of mean (%) for 13 tree, leaf and floral parameters of 45 morphotypes of mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow

Sr. No.	Characters	Range		Grand Mean	CV	PCV %	GCV %	h^2 %	GA	GAM%
		Minimum	Maximum							
1	Trunk girth (cm)	102.50	151.33	134.84	0.97	7.78	7.72	98.40	43.83	32.50
2	Number of secondary branches per tree	12.00	29.00	18.79	5.84	22.46	21.69	93.20	16.70	88.87
3	Leaf length (cm)	17.45	22.78	20.79	6.73	6.74	0.15	0.10	0.00*	0.00
4	Leaf width (cm)	3.95	5.62	4.91	4.22	4.27	0.64	2.30	0.02	0.40
5	Leaf thickness (mm)	0.21	0.38	0.26	4.80	6.28	4.05	14.50	0.02	7.69
6	Petiole lengths (cm)	2.42	4.33	3.19	5.99	6.07	0.99	2.70	0.02	0.62
7	Panicle length (cm)	27.70	37.08	31.50	5.67	9.61	7.75	65.00	8.36	31.50
8	Panicle width (cm)	15.80	25.15	20.12	5.70	11.04	9.45	73.30	6.90	34.29
9	Number of florets/panicle	39.17	66.17	48.17	2.84	12.52	12.19	94.40	24.26	50.36
10	Number of flowers/panicle	1932.83	2979.33	2495.36	0.16	11.39	11.19	99.40	80.78	48.32
11	Initial fruit set per panicle	287.33	421.83	356.21	1.13	12.19	12.13	99.10	182.61	51.17
12	Number of fruit per panicle at pea stage	24.67	37.50	31.63	6.25	9.23	6.78	54.00	6.69	21.15
13	Number of fruit per panicle at maturity stage	1.33	3.50	2.41	29.23	30.77	9.61	9.80	0.30	12.44

CV: Coefficient of variation, PCV: Phenotypic coefficient of variation, GCV: Genotypic coefficient of variation, h^2: heritability, GA: Genetic advance and GAM: Genetic advance as per cent of mean

EXPERIMENT III

4.3 Performance of fruit physico-chemical traits of different Dashehari morphotypes

4.3.1 Fruit morphology

Fruit width (cm)

The range of fruit width was recorded 5.52 to 6.97 cm with the grand mean of 6.24 cm significant variation which exhibited (Table 4.15). The morphotype DM_{41} produced fruit with maximum width (6.97 cm) followed by DM_{9} (6.80 cm) and DM_{13} (6.85 cm) which was significantly higher in comparison to other morphotypes (Table 4.7 and Figure 4.8A). Morphotype DM_{16} showed the lowest fruit width (5.52 cm) after DM_{3} (5.60 cm).

Fruit length (cm)

The fruit length was observed ranged from 9.84 to 12.85 cm with a grand mean of 11.24 cm (Table 4.15). The maximum (12.85 cm), (12.78 cm) and (12.75cm) fruit length was observed for various morphotypes DM_{12} DM_{4} and DM_{13}, respectively were statistically at par followed by morphotype DM_{15} (12.37 cm), DM_{11} (12.19 cm) and DM_{9} (12.12 cm), respectively while, morphotype DM_{31} showed the lowest fruit length (9.84 cm) followed by morphotype DM_{28} (9.89 cm) as shown in Table 4.7 and Figure 4.8B.

Fruit weight (g)

Average weight of fruit significantly varied 191.00 to 342.33 g with a grand mean of 235.16 g (Table 4.15). Average the selected morphotypes DM_{12} had heavier fruit weight (342.33 g) followed by morphotype DM_{38} (289.67 g) and DM_{8} (270.00 g). Whereas, morphotype DM_{31} exhibited the minimum fruit weight (191.00 g) followed by DM_{28} and DM_{34} (201.83 g) which were at par with each other and presented in Table 4.8 and Figure 4.9A.

Fruit volume (ml)

The data pertaining to fruit volume of various morphotypes (Table 4.8 and 4.9B) showed significant variation between the morphotypes. The morphotype

Table 4.7 Average performance of fruit morphological characters in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow

Morphotypes	Fruit width (cm)			Fruit length (cm)		
	2016	2017	Pooled	2016	2017	Pooled
DM_1	6.37	6.60	6.49	10.43	11.57	11.00
DM_2	6.03	6.17	6.10	11.47	10.97	11.22
DM_3	5.83	5.37	5.60	10.87	13.10	11.99
DM_4	5.87	6.87	6.37	13.63	11.93	12.78
DM_5	6.03	6.30	6.17	10.40	12.30	11.35
DM_6	5.10	6.65	5.88	9.73	11.00	10.37
DM_7	6.37	6.20	6.29	10.90	10.23	10.57
DM_8	6.27	6.50	6.39	11.47	10.07	10.77
DM_9	7.10	6.50	6.80	12.77	11.47	12.12
DM_{10}	6.10	5.97	6.04	11.23	12.30	11.77
DM_{11}	5.77	6.10	5.94	12.87	11.50	12.19
DM_{12}	6.47	5.50	5.99	13.83	11.87	12.85
DM_{13}	7.27	6.43	6.85	15.13	10.37	12.75
DM_{14}	6.27	6.53	6.40	11.10	10.10	10.60
DM_{15}	6.23	6.73	6.48	12.77	11.97	12.37
DM_{16}	5.53	5.50	5.52	10.13	11.07	10.60
DM_{17}	6.30	6.07	6.19	11.83	10.50	11.17
DM_{18}	5.43	6.23	5.83	11.07	10.77	10.92
DM_{19}	5.67	5.83	5.75	11.77	10.53	11.15
DM_{20}	6.73	6.03	6.38	11.80	10.80	11.30
DM_{21}	5.63	6.30	5.97	10.50	11.17	10.84

DM_{22}	6.37	6.07	6.22	11.73	10.73	11.23
DM_{23}	6.30	6.10	6.20	10.67	10.17	10.42
DM_{24}	6.17	6.37	6.27	11.10	10.23	10.67
DM_{25}	6.90	5.70	6.30	11.60	10.47	11.04
DM_{26}	6.17	6.50	6.34	11.93	11.20	11.57
DM_{27}	7.50	6.03	6.77	11.67	10.90	11.29
DM_{28}	6.57	5.70	6.14	9.57	10.20	9.89
DM_{29}	6.17	6.30	6.24	10.53	11.40	10.97
DM_{30}	7.17	5.87	6.52	12.33	11.60	11.97
DM_{31}	5.03	6.40	5.72	9.00	10.67	9.84
DM_{32}	5.93	6.23	6.08	10.40	11.77	11.09
DM_{33}	6.67	6.23	6.45	11.63	10.63	11.13
DM_{34}	6.10	6.47	6.29	10.27	11.40	10.84
DM_{35}	6.00	6.50	6.25	10.67	11.30	10.99
DM_{36}	4.93	6.80	5.87	11.70	11.57	11.64
DM_{37}	6.30	7.03	6.67	10.83	12.17	11.50
DM_{38}	6.80	6.10	6.45	9.50	12.80	11.15
DM_{39}	6.13	7.03	6.58	11.77	11.53	11.65
DM_{40}	5.83	7.00	6.42	10.47	11.50	10.99
DM_{41}	7.23	6.70	6.97	10.70	11.70	11.20
DM_{42}	5.63	6.63	6.13	11.70	11.27	11.49
DM_{43}	6.47	6.13	6.30	10.60	11.43	11.02
DM_{44}	6.33	6.90	6.62	10.33	12.93	11.63
DM_{45}	5.50	6.50	6.00	10.97	11.47	11.22
SE(m)±	0.37	0.41	0.28	0.68	0.77	0.51
CD (P=0.05)	**0.73**	**0.81**	**0.55**	**1.34**	**1.52**	**1.00**

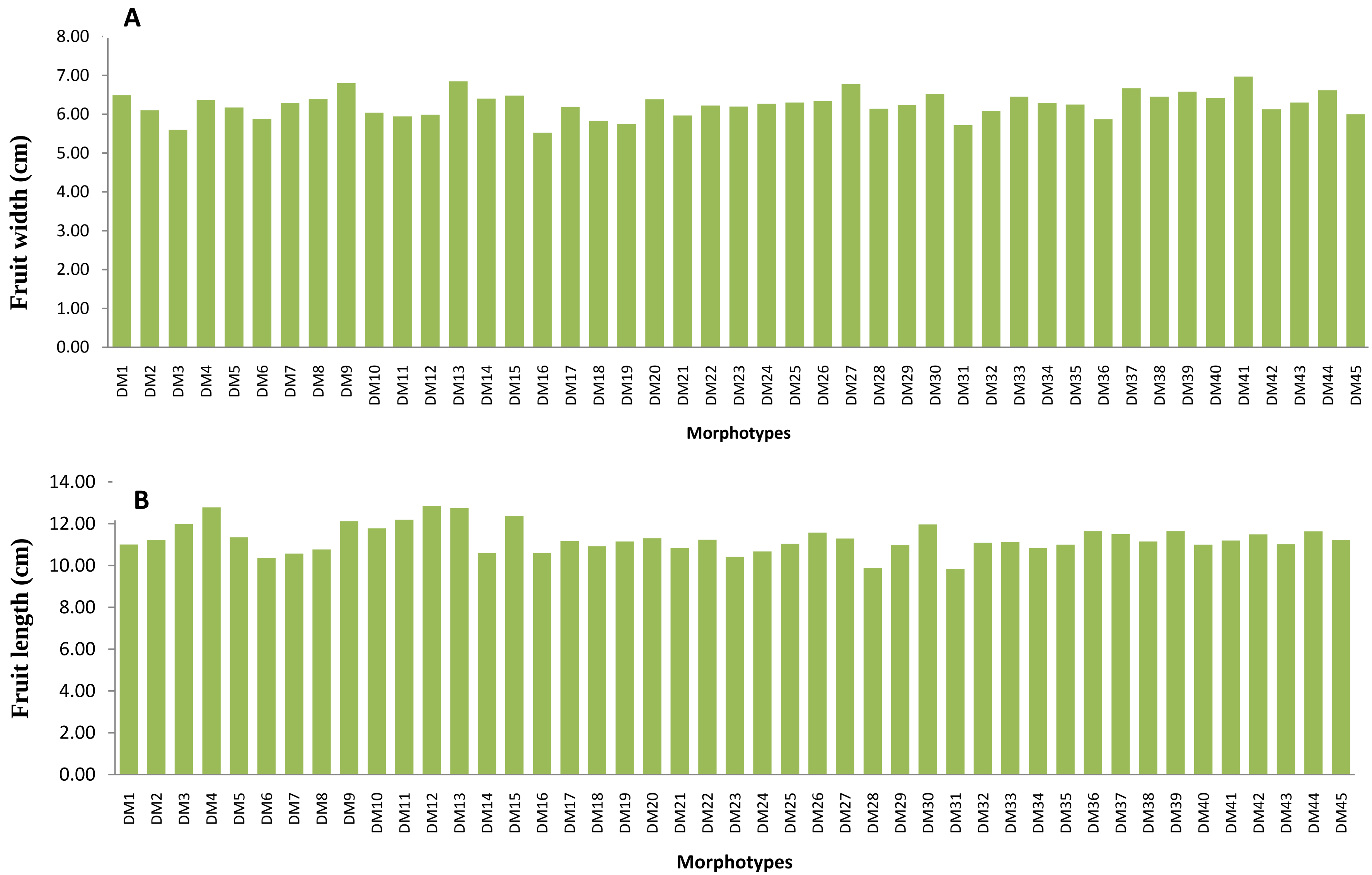


Fig. 4.8 Average performance of (A) fruit width (cm) and (B) fruit length (cm) in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

Table 4.8 Average performance of fruit morphological characters in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow

Morphotypes	Fruit weight (g)			Fruit volume (ml)			Specific gravity of fruit		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
DM_1	248.67	229.00	238.83	238.00	218.33	228.17	1.05	1.05	1.05
DM_2	220.00	203.67	211.83	208.67	196.00	202.33	1.06	1.04	1.05
DM_3	253.00	243.67	248.33	238.33	225.00	231.67	1.06	1.09	1.08
DM_4	208.00	269.33	238.67	211.00	243.33	227.17	0.99	1.10	1.05
DM_5	195.67	268.00	231.83	186.67	250.00	218.33	1.05	1.07	1.06
DM_6	262.33	257.33	259.83	245.00	235.00	240.00	1.07	1.10	1.09
DM_7	197.00	214.67	205.83	209.00	195.00	202.00	1.04	1.08	1.06
DM_8	332.67	207.33	270.00	316.33	196.67	256.50	1.05	1.05	1.05
DM_9	239.67	221.67	230.67	230.00	205.00	217.50	1.04	1.08	1.06
DM_{10}	233.00	219.00	226.00	228.33	205.00	216.67	1.02	1.07	1.05
DM_{11}	279.33	246.33	262.83	270.00	228.33	249.17	1.03	1.08	1.06
DM_{12}	464.00	220.67	342.33	445.00	205.00	325.00	1.10	1.10	1.10
DM_{13}	251.00	199.33	225.17	236.67	191.67	214.17	1.06	1.04	1.05
DM_{14}	313.00	198.00	255.50	298.33	201.67	250.00	1.07	1.03	1.05
DM_{15}	207.00	255.33	231.17	201.67	239.00	220.33	1.03	1.07	1.05
DM_{16}	207.00	225.67	216.33	193.33	210.00	201.67	1.07	1.07	1.07
DM_{17}	254.33	188.00	221.17	235.00	177.33	206.17	1.08	1.06	1.07
DM_{18}	248.00	191.00	219.50	223.33	180.00	201.67	1.10	1.06	1.08
DM_{19}	263.33	208.00	235.67	243.00	201.00	230.00	1.08	1.03	1.06
DM_{20}	296.33	212.33	254.33	270.00	206.67	238.33	1.10	1.02	1.06
DM_{21}	230.33	207.33	218.83	212.33	196.67	204.50	1.09	1.06	1.08
DM_{22}	268.33	214.00	241.17	240.00	201.67	220.83	1.10	1.06	1.08

DM_{23}	247.67	218.67	233.17	223.67	209.00	216.33	1.10	1.04	1.07
DM_{24}	239.00	209.67	224.33	221.33	195.67	208.50	1.08	1.07	1.08
DM_{25}	224.67	216.67	220.67	209.00	201.00	205.00	1.08	1.08	1.08
DM_{26}	251.67	263.00	257.33	237.33	249.67	243.50	1.06	1.05	1.06
DM_{27}	239.67	207.67	223.67	218.67	200.00	209.33	1.10	1.04	1.07
DM_{28}	224.33	179.33	201.83	220.00	173.33	197.67	1.02	1.04	1.03
DM_{29}	196.00	224.00	210.00	191.67	211.67	205.00	1.02	1.06	1.04
DM_{30}	274.33	247.33	260.83	258.33	226.67	242.50	1.06	1.09	1.08
DM_{31}	166.33	215.67	191.00	155.00	196.67	175.83	1.05	0.98	1.02
DM_{32}	199.33	218.67	209.00	191.33	210.67	205.00	1.04	1.04	1.04
DM_{33}	234.33	219.67	227.00	220.00	203.33	211.67	1.07	1.08	1.08
DM_{34}	207.00	196.67	201.83	198.33	186.67	192.50	1.04	1.06	1.05
DM_{35}	195.33	264.33	229.83	187.33	243.33	215.33	1.04	1.09	1.07
DM_{36}	202.67	246.33	224.50	187.00	224.33	205.67	1.08	1.10	1.09
DM_{37}	220.33	292.00	256.17	201.67	278.33	240.00	1.09	1.05	1.07
DM_{38}	244.33	335.00	289.67	229.67	313.33	283.40	1.06	1.07	1.07
DM_{39}	225.67	246.33	236.00	215.00	231.33	223.17	1.05	1.06	1.06
DM_{40}	195.67	292.00	243.83	175.00	273.33	224.17	1.10	1.07	1.09
DM_{41}	234.00	260.67	247.33	222.00	241.67	231.83	1.05	1.08	1.07
DM_{42}	245.00	248.67	246.83	233.33	226.67	230.00	1.05	1.10	1.08
DM_{43}	187.67	229.33	208.50	173.33	206.67	190.00	1.08	1.11	1.10
DM_{44}	195.67	249.67	222.67	184.67	233.33	209.00	1.06	1.07	1.07
DM_{45}	191.67	266.33	229.00	173.67	246.67	210.17	1.10	1.08	1.09
SE(m)±	9.01	10.54	6.93	8.81	8.49	6.12	0.02	0.04	0.02
CD (P=0.05)	**17.83**	**20.86**	**13.72**	**17.44**	**16.81**	**12.11**	**0.03**	**0.07**	**0.03**

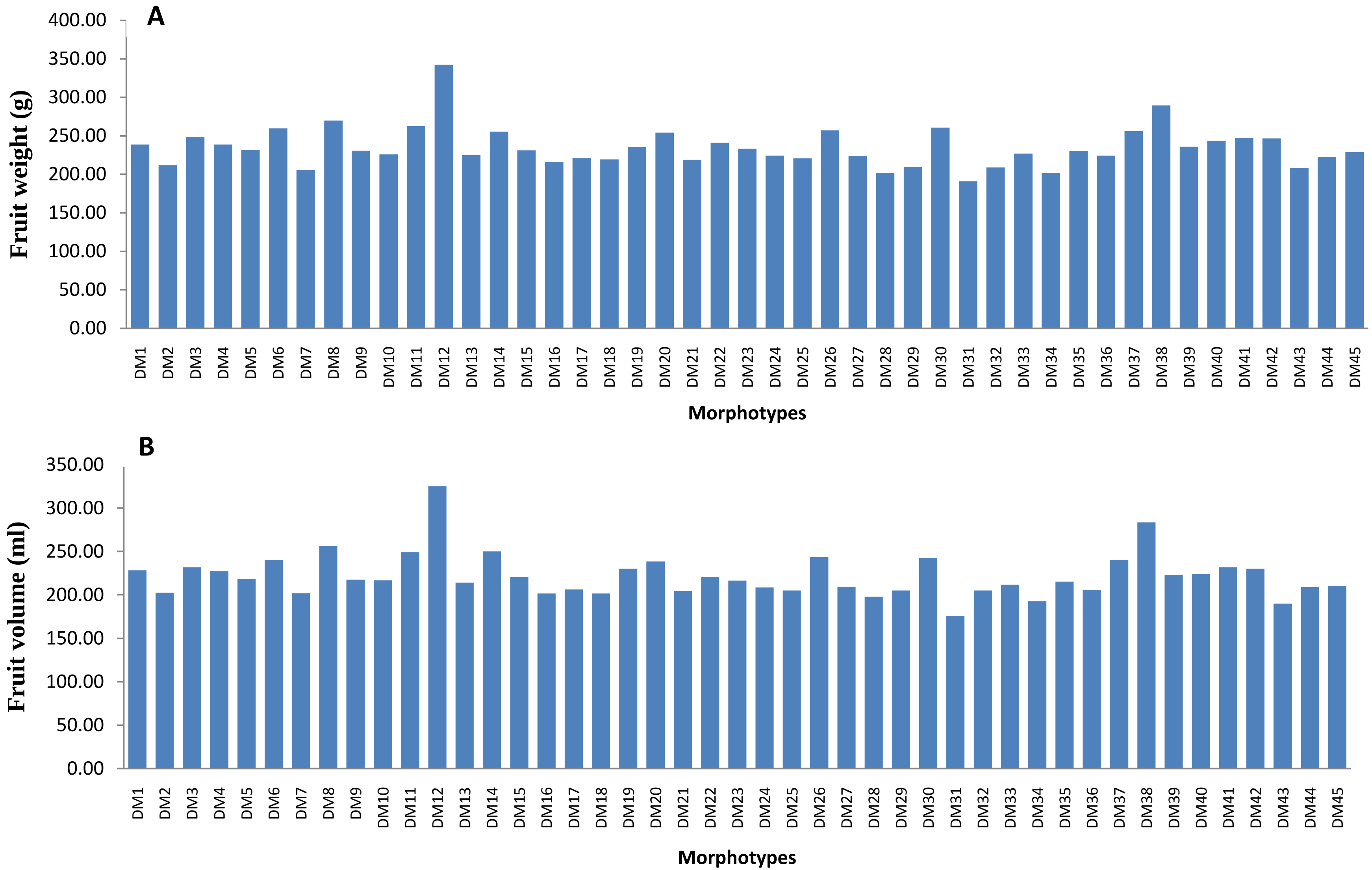


Fig. 4.9 Average performance of (A) fruit weight (g) and (B) fruit volume (ml) in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

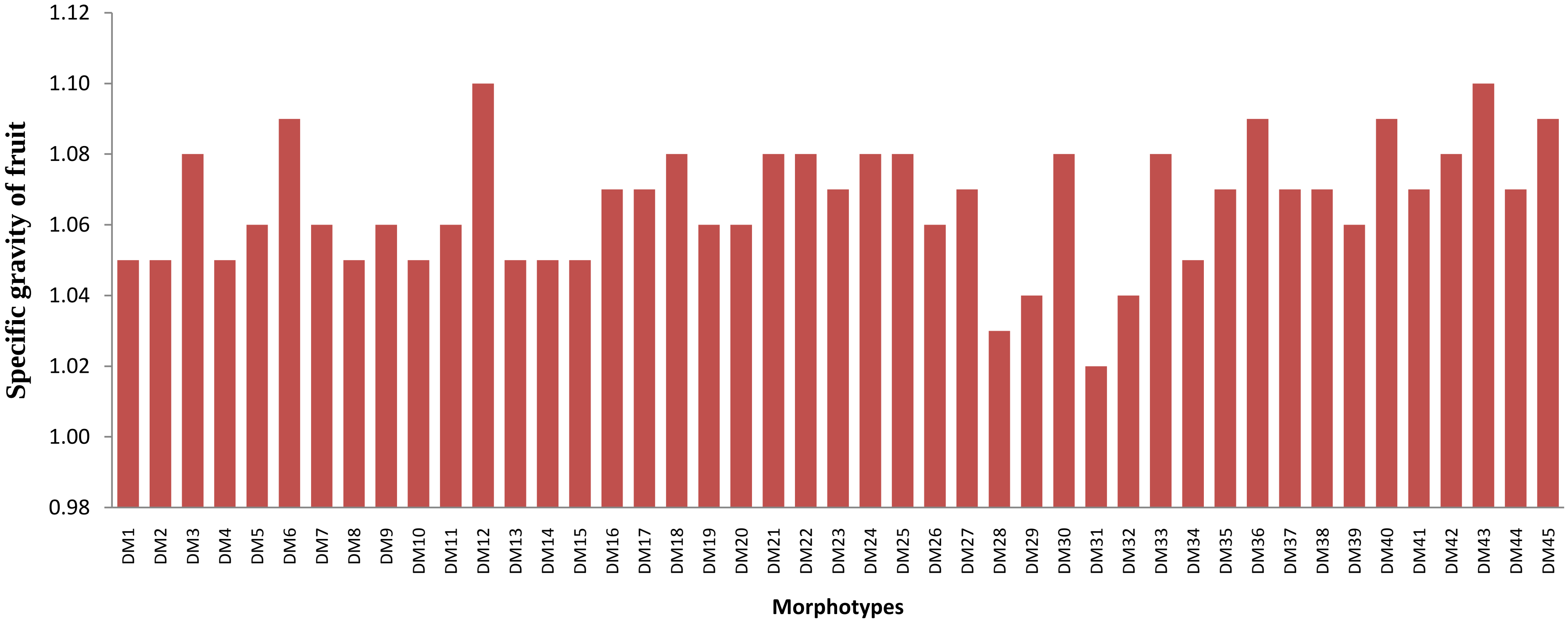


Fig. 4.10 Average performance of specific gravity of fruit in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

A **B**

C

Plate 4: Variation in fruit morphology of 45 morphotypes of mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow

DM_{12} showed the highest fruit volume (325.00 ml) followed by DM_{38} (289.63 ml) and DM8 (256.50 ml). However, morphotype DM_{31} had minimum fruit volume followed by DM_{43} (190.00 ml) which were at par.

Specific gravity of fruit

The range of specific gravity of fruit was recorded from 1.02 to 1.10 with the grand mean 1.06 g/cc (Table 4.15). The maximum specific gravity of fruit (1.10) was recorded for fruits collected from morphotypes DM_{12}, and DM_{43} followed by DM_6, DM_{36}, DM_{40} and DM_{45} (1.09), respectively. The least specific gravity of fruit i.e. 1.02 were observed for morphotype DM_{31} (Table 4.8 and Figure 4.10).

Pulp weight (g)

Fruit pulp weight showed significant variation between various morphotypes and pulp weight varied from 125.83 to 259.67 g with a grand mean of 154.13 g (Table 4.15). The highest pulp weight (259.67 g) was recorded for morphotype DM_{12} followed by morphotype DM_{38} (192.50 g) and DM_8 (191.50 g) and minimum pulp weight (125.83 g) was recorded for morphotype DM_{31} as presented in Table 4.9 and figure 4.11A.

Peel weight (g)

Data pertaining to peel weight of different morphotypes of Dashehari mango revealed significant intra-cultivar variation among morphotypes. Morphotype DM_{38} showed highest peel weight (61.67 g) followed by morphotype DM_{26} (57.33) and DM_{12} (57.00 g), while minimum peel weight (40.00 g) was observed from DM_{34} followed by morphotype DM_{31} (40.00 g) which were at par with each other and as shown in Table 4.9 and Figure 4.11B.

Pulp:peel ratio

Variability was also seen for pulp:peel ratio of different morphotypes which showed variation from 2.71 to 4.40 with a grand mean 3.14 (Table 4.15). The highest pulp:peel ratio (4.40) was estimated for morphotype DM_{12} followed by morphotype DM_8 (3.84) and DM_{11} (3.49) and minimum pulp:peel ratio (2.71) was recorded from morphotype DM_{19} (Table 4.9 and Figure 4.12A).

Table 4.9 Average performance of fruit morphological characters in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow

Morphotypes	Pulp weight (g)			Peel weight (g)			Pulp:peel ratio			Peel thickness (mm)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
DM_1	164.67	156.00	160.33	52.67	44.0	48.33	3.17	3.57	3.36	1.47	2.00	1.74
DM_2	143.33	133.00	138.17	46.67	41.3	44.00	3.10	3.20	3.15	2.13	2.01	2.07
DM_3	165.00	165.67	165.33	56.67	46.7	51.67	2.93	3.53	3.23	2.10	2.21	2.15
DM_4	137.00	183.67	160.33	43.67	52.3	48.00	3.13	3.53	3.34	1.60	2.08	1.84
DM_5	124.33	178.67	151.50	43.00	54.3	48.67	2.90	3.23	3.07	2.13	1.77	1.95
DM_6	170.00	171.00	170.50	59.67	53.7	56.67	2.83	3.20	3.03	1.13	1.35	1.24
DM_7	127.33	138.33	132.83	42.67	46.3	44.50	2.97	3.10	3.04	2.33	1.92	2.13
DM_8	244.33	138.67	191.50	60.00	38.7	49.33	4.07	3.63	3.84	1.33	1.86	1.59
DM_9	156.33	147.33	151.83	51.00	44.0	47.50	3.11	3.37	3.23	2.83	2.05	2.44
DM_{10}	149.67	144.00	146.83	52.67	43.7	48.17	2.87	3.33	3.08	1.53	2.33	1.93
DM_{11}	186.33	171.00	178.67	60.67	44.0	52.33	3.07	3.90	3.49	1.30	1.73	1.51
DM_{12}	370.33	149.00	259.67	72.33	41.7	57.00	5.10	3.67	4.40	3.50	2.05	2.78
DM_{13}	164.00	131.67	147.83	55.33	39.7	47.50	2.97	3.60	3.29	2.37	1.38	1.88
DM_{14}	218.33	123.67	171.00	64.67	43.0	53.83	3.37	2.87	3.12	1.80	2.18	2.01
DM_{15}	134.67	173.33	153.83	44.00	47.7	45.83	3.10	3.63	3.35	2.17	2.13	2.15
DM_{16}	140.00	151.00	154.50	44.67	45.3	45.00	3.17	3.30	3.22	2.43	1.52	1.98
DM_{17}	164.00	119.33	141.67	59.67	39.3	49.50	2.77	3.13	2.94	1.77	2.27	2.02
DM_{18}	160.33	117.00	138.67	56.67	45.0	50.83	2.83	2.60	2.72	2.00	1.70	1.85
DM_{19}	172.00	126.00	149.00	59.00	50.7	54.83	2.97	2.47	2.71	1.37	1.54	1.45
DM_{20}	199.33	132.00	165.67	61.00	49.3	55.17	3.30	2.67	2.96	2.50	1.94	2.22
DM_{21}	150.00	139.00	144.50	50.67	38.0	44.33	2.97	3.70	3.33	1.80	2.00	1.90
DM_{22}	179.00	141.00	160.00	58.33	42.0	50.17	3.07	3.43	3.25	1.40	1.96	1.68

DM_{23}	165.33	141.33	153.33	51.67	44.0	47.83	3.27	3.37	3.30	1.23	1.78	1.51
DM_{24}	154.00	131.33	142.67	53.33	47.3	50.33	2.90	2.90	2.89	2.23	1.77	2.00
DM_{25}	144.00	138.67	141.33	49.33	48.7	49.00	3.00	2.90	2.93	1.97	1.48	1.72
DM_{26}	162.33	175.00	168.67	59.00	55.7	57.33	2.73	3.17	2.96	1.30	1.70	1.50
DM_{27}	155.00	131.00	143.00	51.00	46.3	48.67	3.07	2.90	2.98	1.27	2.36	1.82
DM_{28}	145.00	108.33	126.67	49.33	42.3	45.83	2.93	2.57	2.76	1.93	1.86	1.90
DM_{29}	129.00	144.00	136.50	40.00	48.3	44.17	3.27	2.93	3.10	1.93	1.67	1.80
DM_{30}	183.33	163.00	173.17	59.00	52.3	55.67	3.10	3.17	3.15	2.37	1.96	2.16
DM_{31}	111.33	140.33	125.83	33.67	47.3	40.50	3.37	3.00	3.20	1.27	1.99	1.63
DM_{32}	129.33	135.00	132.17	42.33	53.3	47.83	3.07	2.57	2.81	1.27	1.15	1.21
DM_{33}	149.67	137.33	143.50	52.00	51.0	51.50	2.93	2.70	2.83	2.17	1.97	2.07
DM_{34}	140.00	148.33	134.50	41.67	38.3	40.00	3.40	3.47	3.41	1.37	1.81	1.59
DM_{35}	123.00	176.33	155.50	45.00	57.0	51.00	2.80	3.30	3.05	1.63	1.78	1.70
DM_{36}	133.00	170.00	150.00	43.33	48.3	45.83	3.10	3.50	3.30	1.50	3.09	2.30
DM_{37}	144.00	199.67	171.83	43.67	56.3	50.00	3.30	3.60	3.45	1.63	1.87	1.75
DM_{38}	156.67	228.33	192.50	57.67	65.7	61.67	2.73	3.53	3.14	1.37	2.34	1.85
DM_{39}	146.67	163.33	155.00	50.67	50.0	50.33	2.87	3.40	3.14	2.23	1.98	2.11
DM_{40}	123.33	199.33	161.33	44.67	56.0	50.33	2.77	3.63	3.19	1.43	2.19	1.81
DM_{41}	149.33	167.67	158.50	51.33	60.0	55.67	2.93	2.80	2.87	1.37	1.83	1.60
DM_{42}	159.00	161.67	160.33	53.67	53.0	53.33	2.97	3.03	3.01	1.43	1.58	1.51
DM_{43}	122.67	145.67	134.17	40.00	52.0	46.00	3.13	2.80	2.98	2.13	2.19	2.16
DM_{44}	120.67	164.33	142.50	41.00	53.3	47.17	2.97	3.10	3.04	1.30	2.12	1.71
DM_{45}	113.67	181.00	147.33	45.67	50.0	47.83	2.47	3.63	3.07	1.67	2.41	2.04
SE(m)±	5.01	7.87	9.86	1.81	2.04	4.60	0.26	0.44	0.26	0.10	0.26	0.15
CD (P=0.05)	**9.91**	**15.58**	**19.52**	**3.58**	**4.03**	**9.10**	**0.51**	**0.88**	**0.51**	**0.19**	**0.51**	**0.31**

