DIVERSITY MAPPING AND DATABASE DEVELOPMENT OF BANANA (*Musa* spp.) GERMPLASM IN NAGALAND

Thesis

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HORTICULTURE (FRUIT SCIENCE)

by

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Nagaland

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For my parents who dwells in sweat and blood to see me scale the height of success

DECLARATION

I, Khamrang Mathukmi, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form the basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis had not been submitted by me for any research degree in any other University/Institute.

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CERTIFICATE – I

This is to certify that the thesis entitled **"Diversity mapping and database development of banana (*Musa* spp.) germplasm in Nagaland"** submitted to Nagaland University in partial fulfilment of the requirements for the award of degree of Doctor of Philosophy in Horticulture (Fruit Science) is the record of research work carried out by Mr. Khamrang Mathukmi, Registration No. Ph.D./HOR/00237 under my personal supervision and guidance.

The result of the investigation reported in the thesis has not been submitted for any other degree or diploma. The assistance of all kinds received by the student has been duly acknowledged.

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CERTIFICATE – II

VIVA VOCE ON THESIS OF DOCTOR OF PHILOSOPHY IN HORTICULTURE (FRUIT SCIENCE)

This is to certify that the thesis entitled **"Diversity mapping and database development of banana (*Musa* spp.) germplasm in Nagaland"** submitted by Mr. Khamrang Mathukmi, Admission No. Ph-258/18, Registration No. Ph.D./HOR/00237 to the NAGALAND UNIVERSITY in partial fulfilment of the requirements for the award of degree of Doctor of Philosophy in Horticulture (Fruit Science) has been examined by the Advisory Board on …….....

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Date:

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LIST OF ABBREVIATIONS

APEDA	: Agricultural and Processed Food Products Export Development Authority
ANOVA	: Analysis of Variance
^{0}B	: Degree Brix
BC	: Before Christ
℃	: Degree Celsius
CD	: Critical Difference
CE	: Common Era
Cm	: Centimeter
DEBDOM	: Database Exploring Banana Diversity of Manipur
Df	: Degree of freedom
E	: East
et al.	: Et alilbi and others
etc.	: Et cetera
GCV	: Genotypic Coefficient of Variation
G	: Gram
Ha	: Hectare
IPGRI	: The International Plant Genetic Resources Institute
Kg	: Kilogram
M	: Meter
Max.	: Maximum
Mg	: Milligram
Min.	: Minimum
Mm	: Milimetre
MSS	: Mean Sum of Square
Msl	: Mean sea level
MT	: Metric tonnes
/	: Per

>	: Greater than
%	: Percent
PCA	: Principal component analysis
PCV	: Phenotypic Coefficient of Variation
RBD	: Randomized Block Design
RH	: Relative Huminity
RDA	: Recommended Dietary Allowance
SASRD	: School of Agricultural Sciences and Rural Development
SS	: Sum of Square
Spp.	: Several species
t	: tones
TSS	: Total Soluble Solids
UPOV	: The International Union for the Protection of New Varieties of Plants
US$	: United States Dollar
viz.	: Namely

ABSTRACT

A study entitled “Diversity mapping and database development of banana (*Musa* spp.) germplasm in Nagaland” was conducted during the year 2019-2021 at Department of Horticulture, SASRD, Nagaland University, Medziphema Campus, Nagaland. Altogether, two experiments were carried out to study the taxonomical characters and genetic variability of different *Mus*a spp. and to evaluate the selected germplasm suitable for table purpose based on fruit characters.

Banana genotypes were collected from five districts of Nagaland covering fifteen villages. The morphological characterization was conducted according to the descriptors for banana by IPGRI (The International Plant Genetic Resources Institute) and the genomic groups were determined using the nomenclature scheme based on ploidy level and morphological characters devised by Simmonds and Shepherd.

Analysis of variance revealed significant differences among the genotypes for all the characters studied. Highest genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) was observed for bunch weight indicating selection for such characters would be more reliable to be used as selection for crop improvement. High degree of heritability estimates were obtained in case of fruit weight, pulp weight, girth size and weight of peel. High genetic advance were observed for leaf blade length and pulp weight indicating predominance of additive gene effect and possibilities of effective selection for the improvement of these characters. In correlation studies, fruit weight had significant phenotypic correlation with pseudostem height and pulp peel ratio. Significant genotypic correlation with fruit weight was seen for girth size, petiole length and bunch weight. Path coefficient analysis revealed that pulp weight and weight of peel were the most important trait affecting yield both at phenotypic and genotypic level. Diversity

analysis based on D^2 value grouped all the twenty genotypes into six clusters. Maximum number of genotypes were included in cluster I followed by cluster II and cluster III. Divergence studies revealed fruit weight contributed maximum per cent to the diversity followed by girth size, leaf blade length, petiole length and pulp weight. In principal component analysis, the first four principal components contributed to 78.181 % of the total variation with proportionate contribution value of 34.302 %, 20.563 %, 12.557 % and 10.758 % respectively.

Among the fruit characters, maximum bunch weight, fruit weight, weight of peel and fruit peel thickness was recorded in Grand Naine. Highest number of hands/bunch and number of fingers/hand were recorded in Chinichampa and Nendran has the maximum pulp weight. The maximum total soluble solids, acidity, total sugar and reducing sugar were found in Bhootmanohar, Chinichampa, Grand Naine and Meiteihei respectively. Longest shelf life was recorded in Meiteihei and Bhootmanohar. Highest TSS/Acid ratio, crude protein and total carotene were obtained in Bhootmanohar, Grand Naine and Bharatmani respectively. Maximum concentration of boron, zinc and magnesium were obtained in the pulp of Jahaji. Grand Naine, Meiteihei and Bhootmanohar have the highest concentration of potassium, iron and calcium respectively. Potassium and boron content was found maximum in the peel of Jahaji. Iron, zinc, calcium and magnesium were found maximum in the peel of Nendran, Chinichampa, Grand Naine and Bhootmanohar respectively. Based on five levels Hedonic Scale sensory evaluation, the panelist preferred Grand Naine, Bhootmanohar, Jahaji and Chinichampa in most of the sensory attributes.

Key words: Banana, biodiversity, heritability, physico-chemical, sensory, variability.

CHAPTER I
INTRODUCTION

INTRODUCTION

Banana (*Musa* spp.) is a monocotyledonous, herbaceous, perennial succulent plant and one of the most important edible food crops worldwide. In some of the African countries like Uganda, Bukaba and Tanzania it has established as a staple food and one of the most important traded tropical fruits in the world (Radha and Matthew, 2007). The fruit was known to mankind since the dawn of civilisation. Reference of the fruit is found in the ancient Indian religious literatures as early as 500-600 BC and also in Chinese literature of 200 CE. In ancient India, the plants were considered sacred as these could provide shade and food. It has been deeply interwoven in the cultural heritage of India that its plants, leaves and fruits were considered very auspicious in all the festive occasions, be it a social function or worshipping God. As a diet, it is highly satisfying, easy to digest, nearly fat free, rich source of carbohydrate with calorific value of 67/100g and is free from sodium making it a salt free diet suitable to all the age groups and people of all levels. It contains various vitamins and has therapeutic values for the treatment of many diseases (Singh, 2007).

The banana fruit can be eaten raw or cooked, processed into flour and fermented for the production of beverages such as banana juice, beer, vinegar and wine (Pillay *et al.*, 2002; Nelson *et al*., 2006; Edmeaddes *et al*., 2006; Pillay and Tripathi, 2007). Other parts of the banana plant are also eaten in different parts of the world as vegetables and the corm are consumed as a source of starch (Nelson *et al.,* 2006).

In India maximum production of banana is in Andhra Pradesh (5003.07 thousand MT) followed by Gujarat (4472.32 thousand MT) and Maharashtra (4209.27 thousand MT). The major banana growing states are Andhra Pradesh, Maharashtra, Assam, Bihar, Gujarat, Karnataka, Kerala, Madhya Pradesh,

Orissa and West Bengal (Anon, 2018). Variation in productivity ranges from 13.500 to 63.60 tonnes/ha, which is attributed to cultivars, production system and management strategies. In North East Region of India, the production of banana is 1492 thousand MT from an area of 1.00 lakh with a productivity of 11.32 MT/ha, out of which production in Nagaland is around 117.04 thousand MT from an area of 0.08 lakh with a productivity of 14.03 tonnes / ha. Assam leads in both area (0.53 lakh) and production (913.27 thousand MT) followed by Mizoram with an area of 0.11 lakh and production of 117.04 thousand MT. Lowest production has been found to be in the state of Sikkim (3.71 thousand MT) (Anon, 2018).

India is also one of the major exporters of banana among the Asian countries. India takes the credit of being the highest producers of banana contributing to 27 % share in the world (Anon, 2018). Since the fruit is available 365 days of the year, it could be exported quickly to its export destinations, because it takes 3-12 days to reach any export destination. Affinity to the West Asian and Middle East markets has offered a huge opportunity for Indian exporters to boost their banana consignments to the region. During the year 2011-2012, India exported 45573.24 MT of banana valuing at Rs. 9154.22 lakh but in 2018-2019, India bananas export has risen to 135.20 thousand MT which was valued at Rs. 415.06 crore. The major destinations of India's banana were UAE, Saudi Arbia, Iran, Kuwait and Bharain respectively. These countries have imported more than 50 percent of India's banana during the period.

Banana belongs to the genus *Musa* which is a member of the family Musaceae. The number of species within *Musa* lies between 30 and 40 (Simmonds and Shephard, 1955). Cheesman (1947) classified the genus *Musa* into four sections: *Eumusa*, *Rhodochlamys*, *Australimusa* and *Callimusa*. This classification of *Musa* by Cheesman provides general information of the

taxonomy and has been used for nearly 50 years without any significant changes (De Langhe, 2000). In the course of time, Wong *et al*. (2002) made various changes and some major and minor regroupings of the classification of *Musa.* The present day banana is said to have originated in Southeast Asia, including the Indian subcontinent (Uma *et al*., 2005) and subsequently distributed to other parts of the world (Simmonds and Shephard, 1955). According to Nwakanma *et al*. (2003), the *Eumusa* species of banana, which include modern-day cultivars, appear to be very diverse. Banana and plantains (*Musa* spp.) evolved from intra- and inter-specific crosses of two wild diploid species of *Eumusa*, *M. acuminata* and *M. balbisiana,* which respectively contributed the A and B genomes (Simmonds and Shephard, 1955). *Musa* spp. are further evolved through polyploidization and somatic mutation accumulations (Stover and Simmonds, 1987). Therefore, depending on the contribution of *M. acuminata* (AA) and *M. balbisiana* (BB), most of the present day commercial banana possess different genomic combination such as AA, AB, AAA, AAB, ABB, AAAA, AAAB, AABB and ABBB.

It is a known fact that the basic chromosome number of bananas and plantains is x = 11, with 22 (diploid), 33 (triploid) and 44 (tetraploid) chromosomes (Stover and Simmonds, 1987). Furthermore, there is a wide range of B-rich genomes (AB, AAB, ABB and ABBB) and a great diversity of the B genome (BB) in India (Uma *et al*., 2005). *M. acuminata* is found mainly on tropical rainforests and in a region where the incidence of natural hybridization has been reported often among the sub-specific taxa resulting in a high degree of morphological variability (Simmonds, 1962; Simmonds and Shephard, 1955). Southeast Asia being the primary centre of origin of this wild progenitor (Simmonds and Shephard, 1955; Ude *et al.,* 2002; Racharak and Eiadthong, 2007), particularly Malaysia (Daniells *et al.,* 2001; Wong *et al.,* 2001), and reached Indian subcontinent, the secondary centre of diversity, mainly through human interventions and movement like domestication where it

introgressed with the hardy wild *M. balbisiana* endemic to North-eastern India (Simmonds, 1962). On account of morphological characters, nine *M. acuminata* spp. were reported from Asia (Hakkinen and De Langhe, 2001), *viz*. *M. acuminata* ssp. *banskii*, ssp. *burminaca*, ssp. *burmannicoides,* ssp. *malaccensis*, ssp. *microcarpa*, ssp. *truncata*, ssp. *siamea*, ssp. *errans* and ssp. *zebrina*, of which only *M. acuminata* ssp. *banskii*, ssp. *burminaca*, and ssp. *burmannicoides* represents 37 % of the total diversity seen in India (Uma *et al*., 2005).

Conventional system of identification and classification of edible bananas and their wild relatives' genome are based on morphological characters and their similarity to the two progenitor species, *M. acuminata* and *M. balbisiana*. Since time immemorial, the morphological characters were utilized by farmers for determining of genetic diversity of crops. Vast majority of the present day knowledge on bananas has been contributed significantly by morphological characterization. The process involves the measurement of various morphological traits of germplasm collections. In 1955, Simmonds and Shepherd formulated a new genome based nomenclature system for the edible fruit bearing bananas based on their genotype. They listed out various features that were characteristic of *M. acuminata* and *M. balbisiana* and gave them arbitrary numerical values. They scored plants based on the visual assessment of these characters and assigned them with various genome groups. *Musa acuminata* was designated as genotype AA and *Musa balbisiana* as BB; both are diploid species. The vast majority of the edible banana is triploid but some bananas were found to have an AA or BB genotype. This classification method has become a primarily preferred system for banana genotyping (Atom *et al*., 2015). Nonetheless, the placing of edible bananas into different genome groups purely based on visual assessment requires a high degree of skill but has been practice to the satisfaction for most of the banana cultivars. Modern genetic

technology has largely supported genome assessment made by Simmonds and Shepherd but significant changes have sometimes been made.

For crop improvement programs, germplasm collection and characterization are of fundamental importance because they provide plant breeders with a source of useful traits (Simmonds and Shepherd, 1955; Ortiz, 1997) and increase the knowledge on the genetic background of the crop (Cordeiro *et al.*, 2003). For proper identification and classification of *Musa* species several qualitative and quantitative morphological characters including vegetative part, inflorescence, male flowers and fruit characters are very useful (Simmonds and Shepherd, 1955; Amorim *et al*., 2012). Multivariate statistical approaches are often used to analyse collections with many accessions for determining relationships among the accessions (Bhargava *et al*., 2007). Principal components and cluster analysis are among the appropriate procedures for analyzing genetic variability of the germplasm collections with many accessions and which would help in the identification of patterns and structures in a data set. Moreover, multivariate analyses could effectively be employed as useful tools in understanding studies with complex traits (Iezzoni and Pritts, 1991).

The north-eastern region of India including Nagaland is home to many indigenous *Musa* cultivars and wild/semi wild species. Many of the *Musa* species are extensively found in different agro-climatic condition and are widely distributed in northeast region of India, (Uma *et al*., 2006) which has been primarily considered as the richest sources of natural banana diversity (Hore *et al*., 1992). Occurrence of *Eumusa* species such as *Musa nagalandiana, M. balbisiana, M. cheesmani, M. flaviflora, M. itinerans, M. nagensium* and *M. puspanjaliae* and species of the section *Rhodochlamys* commonly known as ornamental species were reported from Nagaland, Arunachal Pradesh, Tripura

and other parts of Northeast India (Gurumayum *et al*., 2018; Sabu *et al*., 2013; Dey *et al*., 2014; Majumdar *et al.*, 2013).

The states of Nagaland lie at a point where the Indian subcontinent meets the Southeast Asian countries where distinctive concentration of banana diversity were known to occurred in semi-evergreen and sub-tropical forests of hill slopes. Dey *et al*. (2014) discovered *Musa nagalandiana* sp. nov. from Makham village, Zunheboto district, Nagaland. Earlier *Musa cheesmanii* was considered endemic to Nagaland but Joe *et al.* (2014) revealed the extended distribution of the taxon from Arunachal Pradesh to Manipur and it grows abubdantly throughout the states. Similarly, Joe and Sabu (2016) also reported the distribution of *Musa velutina* and its subspecies and botanical variety in the states of Nagaland and other parts of North Eastern states.

However, the correct identification and classification of banana cultivars in the region is hampered by the presence of different tribes and ethnic communities with different dialects and languages. A variety is known by different names based on the dialects and the communities in different regions of the northeast India. The rugged terrain and topography of the region also made it difficult for extensive exploration. Moreover, majority of the wild varieties are exposed to large scale exploitation and destruction as a result of shifting cultivation by the local tribes, thereby wiping out *Musa* natural habitats (Molina and Kudagamage, 2002). This accentuates the need to collect, characterize and document germplasm before its extinction from these areas. Reliable identification and genetic information on the existing banana genetic resources will be useful for the effective breeding and conservation strategies. Only limited information is available regarding the types and amount of variations of *Musa* species of the region. Thus, to make collections of germplasm, determine the variation within the collections; search for desirable

traits and conserving biodiversity would substantiate the ever increasing constraints on the narrow genetic bases and diversity of the *Musa* species.

Keeping in view the above facts, the present investigation entitled **"**Diversity mapping and database development of banana (*Musa* spp.) germplasm in Nagaland**"** was carried out with the following objectives:-

1. To carry out an extensive survey and *ex-situ* conservation to identify the divergent clone of *Musa.*
2. To study taxonomic and morphological characters of *Musa* germplasm collected from different location.
3. To assess the magnitude of variability base on biometrical analysis of collected genotypes of banana.
4. To identify the best table purpose banana based on yield and quality.

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

An attempt has been made to collect and review the relevant literatures available on various aspects of work done so far on morphological traits, genetic variability, character association, divergence association and quality attributes in banana for fruit yield and its component characters. Literatures on above aspect of the present study were reviewed in this chapter under the following heads.

2.1 Survey and *ex-situ* conservation of divergent clone of *Musa* spp.

2.2 Taxonomic and morphological characters of *Musa* spp.

2.3 Variability and biometrical analysis

2.4 Table purpose banana based on yield and quality

2.1 Survey and *ex-situ* conservation of divergent clone of *Musa* spp.

Hasan *et al.* (2011) characterised thirty four (34) types of seeded banana with B genome collected from different agroclimatic zones of West Bengal, at the Horticultural Research Station, West Bengal, during the years 2005-2008 by using 123 plant morphological characters with different multivariate techniques. The proximity matrix, both by squared Euclidean and cophenetic correlation, between types indicated high closeness/similarity among 'Attiakala', 'Bichkela-1', 'Bichkela-2' and 'Hill Banana'. The highest proximity value of 20.62 with 'Kalyani Local-3' showed maximum dissimilarity with 'Maricha' and 'Jhama Diara'. A dendrogram using the single linkage clustering technique on squared Euclidean distance matrix and cophenetic correlation matrix showed 13 and 14 clusters, respectively. PCA was used by considering 13 factors on the basis of variance. Thus considering the dominant characters with positive loading under Factor 1, the positively loaded types were 'Bichkela-1', 'Hill Banana', 'Attiakala', 'Bichkela-2', 'Kalyani Local-1' and 'Jhama Daira'. Factor 1 thus explained 14.21% of the

total variance. Among the 34 seeded banana types, 32 were assessed as parthenocarpic. The two non-parthenocarpic types identified were ‘Baruipur’ and ‘Seed Banana-15’.

Singh *et al*. (2013) had developed a database named DEBDOM describing the diversity of banana resources of Manipur and it comprises twenty eight genotypes of Musaceae. The database DEBDOM provides a sophisticated web based access to the details of the taxonomy, morphological characteristics, utility as well as sites of collection of *Musa* genotypes and it will contribute as a potential gene pool sources for the conservation, sustainability as well as for crop improvement in the future breeding programmes.

Majumdar *et al*. (2013) recorded *Ensete glaucum* in Tripura during floristic investigations, which is an additional banana species for the flora. They observed very limited population in the wild and recorded necessary information on its distribution, habitat association and pollen structure. Their information will be useful for future population assessment, regeneration and other ecological studies to manage its wild stock and to protect this primitive banana from regional extinction**.**

Lia *et al.* (2015) conducted a banana exploration in Madura Island covering areas of Bangkalan, Sampang, Pamekasan and Sumenep Districts. Results showed that banana plants are widely distributed in Madura Island. It grows wild in coastal line, road sides and river banks, or cultivated mostly by small scale farmers in backyards, dry lands, intercropped with annual and/or perennial crops. It is mostly cultivated subsistently with less consideration to cultivation practices for home consumption or for local markets. About 37 recognizable banana cultivars with local Madurese names were known with any possible synonymies within the cultivars. It comprises of 15 dessert bananas, 17 cooking bananas and 5 dual purposes bananas.

Sabu *et al.* (2016) reported that the maximum diversity and distribution of Musaceae is located in the northeastern states, with 30 taxa of which 19 are endemic to the region. This represents about 81% of the total wild Musaceae diversity in India. This also indicates that the region bordering with Bangladesh, China and Myanmar is a biodiversity-rich area for Musaceae and strengthen the view that this region is considered as one of the major centers of origin of family Musaceae. The second largest Musaceae diversity in India is found in Andaman and Nicobar Islands, where three taxa are present all of which are endemic. In the Western Ghats, three taxa are present, including one endemic taxon, and the same is the case in Eastern Ghats. During this work, two species are found to be extinct from the wild and 19 taxa are categorized as threatened.

Nyoman *et al*. (2018) studied the diversity of banana cultivars or sub-species in Bali and its usefulness to determine preferable cultivars for commercial cultivation. They recorded and characterized 43 banana cultivars in 10 villages that represent the 8 regencies and 1 city of Bali province. Out of the 43 cultivars, 7 were highly used and at least one cultivar was discovered in each of the studied village. Among the highly ranked cultivars or species, only *biu kayu* is unique to Bali as it was not found in the closest provinces of East Java and Madura. Hence, the results suggested that to improve the cultivation and production of these 7 highly used cultivars could be an appropriate solution to meet Bali demand of bananas. Furthermore, cultivating *biu kayu* would also help conservation effort since this cultivar is also currently listed as a rare genetic resource.

Gurumayum *et al.* (2018) conducted a study from 2011 to 2018 in the Western, Central and Eastern parts of Arunachal Pradesh, North Eastern India and revealed occurrence of high diversity of wild *Musa* species (Musaceae) under the sections, *Eumusa* and *Rhodochlamys*. A total of 20 *Musa* specimens

consisting of six species under section *Eumusa* and 14 specimens (7 species, 4 unidentified species and 3 hybrids) of *Rhodochlamys* were recorded in the study. *M. cheesmani* among *Eumusa* while *M. velutina* and *M. aurantiaca* among *Rhodochlamys* were most abundant species. All the species and hybrids of *Rhodochlamys* were found growing in disturbed habitats such as degraded foot hills, drying swamps, landslide prone areas and along sides of expanding highway roads. One of the species, *M. rubinea* is at high risk of loss from the natural habitats if proper conservation measures are not taken up immediately.

Rajappa *et al.* (2018) collected endemic wild banana genetic resources from Assam and Arunachal Pradesh for their studies. A total of 23 accessions, 14 from Assam and 9 from Arunachal Pradesh were collected through random sampling. DIVA-GIS versions 7.5 used for converting the ASCII file generated using maximum entropy method. Grid maps were generated for both current and future climates. Bioclimatic variables were used for modeling. Under the current climatic regime potential pockets for its in-situ conservation cultivation exists in parts of Assam, Arunachal Pradesh, Sikkim, Tripura, Manipur and Meghalaya. The grid map generated for future climate (year 2050) indicated that potential pockets from this states would come down.

Rajappa *et al.* (2019) conducted a study to find out the diversity of *Musa* genetic resources explored through rural weekly markets of Meghalaya. A survey was conducted in Ri-bhoi district, and two markets of Garo hills on the varieties that are sold in the markets of Meghalaya. Many cultivars like Jahaji, Cheini Champa, Malbhog and indigenous varieties were found in the markets where the survey was conducted. In the survey, they found that *in-situ* conservation and planting of wild bananas is limited to a few households.

Das *et al.* (2020) evaluated banana genetic resources available in Tripura and parts of north-eastern India. Some wild species of banana like *Musa acuminata, Musa balbisiana, Musa ornata, Musa laterita*- hybrid, *Musa*

flaviflora and *Ensete glaucum*, etc. have been recorded in the Tripura. *Musa flaviflora* and *Ensete glaucum* were also fund in Tripura. Most important banana cultivars are Shabri Kela (AAB), Martaman (AAB), Malbhog (AAB), Samai/Gopi/Bangla Kela-1 (AAB), Samai/Gopi/Bangla Kela-2 (ABB), Champa Kela (AAB), Mizo-Cavindish (AAA), Katch Kela-1 (ABB), Katch Kela-2 (ABB), Katch Kela-3 (ABB), Kanai Bansi (AA), Red Banana (AAA), in addition to the commercial cultivars wild forms like Athia Kela (BB), Athia Kol (BB) and Bhimkol (BB) were distributed in Tripura. Collected genotypes were assigned their genome like AA, AAA, AAB and ABB through 15-character score card systems. Most of the cultivars are triploids in nature and some are classified diploid.

Arne *et al*. (2021) evaluated the genetic diversity and structure of *Musa balbisiana*, important crop wild relatives of plantains, dessert and cooking bananas. They screened the genetic variation and structure present within and between 17 Vietnamese populations and six from China using 18 polymorphic SSR markers. Relatively high variation was found in populations from China and central Vietnam. Populations from northern Vietnam showed varying levels of genetic variation, with low variation in populations near the Red River. Low genetic variation was found in populations of southern Vietnam. Analyses of population structure revealed that populations of northern Vietnam formed a distinct genetic cluster from populations sampled in China. Together with populations of central Vietnam, populations from northern Vietnam could be subdivided into five clusters, likely caused by mountain ranges and connected river systems. Southern range edge populations in central Vietnam had especially high genetic diversity, with a high number of unique alleles and might be connected with core populations in northern Laos and southwest China. Southern Vietnamese populations are considered imported and not native.

2.2 Taxonomic and morphological characters of *Musa* spp.

Simmond and Shepherd (1955) developed a taxonomic scoring method which is used to classify the edible bananas and to provide evidence on their evolution. Edible diploid forms of *Musa acuminata* are thought to be the primary source of the whole group to which another species, *M. baibisiana*, has contributed by hybridization. Thus there exist diploid and triploid edible forms of *M. acuminata* and diploid, triploid and tetraploid hybrid types of genetic constitutions that vary according to their histories. There is a faint possibility that a third wild species has contributed to the origins of a small group of triploid hybrid types. Triploidy was probably established under human selection for vigour and fruit size; tetraploidy is inexplicably rare. The centre of origin of the group is Indo-Malaya and Malaya is probably the primary centre. The two Linnaean species *M. paradisiaca* and *M. sapientum* refer to identifiable edible varieties which are both shown here to be of hybrid origin. The names therefore may be rejected from the nomenclature of the wild bananas.

Valsalakumari and Nair (1993) conducted a study on morphological characters, taxonomic scoring and chromosome numbers of 100 South Indian banana cultivars. The study revealed that many of the cultivar names are synonymous. The cultivars Sanna Chenkadali (AA) and Eraichivazhai (AA) had some characteristics of *Musa balbisiana*. Diploid clones occurred more frequently than has been suggested by Simmonds. The cultivars Krishna vazhai, Vannan, Virupakshi, Sirumalai, Agniswar, Padali Moongil, Kostha Bontha, and Venneettu Mannan were added to the genomic group AB. In the groups AAB and ABB, cultivars exhibited the characteristic traits of *Musa acuminata* and *M. balbisiana* in various degrees. The groups AB, AAB, and ABB were common in the cultivated bananas of India.

Ortiz (1997) evaluated the extent of morphological variation of the *Musa* germplasm maintained in the gene-bank of the International Institute of Tropical Agriculture in southeastern Nigeria. Qualitative and quantitative descriptors were used to evaluate AA, BB, AB, AAA, AAB, AAAA, AAAB and AABB bananas, AAA and ABB cooking bananas, AAA beer bananas and AAB plantains and a few wild species. Univariate and principal component (PCA) analyses were performed to identify the most important descriptors to characterize and classify *Musa* germplasm collections. The quantitative descriptors have a high heritability (>0.8), high repeatability (>2.0) and low coefficient of variation (9–15%) with the exception of the height of the tallest sucker. The paper also proposes a new scientific nomenclature for the triploid *Musa* cultivars.

Muhammad *et al.* (2002) characterized fourteen populations of *Musa acuminata* ranging from populations in the lowlands of northern (*Siamea* ssp.) to central Malaysian region (*Malaccensis* spp.) and highland banana (*Truncate* spp.) based on chromosome number and 46 morphological characters. A large amount of variation was observed within the populations. However, only highland bananas appeared morphologically distinct. Lowland populations both from northern and central Malaysia were found to be overlapping and no distinguishing pattern was observed. The morphological characters found variable within these populations were related to developmental changes and mutations.