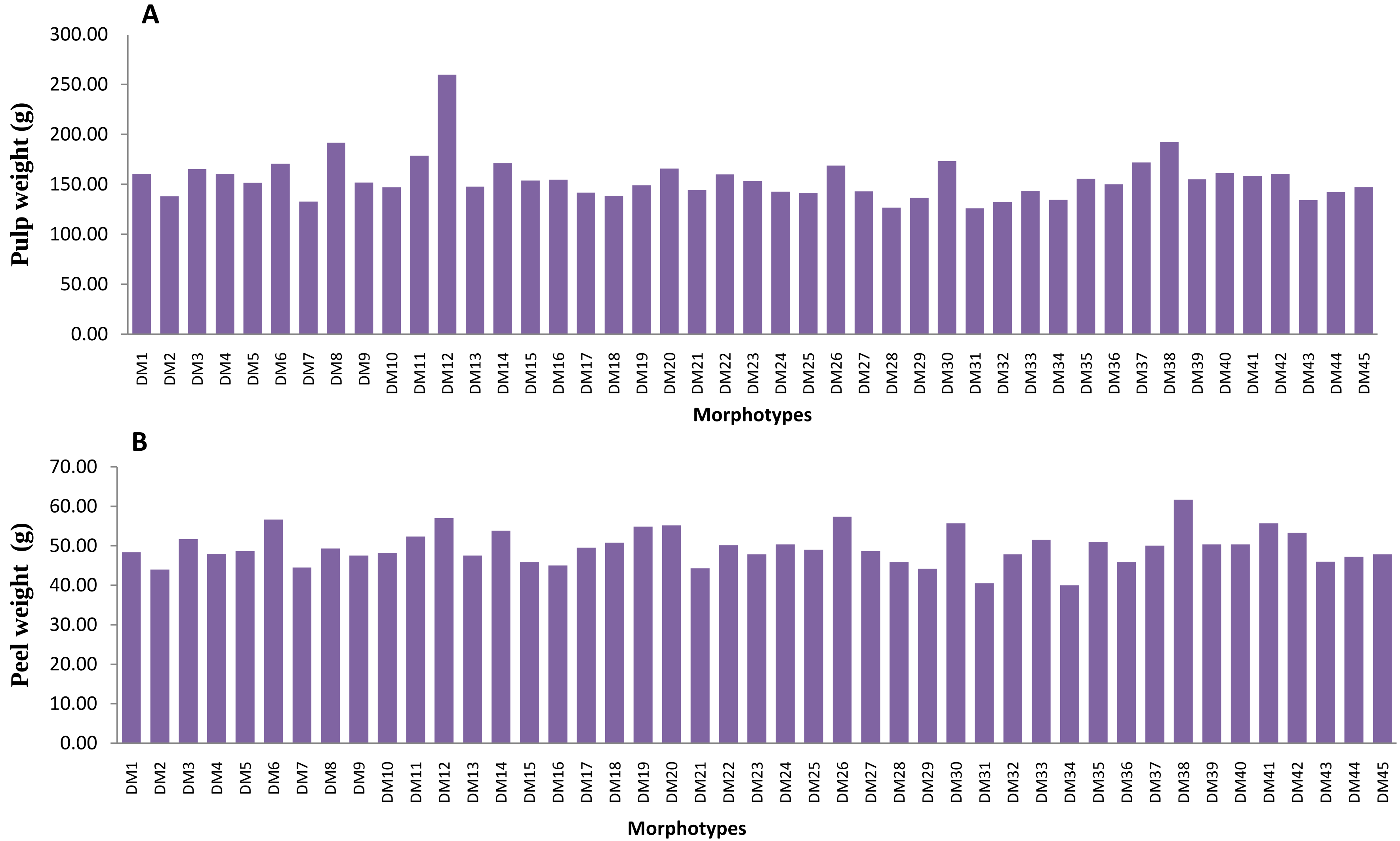


Fig. 4.11 Average performance of (A) pulp weight (g) and (B) peel weight (g) in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

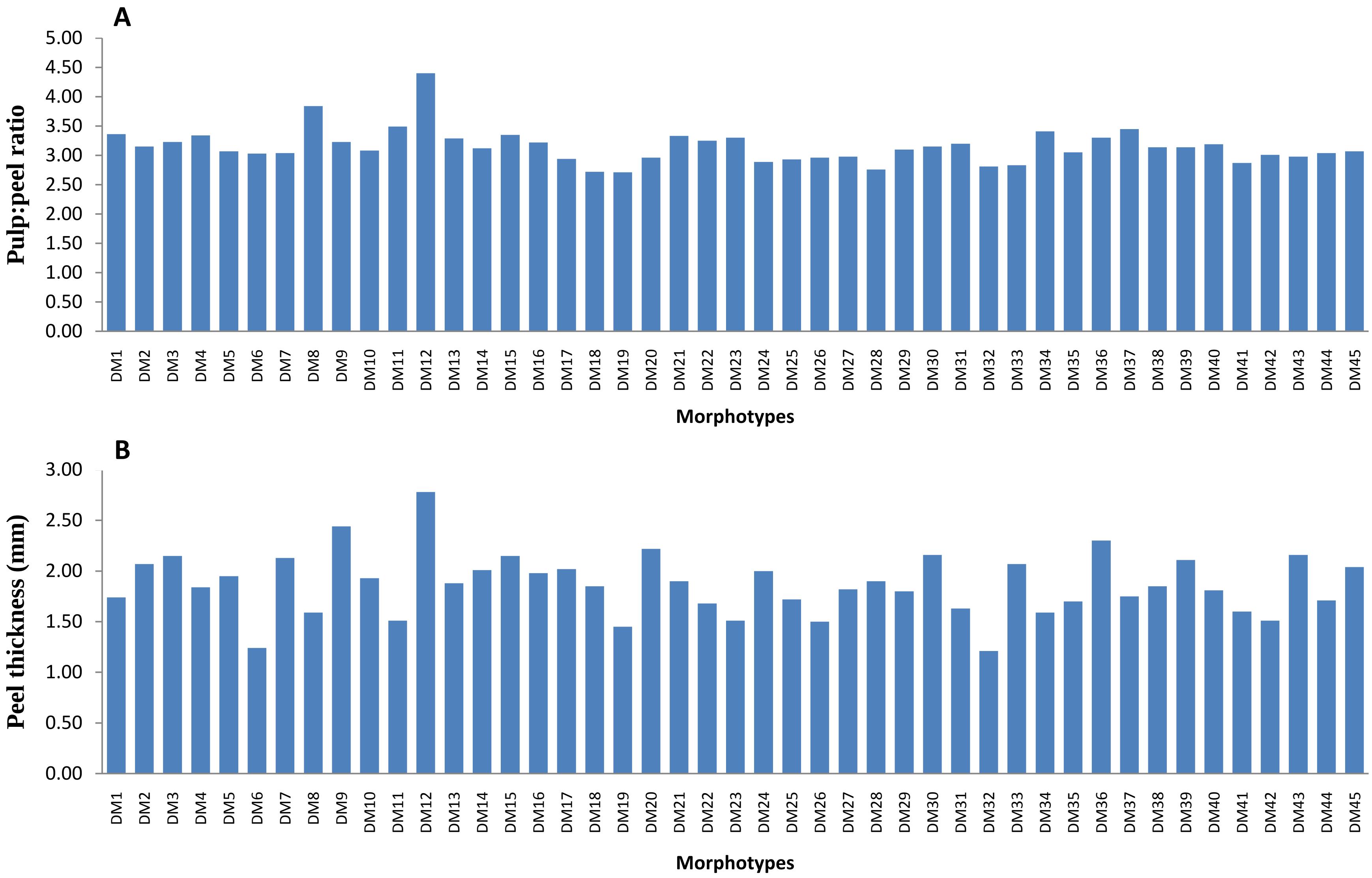


Fig. 4.12 Average performance of (A) pulp:peel ratio and (B) peel thickness (mm) in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

Plate 5: Longitudinal section of fruits of 45 morphotypes of mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow

Peel thickness (mm)

The significant intra-varietal variation was also observed for this character. The peel thickness was observed ranged from 1.21 to 2.71 mm with grand mean 1.86 mm (Table 4.15). The maximum peel thickness (2.78 mm) was observed for morphotype DM_{12} followed by morphotype DM_9 (2.44 mm) and DM_{36} (2.30 mm) and minimum peel thickness (1.21 mm) was recorded for morphotype DM_{32} showing statistically similarity with each other and (Table 4.9 and Figure 4.12B).

4.3.2 Stone morphology

Stone weight (g)

The stone weight ranged from 24.17 to 33.50 g with a grand mean of 29.97 g (Table 4.15). However, the maximum stone weight (33.50 g) was recorded for morphotype DM_{38} (33.50 g) followed by morphotype DM_{37} (32.67 g) and DM_6 (32.33 g) and minimum stone weight (24.17 g) was observed for morphotype DM_{31}. Thus, stone weight of various morphotypes showed wide variation between various morphotypes and presented in Table 4.10 and Figure 4.13A.

Pulp:stone ratio

Pulp:stone ratio also showed significant intra-varietal variation between different morphotypes under the investigation and varied from 4.36 to 8.04 with general mean of 5.17(Table 4.15). The maximum pulp:stone (8.04) ratio was observed for morphotype DM_{12} followed by morphotype DM_8 (6.33) and minimum pulp:stone (4.36) was recorded for morphotype DM_{28} which were at par with each other and as shown in Table 4.10 and Figure 4.13B.

Stone volume (ml)

The stone volume was ranged from 24.17 to 33.50 ml with a grand mean 29.57 ml (Table 4.15). The morphotype DM_{38} showed highest stone volume (31.83 ml) and DM_6 (31.17 ml) followed by morphotype DM_{37} (30.50 ml) and minimum stone volume (22.67 ml) for morphotype DM_{31}. The morphotypes DM_{38} and DM_6 were superior to all other morphotypes in terms of stone volume and as shown in Table 4.10 and Figure 4.14A.

Table 4.10 Average performance of stone morphology of mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow

Morphotypes	Stone weight (g)			Pulp:stone ratio			Volume of stone (ml)			Specific gravity of stone (g/cc)		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2016**	**Pooled**	**2016**	**2017**	**Pooled**
DM_1	30.67	28.33	29.50	5.40	5.50	5.43	29.33	27.33	28.33	1.07	1.03	1.05
DM_2	30.00	29.00	29.50	4.80	4.60	4.70	28.33	27.67	28.00	1.07	1.03	1.05
DM_3	30.33	30.33	30.33	5.43	5.50	5.47	29.00	26.67	27.83	1.03	1.10	1.07
DM_4	26.33	33.33	29.33	5.23	5.53	5.38	25.00	31.00	28.00	1.07	1.08	1.08
DM_5	27.00	34.00	30.50	4.63	5.23	4.92	25.00	31.00	28.00	1.10	1.07	1.09
DM_6	30.67	34.00	32.33	5.57	5.07	5.32	29.67	32.67	31.17	1.07	1.07	1.07
DM_7	25.00	30.00	27.50	5.13	4.60	4.86	22.33	28.67	25.50	1.10	1.07	1.09
DM_8	30.67	29.33	30.00	7.93	4.73	6.33	29.33	28.00	28.67	1.07	1.07	1.07
DM_9	30.33	30.00	30.17	5.17	4.98	5.07	29.33	28.00	28.67	1.03	1.10	1.07
DM_{10}	30.67	30.67	30.67	4.87	4.70	4.80	28.67	29.67	29.17	1.10	1.03	1.07
DM_{11}	31.00	30.00	30.50	6.03	5.67	5.87	29.00	28.33	28.67	1.10	1.07	1.09
DM_{12}	33.33	30.00	31.67	11.10	4.97	8.04	30.67	28.33	29.50	1.10	1.07	1.09
DM_{13}	30.67	28.00	29.33	5.33	4.73	5.03	29.00	27.00	28.00	1.07	1.03	1.05
DM_{14}	29.00	29.33	29.17	7.53	4.20	5.86	27.00	28.67	27.83	1.10	1.00	1.05
DM_{15}	31.00	33.33	32.17	4.37	5.17	4.76	28.33	32.00	30.17	1.10	1.03	1.07
DM_{16}	31.00	30.33	30.67	4.53	5.07	4.79	28.67	29.33	29.00	1.10	1.03	1.07
DM_{17}	29.67	29.67	29.67	5.53	4.03	4.78	28.67	29.67	29.17	1.03	1.00	1.02
DM_{18}	31.00	28.33	29.67	5.20	4.17	4.65	30.00	26.33	28.17	1.03	1.10	1.07
DM_{19}	32.33	31.00	31.67	5.30	4.07	4.70	29.67	29.00	29.33	1.10	1.10	1.10
DM_{20}	31.33	29.67	30.50	6.37	4.47	5.42	29.00	28.00	28.50	1.07	1.07	1.07
DM_{21}	29.67	29.67	29.67	5.07	4.73	4.88	26.33	27.67	27.00	1.10	1.10	1.10

DM_{22}	29.67	30.67	30.17	6.03	4.63	5.33	28.00	28.67	28.33	1.07	1.10	1.09
DM_{23}	30.33	32.00	31.17	5.47	4.40	4.93	28.33	30.00	29.17	1.07	1.07	1.07
DM_{24}	31.00	31.00	31.00	4.97	4.30	4.62	28.33	29.00	28.67	1.10	1.10	1.10
DM_{25}	31.33	29.00	30.17	4.63	4.80	4.71	29.33	27.33	28.33	1.07	1.07	1.07
DM_{26}	30.33	31.33	30.83	5.37	5.57	5.46	28.00	29.67	28.33	1.10	1.07	1.09
DM_{27}	31.67	30.67	31.17	4.90	4.27	4.58	29.33	29.00	29.17	1.10	1.07	1.09
DM_{28}	30.00	28.00	29.00	4.87	3.87	4.36	27.67	26.67	27.17	1.07	1.03	1.05
DM_{29}	26.67	31.33	29.00	4.87	4.56	4.70	24.67	29.00	26.83	1.07	1.10	1.09
DM_{30}	30.33	31.33	30.83	6.10	5.23	5.64	28.33	29.33	28.83	1.07	1.10	1.09
DM_{31}	20.00	28.33	24.17	5.67	4.97	5.29	19.00	26.33	22.67	1.07	1.07	1.07
DM_{32}	26.00	30.00	28.00	5.00	4.50	4.74	23.67	28.00	25.83	1.07	1.10	1.09
DM_{33}	30.33	30.67	30.50	4.93	4.50	4.72	27.67	29.33	28.50	1.10	1.07	1.09
DM_{34}	23.67	27.67	25.67	5.97	4.67	5.31	21.67	25.67	23.67	1.10	1.10	1.10
DM_{35}	25.67	33.33	29.50	4.80	5.67	5.24	24.00	32.33	28.17	1.07	1.00	1.04
DM_{36}	23.67	29.67	26.67	5.73	5.67	5.70	21.33	27.67	24.50	1.07	1.10	1.09
DM_{37}	31.00	34.33	32.67	4.67	5.83	5.24	29.00	32.00	30.50	1.10	1.10	1.10
DM_{38}	29.33	37.67	33.50	5.37	6.10	5.71	27.00	36.67	31.83	1.03	1.03	1.03
DM_{39}	28.00	32.33	30.17	5.27	5.03	5.14	26.00	30.33	28.17	1.03	1.10	1.07
DM_{40}	26.33	35.00	30.67	4.73	5.77	5.24	24.00	33.00	28.50	1.10	1.07	1.09
DM_{41}	31.33	31.33	31.33	4.77	5.33	5.06	29.67	29.33	29.50	1.07	1.10	1.09
DM_{42}	31.67	32.00	31.83	5.03	5.10	5.05	28.67	30.00	29.33	1.10	1.10	1.10
DM_{43}	22.67	28.67	25.67	5.60	5.13	5.35	20.67	26.67	23.67	1.07	1.10	1.09
DM_{44}	26.33	30.67	28.50	4.60	5.33	4.95	24.67	29.00	26.83	1.07	1.07	1.07
DM_{45}	30.00	33.00	31.50	3.77	5.47	4.62	28.00	31.67	29.83	1.10	1.03	1.07
SE(m)±	1.05	2.04	1.30	0.47	0.57	0.37	1.09	1.91	1.28	0.03	0.03	0.02
CD (P=0.05)	**2.07**	**4.04**	**2.58**	**0.93**	**1.13**	**0.73**	**2.15**	**3.78**	**2.53**	**0.05**	**0.05**	**0.03**

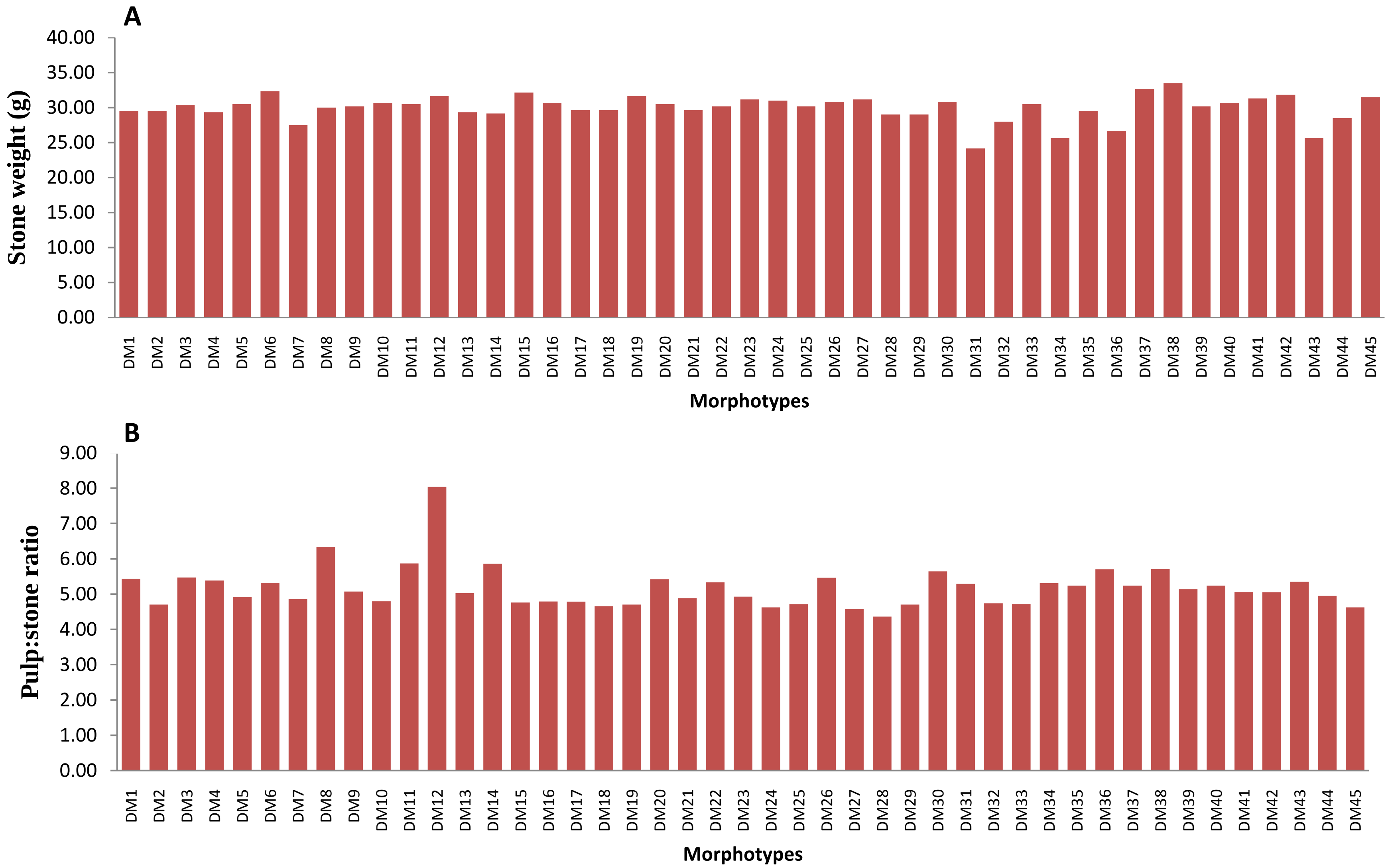


Fig. 4.13 Average performance of (A) stone weight (g) and (B) pulp:stone ratio in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

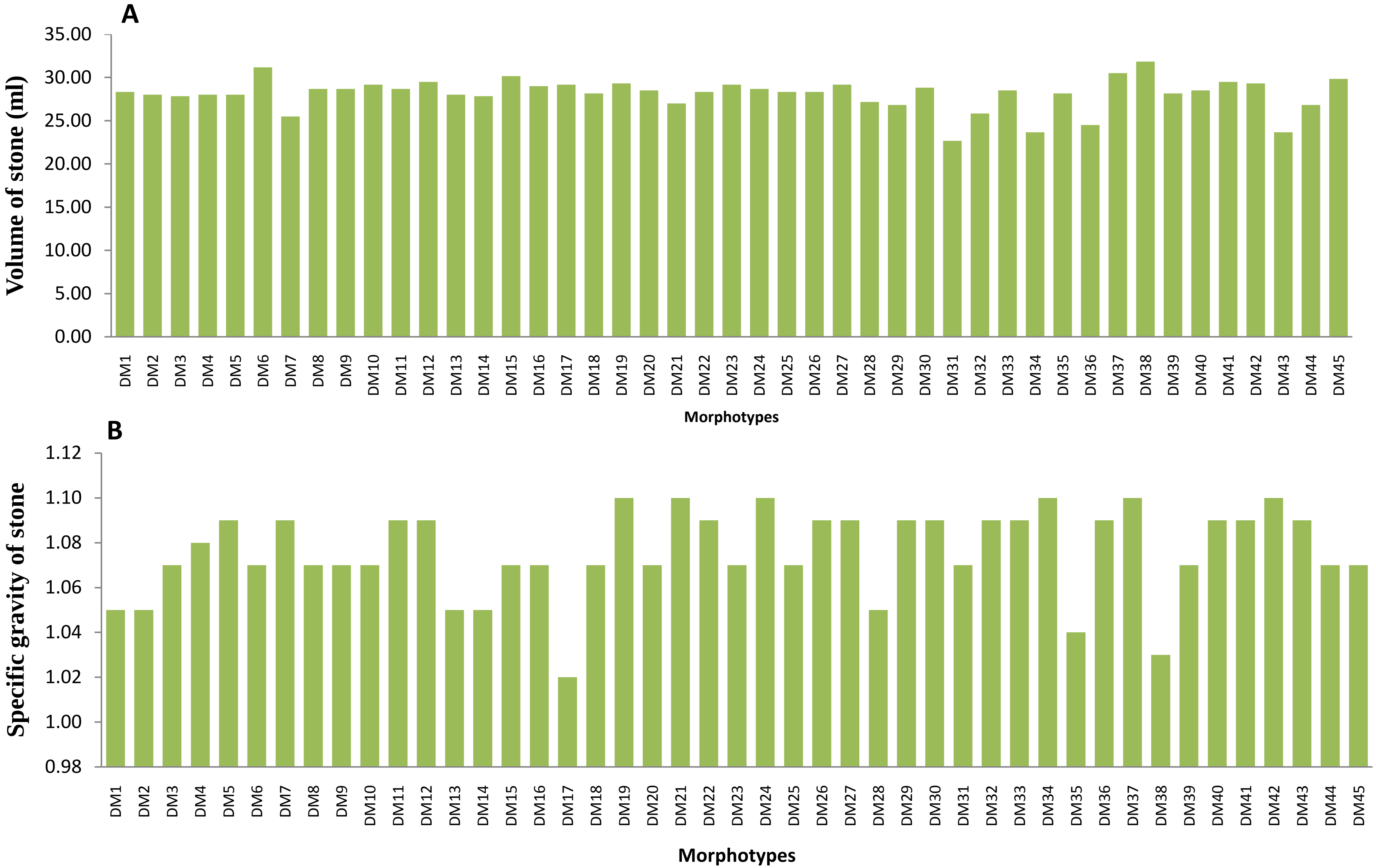


Fig. 4.14 Average performance of (A) stone volume (ml) and (B) specific gravity of stone in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

Specific gravity of stone

The maximum specific gravity of stone (1.10) was observed for morphotype DM_{19}, DM_{21}, DM_{24}, DM_{37} and DM_{41} followed by morphotype DM_7, DM_{10} and DM_{11}(1.09), respectively. The minimum specific gravity of stone (1.02) was recorded for morphotype DM_{38} (Table 4.10 and Figure 4.14B).

Stone length (cm)

The data pertaining to stone length of different morphotypes revealed significant intra-cultivar variation among the morphotypes and stone length varied between 8.99 to 11.75 cm and grand mean of 10.01 cm (Table 4.15). However, the maximum stone length (11.75 cm) was observed for morphotype DM_{12} followed by morphotype DM_9 (11.69 cm), DM_{11} and DM_{39} (11.27 cm) respectively. The shortest stone length (8.99 cm) was observed for morphotype DM_6 which were at par with each other (Table 4.11 and Figure 4.15A).

Stone width (cm)

A significant intra-varietal variation among different morphotypes were recorded for stone width which ranged from 2.72 to 3.85 cm with a grand mean of 3.37 cm (Table 4.15). However, the maximum stone width (4.14 cm) was recorded in morphotype DM_7 followed by DM_{18} (3.87 cm) and DM_{44} (3.83 cm) which was significantly higher in comparison to other morphotypes under study (Table 4.11 and Figure 4.15B). Morphotype DM_{33} showed significant lower stone width (2.72 cm).

Stone thickness (cm)

Stone thickness was ranged from 1.44 to 1.93 cm with 1.67 cm grand mean (Table 4.15). The highest stone thickness (1.93 cm) was recorded for morphotype DM_7 followed by morphotype DM_{42} (1.91 cm) and DM_{45} (1.90 cm). The minimum stone thickness was observed for morphotype DM_9 (1.44 cm) as shown in Table 4.11 and Figure 4.16

Table 4.11 Average performance of stone morphology of mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow

Morphotypes	Stone length (cm)			Stone width (cm)			Stone thickness (cm)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
DM_1	9.10	11.30	10.20	3.17	2.90	3.04	1.39	1.72	1.56
DM_2	9.70	10.53	10.12	3.67	3.23	3.45	1.19	2.06	1.63
DM_3	9.40	11.73	10.57	3.00	3.07	3.04	1.67	1.45	1.56
DM_4	11.07	10.03	10.55	4.13	2.57	3.35	1.49	1.72	1.61
DM_5	9.70	10.57	10.14	2.83	3.20	3.02	1.51	1.56	1.54
DM_6	8.40	9.57	8.99	4.23	3.17	3.70	1.88	1.97	1.55
DM_7	8.97	9.70	9.34	5.17	3.10	4.14	1.53	1.57	1.93
DM_8	10.03	10.97	10.50	3.50	2.90	3.20	1.60	1.89	1.75
DM_9	11.27	12.10	11.69	3.47	2.90	3.19	1.46	1.42	1.44
DM_{10}	9.97	11.17	10.57	3.67	2.93	3.30	1.56	1.75	1.66
DM_{11}	12.20	10.33	11.27	4.07	3.30	3.69	1.69	1.89	1.79
DM_{12}	13.17	10.33	11.75	3.27	3.23	3.25	1.54	1.82	1.68
DM_{13}	11.03	10.97	11.00	3.57	3.27	3.42	1.98	1.71	1.85
DM_{14}	9.07	9.97	9.52	4.43	3.27	3.85	1.50	1.94	1.72
DM_{15}	10.27	9.33	9.80	3.60	3.03	3.32	1.52	1.53	1.53
DM_{16}	9.87	9.80	9.84	3.73	3.13	3.43	1.63	1.63	1.63
DM_{17}	10.07	9.67	9.87	4.63	2.53	3.58	1.62	1.56	1.59
DM_{18}	9.40	9.90	9.65	5.20	2.53	3.87	1.52	1.52	1.52
DM_{19}	10.03	9.50	9.77	4.63	2.80	3.72	1.72	1.55	1.64
DM_{20}	10.03	11.43	10.73	3.60	3.00	3.30	1.74	1.65	1.70
DM_{21}	8.37	9.80	9.09	3.63	2.40	3.02	1.80	1.66	1.73
DM_{22}	10.27	9.97	10.12	3.73	3.00	3.37	1.38	1.66	1.52
DM_{23}	9.00	9.10	9.05	3.17	3.07	3.12	1.71	1.48	1.60

DM_{24}	9.20	10.07	9.64	3.33	3.03	3.18	1.77	1.62	1.70
DM_{25}	8.97	9.77	9.37	3.73	3.00	3.37	1.70	1.77	1.74
DM_{26}	9.97	10.50	10.24	3.643	3.10	3.37	1.63	1.77	1.70
DM_{27}	9.77	9.97	9.87	3.73	3.07	3.40	1.57	1.70	1.64
DM_{28}	8.03	10.67	9.35	3.90	3.23	3.57	1.56	1.69	1.63
DM_{29}	9.13	9.80	9.47	3.13	3.07	3.10	1.90	1.84	1.87
DM_{30}	10.80	9.50	10.15	3.50	3.07	3.29	1.57	1.75	1.66
DM_{31}	8.00	11.23	9.62	3.33	3.50	3.42	1.67	1.66	1.67
DM_{32}	9.07	9.50	9.29	3.20	3.40	3.30	1.69	1.79	1.74
DM_{33}	9.87	9.57	9.72	2.43	3.00	2.72	1.66	1.71	1.69
DM_{34}	8.60	9.40	9.00	3.30	3.17	3.24	1.70	1.81	1.76
DM_{35}	9.27	10.70	9.99	3.37	3.53	3.45	1.51	1.73	1.62
DM_{36}	9.97	10.77	10.37	3.20	3.17	3.19	1.41	1.94	1.68
DM_{37}	9.00	11.83	10.42	3.53	3.57	3.55	1.38	1.88	1.63
DM_{38}	8.10	11.50	9.80	2.93	3.57	3.25	1.62	1.93	1.78
DM_{39}	10.03	12.50	11.27	3.878	3.37	3.62	1.46	1.78	1.62
DM_{40}	8.83	10.53	9.68	3.47	3.17	3.32	1.67	1.86	1.77
DM_{41}	9.00	10.10	9.55	3.43	3.37	3.40	1.72	1.85	1.79
DM_{42}	9.03	9.70	9.37	3.20	3.00	3.10	1.81	2.01	1.91
DM_{43}	8.83	9.53	9.18	3.27	3.20	3.24	1.74	1.64	1.69
DM_{44}	8.80	12.20	10.50	3.83	3.83	3.83	1.53	1.93	1.73
DM_{45}	9.57	11.77	10.67	3.60	3.37	3.49	1.87	1.93	1.90
SE(m)±	0.62	0.62	0.44	0.35	0.24	0.21	0.17	0.20	0.13
CD (P=0.05)	**1.22**	**1.22**	**0.87**	**0.69**	**0.47**	**0.41**	**0.33**	**0.39**	**0.25**

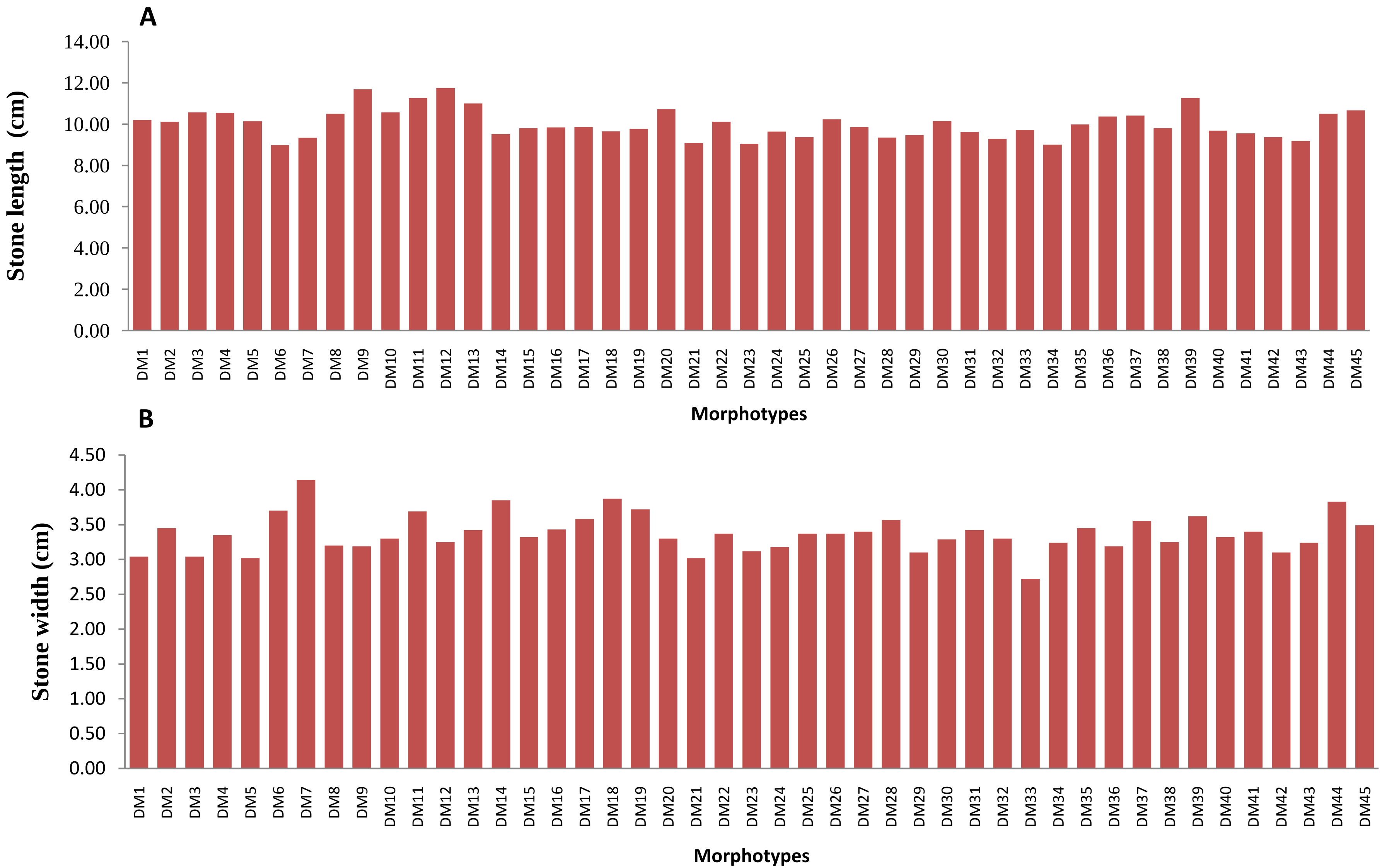


Fig. 4.15 Average performance of (A) stone length (cm) and (B) stone width (cm) in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

Fig. 4.16 Average performance of stone thickness in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

4.3.3 Kernel morphology

Kernel length (cm)

Data pertaining to kernel length of different morphotypes of Dashehari mango revealed significant intra-cultivar variation among different morphotypes (Table 4.12 and Figure 4.17A). Morphotypes DM_{44}, DM_{31}, DM_{38} and DM_{42} had maximum kernel length (6.64 cm), (6.63 cm) and (6.62 cm) followed by morphotype DM_{40} (6.50 cm), DM_{37} (6.48 cm), respectively. However, the minimum kernel width (3.65 cm) was recorded from morphotype DM_{27}.

Kernel width (cm)

The maximum kernel width (41.13 cm) was recorded from morphotype DM_{10} closely followed by morphotype DM_{12} (3.35 cm) and DM_5 (3.29 cm), while the minimum kernel width (1.46 cm) was observed from morphotype DM_{14} as shown in Table 4.12 and Figure 4.17B.

Kernel thickness (cm)

The kernel thickness showed variation among various morphotype varied from 1.04 to 2.07 cm with a grand mean 1.42 cm (Table 4.15). However, the maximum kernel thickness (2.07 cm), (2.06 cm), (2.05 cm) and (2.04 cm) were observed from morphotype DM_{25}, DM $_{20}$, DM_3 and DM_{27}, respectively, and the minimum kernel thickness (1.04 cm) was observed from morphotype DM_1(Table 4.12 and Figure 4.18).

4.3.4 Fruit bio-chemical analysis of different Dashehari morphotypes

Total soluble solid (TSS) (ºBrix)

The significant variation was observed for total soluble solids content in fruit pulp among various morphotype, which ranged from 11.73 to 21.33 ºB with grand mean 15.16 ºB (Table 4.15). Therefore, the highest TSS (21.33ºBrix) and (21.07 ºB) was observed from morphotype (DM_2 and DM_1), respectively followed by morphotype (20.82 ºB) which was at par with morphotype DM_4 (20.45 ºB). DM_{10} showed lowest TSS (11.73 ºB) followed by morphotype DM_{12} (11.80 ºB) as shown in Table 4.13 and Figure 4.19A.

Table 4.12 Average performance of kernel morphology of mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow

Morphotypes	Kernel length (cm)			Kernel width (cm)			Kernel thickness (cm)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
DM_1	5.03	5.93	5.48	2.61	2.30	2.46	1.03	1.04	1.04
DM_2	5.33	5.30	5.32	1.84	1.73	1.79	1.40	1.40	1.40
DM_3	5.53	5.03	5.28	2.27	2.33	2.30	2.07	2.03	2.05
DM_4	5.80	6.10	5.95	3.08	3.00	3.04	1.70	1.67	1.69
DM_5	6.13	4.77	5.45	3.51	3.07	3.29	1.17	1.16	1.17
DM_6	6.13	6.07	6.10	2.48	2.40	2.44	1.33	1.32	1.33
DM_7	4.70	5.37	5.04	2.17	1.97	2.07	1.17	1.16	1.17
DM_8	4.90	4.90	4.90	2.40	2.17	2.29	1.17	1.18	1.18
DM_9	4.43	5.43	4.93	1.58	1.77	1.68	1.20	1.22	1.21
DM_{10}	5.57	5.57	5.57	4.18	4.07	4.13	1.40	1.40	1.40
DM_{11}	5.10	5.00	5.05	1.77	1.50	1.64	1.37	1.37	1.37
DM_{12}	5.80	6.80	6.30	3.49	3.21	3.35	1.10	1.08	1.09
DM_{13}	4.57	4.57	4.57	1.77	1.97	1.87	1.50	1.51	1.51
DM_{14}	6.13	6.50	6.32	1.44	1.47	1.46	1.67	1.65	1.66
DM_{15}	6.20	6.03	6.12	2.66	2.33	2.50	1.27	1.27	1.27
DM_{16}	6.33	6.23	6.28	2.54	2.40	2.47	1.33	1.33	1.33
DM_{17}	5.47	6.10	5.79	2.29	2.10	2.20	1.53	1.53	1.53
DM_{18}	4.53	4.30	4.42	2.70	2.27	2.49	1.37	1.35	1.36
DM_{19}	5.73	5.53	5.63	1.77	1.73	1.75	1.27	1.26	1.27
DM_{20}	4.63	4.50	4.57	2.70	2.30	2.50	2.07	2.05	2.06
DM_{21}	5.60	5.67	5.64	2.40	2.23	2.32	1.43	1.44	1.44
DM_{22}	5.47	5.23	5.35	2.67	2.30	2.49	1.57	1.56	1.57
DM_{23}	6.60	6.37	6.49	2.30	2.17	2.24	1.17	1.17	1.17
DM_{24}	5.50	5.83	5.67	1.70	1.87	1.79	1.53	1.55	1.54
DM_{25}	5.57	5.20	5.39	2.20	2.07	2.14	2.07	2.06	2.07

DM_{26}	4.83	4.57	4.70	2.50	2.17	2.34	2.00	2.01	2.01
DM_{27}	3.83	3.47	3.65	2.63	2.20	2.42	2.04	2.04	2.04
DM_{28}	4.43	4.60	4.52	2.33	2.33	2.33	1.13	1.12	1.13
DM_{29}	4.67	4.33	4.50	1.87	1.97	1.92	1.10	1.10	1.10
DM_{30}	5.65	4.73	5.19	2.70	2.33	2.52	1.13	1.12	1.13
DM_{31}	6.60	6.67	6.64	2.80	2.40	2.60	1.53	1.51	1.52
DM_{32}	5.77	4.70	5.24	2.80	2.63	2.72	1.33	1.34	1.34
DM_{33}	4.37	4.07	4.22	2.27	2.00	2.14	1.17	1.19	1.18
DM_{34}	4.90	5.33	5.12	2.40	2.13	2.27	1.23	1.25	1.24
DM_{35}	4.63	5.07	4.85	2.30	2.73	2.52	1.13	1.14	1.14
DM_{36}	4.93	6.03	5.48	2.33	2.20	2.27	1.40	1.39	1.40
DM_{37}	6.33	6.63	6.48	1.97	3.07	2.52	1.57	1.55	1.56
DM_{38}	6.60	6.17	6.39	3.03	2.97	3.00	1.67	1.65	1.66
DM_{39}	5.33	5.57	5.45	2.57	2.27	2.42	1.33	1.34	1.34
DM_{40}	6.90	6.10	6.50	2.73	2.23	2.48	1.37	1.36	1.37
DM_{41}	6.77	6.20	6.49	2.53	2.20	2.37	1.43	1.43	1.43
DM_{42}	6.87	6.37	6.62	3.27	3.13	3.20	1.47	1.47	1.47
DM_{43}	4.47	4.17	4.32	2.57	2.83	2.70	1.23	1.24	1.24
DM_{44}	6.80	6.47	6.64	2.87	2.53	2.70	1.43	1.45	1.44
DM_{45}	4.87	5.30	5.09	2.67	2.33	2.50	1.60	1.58	1.59
SE(m)±	0.24	0.23	0.17	0.19	0.21	0.14	0.10	0.12	0.07
CD (P=0.05)	**0.47**	**0.45**	**0.33**	**0.37**	**0.41**	**0.27**	**0.19**	**0.23**	**0.13**

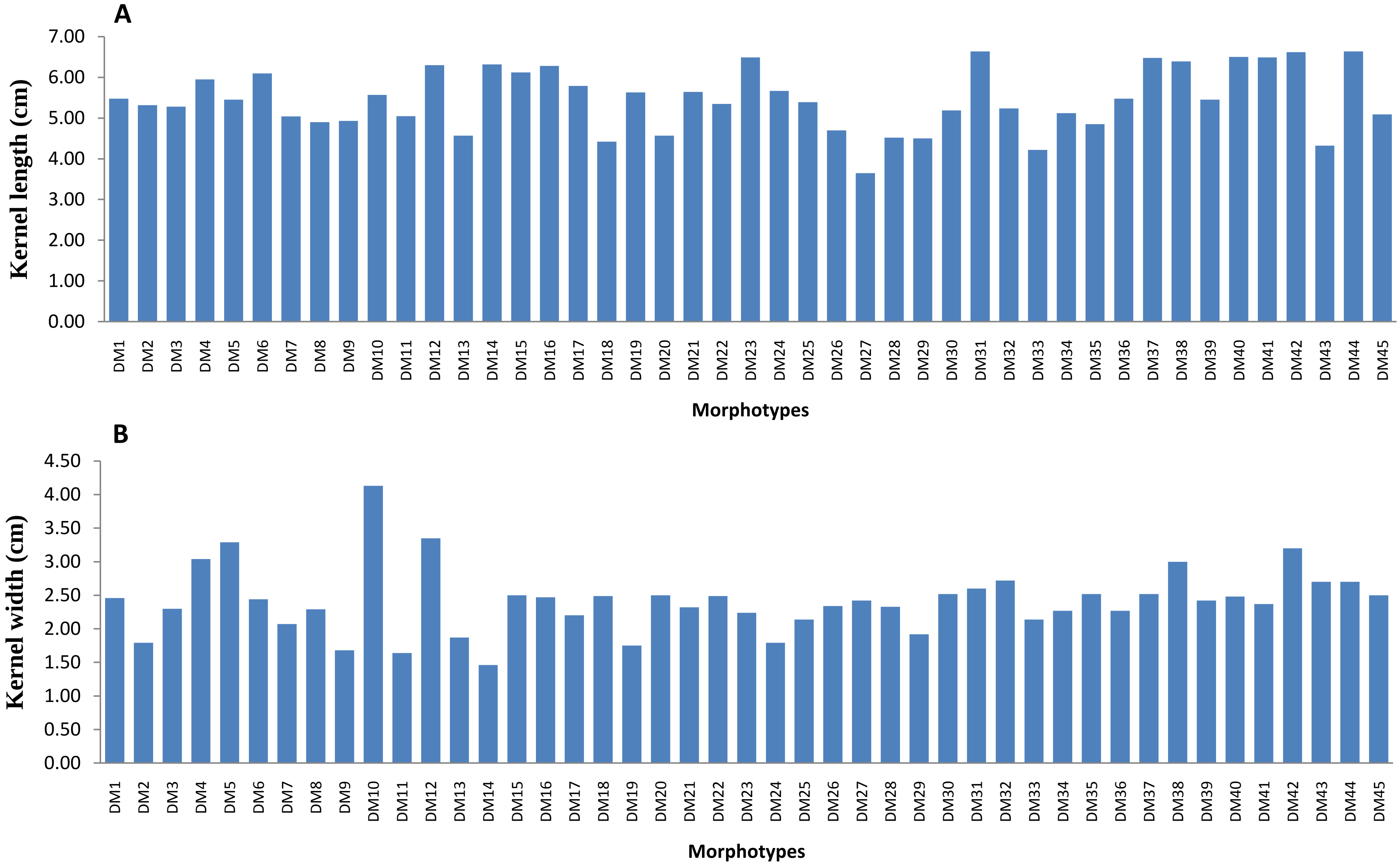


Fig. 4.17 Average performance of (A) kernel length (cm) and (B) kernel width (cm) in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

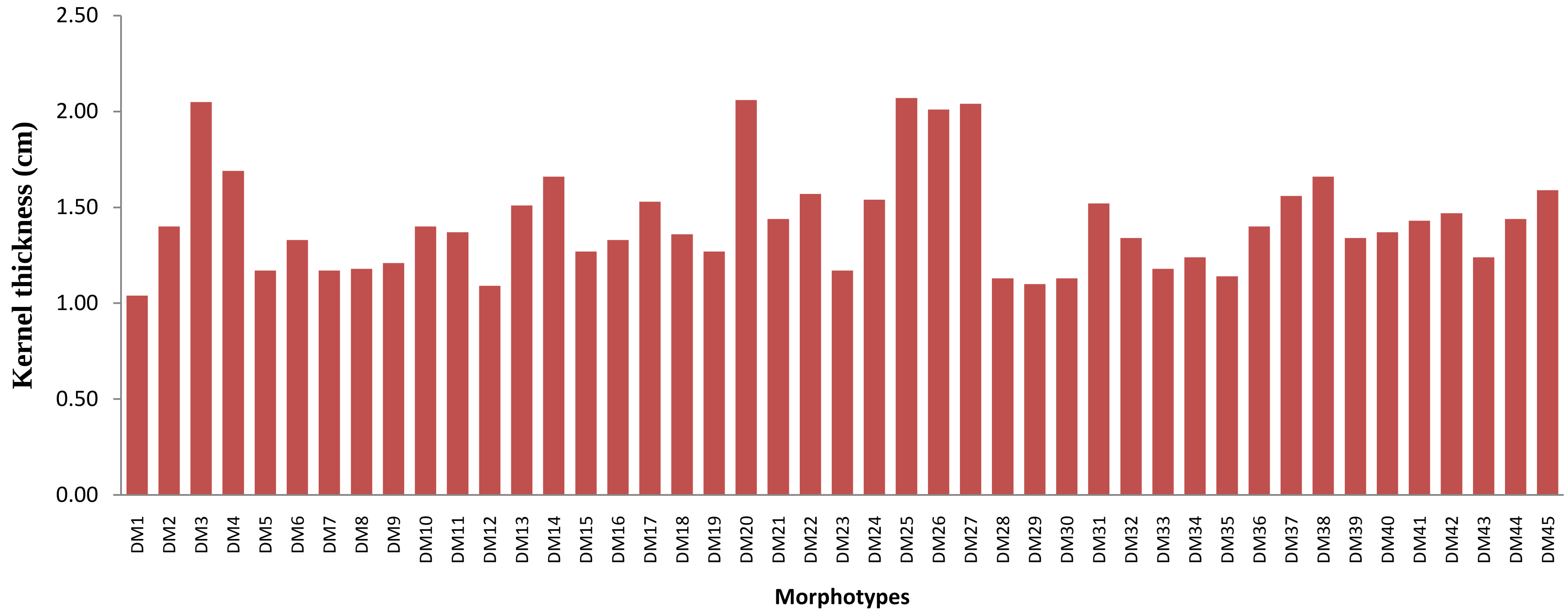


Fig. 4.18 Average performance of kernel thickness (cm) in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

Plate 6: Variation in (A) stone morphology (B) longitudinal section of stone (C) kernel morphology of 45 morphotypes of mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow

pH of the fruit pulp

pH of fruit pulp varied from 4.3 to 7.0 with grand mean of 5.53, showing maximum pH (7.0) in morphotype DM_{24} closely followed by morphotype DM_7 (6.8) and DM_{30} (6.7) which were at par with DM_{36} (6.3), DM_{21} and DM_{35} (6.2). The minimum pH of fruit pulp (4.3) was observed for morphotype DM_{18} followed by morphotype DM_9 (4.5) as shown in Table 4.13 and Figure 4.19B.

Titratable acidity (%)

Titrable acidity in term of citric acid was determined for various morphotypes and it varied from 0.27 to 0.37 % with grand mean of 0.32% (Table 4.15). However, the maximum titrable acidity (0.37 %) was observed from morphotype DM_{26} and DM_{27} closely followed by morphotype DM_{10}, DM_{28}, and DM_{34} (0.36%) respectively while, the minimum titrable acidity (0.27 %) was observed for morphotype DM_{36} followed by morphotype DM_{37} (0.28 %) (Table 4.13 and Figure 4.20A).

TSS:acid ratio

The TSS:acid ratio showed significant intra-varietal variation between different morphotypes. The range of TSS:acid ratio was recorded between 33.16 to 38.74 with a grand mean 47.15 (Table 4.15). However, The highest TSS:acid ratio (68.74) was observed for morphotype DM_1 followed by morphotype DM_2 (67.41). However, the minimum TSS:acid ratio was recorded from morphotype DM_9 (33.07) followed by morphotype DM_{27} (33.16) and as presented in Table 4.13 and Figure 4.20B.

Reducing sugar (%)

The data pertaining to reducing sugar of different Dashehari morphotypes revealed that it varied from 2.52 to 5.48 % with a grand mean 4.15 % (Table 4.15). The maximum reducing sugar (5.48 %) was observed from morphotype DM_{33} followed by morphotype DM_{13} (5.40 %). The minimum reducing sugar (2.52 %) was observed in morphotype DM_9 followed by morphotype DM_{23} (2.68 %) which were at par with each other (Table 4.14 and Figure 4.21A).

Table 4.13 Average performance of fruit bio-chemical parameters in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow

Morphotypes	Total soluble solids (°Brix)			pH of the juice			Titratable acidity (%)			TSS:acid ratio		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
DM_1	21.27	20.9	21.07	5.47	5.00	5.30	0.31	0.30	0.31	68.56	68.91	68.74
DM_2	21.17	21.5	21.33	5.40	5.60	5.50	0.32	0.31	0.32	66.19	68.63	67.41
DM_3	20.90	20.7	20.82	5.90	5.70	5.80	0.32	0.33	0.33	65.37	62.83	64.10
DM_4	20.27	20.6	20.45	5.40	6.10	5.80	0.33	0.32	0.33	60.82	63.83	62.33
DM_5	19.73	20.1	19.90	5.90	5.90	6.00	0.33	0.33	0.33	59.90	61.46	60.68
DM_6	20.13	20.5	20.30	7.13	6.20	6.10	0.34	0.35	0.35	59.23	58.47	58.85
DM_7	18.73	19.0	18.87	4.93	6.40	6.80	0.32	0.33	0.32	59.18	58.18	58.68
DM_8	18.30	17.7	18.02	4.70	5.30	5.10	0.32	0.31	0.32	57.19	56.61	56.90
DM_9	19.00	18.3	18.67	3.43	4.30	4.50	0.31	0.32	0.31	61.95	57.89	59.92
DM_{10}	11.40	12.1	11.73	5.27	6.10	4.80	0.36	0.35	0.36	31.98	34.16	33.07
DM_{11}	13.90	13.1	13.50	5.87	4.90	5.10	0.35	0.36	0.35	39.71	36.75	38.23
DM_{12}	11.93	11.7	11.80	5.90	6.00	5.90	0.35	0.34	0.35	33.77	34.01	33.89
DM_{13}	15.40	16.1	15.73	5.93	5.10	5.50	0.29	0.30	0.29	53.15	54.25	53.70
DM_{14}	14.53	14.8	14.65	3.37	5.60	5.80	0.28	0.27	0.28	51.32	54.04	52.68
DM_{15}	14.60	13.8	14.20	5.03	6.20	4.80	0.30	0.31	0.30	49.20	45.01	47.11
DM_{16}	15.07	14.8	14.92	6.37	5.60	5.30	0.30	0.31	0.30	50.24	48.14	49.19
DM_{17}	11.97	12.6	12.28	3.40	5.20	5.80	0.31	0.32	0.31	38.65	39.81	39.23
DM_{18}	15.27	15.7	15.48	5.20	5.10	4.30	0.32	0.30	0.31	48.23	51.78	50.00
DM_{19}	15.07	14.7	14.88	5.37	4.60	4.90	0.34	0.34	0.34	43.94	43.23	43.59
DM_{20}	12.30	12.7	12.52	6.37	5.90	5.60	0.33	0.34	0.33	37.32	37.84	37.58
DM_{21}	13.50	14.0	13.75	5.10	6.00	6.20	0.34	0.33	0.34	40.12	42.03	41.07
DM_{22}	15.03	15.9	15.48	5.30	4.50	4.80	0.36	0.37	0.36	42.15	43.46	42.80
DM_{23}	15.40	15.9	15.63	7.03	5.60	5.50	0.34	0.35	0.34	45.75	45.79	45.77
DM_{24}	14.23	13.4	13.82	5.83	6.9	7.0	0.31	0.30	0.31	45.98	44.14	45.06

DM_{25}	13.40	12.6	12.98	4.33	5.1	5.5	0.33	0.34	0.33	41.06	36.97	39.02
DM_{26}	15.10	15.9	15.52	5.27	5.4	4.9	0.38	0.36	0.37	40.10	43.86	41.98
DM_{27}	12.57	11.6	12.10	5.30	4.6	4.9	0.37	0.36	0.37	34.27	32.04	33.16
DM_{28}	12.23	12.9	12.57	5.53	5.6	5.5	0.36	0.37	0.36	34.01	35.19	34.60
DM_{29}	14.00	13.5	13.75	7.30	5.8	5.7	0.32	0.33	0.33	43.31	41.37	42.34
DM_{30}	14.43	15.3	14.85	6.17	6.2	6.7	0.28	0.27	0.27	52.19	56.55	54.37
DM_{31}	11.67	12.5	12.08	5.17	6.3	6.3	0.29	0.31	0.30	39.79	40.75	40.27
DM_{32}	14.20	15.4	14.82	5.63	5.0	5.1	0.32	0.31	0.32	44.39	49.25	46.82
DM_{33}	14.03	13.1	13.57	5.33	5.5	5.6	0.34	0.35	0.35	40.87	37.76	39.32
DM_{34}	13.50	14.1	13.80	6.13	5.0	5.2	0.36	0.35	0.36	37.85	39.92	38.88
DM_{35}	15.33	15.9	15.63	6.40	6.3	6.2	0.29	0.30	0.29	52.94	53.76	53.35
DM_{36}	14.63	13.3	13.98	5.23	6.2	6.3	0.27	0.27	0.27	54.91	49.43	52.17
DM_{37}	12.57	13.9	13.22	6.13	5.3	5.3	0.29	0.28	0.28	43.85	49.53	46.69
DM_{38}	12.07	13.3	12.67	5.43	5.6	5.9	0.30	0.31	0.31	39.81	43.26	41.54
DM_{39}	13.70	13.4	13.55	5.13	5.1	5.3	0.31	0.30	0.31	44.69	44.19	44.44
DM_{40}	15.73	16.2	15.95	5.87	5.0	5.1	0.33	0.32	0.32	48.17	50.57	49.37
DM_{41}	15.43	15.8	15.63	4.27	6.0	6.0	0.32	0.32	0.32	48.26	50.05	49.16
DM_{42}	12.47	12.1	12.30	5.13	5.8	5.0	0.34	0.34	0.34	36.31	36.02	36.16
DM_{43}	13.80	12.7	13.23	6.20	5.3	5.2	0.34	0.33	0.34	40.26	38.09	39.17
DM_{44}	15.20	16.0	15.60	5.77	5.8	6.0	0.33	0.34	0.34	45.62	47.53	46.58
DM_{45}	14.37	15.4	14.87	6.10	5.3	5.5	0.35	0.36	0.35	41.07	43.08	42.08
SE(m)±	0.41	0.55	0.34	0.31	0.29	0.21	0.06	0.07	0.04	1.79	1.89	1.30
CD (P=0.05)	**0.81**	**1.08**	**0.67**	**0.61**	**0.57**	**0.41**	**0.11**	**0.13**	**0.07**	**3.54**	**3.74**	**2.57**

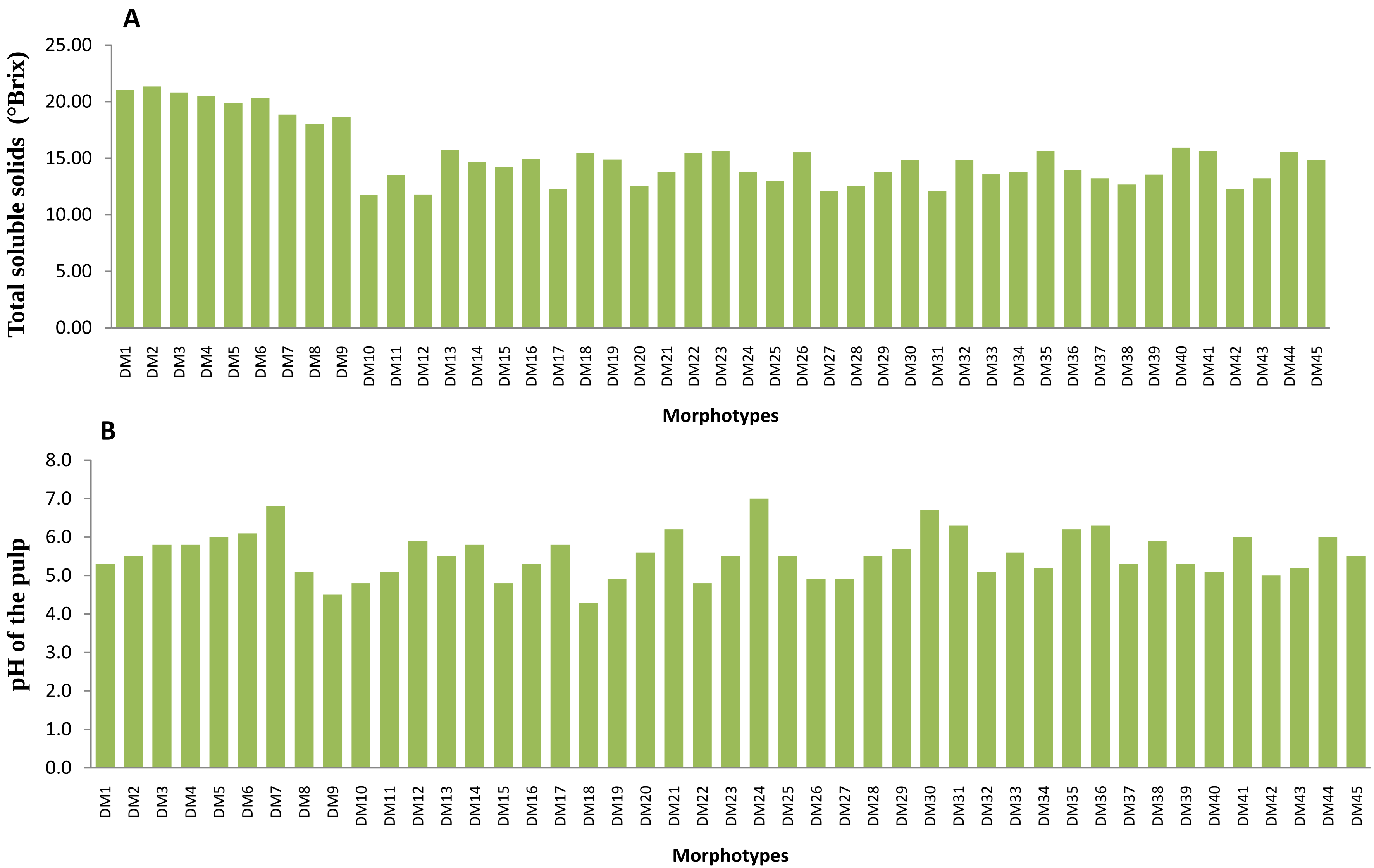


Fig. 4.19 Average performance of (A) total soluble solids (^{0}Brix) and (B) pH of the pulp in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