Det *et al.* (2004) conducted a study and collected 309 wild bananas from five national parks. All samples were examined through classical taxonomy, then major qualitative characteristics were classified into 7 groups. Meanwhile, Hierarchical and K-mean cluster analysis used numerical taxonomy to report examination with these characteristics. There are 7 characteristics of species identification criterion, while other 13 characteristics were subspecies. All

samples were classified into 7 groups at 5 units of re-scaled distance with 80% of similarity by Heirarchical cluster analysis. In addition, the similar classification results which were re-approved by K-means cluster analysis and non-significantly different at P=0.05 from Heirarchical cluster analysis. Discriminant analysis was shown the probability of precise separation and prediction into 7 groups of both cluster techniques at 83-100% with the original and cross validated methods. Both results from numerical morphological classification were synchronized and non-sigficantly different from the result of classical morphological taxonomy with Pearson Chi-square test (P=0.05). Sample in the group 6 was highly different from *M. acuminata* Colla with its erect rachis position that should be a new wild banana group. It is very interesting to focus on re-identification of this sample through banana taxonomic system. The prominent strong convulate with significant 1/3 bright green tip of male bud of the group 2 which was also interesting and might be a new promising subspecies of *M. acuminata* Colla.

Pillay *et al*. (2006) conducted a study to determine the ploidy levels and genome composition of the *Musa* germplasm collection, constituting over 300 accessions, at the International Institute of Tropical Agriculture in Nigeria and Uganda. Flow cytometric analysis of nuclear DNA content was used to estimate ploidy levels, while genome composition was ascertained with RAPD markers that are specific for the A and B genomes of *Musa*. It was determined that at least 8% of the plants in the germplasm collection were miss-classified in terms of ploidy and/or genome composition. The cultivars 'Pisang awak', 'Foulah 4' and 'Nzizi', previously classified as triploids, were found to be tetraploids by flow cytometry and conventional root tip chromosome counts. Similarly, cultivars that were previously classified as diploids including ‘Too’, and ‘Toowoolee’ were found to be triploids in the analysis. Ploidy and genome classification in *Musa* was generally determined from morphological characteristics. While the study showed that such a system is not always

reliable, it was interesting to find that none of the plantains in the germplasm collection were miss-classified with regards to both ploidy and genome composition.

Awah *et al*. (2009) carried out a study to assess the extent and cause of intra-field morphological diversity in plant communities of plantain farmers in Cameroon. Vegetative propagules ascribed by farmers to the popular varieties Asang-Da, Ebang, Elat and Essong were field established at the research stations of the International Institute of Tropical Agriculture for phenotypic evaluation. None of the varieties appeared to be a community of unique morphotypes with average similarity indices of 46.5% for Asang-Da, 48.3% for Ebang, 49.4% for Elat and 55.8% for Essong confirming the mixture nature of the varieties. Inter-variety phenotypic similarity coefficient ranged from 41.7% (Ebang vs Elat) to 45.0% (Ebang vs Essong) equally showing considerable overlaps, yet sufficient phenotypic differentiation between the varieties. Many migrants, being more distantly related to individuals in their respective assigned groups than to individuals ascribed to other groups, were identified in all variety groups, except Ebang.

Issirep and Mera (2010) evaluated the anatomical character and morphology of fives Indonesian banana cultivars based on their level of ploidy. The samples of roots, rhizome, and leaf were collected from five banana cultivars i.e. *Musa acuminata* cv. Penjalin, *M. balbisiana* cv Kluthuk warangan, *M. acuminata* cv Ambon warangan, *M. paradisiaca* cv Raja nangka and *M. paradisiaca* cv Kluthuk susu. Stem and leaf morphology character of diploid level (AA and BB genome) is different with triploid level (AAA, AAB, and ABB genome). Anatomy and morphology character of root and rhizome of banana in diploid level (AA and BB genome) and triploid level (AAA, AAB, and ABB genome) is quite similar. Anatomically, there were no differences in the rhizome structure among five banana cultivars. The row of vascular bundles

acts as demarcation area between peripheric and central zone. In the cultivar with BB genome (diploid) and ABB genome (triploid) the row of vascular bundle was not found.

Onyango *et al.* (2011) conducted a study to identify morphological characters that distinguish the various subgroups of AAB dessert bananas found in East Africa and from other cultivated AA Muraru bananas and to evaluate the relationship among the AAB and among the AA Muraru banana groups of East Africa in relation to other bananas. Forty-three (43) cultivars of AAB, AA groups and outgroups from a large banana collection at the Kenya Agricultural Research Institute, Kisii were characterised in 2007 using morphological traits. Morphological data were collected using 84 characters derived from a modified version of the descriptors for bananas developed by Biodiversity International in conjunction with CIRAD. Techniques of multivariate analysis were employed. Based on unweighted pair group using arithmetic mean (UPGMA), two major clusters of *Musa acuminata* derived cultivars (AAs and AAAs) and hybrids of *Musa balbisiana* and *M. acuminata* (AAB) were produced. Within the major clusters were subclusters conforming to various subgroups. Within the AAB dessert cluster, four distinct subclusters were formed, i.e. Sukari Ndizi, Prata, Mysore and Silk. Muraru also formed a well-defined cluster. Thirty-three (33) characters contributed 71 % of the total variation within the 43 accessions on the first and second principal components, allowing separation of clusters corresponding to genome groups and subgroups.

Lalrinfela and Thangjam (2012) reported that various wild and edible banana and plantains are found in the state of Mizoram. Fourteen (14) varieties of banana were collected and characterized using morphological parameters. 10 varieties were identified under *Musa paradisiaca*, 1 under *M. acuminata* and 1 under *M. balbisiana*. In addition, 2 other varieties were identified as *Ensete*

glaucum and *M. ornata* respectively. Based on the morphological scores, the genome groups of 12 varieties belonging to *Eumusa* section were established under AB, AAB, ABB, AAA, BB and ABBB groups.

Karuna and Rao (2013) observed the growth and yield of different cultivars of banana at 3 different places of Visakhapatnam district, Andhra Pradesh. Six banana cultivars were taken viz., Karpura Chakkarakeli, Dwarf Cavendish, Robusta, Rashtali, Thella Chakkarakeli and Yenugubontha. Maximum plant (pseudostem) height, pseudostem girth, number of suckers at harvest and petiole length was recorded in Yenugubontha. The highest leaf length, width and total leaves per plant were recorded in Robusta. Similarly, more leaf area, LAI was registered in Robusta. The highest bunch weight and per ha yield was recorded in Robusta whereas, finger length, girth, weight and finger volume were maximum in Yenugubontha.

Wahengbam *et al*. (2014) conducted an analysis on banana genome groups of wild and cultivated species of Manipur using sscore card. Many domesticated banana have proved to be triploid, (2n= 3x = 33) with genome constitution of AAA, AAB or ABB. There are also seedless cultivated AA and AB diploid, and tetraploids (2n= 4x = 44) with genome constitution of AAAA, AAAB, AABB and ABBB.

Sagar *et al.* (2014) evaluated twenty three genotypes for growth and yield. The highest leaf length (166.67 cm) and leaf area (0.82 m^2) were observed in Robusta genotype. Whereas, the lowest leaf length (123.63cm) and leaf area (0.45m^2) were recorded in the genotype Mitli. Among the genotypes evaluated, the genotype Mitli performed very poor with the lowest yield (3.84 t/ha). From the investigation, it concluded that the genotype Hanuman is suitable to maximize the yield under Northern Dry Zone of Karnataka

Atom *et al*. (2015) studied the taxonomic identification and genomic classification of banana in Manipur. A total of 27 cultivars were collected in the present study. Of all the cultivars, *Musa balbisiana* clone was represented by 3 cultivars; 8 cultivars were identified under *M. acuminata* clones. Majority of the cultivars (16) were identified as *Musa species*, hybrid of *M. balbisiana* and *M. acuminata*. Among these cultivars, 3 cultivars were classified under BB genome while 3 cultivars were classified under the AA genome group. The ABB genome group was represented by 13 cultivars. 5 non-seeded cultivars were classified under AAA genome group and the AAB group was also represented by 3 sweet smelling cultivars.

Phanideepthi (2016) studied the scoring technique in *Musa balbisiana* which ranges from 15-75 depending upon the genomic group. Evolution of modern banana is chain reaction of *Musa acuminata* and *Musa balbisiana*.

Chang *et al.* (2018) conducted a study and classified 19 *Musa* species and cultivars based on morphological characters. Fifteen morphological characters for *Musa acuminata* and *M. balbisiana* and 50 morphological characters adapted from International Union for the Protection of New Varieties of Plant (UPOV) codes were employed to elucidate the phylogenetic relationship between both banana species. Analyses of genetic similarity based on all of these morphological characters suggested that bananas with A–genomes were in the same cluster. Moreover, a genetic similarity coefficient of 0.36 was obtained between *M. acuminata* and *M. balbisiana* in the analysis with the 15 morphological characters for both species, and 0.47 in the analysis with 50 UPOV–based morphological characters. Moreover, principal component analysis (PCA) of the 15 morphological characters suggested that PC-1 and PC-2 together explained 78.6% of the total variance. A PCA with 50 UPOV–based morphological characters indicated that PC-1 explained 80.6% of the total variance, for which the main variables were pseudostem length, leaf

blade length, and peduncle length. PCA of the 15 morphological characters showed that 'Pei Chiao', 'Giant Cavendish', and 'Dwarf Cavendish' were proximal in the PCA scatterplot. Notably, the PCA of 50 UPOV–based morphological characters indicated that 'Pei Chiao' and 'Giant Cavendish' were near each other in the PCA scatterplot, suggesting that they are phylogenetically related. The PCA of *M. itinerans* var. *formosana* with 15 morphological descriptors showed that this variant is phylogenetically distant from *M. acuminata* and *M. balbisiana* accessions.

Dhimal *et al.* (2018) evaluated the morphological and compositional characters of six commonly grown varieties of banana in Hilley and Shompangkhag under Sarpang. Using quantitative characters, through cluster analysis, they were grouped into four. Significant difference was observed in pseudostem height, pseudostem diameter, leaf blade length, leaf blade width, peduncle width, number of fingers per hand, finger length and finger weight. No significant difference was observed in bunch weight among six varieties. Peduncle length was similar among the varieties. Bunch weight was correlated with peduncle width and number of fingers per hand. Qualitative characters related to leaf, growth habit, bunch, rachis, male bud, bracts, male flower and fingers were observed. Dhusrey had generally different characters compared to other varieties. Through cluster analysis on compositional characters, they were grouped into two. Significant difference was observed in pulp pH and dry matter content while no difference was found in TSS, ash and protein content among six varieties. Compositionally Jhaji had comparatively different characters while others were similar.

Joseph and Simi (2018) conducted a study to characterize the various ecotypes of plantain with respect to clonal characteristics and yield potential. The study revealed that considerable variability existed between the different ecotypes of plantain. The ecotypes varied significantly with respect to all the

clonal characters studied, except the number of ridges. Mettupalayam Nendran produced the highest yield but it had long duration. Zanzibar and Big Ebanga were superior in terms of finger characteristics. PSI (Pedicel Strength Index) was recorded highest in Mettupalayam Nendran (3.17) which was significantly higher than all other clones.

Anu *et al*. (2019) carried out a study to characterize a commonly used varieties of banana morphologically and genotypically based on International Plant Genetic Resources Institute, 1984 (Descriptors for banana *Musa* spp.) and RAPD analysis. Five varieties were morphologically similar in parameters such as leaf habit, pseudo stem appearance and peel color. RAPD analysis proved that these varieties of banana are closely related which coincides with the morphological characterization.

Ernawiati *et al.* (2020) conducted a study to determine the differences in the morphological structure of flowers among the Pisang Kepok cultivars with each other. The research was carried out in two stages. First, field sampling in residential area of Bandar Lampung City, Pesawaran Regency and South Lampung Regency. Second, morphological characterization based on the parameters determined. The results revealed that the cultivar Pisang Kepok had been observed to have almost the same morphological structure except in Kepok Batu. The specific character of Pisang Kepok batu can be seen in the character of the colour of pollen sacs, compound tepal pigmentation, free tepal colour, free tepal apex shape and pistil shape.

2.3 Variability and biometrical analysis

Lorenna *et al.* (2010) conducted a study to characterize 26 banana accessions of the active gene bank of Embraga Cassava and Tropical Fruits (Brazil) for agronomic, physical and physicochemical characteristics. The plant height of the diploid 028003-01 and triploid Walha was short. Regarding the number of fruits and bunch weight, triploids Caipra, Thap Maeo and the

tetraploids Ambrosia and Calipso performed particularly well. Total carotenoid contents were highest in the diploids Jaran and Malbut. The total contents of flavonoid and polyphenol, two natural antioxidants, were highest in tetraploid Terapod. Wide genetic variability was detected for most agronomic, physical and chemical characteristics of the fruits of the banana accessions.

Rajamanickam and Rajmohan (2010) evaluated six Palayankodan ecotypes of banana belonging to AAB genomic group for genetic variability among quantitative traits. Genotypic and phenotypic coefficient of variation, heritability and genetic advance were estimated for eighteen traits that included plant height, pseudostem girth, number of leaves per plant, leaf width, number of sucker per plant, days taken from planting to shooting, total crop duration; length, girth, weight and volume of finger; hand weight, bunch weight, number of fingers per bunch, number of fingers per hand, ripe-fruit weight, sugar/acid ratio and pulp weight. Remarkable variability was observed among the collections for these characters. Bunch weight, number of fingers per bunch and number of suckers per plant with very high value of PCV, GCV, heritability and genetic advance makes it prime traits for direct selection. Plant height, pseudostem girth, total crop duration, sugar:acid ratio, finger length and days taken from planting to shooting recorded high value of heritability and moderate value of genetic advance. PCV are other important traits which need to be considered for selection. The volume of finger with low values for GCV, PCV, heritability and genetic advance as percent of mean implies that it is highly influenced by environment and should not be taken as a criterion for selection. Plant height, total crop duration, sugar:acid ratio, finger length, pseudostem girth, number of fingers per bunch and days taken from planting to shooting showed high genetic advance and heritability and important characters to be considered for selection of ecotypes.

Mohammed *et al*. (2014) evaluated the genetic variation among 4 local and 11 introduced desert banana (*Musa* spp.) genotypes. Genetic variability components analyses were conducted considering 20 morpho-physicochemical traits. Phenotypic and genotypic coefficient of variations ranged from 8.95 to 52.63% and 7.2 to 48.16%, respectively, with low magnitude of differences and moderate to high for most of the traits. Heritability (H^2) and genetic gain (GA) values were ranged from 14.69 to 98 and 7.4 to 81.45%, respectively, and both H^2 and GA values were high and moderate for 16 traits. Fruit yield showed strong genotypic and phenotypic correlations with all growth traits and yield components with higher magnitude of genotypic correlation coefficients. Euclidean distance ranged from 2.36 to 7.6 which distinctly grouped genotypes into two clusters and five sub-groups. Moreover, the local clones were more distant each other and with introduced genotypes and performed better than introduced genotypes for most of the traits including fruit yield. The study revealed the presence of genetic variation among local and introduced genotypes and most of the traits were controlled more of by genetic factors.

Sawant *et al*. (2016) carried out an experiment to investigate the growth, yield performance and the extent of genetic variation in thirty banana genotypes found in West Coastal Zone of India for fourteen characters. The genotypes showed substantial variation and the PCV were found greater than GCV for all the characters studied. High heritability in broad sense (h^2b) coupled with high genetic advance (GAM) was noticed for 'number of living leaves at harvest' and 'fruit peel thickness' indicating the role of additive gene action. The important yield characters *viz*., bunch and fruit weight with high PCV, GCV, heritability and moderate to high GAM were proved as the primary selection criteria. The genomic group AAA was found better than others in both yield and quality characters at a time. The genotypes 'Pache Bontha Bathesa' (ABB) and 'Udhayam' (ABB) were found high yielding but

considering quality characters, ‘Grand Naine’ (AAA) was found as the best in ecological conditions of the West Coastal Zone of India.

Smrutirekha and Das (2018) conducted an experiment to study 13 cooking banana genotypes laid out in a Randomize Block Design with 5 replications at All India Coordinated Research Project (Banana), Horticultural Research Station, Bhubaneswar, Odisha. The data were recorded for 11 quantitative characters to study genetic variability, heritability, genetic advance, correlation coefficient analysis and path analysis. On the basis of mean performance, Plant morphology and quantitative yield parameters were recorded. Maximum pseudostem girth, total number of leaves, average number of hands, fingers and bunch weight was recorded in Bantala Sambalpuri (Patiapalli). Least pseudostem height, girth, bunch weight were recorded in Dakhinisagar. Analysis of variance among 13 genotypes showed significant difference for all characters studied. Highest genotypic coefficient of variation (GCV) & phenotypic coefficient variation (PCV) was observed for number of fingers per bunch, number of hands per bunch, and bunch weight indicating selection for such characters would be more reliable to be used as selection for crop improvement. High degree of heritability estimates were obtained in case of length and breadth of leaf, number of fingers per bunch. High genetic advance were observed for number of fingers per bunch and pseudostem height indicating predominance of additive gene effects and possibilities of effective selection for the improvement of these characters.

Rajamanickam (2020) evaluated the genotypic and phenotypic coefficient of variation, heritability, genetic advance and correlation coefficient of Nendran ecotypes of banana for seventeen traits which included plant height, number of suckers per plant, number of leaves per plant, leaf width, days taken from planting to shooting, bunch weight, bunch length, hand weight, number of fingers per bunch, number of fingers per hand, length, girth, weight and volume

of finger, ripe fruit weight, sugar:acid ratio and pulp weight. A remarkable variability was observed among the collections for these characters. All the characters showed the highest estimates of broad sense heritability whereas genetic advance as percentage of mean recorded higher in traits such as volume of finger, finger weight, ripe fruit weight, pulp weight and number of fingers per bunch. The value of high PCV, GCV, heritability and genetic advance makes it a prime character for the direct selection. Weight of finger, bunch weight, volume of finger and number of fingers per bunch showed high genetic advance and high heritability are the other important characters which have to be considered for selection of the ecotypes.

Rajamanickam and Rajmohan (2020) conducted a study to determine the variability, heritability, genetic advance and correlation for their eighteen morphological and quality traits. The genotypic and phenotypic coefficient of variance, heritability and genetic advance were estimated for eighteen traits. The high magnitude of PCV and GCV were recorded for number of fingers per bunch, ripe fruit weight, pulp weight, sugar: acid ratio, finger weight and number of suckers per plant. All the characters showed higher estimates of broad sense of heritability whereas genetic advance was recorded very high in bunch weight, followed by finger weight, ripe fruit weight, pulp weight and number of fingers per bunch. Regarding correlation studies, bunch weight had significantly positively correlated with plant height, psuedostem girth, number of leaves per plant, leaf width, days taken for planting to flowering, number of fruits per bunch, number of fruits per hand and hand weight.

2.4 Table purpose banana based on yield and quality

Joomwong and Joomwong (2008) conducted a study on banana *Musa* (ABBB group) ‘Kluai Teparod’ which were harvested at mature green and allowed to ripen at 20°C (RH 85-90%). Some physical (texture and colour), chemical (soluble solids and starch) properties and sensory attributes

(appearance, flavour, odour, colour, firmness and acceptability) of banana fruit were determined in order to assess quality and consumer acceptability. Significant differences ($P<0.05$) were found between values for texture, colour of peel and pulp at each ripening stage, as well as between soluble solids and starch. Panelist preferred the appearance and colour of fruit at ripening stage 3 (more green than yellow), while the most preferred tastes were that of stage 4 (yellow with softening pulp).

Anhwange *et al.* (2009) analysed *Musa sapientum* peels for minerals, nutritional and anti – nutritional contents. The result of mineral content indicate the concentrations (mg/g) of potassium, calcium, sodium, iron, manganese, bromine, rubidium, strontium, zirconium and niobium to be 78.10, 19.20, 24.30, 0.61, 76.20, 0.04, 0.21, 0.03, 0.02 and 0.02 respectively. The percentage concentrations of protein, crude lipid, carbohydrate and crude fibre were 0.90, 1.70, 59.00 and 31.70 respectively. The results indicate that if the peels are properly exploited and process, they could be a high-quality and cheap source of carbohydrates and minerals for livestock.

Mahesh *et al.* (2009) analysed eleven cultivars of banana from southern India for different biochemical parameters. 'Nendran' showed highest content of total carotene and reducing sugars, whereas 'Grand Naine' showed highest activity of enzyme PPO in the pulp. 'Rasbalei' exhibited high levels of total phenolics and flavonoids. Mineral analysis depicted 'Basrai' and 'Jawari' to be rich sources of iron and zinc, respectively. Significant cultivar differences with reference to geographical distribution were revealed by Bray Curtis Cluster and Principal Component analysis. Their study also adds to the current knowledge of the nutritive values (micronutrients), antioxidant potential, PPO enzyme, and some biochemical aspects of banana

Abbas *et al*. (2010) conducted a study on physicochemical properties of banana peel flour (BPF) in two varieties (Cavendish and Dream) and two

stages of ripeness (green and ripe). BPF's were analysed for pH, total soluble solids (TSS), water holding capacity (WHC) at 40, 60 and 80^{0}C, oil holding capacity (OHC) at 40, 60 and 80^{0}C, colour values L*, a* and b*, back extrusion force and viscosity and the data were analysed using MANOVA, discriminant analysis and cluster analysis. All statistical analyses showed that physic-chemical properties in variety and stage of ripeness were different from each other. Viscosity and WHC80 were recommended as testing methods to differentiate BPF between the two varieties, whilst TSS and viscosity were recommended for differentiation of BPF from green and ripe stages.

Soltani *et al*. (2011) carried out an experiment on some physical properties of banana fruit cv. Cavendish. Properties which were measured included weight of whole fruit peel and pulp weight, dimensions, surface area and projected area. The actual surface area and projected area were measured by image processing technique. The calculated attributes were geometric mean diameter, sphericity, radius of curvature, assumed ellipsoidal volume, surface area and projected area. The diameters of fruit varied as quadratic form. High correlation was observed among assumed ellipsoidal attributes and measured properties. The highest correlation was between estimated projected area and measured projected area as $r^2 = 0.978$.

Jose *et al.* (2012) studied the effect of bio fertilizer application to "Grand Naine" plantain on the physic-chemical and sensory characteristics of the plantain. Two treatments were established: I) Bio fertilization (BIOF); and II) Conventional fertilization (CONV) practiced by farmers. When BIOF was exclusively applied as a fertilization strategy, similar values ($p > 0.05$) were obtained, like the ones in CONV, in all physical characteristics assessed in the fruits. In the fruits' chemical composition, difference in sugar and vitamin C ($p < 0.05$) contents was found; the contents in fruits coming from BIOF were higher. The difference in sugar content, also detected and verified by trained

judges, scored BIOF fruits with a 2.62 value versus 1.36 for CONV ones in relation to sweetness descriptor. These results demonstrate that biofertilization can replace synthetic fertilizers action on plant nutrition and consequently can lead to the obtaining of fruits with similar quality, higher sugar and ascorbic acid contents.

Tapre and Jain (2012) analysed three advanced stages of maturity of banana cv. Robusta *i.e*. stage 5, 6 and 7 for their physico-chemical and mechanical properties. Fruits were treated with 500 ppm ethrel solution and kept for ripening under controlled conditions at 20±1°C and maturity stages were selected on the basis of the standard colour chart. As the ripening progressed, various physical changes observed in fruit such as increased in pulp to peel ratio, decreased in the intensity of greenness of peel and also polyphenol oxidase activity decreased. Mechanical properties decreased significantly from stage 5 to stage 7. A similar trend was observed for other mechanical properties such as cohesiveness, chewiness, fracture force and stiffness during the different stages of ripening. Moisture content, titratable acidity, pectin content, total sugar and TSS of pulp showed an increasing trend from stage 5 to stage 7 whereas starch content progressively decreased during ripening.

Ambuko *et al*. (2013) conducted a study to determine the quality attributes of banana cv. Williams and Grande naine produced under low chemical production system (LCPS) and conventional production systems (CPS) in Ecuador. The fruits produced under the two production systems were evaluated for various physicochemical attributes including peel hue angle, firmness, moisture content, starch, soluble sugars and titratable acidity (TTA). Sensory evaluation by untrained panelists was done to compare the organoleptic attributes of the banana fruits. The results showed that ‘Williams’ bananas from the LCPS had better eating quality as evidenced by higher

soluble sugars, less starch and lower firmness and higher moisture content of ripened fruits' flesh. 'Grande naine' bananas generally had higher levels of TTA compared to 'Williams' and in both cultivars LCPS bananas had higher TTA levels compared to CPS bananas. Sensory panelists did not clearly discriminate between LCPS and CPS bananas but showed preference for 'Williams' bananas over 'Grande naine' bananas. These results show that banana variety, cultural practices and harvest season affect the banana quality attributes at harvest and affect the eating quality of the fruits.

Akter *et al.* (2013) investigated the effect of different postharvest treatments such as modified atmosphere with or without ethylene scavenging chemical ($KMnO_4$), cooling, low temperature and hot water treatment on shelf life and quality of 3 commercially important bananas cv. Sabri, Champa and Amritasagar. Longer period was required to reach ripening stages in variety Sabri than those of Champa and Amritasagar. The variety Sabri had the highest TSS content than that of Champa and Amritasagar. Modified atmosphere packaging with ethylene scavenger ($KMnO_4$) and storage of banana at 15^0C resulted in reduced disease. Results showed that the shelf lives of bananas of the variety Sabri, Amritasagar and Champa were 10.81, 9.00 and 10.11 days, respectively. The longest shelf life of 15.58 days was observed in bananas held at 15^0C temperature.

Aline and Marcelo (2014) evaluated the phytochemical properties and biological activities of *Musa* spp. fruit pulp and peel. The chemical composition of banana's peel and pulp comprise mostly carotenoids, phenolic compounds and biogenic amines. The biological potential of those biomasses is directly related to their chemical composition particularly as pro-vitamin A supplementation, as potential antioxidants attributed to their phenolic constituents as well as in the treatment of Parkinson's disease considering their contents in L-dopa and dopamine.

Claudine *et al.* (2014) conducted a study to understand the contribution of the fruit physicochemical parameters to *Musa* spp. diversity and plantain ripening stages. A discriminant analysis was first performed on a collection of 35 *Musa* spp. cultivars, organized in six groups based on the consumption mode (dessert or cooking banana) and the genomic constitution. A principal component analysis reinforced by a logistic regression on plantain cultivars was proposed as an analytical approach to describe the plantain ripening stages. The results of the discriminant analysis showed that edible fraction, peel pH, pulp water content, and pulp total phenolics were among the most contributing attributes for the discrimination of the cultivar groups. With mean values ranging from 65.4 to 247.3 mg of gallic acid equivalents/100 g of fresh weight, the pulp total phenolics strongly differed between interspecific and monospecific cultivars within dessert and non-plantain cooking bananas. The results of the logistic regression revealed that the best models according to fitting parameters involved more than one physicochemical attribute.

Fahrasmane *et al.* (2014) analysed the importance of banana on health preservation potentialities. The medicinal properties of banana are part of the folk medicine of all tropical countries. Bananas are used in special diets where ease of digestibility, low fat, minerals and vitamins are required. These special diets are used for babies, the elderly and patients with stomach problems, gout, and arthritis. Anti-ulcerogenic properties of banana are reported. Green banana has antidiarrheal properties; it is traditionally used to cure dyspepsia. Flavonoids, carotenoids and polysaccharides from banana are recognized having health benefits for humans, acting in the digestive tract and in other organs through antioxidant activities. Nowadays, it is important to elaborate new knowledge about bananas health effects in order to improve their consumption.

Haftom *et al.* (2015) evaluated the physico-chemical and sensory properties of banana flour-sesame paste blends. The experiment consisted of ripe banana flour + sesame paste proportions: 55 + 45% (B_fBR_1), 45 + 55% (B_fBR_2) and 35 + 65% (B_fBR_3) respectively. Sesame paste made from 50% sugar syrup was used as a control. Banana flour-sesame pastes showed a significant ($p<0.05$) increase in moisture (wb), fiber, ash, fat, protein from 3.33, 3.12, 3.28, 23.27, 11.76 (%) in the control to 5.24-6.42, 3.71-4.73, 4.94-5.12, 23.42-33.56, 11.96-15.89 (%) in the different blends respectively. Similarly Ca, Zn, Fe (db) were increased from 522.94, 2.09, 5.17 mg/100g in the control to 531.75-767.98, 2.27-2.83, 5.37-7.30 mg/100g in the blends respectively. But the carbohydrate content was reduced from the control value of 50.44% to 34.07-49.05% in the various blended pastes. The total phenolic content (mg GAE/g), ferric ion reducing power (FRP) (µmol/g) and phytic acid (mg/100g) contents at B_fBR_2 and B_fBR_3 were increased from control value of 11.16, 15.68 and 164.96 to 11.99-16.19, 16.22-21.88 and 144.41-208.01 in the blended pastes, respectively. Sensory evaluation revealed that the most acceptable paste product for its flavor was obtained from 55% sesame paste higher than the control value. Descriptive sensory analysis revealed that all products had light brown and light yellow color, roasted nutty flavor and sweet taste.