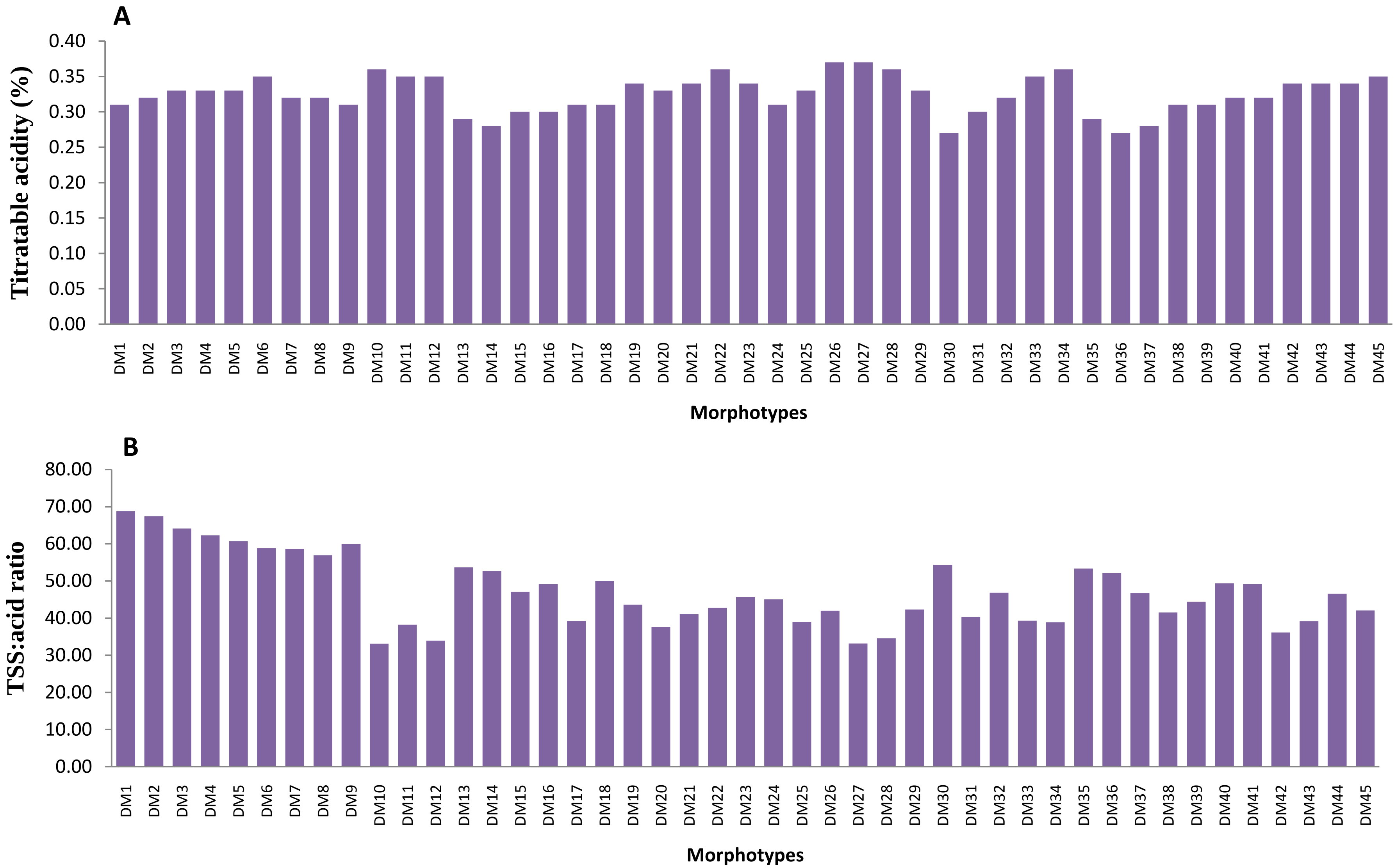


Fig. 4.20 Average performance of (A) titratable acidity (%) and (B) TSS:acid ratio in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

Table 4.14 Average performance of fruit bio-chemical parameters in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow

Morphotypes	Reducing sugar (%)			Non-reducing sugar (%)			Total sugars (%)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
DM_1	3.30	3.13	3.22	11.87	11.90	11.88	15.17	15.03	15.10
DM_2	3.50	3.57	3.53	12.07	12.00	12.03	15.57	15.57	15.57
DM_3	3.70	3.57	3.63	12.03	12.20	12.12	15.73	15.77	15.75
DM_4	4.00	3.77	3.88	10.97	11.73	11.35	14.97	15.50	15.23
DM_5	4.00	4.20	4.10	10.83	11.47	11.15	14.83	15.67	15.25
DM_6	3.50	3.57	3.53	10.70	10.60	10.65	14.20	14.17	14.18
DM_7	4.57	4.57	4.57	11.53	11.40	11.47	16.10	15.97	16.03
DM_8	3.23	3.37	3.30	11.50	11.73	11.62	14.73	15.10	14.92
DM_9	2.37	2.67	2.52	11.53	12.03	11.78	13.90	14.70	14.30
DM_{10}	4.27	4.27	4.27	10.87	10.77	10.82	15.13	15.03	15.08
DM_{11}	5.33	5.30	5.32	10.80	10.80	10.80	16.13	16.10	16.12
DM_{12}	4.80	4.93	4.87	11.63	11.63	11.63	16.43	16.57	16.50
DM_{13}	5.60	5.20	5.40	9.63	9.73	9.68	15.23	14.93	15.08
DM_{14}	5.10	4.80	4.95	10.07	10.17	10.12	15.17	14.97	15.07
DM_{15}	4.73	4.40	4.57	10.17	10.03	10.10	14.90	14.43	14.67
DM_{16}	4.67	4.57	4.62	12.40	12.27	12.33	17.07	16.83	16.95
DM_{17}	4.90	4.67	4.78	11.07	10.97	11.02	15.97	15.63	15.80
DM_{18}	4.27	4.13	4.20	10.70	10.07	10.38	14.97	14.20	14.58
DM_{19}	3.63	3.43	3.53	12.40	11.63	12.02	16.03	15.07	15.55
DM_{20}	4.37	4.20	4.28	12.23	11.30	11.77	16.60	15.50	16.05
DM_{21}	3.50	3.50	3.50	12.03	11.87	11.95	15.53	15.37	15.45
DM_{22}	3.13	3.30	3.22	10.47	10.90	10.68	13.60	14.20	13.90

DM_{23}	2.73	2.63	2.68	10.73	11.07	10.90	13.47	13.70	13.58
DM_{24}	3.37	3.37	3.37	11.87	11.33	11.60	15.23	14.70	14.97
DM_{25}	3.63	3.30	3.47	12.07	11.53	11.80	15.70	14.83	15.27
DM_{26}	4.33	4.20	4.27	12.03	11.23	11.63	16.37	15.43	15.90
DM_{27}	4.20	4.03	4.12	10.97	9.73	10.35	15.17	13.77	14.47
DM_{28}	3.27	3.37	3.32	10.83	10.17	10.50	14.10	13.53	13.82
DM_{29}	4.50	4.37	4.43	10.70	10.03	10.37	15.20	14.40	14.80
DM_{30}	5.37	5.13	5.25	11.53	12.27	11.90	16.90	17.40	17.15
DM_{31}	5.33	5.37	5.35	11.50	10.97	11.23	16.83	16.33	16.58
DM_{32}	4.80	4.77	4.78	11.53	10.07	10.80	16.33	14.83	15.58
DM_{33}	5.60	5.37	5.48	10.87	11.63	11.25	16.47	17.00	16.73
DM_{34}	5.10	4.87	4.98	10.80	11.30	11.05	15.90	16.17	16.03
DM_{35}	4.73	4.47	4.60	11.63	11.87	11.75	16.37	16.33	16.35
DM_{36}	4.67	4.57	4.62	12.33	10.90	11.62	17.00	15.47	16.23
DM_{37}	4.90	5.00	4.95	10.07	10.07	10.07	14.97	15.07	15.02
DM_{38}	4.27	4.27	4.27	10.83	8.00	9.42	15.10	12.27	13.68
DM_{39}	3.63	3.57	3.60	10.70	11.03	10.87	14.33	14.60	14.47
DM_{40}	5.30	5.20	5.25	11.60	11.60	11.60	16.90	16.80	16.85
DM_{41}	3.30	3.17	3.23	10.60	10.60	10.60	13.90	13.77	13.83
DM_{42}	3.50	3.40	3.45	11.83	11.83	11.83	15.33	15.23	15.28
DM_{43}	3.70	3.77	3.73	11.27	11.23	11.25	14.97	15.00	14.98
DM_{44}	4.33	4.00	4.17	10.00	10.13	10.07	14.33	14.13	14.23
DM_{45}	4.00	3.90	3.95	10.70	10.70	10.70	14.70	14.60	14.65
SE(m)±	0.35	0.30	0.23	0.59	0.41	0.36	0.69	0.53	0.43
CD (P=0.05)	**0.69**	**0.59**	**0.45**	**1.16**	**0.81**	**0.71**	**1.36**	**1.04**	**0.85**

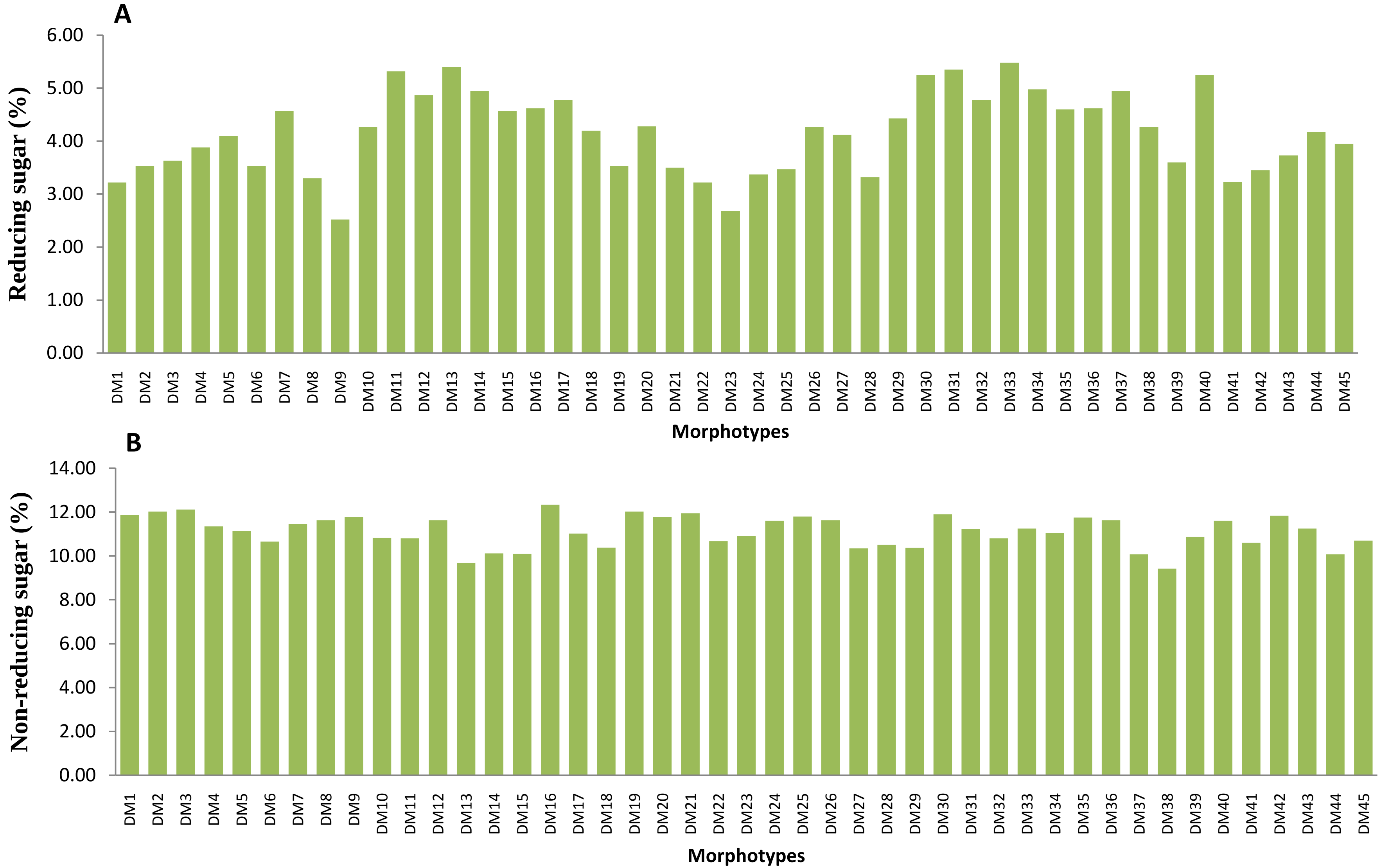


Fig. 4.21 Average performance of (A) reducing sugar (%) and (B) non-reducing sugar (%) in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

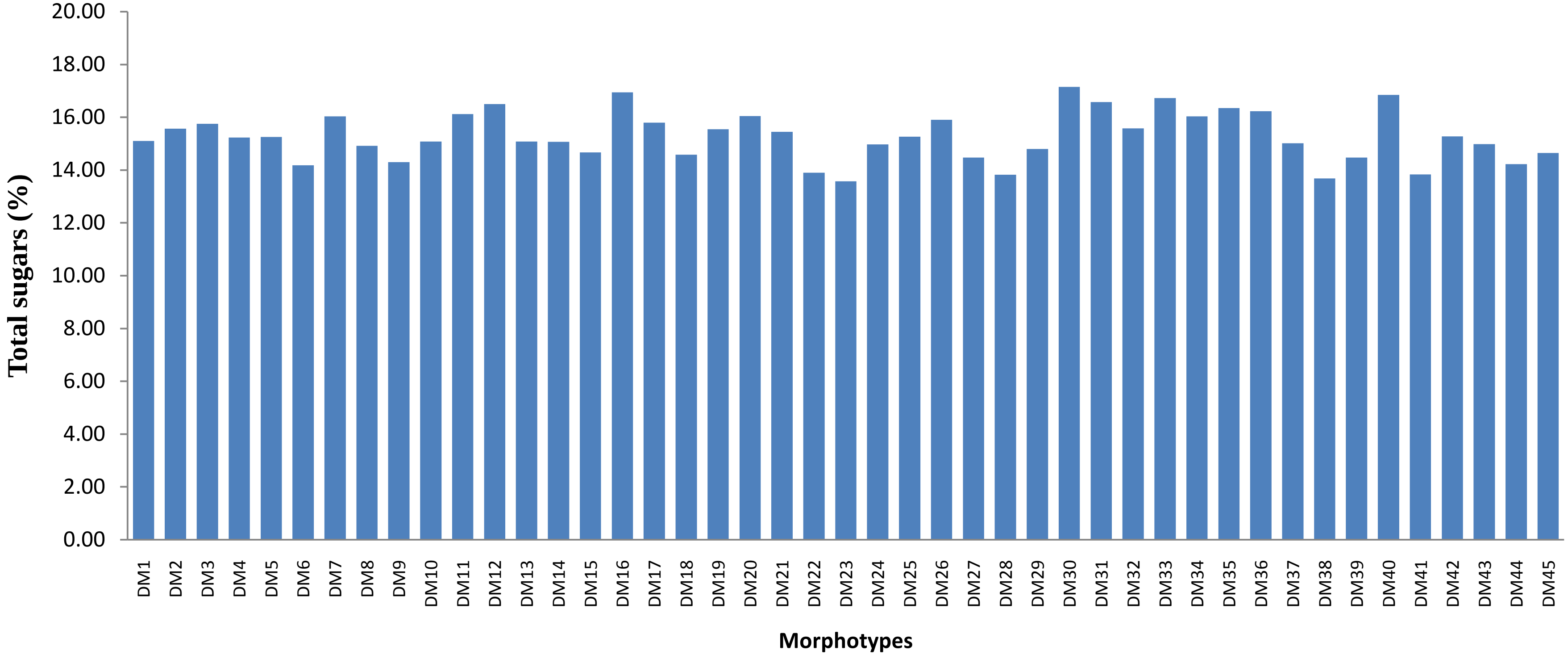


Fig. 4.22 Average performance of total sugars (%) in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

Non-reducing sugar (%)

Non-reducing sugar ranged from 9.42 to 12.12 % with a grand mean of 11.15% (Table 4.15). The morphotype DM_3 (12.12%), showed significantly higher level of non-reducing sugar in comparison to other morphotypes under study. Lowest non-reducing sugar of 9.42 % was registered in morphotype DM_{38} (Table 4.14 and Figure 4.21B).

Total sugars (%)

The total sugars varied between 13.58 to 16.58% and its general mean was recorded 15.31% (Table 4.5). The highest level of total sugars (16.95%) was recorded for morphotype DM_{16} and DM_{23} contained least total sugars as shown in Table 4.14 and Figure 4.22.

Biometrical techniques for assessment of intravarietal variability for fruit physico-chemical traits of 45 Dashehari morphotypes:

The morphological data recorded was subjected to biometrical techniques for assessment which was computed through simple measures of variability viz., range, grand mean and coefficient of variation (CV), genetic variability (PCV % and GCV %), heritability, genetic advance and genetic advance as percent of mean (%) for further elucidation of the data recorded. Coefficient of variation, phenotypic coefficient of variation, genotypic coefficient of variation, heritability, genetic advance and genetic advance as percent of mean for fruit morphological characters showed more environmental influence (Table 4.15). However, the highest coefficient of variation (13.32), PCV (13.66%), GCV (3.00%), heritability (4.80%), genetic advance (0.62%) and genetic advance as percent of mean (33.33%) were observed for peel thickness of fruit. Among the fruit morphology most of the characters showed very negligible value for these CV, PCV, GCV, heritability, genetic advance and genetic advance as percent of mean which indicates environmental effect. CV, PCV, GCV, heritability, genetic advance and genetic advance as percent of mean were analyzed for stone morphology which showed wide variation between PCV and GCV (Table 4.15). The highest coefficient of variation (14.11) and PCV (14.24%) were recorded for stone thickness whereas, the highest GCV (2.94%) and heritability (32.90%) were recorded for the parameter

Table 4.15 Range (minimum and maximum), grand mean, coefficient of variation, phenotypic coefficient of variation (PCV %), genotypic coefficient of variation (GCV %), heritability (%), genetic advance (%) and genetic advance as percent of mean (%) for 26 fruit, stone, kernel and biochemical parameters of 45 morphotypes of mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow

Sr. No.	Characters	Range		Grand Mean	CV	PCV %	GCV %	h^2 %	GA	GAM%
1	Fruit width (cm)	5.52	6.97	6.24	7.82	7.84	0.51	0.40	0.00*	0.00*
2	Fruit length (cm)	9.84	12.85	11.24	7.95	7.96	0.28	0.10	0.00*	0.00*
3	Fruit weight (g)	191.00	342.33	235.16	5.11	5.11	0.01	0.00*	0.00*	0.00*
4	Fruit volume (ml)	175.83	325.00	221.10	4.79	4.80	0.01	0.00*	0.00*	0.00*
5	Fruit specific gravity (g/cc)	1.02	1.10	1.06	4.18	5.13	2.97	33.00	0.08	7.54
6	Pulp weight (g)	125.83	259.67	155.13	5.21	5.21	0.02	0.00*	0.00*	0.00*
7	Peel weight (g)	40.00	61.67	49.57	4.77	4.78	0.06	0.00*	0.00*	0.00*
8	Peel thickness (mm)	1.21	2.71	1.86	13.32	13.66	3.00	4.80	0.62	33.33
9	Stone weight (g)	24.17	33.50	29.97	6.65	7.05	2.33	10.90	0.99	3.30
10	Stone volume (ml)	22.67	31.83	28.12	6.77	7.33	2.79	14.50	1.27	4.51
11	Stone specific gravity (g/cc)	1.02	1.10	1.07	4.20	5.13	2.94	32.90	0.08	7.55
12	Stone length (cm)	8.99	11.75	10.01	7.63	7.88	1.95	6.10	0.21	2.09
13	Stone width (cm)	2.72	3.85	3.37	11.12	11.16	0.94	0.70	0.03	0.89
14	Stone thickness (cm)	1.44	1.93	1.67	14.11	14.24	1.88	1.70	0.21	2.09
15	Kernel length (cm)	4.32	6.64	5.45	5.39	14.16	13.09	85.50	2.80	51.37

16	Kernel width (cm)	1.46	3.29	2.41	10.34	22.15	19.65	78.20	1.77	73.44
17	Kernel thickness (cm)	1.04	2.07	1.42	9.36	21.77	19.58	81.50	1.07	75.35
18	Pulp:peel ratio	2.71	4.40	3.14	14.33	15.22	5.11	11.3	0.22	7.00
19	Pulp:stone ratio	4.36	8.04	5.17	12.45	12.47	0.61	0.20	0.00*	0.00*
20	Total soluble solids (ºBrix)	11.73	21.33	15.16	3.94	18.27	17.84	95.30	11.20	73.87
21	pH of the pulp	4.30	7.0	5.53	6.86	10.38	7.79	56.20	1.38	24.95
22	Titrable acidity (%)	0.27	0.37	0.32	2.44	8.09	7.71	90.90	0.10	31.25
23	TSS:acid ratio	33.16	68.74	47.15	4.78	20.33	19.76	94.50	38.41	81.46
24	Reducing sugar (%)	2.52	5.48	4.15	9.76	20.75	18.31	77.90	2.84	68.43
25	Non-reducing sugar (%)	9.42	12.12	11.15	5.62	7.82	5.44	48.30	1.79	16.05
26	Total sugars (%)	13.58	16.58	15.31	4.97	7.44	5.53	55.30	2.67	17.43

CV: Coefficient of variation, PCV: Phenotypic coefficient of variation, GCV: Genotypic coefficient of variation, h^2: heritability , GA: Genetic advance and GAM: Genetic advance as per cent of mean specific gravity of stone. However, the maximum genetic advance (1.27%) and genetic advance as percent of mean (4.51%) were observed for stone volume (Table 4.15). However, kernel morphology showed narrow difference between PCV and GCV. The highest coefficient of variation (10.34) was observed for kernel width (Table 4.15) similarly, the highest PCV (22.15%) and GCV (19.65%) were recorded for kernel width while, the highest heritability (85.50%) and genetic advance (2.80%) were observed for kernel length. The maximum genetic advance as percent of means (75.35%) was recorded for kernel thickness (Table 4.15). The highest coefficient of variation (9.76) and PCV (20.75%) were recorded for reducing sugar while the highest GCV (19.76%), genetic advance (38.41%) genetic advance as percent of means (81.46%) were observed for TSS:acid ratio. However, the highest heritability (95.30%) was recorded for total soluble solids content (Table 4.15).

EXPERIMENT IV

4.4.1 Microscopy studies for exploring intravarietal variability in mango cv. Dashehari

Stomatal length (µm)

The significant variation was recorded in stomatal length of 45 Dashehari morphotypes under the study and varied from 5.32 to 17.56 µm with a grand mean 8.45 µm (Table 4.18). However, the maximum stomatal length (17.56 µm) was recorded for morphotype DM_{28} followed by morphotype DM_5 (16.30 µm) and DM_{32} (15.62 µm). Therefore, the minimum stomatal length (6.00 µm) was recorded from morphotype DM_{16} followed by morphotype DM_{19} (6.04 µm). Based on stomatal length morphotype DM_{28} and DM_5 superior among the morphotype and presented in Table 4.16 and Figure 4.23A.

Stomatal width (µm)

Stomatal width showed wide variation among various morphotypes under the study and varied from6.00 to 12.72 µm with a grand mean 7.60 (Table 4.18). The maximum stomatal width (15.00 µm) was observed from morphotype DM_5 closely followed by morphotype DM_{28} (12.72 µm), DM_{32} (11.20 µm) and DM_1 (11.12 µm), while the minimum stomatal width (5.12 µm) was observed for morphotype DM_{16} followed by morphotype DM_{19} (5.32 µm) as shown in Table 4.16 and Figure 4.23B.

Table 4.16 Average performance of stomatal characters in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow

Morphotypes	Stomatal length (µm)	Stomatal width (µm)	Stomatal pore size		Trichome Size		Stomatal density (μm^{-2})
			Length (µm)	Width (µm)	Length (µm)	Width (µm)	
DM_1	11.13	11.12	1.96	4.03	38.85	45.20	29.0
DM_2	12.07	10.83	3.97	5.17	40.07	40.80	43.0
DM_3	9.75	8.48	2.40	4.24	30.22	39.20	37.0
DM_4	10.44	8.26	2.56	2.97	32.21	31.57	37.0
DM_5	16.30	15.00	2.40	4.01	33.66	34.80	44.0
DM_6	8.73	7.36	3.89	2.40	31.64	32.80	39.0
DM_7	10.39	10.45	3.20	5.15	32.69	39.30	40.0
DM_8	8.93	7.76	3.32	4.56	36.01	39.60	36.0
DM_9	8.48	7.12	2.92	4.64	32.02	32.00	40.0
DM_{10}	8.00	7.68	2.00	3.21	28.98	30.41	25.0
DM_{11}	9.08	9.08	2.60	4.72	32.40	34.80	35.0
DM_{12}	9.52	8.88	3.72	5.12	32.80	33.21	33.0
DM_{13}	8.32	7.44	3.32	4.64	29.67	30.82	36.0
DM_{14}	7.92	7.48	2.52	3.24	33.20	32.41	31.0
DM_{15}	7.24	7.80	1.80	3.52	32.00	31.20	37.0
DM_{16}	6.00	5.12	2.44	2.32	35.20	37.20	46.0
DM_{17}	9.32	6.52	2.68	5.45	34.86	35.20	27.0
DM_{18}	7.00	6.80	2.80	4.08	34.40	32.00	31.0
DM_{19}	6.04	5.32	2.72	4.00	29.62	31.20	40.0
DM_{20}	6.53	5.76	2.52	3.52	36.88	34.00	35.0
DM_{21}	6.84	5.68	3.56	3.80	36.88	34.00	28.0
DM_{22}	6.36	6.88	2.88	3.92	30.00	32.00	35.0
DM_{23}	6.88	5.80	2.40	4.04	35.60	35.20	38.0
DM_{24}	6.84	6.12	2.68	3.24	27.60	28.81	30.0
DM_{25}	7.00	5.92	2.72	4.08	33.66	38.40	28.0
DM_{26}	7.36	7.00	2.68	4.12	36.80	41.60	31.0

DM_{27}	8.93	6.40	2.80	3.76	34.86	40.43	42.0
DM_{28}	17.56	12.72	6.56	11.70	31.20	32.81	24.0
DM_{29}	6.59	7.48	2.16	2.92	38.82	40.01	32.0
DM_{30}	7.36	6.08	2.60	3.48	42.82	40.40	35.0
DM_{31}	7.01	6.40	3.32	3.16	32.60	32.81	33.0
DM_{32}	15.62	11.20	6.16	10.59	41.83	40.80	26.0
DM_{33}	8.03	6.91	2.41	4.22	32.40	30.80	35.0
DM_{34}	7.72	8.00	3.24	3.57	34.88	34.04	34.3
DM_{35}	7.69	8.16	3.52	4.28	35.60	33.60	33.0
DM_{36}	7.48	8.51	4.52	4.06	32.82	32.81	35.0
DM_{37}	6.68	6.84	3.20	2.60	33.20	33.20	39.0
DM_{38}	7.12	5.92	2.44	5.92	32.02	30.41	39.0
DM_{39}	7.84	7.28	3.24	4.68	33.20	35.61	31.0
DM_{40}	7.08	7.40	3.30	3.60	29.62	34.00	36.0
DM_{41}	7.62	8.03	3.62	3.79	34.41	33.21	41.0
DM_{42}	7.43	7.08	3.80	3.77	40.40	38.40	35.0
DM_{43}	6.48	6.76	2.88	4.00	34.06	35.20	36.0
DM_{44}	6.28	5.64	2.40	2.96	28.40	29.60	36.0
DM_{45}	8.00	6.08	1.68	4.00	28.81	28.00	37.3
SE(m)±	0.51	0.38	0.44	0.54	0.47	0.49	0.83
CD (P=0.05)	**1.02**	**0.76**	**0.87**	**1.06**	**0.93**	**0.98**	**1.63**

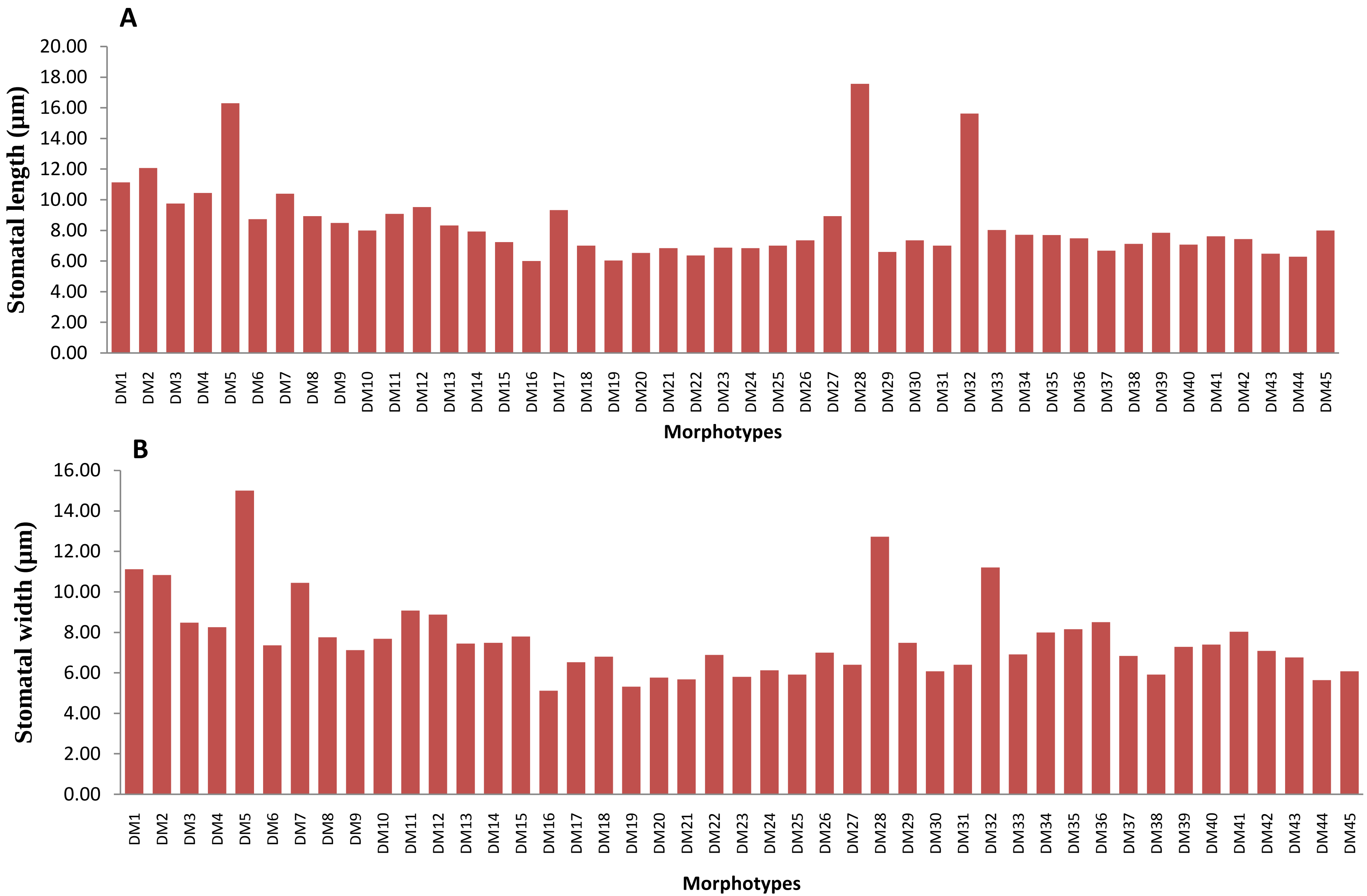


Fig. 4.23 Average performance of (A) stomatal length (µm) and (B) stomatal width (µm) in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

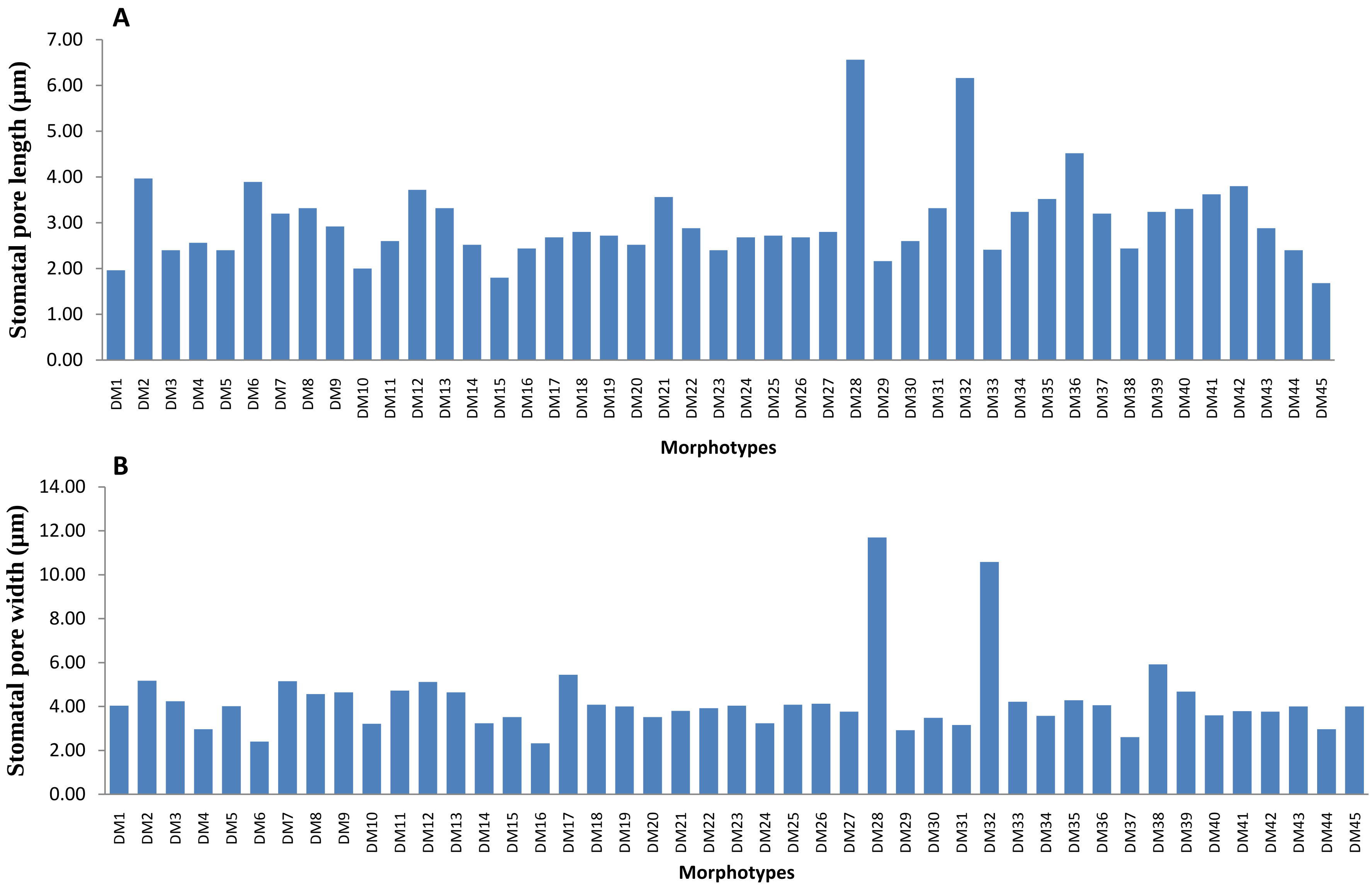


Fig. 4.24 Average performance of (A) stomatal pore length (µm) and (B) stomatal pore width (µm) in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

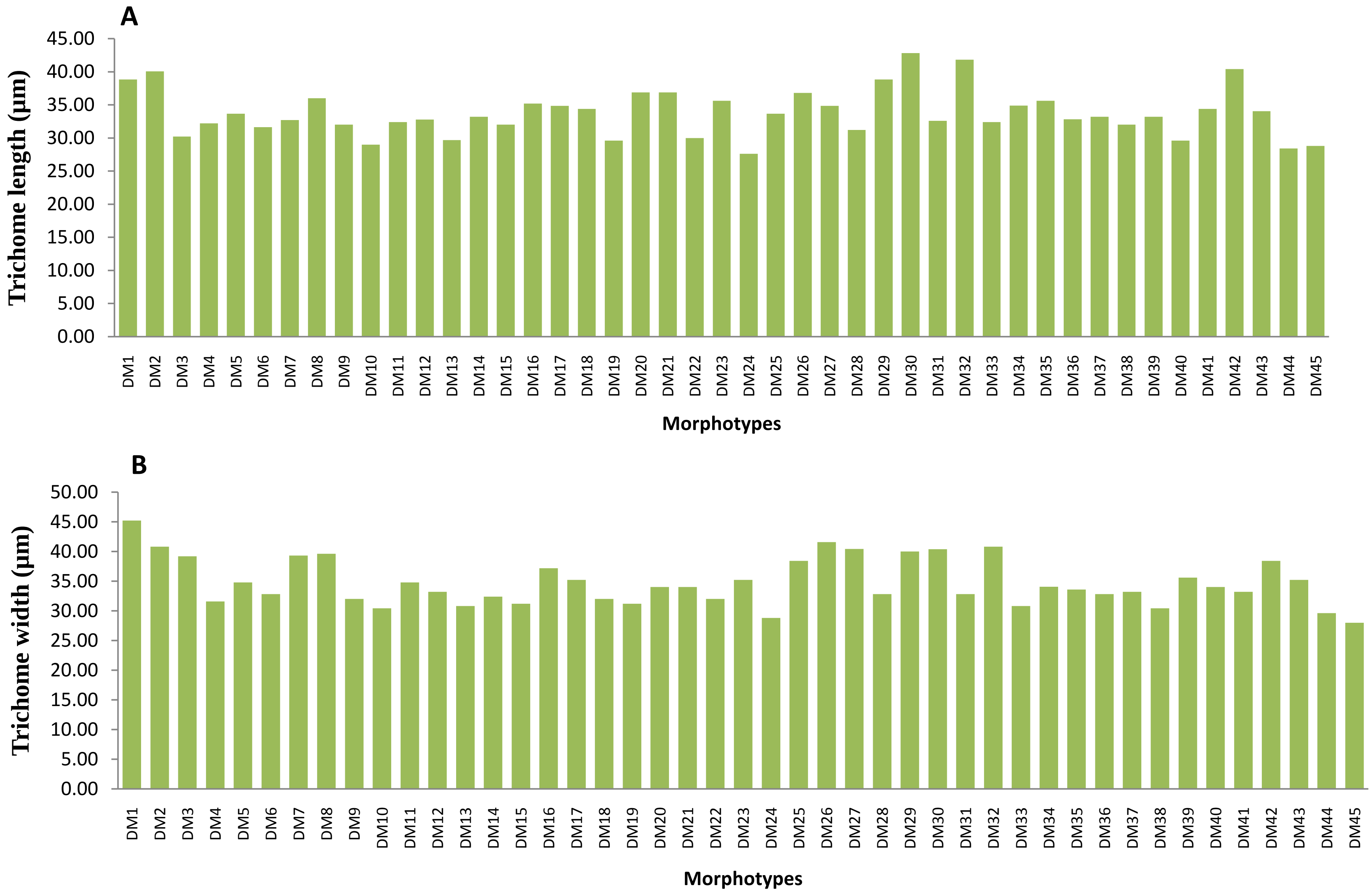


Fig. 4.25 Average performance of (A) trichome length (µm) and (B) trichome width (µm) in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow

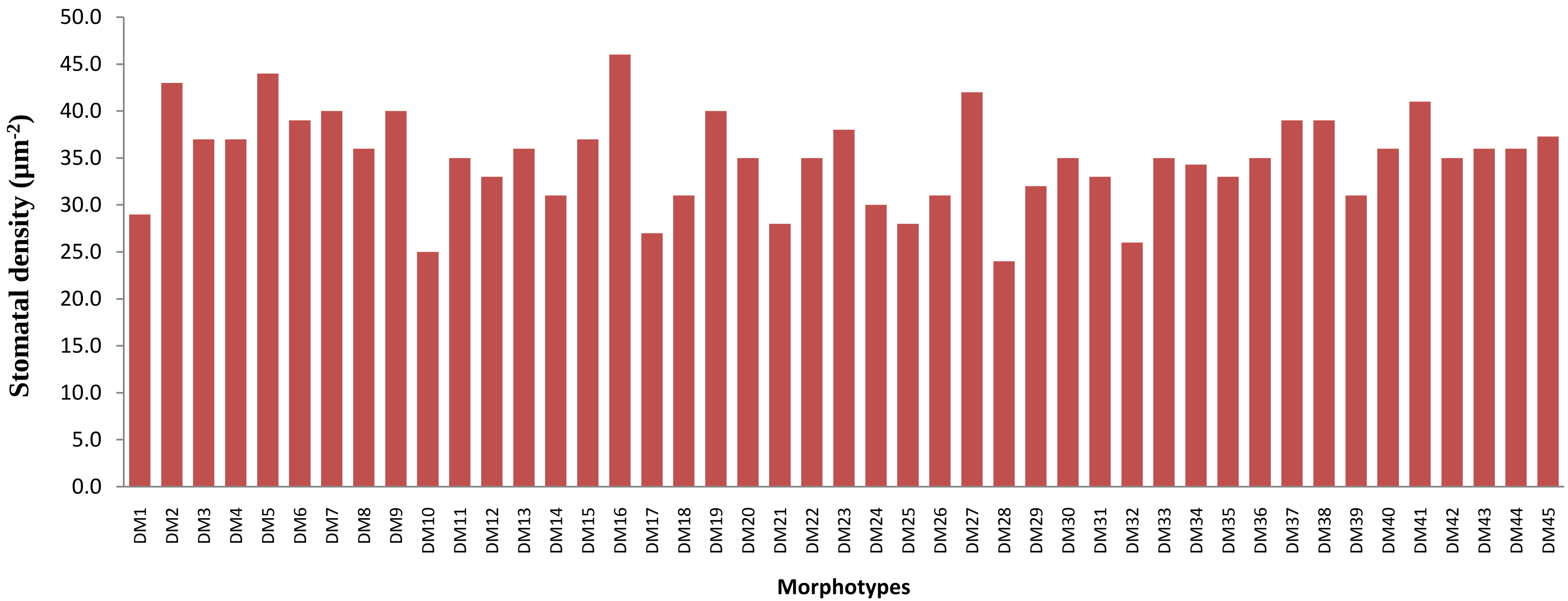
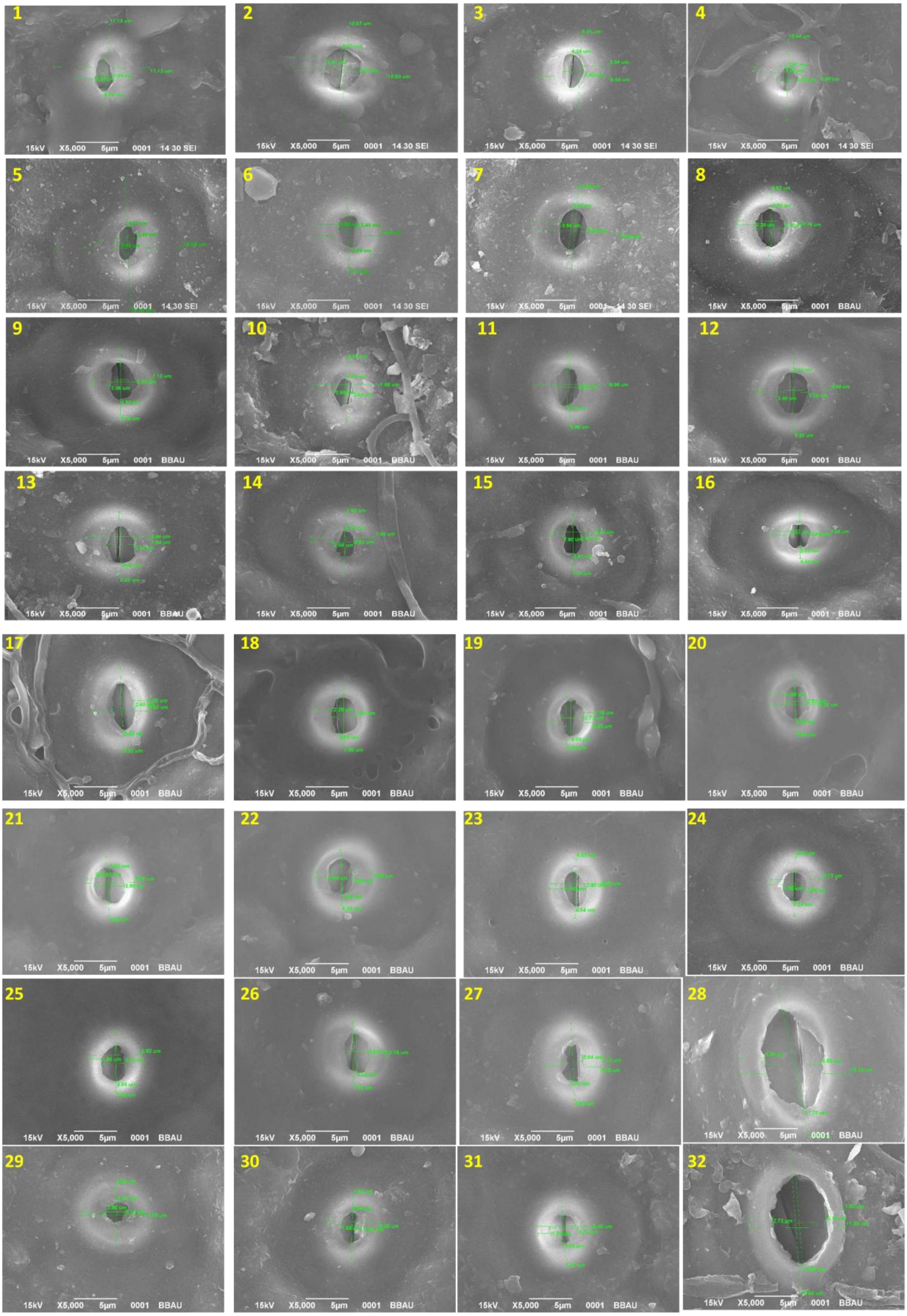


Fig. 4.26 Average performance of stomatal density (µm^{-2}) in mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal blocks of district Lucknow


1
15kV X5,000 5µm 0001 14 30 SEI
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15kV X5,000 5µm 0001 BBAU
9
15kV X5,000 5µm 0001 BBAU
10
15kV X5,000 5µm 0001 BBAU
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15kV X5,000 5µm 0001 BBAU
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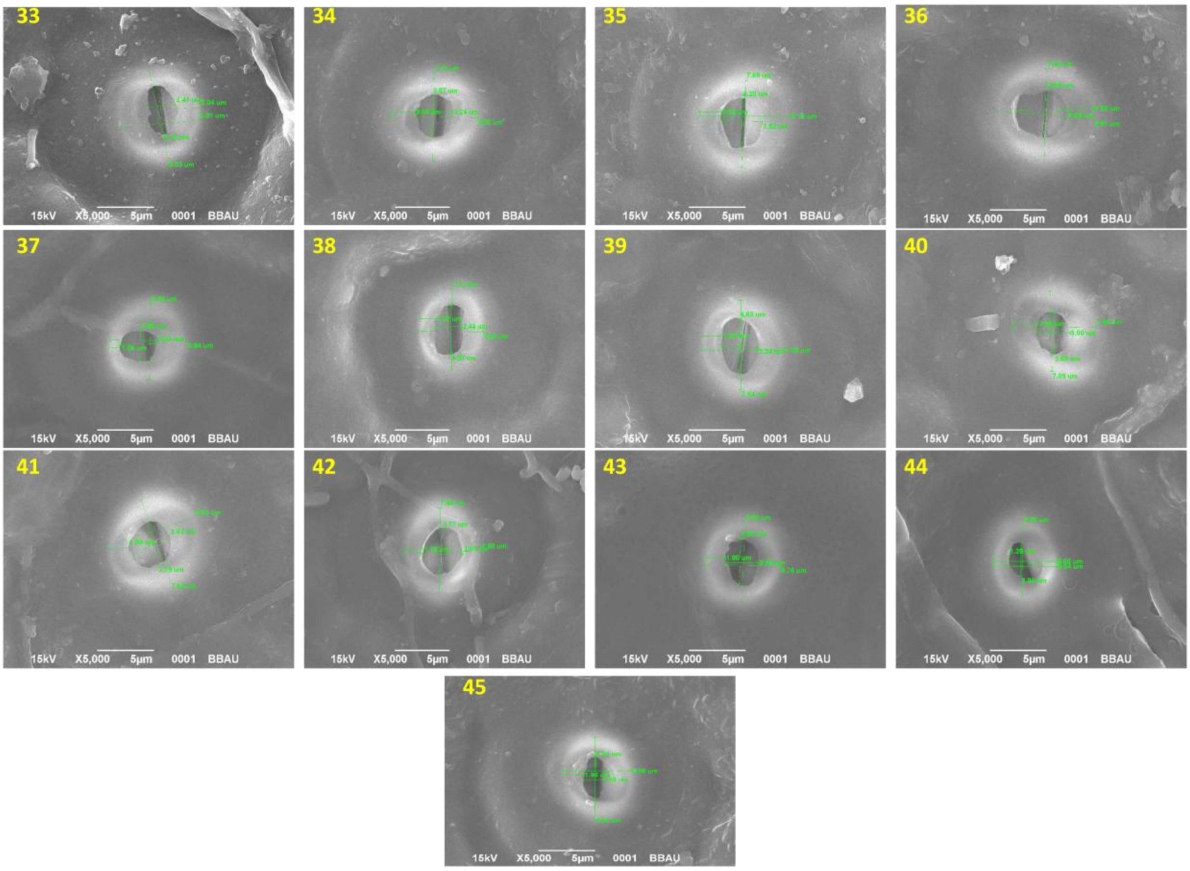


Plate 7: Variation in stomatal pore size of 45 morphotypes of mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow

Stomatal pore length (µm)

Stomatal pore length showed significant variation and ranged from 1.68 to 6.56 µm with a grand mean 3.04 µm (Table 4.18). DM_{28} showed the maximum stomatal pore length (6.56 µm) was observed for morphotype followed by morphotype DM_{36} (4.52 µm) and the minimum stomatal pore length (1.68 µm) was observed for morphotype DM_{45} followed by morphotype DM_{1} (1.97 µm) (Table 4.16 and Figure 4.24A).

Stomatal pore width (µm)

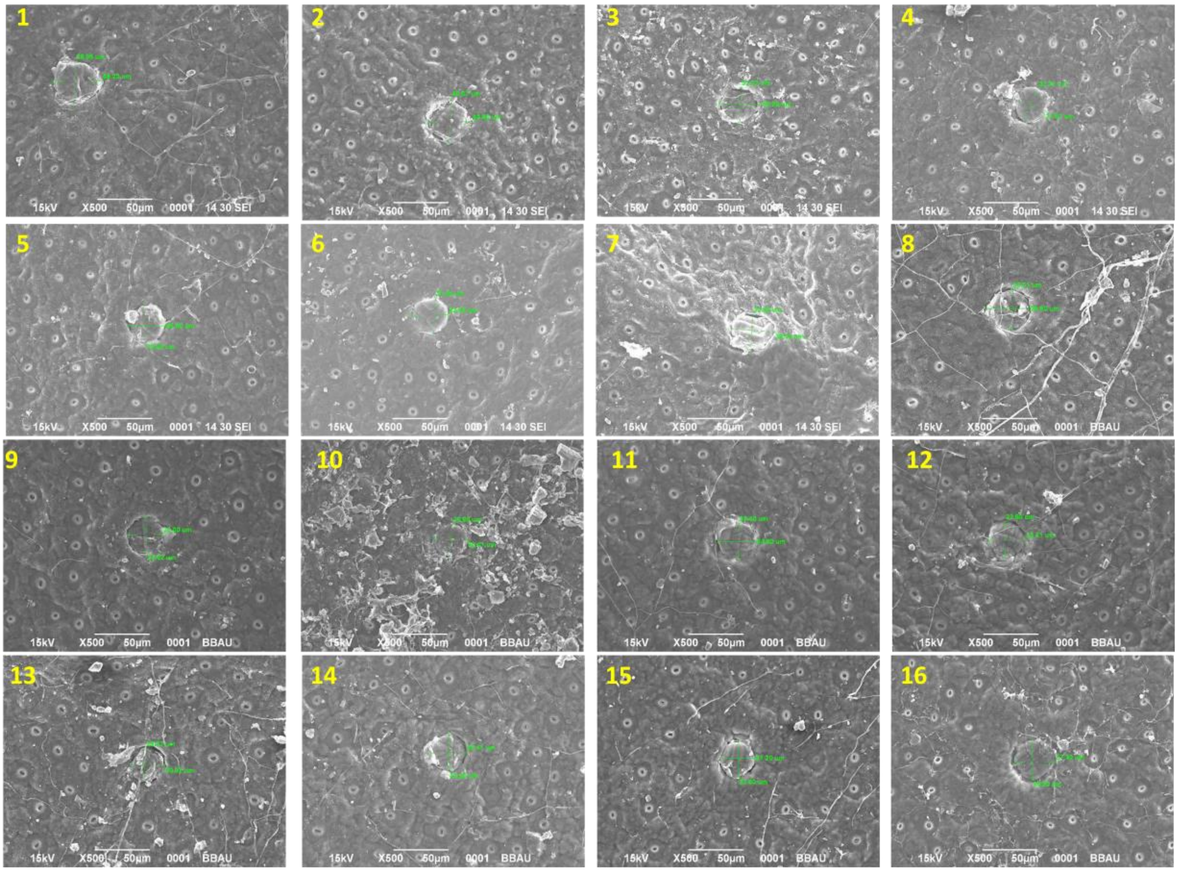
Stomatal pore width showed significant variation between different morphotypes during study and varied between 2.32 to 11.70 µm and grand mean of 4.27 µm (Table 4.18). The widest stomatal pore width (11.70 µm) was recorded from morphotype DM28 followed by morphotype DM_{32} (10.59 µm). However, the lowest stomatal pore width (2.32 µm) was recorded from morphotype DM_{16} followed by morphotype DM_{6} (2.40 µm) as shown in Table 4.16 and Figure 4.24B.

Trichome length (µm)

The data pertaining to trichome length of different morphotypes of Dashehari mango revealed significant intra-cultivar variation. The trichome length was ranged from 27.60 to 42.82 µm with a grand mean 33.76 µm (Table 4.18). The maximum trichome length (42.82 µm) was observed for morphotype DM_{30} followed by morphotype DM_{32} (41.83 µm). The shortest trichome length (27.60 µm) was observed in morphotype DM_{24} followed by morphotype DM_{44} (28. 40 µm) which were at par with each other (Table 4.16 and Figure 4.25A).

Trichome width (µm)

The trichome width showed significant variation between various morphotypes and varied between 28.00 and 45.20 µm and grand mean of 34.78 µm (Table 4.18). The data on trichome width are presented in Table 4.16 and Figure 4.25B. The highest trichome width (45.20 µm) was recorded from morphotype DM_{1} followed by morphotype DM_{26} (41.60 µm) and minimum was recorded from morphotype DM_{45} (28.00 µm) which was significantly lower than other morphotypes.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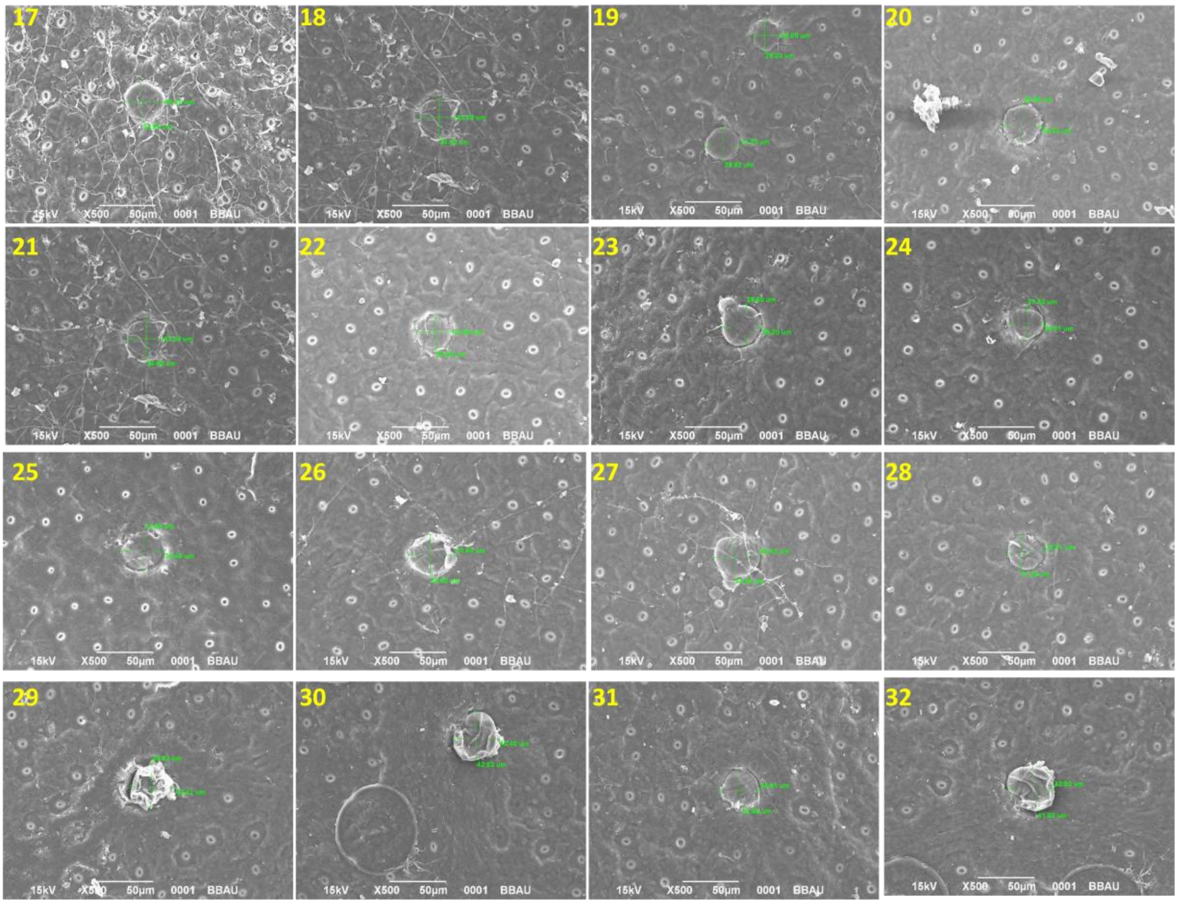
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Contd......plate 8

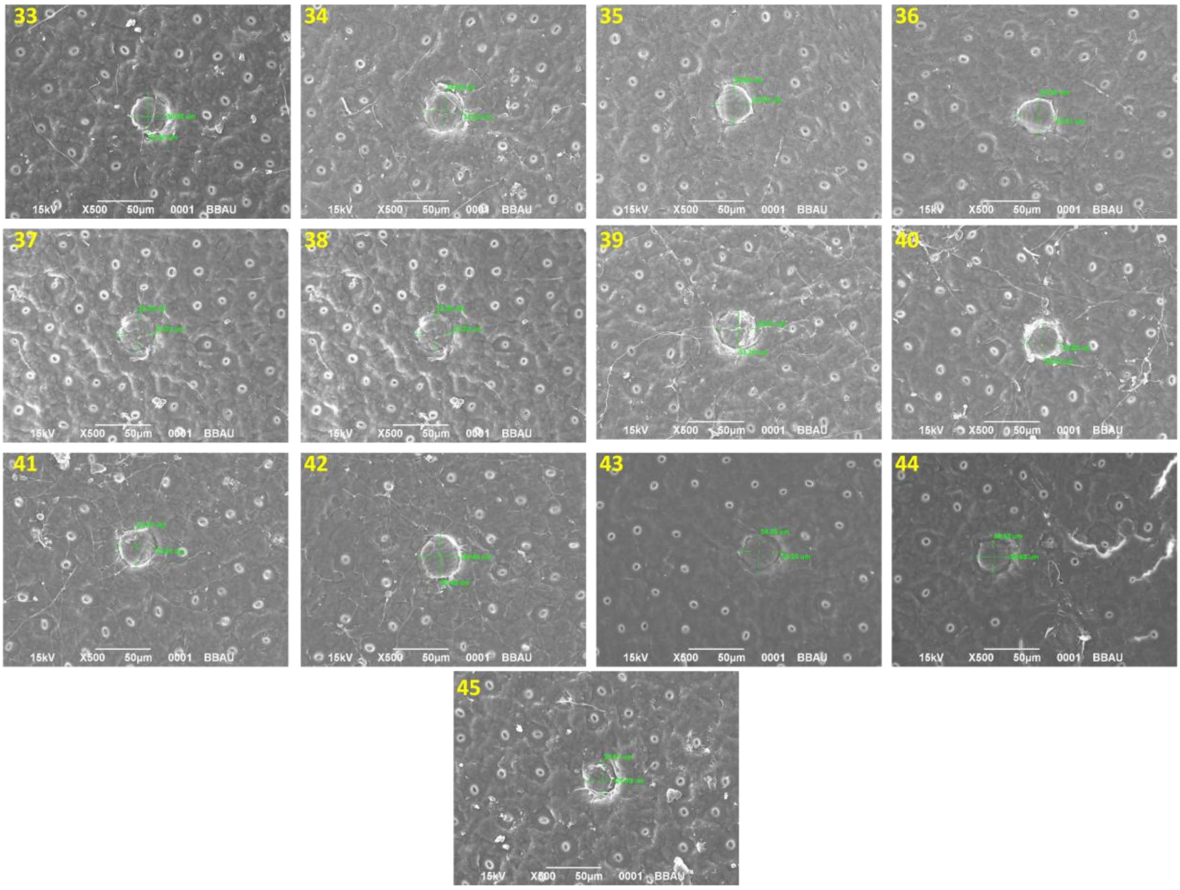
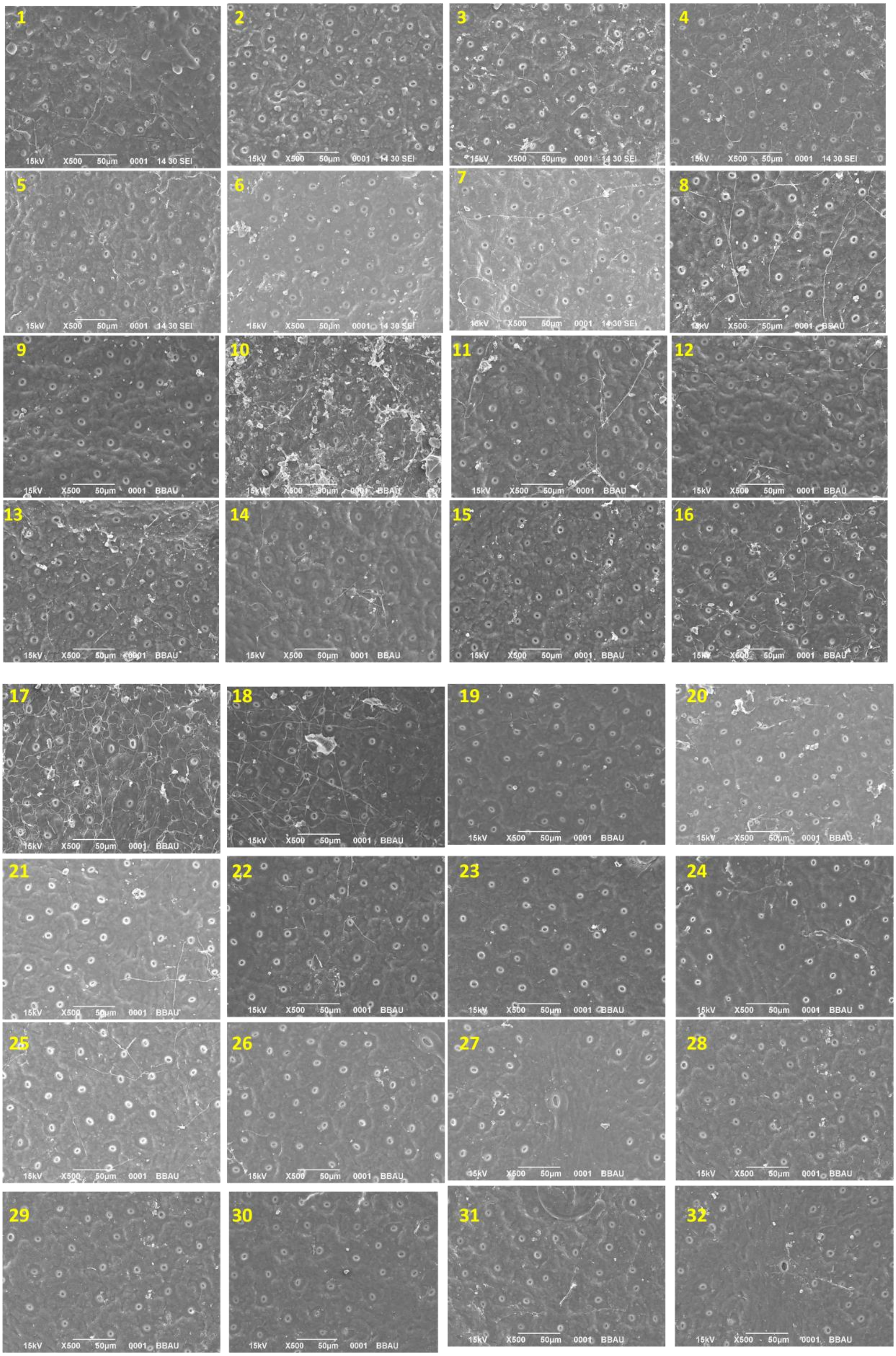