Okorie *et al.* (2015) conducted a study to investigate the total protein, calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), phosphorous (P), zinc (Zn), copper (Cu) and lead (Pb) composition of the peels of unripe plantain, ripe plantain, unripe banana and ripe banana. All the peel samples studied contained considerable amounts of Ca, Mg, K, Na, P, Zn, Cu, and protein while the amount of Pb in all the peel samples were quite low to cause any deleterious effects.

Tonna *et al*. (2015) conducted a study to characterize banana cultivars Luvhele, Mabonde and Muomvared for morphological, physicochemical, and

antioxidant properties. All three cultivars varied significantly ($P < 0.05$) in their morphology, pH, titratable acidity and total soluble solids with no significant difference in their ash content. Individual cultivars showed variations in flour starch granule when observed using a scanning electron microscope. Characterization of cultivars for total polyphenols (TPs) and antioxidant activity upon pretreatment with ascorbic, citric, and lactic acid shows that the 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging assay of samples varied significantly as Muomva-red cultivar (1.02 ± 0.01 mg GA/g) expressed the highest DPPH activity at lactic acid concentration of 20 g/L. Total polyphenol content was also highest for Muomva-red (1091.76 ± 122.81 mg GAE/100g).

Ahmed *et al.* (2016) carried out a study to investigate the chemical composition and biological activity of banana peel extracts; the efficiency of the different solvent systems: aqueous, 80 % methanol, 80% ethanol and 80% acetone was used for extraction of phenolic, flavonoid and tannin compounds. Banana peel relative antioxidants potential by four assays DPPH·, Fe^{2+}chelating, Reducing power and ABTS + inhibitor activities was evaluated. Analysis showed that the percentage of moisture, protein, crude fat and total carbohydrates were 88.10, 13.42, 7.57, 10.44 and 68.31 g/100g respectively. For mineral content, potassium is the major element found in banana peel was (9.39 %) followed by magnesium, calcium, sodium and phosphorus were (0.71, 0.44, 0.18 and 0.09 %), respectively. Also, the content of microelement including iron, manganese, zinc and copper were 96.50, 35.01, 27.95 and 3.37 ppm, respectively. Methanolic extract (80%) had the highest content of total phenolic; flavonoid and tannin were 17.89, 21.04 and 24.21 mg/g respectively. Most of acetone banana peel extracts (80%) was found to be highest antioxidant and antimicrobial activity at 600 ppm against gram positive and negative bacteria, fungi and yeast. The phenolic profiles of banana peel acetone

extract were identified by HPLC. The main phenolic compounds were chyrsin, quercetein and catchin.

Lia and Dewi (2016) evaluated the morphology and analyse nutrient values of mature fruits at three different genomic groups of Indonesian banana cultivars including Pisang Berlin (AA), Ambon Hijau (AAA), Raja Bandung (ABB) and Kepok (ABB). Fruit characterization results show that each banana cultivar had specific characteristics related to their genomic group. Pisang Berlin has bright yellow peel and pulp and sugary taste. Pisang Ambon Hijau has fine curved fruit shape, sweet taste and aromatic. Pisang Raja Bandung has medium thickness and yellow peel, firm flesh, sweet and slightly acidic taste. Pisang Kepok has thick coarse and yellow peel with dark brown blotches, mild sweet taste. Fruit characters of Pisang Berlin and Ambon Hijau are close related to their ancestral parents' *Musa acuminata* wild species, whereas Pisang Kepok and Pisang Raja Bandung as hybrid cultivars have intermediate characters between *Musa acuminata* and *Musa balbisiana* wild species. Nutrient analysis revealed that mature banana pulp contain of high carbo-hydrates (16.72-35.24g/100g), total sugar (12.12-20.82g/100g), vitamin C (16.45-30.27g/100g) and potassium (275-375g/100g); moderate protein (1.48-1.78 g/100g) and low fat (0.03-0.08 g/100g). About 100 g edible portion of banana fruit produce 73.43 to 148.80 calories.

Ekesa *et al.* (2017) conducted a study to compare the consumer preference of the pVAC - rich (pro-vitamin A carotenoids) banana cultivars with that of local cultivars of the same genome and following similar postharvest handling treatments. During sensory evaluations 450 panellists (50% male and 50% female) tested the products using standard procedures and rated them on a 5-point hedonic scale. Dessert types were served raw; cooking types were boiled, roasted and pan-fried. The attributes evaluated included: peel appearance, ease of peeling, pulp appearance, aroma, texture in hand,

texture in mouth, taste and overall acceptability. In Burundi, all the cultivars had overall acceptability median scores of 4 (good). In North Kivu, the overall acceptability medians ranged from fair to very good (3-5). In South Kivu, the median overall acceptability scores were good (4) for all cultivars except 'To'o' and 'Gros Michel' that scored 3 and 5 respectively (fair and very good). In all three sites and for all the cultivars, there was a significant correlation between the scores for texture in the mouth, taste and the scores for overall acceptability.

Gayathri and Nair (2017) carried out a study to understand the activity of five major fruit ripening enzymes (PG, PME, cellulase, invertase and xylanase) in the fruits of eight *M. acuminata* cultivars *viz.* Palayancodan (AAB), Nendran (AAB), Poovan (AAB), Robusta (AAA), Red banana (AAA), Kadali (AA), Matti (AA) and Njalipoovan (AB) at early ripened, ripened and late ripened stage of fruit maturation. Preliminary biochemical estimation was carried out in the fruits from the selected cultivars for total carbohydrates, reducing sugar, amino acids, total proteins, and β-carotenes in early ripened, ripened and late ripened stages. Carbohydrate content was maximum in Red banana (2689.6 μg/g) and minimum in Matti (1267.16 μg/g). Amino acid content was maximum in Kadali and minimum in Red banana and Poovan. Maximum protein was observed in Kadali (698.4 μg/g) and minimum in Red banana and Poovan. β-carotene content was maximum in Nendran (412.16 μg/g) and least in Matti (124.03 μg/g). The cell wall hydrolyzing enzymes except invertase showed maximum activity in ripened fruits of Palayancodan. Invertase activity is maximum in Njalipoovan and this can be linked with its higher non-reducing sugar content.

Sijji and Nandini (2017) evaluated the chemical and nutrient compositions of eight banana varieties. TSS was found to be more in Kadali (23.90 ^{0}Brix) followed by Rasakadali (23.830 Brix) and Nendran (22^{0} Brix).

Maximum acidity was noticed in Poovan (1.28%). The variety Nendran exhibited highest carbohydrate content (41.33g/100g) whereas protein content was found to be higher in variety Poovan (1.37g/100g). Total mineral content of banana varieties ranged between 0.17g - 0.70g/100g and varieties such as Rasakadali (260 mg/100g) and Nendran (546.66 mg/100g) exhibited highest content of Na and K respectively. The calcium content of the selected banana varieties ranged between 0.35-1.35 mg/ 100g.

Jennifer *et al*. (2017) conducted a study to characterize a banana pulp dehydrated in sheets and its further sensory evaluation. For the drying tests, a static type equipment was used, and the fresh and dehydrated banana pulp was characterized taking into account its moisture content, soluble solids, pH, acidity and proximal analysis. The conservation parameters of the dehydrated pulp were satisfactory, which are favored by the low water activity reached in the dehydrated product. The sensorial analysis showed that temperature and speed of the drying air exert a big influence in the quality factor appearance and color.

Ravinder *et al.* (2017) conducted an experiment to assessed ripe banana flour, unripe banana flour and cooked banana flour for physicochemical and functional properties such as pH, total soluble solids (TSS), water absorption capacities, and oil absorption capacities at 40, 60 and 80°C, colour values *L**, *a** and *b**, bulk density, foaming capacity and foaming stability, emulsion activity and stability, dispersibility and wet ability. Data obtained were analysed by standard deviation and average based. All statistical analyses showed that physicochemical and functional properties prepared from ripe green and cooked banana were different from each other. pH, TSS, WAC, bulk density and colour values used to discriminate between ripe, unripe and cooked banana flour.

Ashraf *et al.* (2018) conducted a study to improve banana crop growth and productivity by planting cultivars that may be tolerant to banana diseases with high productivity and quality. Three imported cultivars Zeef, Grand Naine, and Canary were evaluated for two seasons. The results of this work indicated that Zeef and Grand Naine were significantly higher in growth parameters such as plants length and number of functional leaves than Canary. Similar results were noticed in productivity parameters where Zeef plants and Grand Naine were significantly higher than Canary such as total yield, bunch weight, bunch length, finger length and diameter, while no clear differences were found in quality components. In the second season the first sucker was higher than the first one (mother plant) in the three cultivars in all parameters. Also Zeef plants and Grand Naine recorded the highest value for each of antioxidants enzymes, soluble sugars and proline.

Hassan *et al*. (2018) conducted a study to determine the proximate and mineral level of banana (*Musa sapientum*) peel using standard methods of analyses of AOAC and atomic absorption spectrophotometric method. The peels contained 1.95 ± 0.14 % crude proteins, 5.93 ± 0.13 % crude fat, 8.37 ± 0.18 % crude fibre, and 11.82± 2.17 % carbohydrate. The banana peel investigated contained phosphorus (211.30± 1.24 mg/100 g), iron (47.00 ± 1.26 mg/100 g), calcium (59.10 ± 0.85 mg/100 g), magnesium (44.50 ± 0.08 mg/100 g), sodium (115.10 ± 0.26 mg/100 g) with low content in zinc (0.033 ± 0.04 mg/100 g), copper (0.51 ± 0.02 mg/100g), potassium (4.39 ± 0.15 mg/100 g) and manganese (0.702 ± 0.09 mg/100g).

Hassan and Peh (2018) conducted an experiment to evaluate banana peel for their nutrients and anti-nutrients content. The results showed that water content, crude protein content, crude lipid content, crude fiber, total ash content and carbohydrate in banana peels were 50.5, 5.3, 1.6, 19.2, 8.8 and 14.6% respectively. The results indicate that if the peels are properly exploited and

processed, they could be good ingredients and cheap source of carbohydrates for culture media.

Jiwan and Tasleem (2018) critically reviewed about bioactive compounds in banana fruits and their health benefits. Banana is known to be rich not only in carbohydrates, dietary fibres, certain vitamins and minerals, but is also rich in many health-promoting bioactive phytochemicals. General composition including various bioactives and their health contributions has been reviewed.

Parag *et al.* (2018) conducted an experiment and revealed that storage at 13ºC with 95% RH was the best condition to maintain the shelf-life of the Banana fruit cv. Grande Naine. Fruit at green stage-1 that were treated with 1% Alum and 1% Benomyl for 10 minutes simultaneously and then vacuum packed in LDPE bag and stored inside cold room of Eco-frost retained a maximum storage life upto 25 to 30 days and the post-storage life was recorded as 2 to 3.5 days. Shelf life was recorded to be 4 to 6 days in ordinary room condition. Chilling injury, decay, crown rot severity and stem rot were noted as zero percentage inside cold room since starting of the experiment.

Santhosh and Appachanda (2018) conducted a study on variations in the nutritional and biochemical compositions associated with ripened and unripened stages of banana fruits. Proximate composition, mineral and phytochemical compositions of ripened and unripened banana flours were analysed and the total soluble sugars in unripened banana range from 1.70 to 2.15 mg/100g of the samples and that of ripened banana range from 37.5 to 43.8 mg/100g of the samples. Mineral compositions show that they are rich sources of calcium, phosphorus and iron. In addition to this they are rich sources of antioxidant potential phytochemicals such as polyphenols, flavanoids, vitamin C and lesser in quantity of anti-nutritional factors such as phytates and oxalates.

Barnabas and Anthony (2019) conducted a study and evaluate the nutritional and mineral composition of the flesh, peel, and peel extract components of *Musa sinensis* L. and *Musa paradisiaca* L. fruits as well as their nutritional and therapeutic potentials. Proximate and antinutritional analyses were carried out using standard analytical methods of the Association of Official Analytical Chemists (AOAC), while the mineral constituents were evaluated using inductively coupled plasma optical emission spectroscopy (ICP-OES). Proximate analysis revealed that the flesh and peel of *M. sinensis* L. and *M. paradisiaca* L. contain substantial amounts of moisture, fiber, carbohydrates, and low fat content, while minerals K, Mg, Ca, Na, P, and N were substantially concentrated in the peels and peel extracts in particular. The antinutrients alkaloid, oxalate, saponin and phytate were detected in safe amounts according to the World Health Organization (WHO).

Kalyani and Chaitali (2019) investigated on the effects of the chemical composition and properties of the banana peel dietary fiber concentrate (BDFC). There are various nutrient content which can be used in various ways. In the present study, dietary fiber can be extracted from banana peel powder obtained by sun drying and peel powder can be used as nutritional juice which is used for medicinal purpose also.

Thales and Mirian (2019) conducted a study to produce dried banana by means of drying the fresh banana cv. Cavendish and evaluate the influence of pre-treatments on the product's quality and acceptability. Three samples were used: T_1 was the control and had no pre-treatment; T_2 received a pre-treatment composed of a sodium metabisulphite additive solution; and T_3 was pre-treated with a citric and an ascorbic acid antioxidant solution. The samples were characterized according to yield calculation, moisture, titratable acidity, soluble solids, pH, water activity (aw), color parameters, instrumental texture, and sensory analyses for their overall acceptance and purchase intention. The yield

was approximately 30% and there was low water activity and moisture in the product, even after drying for all treatments. There was also an influence of the pre-treatments on the physical, chemical and sensory characteristics of the dried banana.

Ibiyinka *et al.* (2021) conducted a study on ripe and unripe banana peels as potential sources of nutrients, essential minerals and antioxidants. The study revealed that the percentage moisture of the unripe and ripe banana peels ranged from 4.60 – 17.8, crude protein 1.94 – 2.73, fat 1.76 – 3.25, ash content 11.3 – 14.7, crude fibre 14.2 – 15.5 and carbohydrates 48.4 – 52.7. Mineral content showed significantly high levels of Na, K, Ca, Zn, Fe in unripe peels while that of ripe exhibited higher levels of Mn and P. Na/K for both ripe and unripe banana peels is less than 1 while Ca/P ranged from 1.63 - 2.64. The antioxidant capacity using 2, 2-diphenyl-1-picryl-hydrazyl-hydrate (DPPH) assay ranged from 3.75 - 13.6 mg TE/g and total phenolic content in unripe and ripe banana peels ranged from 8.42 - 15.8 mgGAE/g with higher value in unripe peels. The results indicate that the peels can be utilized as sources of fibre, carbohydrate and essential minerals in fortification of animal feeds.

Kinde (2021) evaluated seven dessert Banana cultivars at West Hararghe, Mechara. The analysis of variance indicates that there was highly significant ($p < .001$) difference of all morphological traits except fruit diameter and fruit length. The highest yield was recorded for variety of Giant Cavendish (11.83 ton ha^{-1}) but statistically at par with Robusta (10.67 ton ha^{-1}) and Williams-I (10 ton ha−1) and farmers in the study areas prefer Giant Cavendish, Robusta and Williams-I for yield and different morphological traits. These varieties also have the highest number of leaves as well as pseudo stem girth and plant height.

Syukriani *et al.* (2021) conducted a study to determine the characteristics of banana cv. Raja Flour from peel, flesh and fruit and its

minerals content. The results obtained from the analysis of moisture content ranged from 6.21 to 39.33%, ash content was 1.33-1.86%, and protein content was 2%. The content of vitamin C in the peel, fruit and flesh of bananas is 32.3 mg/100 g, 7.18 mg/100g and 4.99 mg/100g respectively. The mineral content of potassium (K) and calcium (Ca) in banana peels is higher than the flesh and fruit of bananas such as 73.03% and 16.12%, while the content of phosphorus (P), magnesium (Mg) and chlorine (Cl) in the pulp was higher than the skin and banana fruit 10.52%, 6.58%, and 4.37% respectively. The crystalline structure of banana flour from banana peels, fruit flesh and fruit shows the same type is type A and the gelatinization temperature ranges from 74.85 to 76.90C within 8.6 to 10.6 minutes.

CHAPTER III

MATERIALS AND METHODS

MARERIALS AND METHODS

The present investigation entitled “Diversity mapping and database development of banana (*Musa* spp.) germplasm in Nagaland” was conducted during the year 2019 – 2021 to trace out a wide spectrum of variability of various characters with potentiality of genotypes of different germplasms of *Musa* spp., a survey work was conducted based on IPGRI (International Plant Genetic Resources Institute) Descriptors for Banana (*Musa* spp.) during the given period in their natural habitat and the fruit samples was collected, *in-situ,* from various locations of Nagaland. The collected genotypes were conserved *in-situ* at Instructional cum Research Farm, Department of Horticulture, School of Agricultural Science and Rural Development, Nagaland University, Medziphema Campus for further evaluation and documentation.

3.1 General information

3.1.1 Location

The study was carried out in the state of Nagaland under the district of Dimapur, Peren, Kohima, Wokha and Mokochung covering fifteen villages altogether (table 3.1). Twenty genotypes of banana (*Musa* spp.) were collected to conduct the experiment.

Table 3.1: Information on different collection site of banana (*Musa* spp.) genotypes

Genotypes	Collection site	District	Longitudes	Latitudes	Altitude (msl)
G-1(Bhootmanohar)	Sirhi Angami	Kohima	25.7126°N	93.9976°E	465
G-2 (Chinichampa)	Medziphema	Dimapur	25.7566°N	93.8681°E	360
G-3 (Jahaji)	Medziphema	Dimapur	25.7556°N	93.8671°E	360
G-4 (Kanthali)	Piphema	Dimapur	25.7286°N	93.9403°E	156
G-5 (Lumungashe)	Bade	Dimapur	25.5445°N	93.4430°E	145
G-6 (Bharatmani)	Punglwa	Peren	25.6792°N	93.8418°E	428
G-7 (Nendran)	Rai Basti	Dimapur	25.7506°N	93.8896°E	400
G-8 (Grand Naine)	Medziphema	Dimapur	25.7556°N	93.8671°E	360
G-9 (Kwetho)	Punglwa	Peren	25.6792°N	93.8418°E	428
G-10 (Meitei Hei)	Molvom	Dimapur	25.7566°N	93.8681°E	360
G-11 (Lumungto)	Peace Camp	Dimapur	25.6625°N	93.4654°E	158
G-12 (Subjikol)	Tsuuma	Dimapur	25.7286°N	93.9403°E	156
G-13 (Kwegha)	Gaili	Peren	25.7286°N	93.9403°E	156
G-14 (Gumsang)	Gaili	Peren	25.8210°N	93.6626°E	158
G-15 (Luipet)	Jalukie	Peren	25.7126°N	93.9976°E	400
G-16 (Rakannak)	Chuchuyimlang	Mokokchung	26.4064°N	99.4599°E	1054
G-17 (Phfeprei)	Sirhi Angami	Kohima	26.5123°N	94.1552°E	465
G-18 (Yhuro)	Longsachung	Wokha	26.0524°N	94.2602°E	1313
G-19 (*M. velutina*)	Niroyo	Wokha	26.0629°N	94.2651°E	1313
G-20 (Red Banana)	Heningkungwa	Peren	25.6625°N	93.7784°E	358

3.1.2 Climatic condition

The climate of the experimental locations under the selected districts of Nagaland represents sub-humid tropical climate zone with moderate temperature and medium to high rainfall. The relative humidity ranges from 75% to 85%. The mean temperature ranges from 21°C to 30°C during summer and rarely goes below 8°C in winter due to high atmospheric humidity. The average rainfall varies between 2000 - 2500 mm starting from April and ends

with the month of September while the period from October to March remains completely dry.

Table 3.2 Meteorological data recorded during the period of crop investigation (September 2019 to December 2021) under *ex-situ* (Experiment – 2)

Year	Month	Min. temp. (^{0}C)	Max. temp. (^{0}C)	Min. RH (%)	Max. RH (%)	Avg. sunshine hr.	Total rainfall (mm)
2019	September	23.90	32.70	72.00	94.00	4.10	173.40
	October	21.70	30.30	73.00	95.00	5.90	244.80
	November	16.30	28.80	64.00	97.00	7.00	52.90
	December	10.04	23.70	62.00	97.00	6.10	0.90
2020	January	9.60	22.40	61.00	97.00	5.00	18.50
	February	11.10	24.80	51.00	96.00	5.20	9.70
	March	14.10	30.10	41.00	94.00	6.90	22.50
	April	17.10	30.70	52.00	90.00	5.40	153.90
	May	21.10	30.50	64.00	90.00	4.80	134.20
	June	23.80	32.40	72.00	92.00	3.90	266.20
	July	24.50	32.40	74.00	94.00	2.60	199.90
	August	25.00	33.70	70.00	93.00	4.40	80.30
	September	24.30	32.50	73.00	95.00	4.80	157.60
	October	23.00	31.20	74.00	95.00	5.20	175.70
	November	9.80	24.50	52.00	95.00	7.00	35.20
	December	15.60	27.90	59.00	97.00	6.70	0.00
2021	January	8.90	24.00	50.00	96.00	6.30	3.40
	February	9.70	27.10	40.00	95.00	7.20	2.30
	March	14.90	31.10	41.00	93.00	6.40	43.50
	April	17.90	33.10	34.00	87.00	7.00	59.60
	May	21.90	2.80	58.00	90.00	4.70	90.80
	June	24.30	33.10	69.00	93.00	3.40	125.50
	July	24.50	32.40	74.00	94.00	2.60	199.90
	August	23.00	31.20	74.00	95.00	5.20	175.70
	September	25.00	33.70	70.00	93.00	4.40	80.30
	October	24.50	32.40	74.00	94.00	2.60	199.90
	November	10.04	23.70	62.00	97.00	6.10	0.90
	December	17.00	27.30	60.00	97.40	7.00	0.00

Source: ICAR Research Complex for NEH Region, Nagaland Centre

3.1.3 Soil condition

The soil of the experiment site was categorized as sandy clay loam and sandy clay and well drained with mean pH of 5.1.

3.2 Experiment – 1: To study the taxonomical characters and genetic diversity of different *Musa* spp.

Crop	: Banana (*Musa* spp.)
Survey area	: Nagaland
No. of replication	: 20 (Twenty)
No. of genotypes	: 3 (Three)
No. of characters studied	: 32

3.2.1 Observations recorded

3.2.1.1 Survey schedule

3.2.1.2.1 Collection number

Explorations were carried out on selected bananas growing region of Nagaland covering the districts of Peren, Kohima, Dimapur, Wokha and Mokokchung. Banana genotypes were collected from farm, forest and homestead garden. Collection number was assigned to each genotype for future reference and documentation and was conserved *ex-situ* in the Instructional cum Research Farm, Department of Horticulture, School of Agricultural Science and Rural Development, Nagaland University, Medziphema Campus.

3.2.1.2.2 Location of collecting site

Preliminary information on banana growing areas was gathered from local markets. The location for collection was chosen based on information and recommendations from the local fruit traders and fruit sellers via open-ended

interview. Some factors were considered regarding the information of the locations prior to collection such as; the total area of banana farms in the area/village, genotype distribution and production of banana fruits.

3.2.1.2.3 Elevation or altitude of collecting site (m)

Topographically Nagaland is much dissected, full of hill ranges, which break into a wide chaos of spurs and ridges. Longitudinal and latitudinal extend of Nagaland is located at 26.1584°N and 94.5624°E. Sites information including longitude and latitude location of the genotypes was collected using Google Earth. The banana genotypes were collected from Peren, Kohima, Dimapur, Wokha and Mokokchung districts of Nagaland and the elevation of the sites were 1445 m, 1444 m, 145 m, 1313 m and 1325 m respectively.

3.2.1.2.4 Collecting source

Extensive survey work was carried out in the selected districts of Nagaland to collect wild and cultivated species of *Musa* spp. Prior to collection of banana genotype, local people were interviewed to generate preliminary list of cultivars to look for in the area/village. The cultivated species of *Musa* was collected from fields and homestead garden and the wild species were collected from forest area under the guidance of the local contact.

3.2.1.2.5 Type of sample

Banana is propagated by suckers. Samples were collected from healthy plants as suckers and information on diseases and utility were also gathered from the sites of collection. A minimum of three suckers per genotype were collected for *ex-situ* conservation at Horticulture Experimental Farm, SASRD, Nagaland University.

3.2.1.2.6 Local Name

Nagaland is inhabited by different tribes and ethnic communities with different dialects and languages. A variety is known by different names base on the dialects and the communities in different regions. Therefore, each genotypes collected were given different local names along with accession number.

3.2.1.2.7 Number of plants sampled

Live specimens in the form of suckers were collected. A minimum of three suckers were collected from each genotype. The collected suckers were planted in the Instructional cum Research Farm, Department of Horticulture, School of Agricultural Science and Rural Development, Nagaland University, Medziphema Campus for *ex-situ* conservation.

3.2.1.2.8 Uses of fruits based on farmer's preference

Banana fruits were used in different forms depending on the cultivars/species. The genotypes collected were consumed mostly as dessert. Some cultivars were used for cooking purposes and chips preparation. Wild seeded species were used for local wine preparation.

3.2.1.2.9 Other parts of the plant used

Almost all the plant parts were used for different purposes. The pseudostem core and male buds were used for different culinary purposes and also as animal feeds. The leaves were used for wrapping purposes and in some case as organic plate in community feast.

3.2.1.2.10 Type of soil and pH

Nagaland is a hilly state with heavy annual rainfall ranging from 120 cm to 240 cm. Soil sample were collected from each location where the genotypes were sampled. The collected soil sample was analyzed at Department of Soil

Science and Agricultural Chemistry, SASRD, Nagaland University, Medziphema campus.

3.2.1.2 Plant general appearance

Morphological data of the genotypes were taken *in-situ.* The collected genotypes of banana were morphologically analyzed for their features based on the IPGRI (1996), descriptors for banana.

3.2.1.2.1 Leaf habit

The genotypes were differentiated from their leaf habits either in the form of erect, intermediate and drooping.

(i) (ii) (iii)

3.2.1.2.2 Dwarfism

The leaf ratio was measured on the third leaf, counting from the last one that emerged. It was differentiated either -

a) Normal: Leaves not overlapped and leaf ratio inferior to 2.5

b) Dwarf type: Leaves strongly overlapped and leaf ratio superior

3.2.1.2.3 Pseudostem height (m)

The height of the pseudostem was recorded by measuring the length between the base of the pseudostem and the emerging point of the peduncle.

3.2.1.2.4 Girth size (cm)

Girth size of the pseudostem was measured 30 cm above the ground level (UPOV, 2010).

3.2.1.2.5 Pseudostem colour

Colour of the pseudostem was recorded by removing the external sheaths without taking into account the colour of the old dried leaf sheaths were recorded as follows:

a) Green-yellow
b) Medium green
c) Green
d) Dark green
e) Red
f) Red - purple
g) Blue
h) Chimerical
i) Other

3.2.1.2.6 Number of suckers

Number of suckers emerging from the mother plant were counted and recorded.

3.2.1.2.7 Position of suckers

Position of the suckers were observed and recorded as follows:

i) Far from parent plant (Emerging >50 cm from parent plant)

ii) Close to parent (Vertical growth)

iii) Close to parent (Growing at an angle)

3.2.1.2.8 Leaf blade length (cm)

The leaf blade length was measured at its maximum point and was recorded in centimeter.

3.2.1.2.9 Leaf blade width (cm)

The leaf blade width was measured at its maximum point and was recorded in centimeter.

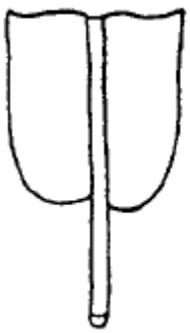
3.2.1.2.10 Colour of leaf upper surface

Colour of the leaf upper surface was recorded base on the following parameters:

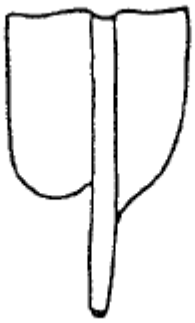
(i) Green – yellow
(ii) Medium Green
(iii) Green
(iv) Dark green
(v) Drak green with red purple (Presence of large blotches of red-purple)
(vi) Blue

3.2.1.2.11 Leaf blade base shape

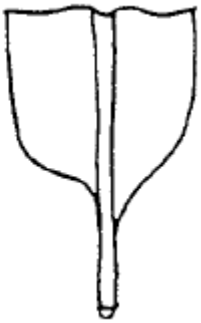
(i) Both sides rounded
(ii) One side rounded, one pointed
(iii) Both sides pointed



(i)



(ii)



(iii)

3.2.1.2.12 Petiole length (cm)

Petiole length is the length between the pseudostem and the base of leaf lamina. It was measured in centimeter.

3.2.1.2.13 Petiole canal leaf III

Petiole canal leaf III is the third leaf counted from the last leaf (leaf I) produced before bunch emergence. The petiole was cut half way between the pseudostem and the leaf blade and examines the cross section.

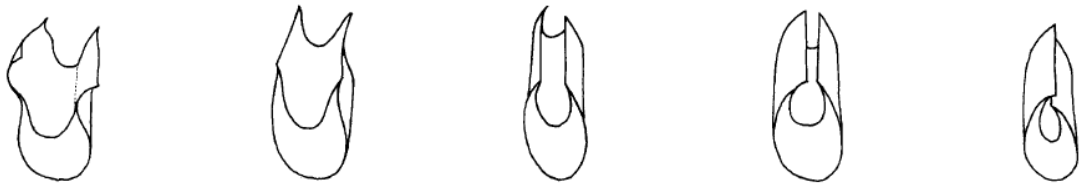
(i) Open with margins spreading

(ii) Wide with erect margins

(iii) Straight with erect margins

(iv) Margins curved inward

(v) Margins overlapping



(i) (ii) (iii) (iv) (v)

3.2.1.3 Flower characters

3.2.1.3.1 Flowering time

Flowering time was recorded through the information obtained from the farmer. Probable months and time for flower initiation of the genotype was recorded.

3.2.1.3.2 Male bud shape

The general shape of the male bud was recorded during the harvest. The shape of the male bud was determined based on the following parameters:

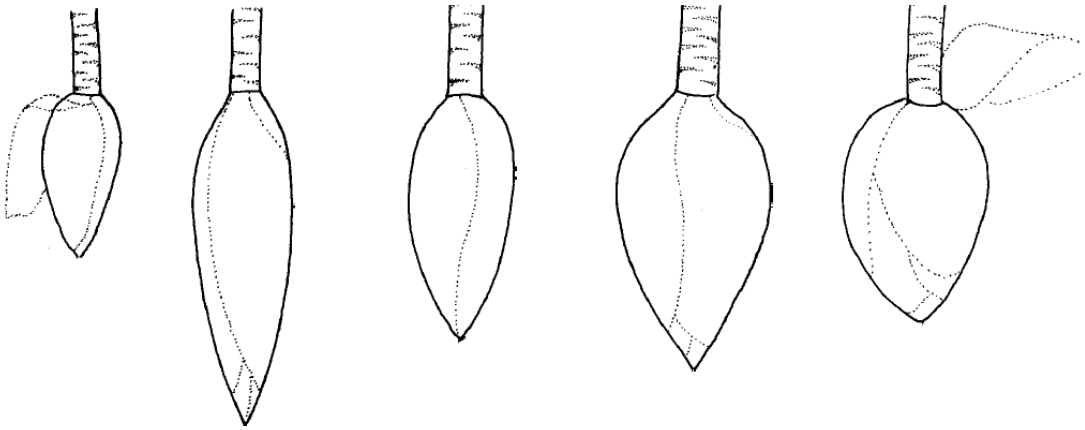
(i) Like a top

(ii) Lanceolate

(iii) Intermediate

(iv) Ovoid

(v) Rounded



(i) (ii) (iii) (iv) (v)

3.2.1.3.3 Bract apex shape

The apex of the bract was flattened to observe the shape. Shape of the bract apex was recorded as follows:

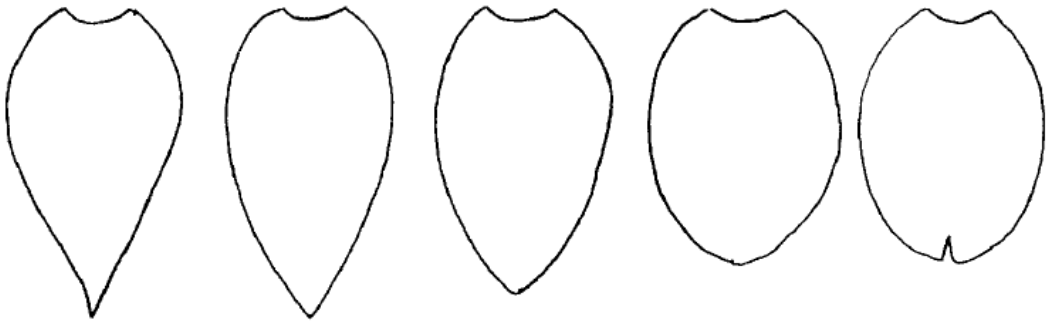
(i) Pointed

(ii) Slightly pointed

(iii) Intermediate

(iv) Obtuse

(v) Obtuse and split



(i) (ii) (iii) (iv) (v)

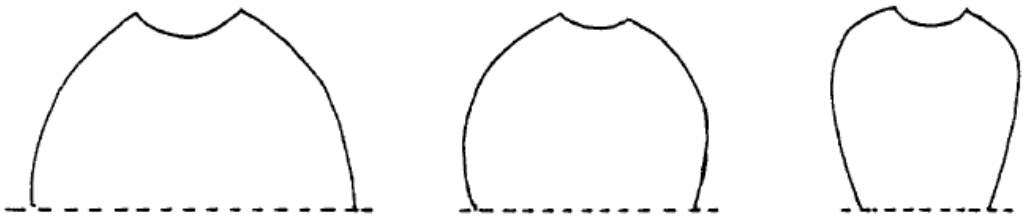
3.2.1.3.4 Bract base shape

Bract base shape was recorded as follows:

(i) Small shoulder

(ii) Medium

(iii) Large shoulder



(i) (ii) (iii)

3.2.1.3.5 Colour of bracts (External)

External colour of bracts was recorded as follows:

(i) Yellow

(ii) Green

(iii) Red

(iv) Red – purple

(v) Purple – brown

(vi) Purple

(vii) Blue

(viii) Pink – purple

(ix) Orange – red

(x) Other

3.2.1.3.6 Colour of the bracts (Internal)

Internal colour of the bracts was recorded as follows:

(i) Whitish
(ii) Yellow or green
(iii) Orange red
(iv) Red
(v) Purple
(vi) Purple brown
(vii) Pink – purple
(viii) Other

3.2.1.3.7 Free tepal shape

Free tepal shape was recorded as follows:

(i) Rectangular
(ii) Oval
(iii) Rounded
(iv) Fan – shaped

3.2.1.3.8 Free tepal coulour

Free tepal colour was recorded as follows:

(i) Translucent white
(ii) Opaque white
(iii) Tinted with yellow
(iv) Tinted with pink

3.2.1.3.9 Compound tepal colour

Compound tepal colour was recorded without considering the lobe colour as follows:

(i) White
(ii) Yellow

(iii) Orange

(iv) Pink/pink – purple

(v) Other

3.2.1.3.10 Ovary shape

Ovary shape was recorded as follows:

(i) Straight

(ii) Arched

(i) (ii)

3.2.1.3.11 Stigma colour

Stigma colour was recorded as follows:

(i) Cream
(ii) Yellow
(iii) Pink/pink – purple
(iv) Bright yellow
(v) Orange
(vi) Other

3.2.1.4 Scoring system of banana

For genome classification, the morphological characters of vegetative, male and female inflorescence based on fifteen characters suggested by Simmonds and Shepherds (1955) were evaluated.

Table 3.3 Simmonds and Shepherd's banana scoring system

Character	*Musa acuminata*	*Musa balbisiana*
Pseudostem colour	More or less heavily marked with brown or black blotches	Blotch very slight or absent
Petiole canal	Margin erect or spreading with scarious wings below, not clasping pseudostem	Margin enclosed, not winged but clasping pseudostem
Peduncle	Usually downy or hairy	Glabrous
Pedicels	Short	Long
Ovules	Two regular rows in each loculus	Four irregular rows in each loculus
Bract shoulder	Usually high (ratio>0.28)	Usually low (ratio>0.30)
Bract curling	Bract reflex and roll back after opening	Bract do not reflex
Bract shape	Lanceolate or narrowly ovate, tapering sharply from the shoulder	Broadly ovate, not tapering sharply
Bract apex	Acute	Obtuse
Bract colour	Red, dull purple or yellow outside; pink, dull purple or yellow inside	Distinctive brownish-purple outside; bright crimson inside
Colour fading	Inside bract colour usually fades to yellow towards the base	Inside bract colour usually continuous to base
Bract scars	Prominent	Scarcely prominent
Free tepal of male flower	Variably corrugated below tip	Rarely corrugated
Male flower colour	Creamy white	Variably flushed with pink
Stigma colour	Orange rich yellow	Cream, pale yellow or pale pink

3.2.1.4 Fruit characters

3.2.1.4.1 Bunch weight (kg)

Fully mature banana was harvested from the field and the bunch weight was recorded through digital weighing balance. It was expressed in kilogram (kg).

3.2.1.4.2 Number of hands/bunch

The number of hands/bunch was obtained by counting the number of hands in the whole bunch for each banana genotypes.

3.2.1.4.3 Number of fingers/hand

The numbers of fruit/hand were recorded by counting the number of fruits bearing in the hand for each genotype.

3.2.1.4.4 Fruit weight (g)

The weight of the fruit was taken by detaching a single fruit from the hand in the electronic weighing balance. Five random fruits were taken and an average fruit weight was recorded. It was expressed in gram (g).

3.2.1.4.5 Pulp weight (g)

The weight of the pulp was recorded after removing the peel from the fruit in the electronic weighing balance. Pulp of five random fruits was taken and average pulp weight was calculated. It was expressed in gram (g).

3.2.1.4.6 Peel weight (g)

Weight of the peel was recorded after separating the peel from the fruit pulp with the help of the electronic weighing balance. Peel of five random fruits was taken and an average peel weight was calculated. It was represented in terms of gram (g).

3.2.1.4.7 Fruit peel thickness (mm)

Fruit peel thickness was recorded at fruit maturity when the fruit was ripe and ready to eat but not over-ripe; full yellow stage. It was measured by Vernier Caliper and expressed in millimeter.

3.2.1.4.8 Pulp:peel ratio

The weight of pulp and peel of the fully ripened sample were recorded and dividing the pulp weight by peel weight to calculate pulp peel ratio.

3.3 Experiment – 2: To evaluate the selected germplasm based on fruit performance of characters.

Out of the twenty banana genotypes, ten were selected and evaluated for table purposes based on farmer's preference and marketability from wide spectrum of variability and diversity.

Design : Randomized Block Design

Genotypes : Superior genotypes as identified

Replication : 3 (Three)

No. of characters studied : 13

R1	R2	R3
Bhootmanohar	Grand Naine	Kanthali
Chinichampa	Bharatmani	Kwetho
Jahaji	Lumungashe	Chinichampa
Kanthali	Bhootmanohar	Meitei Hei
Lumungashe	Kwetho	Jahaji
Bharatmani	Meitei Hei	Bhootmanohar
Nendran	Chinichampa	Lumungashe
Grand Naine	Jahaji	Bharatmani
Kwetho	Kanthali	Nendran
Meitei Hei	Nendran	Grand Naine

Figure 3.1 Layout plan of experimental field

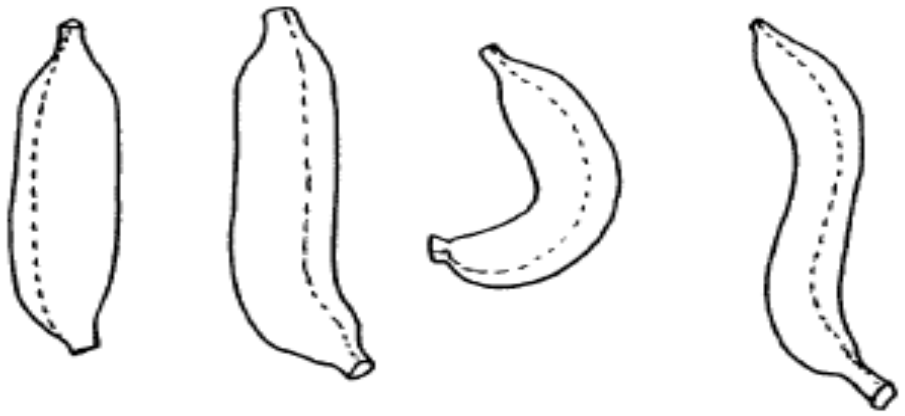
3.3.1 Observation recorded

3.3.1.1 Fruit characters

3.3.1.1.1 Fruit shape

Fruit shape was recorded as follows:

(i) Straight (or slightly curved)
(ii) Straight in the distal part
(iii) Curved (sharp curve)
(iv) Curved in 'S' shape (double curvature)
(v) Other



(i) (ii) (iii) (iv)

3.3.1.1.2 Fruit apex

Fruit apex was observed at the distal end of the fruit and recorded as follows:

(i) Pointed
(ii) Lengthily pointed
(iii) Blunt-tipped
(iv) Bottle-necked
(v) Rounded

(i) (ii) (iii) (iv) (v)

3.3.1.1.3 Immature fruit peel colour

Immature fruit peel was recorded on the youngest hand of the bunch, before maturity.

(i) Yellow
(ii) Light green
(iii) Green
(iv) Green and pink, red or purple
(v) Silvery
(vi) Dark green
(vii) Brown/rusty brown
(viii)Pink, red or purple
(ix) Black
(x) Other

3.3.1.1.4 Mature fruit peel colour

Peel colour of the mature fruit was recorded at fruit maturity when the fruit wass riped but not over ripened; full yellow stage.

(i) Yellow
(ii) Bright yellow
(iii) Orange
(iv) Grey spots

(v) Brown/rusty brown

(vi) Orange red, red or pink/pink purple

(vii) Red-purple

(viii) Black

(ix) Other

3.3.1.1.5 Fruit peel thickness (mm)

Fruit peel thickness was recorded at fruit maturity when the fruit was ripened and ready to eat but not over-ripe; full yellow stage. It was measured by Vernier Caliper and express in millimeter.

3.3.1.1.6 Pulp colour

Pulp colour of the fruit was recorded when the fruit was riped but not over-ripened; full yellow stage.

(i) White

(ii) Cream

(iii) Ivory

(iv) Yellow

(v) Orange

(vi) Beige-pink

(vii) Other

3.3.1.1.7 Flesh texture

Flesh texture was recorded either as:

(i) Firm

(ii) Soft

3.3.1.1.8 Seed (Presence/absence)

The banana genotypes collected were checked for presence or absent of seed. The mature fruit were cut open horizontally and vertically and checked for presence of seed. The banana genotypes were grouped as seeded and seedless.

3.3.1.1.9 Bunch weight (kg)

Fully mature banana are harvested from the field and the bunch weight was recorded through digital weight machine. It was expressed in kilogram.

3.3.1.1.10 Number of hands/bunch

The number of hands/bunch was obtained by counting the number of hands in the whole bunch for each banana genotypes.

3.3.1.1.11 Number of fruits/hand

The numbers of fruit/hand were recorded by counting the number of fruits bearing in the hand for each genotype.

3.3.1.1.12 Fruit weight (g)

The weight of the fruit was taken by detaching a single fruit from the hand in the electronic weighing balance. Five random fruits were taken and an average fruit weight was recorded. It was expressed in gram (g).

3.3.1.1.13 Pulp weight (g)

The weight of the pulp was recorded after removing the peel from the fruit in the electronic weighing balance. Pulp of five random fruits was taken and average pulp weight was calculated by dividing the weight of the sample. It was expressed in gram (g).

3.3.1.2 Biochemical analysis of fruit

3.3.1.2.1 Total soluble solids (^{0}B)

The TSS content of the selected fruit samples was determined with hand refractometer. The refractometer was washed with distilled water each time after use and dried with blotting paper and was expressed in ^{o}B.

3.3.1.2.2 Titratable Acidity (%)

Titratable acidity of the extracted juice was determined by treating the diluted fruit juice against 0.1N NAOH solution using phenolphthalein as an indicator and expressed in terms of percentage.

3.3.1.2.3 Total sugar (%)

The total sugar content of the fruit juice was determined by titrating against Fehling A and Fehling B reagents using methylene blue as an indicator. From the Titratable value, percentage of total sugar was calculated (A.O.A.C., 1984).

3.3.1.2.4 Reducing sugar (%)

The reducing sugar content of the fruit juice was determined by titrating against Fehling A and Fehling B reagents using methylene blue as an indicator. Precipitation of deep brick color of the solution indicated the end point and the titratable value were expressed in %.

3.3.1.2.5 Shelf life (Day)

To study the shelf life of banana, three fruit from each treatment per replication were kept at room temperature till the fruit start spoilage and were expressed in terms of number of days.

3.3.1.2.6 TSS/Acid ratio

Calculated by recording the mean TSS and titratable acidity of the fruit separately and the ratio was calculated as follows:

$$\text{TSS:Acid ratio} = \frac{\text{TSS}}{\text{Acid}}$$

3.3.1.2.7 Crude protein (g/100g)

The nitrogen content of banana samples was estimated by micro Kjeldahl's wet digestion method. The values of nitrogen contents were multiplied by the factors 6.25 to get crude protein content (AOAC, 2000).

3.3.1.2.8 Total carotene (mg/100g)

Total carotenoids content of banana fruit pulp was determined by the method of Roy (1973) with some modifications. 5 g of pulp was crushed in acetone till the tissue became colourless. Then the extracted solution was poured into the separating funnel. Petroleum ether and small amount of sodium sulphate solution were added and shaken rigorously. Then the separating funnel was kept undisturbed to separate the carotenoids from acetone to petroleum ether layer. After that, coloured solution was separated in a 50 ml volumetric flask and the volume was adjusted with petroleum ether. Finally, the sample absorbance was measured at 452 nm against petroleum ether using 1 cm cuvette in a spectrophotometer. The results were expressed as mg/100 g FW of pulp basis.

$$\text{Total carotenoids content (mg/100g)} = \frac{3.87 \text{ X O.D X Volume made}}{\text{Weight of sample X 1000}} \text{ X } 100$$

O.D = Optical density

3.3.1.3 Mineral content (Peel and pulp)

3.3.1.3.1 Preparation of the plant

The peels were washed and drained before being placed on foil paper. The peels were let to air dry for two weeks. Prior to examination, the dried materials were crushed using an electronic blending machine and stored in a plastic container.

3.3.1.3.2 Dry ashing

The samples were ashed in a muffle furnace/oven at 550^{o}C. The resulting white ash was then dissolved in 2ml of HCl 1:1 (v/v). The residue was dissolved in deionized water and adjusted the volume to 50ml for the determination of macro and micro elements.

3.3.1.3.3 Analysis of Mineral composition

3.3.1.3.3.1 Potassium

Total Potassium was estimated by flame photometry method of Jackson (1973). Potassium standards of 25 ppm, 50 ppm and 100 ppm were used.

3.3.1.3.3.2 Boron

Boron content was determined by Azomethine-H Method (Wolf, 1971; Gupta, 1979). Five ml of sample aliquot, 2 ml of ammonium acetate buffer (pH 5.5) and 2 ml of 0.02 M EDTA were added to a 20 ml free test tube and vortexed. After adding 1 ml of azomethine-H reagent (0.9% azomethineH + 2% ascorbic acid solution) the tube was again vortexed, allowed to stand for 1 h at ∼25 ◦C, and vortexed again, and the readings were taken at 420 nm using the spectrophotometer.

3.3.1.3.3.3 Iron

The iron content was determined based on the method described by Atomic Absorption Spectrophotometry (AOAC, 1990). The sample extract/solution was sprayed into an atomic absorption spectrophotometer to determine the concentration of iron. The iron standards used were 0 ppm, 1 ppm, 2 ppm, 3 ppm and 4 ppm.

3.3.1.3.3.4 Zinc

Zinc was determined after digestion of sample by Atomic Absorption Spectropho-tometer (AAS) (AOAC, 1990). Zinc level was then estimated from standard calibration curve (0.5 - 3.0 μg Zn/ml) prepared from ZnO.

3.3.1.3.3.5 Calcium

The calcium content was determined based on the method of Atomic Absorption Spectrophotometry (AOAC, 1990). The sample extract/solution was sprayed into atomic absorption spectrophotometer to determine the concentration of calcium. The calcium standards used were 0 ppm, 5 ppm, 10 ppm, 20 ppm and 30 ppm.

3.3.1.3.3.6 Magnesium

Magnesium was determined by Atomic Absorption Spectrophotometry (AOAC, 1990). To evaluate the magnesium concentration, the sample extract/solution was sprayed into an atomic absorption spectrophotometer. Magnesium standards of 0ppm, 0.5ppm, 1ppm, 1.5, and 2 ppm were used.

3.3.1.4 Sensory evaluation

The sensory evaluation was carried out using five level Hedonic Scale developed by Amerine *et al*., (1965). The level of appearance and taste were rated at five different levels as mentioned.

1. Bad
2. Satisfactory
3. Good
4. Very good
5. Excellent

3.4 Statistical analysis

Mean values of data obtained from various experiments was subjected to suitable statistical analysis after transformation (if necessary) to test the treatment effect of genotypes and interpretation of the results.

3.4.1 Analysis of variance (ANOVA)

The data obtained during the period of investigation was statistically analyzed. Mean, ranges of variation, standard error of mean and critical difference for each quantitative character were worked out by method of analysis of variance using Randomized Block Design (ANOVA by Panse and Sukhatme, 1967). Difference among the treatment means were tested by Duncan's Multiple Range Test (Duncan, 1955).

3.4.2 Estimation of coefficients of variation

The coefficient of variation for different characters will be estimated by formula as suggested by Burton (1952).

$$GCV\ (\%) = \frac{\sqrt{\sigma\ 2g}}{\overline{X}} X\ 100$$

$$PCV\ (\%) = \frac{\sqrt{\sigma\ 2p}}{\overline{X}}\ X\ 100$$

Where,

PCV = Phenotypic coefficient of variation

GCV = Genotypic coefficient of variation

$\overline{X}$ = Mean of character

$\sigma^2 g$ = Genotypic variance

$\sigma^2 p$ = Phenotypic variance

The estimates of genotypic and phenotypic coefficient of variance were classified as low (less than 10%), moderate (10 to 20%) and high (more than 20%).

3.4.3 Genetic advance

Improvement in the mean genotypic value of selected plants over the parental population is known as genetic advance. The expected advance was calculated by the formula given by Johnson *et al.* (1955) as described below.

$$GA = K.h^2.\sigma p$$

Where,

GA = Genetic advance

K = Constant (Standardized selection differential) having value of 2.06 at 5% level of selection intensity.

h^2 = Heritability of the character

σp = Phenotypic standard deviation

The genetic advance as percentage of mean was estimated as per the below formula

$$\text{Genetic advance as percent of mean} = \frac{\text{Genetic advance}}{\text{General mean}} \text{ X } 100$$

The magnitude of genetic advance as percent of mean was categorized as high (more than 20%), moderate (20-10%) and low (less than10%).

3.4.4 Estimation of heritability

Heritability in broad sense $h^2_{(bs)}$ defined as the proportion of the genotypic variance to the total variance (phenotypic) was calculated as per the formula suggested by Burton and De Vane (1953).

$$h^2_{(bs)} \% = \frac{\sigma^2_g}{\sigma^2_P} \text{ X } 100$$

Where,

$h^2_{(bs)}$ = Heritability in broad sense

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

The broad sense heritability estimates were classified as low (<50%), moderate (50-70%) and high (<70%).

3.4.5 Estimation of correlation coefficient

Correlation coefficient analysis measures the mutual relationship between various characters at genotypic (g), phenotypic (p) and environmental levels and was estimated with the help of formula suggested by Miller *et al.* (1958).

1. Genotypic correlation coefficient character x and y

   $$rxy\ (g) = Covxy(g) / \sqrt{varx(g) \times vary(g)}$$

2. Phenotypic correlation coefficient between character x and y

   $$rxy(p) = Covxy(p) / \sqrt{varx(p) \times vary(p)}$$

3. Environmental correlation coefficient between characters x and y

   $$rxy\ (e) = Covxy(e) / \sqrt{varx(e) \times vary(e)}$$

Where,

Covxy (p), covxy (g), covxy (e) = Phenotypic, genotypic & environmental co variances between character x and y, respectively.

Var x (p), var x (g), var x (e) = Phenotypic, genotypic & environmental covariance character x, respectively.

Vary(p), var y(g), var y(e) = Phenotypic, genotypic & environmental covariance character y, respectively.

The significance of correlation coefficient (r) was tested by comparing "t" value at (n-2) degree of freedom

$$t = \sqrt{r\ (n - 2\ /\ 1 - r2)}$$

If calculated "t" is greater than tabulated "t" at (n-2) degree of freedom at given probability level, the coefficient of correlation is taken as significant.

3.4.6 Path coefficient analysis

The genotypic correlation coefficients were further partitioned into direct and indirect effects with the help of path coefficient analysis as suggested by Wright (1921) and elaborated by Dewey and Lu (1959). Path co efficient analysis is simply a standardized partial regression coefficient which splits the correlation coefficient into the measures of direct and indirect effects.

Path coefficient was estimated using, simultaneous equations, the equations showed a basic relationship between correlation coefficient and path coefficient. These equations were solved by presenting them in matrix notations.

$$A = B.C$$

The solution for the vector "C" may be obtained by multiplying both sides by inverse of "B" matrix i.e. $B^{-1} A = C$

After calculation of values of path coefficient i.e. "C" vector, it is possible to obtain path values for residual (R). Residual effect was calculated using formula referred from Singh and Chaudhary (1985).

$$R = \sqrt{1 - d_i \times r_{ij}}$$

. Where,

Di = direct effect of i^{th} character

r_{ij} = correlation coefficient of i^{th} character with j^{th} character

A direct and indirect effect of different characters on bulb yield was calculated at genotypic level.

3.4.7 Genetic divergence analysis (D^2)

The Mahalanobis (1936) D^2 statistic is to be used to measure the genetic divergence between the populations. The D^2 value was estimated on the basis of "P" character by the formula:

Formula:

$$D^2 P = \sum p = \sum p = (\lambda_{ij})\ \lambda_i\ \lambda_j$$

$$i=1 \quad j=1$$

Where,

(ʎ,i,j) is the reciprocal or (ʎ,i,j), the pooled common dispersion matrix (i.e. error matrix)

i = the difference in the mean value for the i^{th} character

j = the difference in the mean value for the j^{th} character

For calculating the D^2 values, the variance and covariance was calculated. The genotypes were grouped into different clusters by Ward's method. The population was arranged in order of their relative distances from each other. For including a particular population in the clusters, a level of D^2 was fixed by taking the maximum D^2 values between any two populations in the first row of the table where D^2 values were arranged in increasing order of magnitude.

3.4.8 Principal component analysis

PCA analysis was carried out according to the procedure described by Banfield (1978) using SPSS version 16 software to clarify the relationship between two or more characters to divide the total variance of the original characters into limited number of uncorrelated new variables. PCA is method of data reduction and the main objectives of it are:

- To discover or reduce the dimensionality of the data set.
- To identify new meaningful under laying variables.

PCA can be performed on two types of data matrix viz. variance-covariance matrix and correlation matrix. With characters of different scale, a correlation matrix standardizing the original data set is preferred. If the characters of same scale a variance-covariance matrix can be used. In the present study PCA was performed on correlation matrix of data (traits), thereby removing the effect of scale (Jackson, 1991). The main reasons for the use of correlation matrix are:

- The presence of original variables in the different units.
- Existence of differences in the variances, in case of original variables having the same units.

The eigen values and eigen vectors were computed from the data matrix. Eigen values define the amount of total variation that is displayed on the principal components. The proportion of variation accounted for each principal component (PC) is expressed as the eigen value divided by the sum of eigen values.

$$\text{Percent variance explained for PC1} = \frac{\text{Eigen value (PC1)}}{\text{Sum of Eigen value}}$$

The eigen vector (loading) defines the correlation of each variable with the principal components.

The principal components were identified by the following procedure.