Plate 8: Variation in trichome size of 45 morphotypes of mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow


1
15kV X500 50µm 0001 14 30 SEI
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15kV X500 50µm 0001 14 30 SEI
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15kV X500 50µm 0001 14 30 SEI
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15kV X500 50µm 0001 14 30 SEI
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15kV X500 50µm 0001 BBAU

Contd......plate 9

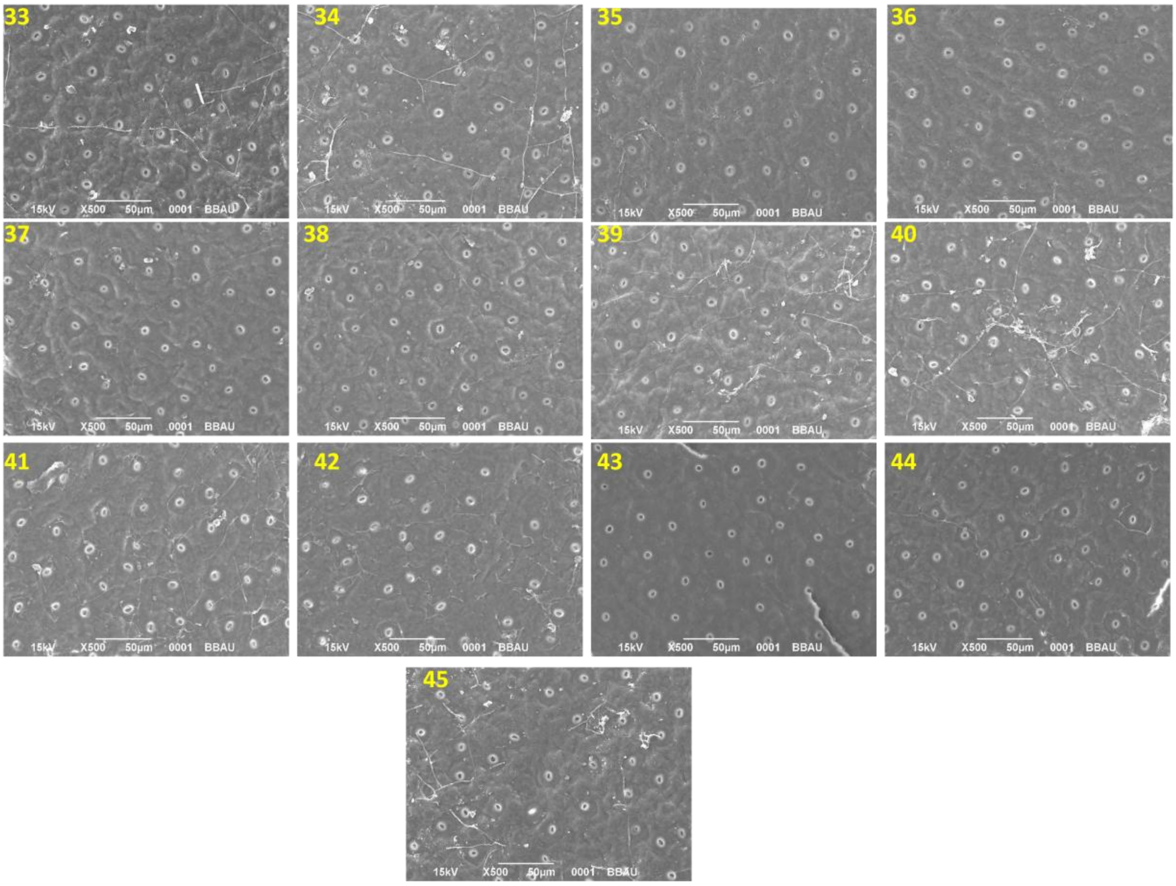

Plate 9: Variation in stomatal density of 45 morphotypes of mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow

Stomatal density (μm^{-2})

Stomatal density (number of stomata per microscopic field at 500 X magnifications) differed significantly among morphotypes. Stomatal density ranging 24.0 to 46.0μm^{-2} with a grand mean of 35.03μm^{-2} (Table 4.18). The highest stomatal density (46.0μm^{-2}) was recorded from morphotype DM_{16} followed by morphotype DM_5 (44.0μm^{-2}) and DM_2 (43.0 μm^{-2}). However, the lowest stomatal density was recorded from morphotype DM_{28} (24.0 μm^{-2}) followed by morphotype DM_{10} (25.0μm^{-2}) which was at par with each other and presented and shown in Table 4.16 and Figure 4.26.

Biometrical techniques for assessment of intravarietal variability for fruit stomatal traits of 45 Dashehari morphotypes:

A UPGMA dendrogram was prepared on the basis of stomatal characteristics of 45 Dashehari morphotypes in order to establish their relatedness to each other. The 45 Dashehari morphotypes under study were found to be very closely related and grouped into only two major clusters (cluster I and II) (Table 4.17) with additional sub-clusters, differentiating the morphotypes collected from different areas. Cluster-I consisted of 43 morphotypes which further divided into five sub-groups (cluster IA, IB, IC, ID and IE) while cluster-II comprised two morphotypes which was divided into two sub-groups (cluster IIA and IIB) (Table 4.17 and Plate 10).

The stomatal morphological data recorded was subjected to biometrical techniques for assessment computed through simple measures of variability viz., range, grand mean and coefficient of variation (CV), genetic variability (PCV % and GCV %), heritability, genetic advance and genetic as percent of mean (%) for further elucidation of the data recorded. Among the stomatal traits the stomatal pore showed maximum coefficient of variation (18.46) (Table 4.18). However, the maximum PCV (41.59%) and GCV (38.27%) were recorded for stomatal pore width (µm) while, highest heritability (97.50%) and genetic advance (20.86%) were recorded for stomatal density. While, the maximum genetic advance as percent of mean (149.41%) was observed for stomatal pore length (Table 4.18).

Table 4.17 Non-hierarchical Euclidean cluster analysis in 45 morphotypes of Dashehari mango (*Mangifera indica* L.) on the basis of stomatal characters

Clusters	Morphotypes
Cluster I	DM_1, DM_2, DM_3, DM_4, DM_5, DM_6, DM_7, DM_8, DM_9, DM_{10}, DM_{11}, DM_{12}, DM_{13}, DM_{14}, DM_{15}, DM_{16}, DM_{17}, DM_{18}, DM_{19}, DM_{20}, DM_{21}, DM_{22}, DM_{23}, DM_{24}, DM_{25}, DM_{26}, DM_{27}, DM_{29}, DM_{30}, DM_{31}, DM_{33}, DM_{34}, DM_{35}, DM_{36}, DM_{37}, DM_{38}, DM_{39}, DM_{40}, DM_{42}, DM_{43}, DM_{44}, DM_{45}
Cluster II	DM_{28}, DM_{32}

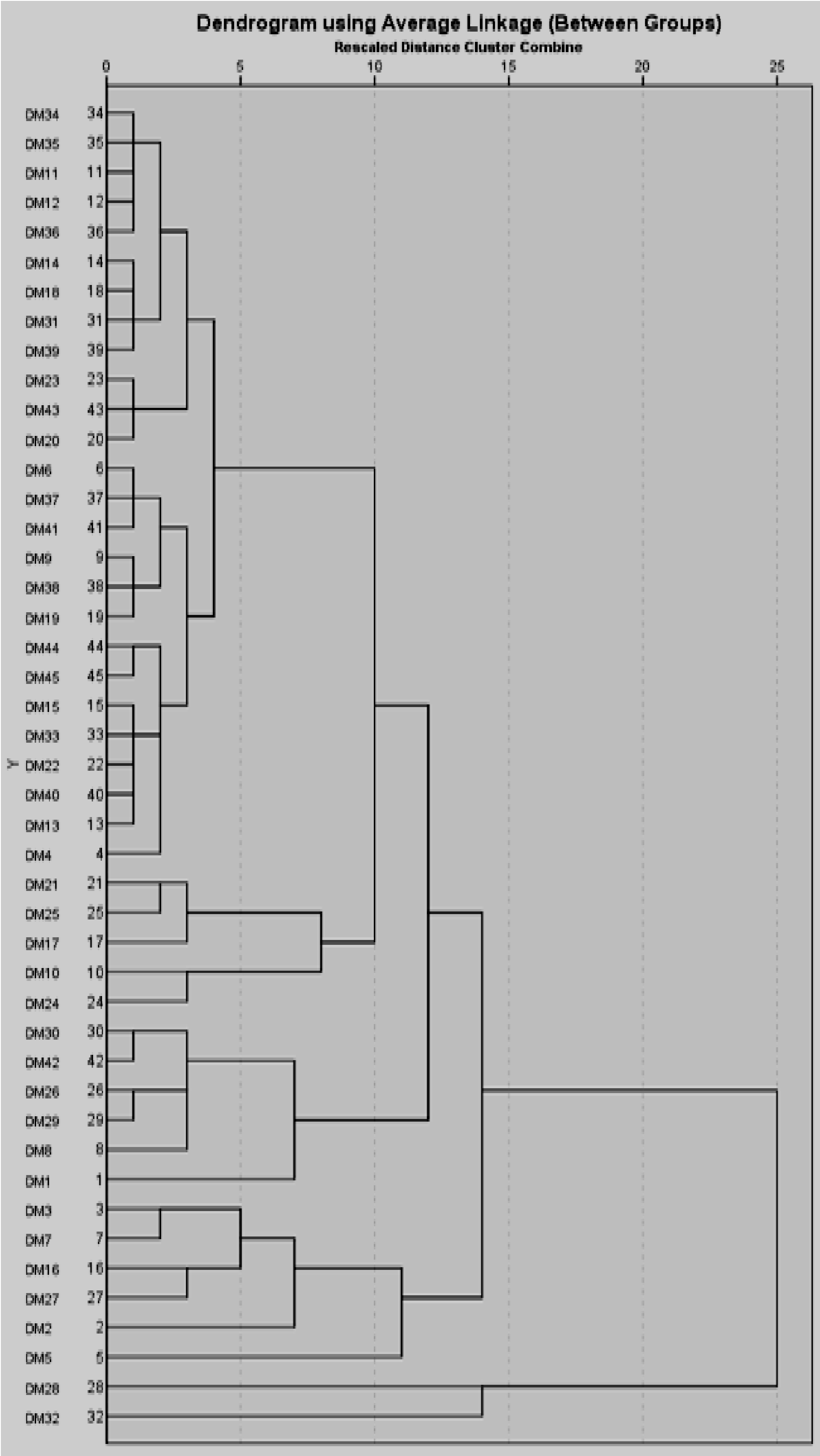

Plate 10: Dendrogram of 45 Dashehari morphotypes of mango (*Mangifera indica* L.) based on stomatal data

Table 4.18 Range (minimum and maximum) mean, phenotypic coefficient of variation (PCV %), genotypic coefficient of variation (GCV %), heritability (%), genetic advance (%) and genetic advance as percent of mean (%) for stomatal characters of 45 morphotypes of mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow

Sr. No.	Characters	Range		Grand Mean	CV	PCV %	GCV %	h^2 %	GA	GAM%
1	Stomatal length (µm)	5.32	17.56	8.45	7.69	30.79	29.81	93.80	10.36	122.60
2	Stomatal width (µm)	6.00	12.72	7.60	6.45	27.13	26.35	94.30	8.26	108.68
3	Stomatal pore length (µm)	1.68	6.56	3.04	18.46	34.28	28.88	71.0	3.13	102.96
4	Stomatal pore width (µm)	2.32	11.70	4.27	16.29	41.59	38.27	84.70	6.38	149.41
5	Trichome length (µm)	27.60	42.82	33.76	1.72	10.48	10.34	97.30	14.60	43.24
6	Trichome width (µm)	28.00	45.20	34.78	1.78	11.33	11.19	95.90	16.31	46.89
7	Stomata density (μm^{-2})	24.00	46.00	35.03	2.97	14.64	14.34	97.50	20.86	59.54

CV: Coefficient of variation, PCV: Phenotypic coefficient of variation, GCV: genotypic coefficient of variation, h2: heritability, GA: genetic advance and GAM%: genetic advance as percent of mean

EXPERIMENT V

4.5 Molecular analysis of intravarietal variability in mango cv. Dashehari

Knowledge of genetic diversity and homozygosity in the germplasm is a prerequisite for any crop improvement programme. Fraction of proteins bands by Sodium Dodecyl Sulphate Polyacrylamide Gel Electrophoresis (SDS-PAGE) serve as an indispensable tool for assessing genetic diversity and species relationship. Protein profile of 45 Dashehari morphotypes was prepared using SDS-PAGE for estimation of their genetic diversity at molecular level. The profiles are presented in Plate 11.

The protein profiling showed distinct polymorphism in electrophoretic banding patterns and led to the detection of total of 10 bands. In the initial screening the molecular weight of the 10 bands obtained ranged from 242 kDa to 8 kDa. The morphotype DM_4 and DM_{11} having maximum (242 kDa) value band which was not present in other morphotypes and minimum (8 kDa) value band was found in morphotypes DM_{13}. The maximum number of bands (10 bands) was reported for morphotype DM_{21} and DM_{41} followed by DM_6, DM_{13}, DM_{21}, DM_{23} and DM_{40} (9 bands), respectively. The minimum number of bands (2 bands) was reported for morphotype DM_2 and DM_9 (Table 4.19).

Genetic relationships would be useful in utilization and management of the morphotypes during intravarietal breeding programs. The genetic relationships among the Dashehari morphotypes were assessed by a cluster analysis of the similarity matrix. Jaccard's coefficient of similarity was used to evaluate the similarity between the morphotypes based on the protein profiling. The value of similarity index (SI) is presented in Table 4.15. 0.8% similarity was observed for morphotype DM_1 with DM_6, DM_{12} with DM_{16} and DM_{17} and DM_{38} with DM_{40} showed 0.8% similarity followed by DM_4 with DM_{11}, DM_7 with DM_{14}, DM_8 with DM_{15}, DM_{10} with DM_{16} and DM_{17}, DM_{19} with DM_{20} and DM_{38} with DM_{45} showed 0.7% similarity and morphotype DM_{24} showed very negligible (0.0%) similarity (Table 4.20).

The UPGMA dendrogram of the protein profile obtained using hierarchical genetic distance based clustering revealed two main clusters (Plate 12). Cluster-II contained only one morphotypes (DM_{24}). Cluster-I was further divided into four sub-clusters (IA, IB, IC and ID). Sub cluster-IA consist 12 morphotypes (DM_1, DM_6, DM_{13}, DM_2,

Table 4.19 Protein profiling for 45 morphotypes of mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow showing different bands their corresponding molecular weight (kDa)

S.N.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
1	228	-	-	242	236	227	234	-	-	-	242	-	-	-	-	-	185	89	209	227	232	218	212	220	215	144	144	222	152	232	157	149	186	201	223	204	213	134	117	225	164	68	169	39	39
2	-	-	-	-	-	140	-	-	-	-	-	236	-	234	-	-	84	62	93	177	191	194	154	181	159	70	77	154	76	141	71	79	116	117	116	112	116	120	80	187	62	43	39	32	32
3	123	-	-	130	127	121	125	-	-	-	-	-	227	-	-	-	59	43	36	96	157	154	118	90	69	44	26	88	26	69	44	30	36	36	37	35	80	38	23	116	38	31	33	24	24
4	-	-	98	-	-	95	-	-	-	-	-	-	14	-	-	-	34	33	25	67	98	116	90	65	46	26	-	65	23	27	26	27	24	28	25	25	36	31	17	80	32	24	24	24	23
5	85	-	-	-	86	80	87	-	-	-	13	127	121	125	-	-	25	24	-	36	62	92	63	35	26	22	-	27	21	22	21	22		25	20	20	24	25	-	53	29	23	24	22	22
6	-	-	-	-	-	-	-	-	-	98	-	-	95	-	-	-	-	-	-	26	47	64	44	27	23	20	-	23	20	20	-	-	-	17	-	-	21	18	-	37	26	22	23	22	22
7	-	-	61	-	-	-	-	-	-	-	-	86	-	87	-	-	-	-	-	23	36	35	35	-	20	-	-	21	-	-	-	-	-	-	-	-	-	17	-	25	24	22	22	-	-
8	-	47	45	45	-	-	44	45	-	-	-	-	8	-	-	-	-	-	-	-	26	27	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22	24	-	-	-	-
9	41	-	-	-	42	42	-	-	-	61	-	-	-	-	-	-	-	-	-	-	25	26	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	23	-	-	-	-
10	31	-	-	-	31	31	31	-	47	45	45	-	-	44	45	45	-	-	-	-	-	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22	-	-	-	-
11	28	27	28	27	28	-	-	27	-	-	-	42	42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	25	-	25	-	26	25	-	-	-	-	-	31	31	31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	24	-	24	24	24	24	24	24	27	28	27	28	-	-	27	28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	25	-	26	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	24	24	24	24	24	24	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TNB	8	2	6	5	8	9	6	3	2	6	4	8	9	6	3	3	5	5	4	7	9	10	9	6	7	6	3	7	6	6	5	5	4	6	5	5	6	7	4	9	10	7	7	6	6

1: DM_1, 2: DM_2, 3: DM_3, 4: DM_4, 5: DM_5, 6: DM_6, 7: DM_7, 8: DM_8, 9: DM_9, 10: DM_{10}, 11: DM_{11}, 12: DM_{12}, 13: DM_{13}, 14: DM_{14}, 15: DM_{15}, 16: DM_{16}, 17: DM_{17}, 18: DM_{18}, 19: DM_{19}, 20: DM_{20}, 21: DM_{21}, 22: DM_{22}, 23: DM_{23}, 24: DM_{24}, 25: DM_{25}, 26: DM_{26}, 27: DM_{27}, 28: DM_{28}, 29: DM_{29}, 30: DM_{30}, 31: DM_{31}, 32: DM_{32}, 33: DM_{33}, 34: DM_{34}, 35: DM_{35}, 36: DM_{36}, 37: DM_{37}, 38: DM_{38}, 39: DM_{39}, 40: DM_{40}, 41: DM_{41}, 42: DM_{42}, 43: DM_{43}, 44: DM_{44}, 45: DM_{45} and TNB: Total number of bands

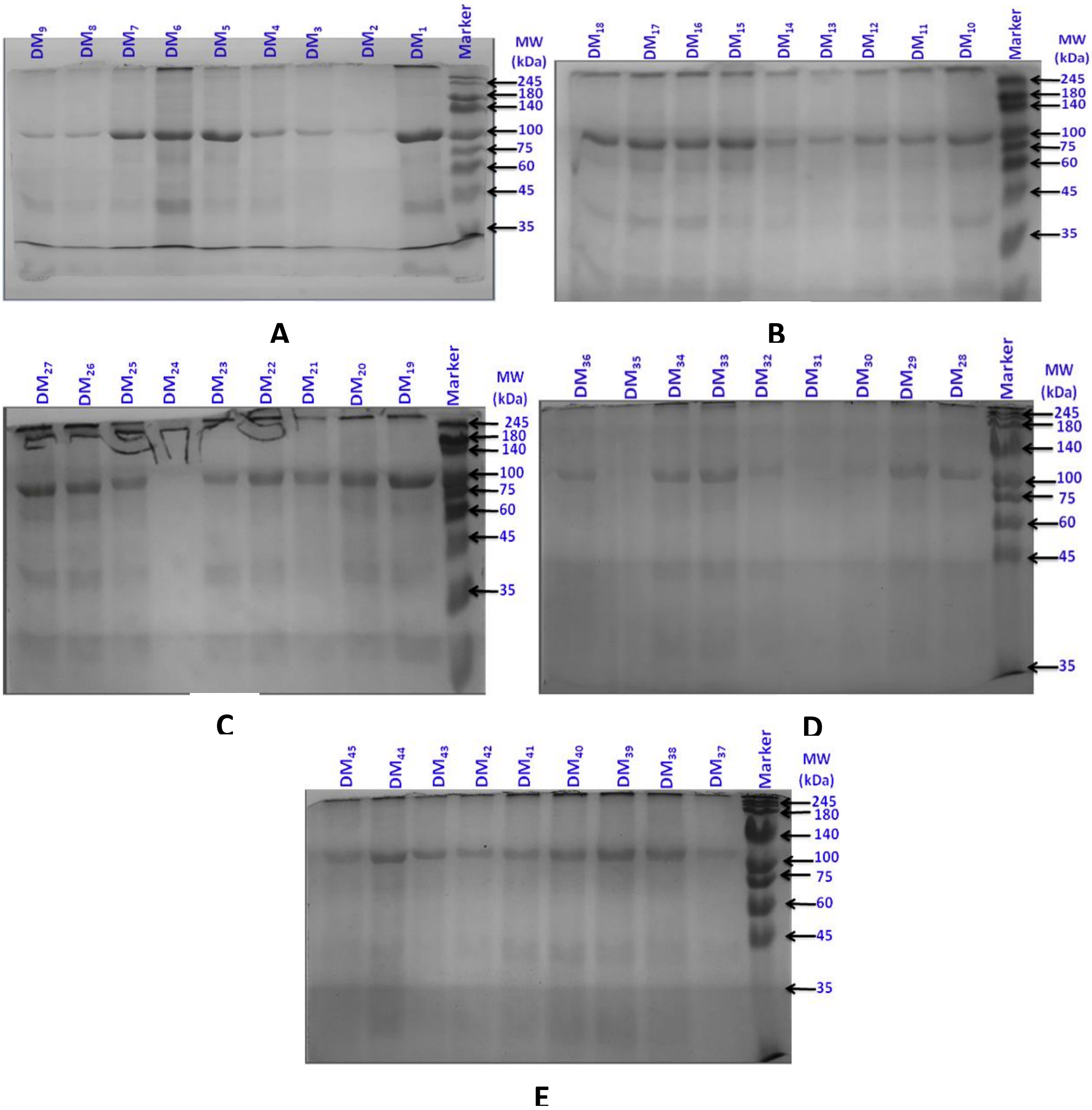

Plate 11: Protein profiling for 45 Dashehari morphotypes showing different bands their corresponding molecular weight (kDa)

Table 4.20 Jaccard's coefficient of similarity values between 45 morphotypes of Mango (*Mangifera indica* L.) cv. Dashehari collected from 15 different orchards in Malihabad and Mal block of district Lucknow

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**
1	1.0	0.5	0.1	0.3	0.3	0.8	0.5	0.4	0.2	0.1	0.2	0.1	0.6	0.5	0.3	0.1	0.1	0.3	0.3	0.3	0.2	0.2	0.2	0.0	0.4	0.3	0.2	0.1	0.1	0.2	0.1	0.2	0.1	0.2	0.2	0.1	0.4	0.3	0.3	0.3	0.2	0.3	0.1	0.2	0.2
2		1.0	0.0	0.1	0.1	0.5	0.5	0.3	0.0	0.1	0.2	0.2	0.6	0.6	0.4	0.2	0.2	0.3	0.2	0.2	0.1	0.4	0.1	0.0	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.2	0.3	0.4	0.3	0.3	0.4	0.2	0.4	0.2
3			1.0	0.3	0.4	0.1	0.0	0.1	0.7	0.3	0.1	0.2	0.0	0.0	0.1	0.3	0.3	0.1	0.0	0.2	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.3	0.3	0.2	0.1	0.2	0.3	0.2	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4				1.0	0.4	0.3	0.3	0.2	0.5	0.3	0.7	0.3	0.2	0.2	0.1	0.3	0.3	0.2	0.1	0.2	0.3	0.2	0.4	0.0	0.3	0.4	0.3	0.2	0.3	0.1	0.3	0.1	0.3	0.1	0.1	0.1	0.3	0.2	0.2	0.2	0.1	0.2	0.0	0.1	0.1
5					1.0	0.3	0.2	0.4	0.6	0.2	0.2	0.3	0.2	0.2	0.2	0.1	0.1	0.2	0.1	0.3	0.1	0.0	0.2	0.0	0.3	0.3	0.1	0.2	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1
6						1.0	0.5	0.6	0.2	0.1	0.2	0.1	0.8	0.5	0.4	0.1	0.1	0.5	0.3	0.3	0.2	0.2	0.3	0.0	0.4	0.3	0.2	0.1	0.1	0.2	0.1	0.2	0.1	0.2	0.2	0.1	0.4	0.3	0.3	0.3	0.2	0.3	0.1	0.2	0.2
7							1.0	0.4	0.1	0.1	0.3	0.1	0.5	0.7	0.3	0.1	0.1	0.3	0.3	0.3	0.3	0.3	0.4	0.0	0.5	0.4	0.2	0.0	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.0	0.3	0.3	0.4	0.3	0.2	0.2	0.1	0.3	0.2
8								1.0	0.3	0.1	0.2	0.1	0.6	0.4	0.7	0.1	0.1	0.4	0.4	0.6	0.3	0.1	0.4	0.0	0.2	0.4	0.1	0.1	0.1	0.1	0.0	0.1	0.2	0.1	0.1	0.0	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.3	0.2
9									1.0	0.3	0.3	0.2	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.3	0.2	0.0	0.2	0.0	0.2	0.2	0.1	0.3	0.3	0.2	0.1	0.1	0.2	0.1	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1
10										1.0	0.3	0.5	0.1	0.0	0.1	0.7	0.7	0.3	0.0	0.2	0.0	0.1	0.2	0.0	0.1	0.2	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.3	0.1	0.2	0.2	0.0	0.1	0.0	0.0	0.0
11											1.0	0.4	0.3	0.3	0.2	0.5	0.5	0.2	0.1	0.2	0.3	0.3	0.4	0.0	0.2	0.4	0.2	0.2	0.3	0.0	0.3	0.1	0.3	0.1	0.0	0.1	0.3	0.3	0.4	0.4	0.2	0.3	0.0	0.2	0.2
12												1.0	0.2	0.1	0.3	0.8	0.8	0.2	0.0	0.1	0.0	0.2	0.2	0.0	0.1	0.2	0.0	0.3	0.2	0.0	0.1	0.1	0.2	0.1	0.0	0.3	0.2	0.3	0.3	0.3	0.1	0.2	0.0	0.1	0.1
13													1.0	0.6	0.6	0.2	0.2	0.5	0.3	0.3	0.2	0.3	0.3	0.0	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.4	0.4	0.4	0.4	0.3	0.4	0.1	0.3	0.3
14														1.0	0.4	0.1	0.1	0.2	0.3	0.3	0.3	0.4	0.2	0.0	0.3	0.3	0.2	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.1	0.1	0.2	0.3	0.4	0.3	0.3	0.3	0.1	0.4	0.3
15															1.0	0.3	0.3	0.4	0.2	0.4	0.1	0.2	0.3	0.0	0.1	0.3	0.1	0.2	0.2	0.1	0.1	0.2	0.3	0.2	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.1	0.3	0.2
16																1.0	1.0	0.2	0.0	0.1	0.0	0.3	0.2	0.0	0.1	0.2	0.0	0.3	0.3	0.0	0.1	0.1	0.2	0.1	0.0	0.1	0.2	0.3	0.3	0.3	0.1	0.3	0.0	0.1	0.1
17																	1.0	0.2	0.0	0.1	0.0	0.3	0.2	0.0	0.1	0.2	0.0	0.3	0.3	0.0	0.1	0.1	0.2	0.1	0.0	0.1	0.2	0.3	0.3	0.3	0.1	0.3	0.0	0.1	0.1
18																		1.0	0.1	0.2	0.1	0.4	0.4	0.0	0.3	0.4	0.2	0.2	0.2	0.0	0.1	0.1	0.1	0.3	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.1	0.0
19																			1.0	0.7	0.3	0.1	0.3	0.0	0.3	0.3	0.1	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.1	0.1	0.3	0.2	0.3	0.3	0.4	0.2	0.3	0.6	0.4
20																				1.0	0.3	0.1	0.4	0.0	0.3	0.4	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.3	0.2	0.3	0.3	0.4	0.2	0.3	0.4	0.4
21																					1.0	0.2	0.3	0.0	0.4	0.3	0.4	0.0	0.0	0.0	0.2	0.0	0.0	0.1	0.0	0.0	0.2	0.1	0.1	0.1	0.3	0.1	0.0	0.2	0.1
22																						1.0	0.3	0.0	0.3	0.3	0.3	0.2	0.2	0.0	0.3	0.2	0.1	0.5	0.0	0.2	0.1	0.2	0.3	0.2	0.1	0.2	0.0	0.2	0.1
23																							1.0	0.0	0.6	0.6	0.3	0.2	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.0	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.2	0.2
24																								1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25																									1.0	0.6	0.5	0.1	0.1	0.2	0.3	0.2	0.1	0.3	0.2	0.1	0.2	0.1	0.2	0.2	0.2	0.1	0.1	0.2	0.1
26																										1.0	0.3	0.3	0.1	0.0	0.1	0.1	0.1	0.2	0.0	0.0	0.2	0.3	0.2	0.3	0.2	0.1	0.1	0.2	0.3
27																											1.0	0.2	0.2	0.1	0.6	0.2	0.2	0.4	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0
28																												1.0	0.4	0.3	0.4	0.6	0.4	0.4	0.1	0.2	0.0	0.3	0.1	0.2	0.1	0.2	0.1	0.2	0.3
29																													1.0	0.4	0.4	0.3	0.7	0.3	0.3	0.3	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.2
30																														1.0	0.2	0.5	0.3	0.1	0.8	0.1	0.2	0.3	0.1	0.1	0.1	0.2	0.3	0.2	0.3
31																															1.0	0.5	0.4	0.3	0.1	0.2	0.0	0.2	0.1	0.1	0.2	0.2	0.1	0.1	0.2
32																																1.0	0.3	0.4	0.3	0.2	0.1	0.4	0.3	0.3	0.2	0.3	0.3	0.3	0.4

33	1.0	0.2	0.2	0.2	0.0	0.2	0.1	0.1	0.2	0.3	0.2	0.2	0.2
34		1.0	0.1	0.4	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.2	0.1
35			1.0	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1
36				1.0	0.0	0.1	0.1	0.1	0.1	0.2	0.0	0.2	0.1
37					1.0	0.5	0.6	0.6	0.3	0.4	0.2	0.2	0.3
38						1.0	0.6	0.8	0.3	0.6	0.3	0.4	0.7
39							1.0	0.7	0.4	0.5	0.1	0.4	0.4
40								1.0	0.4	0.5	0.1	0.3	0.6
41									1.0	0.4	0.4	0.5	0.5
42										1.0	0.4	0.5	0.4
43											1.0	0.4	0.4
44												1.0	0.5
45													1.0

1: DM_1, 2: DM_2, 3: DM_3, 4: DM_4, 5: DM_5, 6: DM_6, 7: DM_7, 8: DM_8, 9: DM_9, 10: DM_{10}, 11: DM_{11}, 12: DM_{12}, 13: DM_{13}, 14: DM_{14}, 15: DM_{15}, 16: DM_{16}, 17: DM_{17}, 18: DM_{18}, 19: DM_{19}, 20: DM_{20}, 21: DM_{21}, 22: DM_{22}, 23: DM_{23}, 24: DM_{24}, 25: DM_{25}, 26: DM_{26}, 27: DM_{27}, 28: DM_{28}, 29: DM_{29}, 30: DM_{30}, 31: DM_{31}, 32: DM_{32}, 33: DM_{33}, 34: DM_{34}, 35: DM_{35}, 36: DM_{36}, 37: DM_{37}, 38: DM_{38}, 39: DM_{39}, 40: DM_{40}, 41: DM_{41}, 42: DM_{42}, 43: DM_{43}, 44: DM_{44} and 45: DM_{45}

DM_7, DM_{14}, DM_8, DM_{15}, DM_{18}, DM_{25}, DM_{23} and DM_{26}), sub cluster-IB consist 11 morphotypes (DM_{41}, DM_{44}, DM_{43}, DM_{19}, DM_{20}, DM_{37}, DM_{39}, DM_{42}, DM_{45}, DM_{38} and DM_{40}), sub cluster-IC consist 9 morphotypes (DM_3, DM_9, DM_5, DM_4, DM_{11}, DM_{10}, DM_{12}, DM_{16} and DM_{17}) and sub cluster-ID consist 12 morphotypes (DM_{27}, DM_{31}, DM_{21}, DM_{36}, DM_{22}, DM_{34}, DM_{30}, DM_{35}, $DM2_8$, DM_{32}, DM_{29}, DM_{33} and DM_{24}) presented in table 4.21.