The j^{th} principal component (Y_j) of the observations X is the linear combination given as follows:

$Y_j = A_{1j}X_1 + \ldots\ldots\ldots\ldots + A_{pj}X_p$

Where, A_{1j} are found such that Y_j is uncorrelated Y_1, Y_2,……., Y_{j-1} the jth largest variance. The A_{1j} are the elements of the normalized eigen vector associated with largest j^{th} eigen value. The variance of the j^{th} principal component of the λ_j and the total system variance trace (S) = $\lambda_1 + \lambda_2 + \ldots\ldots..+ \lambda_P$. The importance of the jth principal component is given by λ_j, trace (S).

This is informative about the proportion of total variation that can be accounted for the jth principal component. The correlation between the i^{th} original variable X_1 and the jth principal component Y_j is given by

$\rho\ (X_i, Y_j) = A\delta\ \sqrt{\lambda}j\ /\ \sqrt{S}i$

Where S_i is the standard deviation of X_i

Thus, a principal component is a linear function of the test variables as described below.

Principal component = ax1 + ax2 + …….+ $h_{x\delta}$

Where, a, b,…… are coefficient and x1, x2,……etc., are the variables in such a way that the principal component has a unit variance. PCA scores for each genotype under concerned principal components (PCs) were computed and utilized to derive a 3D (dimensional) scatter plot of individuals.

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The present study entitled "Diversity mapping and database development of banana (*Musa* spp.) germplasm in Nagaland" was carried out by conducting survey work on five districts of Nagaland covering fifteen villages. The morphological characterization was conducted according to the Descriptors for Banana by IPGRI (International Bureau of Plant Genetic Resources Institute). The detailed data collected during the study and the results have been presented in this chapter supported by respective tables and figures.

4.1 Experiment – 1

The present study was conducted to identify the divergent clone of *Musa* germplasm in the states of Nagaland. An extensive survey was conducted in five districts of Nagaland and the germplasm collected were conserved *ex-situ* in the Horticultural Research Farm, NU; SASRD. The morphological and taxonomical characters of the *Musa* germplasm were characterized based on IPGRI Descriptors for Banana (1996). The genetic variability, correlation coefficient, path analysis, genetic divergence and principal component analysis were estimated to study the genetic diversity of the *Musa* germplasm.

4.1.1 Survey schedule

The findings of collected data through survey schedule have been depicted in table 4.1. Nagaland is a state inhabited by many tribes and every tribe has different dialect. Banana is known by different names based on the tribes and their dialects in different location such as awucho among Sema tribe, youthi in Lotha, mangu in Ao, thaye in Angami and ngou in Phom. In a similar way, different banana genotypes are also known in different names. Many exploratory and survey work has been carried out in different parts of northeast

region for characterization of genetic resources and documentation. In the states of Arunachal Pradesh, a survey work was carried out by Gurumayum *et al*. (2018) and altogether 20 genotypes were collected from five districts representing Western, Central and Eastern areas. In Manipur, Wahengbam *et al.* (2014) and Atom *et al.* (2015) collected 16 and 27 banana cultivars respectively from different districts and has been classified based on morphological characters. Lalrinfela and Thangjam (2012) also collected 14 varieties from different regions of Mizoram and were characterized based on morphological characters.

The whole banana plant was utilized in many ways as revealed during the course of the study. Most of the fruits were used for dessert purpose and only selected few were used for cooking and chips making. The pseudostem and male bud were used for culinary purposes and also as a feed for livestocks. Young shoots that emerged from cut pseudostem of the wild and seeded banana genotypes were considered as one of the best part for culinary purpose. The leaf of banana was widely used as organic plate in community feast and as a wrapping material for vegetables in roadside market, axone (fermented soyabean), moti (cooked meat), etc. Different uses of whole banana plant and fruit have also been reported by Nelson *et al*. (2006) and Nyoman *et al*. (2018).

Table 4.1: Survey schedule of the different banana genotypes collected from Nagaland

Collection no.	Location	District	Elevation (m)	Collecting source	Type of sample	Common/local name	No. of sample	Uses of fruits	Uses of other parts	Types of soil	Soil pH
G – 1	Sirhi Angami	Kohima	465	Garden	Sucker	Bhootmanohar	3	Dessert	Pseudostem and male bud	Sandy clay	4.91
G – 2	Medziphema	Dimapur	360	Garden	Sucker	Chini Champa	3	Dessert	Pseudostem and male bud	Sandy clay	4.75
G – 3	Medziphema	Dimapur	360	Garden	Sucker	Jahaji	3	Dessert	Pseudostem and male bud	Sandy clay	5.01
G – 4	Piphema	Dimapur	156	Garden	Sucker	Kanthali	3	Dessert	Pseudostem and male bud	Sandy clay loam	5.56
G – 5	Bade	Dimapur	145	Farm	Sucker	Lumungashe	3	Dessert	Pseudostem and male bud	Sandy clay loam	5.23
G – 6	Punglwa	Peren	428	Garden	Sucker	Bharatmani	3	Dessert	Pseudostem and male bud	Sandy clay loam	5.2
G – 7	Rai Basti	Dimapur	400	Garden	Sucker	Nendran	3	Cooking	Pseudostem and male bud	Sandy clay	4.84
G – 8	Medziphema	Dimapur	360	Garden	Sucker	Grand Naine	3	Dessert	Pseudostem and male bud	Sandy clay	5.12
G – 9	Punglwa	Peren	428	Garden	Sucker	Kwetho	3	Dessert	Pseudostem and male bud	Sandy clay	4.68
G – 10	Molvom	Dimapur	360	Garden	Sucker	Meitei Hei	3	Dessert	Pseudostem and male bud	Sandy clay loam	5.56
G – 11	Peace Camp	Dimapur	158	Garden	Sucker	Lumumgto	3	Dessert	Pseudostem and male bud	Sandy clay loam	5.18
G – 12	Tsuuma	Dimapur	156	Garden	Sucker	Subjikol	3	Cooking	Pseudostem and male bud	Sandy clay	4.98
G – 13	Gaili	Peren	156	Garden	Sucker	Kwegha	3	Dessert	Pseudostem and male bud	Sandy clay loam	5.27
G – 14	Gaili	Peren	158	Garden	Sucker	Gumsang	3	Dessert	Pseudostem and male bud	Sandy clay loam	5.3
G – 15	Jalukie	Peren	400	Garden	Sucker	Luipet	3	-	Pseudostem, male bud	Sandy clay loam	5.24
G – 16	Chuchuyimlan	Mokokchung	1054	Forest	Sucker	Rakannak	3	-	Pseudostem, male bud	Sandy clay loam	5.06
G – 17	Sirhi Angami	Kohima	465	Garden	Sucker	Phfeprei	3	-	Leaf, pseudostem, male bud	Sandy clay	4.74
G – 18	Longsachung	Wokha	1313	Garden	Sucker	Yhuro	3	-	Leaf, pseudostem, male bud	Sandy clay loam	5.29
G – 19	Niroyo	Wokha	1313	Garden	Sucker	*M. velutina*	3	-	Ornamental	Sandy clay	5.22
G – 20	Heningkungwa	Peren	358	Garden	Sucker	Red banana	3	Dessert	Pseudostem and male bud	Sandy clay	4.99

Plate 1. Exploration of banana biodiversity in different places of Nagaland

G-1
Bhootmanohar

G-2
Chinichampa

G-3
Jahaji

G-4
Kanthali

Plate 2: Banana genotypes (1 – 4)

G-5
Lumungashe

G-6
Bharatmani

G-7
Nendran

G-8
Grand Naine

Plate 3: Banana genotypes (5 – 8)

G-9
Kwetho

G-10
Meiteihei

G-11
Lumungto

G-12
Subjikol

Plate 4: Banana genotypes (9 – 12)

G-13
Kwegha

G-14
Gumsang

G-15
Luipet

G-16
Rakannak

Plate 5: Banana genotypes (13 – 16)

G-17
Pfheprei

G-18
Yhuro

G-19
Musa velutina

G-20
Red Banana

Plate 6: Banana genotypes (17 – 20)

4.1.2 Genome groupings

The genome grouping of twenty banana genotypes collected from different location of Nagaland has been presented in table 4.2. Important plant parts of banana like female flower, male flowers, bracts etc. are collected and examined systematically. Fifteen important characters of banana plants were used for genome classification of banana as given by Simmond and Shepherd (1955). Some researchers have used modified genome score card (Singh and Uma, 1996; Silayoi and Chomchalow, 1987).

Most of the edible banana have triploid genome and are seedless cultivars while some are tetraploid and diploid. Diploid types are very rare and mostly the fruits are seeded. Among the twenty genotypes under study, genotypes Bhootmanohar, Kanthali, Lumungashe, Meiteihei, Lumungto, Subjikol and Kwegha was grouped under ABB genome group. The genotypes under AAB groups were Chinichampa, Bharatmani, Nendran, Kwetho and Gumsang. Three genotypes including Jahaji, Grand Naine and Red Banana were placed under AAA genome while Luipet, Rakannak and Yhuro were grouped as AB and they were found to have a seeded fruit. The only genotype under BB/BBB groups was Phfeprei and the fruits were found to be heavily seeded. *Musa velutina* was not considered for genome scoring as they are under section Rhodochlamys. The genome score of Luipet, Rakannak and Yhuro were 48, 48 and 47 respectively but there was no specific genome type under Simmond and Shepherd (1955) scoring system. Therefore, based on Singh and Uma (1996) modified score card, the three genotypes were placed under the genome group AB. The present study revealed many overlapping scores between the genome types and was found to be of same genome types but with different scores. Therefore, these need to be further characterized by using molecular markers.

Table 4.2 Genome scores of the twenty banana genotypes in Nagaland during survey

Collection no.	Genotypes	Scores	Species/hybrid	Genome types
G-1	Bhootmanohar	59	*Musa* spp.	ABB
G-2	Chinichampa	37	*Musa* spp.	AAB
G-3	Jahaji	23	*Musa acuminata*	AAA
G-4	Kanthali	63	*Musa* spp.	ABB
G-5	Lumungashe	59	*Musa* spp.	ABB
G-6	Bharatmani	27	*Musa* spp.	AAB
G-7	Nendran	43	*Musa* spp.	AAB
G-8	Grand Naine	23	*Musa acuminata*	AAA
G-9	Kwetho	45	*Musa* spp.	AAB
G-10	Meitei Hei	61	*Musa* spp.	ABB
G-11	Lumungto	60	*Musa* spp.	ABB
G-12	Subjikol	63	*Musa* spp.	ABB
G-13	Kwegha	59	*Musa* spp	ABB
G-14	Gumsang	44	*Musa* spp.	AAB
G-15	Luipet	48	*Musa* spp.	AB
G-16	Rakannak	48	*Musa* spp.	AB
G-17	Phfeprei	73	*Musa balbisiana*	BB/BBB
G-18	Yhuro	47	*Musa* spp.	AB
G-19	*Musa velutina*	-	-	-
G-20	Red Banana	22	*Musa acuminata*	AAA

4.1.3 Plant general appearance

The observations recorded on plant general appearance of different banana genotypes has been presented in table 4.3 and table 4.4.

4.1.3.1 Leaf habit

The data observed with respect to leaf habit of different genotypes have been presented in table 4.3.

Leaf habit of twenty banana genotypes were visually recorded in their natural habitat. The genotypes were differentiated from their leaf habits either in the form of erect, intermediate and drooping. Most of the genotypes exhibit drooping and intermediate leaf habit except for Luipet, Rakannak and Yhuro which was found to have erect leaf habit. Among the twenty genotypes, eight genotypes show drooping leaf habit, nine intermediate habits and three erect. It was observed that triploid genotypes with more B genome have more tendencies for drooping leaf habit. Out of the twenty genotypes eight have drooping leaf habits and were made up of ABB genome except for Chinichampa and Gumsang which has AAB. Similarly, a genotype with more A genome have an inclination to show intermediate leaf habit. All the genotypes that exhibit intermediate leaf habit were either AAA or AAB genome except for Subjikol which was ABB. In the present study, a genotype with diploid genome show erect leaf habit. The difference in nature of leaf habit might have been influenced by a variation in ploidy status of the genotypes. A finding by Uthaiah *et al.,* (1992) and Ram *et al.,* (1994) revealed that difference in genomic makeup can affect the morphological traits of the genotypes.

4.1.3.2 Leaf blade length and width (cm)

The data pertaining to leaf blade length and width has been specified in table 4.4 and graphically in figure 4.3. The length and width of the leaf was

recorded from leaf III which is the third leaf counted from the last leaf produce before bunch emergence.

As evident from the data, wide variation was observed with respect to leaf blade length and width among all the genotypes. Leaf blade length was observed in the range of 71.00 cm to 309.00 cm. The maximum length was observed in Phfeprei (309.00 cm) tailed by Bhootmanohar (270.00 cm) which was statistically similar to Kwetho (269.00 cm). Genotypes such as Jahaji (221.00 cm), Nendran (224.00 cm), Grand Naine (221.00 cm) and Yhuro (226.00 cm) were all statistically at par. However, minimum leaf blade length was observed in Meitei Hei (71.00 cm). In case of width, maximum value was recorded in Red Banana (91.00 cm) followed by Yhuro (84.00 cm) and Kwetho (82.00 cm). Some genotypes were statistically similar such as Jahaji (63.33 cm), Kanthali (62.67 cm) and Grand Naine (62.00 cm). The least leaf width was recorded in Gumsang (49.00 cm) which was statistically at par with *Musa velutina* (50.33 cm). Significant variation in the leaf length and width among different genotypes of banana was observed by Smith *et al*. (2014) as well as Rajamanickam and Rajmohan (2010). Varietal variation in banana with respect to leaf length, width and area has also been reported by Ahmed *et al.* (1974), Shaikh (1985) and Medhi (1994).

4.1.3.3 Colour of leaf upper surface

The colour of leaf upper surface was recorded as shown in table 4.3. Most of the genotypes were found to have green and dark green colour. The genotypes Bhootmanohar, Chinichampa, Kanthali, Lumungashe, Bharatmani, Kwetho, Lumungto, Kwegha, Gumsang, Luipet and Red Banana were found to have green colour. On the other hand, Jahaji, Nendran, Grand Naine, Meiteihei, Rakannak, Phfeprei, Yhuro and *M. velutina* were recorded dark green colour. The genotype Subjikol was the only genotypes that exhibit green-yellow colour.

Table 4.3 Plant general appearance of various characters of banana genotypes

Genotypes	Leaf habit	Colour of leaf upper surface	Dwarfism	Pseudostem colour	Position of suckers	Leaf base shape	Petiole canal leaf III
Bhootmanohar	Drooping	Green	Normal	Medium green	Close-vertical	Both sides rounded	Margin curved inward
Chinichampa	Drooping	Green	Normal	Green -yellow	Close-vertical	Both sides rounded	Wide with erect margin
Jahaji	Intermediate	Dark green	Dwarf	Green-yellow	Close-vertical	One side rounded, one pointed	Open with margin spreading
Kanthali	Drooping	Green	Normal	Green red	Close- vertical	Both sides rounded	Open with margin spreading
Lumungashe	Drooping	Green	Normal	Green-yellow	Close-vertical	Both sides rounded	Margin curved inward
Bharatmani	Intermediate	Green	Normal	Green-red	Close-vertical	One side rounded, one pointed	Open with margin spreading
Nendran	Intermediate	Dark green	Normal	Green-red	Close-vertical	Both side rounded	Margin curved inward
Grand Naine	Intermediate	Dark green	Normal	Green-yellow	Close-vertical	One side rounded, one pointed	Open with margin spreading
Kwetho	Intermediate	Green	Normal	Green	Close-vertical	Both sides rounded	Straight with erect margin
Meitei Hei	Drooping	Dark green	Normal	Green-yellow	Close-vertical	Both sides rounded	Margins overlapping
Lumungto	Drooping	Green	Normal	Green-yellow	Close-vertical	Both sides rounded	Wide with erect margin
Subjikol	Intermediate	Green-yellow	Normal	Green yellow	Close-vertical	Both sides rounded	Margin curved inward
Kwegha	Drooping	Green	Normal	Green-yellow	Close-vertical	Both sides rounded	Straight with erect margin
Gumsang	Drooping	Green	Normal	Green-red	Close-vertical	One side rounded, one pointed	Margins curved inward
Luipet	Erect	Green	Normal	Green-red	Close-vertical	Both side rounded	Wide with erect margin
Rakannak	Erect	Dark green	Normal	Green-yellow	Close-vertical	One side rounded, one pointed	Wide with erect margin
Phfeprei	Intermediate	Dark green	Normal	Green yellow	Close-vertical	Both sides rounded	Straight with erect margin
Yhuro	Erect	Dark green	Normal	Medium green	Close-vertical	Both sides rounded	Straight with erect margin
Musa velutina	Intermediate	Dark green	Dwarf	Green red	Close-vertical	Both sides rounded	Straight with erect margin
Red Banana	Intermediate	Green	Normal	Red	Close-vertical	Both sides rounded	Wide with erect margin

4.1.3.4 Dwarfism

The data recorded on dwarfism has presented in table 4.3. Dwarfism of the banana plant was recorded based on measurement of the leaf ratio of the third leaf, counting from the last one that emerged. It was differentiated either normal or dwarf type. Almost all the genotypes exhibit normal dwarfism except the genotypes Jahaji and *M. velutina* which possessed dwarf type.

4.1.3.5 Pseudostem height (m)

The data observed with respect to pseudostem height of different genotypes have been presented in table 4.4 and displayed graphically in figure 4.2.

The data clearly revealed a significant variation for pseudostem height among the genotypes. The pseudostem height was observed in the range of 2.03 m to 8.07 m. The maximum pseudostem height was recorded in Kwetho (8.07 m) which was statistically at par with Bhootnanohar (8.03 m) whereas minimum pseudostem height was recorded in *M. velutina* (2.03 m). The variation in pseudostem height might have been contributed by the difference in ploidy status. It was noticed that the triploid genotype containing only A genome was shorter as compared to the genotype containing B genome also. This result was in agreement with the findings of Uthaiah *et al.* (1992) and Ram *et al.* (1994) where they observed more height in AAB and ABB genome cultivars than cultivars having AAA genome. It was also reported that some genotypes when grown in different locations showed less variation in their height while other showed much variation (Smith *et al.*, 2014). Variation in pseudostem height among the genotypes were also reported by Nair and Nair (1969), George *et al.* (1991), Rajamanickam (2003), Mattos *et al.* (2010a) in their study.

4.1.3.6 Girth size (cm)

The data related to girth size of different banana genotypes have been presented in table 4.4 and illustrated graphically in figure 4.1.

A critical examination of the data distinctly shows a wide variation in girth size of the pseudostem. It was recorded in the range of 24.27 cm to100.17 cm. The maximum girth size was recorded in Kwetho (100.17cm) followed by Kwegha (85.80 cm) which was statistically similar to Lumungashe (84.20 cm). However, minimum girth size was observed in *M. velutina* (24.27 cm). Differences in girth size among the genotypes were also reported by Balakrishnan (1980), George *et al.* (1991), Uthaiah *et al.* (1992) and Ascenao and Dubery (2002) in their study. Rajeevan (1985) observed that girth size showed significant variation during the later stages of growth. Therefore, the variation in girth size in the present study may also be due to the difference in maturity stage of the pseudostem as the growth stage at the time of investigation was not ascertained. Ram *et al*. (1994) reported that a triploid genotype containing only A genome has thinner girth size than genotype containing B genome. Such type of variation may be attributed to varietal characters and environmental effect.

4.1.3.7 Pseudostem colour

The data pertaining to pseudostem colour of banana genotypes has been presented in table 4.3. Colour of the pseudostem was recorded without removing the external sheaths and without taking into account the colour of the old dried leaf sheaths. The result revealed that the most prominent pseudostem colours among the genotypes were green-yellow. The genotypes that possessed green-yellow pseudostem colour were Chinichampa, Jahaji, Lumungashe, Grand Naine, Meiteihei, Lumungto, Subjikol, Kwegha, Rakannak and Phfeprei. Similarly, the genotypes that exhibits green-red pseudostem colour were Kanthali, Bharatmani, Nendran, Kwetho, Gumsang, Luipet and *M. velutina.*

Out of the remaining genotypes, Bhootmanohar and Yhuro exhibits medium green pseudostem colour while Kwetho and Red Banana were green and red in colour respectively.

4.1.3.8 Number of suckers

The data taken for number of suckers has been given in table 4.4. Number of suckers emerging from the mother plant were counted and recorded. As evident from table 4.4, the numbers of suckers emerging from the mother plant was more or less similar with little variation. The maximum numbers of suckers were recorded in *M. velutina* (4.67) followed by Jahaji (4.33) and Grand Naine (4.00). Minimum sucker productions were found in Kanthali, Kwetho, Meiteihei, Red Banana and Phfeprei where all the genotypes produced 2.33 suckers in an average.

4.1.3.9 Position of suckers

The observations related to position of suckers has been presented in table 4.3. The result revealed that all the suckers of the genotypes emerged very close to the parent plant. And at the same time all the suckers exhibit a vertical growth with respect to the parent plant.

4.1.3.10 Leaf blade base shape

The data obtained by visual observation of leaf blade base shape was recorded and presented in table 4.3. In the study Bhootmanohar, Chinichampa, Kanthali, Lumungashe, Nendran, Kwetho, Meiteihei, Lumungto, Subjikol, Kwegha, Luipet, Phfeprei, Yhuro, *M. velutina* and Red banana were found to have both sides rounded leaf blade base shape. While the remaining genotypes were found to exhibits one side rounded and one side pointed leaf blade base shape.

4.1.3.11 Petiole canal leaf III

Leaf III is the third leaf counted from the last leaf (leaf I) produced before bunch emergence. The petiole was cut half way between the pseudostem and the leaf blade and examines the cross section. The observation related to petiole canal leaf III have been presented in table 4.3. Among the genotypes, Bhootmanohar, Lumungashe, Nendran, Subjikol and Gumsang showed margin curved inward and genotypes Kwetho, Kwegha, Phfeprei, Yhuro and *M. velutina* exhibit straight with erect margin. Similarly, the genotypes Chinichampa, Lumungto, Luipet, Rakannak and Red Banana demonstrated wide with erect margin and the genotypes Jahaji, Kanthali, Bharatmani and Grand Naine displayed open with erect margin. Of all the genotypes only Meiteihei showed overlapping margin.

4.1.3.12 Petiole Length (cm)

The data with respect to petiole length has been presented in table 4.4 and illustrated graphically in figure 4.4. It was observed that there was significant difference on petiole length among the twenty genotypes. It was evident from the data (table 4.4) that petiole length ranged from 24.33 cm to 84.67 cm. The maximum mean petiole length was observed in Rakannak (84.67 cm) followed by Luipet (78.33 cm), Phfeprei (76.67 cm) and Lumungashe (75.67 cm) and were statistically at par. Minimum petiole length was recorded in Bharatmani (24.33 cm). A study by Ara *et al.* (2011) concluded that the differences in length and width of leaf and petiole length were due to the diversity of prevailing climate, season and varieties. This finding was in accordance with the present findings.

Table 4.4 Growth performance of twenty banana genotypes

Genotypes	No. of suckers	Girth size (cm)	Pseudostem height (m)	Leaf blade length (cm)	Leaf blade width (cm)	Petiole length (cm)
Bhootmanohar	2.67^{de}	81.10^{c}	8.03^{a}	270^{b}	76.00^{d}	65.33^{c}
Chinichampa	3.33^{bcde}	56.83^{h}	5.10^{fg}	205^{efg}	75.00^{de}	61.00^{d}
Jahaji	4.33^{ab}	71.97^{e}	4.27^{h}	221^{def}	63.33^{g}	29.67^{i}
Kanthali	2.33^{e}	54.50^{h}	5.27^{fg}	210^{ef}	62.67^{g}	65.00^{c}
Lumungashe	2.67^{de}	84.20^{b}	6.73^{bc}	250^{bcd}	70.33^{f}	75.67^{b}
Bharatmani	3.33^{bcde}	61.00^{g}	5.10^{fg}	210^{ef}	61.00^{gh}	24.33^{j}
Nendran	3.00^{cde}	60.90^{g}	5.20^{fg}	224^{def}	67.67^{f}	57.67^{def}
Grand Naine	4.00^{abc}	77.63^{d}	4.83^{gh}	221^{def}	62.00^{g}	35.00^{h}
Kwetho	2.33^{e}	100.17^{a}	8.07^{a}	269^{b}	82.00^{bc}	60.33^{d}
Meitei Hei	2.33^{e}	44.47^{i}	5.03^{g}	71^{i}	56.67^{hi}	58.33^{de}
Lumungto	3.00^{cde}	79.57^{cd}	6.37^{cd}	201^{fg}	78.33^{cd}	54.00^{f}
Subjikol	3.33^{bcde}	64.77^{f}	5.77^{def}	176^{g}	57.33^{hi}	49.67^{g}
Kwegha	3.33^{bcde}	85.80^{b}	7.07^{b}	261^{bc}	71.00^{ef}	55.67^{ef}
Gumsang	3.33^{bcde}	67.10^{f}	7.03^{b}	201^{fg}	49.00^{k}	55.00^{ef}
Luipet	3.67^{abcd}	36.37^{j}	5.07^{g}	207^{efg}	54.33^{ij}	78.33^{b}
Rakannak	3.00^{cde}	46.17^{i}	5.50^{efg}	237^{cde}	60.67^{gh}	84.67^{a}
Phfeprei	2.33^{e}	56.43^{h}	6.10^{cde}	309^{a}	61.00^{gh}	76.67^{b}
Yhuro	3.67^{abcd}	67.43^{f}	6.07^{de}	226^{def}	84.00^{b}	54.333^{f}
Musa velutina	4.67^{a}	24.27^{k}	2.03^{i}	126^{h}	50.33^{k}	65.67^{c}
Red Banana	2.33^{e}	61.33^{g}	4.90^{gh}	252^{bcd}	91.00^{a}	59.67^{d}
CD (0.05)	1.02	2.56	0.61	4.62	4.22	3.50
SE(m)±	0.36	0.89	0.21	1.61	1.47	1.22
Range	2.33-4.67	24.27-100.17	2.03-8.07	71.00-309.00	49.00-91.00	24.33-84.67

*Means with different superscript letters within column are significantly different from each other by Duncan Multiple Range Test (p = 0.05)

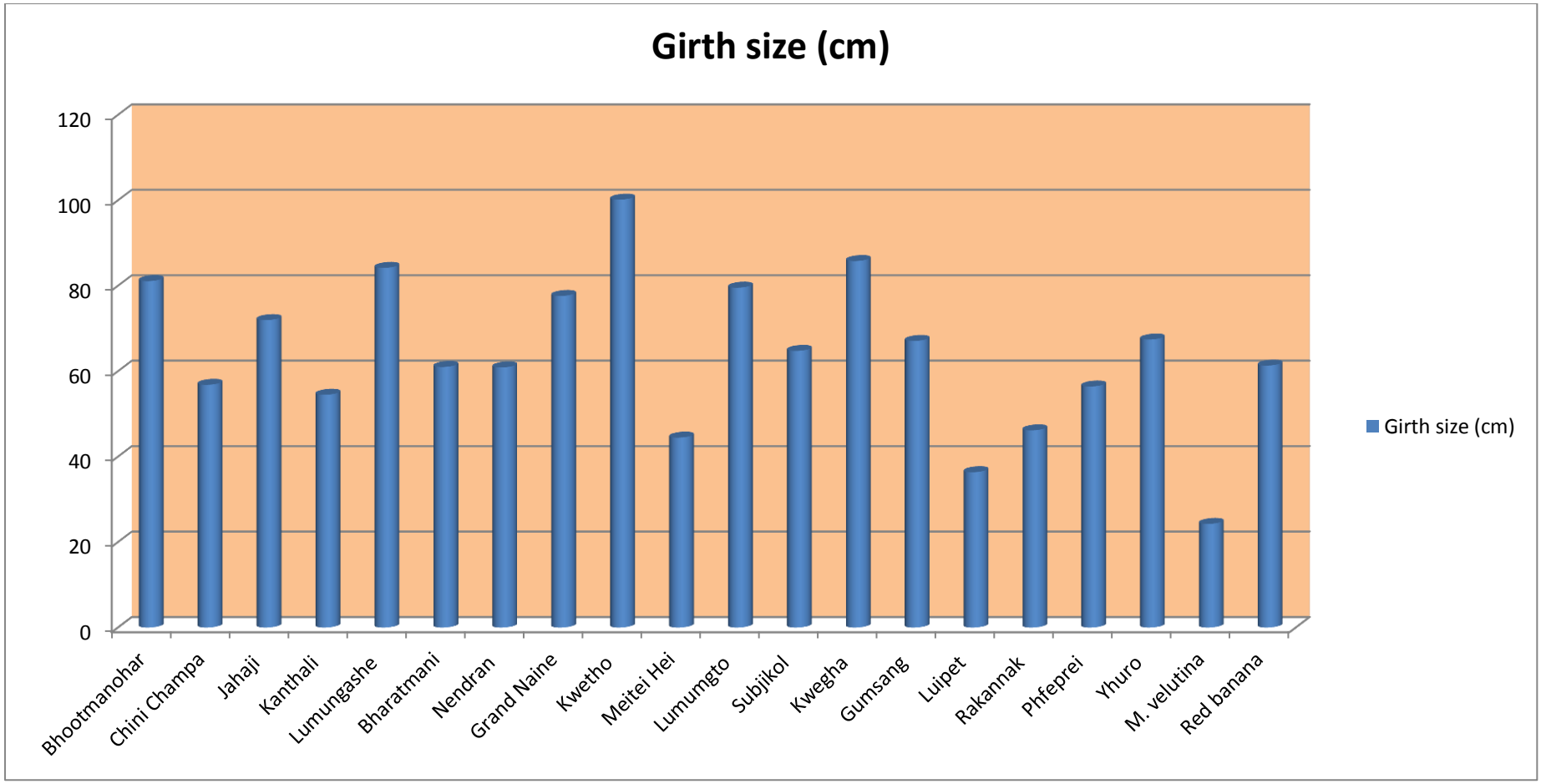


Figure 4.1 Bar diagram depicting girth size of the twenty banana genotypes

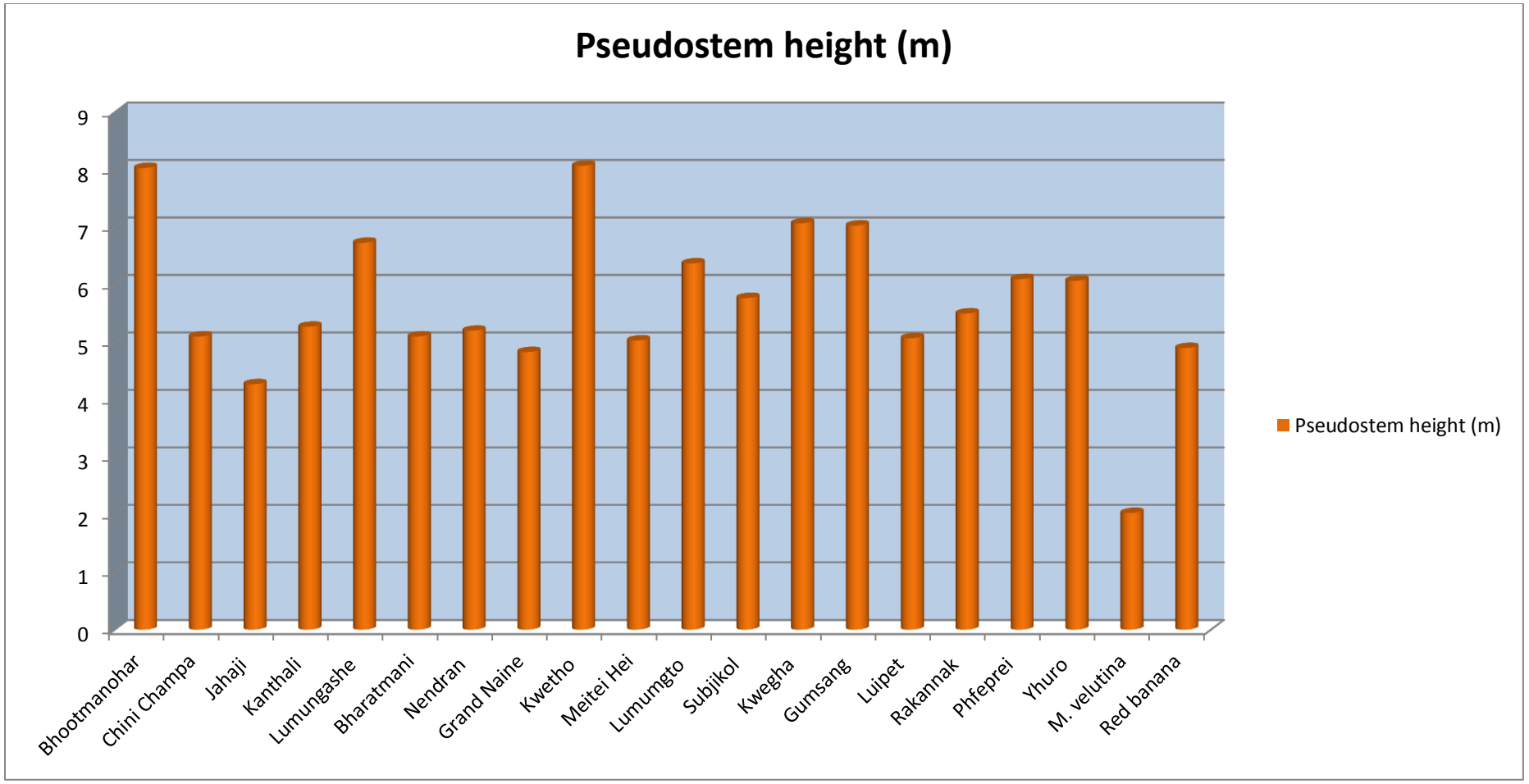


Figure 4.2 Bar diagram depicting pseudostem height of the twenty banana genotypes

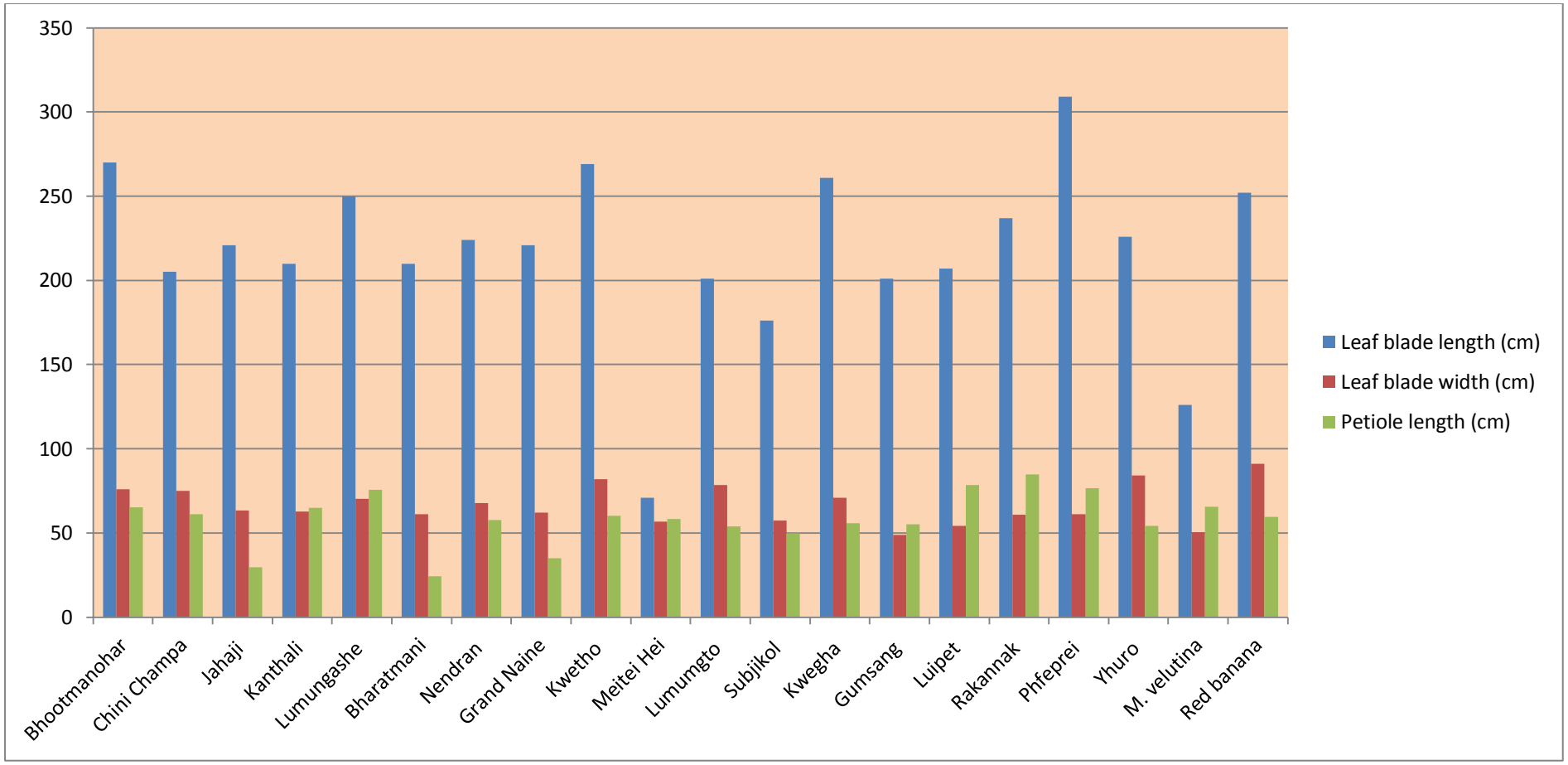


Figure 4.3 Bar diagram depicting leaf blade length, leaf blade width and petiole length of the twenty banana genotypes

4.1.4 Flower characters

The observations recorded on flower characters of different banana genotypes have been presented in table 4.5.

4.1.4.1 Flowering time

Flowering time was recorded through the information obtained from the farmers. Probable months and time for flower initiation of the genotype was recorded. As given in table 4.5, flowering starts from the month of April and continued till the month of August. Mentioned may be made that most of the genotypes initiate flowering during the month of May-June. Unlike many temperate crops, bananas exhibit flowering and fruiting stages that seem to be independent of temperature and light (Robinson and Human, 1988). In the tropics, Vargas *et al.* (2009) reported that flowering occurred after a cumulative leaf number (CLN) of 37 to 46 has been reached.

4.1.4.2 Male bud shape

The general shape of the male bud was recorded during the harvest. As presented in table 4.5 majority of the banana genotypes exhibit top like male bud shape. Ovoid male bud shape was observed in five genotypes and intermediate male bud shape in four genotypes. Only two genotypes were found to have lanceolate shape.

4.1.4.3 Bract apex shape

The observation related to bract apex shape of banana genotypes have been presented in table 4.5. The banana genotypes recorded five types of bract apex shape namely intermediate, obtuse and split, slightly pointed, obtuse and pointed. Nine genotypes Bhootmanohar, Chinichampa, Jahaji, Kanthali, Grand Naine, Lumungto, Subjikol, Luipet and Red Banana were found to have intermediate bract apex shape, four genotypes Kwetho, Meiteihei, Kwegha and

Gumsang were found to have obtuse bract apex shape and three genotype each has obtuse and split and slightly pointed bract apex shape respectively. Only genotype *M. velutina* has pointed bract apex.

4.1.4.4 Bract base shape

The data recorded on bract base shape has been presented in table 4.5. Among the genotypes, Bhootmanohar, Chinichampa, Kwetho, Meiteihei, Luipet and Phfeprei showed small shoulder. Genotypes Kanthali, Lumungashe and Red Banana were recorded as medium and the rest of the genotypes were found to have large shoulder.

4.1.4.5 Colour of bracts (external)

The data on external colour of bracts were recorded and given in table 4.5. Red purple colour was observed in genotypes Kanthali, Kwetho, Lumumgto and Phfeprei while pink purple colour in Rakannak and *M. velutina*. Genotypes Luipet and Red Banana showed red external bract colour and Bhootmanohar and Chinichampa was recorded as orange red and purple respectively. The remaining genotypes were dominated by purple brown colour.

4.1.4.6 Colour of bracts (internal)

The result obtained on internal colour of bract has been presented in table 4.5. It was observed that genotypes Bhootmanohar, Chinichampa, Kanthali, Kwetho, Meiteihei, Gumsang and *M. velutina* showed red internal colour of bract. Orange red colour was visible in genotypes Jahaji, Grand Naine, Rakannak and Yhuro. Similarly, Purple brown colour was visible in genotypes Lumungashe, Lumumgto, Kwegha and Phfeprei. The remaining genotypes Nendran, Red Banana and Subjikol were found to have crimson, purple and red purple respectively.

4.1.4.7 Free tepal shape

The free tepal shape was observed after separating the free tepal from the male flower. The data recorded through visual observation has been presented in table 4.5. The data revealed no significant variation in free tepal shape among the twenty banana genotypes. Out of the twenty genotypes, Nendran and *M. velutina* were found to have fan shaped free tepal while it was oval for the remaining genotypes.

4.1.4.8 Free tepal colour

The data on free tepal colour was recorded as shown in table 4.5. It was observed that genotypes Bhootmanohar, Chinichampa, Jahaji, Kanthali, Lumungashe, Bharatmani, Nendran, Grand Naine, Lumumgto, Gumsang, Luipet, Phfeprei and *M. velutina* were found to have translucent white free tepal colour. Likewise, genotypes Kwetho, Subjikol, Kwegha and Red Banana have free tepal colour tinted with pink while Meiteihei, Rakannak and Yhuro were found to have free tepal colour tinted with yellow.

4.1.4.9 Compound tepal colour

The result obtained for compound tepal colour by visual observation has been presented in table 4.5. It was recorded that genotypes Bhootmanohar, Chinichampa, Kanthali, Lumungashe, Kwetho, Meiteihei, Subjikol, Kwegha, Phfeprei and Red Banana showed pink purple compound tepal colour. Genotypes such as Nendran, Rakannak, *M. velutina* and Grand Naine were found to have orange red colour on the compound tepal. Meanwhile white colour was the dominant colour of compound tepal for genotypes Jahaji, Bharatmani and Gumsang and cream colour for genotypes Luipet and Yhuro. Only genotypes Lumumgto was found to have pink colour compound tepal.

4.1.4.10 Ovary shape

The data related to ovary shape has been presented in table 4.5. After critical visualization of the ovary it was recorded that most of the genotypes has arched ovary shape except for genotype Jahaji, Grand Naine, Meiteihei and Kwegha which was found to have straight ovary shape.

4.1.4.11 Stigma colour

The observation related to stigma colour has been presented in table 4.5. The banana genotypes recorded four types of stigma colour namely yellow, cream, bright yellow and orange. Most of the genotypes expressed cream colour that includes Chinichampa, Kanthali, Lumungashe, Nendran, Kwetho, Lumumgto, Subjikol, Kwegha, Gumsang, Rakannak, Phfeprei and Red Banana. Yellow colour of stigma was observed in genotypes Bhootmanohar, Jahaji, Grand Naine, Meiteihei, Yhuro and *M. velutina*. The genotypes Bharatmani and Luipet recorded bright yellow and orange respectively.

Table 4.5 (a) Flower characters of twenty banana genotypes

Collection no.	Genotypes	Flowering time	Male bud shape	Bract apex shape
G – 1	Bhootmanohar	May - June	Intermediate	Intermediate
G – 2	Chini Champa	May - June	Like a top	Intermediate
G – 3	Jahaji	May - June	Ovoid	Intermediate
G – 4	Kanthali	May - June	Intermediate	Intermediate
G – 5	Lumungashe	June - July	Intermediate	Obtuse and split
G – 6	Bharatmani	May - June	Like a top	Slightly pointed
G – 7	Nendran	May - June	Intermediate	Obtuse and split
G – 8	Grand Naine	April - May	Ovoid	Intermediate
G – 9	Kwetho	April - May	Ovoid	Obtuse
G – 10	Meitei Hei	June - July	Ovoid	Obtuse
G – 11	Lumumgto	June - July	Like a top	Intermediate
G – 12	Subjikol	May - June	Like top	Intermediate
G – 13	Kwegha	April - May	Like top	Obtuse
G – 14	Gumsang	June - July	Like top	Obtuse
G – 15	Luipet	April - May	Lanceolate	Intermediate
G – 16	Rakannak	May - June	Like top	Slightly pointed
G – 17	Phfeprei	May - June	Ovoid	Obtuse and split
G – 18	Yhuro	July - August	Lanceolate	Slightly pointed
G – 19	*M. velutina*	May - June	Like top	Pointed
G – 20	Red Banana	September - October	Like top	Intermediate

Table 4.5 (b) Flower characters of twenty banana genotypes

Collection no.	Genotypes	Bract base shape	Colour of bracts (external)	Colour of bract (internal)	Free tepal shape
G – 1	Bhootmanohar	Small	Orange red	Red	Oval
G – 2	Chini Champa	Small	Purple	Red	Oval
G – 3	Jahaji	Large shoulder	Purple brown	Orange red	Oval
G – 4	Kanthali	Medium	Red purple	Red	Oval
G – 5	Lumungashe	Medium	Purple brown	Purple brown	Oval
G – 6	Bharatmani	Large shoulder	Purple brown	Whitish	Oval
G – 7	Nendran	Large shoulder	Purple brown	Crimson	Fan shape
G – 8	Grand Naine	Large shoulder	Purple brown	Orange red	Oval
G – 9	Kwetho	Small	Red purple	Red	Oval
G – 10	Meitei Hei	Small shoulder	Purple brown	Red	Oval
G – 11	Lumumgto	Large shoulder	Red purple	Purple brown	Oval
G – 12	Subjikol	Large shoulder	Purple brown	Purple brown	Oval
G – 13	Kwegha	Large shoulder	Purple brown	Purple brown	Oval
G – 14	Gumsang	Large shoulder	Purple brown	Red	Oval
G – 15	Luipet	Small	Red	Whitish	Oval
G – 16	Rakannak	Large shoulder	Pink purple	Orange red	Oval
G – 17	Phfeprei	Small	Red purple	Purple brown	Oval
G – 18	Yhuro	Large shoulder	Purple brown	Orange red	Oval
G – 19	*M. velutina*	Large shoulder	Pink purple	Red	Fan shape
G – 20	Red Banana	Medium	Red	Purple	Oval

Table 4.5 (c) Flower characters of twenty banana genotypes

Collection no.	Genotypes	Free tepal colour	Compound tepal colour	Ovary shape	Stigma colour
G – 1	Bhootmanohar	Translucent white	Pink purple	Arched	Yellow
G – 2	Chini Champa	Translucent white	Pink purple	Arched	Cream
G – 3	Jahaji	Translucent white	White	Straight	Yellow
G – 4	Kanthali	Translucent white	Pink purple	Arched	Cream
G – 5	Lumungashe	Translucent white	Pink purple	Arched	Cream
G – 6	Bharatmani	Translucent white	White	Arched	Bright yellow
G – 7	Nendran	Translucent white	Orange	Arched	Cream
G – 8	Grand Naine	Translucent white	White	Straight	Yellow
G – 9	Kwetho	Tinted with pink	Pink purple	Arched	Cream
G – 10	Meitei Hei	Tinted with yellow	Pink purple	Straight	Yellow
G – 11	Lumumgto	Translucent white	Pink	Arched	Cream
G – 12	Subjikol	Tinted with pink	Pink purple	Arched	Cream
G – 13	Kwegha	Tinted with pink	Pink purple	Straight	Cream
G – 14	Gumsang	Translucent white	White	Arched	Cream
G – 15	Luipet	Translucent white	Cream	Arched	Orange
G – 16	Rakannak	Tinted with yellow	Orange	Arched	Cream
G – 17	Phfeprei	Translucent white	Pink purple	Arched	Cream
G – 18	Yhuro	Tinted with yellow	Cream	Arched	Yellow
G – 19	*M. velutina*	Translucent white	Orange	Arched	Yellow
G – 20	Red Banana	Tinted with pink	Pink purple	Arched	Cream

G-1
Bhootmanohar

G-2
Chinichampa

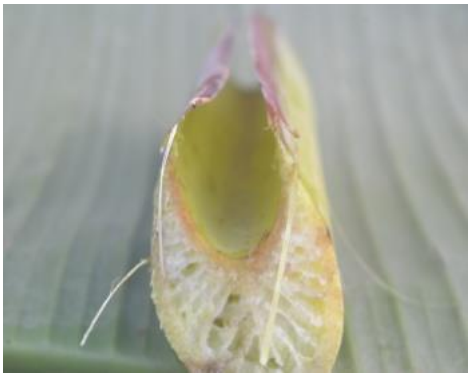
G-3
Jahaji

G-4
Kanthali

G-5
Lumungashe

G-6
Bharatmani

Plate 7. Petiole canal leaf III (Genotype 1 – 6)



G-7
Nendran

G-8
Grand Naine

G-9
Kwetho

G-10
Meiteihei

G-11
Lumumgto

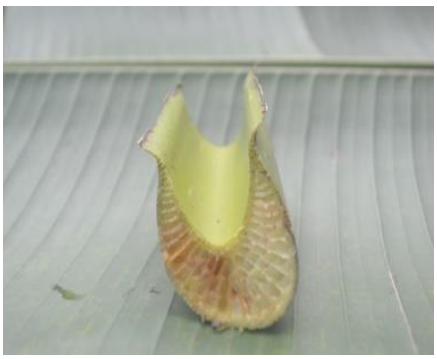
G-12
Subjikol

Plate 8. Petiole canal leaf III (Genotype 7 – 12)

G-13
Kwegha

G-14
Gumsang

G-15
Luipet



G-16
Rakannak

G-17
Pfheprei

G-18
Yhuro

Plate 9. Petiole canal leaf III (Genotype 13 – 18)

G-19
M. velutina

G-20
Red banana

Plate 10. Petiole canal leaf III (Genotype 19 – 20)

G-1
Bhootmanohar

G-2
Chinichampa

G-3
Jahaji

G-4
Kanthali

Plate 11. Male bud of banana (Genotype 1 – 4)

G-5
Lumungashe

G-6
Bharatmani

G-7
Nendran

G-8
Grand Naine

Plate 12. Male bud of banana (Genotype 4 – 8)

G-9
Kwetho

G-10
Meiteihei

G-11
Lumungto

G-12
Subjikol

Plate 13. Male bud of banana (Genotype 9 – 12)

G-13
Kwegha

G-14
Gumsang

G-15
Luipet

G-16
Rakannak

Plate 14. Male bud of banana (Genotype 13 – 16)

G-17
Pfheprei

G-18
Yhuro

G-19
M. velutina

G-20
Red banana

Plate 15. Male bud of banana (Genotype 17 – 20)

G-1
Bhootmanohar

G-2
Chinichampa

G-3
Jahaji

G-4
Kanthali

G-5
Lumungashe

G-6
Bharatmani

Plate 16. Male flower of banana (Genotypes 1-6)

G-7
Nendran

G-8
Grand Naine

G-9
Kwetho

G-10
Meiteihei

G-11
Lumungto

G-12
Subjikol

Plate 17. Male flower of banana (Genotypes 7-12)

G-13
Kwegha

G-14
Gumsang

G-15
Luipet

G-16
Rakannak

G-17
Pfheprei

G-18
Yhuro

Plate 18. Male flower of banana (Genotypes 13-18)

G-19
M. velutina

G-20
Red banana

Plate 19. Male flower of banana (Genotypes 19-20)

4.1.5 Fruit characters

The observations recorded on fruit characters of different banana genotypes have been presented in table 4.6.

4.1.5.1 Bunch weight (kg)

The data recorded with respect to bunch weight of different banana genotypes have been presented in table 4.6 and graphically in figure 4.4.

The depicted data clearly shows that the genotype differs significantly for bunch weight which was recorded in the range of 1.22 kg to 18.15 kg. The maximum bunch weight was recorded in Grand Naine (18.15 kg) followed by Subjikol (17.71 kg) and Chinichampa (17.05 kg). On the other hand, minimum bunch weight was recorded in *M. velutina* (1.22 kg) which was at par with Luipet (1.40 kg). A similar finding was recorded by Rajeevan and Molunakumaran (1993) where significant variation in bunch weight was observed in the main crop and first ratoon crop among the twenty four accession of Palayankodan banana. In a study by Babu (2001) it was noted that agro-climate and genetic variation were important factors that affect bunch weight. Bunch weight is an important character that has direct impact on yield. It is also a known fact that bunch weight is closely correlated with number of hands, number of fingers and weight of fingers.

4.1.5.2 Number of hands/bunch

Table 4.6 and figure 4.5 depicted the mean data on number of hands/bunch recorded by counting the number of hands in the bunch. It was recorded in the range of 4.67 to 15.00 hands/bunch. As indicated in the data there was significant variation in the number of hands/bunch. The highest number of hands was recorded in Chinichampa (15.00) and distantly tailed by Lumungashe (11.67). The lowest number of hands was recorded in Yhuro (4.67) which was statistically at par with Luipet (5.33), *M. velutina* (5.33) and

Red Banana (5.67). A similar finding was recorded by Rajeevan and Molunakumaran (1993) where significant variation was observed in number of hands in the main crop and first ratoon crop among the twenty four accession of Palayankodan banana. The variation in number of fingers in banana bunch may be due to the relative water content where it helps in better translocation of photosynthates to fingers for better filling. In a study by Murali *et al*. (2005) on yield and yield parameters of banana under the effect of soil moisture stress at different stages of growth revealed that highest fruit yield was obtained under no stress followed by stress at fruiting stage. A similar observation was reported by Surendar *et al*. (2013) while studying the effect of water deficit on relationship between yield and physiological attributes of banana cultivars and hybrids reported that water deficit cause reduction in number of hands per bunch. Besides, an increase in the number of hands can result in a higher bunch weight, a character that expresses the productivity of a genotype (Silva *et al*., 2002b and Silva *et al*., 2003).

4.1.5.3 Number of fingers/hand

The data pertaining to number of fingers/hand has been presented in table 4.6 and graphically in figure 4.5. The presented result showed a significant variation in the number of fingers/hand. The result showed number of fingers in the range of 4.91 to 17.27 where the highest number of fingers/hand was recorded in Chinichampa and lowest in *M. velutina*. Genotypes such as Jahaji (13.23), Lumungashe (12.97) and Red Banana (13.38) were statistically at par. A similar finding was recorded by Rajeevan and Molunakumaran (1993) where significant variation in number of fingers in the main crop and first ratoon crop among the twenty four accession of Palayankodan banana. Other prominent researchers are of the view that variation in number of fingers in banana bunch may be due to the relative water content where it helps in better translocation of photosynthates to fingers for

better filling. In a study by Murali *et al*. (2005) on yield and yield parameters of banana under the effect of soil moisture stress at different stages of growth revealed that highest fruit yield was obtained under no stress followed by stress at fruiting stage.

4.1.5.4 Fruit weight (g)

The observations taken for fruit weight (g) have been given in table 4.6 and graphically in figure 4.6. The result indicated that there was significant variation in fruit weight among different genotypes which was observed in the range of 29.98 g to 183.11 g. The highest fruit weight was recorded in Subjikol (183.11 g) followed by Grand Naine (163.22 g) and Nendran (153.20 g). The lowest fruit weight was noted in Luipet (29.98 g) which was significantly equal to Rakannak (31.33 g). It is to be noted that the ultimate size attained by each finger is a function of conditions prevailing after flower initiation and is determined by soil fertility, moisture availability, temperature, leaf number and area during bunch development and stage of maturity at harvest. Variation in fruit weight was reported by Sunilkumar (1997), Mattos *et al*. (2010b) and Smith *et al*. (2014) which were in confirmation with the present study. Baker and Davis (1951) asserted that variation in fruit size may due to the difference in characters of the pericarp like cell size and intercellular space in different tissues of the fruit which contribute to increase in length, breadth and thickness of the fruits. Crane and Brown (1950) also mentioned that the increase in fruit size, weight and other parameters are due to accumulation of carbohydrates in fruit. The growth of fruit size in the later stage was due to osmotic accumulation of food substance and water (Combe, 1960).