Table 4.21 Non hierarchical euclidean cluster analysis in 45 morphotypes of Dashehari mango (*Mangifera indica* L.) on the basis of protein profiling

Clusters	Morphotypes
Cluster I	DM_1, DM_2, DM_3, DM_4, DM_5, DM_6, DM_7, DM_8, DM_9, DM_{10}, DM_{11}, DM_{12}, DM_{13}, DM_{14}, DM_{15}, DM_{16}, DM_{17}, DM_{18}, DM_{19}, DM_{20}, DM_{21}, DM_{22}, DM_{23}, DM_{24}, DM_{25}, DM_{26}, DM_{27}, DM_{28}, DM_{29}, DM_{30}, DM_{31}, DM_{32}, DM33, DM_{34}, DM_{35}, DM_{36}, DM_{37}, DM_{38}, DM_{39}, DM_{40}, DM_{42}, DM_{43}, DM_{44}, DM_{45}
Cluster II	DM_{24}

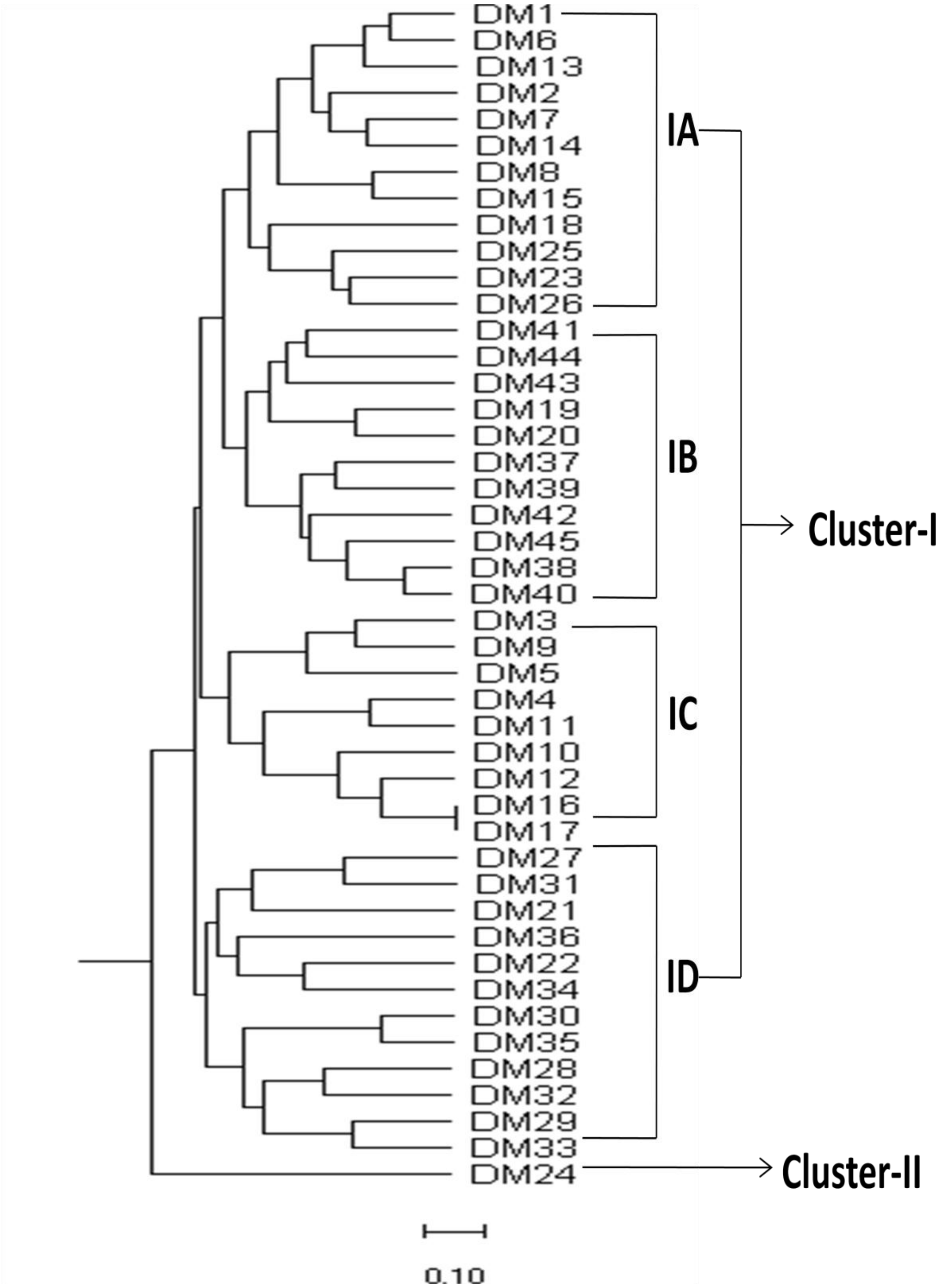

Plate 12: Dendrogram of 45 Dashehari morphotypes of mango (*Mangifera indica* L.) based on protein profiling

DISCUSSION

In this chapter an attempt has been made to explain the findings of the present investigation entitled "**Morphological and Molecular Analysis of Intravarietal Variability in Mango (*Mangifera indica* L.) cv. Dashehari in Lucknow region"** on the basis of literature of previous studies which has been combed critically to discuss the results of the study in the light of literature reviewed, as per objectives of the study in order to draw a scientific and logical conclusion:

<u>EXPERIMENT I</u>

5.1 To survey the possibility of genetic diversity and variability in Dashehari mango in two Blocks of district Lucknow

Survey was conducted in two blocks *viz.* Malihabad and Mal of district Lucknow through questionnaire (Appendix III) for exploring the possibility of intravarietal variability in mango orchards cv. Dashehari. Variability was observed in age when trees came into bearing, flowering behaviour, fruiting behaviour, fruit quality, fruit weight (g) and fruit yield (quintal per tree) during the discussion with mango growers and on the basis of data collected through questionnaire and has been reported in the preceeding chapter. Mukherjee (1983) conducted similar survey in mango growing belts in West Bengal for description and characterization of variability in several clones of important mango varieties through morphological features of leaf, inflorescence, fruit and tolerance to biotic and abiotic stress conditions. Exploration of intra-varietal variability in mango on the basis of survey has been reported by several researchers (Begum *et al.,* 2014; Singh *et al*., 2009; de Souza and Lima, 2004; Rocha *et al*., 2012) which were later supported with molecular analysis in 'Cherukurasam' cultivar of mango. Begum *et al.* (2014c) conducted eco-geographic survey, in Baneshan, the choicest table cultivar of mango (*Mangifera indica* L.) cultivated commercially for more than a century, covering the three regions of Andhra Pradesh to study intracultivar heterogeneity based on morphological fruit traits and microsatellite markers. Similar surveys have also been conducted by Suriyagoda *et al.* (2008) and Deb *et al*. (2013) for water chestnut in India and other countries such as Japan, China and Sri Lanka, etc. Similar preliminary surveys, collection and evaluation studies were done in water chestnut by Suriyagoda *et al.* (2008) and Dwivedi *et al.* (2011) in order to explore the possibility of genetic variability in water chestnut., on the basis of morphological performance of plant, fruit and its yield, and by Arima (1999), who surveyed local lines of 7 species i.e. 5 small and 2 medium from Japan and 5 large fruit lines from China through a survey and analyzed vegetative and yield performance of water chestnuts.

EXPERIMENT II

5.2 To evaluate the intravarietal variability in mango cv. Dashehari on the basis of vegetative characters

In fruit tree species, quantitative and qualitative fruit traits have been found useful in identification and assessment of intravarietal heterogeneity and selection of elite forms for fruit production on a large scale (Arima, 1999; de Souza and Lima, 2004; Suriyagoda *et al.*, 2008; Singh *et al*., 2009; Dwivedi *et al.*, 2011; Rocha *et al*., 2012; Begum *et al.*, 2014a) as these traits help in developing ideotypes of the crop. In mango, morphological traits are the oldest and most widely used markers , which may still be optimal for certain cases, where the cultivars are identified based on leaf, panicle, fruit and other physical characteristics.

In the present study also a wide variation was observed in tree, leaf and flowering characters of mango which indicated the presence of variability in the sample population. The significant variability in trunk girth was observed to range from (102.50 to 151.33 cm), number of secondary branches per plant (12 to 29), leaf length (17.45 to 22.55 cm), leaf width (3.95 to 5.62 cm), leaf thickness (0.21 to 0.38 mm) and petiole length (2.42 to 4.35 cm) (Table 4.6). Among panicle characters, panicle length ranged from (27.70 to 37.08 cm), panicle width (15.80 to 25.25 cm), number of florets per panicle (38.83 to 66.17) and number of flowers per panicle (1932.83 to 2979.33) (Table 4.6) and also in fruit set study *viz.,* initial fruit set per panicle (287.33 to 421.83), number of fruits per panicle at pea stage (24.67 to 37.50) and number of fruit per panicle at maturity stage (1.33 to 3.50) (Table 4.6) duly reported in the previous chapter.

Most cultivars of mango, a highly cross-pollinated and heterozygous genus, have arisen through selection of desirable types from naturally produced seedlings

(Karihaloo *et al.,* 2003) where each cultivar is identified by the characteristic combination of properties such as plant architecture, fruit size, color, taste, flavor etc. (Anu *et al.,* 2015), performance of which varies with the climate resulting in a high level of genetic diversity. Thus, variations between cultivars are easily explained. The question that needs attention is regarding variations observed in fruit and tree characters even within one cultivar where trees are propagated clonally and thus, in principle, should be true to type without any deviation from parent characteristics. It is noteworthy that in the present study variations have been reported by farmers in cv. Dashehari, and this claim of farmers has been established through the scientifically designed experiments where data collected was analysed and stastically significant variation was found to be existent.

Intracultivar heterogeneity in mango and other crops fruit crops has been characterized mostly at the morphological level by several researchers (Gan *et al.,* 1981; Pandey, 1998) who used morphology-based methods for the characterization of intra-varietal variability in mango where significant variation among the trees of the same variety in an orchard with regard to fruit shape, size, colour and quality of the fruits has been observed which was ascribed to bud mutations (Singh *et al.,* 2009; Begum *et al.,* 2014).

The growth and development of any variety having a definite genetic character in particular set of environmental conditions, shows a positive relation. The variation in vegetative growth characters among mango varieties might be due to variation in genetic makeup. High variability in vegetative growth among the mango varieties have also been reported by Singh *et al.* (1998) and Murti and Upreti (2004). Similarly, the variations observed in fruiting behaviours may also be attributed equally to the genetic nature of varieties and weather parameter (Muhammad *et al*., 2002; Kumar and Jaiswal, 2004). However, in spite of such characterization studies, actual identity of some cultivars is still in question (Lakshminarayana, 1980).

The tree and leaf traits were controlled by additive and peliotropic gene effect hence a dendrogram was prepared on the basis of tree and leaf data (Table 4.5 and Plate 2) of 45 Dashehari morphotypes in order to establish their relatedness to each other. Samples were found to be very closely related and grouped into only three major clusters (cluster I, II and III) with additional sub-clusters, differentiating the morphotypes collected from different areas. Cluster-I consisted of 44 morphotypes which further divided into five sub-groups (cluster IA, IB, IC, ID and IE) while cluster-II and cluster- III comprised only one morphotype each. Anu *et al.,* (2015) prepared a dendrogram on the basis of RAPD data and observed different clad in Langra mango.

Variability among the population is a pre-requisite for genetic improvement for any breeding programme. In fact, high magnitude of genetic variability, heritability and expected genetic advance and genetic advance as percent of mean reveals the possibility of profitable selection. The relative values of coefficients of variation (PCV and GCV) give an idea about the extent of variability present in a population (Sridhar *et al.,* 2018).

The high PCV and GCV of characters indicated the presence of large amount of variation. Therefore, the chances of improvement in these characters through selection would be more. Moreover, high genetic variance also showed that the fluctuations due to environmental effects were undoubtedly tolerable. Samanta *et al.* (1999) have reported high range of phenotypic and genotypic variation for vegetative characters. However, GCV, PCV analysis in present study showed the variation is significantly influenced by external environmental factors rather than the genotype. The prime advantages of morphological traits are simplicity and rapidity, inexpensive assays, even from herbarium specimens and other dead tissues (Begum, *et al.,* 2014). Differences in fruit size are reported primarily due to plant vigour, competition among fruits in the inflorescence, number and size of developed achenes, differences in activity among the achenes in the production of growth material, climatic conditions, irrigation and plant nutrients. High heritability estimates for the characters indicate less influence of the environment and so there is a good scope for the improvement of these traits through direct selection (Kumar *et al.,* 2012).

The genotypic and phenotypic coefficient of variation, heritability, genetic advance and genetic advance as percent of mean (GAM%) of tree, leaf and panicle traits of mango are presented in (Table 4.6). The estimates of phenotypic coefficient of variation were higher than the genotypic coefficient of variation for all the characters studied, indicating the influence of environment on the expression of these characters under investigation (Majumder *et al.,* 2012). However, there was a very narrow difference between PCV and GCV values for number of secondary branches (22.46 and 21.69%), number of florets per panicle (12.52 and 12.19%), number of flowers per panicle (11.39 and 11.19%), trunk girth (7.78 and 7.72%) presented in table 4.6, which indicates that expression of these characters is governed by the genotype of the sample rather than being influenced by environment. The findings are supported by (Ogunniyan and Olakojo, 2014) Singh *et al.,* 2014) who concluded that these characters not more reliable for crop improvement through selection (Ranpise and Desai, 2003) in lime.

Although the genotypic coefficient of variation and phenotypic coefficient of variation are the measures of genetic variability however, Swarup and Chougule (1962) suggested that the estimates of genotypic coefficient of variation alone was not sufficient to quantify the amount of variation which is heritable while inferred that genotypic coefficient of variation effects together with heritability estimates would furnish more reliable information. In the present study, heritability estimates were high for most of the characters *viz.,* trunk girth (98.40%), number of secondary branches (93.20%), panicle length (65.00%), panicle width (73.30%), number of florets per panicle (94.40%) and number of flowers per panicle (99.40%) and very low estimates from remaining characters (Table 4.6). Higher heritability value indicates that these were inherited characters governed by major genes or additive gene effects and therefore, selection of these characters would be more effective for further crop improvement which was also suggested by (Sridhar *et al.,* 2018).

The genetic advance expressed in percent mean was very high for some of the characters, such as number of secondary branches (88.87%), number of florets per panicle (50.56%) and number of flowers per panicle (48.32%) (Table 4.6). Heritability and genetic gain (GA) in referring valuable conclusion for effective selection based on the phenotypic coefficient of variation (Sridhar *et al.,* 2018). The characters having high heritability as well as moderate to high genetic advance and narrow difference between GCV and PCV indicate predominance of additive gene action for these characters and these characters would have possibilities of selection towards desired direction.

EXPERIMENT III

5.3 To establish intravarietal variability in mango cv. Dashehari on the basis of physico-chemical characters of the fruit

In most cases, morphological traits are evaluated manually and are thereby subjective and do not define the potential use of any genotype, even though these traits have long been the means of studying variability among populations in fruit crops. Quantitative and qualitative fruit traits have been found useful in identification and assessment of intravarietal heterogeneity and selection of elite forms for fruit production on a large scale.

Singh *et al*. (2009) detected prominent intravarietal variation in the cultivar Banganapalli based on morphological analysis of 17 fruit characters and Bally *et al*. (1996) also observed variation in the type of fruit in 15 accessions of Kensington Pride, a polyembryonic cultivar of mango. From the results of these studies on fruit morphology a clear idea can be generated regarding the possibility of intravarietal variability in Dashehari mango conserved in farmer's orchards in the collection sites which could be established through fruit morphology studies as above since existence of intravarietal variability on the basis of tree, leaf and flower morphology has already been established above through the previous experiment. Conventionally also, the intracultivar heterogeneity of mango has been characterized mostly through fruit morphological studies by several researchers (Gan *et al*., 1981; Pandey, 1998; Singh *et al*., 2009).

From the results of mean range, grand mean, coefficient of variation, it is evident that there was significant variation in fruit, stone and kernel morphology among 45 morphotypes of Dashehari mango under study. The fruit width ranged from 5.52 to 6.97 cm, fruit length 9.84 to 12.85 cm, fruit weight ranged from (191.00 to 342.33 g), fruit volume 325.00 to 175.83 ml, specific gravity of fruit 1.02 to 1.10, pulp weight 125.83 to 259.67 g, peel weight 40.00 to 61.67 g, pulp:peel ratio 2.71 to 4.40, peel thickness 1.21 to 2.78 mm (Table 4.15). The stone weight was ranged from 24.17 to 33.50 g, pulp:stone ratio 4.36 to 8.40, stone volume 31.83 to 22.67 ml, specific gravity of stone 1.02 to 1.10, stone length 11.75 to 8.99 cm, stone width 2.72 to 4.14 cm and stone thickness 1.44 to 1.93 cm (Table 4.15). The kernel length was ranged from 3.65 to 6.64 cm, kernel width 1.46 to 4.13 cm and kernel thickness 1.04 to 2.07 cm (Table 4.15). In the present study, fruits, stone and kernel of all morphotypes of Dashehari mango were found variable.

Qualitative characteristics provide quite useful information particularly from nutritional and biochemical point of view. The main factors responsible for variation in fruit composition are climatic and nutritional conditions and fruit load on plants.

In the present study the content of total soluble solids in Dashehari morphotypes fruit varied from 11.73 to 21.33^0Brix, pH of the pulp ranged from 4.3 to 7.0, titrable acidity percentage ranged from 0.27 to 0.37% and TSS:acid ratio ranged from 33.16 to 38.74 (Table 4.15). The reducing sugar percentage ranged from 2.52 to 5.48%, non-reducing percentage ranged from 9.42 to 12.12% and total sugars percentage ranged from 13.58 to 16.58% (Table 4.15), however, these findings partially agreed with the result of Bhuyan and Guha (1995), who also reported TSS from 16.22 to 24.14 ºBrix in 14 mango germplasm under the climatic conditions of Rajshahi. Similar variation in TSS (16.11 to 23.00 ºBrix) is also reported by Singh (2002).

The values of titrable acidity are in accordance with the results of Kumar (1998), who reported the range of 0.17 to 0.33 % in different mango cultivars. The TSS:acid ratio as reported in present study were similar to those of Mitra and Mitra (2001). Significant variation observed in sugar content is also accordance with Mitra *et al.* (2001). The reason for deviation in sugar content in fruit may be ascribed due to differences in growing conditions and climatic variations as reported by Polovyanov (1985).

The extent of variability among genotypes was determined in terms of PCV, GCV, heritability, genetic advance as well as genetic advance as percent of mean (GAM%). The PCV for all the characters was slightly higher than the GCV. PCV (22.15%) and GCV (19.65%) were recorded as highest for kernel width.

PCV was found higher than GCV for all the character, which signifies the presence of environmental influence in the phenotypic expression of characters. Since, many economic traits are quantitative in nature and highly influenced by the environment, the progress of breeding is governed by the nature of genetic and non-genetic variations; it will be useful to partition the overall variability into its heritable and non-heritable components to know whether superiority of selection is inherited by the progenies. Effective selection of genotypes for desirable traits is determined by the estimates of heritability along with genetic advance. However, the present results found similarity with the findings of Singh (2000) who suggested that heritable variation is useful for permanent genetic improvement in strawberry. The GCV, along with heritability estimates study in the present investigation shall provide reliable estimates of the amount of GA to be expected through phenotypic selection. High heritability estimates for the characters indicated less influence of the environment and so there is a good scope for the improvement of these traits through direct selection (Kumar *et al.*, 2012).

There was close difference between PCV and GCV for kernel thickness (21.77 and 19.58 %), reducing sugar (20.75 and 18.31 %), TSS:acid ratio (20.33 and 19.76 %), total soluble solids (18.27 and 17.84 %) and kernel length (14.16 and 13.09 %) (Table 4.15) which indicates expression of these characters less influenced by environment effect and they have a wide scope for improvement through selection. However, remaining characters (Table 4.17) showed wide difference between PCV and GCV which indicates expression of these characters influence by environmental effect thus, these characters are not more reliable for crop improvement through selection (Ranpise and Desai, 2003) in lime. As far as the chemical constituents are concerned, Prasad (1987) reported the high range of variations for reducing sugars and ascorbic acid contents. Karibasappa *et al.* (1999) recorded high range of phenotypic and genotypic variations for different morpho-phenological and physico-chemical characters in mango. Attri *et al.* (1999) and Samanta *et al.* (1999) have reported high range of phenotypic and genotypic variations for fruit weight, its volume, pulp and carotenoid contents. Similarly, Yadav *et al.* (2003) and Rai *et al.* (2001) found high range of variations for peel, pulp and stone weight including yield per plant.

However, heritability estimates were high for most of the characters total soluble solids (95.30%), tss:acid ratio (94.50 %), tritable acidity (90.0%), kernel length (85.50%), kernel thickness (81.50%), kernel width (78.20%) and reducing sugar (77.90%) and very low estimates from remaining characters (Table 4.15). Higher heritability value indicates that these were inherited characters governed by major genes or additive gene effects and therefore, selection of these characters would be more effective for further crop improvement which was also suggested by (Sridhar *et al.*, 2018).

The genetic advance (38.41%) and genetic advance as percent of mean (81.86%) were recorded from Tss:acid ratio (Table 4.15) which was coupled with heritability which indicates influence of these characters not governed by environmental effect. The high genetic advance would be obtainable when heritability is chiefly due to dominance and epistasis (non additive gene action), consequently genetic advance would also below.

The prime advantages of morphological traits are simplicity and rapid, inexpensive assays, even from herbarium specimens and other dead tissues. Although morphological traits are very useful, they have several disadvantages. They are often limited in number. They suffer from lack of decisiveness. They face heritability problems as they may be controlled by epistatic and pleiotropic gene effects. Morphological characterizations are error prone due to environmental variations affecting expression of these characteristics. In addition, these observations are time consuming and this mode of identification is slow because of long juvenile periods. Thus, these morphological characters may not adequately represent the genetic heterogeneity among accessions of a cultivar. Hence, characterization of intravarietal heterogeneity based on morphological traits needs complementation with microscopic studies and protein profiling as they can contribute greatly to the utilization of intravarietal heterogeneity through descriptive information of structure of genotypes, analyses of relatedness, the study of identity and location diversity.

EXPERIMENT IV

5.4 Microscopy studies for exploring intravarietal variability in mango cv. Dashehari

Microscopic study of the mango leaf showed significant variation among the stomatal traits. The stomatal length ranged from 6.00 to 17.56 µm and width 5.32 to 12.72 µm (Table 4.18). The stomatal pore width and length was ranged from 1.68 to 6.56 µm and 2.32 to 11.70 µm, respectively. Trichome length ranged from 27.60 to 42.82 µm and width was ranged from 28.00 to 45.20 µm. The stomatal density was ranged from 24.00 to 46.00 ($µm^{-1}$) are presented in Table 4.18. This conforms with earlier studies in stomatal length and density in poplar (Ferris *et al.*, 2002; Tognetti *et al.*, 2004) which has been used as a parameter for establishing the existence of the clonal variability in germplasm. Marron (2005) postulated that stomatal traits could be used as early indicators of growth potential in poplar as well as a criteria for clonal discrimination in the genus and stomatal density is reported to differ significantly even among clones belonging to different parentages, between different canopy positions and on leaf surfaces besides varying within leaves, plants, and individuals of a single species (Afas *et al.,* 2006). Stomatal length has also been reported to correlate with genome size (Xu and Zhou, 2008). Therefore, the genetic and developmental basis for high stomatal density and stomatal conductance and its application in germplasm studies is exploited as a research priority in plant physiology, agriculture, and paleo-biology (Roche, 2015; Wang *et al.*, 2015).

The information obtained from intravarietal diversity analysis can be utilized in making the crosses and selection of divergent parents to maximize heterosis in future intravarietal breeding programmes on the basis of fruit, stone and kernel morphology and stomatal characteristics. Considering the stability of stomatal characteristics at the genetic level as above, a dendrogram was prepared on the basis of stomatal characteristics (Table 4.17 and Plate 10) of 45 Dashehari morphotypes in order to establish their relatedness to each other. The 45 Dashehari morphotypes under study, were found to be very closely related and grouped into only two major clusters (cluster I and II) with additional sub-clusters, differentiating the morphotypes collected from different areas. Cluster-I consisted of 43 morphotypes which further divided into five sub-groups (cluster IA, IB, IC, ID and IE) while cluster-II comprised two morphotypes which was divided into two sub-groups (cluster IIA and IIB). Anu *et al.,* 2015 prepared a dendrogram on the basis of RAPD data in Langra mango, who observed different clad.

The extent of variability among the morphotypes was determined in terms of PCV, GCV, heritability, genetic advance and GAM%. The PCV for all the characters was slightly higher than the GCV. The highest PCV (41.59), GCV (38.27) and GAM% (149.41) were observed for stomatal pore size width (Table 4.18) indicating higher degree of genetic variability among the stomatal characteristics and the germplasm. In general, stomatal initiation is controlled by both environmental and genetic factors (Casson and Hetherington, 2010) and is indicative of clonal variability. As a quantitative trait, stomatal density is genetically determined (Gailing *et al.*, 2008) and stomatal length has been reported to correlate with genome size (Xu and Zhou, 2008). In the present study all stomatal characteristics showed narrow differences between PCV and GCV (Table 4.18) which indicates the negligible environmental effect on these characters and a greater regulation at the genetic level creating scope for further crop improvement through selection at an early stage on the basis of these characters (Majumder *et al.*, 2012). These results are similar to those of Riaz and Chaudhary (2003) in wheat who observed genotypic and phenotypic coefficient of variation (7.43 and 7.29%) for stomatal size indicating that all of the variation for the trait was due to genetic causes and highly heritable in case of wheat.

Although, the genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) are the measures of genetic variability however, the amount of genetic gain can be estimated from genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) along with heritability (Majumder *et al.*, 2012). Similarly in the present study, higher heritability (97.50) and genetic advance (20.86) were observed for stomatal density (Table 4.18) which is reported (Gailing *et al.*, 2008) to be genetically determined and controlled by additive genes. These results are in consonance with those of Riaz and Chaudhary (2003) that high estimates of heritability for stomatal characters indicate that these traits are transmitted to the offspring and were governed by additive gene. Usefulness of any character is related to its onward transmission to the progeny and characters with high heritable are easy to select for breeding purpose. Higher values of heritability of stomatal characters in the present study indicates that either these were simply inherited characters governed by a few major genes or additive gene effects even if, they were under polygenic control and therefore, selection of these characters would be more effective for improvement and can be exploited at an early stage of development of the plants. Thus, heritability and genetic gain (GA) aid in referring valuable conclusion for effective selection in a germplasm.

EXPERIMENT V

5.5 Molecular analysis of intravarietal variability in mango cv. Dashehari

Genetic diversity represents the heritable variation within and between populations of organisms. It is the basis of survival and adaptation and makes it possible to advance the adaptive process on which evolutionary success, and to some extent, the survival of species depends (Rao and Hodgkin, 2002). A better understanding of genetic diversity and distribution is essential for it conservation and use. It helps in determining what to conserve as well as where to conserve.

Smith and Smith (1992) have concluded that morphological differences cannot be interpreted to provide accurate estimates of genetic differences. Moreover, identification of cultivars using classical methods based on morphological and physiological characters has become increasingly difficult because of the large number of lines being released and convergence of these lines on a few of the most desirable characters. Time and resource requirements of grow out tests and their dependence on normal environmental conditions make such procedure impractical for routine screening (Weeden, 1984). Thus, identification of crop cultivars through biochemical markers i.e. proteins, have been used to measure the genetic diversity for conspicuous species and specific and highly stable characteristics. Accessions among cultivated plants from different geographical areas and adapted to diverse ecological zone still possess the same basic profile (Sridhar *et al.*, 2018). Seed protein variants have been observed to be the most widely used biochemical markers during the last century. Its reliability depends on polymorphism of seed and seedlings proteins and the fact that these proteins represent primary gene products. Moreover these have advantage of being scorable from inevitable organs or tissues and the electrophoretic protocol for bulk protein assay is generally simpler than of isozyme (Cooke, 1984). Mann *et al.* (2005) reported that the number of bands give an account of polypeptides present in a protein. As equal amount of proteins is loaded in all, thus the banding pattern is indicative of the range of the proteins present in the different varieties.

In the present study the protein profiling showed distinct polymorphism in electrophoretic banding patterns and led to the detection of total of 10 bands. In the initial screening the molecular weight of the 10 bands obtained ranged from 242 kDa to 8 kDa (Table 4.19). The morphotype DM_4 and DM_{11} having maximum (242 kDa) value band which was not present in other morphotypes and minimum (8 kDa) value band was hound in morphotypes DM_{13}. The maximum number of bands (10 bands) was reported for morphotype DM_{21} and DM_{41} followed by DM_6, DM_{13}, DM_{21}, DM_{23} and DM_{40} (9 bands) (Table 4.19), respectively. The minimum number of bands (2 bands) was reported for morphotype DM_2 and DM_9. These results were in conformity with those in pumpkin (Kumar *et al*., 2006) and other cucurbits like bittergourd (Tewari, 1997), muskmelon (Yadav *et al.,* 1998; Singh *et al.*, 1999; Choudhary and Ram, 2000) and cucumber (Singh and Ram, 2003).

Similarity matrix and UPGMA cluster analysis

The proximity or similarity matrix was created for 45 Dashehari morphotypes, based on the presence and absence of protein bands. Jaccard's coefficient of similarity was used to evaluate the similarity.

The similarity per cent varied from a minimum 0.0 % to a maximum of 0.80 % for Dashehari morphotypes. morphotype DM_1 with DM_6, DM_{12} with DM_{16} and DM_{17} and DM_{38} with DM_{40} showed 0.8% similarity followed by DM_4 with DM_{11}, DM_7 with DM_{14}, DM_8 with DM_{15}, DM_{10} with DM_{16} and DM_{17}, DM_{19} with DM_{20} and DM_{38} with DM_{45} showed 0.7% similarity and morphotype DM_{24} showed very negligible (0.0%) similarity (Table 4.20).