Table 4.6 Quantitative fruit characters of twenty banana genotypes

Genotypes	Bunch weight (kg)	No. of hands/bunch	No. of fingers/hand	Fruit weight (g)	Pulp weight (g)	Weight of peel (g)	Fruit peel thickness (mm)	Pulp:peel ratio
Bhootmanohar	16.31^{bc}	9.67^{bcd}	13.55^{efg}	142.30^{d}	107.00^{c}	35.30^{d}	2.53^{f}	3.03^{cd}
Chinichampa	17.05^{abc}	15.00^{a}	17.27^{a}	66.00^{l}	47.07^{jk}	18.93^{k}	1.40^{h}	2.50^{fg}
Jahaji	14.06^{d}	9.33^{cde}	13.23^{efgh}	78.04^{k}	57.95^{h}	20.09^{jk}	3.53^{c}	2.89^{de}
Kanthali	7.04^{gh}	8.67^{defg}	11.76^{h}	66.05^{l}	46.05^{k}	20.00^{jk}	2.03^{g}	2.31^{gh}
Lumungashe	16.07^{c}	11.67^{bc}	12.97^{efgh}	97.10^{h}	63.00^{g}	34.10^{de}	3.13^{de}	1.85^{j}
Bharatmani	9.05^{ef}	9.33^{cde}	15.87^{abc}	112.23^{g}	77.20^{f}	35.03^{d}	3.23^{cd}	2.21^{ghi}
Nendran	6.54^{gh}	6.67^{fghi}	7.58^{j}	153.20^{c}	117.59^{b}	35.61^{d}	2.63^{f}	3.31^{bc}
Grand Naine	18.15^{a}	10.33^{bcd}	15.55^{bcd}	163.22^{b}	108.00^{c}	55.22^{b}	4.63^{a}	1.96^{ij}
Kwetho	7.93^{fg}	8.33^{defgh}	14.08^{def}	90.00^{i}	64.37^{g}	25.63^{g}	2.63^{f}	2.54^{fg}
Meitei Hei	6.89^{gh}	8.33^{defgh}	9.23^{i}	77.09^{k}	53.11^{i}	23.98^{gh}	2.13^{g}	2.22^{ghi}
Lumungto	9.14^{ef}	6.00^{hi}	12.65^{fgh}	117.44^{f}	95.89^{d}	21.56^{ij}	2.63^{f}	4.45^{a}
Subjikol	17.71^{ab}	6.33^{ghi}	12.86^{fgh}	183.11^{a}	138.09^{a}	45.02^{c}	3.47^{c}	3.07^{cd}
Kwegha	10.40^{e}	7.00^{efghi}	14.14^{def}	80.84^{j}	55.89^{h}	24.78^{gh}	2.83^{ef}	2.26^{ghi}
Gumsang	10.117^{e}	10.33^{bcd}	12.13^{gh}	76.99^{k}	48.89^{j}	28.11^{f}	3.13^{de}	1.74^{j}
Luipet	1.40^{j}	5.33^{i}	14.67^{cde}	29.98^{o}	19.92^{n}	10.06^{m}	1.87^{g}	1.98^{hij}
Rakannak	5.56^{hi}	12.00^{b}	17.14^{ab}	31.33^{o}	24.16^{m}	7.17^{n}	1.47^{h}	3.42^{b}
Phfeprei	7.22^{g}	9.00^{def}	11.69^{h}	54.52^{m}	31.39^{l}	23.12^{hi}	4.10^{b}	1.36^{k}
Yhuro	4.67^{i}	4.67^{i}	8.67^{ij}	139.44^{e}	75.33^{f}	64.11^{a}	3.97^{b}	1.18^{k}
Musa velutina	1.22^{j}	5.33^{i}	4.91^{k}	36.78^{n}	20.78^{n}	16.00^{l}	1.97^{g}	1.30^{k}
Red Banana	6.67^{gh}	5.67^{i}	13.38^{efgh}	119.77^{f}	87.00^{e}	32.77^{e}	2.73^{f}	2.65^{ef}
CD (0.05)	1.347	2.192	1.552	2.738	2.246	1.965	0.306	0.307
SE(m)±	0.469	0.763	0.540	0.953	0.782	0.684	0.106	0.107
Range	1.22-18.15	4.67-15.00	4.91-17.27	29.98-183.11	19.92-138.09	7.17-64.11	1.40-4.63	1.18-4.45

*Means with different superscript letters within column are significantly different from each other by Duncan Multiple Range Test (p = 0.05)

4.1.5.5 Pulp weight (g)

The data for the pulp weight (g) were recorded and presented in table 4.6 and graphically in figure 4.6. The result showed a significant variation among the twenty genotypes. The pulp weight was observed in the range of 19.92 g to 138.09 g. the maximum pulp weight was recorded in Subjikol (138.09 g) followed by Nendran (117.59 g) and Grand Naine (108.00 g) which was at par with Bhootmanohar (107.00 g). The minimum pulp weight was recorded in Luipet (19.92 g) which was similar to *M. velutina* (20.78 g). A critical examination of the result revealed that pulp weight was directly proportional to fruit weight.

4.1.5.6 Weight of peel (g)

Weight of the peel was recorded after separating the peel from the fruit pulp and the data has been presented in table 4.6 and graphically in figure 4.6. The data indicated that there was significant variation among the genotype where it was recorded in the range of 10.06 g to 64.11 g. Maximum weight of peel was recorded in Yhuro (64.11 g) followed by Grand Naine (55.22 g). Meanwhile genotypes Bhootmanohar (35.30 g), Bharatmani (35.03 g) and Nendran (35.61 g) were statistically at par. The lowest weight of peel was recorded in Rakannak (7.17 g) tailed by Luipet (10.06 g) and *M. velutina* (16.00 g).

4.1.5.7 Fruit peel thickness (mm)

Fruit peel thickness was recorded at fruit maturity when the fruit was ripe and ready to eat but not over-ripe; full yellow stage and was measured with the help of Vernier Caliper. The data regarding peel thickness of different banana genotypes has been presented in table 4.6. The result indicates variation in peel thickness among different banana genotypes within the range of 1.40 mm to 4.63 mm. It was observed that maximum peel thickness was in genotype

Grand Naine (4.63 mm) followed by Phfeprei (4.10 mm) which was similar to Yhuro (3.97 mm). Minimum peel thickness was recorded in Chinichampa (1.40 mm) which was at par with Rakannak (1.47 mm). Genotypes such as Kanthali (2.03 mm), Meiteihei (2.13 mm), Luipet (1.87 mm) and *M. velutina* (1.97 mm) were statistically at par.

4.1.5.8 Pulp:peel ratio

The results of pulp:peel ratio were displayed in table 4.6. There was a significant variation in pulp:peel ratio among the genotypes. It was recorded that genotypes Lumumgto (4.45) had the highest pulp:peel ratio followed by Rakannak (3.42), Nendran (3.31) and Subjikol (3.07) which was similar to Bhootmanohar (3.03). The least pulp:peel ratio was observed in Yhuro (1.18) which was at par with *M. velutina* (1.30) and Phfeprei (1.36) followed by Gumsang (1.74) which was also similar to Lumungashe (1.85). The variation in pulp and peel is a varietal character and can also be influenced by the prevailing environmental condition. Rajamanickam (2003) evaluated twenty eight cultivars and found significant variation in pulp:peel ratio among the cultivars ranging between 2.53 to 9.43. The difference in pulp:peel ratio can also be explained by its varietal behavior in consumption of its food material manufactured during the process of photosynthesis. Some varieties have the tendency to divert its manufactured food material towards mesocarp resulting in increased in the pulp percentage. Similarly if more food is diverted towards the exocarp ultimately the peel percentage will be improved. The percentage of pulp is an important standard for the assessment of cultivars since this is the part of the fruit which is ultimately ultilized by the consumer. In addition, the increase of the pulp:peel ratio can also be attributed to the migration of water from peel to the pulp because of the osmotic gradient due to the increase of the sugar contents in the pulp in relation to the peel (Aquino *et al*., 2017).

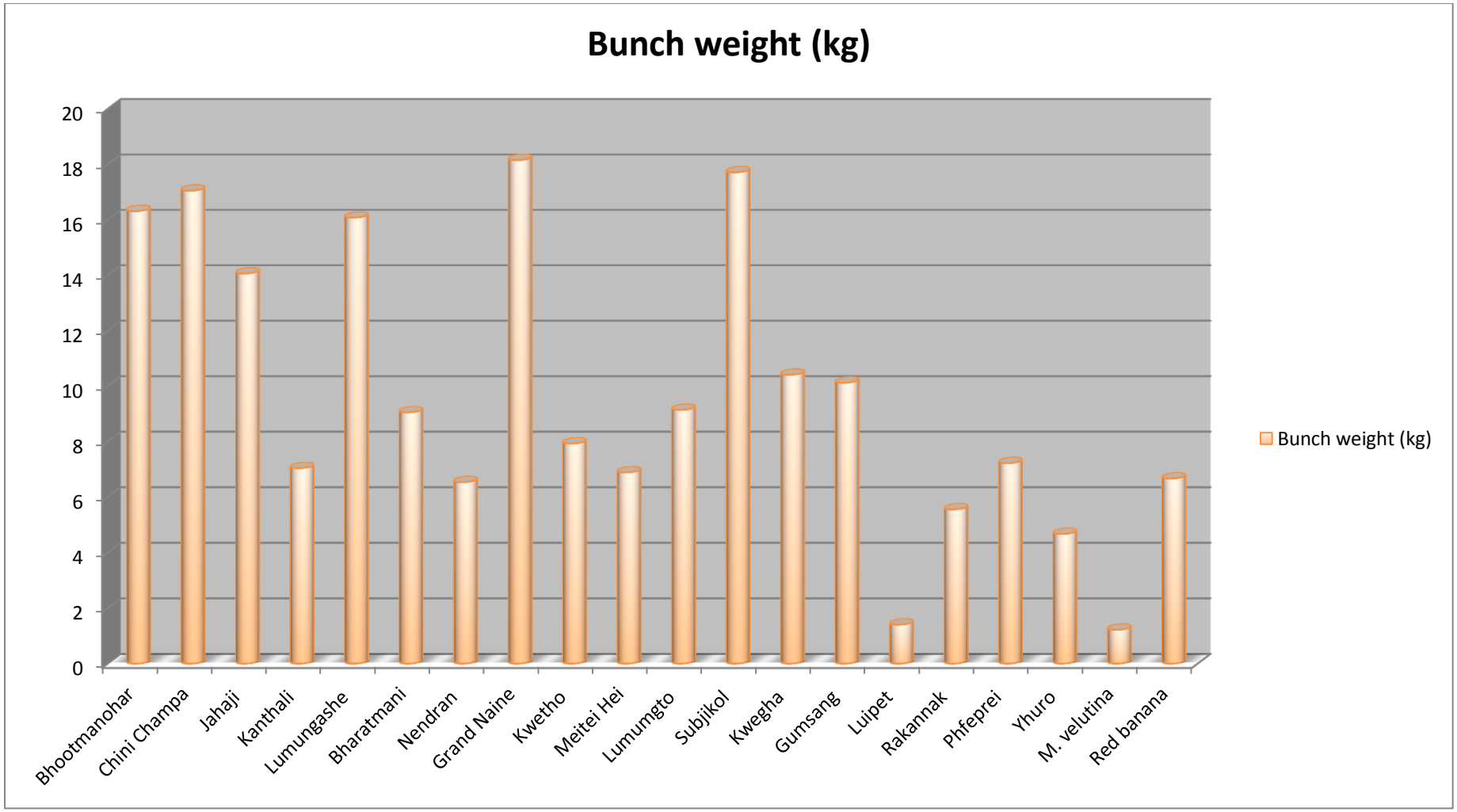


Figure 4.4 Bar diagram depicting bunch weight of the twenty banana genotypes

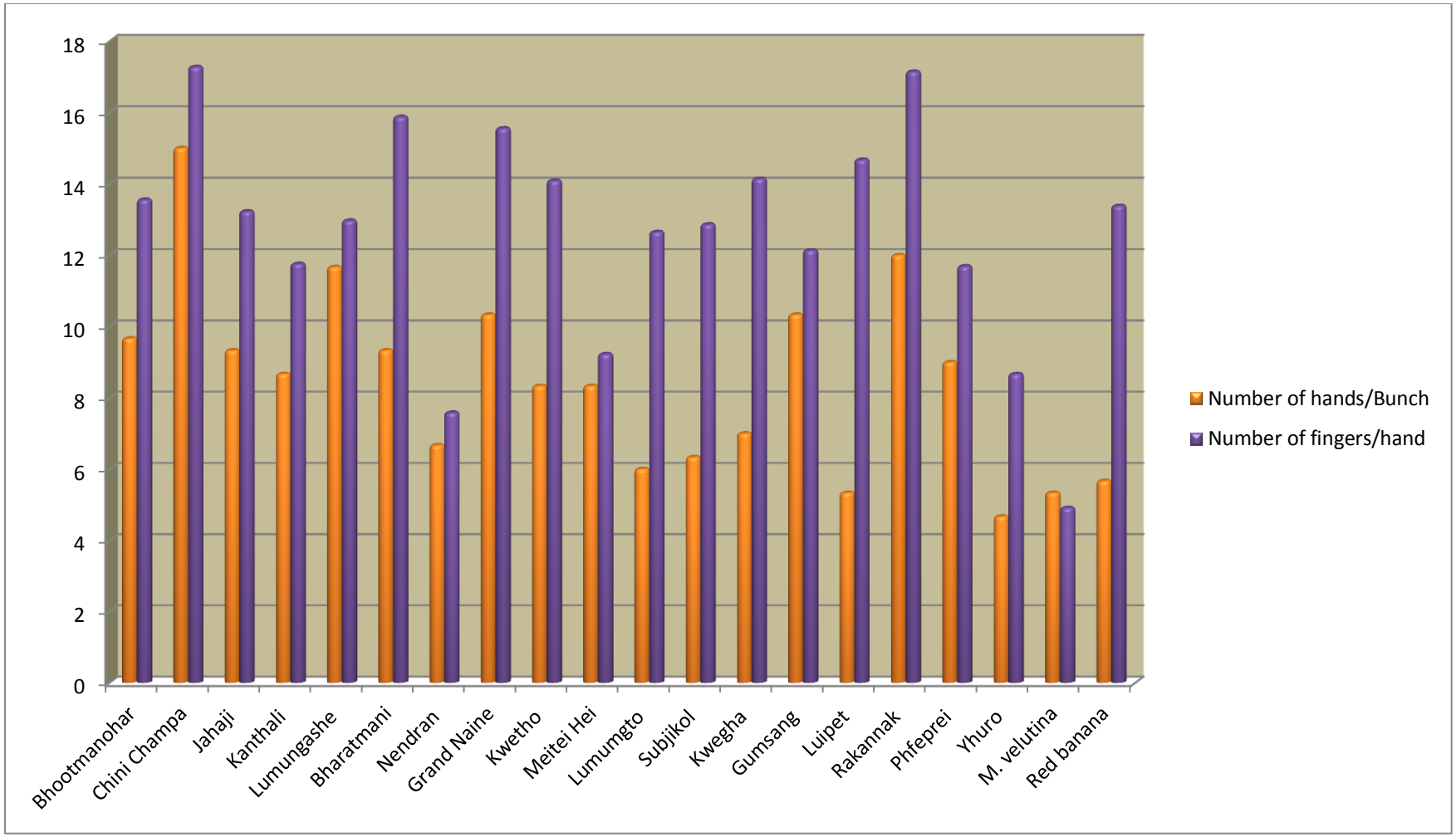


Figure 4.5 Bar diagram depicting number of hands/bunch and number of fingers/hand of twenty banana genotypes

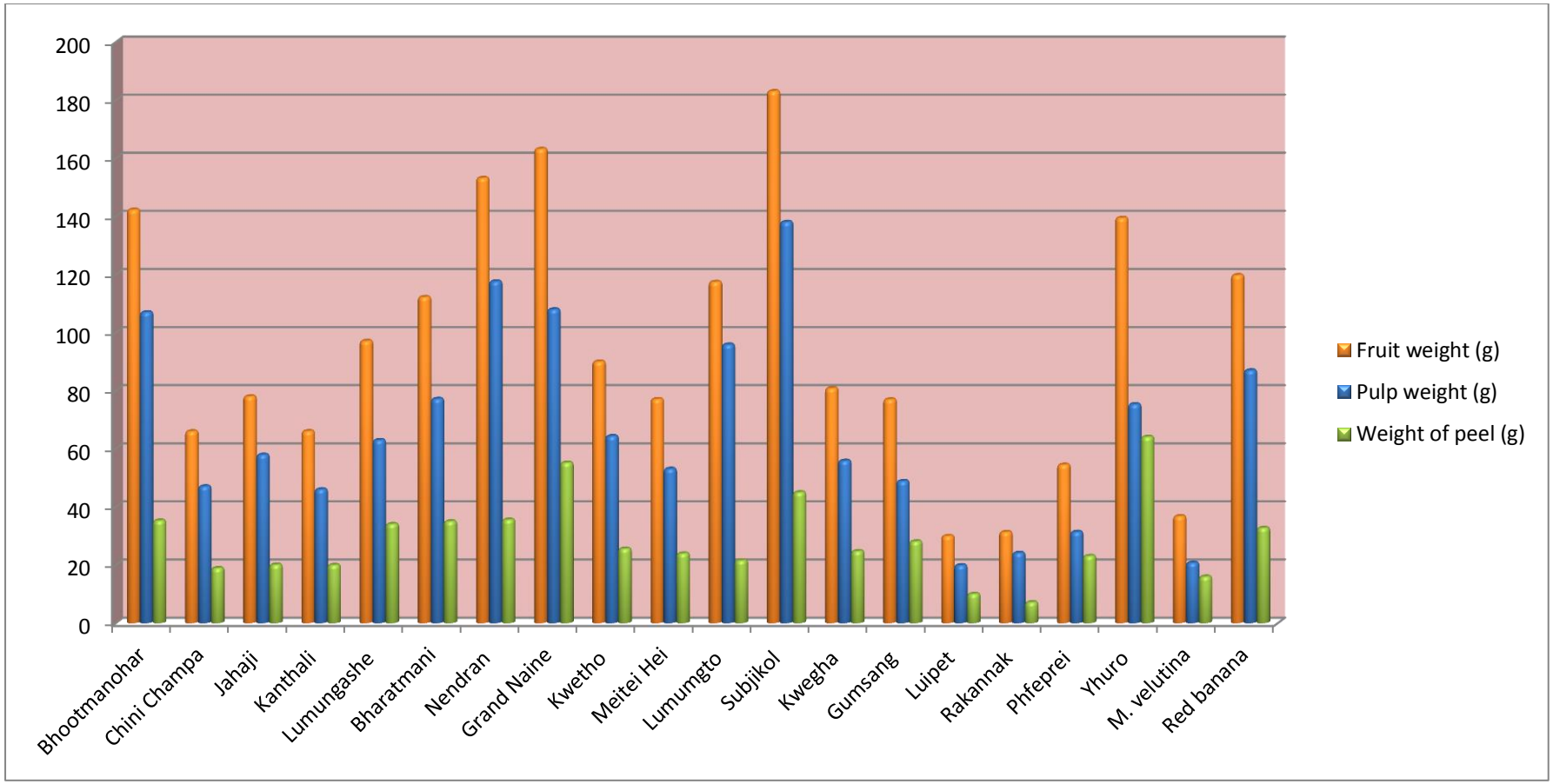


Figure 4.6 Bar diagram depicting fruit weight, pulp weight and weight of peel of twenty banana genotypes

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4.1.6 Genetic parameters

4.1.6.1 Estimation of coefficients of variation

The component of variation such as genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) have been computed. It is essential to know about the selection by separating out the environmental influences from total variability. This indicates the accuracy with which a genotype can be identified by its phenotypic performance. Genotypic and phenotypic coefficients of variation are simple measure of variability and these measures are commonly used for the assessment of variability. The relative value of these types of coefficients gives an idea about the magnitude of variability present in genetic population. Thus, the component of variation such as genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were compared. Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) are categorized as low (less than 10%), moderate (10-20%) and high (more than 20%) as suggested by Subramaniam and Menon (1973).

The estimates of phenotypic coefficients of variation (PCV) and genotypic coefficients of variation (GCV) have been presented in table 4.7. In the present study, PCV ranged from 0.72% to 53.05%. Highest PCV was observed in bunch weight (53.05%) followed by pulp weight (50.20%), weight of peel (48.83%) and fruit weight (46.45 %). Lowest PCV value was seen in number of suckers (0.72%) followed by leaf blade width (17.55%) and leaf blade length (23.99%). On the other hand, the value of GCV ranged between 0.34% and 52.58%. Highest GCV was recorded for bunch weight (52.58%) followed by pulp weight (50.07%), weight of peel (48.67%) and fruit weight (46.42%). Lowest GCV was observed in number of suckers (0.34%) followed by leaf blade width (17.55%). These findings were in lines with the results of

Rajamanickam and Rajmohan (2010), Rajeevan and Geetha (1982) and Valsalakumari and Nair (1986).

The phenotypic coefficient of variation was marginally higher than the corresponding genotypic coefficient of variation for all the characters which indicates the influence of environment in the phenotypic expression of the character under study. Overall not much difference was observed between PCV and GCV for the traits under study which indicates the maximum expression of genotype with less effect of environment on the traits. The traits which showed high phenotypic and genotypic coefficient of variations were of economic importance and there is scope for improvement of these traits through selection.

4.1.6.2 Heritability (h^2_{bs}) and genetic advance (GA)

Heritability governed the resemblance between parents and their progeny whereas, the genetic advance provide the knowledge about expected gain for a particular character after selection. Heritability suggests the relative role of genetic factors in expression of phenotypes and also acts as an index of transmissibility of a particular trait to its off springs. However, the knowledge of heritability alone does not help to formulate a concrete breeding programme. Genetic advance along with heritability help to ascertain the possible genetic control for any particular trait. The nature and extent of the inherent ability of a genotype for a character is an important parameter determining the extent of improvement of any crop species. Heritability and genetic advance are the important genetic parameters for selecting a genotype that permit greater effectiveness of selection by separating out environmental influence from total variability.

Heritability estimates provides the information regarding the amount of transmissible genetic variation to total variation and determine genetic improvement and response to selection. Heritability estimates along with genetic advance are normally more useful in predicting the gain under selection

than that of heritability alone. However it is not necessary that a character showing high heritability will also exhibit high genetic advance. The heritability are usually considered to be low if it is less than 30%, moderate between 30% and 60% and high heritability if it is more than 60% (Robinson *et al.,* 1949) and as Johnson *et al.* (1955) suggested genetic advance as per cent mean can be categorized as low (0-10%), moderate (10-20%) and high (20% and above). Heritability estimates provides the information regarding the amount of transmissible genetic variation to total variation and determine genetic improvement and response to selection.

Heritability in broad sense gives the amount of heritable portion of a character. Characters with high heritability can be selected directly for improvement as they are less affected by the environment. In the present study, the result revealed high heritability (table 4.7) which ranged from 47.57 % (number of suckers) to 99.86 % (fruit weight). The characters such as fruit weight (99.86%), pulp weight (99.45%), weight of peel (99.29%), girth size (99.28%), leaf blade length (98.63%), bunch weight (98.23%), petiole length (98.16%), pseudostem height (97.09%), fruit peel thickness (95.63 %), leaf blade width (95.29%), pulp:peel ratio (94.86%), number of hands/bunch (91.74 %) and number of fingers/hand (91.56%) recorded the higher heritability. Relatively higher values of heritability for these characters indicate that a large proportion of phenotypic coefficient of variance was attributable to the genotypic coefficient of variance. Sreerangaswamy *et al*. (1980) has obtained high values of heritability for number of fingers/bunch, plant height and number of fingers/hand which was in line with the present findings. High heritability has also been described for pulp weight (Singh and Sharma, 1997), pseudostem girth size, bunch weight, number of fingers/bunch (Rajeevan and Geetha, 1982), pseudostem height, bunch weight, girth size (Valsalakumari and Nair, 1986) and bunch weight, plant height (Uma *et al*., 2000) and weight of finger, pulp weight, plant height and bunch weight (Rajamanickam, 2020).

Heritability estimates along with genetic advance are more useful than the heritability value alone for selecting the best individual. Katiyar *et al*. (1974) illustrated that heritability values alone are inadequate and cannot be taken as tool to calculate the amount of genetic progress achieved by selecting the best individual. Ramanujan and Thirumalachar (1967) observed that heritability estimates could be reliable if accompanied by a high genetic advance.

In the present study a wide variation among characters for genetic advance was observed. Genetic advance as per cent of mean varied between 25.74 % for number of suckers and 107.34 % for bunch weight. High genetic advance as per cent of mean was recorded in almost all characters except for number of suckers. A relatively high genetic advance as per cent mean was observed in characters such as bunch weight (107.34 %), pulp weight (102.86 %), weight of peel (99.88 %), fruit weight (95.56 %), pulp:peel ratio (66.29 %) and fruit peel thickness (61.87 %). As evident from the data, most of the traits exhibits high genetic advance where it can be assumed that these characters are governed by additive gene effects (Johnson *et al*., 1955). Similar findings were reported by Rosamma and Namboodiri (1990) and Uma *et al*. (2000). These findings inferred that selection of bunch weight, pulp weight, weight of peel and fruit weight can bring about effective improvement and therefore maybe exploited in breeding programmes. High heritability does not necessary mean a high genetic advance for particular characters (Allard, 1960). Heritability along with genetic advance is more advantageous than heritability alone in predicting the result and effectiveness in selecting the best traits (Johnson *et al*., 1955).

Bunch weight and pulp weight recorded high estimates of PCV and GCV along with high heritability and genetic advance as per cent of mean revealing relatively low influence of environment on the traits proving themselves as primary selection criteria for improvement in banana. Similar

findings were reported by Rekha and Prasad (1993), Uma *et al*. (2000), Kulkarni *et al*. (2002), Kavitha *et al*. (2008) and Rajamanickam and Rajmohan (2010). Similarly, fruit peel thickness recorded higher values of PCV, GCV and high estimates of heritability along with genetic advance as per cent of mean in the present study. The findings were in accordance with the observation of Sawant *et al*. (2016).

Table 4.7 Genetic parameters on growth attributes of twenty banana genotypes

Characters	Grand mean	SEm±	Range Min-Max	GCV (%)	PCV (%)	ECV (%)	Heritability (%)	Genetic advance	Genetic Advance as % of mean
Number of suckers	3.23	0.36	2.30 – 4.67	0.34	0.72	0.38	47.57	0.83	25.74
Girth Size (cm)	64.10	0.89	24.27 – 100.17	28.30	28.40	2.40	99.28	37.22	58.07
Pseudostem height (m)	5.53	0.15	2.03 – 8.07	26.87	27.27	4.65	97.09	3.02	54.54
Leaf blade length	217.47	3.5	71.00 – 309.00	23.82	23.99	2.81	98.63	105.98	48.74
Leaf blade width	66.68	1.47	49.00- 91.00	17.13	17.55	3.81	95.29	22.97	34.45
Petiole length (cm)	58.30	1.22	24.33 – 84.67	26.43	26.68	3.62	98.16	0.98	53.95
Bunch weight (kg)	9.80	0.40	1.22 – 17.05	52.58	53.05	7.05	98.23	10.52	107.34
No. of hands/bunch	8.63	0.45	4.67 – 15.00	30.05	31.38	9.02	91.74	5.12	59.30
No. of fingers/hand	12.67	0.54	4.91 – 17.27	24.31	25.41	7.38	91.56	6.07	47.93
Fruit weight (g)	95.77	0.95	29.98 – 183.11	46.42	46.45	1.72	99.86	91.52	95.56
Pulp weight (g)	66.97	1.43	19.92 – 138.09	50.07	50.20	3.71	99.45	68.88	102.86
Weight of peel (g)	28.83	0.68	7.17 – 64.11	48.66	48.83	4.11	99.29	28.79	99.88
Fruit peel thickness	2.80	0.11	1.40 – 4.63	30.71	31.41	6.57	95.63	1.73	61.87
Pulp:peel ratio	2.41	0.11	1.18 – 4.45	33.04	33.92	7.70	94.86	1.60	66.29

4.1.6.3 Correlation studies

The phenotypic and genotypic correlation coefficients of fourteen characters were worked out in all possible combinations and presented in table 4.8 and 4.9.

Correlation provides information on the nature and magnitude of association between characters in a population. When a trait is selected for improvement, the population under selection is improved not only for traits but also for other traits associated with it. This paves the way for simultaneous improvement of two or more characters. Therefore, analysis of yield in terms of phenotypic and genotypic correlation coefficients of component characters helps in understanding the characters that can form basis of selection.

The present study revealed that pulp weight has significant genotypic correlation with girth size (0.500), petiole length (0.487), fruit peel thickness ().444) and bunch weight (0.539). Significant genotypical correlation with fruit weight was observed in girth size (0.506) and bunch weight (0.516) while it exhibit negative genotypical association with petiole length (-0.515).