The UPGMA dendrogram of the protein profile obtained using hierarchical genetic distance based clustering revealed two main clusters (Table 4.21 and Plate 12). Cluster-II contained only one morphotypes (DM_{24}). Cluster-I was further divided into four sub-clusters (IA, IB, IC and ID). Sub cluster-IA consist 12 morphotypes (DM_1, DM_6, DM_{13}, DM_2, DM_7, DM_{14}, DM_8, DM_{15}, DM_{18}, DM_{25}, DM_{23} and DM_{26}), sub cluster-IB consist 11 morphotypes (DM_{41}, DM_{44}, DM_{43}, DM_{19}, DM_{20}, DM_{37}, DM_{39}, DM_{42}, DM_{45}, DM_{38} and DM_{40}), sub cluster-IC consist 9 morphotypes (DM_3, DM_9, DM_5, DM_4, DM_{11}, DM_{10}, DM_{12}, DM_{16} and DM_{17}) and sub cluster-ID consist 12 morphotypes (DM_{27}, DM_{31}, DM_{21}, DM_{36}, DM_{22}, DM_{34}, DM_{30}, DM_{35}, $DM2_8$, DM_{32}, DM_{29}, DM_{33} and DM_{24}) (Table 4.21). Thus, it was evident that the genotypes with similar morphological traits were accordingly grouped together and could be easily distinguished through electrophoresis. This was in conformation with the study in bottle gourd (Padiyar, 2007) and Anu *et al.*, 2015 prepared a dendrogram on the basis of RAPD data and observed different clad in Langra mango.

SUMMARY AND CONCLUSION

The present investigation entitled **“Morphological and Molecular Analysis of Intravarietal Variability in mango (*Mangifera indica* L.) cv. Dashehari in Lucknow region”** was conducted during the year 2016-2018 in Malihabad and Mal block of District Lucknow and Ph. D Horticultural Laboratory, Department of Horticulture, School of Agricultural Sciences and Technology, Babasaheb Bhimrao Ambedkar University, Lucknow with the following objective

1. survey the possibility of genetic diversity and variability in Dashehari mango in tow Blocks of district Lucknow i.e. Malihabad and Mall.
2. To evaluate the intravarietal variability in mango cv. Dashehari on the basis of vegetative characters.
3. To establish intravarietal variability in mango cv. Dashaheri on the basis of physico-chemical characters of the fruit.
4. Microscopy studies for exploring intravarietal variability in mango cv. Dashehari.
5. Molecular analysis of intravarietal variability in mango cv. Dashehari.

Data of 45 morphotypes were analyzed for exploring intravarietal variability in vegetative, floral, physico-chemical and stomatal characters and protein profiling. The experiment was laid out in Completely Randomized Design (CRD) with 15 treatments (orchards) and from each, three replications (trees) were selected for the study. Standard methods and procedures were followed for recording various vegetative, floral, physico-chemicals and stomatal attributes and protein profiling. The salient findings are summarized below.

6.1 Vegetative parameters

Among 45 Dashehari morphotypes the morphotypes DM_{25} and DM_{14} was superior for trunk girth (cm) and number of secondary branches/per tree. However, the highest leaf length (cm) and petiole length was observed for morphotype DM_{38} while, maximum leaf width (cm) and leaf thickness was observed for morphotypes DM_5 and DM_9.

A statistically significant variability were found in floral parameters and the morphotype DM_{12} was better for panicle length (cm), panicle width (cm), number of florets per panicle, number of flowers per panicle, fruit set per panicle at mustard stage, fruit set per panicle at pea stage, final fruit set per panicle.

Variability analysis for vegetative and floral parameters in terms of phenotypic coefficient of variation (PCV %), genotypic coefficient of variation (GCV %), heritability (h^2 %), genetic advance (GA) and genetic advance as percent of mean (GAM %). The highest PCV, GCV and genetic advance as percent of mean was recorded for number of secondary branches while number of florets per panicle, fruit set at mustard stage, number of flowers per panicle and trunk girth (cm) showed narrow differences between PCV and GCV. However, the highest heritability and genetic advance was observed for number of flowers per panicle while, fruit set at mustard stage, trunk girth (cm), number of secondary branches per tree and number of florets per panicle showed reliable amount of heritability and genetic advance.

UPGMA dendrogram was prepared on the basis of tree and leaf data of 45 Dashehari morphotypes in order to establish their relatedness to each other. Samples were found to be very closely related and grouped into only three major clusters (cluster I, II and III) with additional sub-clusters.

6.2 Fruit physico-chemical traits

The significant variability was observed among the fruit physic-chemical attributes. The morphotype DM_{12} was superior for fruit length (cm), fruit weight (g), fruit volume (ml), specific gravity of fruit, pulp weight (g), pulp:peel ratio, peel thickness (mm), pulp stone ratio and stone length while, morphotype DM_{38} was better for peel weight (g), stone weight (g) and stone volume (ml). However, morphotype DM_7 was best for stone width (cm) and stone thickness (cm). The morphotype DM_1, DM_2, DM_3, DM_{10}, DM_{24}, DM_{25}, DM_{27}, DM_{33}, DM_{40}, DM_{41} and DM_{44} was superior for TSS:acid ratio, total soluble solids (0Brix), non-reducing sugar (%), kernel width (cm), pH of the pulp, kernel thickness, titrable acidity (%), reducing sugar (%), total sugar (%), fruit length (cm) and kernel length.

Analysis of Phenotypic coefficient of variation (PCV %), genotypic coefficient of variation (GCV %), heritability (h^2), genetic advance (GA) and genetic advance as percent of mean (GAM %). The highest PCV and GCV was found for kernel width (cm), kernel thickness (cm), TSS:acid ratio, reducing sugar (%) and total soluble solids. However, the highest heritability (%), genetic advance (%) and genetic advance as percent of mean (%) were observed for TSS:acid ratio, total soluble solids, reducing sugar (%) and kernel width.

6.3 Microscopy studies of different Dashehari morphotypes

Stomatal traits found highly variable among the different Dashehari morphotypes. The morphotypes DM_{28} better for stomatal length (µm), stomatal pore length (µm) and stomatal pore width (µm) while, morphotype DM_5 best for stomatal width (µm). However, morphotype DM_1 and DM_{30} was superior for trichome length (µm) and trichome width (µm). Morphotype DM16 was better for stomatal density (μm^{-2}).

Variability analysis for stomatal traits in terms of phenotypic coefficient of variation (PCV %), genotypic coefficient of variation (GCV %), heritability (h^2 %), genetic advance (GA) and genetic advance as percent of mean (GAM %). All stomatal traits showed narrow differences between PCV and GCV. The highest PCV and GCV were observed for stomatal pore width (µm). However, the highest heritability and genetic advance were observed for trichome length (µm), trichome width (µm) and stomatal density (μm^{-1}) while, genetic advance as percent of mean was observed for stomatal pore width (µm)and stomatal length (µm).

A UPGMA dendrogram was prepared on the basis of stomatal characteristics of 45 Dashehari morphotypes in order to establish their relatedness to each other. The 45 Dashehari morphotypes under study were found to be very closely related and grouped into only two major clusters (cluster I and II) with additional sub-clusters, differentiating the morphotypes collected from different areas. Cluster-I consisted of 43 morphotypes which further divided into five sub-groups (cluster IA, IB, IC, ID and IE) while cluster-II comprised two morphotypes which was divided into two sub-groups (cluster IIA and IIB).

6.4 Protein profiling of different Dashehari morphotypes

The protein profiling showed distinct polymorphism in electrophoretic banding patterns and led to the detection of total of 10 bands**.** The maximum number of bands (10 bands) was reported for morphotype DM_{21} and DM_{41} followed by DM_6, DM_{13}, DM_{21}, DM_{23} and DM_{40} (9 bands), respectively.

In the initial screening the molecular weight of the 10 bands obtained ranged from 242 kDa to 8 kDa. The morphotype DM_4 and DM_{11} having maximum (242 kDa) band size.

The value of similarity index (SI) is presented in Table 4.15. 0.8% similarity was observed for morphotype DM_1 with DM_6, DM_{12} with DM_{16} and DM_{17} and DM_{38} with DM_{40} showed 0.8% similarity.

The UPGMA dendrogram of the protein profile obtained using hierarchical genetic distance based clustering revealed two main clusters (Plate 12). Cluster-II contained only one morphotypes (DM_{24}). Cluster-I was further divided into four sub-clusters (IA, IB, IC and ID).

CONCLUSION

Statistically significant intravarietal variation was recorded in the fruit morphology of 45 Dashehari morphotypes of mango under the study which could be substantiated with variations observed in the stomatal characteristics.

Estimates of genetic components for vegetative, floral characters, fruit morphology, fruit chemical parameters and stomatal characters. Among them the number of secondary branches, flowers per panicle, kernel parameters, reducing sugar , TSS:acid ratio, stomatal pore size and stomatal density are inherent characters and helpful for breeding program for further crop improvement.

The UPGMA dendrogram was prepared on the basis of stomatal and molecular data and the sample population was grouped into two main clusters which subdivided into further sub-groups.

Intravarietal variation in the population could be because of the lack of availability of true-to-type planting material at the time of establishment of these orchards. It could also be an expression of the adaptations of trees to variable microenvironment and edaphic factors of the orchards under study or of the stionic effect in the plants since they are all propagated on seedling rootstocks through approach grafting.

On the basis of present study using SDS-PAGE in mango a usable protein band polymorphism has been observed which can be exploited to study intravarietal variability of the morphotypes as per clustering in the morphotypes with similar band patterns.

However, this clearly indicated that morphological, stomatal, biochemical and molecular methods of morphotype characterization of mango are not alternative methods, but they are complimentary to each other.

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Appendices

Appendix I. Mean monthly metrological data of district Lucknow during period of (2016-17 to 2017-18)

Period	Mean temperature (ºC)		Relative humidity (%)		Total rainfall (mm)	Wind velocity (km/hr.)
Month	Maximum	Minimum	Maximum	Minimum		
January, 16	17.40	8.20	95.33	72.00	0.00	1.60
February,16	19.75	11.35	93.00	47.00	0.00	2.95
March,16	29.50	14.48	89.00	46.60	0.00	4.00
April, 16	40.20	23.30	46.80	16.10	0.00	9.50
May, 16	39.00	25.40	64.50	35.50	39.60	7.00
June, 16	37.90	27.60	77.40	51.00	92.40	5.90
July,16	33.40	26.33	92.00	76.60	219.60	3.00
August, 16	33.70	25.70	89.70	73.20	243.40	3.00
September, 16	33.40	25.20	92.20	79.00	202.40	3.20
October, 16	33.50	19.70	92.20	45.90	54.60	2.80
November, 16	28.60	11.90	95.40	42.10	0.00	1.70
December, 16	22.20	9.10	97.50	61.70	0.00	0.80
January, 17	22.00	7.80	94.60	51.50	16.50	1.70
February,17	25.80	10.30	91.30	36.30	0.40	2.90
March,17	31.80	17.10	75.80	25.30	5.40	4.50
April, 17	38.40	22.20	60.60	24.20	0.00	4.1
May, 17	39.50	24.90	67.10	31.60	18.40	3.50
June, 17	38.70	26.80	74.40	43.50	85.00	3.10
July,17	32.60	25.90	91.30	78.00	336.40	2.2
August, 17	33.30	26.30	91.90	75.40	232.2	2.60
September, 17	34.30	25.40	90.50	63.90	54.00	2.10
October, 17	34.30	19.90	95.60	45.60	0.00	1.00
November, 17	28.30	11.70	93.60	41.50	0.00	1.20
December, 17	24.30	8.70	94.40	45.00	0.40	1.60
January, 18	20.40	5.40	80.70	51.70	4.00	1.90
February,18	26.80	10.40	89.10	38.60	0.00	3.20

March,18	33.60	15.60	73.10	24.50	0.00	4.30
April, 18	36.90	19.90	61.20	26.50	9.20	3.60
May, 18	38.60	24.80	67.20	36.80	16.80	2.90
June, 18	38.90	27.30	70.40	45.20	123.40	3.60
July,18	34.40	26.20	88.50	68.40	318.70	2.90
August, 18	32.40	25.40	94.50	77.60	564.40	2.00
September, 18	34.20	23.90	89.90	65.10	227.80	3.40
October, 18	33.80	17.60	91.80	36.80	0.00	1.60
November, 18	28.80	11.60	92.40	39.10	0.00	1.40
December, 18	23.70	5.00	95.00	37.00	0.00	1.50

Source: IISR (Indian Institute of Sugarcane Research, Lucknow)

Appendix II. Questionnaire for study of 100 mango orchardist in Malihabad and Mal district Lucknow for establishing presence of Intravarietal variability in mango cv. Dashehari

1. **Name of the farmers:-**
2. **Address of the farmers:-**
3. **Mobile No.:-**
4. **Source of plant:-**
    - Government nursery ☐
    - Private nursery ☐

5- **Method of propagation:-**

- Vegetatively propagated ☐
- Sexualy propagated ☐

6- **Age of plant:-**

20 ☐ 25 years ☐ 30 years ☐

7- **Total number of variety of in your orchard:-**

8- **Total number of plants in orchard:-**

9- **Total number of plant of cv. Dashehari:-**

10- **In how many days plants come under bearing habit:-**

11- **Time of flowering:-**

12- **Do all plants of orchard come under flowering at the same time**

Yes ☐ No ☐

13- **Do all plants of orchard come under flowering at the different time**

Yes ☐ No ☐

14- **If know then how many plants come under flowering at the same time:-**

15- If know how many plants come under flowering at the different time:-

16- How many days plants take to give commercial fruits yield:-

17- Plants give same size fruits:-

Yes ☐ No ☐

18- Weight of fruits:-

100g ☐ 150g ☐ 200g ☐ 250g ☐ 300g ☐

350g ☐ 400g ☐ 450g ☐ 500g ☐

19- Is there problem of alternate bearing in your orchard:-

Yes ☐ No ☐

20- Which variety shows maximum alternate bearing in orchard:-

21- Is there problem of bacterial rot in your orchard:-

22- How many plant suffer bacterial rot in trees cultivar Dashehari:-

23- How many fruits obtain from one plant:-

24- Total yield from one plant:-

Appendix III. Survey of mango growers of two blocks (Malihabad and Mal) district Lucknow

Farmer name	Village	Block	Source of plant	Method of Propagation	AP	TNV	TNP	TNP cv. Dashehari	FP at same time	FP at different time (%)	PGCY (in year after planting)	FW (g)	Yield (q/tree)
Balram	Bahelia	Malihabad	Private nursery	Vegetative	25.0	5.0	100.0	85.0	60.0	15.0	5.0	300.0	2.0
Deshraj	Bahelia	Malihabad	Private nursery	Vegetative	25.0	5.0	200.0	170.0	50.0	10.0	4.0	180.0	1.0
Indra Pal	Bahelia	Malihabad	Private nursery	Vegetative	25.0	2.0	50.0	45.0	70.0	20.0	3.0	250.0	2.0
Shailendra Yadav	Bahelia	Malihabad	Private nursery	Vegetative	25.0	3.0	90.0	80.0	60.0	10.0	3.5	200.0	1.0
Raja Ram Yadav	Bahelia	Malihabad	Private nursery	Vegetative	25.0	1.0	100.0	100.0	70.0	15.0	4.0	300.0	1.5
Ram Kumar	Bahelia	Malihabad	Private nursery	Vegetative	23.0	1.0	90.0	90.0	60.0	10.0	5.0	300.0	2.0
Shiv Kumar	Bahelia	Malihabad	Private nursery	Vegetative	25.0	3.0	30.0	25.0	60.0	10.0	4.0	300.0	1.5
Ram Shankar	Bahelia	Malihabad	Private nursery	Vegetative	25.0	2.0	100.0	80.0	50.0	15.0	5.0	250.0	2.0
Ram Kishor	Bahelia	Malihabad	Private nursery	Vegetative	25.0	4.0	80.0	60.0	60.0	15.0	3.0	200.0	2.5
Ayaz Ahemad	Kasmandi Kalan	Malihabad	Private nursery	Vegetative	25.0	3.0	45.0	38.0	65.0	10.0	3.0	250.0	2.0
Panna Lal	Kasmandi Kalan	Malihabad	Private nursery	Vegetative	20.0	3.0	65.0	40.0	50.0	10.0	5.0	300.0	1.0
Ram Autar	Kasmandi Kalan	Malihabad	Private nursery	Vegetative	23.0	3.0	40.0	32.0	60.0	10.0	3.5	250.0	2.0
Nawab Hasan	Kasmandi Kalan	Malihabad	Private nursery	Vegetative	25.0	5.0	150.0	100.0	60.0	10.0	4.0	200.0	1.5
Jehrul Hasan	Kasmandi Kalan	Malihabad	Private nursery	Vegetative	25.0	4.0	200.0	165.0	70.0	10.0	5.0	280.0	2.0
Shiv Ram	Banshi Garhi	Malihabad	Private nursery	Vegetative	25.0	3.0	80.0	60.0	75.0	15.0	3.0	300.0	1.5
Radhey Lal	Banshi Garhi	Malihabad	Private nursery	Vegetative	25.0	3.0	100.0	80.0	60.0	10.0	3.5	250.0	1.5
Suresh	Banshi Garhi	Malihabad	Private nursery	Vegetative	25.0	2.0	50.0	35.0	70.0	10.0	4.0	300.0	2.0
Mahes Chandra	Bhatkherwa	Malihabad	Private nursery	Vegetative	25.0	5.0	200.0	150.0	75.0	10.0	3.0	300.0	2.0
Amrit Lal	Bhatkherwa	Malihabad	Private nursery	Vegetative	25.0	3.0	100.0	85.0	70.0	5.0	4.5	250.0	2.0
Jai Narayan	Bhatkherwa	Malihabad	Private nursery	Vegetative	25.0	2.0	70.0	68.0	60.0	10.0	3.0	200.0	2.0
Raja Ram	Shivdas Pur	Malihabad	Private nursery	Vegetative	25.0	3.0	40.0	35.0	70.0	15.0	3.5	200.0	2.0
Ram Kumar	Shivdas Pur	Malihabad	Private nursery	Vegetative	25.0	2.0	45.0	40.0	65.0	10.0	3.0	250.0	1.0
Vipin Kumar	Shivdas Pur	Malihabad	Private nursery	Vegetative	22.0	1.0	40.0	40.0	60.0	10.0	4.0	200.0	1.5
Sravan Kumar	Shivdas Pur	Malihabad	Private nursery	Vegetative	22.0	2.0	40.0	35.0	65.0	15.0	5.0	250.0	1.5
Sareef	Hamira Pur	Malihabad	Private nursery	Vegetative	20.0	3.0	70.0	50.0	60.0	10.0	3.5	250.0	1.0
Moh. Haseeb	Hamira Pur	Malihabad	Private nursery	Vegetative	25.0	2.0	45.0	40.0	80.0	15.0	4.0	200.0	1.5
Kallu	Hamira Pur	Malihabad	Private nursery	Vegetative	25.0	1.0	70.0	70.0	75.0	20.0	3.0	250.0	2.0

Hariram	Kithai Para	Malihabad	Private nursery	Vegetative	30.0	3.0	40.0	32.0	60.0	10.0	3.0	200.0	1.5
Ram Prakash	Kithai Para	Malihabad	Private nursery	Vegetative	25.0	5.0	140.0	100.0	60.0	5.0	5.0	200.0	1.5
Babu Das	Kithai Para	Malihabad	Private nursery	Vegetative	23.0	4.0	190.0	160.0	70.0	10.0	5.0	250.0	2.0
Jodha	Kithai Para	Malihabad	Private nursery	Vegetative	20.0	3.0	80.0	60.0	75.0	15.0	4.0	200.0	1.5
Ram Babu	Bhadwana	Malihabad	Private nursery	Vegetative	25.0	3.0	100.0	80.0	60.0	10.0	3.0	180.0	1.5
Babu Lal	Bhadwana	Malihabad	Private nursery	Vegetative	22.0	2.0	50.0	35.0	50.0	20.0	4.0	200.0	1.5
Chote Lal	Bhadwana	Malihabad	Private nursery	Vegetative	20.0	5.0	200.0	130.0	75.0	10.0	3.0	200.0	2.0
Sushil Kumar	Bhadwana	Malihabad	Private nursery	Vegetative	20.0	3.0	100.0	85.0	70.0	10.0	5.0	250.0	1.0
Makrand	Choti Kasmandi	Malihabad	Private nursery	Vegetative	25.0	2.0	70.0	68.0	60.0	15.0	3.0	200.0	1.0
Pappu	Choti Kasmandi	Malihabad	Private nursery	Vegetative	25.0	3.0	40.0	35.0	70.0	15.0	5.0	180.0	1.5
Rajaram	Choti Kasmandi	Malihabad	Private nursery	Vegetative	20.0	2.0	70.0	60.0	70.0	10.0	3.0	300.0	1.0
Haseeb	Choti Kasmandi	Malihabad	Private nursery	Vegetative	20.0	3.0	70.0	65.0	80.0	20.0	4.0	200.0	1.5
Nand Kumar	Navi Panah	Malihabad	Private nursery	Vegetative	20.0	5.0	200.0	150.0	75.0	10.0	5.0	200.0	1.0
Gyanendra Kumar	Navi Panah	Malihabad	Private nursery	Vegetative	20.0	3.0	100.0	85.0	70.0	15.0	4.5	300.0	1.5
Ram Charan	Navi Panah	Malihabad	Private nursery	Vegetative	25.0	2.0	70.0	68.0	60.0	10.0	5.0	250.0	1.5
Sanjay	Navi Panah	Malihabad	Private nursery	Vegetative	25.0	3.0	40.0	35.0	70.0	15.0	5.0	280.0	2.0
Raja Ram	Mahmood Nagar	Malihabad	Private nursery	Vegetative	20.0	2.0	70.0	60.0	70.0	10.0	5.0	200.0	1.5
Suresh Kumar	Mahmood Nagar	Malihabad	Private nursery	Vegetative	20.0	3.0	70.0	65.0	80.0	10.0	4.0	250.0	2.0
Nitin Kumar	Mahmood Nagar	Malihabad	Private nursery	Vegetative	20.0	2.0	45.0	40.0	65.0	20.0	5.0	280.0	1.5
Guddu	Mahmood Nagar	Malihabad	Private nursery	Vegetative	22.0	5.0	100.0	85.0	60.0	15.0	4.0	200.0	1.5
Ram Prasad	Jagta Pur	Malihabad	Private nursery	Vegetative	20.0	4.0	140.0	100.0	50.0	25.0	5.0	300.0	2.0
Kaushlendra	Jagta Pur	Malihabad	Private nursery	Vegetative	22.0	2.0	50.0	45.0	70.0	20.0	5.0	250.0	2.0
Dhirendra Kumar	Jagta Pur	Malihabad	Private nursery	Vegetative	25.0	3.0	90.0	80.0	60.0	10.0	5.0	200.0	2.0
Gomti Yadav	Jagta Pur	Malihabad	Private nursery	Vegetative	20.0	3.0	70.0	65.0	80.0	10.0	5.0	200.0	2.0
Mahendra Kumar	Jagta Pur	Malihabad	Private nursery	Vegetative	20.0	2.0	70.0	60.0	70.0	25.0	5.0	200.0	2.0
Atul Kumar	Ptauna	Mal	Private nursery	Vegetative	25.0	2.0	40.0	35.0	70.0	15.0	5.0	250.0	1.0
Vipin Kumar	Ptauna	Mal	Private nursery	Vegetative	25.0	5.0	40.0	30.0	75.0	15.0	4.5	300.0	2.0
Virendra Kumar	Ptauna	Mal	Private nursery	Vegetative	25.0	4.0	40.0	35.0	70.0	10.0	5.0	350.0	1.5
Munni Lal	Ptauna	Mal	Private nursery	Vegetative	23.0	2.0	50.0	45.0	70.0	10.0	3.5	250.0	2.0
Saroj Kumar	Raniya Mau	Mal	Private nursery	Vegetative	22.0	3.0	50.0	40.0	70.0	15.0	4.0	200.0	1.0
Murari Lal	Raniya Mau	Mal	Private nursery	Vegetative	25.0	4.0	60.0	55.0	70.0	10.0	3.0	350.0	2.5
Ajay Singh	Raniya Mau	Mal	Private nursery	Vegetative	25.0	3.0	120.0	80.0	80.0	10.0	5.0	300.0	2.0

Bramha	Raniya Mau	Mal	Private nursery	Vegetative	20.0	4.0	100.0	90.0	75.0	10.0	5.0	300.0	1.5
Sunil Kumar	Raniya Mau	Mal	Private nursery	Vegetative	25.0	2.0	50.0	40.0	65.0	20.0	4.0	250.0	2.0
Virendra Kumar	Raniya Mau	Mal	Private nursery	Vegetative	25.0	2.0	70.0	60.0	70.0	10.0	3.0	200.0	2.5
Ram Bhadur	Raniya Mau	Mal	Private nursery	Vegetative	25.0	3.0	70.0	65.0	80.0	10.0	4.5	250.0	1.5
Chet Ram	Raja Khera	Mal	Private nursery	Vegetative	25.0	2.0	120.0	115.0	75.0	15.0	4.5	300.0	2.0
Badlu Prashad	Raja Khera	Mal	Private nursery	Vegetative	25.0	2.0	100.0	90.0	70.0	10.0	3.0	300.0	2.0
Raja Ram	Raja Khera	Mal	Private nursery	Vegetative	20.0	4.0	70.0	65.0	60.0	15.0	5.0	250.0	2.0
Babu Lal	Raja Khera	Mal	Private nursery	Vegetative	25.0	2.0	65.0	60.0	70.0	10.0	5.0	200.0	2.0
Munnu Lal	Kushambahri	Mal	Private nursery	Vegetative	27.0	2.0	70.0	68.0	60.0	20.0	3.0	200.0	2.0
Ram Lal	Kushambahri	Mal	Private nursery	Vegetative	25.0	3.0	40.0	35.0	70.0	15.0	4.0	200.0	2.0
Balak	Kushambahri	Mal	Private nursery	Vegetative	20.0	2.0	45.0	40.0	65.0	10.0	3.5	250.0	1.0
Ram Bharose	Kushambahri	Mal	Private nursery	Vegetative	22.0	5.0	100.0	85.0	60.0	20.0	4.0	200.0	1.0
Virendra Kumar	Padra	Mal	Private nursery	Vegetative	20.0	4.0	140.0	100.0	50.0	25.0	5.0	250.0	1.5
Prem Singh	Padra	Mal	Private nursery	Vegetative	22.0	2.0	50.0	45.0	70.0	20.0	3.5	200.0	2.0
Madan Lal	Padra	Mal	Private nursery	Vegetative	25.0	3.0	90.0	80.0	60.0	10.0	3.0	300.0	1.5
Kedar Singh	Padra	Mal	Private nursery	Vegetative	20.0	1.0	90.0	95.0	70.0	15.0	4.0	250.0	2.0
Rakesh	Padra	Mal	Private nursery	Vegetative	20.0	1.0	90.0	90.0	60.0	10.0	5.0	200.0	2.5
Ajay Kumar	Au Mau	Mal	Private nursery	Vegetative	27.0	3.0	30.0	25.0	60.0	10.0	5.0	300.0	1.5
Pradeep Kumar	Au Mau	Mal	Private nursery	Vegetative	20.0	2.0	100.0	80.0	50.0	15.0	5.0	250.0	2.0
Radhey Lal	Au Mau	Mal	Private nursery	Vegetative	25.0	4.0	80.0	60.0	60.0	15.0	5.0	200.0	2.5
Chandra Pal	Lalai Kheda	Mal	Private nursery	Vegetative	20.0	3.0	100.0	80.0	60.0	10.0	3.5	250.0	2.0
Dori Lal	Lalai Kheda	Mal	Private nursery	Vegetative	20.0	2.0	50.0	35.0	70.0	10.0	4.0	300.0	1.0
Neel Kanth	Lalai Kheda	Mal	Private nursery	Vegetative	20.0	5.0	200.0	150.0	75.0	10.0	3.5	250.0	2.0
Kushehar	Lalai Kheda	Mal	Private nursery	Vegetative	20.0	3.0	100.0	85.0	70.0	5.0	4.0	200.0	2.0
Naresh Kumar	Atari	Mal	Private nursery	Vegetative	24.0	2.0	120.0	115.0	75.0	15.0	4.0	200.0	1.0
Sudhir Kumar	Atari	Mal	Private nursery	Vegetative	25.0	2.0	100.0	90.0	70.0	10.0	3.0	200.0	2.0
Surendra Kumar	Atari	Mal	Private nursery	Vegetative	20.0	3.0	40.0	35.0	70.0	15.0	3.0	250.0	1.5
Babu Lal	Garhi	Mal	Private nursery	Vegetative	27.0	3.0	30.0	25.0	60.0	10.0	4.0	200.0	1.5
Rizwan	Garhi	Mal	Private nursery	Vegetative	20.0	2.0	100.0	80.0	50.0	15.0	5.0	300.0	2.0
Kallu	Garhi	Mal	Private nursery	Vegetative	25.0	4.0	80.0	60.0	60.0	15.0	5.0	200.0	2.0
Maharaj Singh	Garhi	Mal	Private nursery	Vegetative	25.0	3.0	30.0	25.0	60.0	20.0	5.0	200.0	2.0
Satrohan	Jalauli	Mal	Private nursery	Vegetative	25.0	2.0	100.0	80.0	50.0	15.0	5.0	200.0	2.0

Rama Pati	Jalauli	Mal	Private nursery	Vegetative	25.0	4.0	80.0	60.0	60.0	15.0	3.0	200.0	2.0
Lekhpal	Jalauli	Mal	Private nursery	Vegetative	25.0	3.0	45.0	38.0	65.0	10.0	3.0	250.0	1.0
Ram Lal	Pipri	Mal	Private nursery	Vegetative	20.0	3.0	65.0	40.0	50.0	5.0	5.0	250.0	1.0
Suresh Kumar	Pipri	Mal	Private nursery	Vegetative	23.0	3.0	40.0	32.0	60.0	10.0	3.5	300.0	2.0
Dinesh Kumar	Pipri	Mal	Private nursery	Vegetative	20.0	3.0	40.0	35.0	70.0	15.0	4.0	350.0	2.0
Mahesh	Kadaura	Mal	Private nursery	Vegetative	20.0	2.0	50.0	50.0	65.0	20.0	5.0	250.0	2.5
Raju Kumar	Kadaura	Mal	Private nursery	Vegetative	20.0	3.0	40.0	35.0	70.0	15.0	3.0	200.0	1.5
Rajendra Prasad	Kadaura	Mal	Private nursery	Vegetative	25.0	3.0	100.0	85.0	70.0	5.0	4.0	250.0	1.0
Rakesh Kumar	Kadaura	Mal	Private nursery	Vegetative	25.0	2.0	70.0	68.0	60.0	20.0	3.0	200.0	2.0

AP: Age of plant, TNV: total number of variety, TNP: total number of plants, TNP: total number of plants cv. Dashehari, FP: flowering plant at same time, FP: flowering plant at different time and FW: fruit weigh

Appendix IV. Details of 15 orchards of mango (*Mangifera indica* L.) cv. Dashehari which was selected for study from two bocks *viz.* Malihabad and Mal district of Lucknow

Sr. No.	Orchard	Farmer name	Village	Block
1	Orchard-1	Balram	Bahelia	Malihabad
2	Orchard-2	Deshraj	Bahelia	Malihabad
3	Orchard-3	Indra Pal	Bahelia	Malihabad
4	Orchard-4	Panna Lal	Kasmandi Kalan	Malihabad
5	Orchard-5	Ayaz Ahmad	Kasmandi Kalan	Malihabad
6	Orchard-6	Nawab Hasan	Kasmandi Kalan	Malihabad
7	Orchard-7	Atul Kumar	Patauna	Mal
8	Orchard-8	Virendra Kumar	Patauna	Mal
9	Orchard-9	Vipin Singh	Patauna	Mal
10	Orchard-10	Chetram	Raja Khera	Mal
11	Orchard-11	Ram Kumar	Raja Khera	Mal
12	Orchard-12	Rajaram	Raja Khera	Mal
13	Orchard-13	Saroj Kumar	Raniya Mau	Mal
14	Orchard-14	Ajay Singh	Raniya Mau	Mal
15	Orchard-15	Sunil Kumar	Raniya Mau	Mal