Leaf blade width (0.486) and pseudostem height (0.560) showed positive and significant genotypic correlation with leaf blade length. Bunch weight has positive and significant positive genotypic correlation with girth size (0.559) and pseudostem height (0.313). Number of fingers/hand and pulp:peel ratio also showed significant and positive genotypic correlation with bunch weight (0.486) and pulp weight (0.454) respectively. However, number of suckers, petiole length and weight of peel exhibit negative and significant genotypical association with pseudostem height, number of suckers (-0.556) and petiole length (-0.465) respectively.

Bunch weight has a positive phenotypical correlation with pseudostem height (0.306) and fruit peel thickness. Likewise, fruit weight has significant

positive phenotypical correlation with pseudostem height and pulp:peel ration. Pulp:peel ratio also showed positive phenotypical association with leaf blade width and number of fingers/hand but negative association with fruit peel thickness.

Fruit peel thickness (0.269) and pulp weight (0.283) has significant positive phenotypical correlation with pseudostem height. Number of fruits/hand and weight of peel also has positive phenotypical association with girth size (0.323) and leaf blade width (0.316) respectively. However, petiole length has negative phenotypical correlation with both girth size (-0.293) and number of suckers (-0.317).

It was evident from the result that genotypic correlation coefficient (r_g) values were higher in magnitude than phenotypic correlation coefficient (r_p) values among the traits. It indicates that indirect selection of growth traits and fruit yield parameters may be used to increase fruit yield per hectare. This finding is in agreement with the observation of Sirisenaa and Senanayake (2000) who reported that selection in favour of average fruit weight increases the total fruit weight more than the selection for bunch weight. Similar observation was also reported by Tenkouano *et al*. (2002) where positive and significant genotypic correlations was higher than phenotypic correlation between bunch weight and its components except with number of fingers per hand. Krishnan and Shanmughavelu (1983) reported a positive and significant phenotypic and genotypic correlation of bunch weight with pseudostem height which was in accordance with the present findings. Positive genotypic correlation of bunch weight of banana with number of fingers/hand was also reported by Krishnan and Shanmughavelu (1983) and Rosamma and Namboodiri (1990) which validated the present findings.

Table 4.8 Phenotypical correlation coefficient (r_p) between fourteen traits of banana

Character	LBL	LBW	PH	GS	NS	PL	FPT	BW	NH	NF	PW	WP	PPR	FW
LBL		0.462	0.546	0.555	-0.160	0.174	0.314	0.187	0.144	0.406	0.074	0.104	0.033	0.088
LBW			0.372	0.554	-0.088	-0.009	0.044	0.109	-0.126	0.169	0.348	0.316*	0.260*	0.362
PH				0.755	-0.361	0.090	0.269*	0.306*	0.115	0.346	0.283*	0.245	0.160	0.290*
GS					-0.245	-0.293*	0.436	0.549	0.153	0.323*	0.498	0.407	0.252	0.505
NS						-0.317*	0.121	-0.065	-0.225	-0.056	-0.009	0.106	-0.156	0.025
PL							-0.500	-0.357	0.013	-0.071	-0.481	-0.460	-0.076	-0.509
FPT								0.319*	-0.139	-0.066	0.434	0.719	-0.284*	0.555
BW									0.559	0.456	0.533	0.349	0.239	0.512
NH										0.574	-0.183	-0.211	0.068	-0.204
NF												-0.153	0.279*	-0.052
PW												0.695	0.443	0.972
WP													-0.234	0.841
PPR														0.261*
FW														

Residual Effect = 0.0012

Where,

LBL=Leaf Blade length, LBW=Leaf blade width, PH=Pseudostem height, GS=Girth size, NS=Number of sucker, PL=Petiole length, FPT=Fruit peel thickness, BW=Bunch weight, NH=Number of hand/bunch, NF=Number of finger/hand, PW=Pulp weight, WP=Weight of peel, PPR=Pulp peel ratio, FW=Fruit weight.

Table 4.9 Genotypical correlation coefficient (r_g) between fourteen traits of banana

Characters	LBL	LBW	PH	GS	NS	PL	FPT	BW	NH	NF	PW	WP	PPR	FW
LBL		0.486*	0.560*	0.562	-0.258	0.177	0.322	0.192	0.146	0.423	0.075	0.106	0.035	0.090
LBW			0.385	0.567	-0.134	-0.011	0.066	0.109	-0.133	0.160	0.354	0.320	0.280	0.367
PH				0.772	-0.556*	0.098	0.275	0.313*	0.130	0.369	0.289	0.253	0.161	0.296
GS					-0.329	-0.302	0.450	0.559*	0.158	0.340	0.500*	0.409	0.261	0.506*
NS						-0.456*	0.176	-0.106	-0.260	-0.164	-.0.020	0.135	-0.193	0.030
PL							-0.176	-0.358	0.001	-0.083	0.487*	-0.465*	-0.079	-0.515*
FPT								0.327	-0.147	-0.062	0.444*	0.743	-0.309	0.570
BW									0.597	0.486*	0.539*	0.351	0.249	0.516*
NH										0.615	-0.188	-0.219	0.064	-0.212
NF											-0.005	-0.160	0.305	-0.055
PW												0.6989	0.4537*	0.9745
WP													-0.226	0.8424
PPR														0.2698
FW														

Residual Effect = 0.0012

Where,

LBL=Leaf Blade length, LBW=Leaf blade width, PH=Pseudostem height, GS=Girth size, NS=Number of sucker, PL=Petiole length, FPT=Fruit peel thickness, BW=Bunch weight, NH=Number of hand/bunch, NF=Number of finger/hand, PW=Pulp weight, WP=Weight of peel, PPR=Pulp peel ratio, FW=Fruit weight.

4.1.6.4 Path coefficient analysis

Path coefficient analysis at phenotypic and genotypic level was worked out to study the effect of various traits. The results have been presented in table 4.10 and 4.11.

4.1.6.4.1 Path coefficient analysis at phenotypic level

As indicated in the data, the phenotypic path coefficient analysis revealed that maximum direct positive effect on yield was imposed by pulp weight (0.7310) followed by weight of peel (0.3342), bunch weight (0.0058), leaf blade length (0.0034) and pseudostem height (0.0004). While maximum negative direct effects on yield were recorded for pulp:peel ratio (-0.0139) trailed by petiole length (-0.0060), number of suckers (-0.0048), number of hands/bunch (-0.0042), girth size (-0.0036), fruit peel thickness (-0.0031), number of fingers/hand (-0.0027) and leaf blade width (-0.0021).

The maximum positive indirect effect on yield was imposed by pulp weight through weight of peel (0.5081), bunch weight (0.3899), girth size (0.3643), pulp:peel ratio (0.3237), fruit peel thickness (0.3172) and leaf blade width (0.2541). The maximum negative indirect effect on yield was imposed by characters pulp weight (-0.3513) and weight of peel (-0.1536) through petiole length and pulp weight through number of hands/bunch (-0.1335). Residual effect at phenotypical level was observed to be 0.0012.

4.1.6.4.2 Path coefficient analysis at genotypic level

Pulp weight (0.7900) has maximum direct effect on yield followed by weight of peel (0.2933), girth size (0.0218) and petiole length (0.0112). However, maximum direct negative effect on yield was imposed by bunch weight (-0.0240) followed by pulp:peel ratio (-0.0172) and leaf blade length (-0.0131).

The maximum and indirect positive effect on yield was imposed by pulp weight through weight of peel (0.5521), bunch weight (0.4256), girth size (0.3952), pulp:peel ratio (0.3584) and fruit peel thickness (0.3511). Meanwhile, maximum negative indirect effect on yield was imposed by characters like pulp weight through petiole length (-0.3848) and number of hands/bunch (-0.1487) followed by weight of peel through petiole length (-0.1365). Residual effect at genotypic level was observed to be 0.0012.

Yield being a complex trait, it is difficult to exploit various yield contributing characters through the knowledge of correlation, therefore it is important to carry out other analysis including path coefficient that provide a clear indication for selection criterion (McGiffen *et al*., 1994). The coefficients generated by path analysis measure the direct and indirect influence of variable upon other (Dewey and Lu, 1959). The present study suggest that more emphasis should be given to selecting genotypes having pulp weight, weight of peel, pulp:peel ratio, bunch weight, girth size and petiole length. Directly or indirectly all the characters show positive effect on fruit yield. Mir *et al*. (2006) reported that fruit weight has direct positive effect on yield in pomegranate and ber. An observation in mango fruit by Prasad (1987) revealed that the indirect effect for fruit yield were mostly imposed by plant height, girth size and canopy spread. Baiyer and Ortiz (1995) also reported that yield was more closely related to number of fruits per plant in pomegranate and Banana.

Table 4.10 Direct and indirect effects of yield components at phenotypic level in banana

Characters	LBL	LBW	PH	GS	NS	PL	FPT	BW	NH	NF	PW	WP	PPR	r_p with yield
LBL	**0.0034**	-0.0010	0.0002	-0.0020	0.0008	-0.0011	-0.0010	0.0011	-0.0006	-0.0011	0.0541	0.0348	0.0005	0.0882
LBW	0.0016	**-0.0021**	0.0002	-0.0020	0.0004	0.0001	-0.0001	0.0006	0.0005	-0.0005	0.2541	0.1056	0.0036	0.362
PH	0.0018	-0.0008	**0.0004**	-0.0027	0.0017	-0.0005	-0.0008	0.0018	-0.0005	-0.0009	0.2065	0.0819	0.0022	0.2902*
GS	0.0019	-0.0012	0.0003	**-0.0036**	0.0012	0.0018	-0.0014	0.0032	-0.0006	-0.0009	0.3643	0.1359	0.0035	0.5045
NS	-0.0005	0.0002	-0.0002	0.0009	**-0.0048**	0.0019	-0.0004	-0.0004	0.0009	0.0002	-0.0064	0.0353	-0.0022	0.0245
PL	0.0006	0.0000	0.0000	0.0010	0.0015	**-0.0060**	0.0016	-0.0021	-0.0001	0.0002	-0.3513	-0.1536	-0.0011	0.5091
FPT	0.0011	-0.0010	0.0001	-0.0015	-0.0006	0.0030	**-0.0031**	0.0019	0.0006	0.0002	0.3172	0.2404	-0.0040	0.5551
BW	0.0006	-0.0002	0.0001	-0.0019	0.0003	0.0022	-0.0020	**0.0058**	-0.0023	-0.0012	0.3899	0.1166	0.0033	0.5121
NH	0.0005	0.0001	0.0001	-0.0005	0.0011	-0.0001	0.0004	0.0033	**-0.0042**	-0.0015	-0.1335	-0.0704	0.0009	-0.2037
NF	0.0013	-0.0004	0.0002	-0.0012	0.0003	0.0004	0.0002	0.0028	-0.0024	**-0.0027**	-0.0035	-0.0510	0.0039	-0.0521
PW	0.0003	-0.0007	0.0001	-0.0018	0.0000	0.0029	-0.0013	0.0031	0.0008	0.0000	**0.7310**	0.2323	0.0062	0.9728
WP	0.0004	-0.0007	0.0001	-0.0014	-0.0005	0.0028	-0.0022	0.0020	0.0009	0.0004	0.5081	**0.3342**	-0.0031	0.8407
PPR	0.0001	-0.0006	0.0001	-0.0009	0.0008	0.0005	0.0009	0.0014	-0.0003	-0.0008	0.3237	0.0781	**-0.0139**	0.2607*

Residual effect = 0.0012

Where,

LBL=Leaf Blade length, LBW=Leaf blade width, PH=Pseudostem height, GS=Girth size, NS=Number of sucker, PL=Petiole length, FPT=Fruit peel thickness, BW=Bunch weight, NH=Number of hand/bunch, NF=Number of finger/hand, PW=Pulp weight, WP=Weight of peel, PPR=Pulp peel ratio, FW=Fruit weight

Table 4.11 Direct and indirect effects of yield components at genotypic level in banana

Characters	LBL	LBW	PH	GS	NS	PL	FPT	BW	NH	NF	PW	WP	PPR	r_g with yield
LBL	**-0.0131**	0.0001	-0.0056	0.0123	-0.0027	0.0032	0.0036	-0.0046	0.0020	0.0045	0.0594	0.0311	-0.0006	0.0896
LBW	-0.0064	**0.0002**	-0.0038	0.0124	-0.0014	-0.0002	0.0007	-0.0026	-0.0018	0.0017	0.2796	0.0939	-0.0048	0.3674
PH	-0.0074	0.0001	**-0.0099**	0.0169	-0.0059	0.0018	0.0031	-0.0075	0.0018	0.0040	0.2280	0.0743	-0.0028	0.2964
GS	-0.0074	0.0001	-0.0077	**0.0218**	-0.0035	-0.0055	0.0050	-0.0134	0.0022	0.0037	0.3952	0.1200	-0.0045	0.5060*
NS	0.0034	0.0000	0.0055	-0.0072	**0.0106**	-0.0083	0.0020	0.0025	-0.0036	-0.0018	-0.0159	0.0396	0.0033	0.0302
PL	-0.0023	0.0000	-0.0008	-0.0066	-0.0048	**0.01828**	-0.0058	0.00860	0.00001	-0.0009	-0.3848	-0.1365	0.0014	-0.515*
FPT	-0.0042	0.0000	-0.0027	0.0098	0.0019	-0.0095	**0.0112**	-0.0078	-0.0020	-0.0007	0.3511	0.2180	0.0053	0.5700*
BW	-0.0025	0.0000	-0.0031	0.0122	-0.0011	-0.0065	0.0036	**-0.0240**	0.0082	0.0052	0.4256	0.1031	-0.0043	0.5160*
NH	-0.0019	0.0000	-0.0013	0.0034	-0.0028	0.0000	-0.0016	-0.0143	**0.0137**	0.0066	-0.1487	-0.0642	-0.0011	-0.2120
NF	-0.0056	0.0000	-0.0037	0.0074	-0.0017	-0.0015	-0.0007	-0.0117	0.0084	**0.0108**	-0.0041	-0.0470	-0.0052	-0.0545
PW	-0.0010	0.0001	-0.0029	0.0109	-0.0002	-0.0089	0.0050	-0.0129	-0.0026	-0.0001	**0.7900**	0.2050	-0.0078	0.9750
WP	-0.0014	0.0001	-0.0025	0.0089	0.0014	-0.0085	0.0083	-0.0084	-0.0030	-0.0017	0.5521	**0.2933**	0.0039	0.8420
PPR	-0.0005	0.0001	-0.0016	0.0057	-0.0021	-0.0015	-0.0035	-0.0060	0.0009	0.0033	0.3584	-0.0663	**-0.0172**	0.2698

Residual effect = 0.0012

Where, LBL=Leaf Blade length, LBW=Leaf blade width, PH=Pseudostem height, GS=Girth size, NS=Number of sucker, PL=Petiole length, FPT=Fruit peel thickness, BW=Bunch weight, NH=Number of hand/bunch, NF=Number of finger/hand, PW=Pulp weight, WP=Weight of peel, PPR=Pulp peel ratio, FW=Fruit weight

4.1.6.5 Divergence analysis

The concept of D^2 statistic was originally developed by Mahalanobis (1936). Then Rao (1952) suggested the application of this technique for the arrangement of genetic diversity in plant breeding. Now this technique is being extensively used in vegetable breeding also to study the selection of different parents. Genetic variability and selection of parents from diverse breeding material including germplasm and there diverse parents, can be used for the development of hybrids in banana.

Percentage contribution of fourteen characters towards diversity in banana genotypes has been presented in table 4.12 and graphically in figure 4.7. The genetic diversity among twenty banana genotypes shows that out of the fourteen characters studied fruit weight (63.51%) contributed maximum percent to the diversity followed by girth size (10.74%), leaf blade length (5.44%), petiole length (5.02%), weight of peel (3.90%), bunch weight (3.41%), pseudostem height (3.27%), fruit peel thickness (2.66%), number of fingers/hand (0.78%), no. of hands/bunch (0.74%) and leaf blade width (0.44%).

Table 4.12 Percentage contribution of fourteen characters towards diversity in banana genotypes

Characters	Contribution (%)
Girth size	10.74
Pseudostem height	3.27
Leaf blade length	5.44
Leaf blade width	0.44
Petiole length	5.02
Bunch weight	3.41
No. of hands/bunch	0.74
No. of fingers/hand	0.78
Fruit weight	63.51
Weight of peel	3.90
Fruit peel thickness	2.66

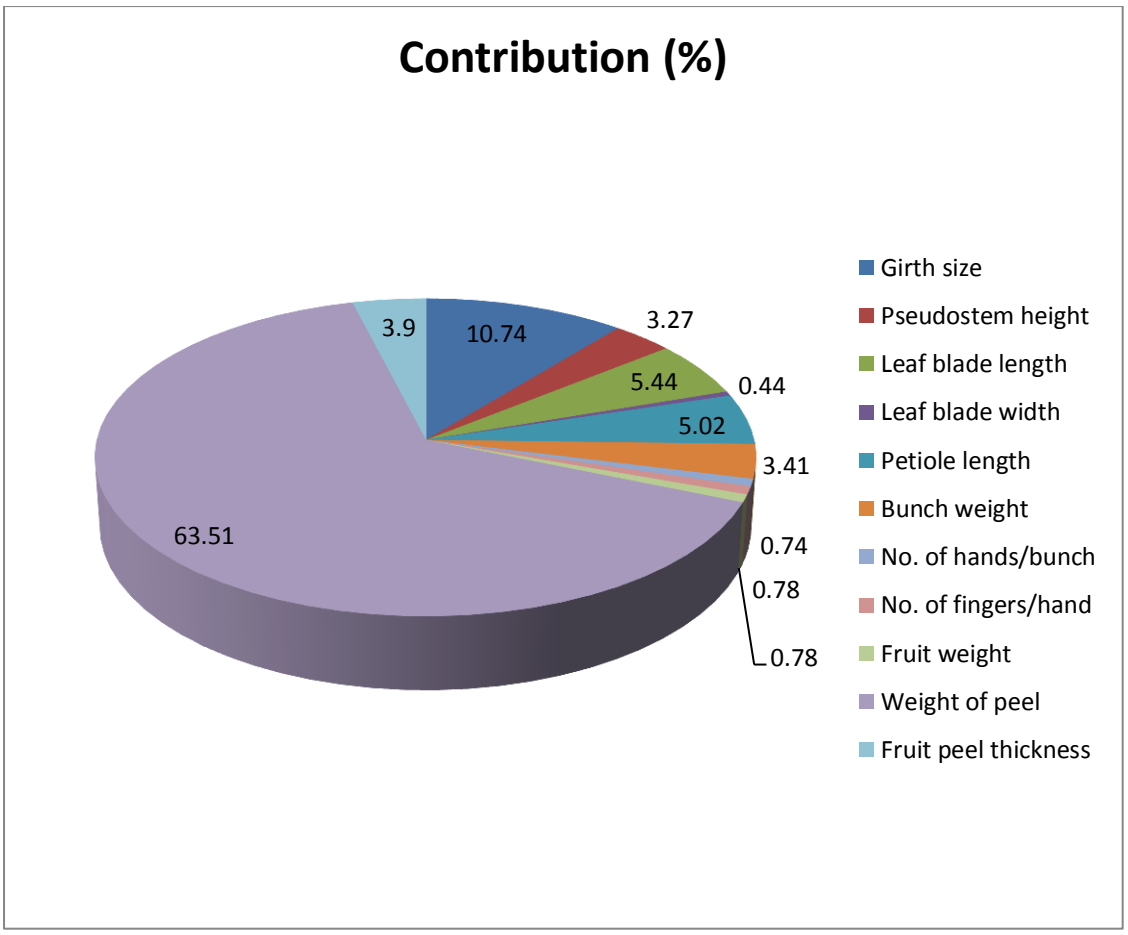


Figure 4.7 Contribution (%) of various quantitative characters of banana genotypes towards genetic divergence

Based on D^2 value, twenty genotypes were grouped into six clusters (table 4.13 and figure 4.8). The clusters were based on the fourteen quantitative characters under study. Maximum number of genotypes was included in cluster I with 8 genotypes *viz.* Jahaji, Lumungashe, Bharatmani, Kwetho, Lumumgto, Kwegha, Gumsang and Red Banana followed by cluster II which comprised of 5 genotypes that includes Chinichampa, Kanthali, Luipet, Rakannak and Phfeprei. Cluster III was made up of Bhootmanohar, Nendran, Subjikol and Grand Naine. The remaining clusters IV, V and VI consist of genotypes Meiteihei, Yhuro and *M. velutina* respectively.

Table 4.13 Grouping of banana genotypes based on D^2 analysis

Cluster	Number of genotypes	Genotypes
Cluster I	8	G-3, G-5, G-6, G-9, G-11, G-13, G-14, G-20
Cluster II	5	G-2, G-4, G-15, G-16, G-17
Cluster III	4	G-1, G-7, G-8, G-12
Cluster IV	1	G-10
Cluster V	1	G-18
Cluster VI	1	G-19

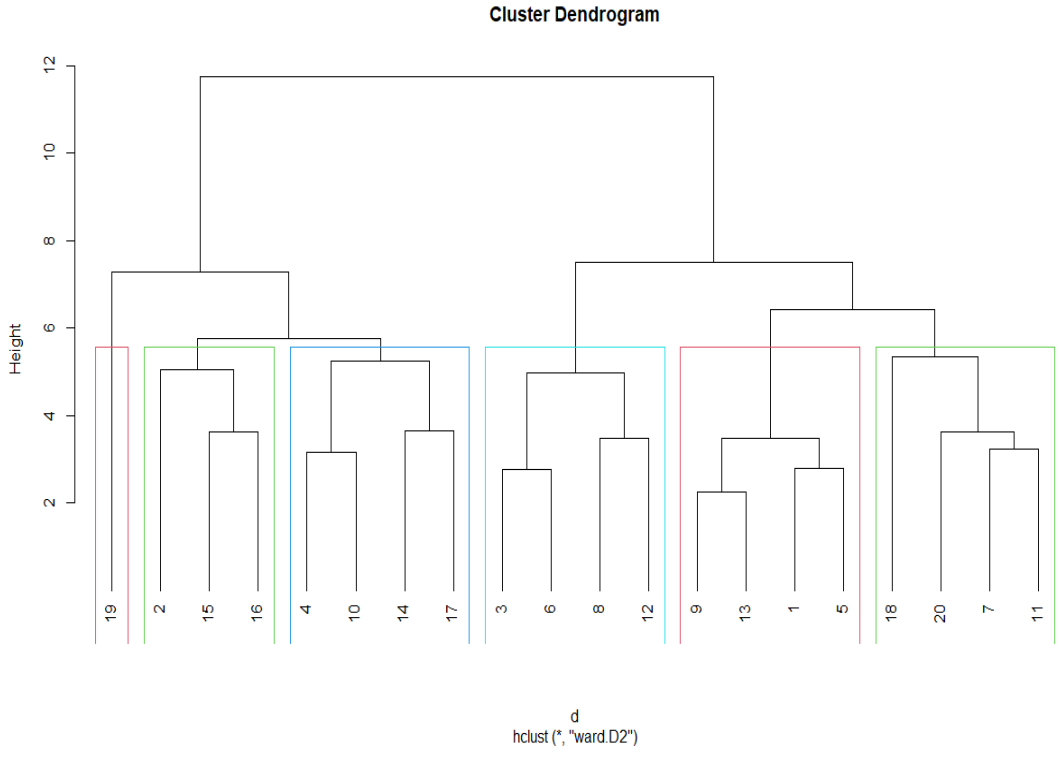


Figure 4.8 Tree diagrams of twenty genotypes of banana for fourteen studied characters using hierarchical cluster analysis (Ward's Method)

4.1.6.5.1 Inter and intra cluster distance

Inter cluster D^2 values are given in the table 4.14. The inter cluster D^2 value was maximum (6.696) between cluster I and II. The minimum (4.632) distance was observed between cluster IV and VI which indicated close relationship among the genotypes included in these two clusters.

The highest intra cluster distance was observed in cluster V (4.414) followed by cluster I (3.866) and cluster IV (3.738). While lowest intra cluster distance was observed in cluster VI (3.433) followed by cluster III (3.480). Intra cluster D^2 values have been presented in the table 4.14.

The intercluster D^2 values were expressed as the diversification among the groups of genotypes resembling each other and intracluster D^2 values were expressed as the magnitude of divergence between clones within a cluster. The higher inter-cluster distances in present investigation reflecting the wider diversity among the breeding lines of the different group. Hence, it is suggested that intercrossing of genotypes from diverse clusters showing high mean performance will be helpful in obtaining better recombinants with higher genetic variability. Similar findings were also observed by Valsalakumari *et al*. (1985), Mercy and George (1987) and Rajamanickam and Rajmohan (2010).

Table 4.14 Average inter and intra cluster distance (D^2)

Cluster number	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI
Cluster I	**3.866**	6.696	4.981	4.648	6.142	4.889
Cluster II		**3.699**	5.823	5.972	5.315	4.983
Cluster III			**3.480**	4.691	6.235	4.744
Cluster IV				**3.738**	6.252	4.632
Cluster V					**4.414**	5.556
Cluster VI						**3.433**

4.1.6.5.2 Cluster mean analysis

Cluster mean analysis was computed in all 6 clusters for 14 characters studied and presented in table 4.15. It can be seen from the cluster means that each cluster has its uniqueness that separated it from other clusters. The data revealed that mean values of leaf blade length were found to be maximum (258.33) in cluster VI and minimum (153.41) in cluster V. The mean values of leaf blade width were recorded maximum (87.50) in cluster I and minimum (153.41) in cluster V. With respect to pseudostem height and girth size cluster VI was found to be maximum (7.40, 78.74) and minimum (3.77, 39.90) in cluster VI respectively. Number of suckers was found maximum (3.89) in cluster III and minimum (2.80) in cluster VI. Petiole length was found maximum (72.83) in cluster II and minimum (29.67) in cluster III. Mean values of fruit peel thickness was found maximum (3.35) in cluster I and minimum (1.43) in cluster II. Bunch weight was recorded highest (13.75) in cluster III and lowest (4.50) in cluster V. Cluster mean values for number of hands/bunch was maximum (13.50) in cluster II and minimum (5.17) in cluster I. Number of finger/hand was recorded maximum (17.21) in cluster II and minimum (10.14) in cluster V. Pulp weight was found maximum (114.81) in cluster IV and minimum (34.96) in cluster V. Weight of peel was highest (48.44) in cluster I and lowest (13.05) in cluster II. Pulp:peel ratio was recorded highest (3.46) in cluster IV and lowest (1.91) in cluster I. Cluster mean values for fruit weight was highest (149.01) in cluster IV and lowest (48.67) in cluster II. Mean values for different traits in various clusters portrayed an interesting concept of the nature of diversity. Considerable differences in cluster mean values were visible for all the characters.

Table 4.15 Mean values of clusters for fourteen characters studied in banana genotypes

Cluster number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Cluster I	238.33	87.50	5.48	64.38	3.83	57.00	3.35	5.66	5.17	11.02	81.17	48.44	1.91	129.61
Cluster II	220.83	67.83	5.03	51.50	3.17	72.83	1.43	11.86	13.50	17.21	35.62	13.05	2.96	48.67
Cluster III	217.89	62.11	4.85	70.20	3.89	29.67	3.80	13.75	10.11	14.88	81.05	36.78	2.35	117.83
Cluster IV	218.00	69.83	6.22	71.58	3.00	56.67	2.82	12.54	7.42	11.66	114.81	34.37	3.46	149.01
Cluster V	153.41	56.00	3.77	39.90	3.25	66.83	2.00	4.50	7.08	10.14	34.96	17.51	1.95	52.47
Cluster VI	258.33	66.67	7.00	78.74	2.80	64.67	3.17	10.30	9.40	13.00	52.71	27.15	1.95	79.89

Where,

1=Leaf Blade length, 2=Leaf blade width, 3=Pseudostem height, 4=Girth size, 5=Number of sucker, 6=Petiole length, 7=Fruit peel thickness, 8=Bunch weight, 9=Number of hand/bunch, 10=Number of finger/hand, 11=Pulp weight, 12=Weight of peel, 13=Pulp peel ratio, 14=Fruit weight

4.1.6.6 Principal component analysis

The Principal Component Analysis (PCA) of all the fourteen characters of banana genotypes was performed by using correlation matrix. The principal components, Eigen values, per cent variability, cumulative per cent of variability and component loading of different quantitative traits studied has been presented in table 4.16 and figure 4.9 and 4.10. The principal components with Eigen values less than one were considered to be non-significant as per the procedure. In the present study, four principal components with Eigen values more than one contributed to 78.18% of cumulative variability among 20 genotypes of banana evaluated for 14 quantitative characters. The first four principal components which contributed 78.18% of the total cumulative variance with proportionate contribution value were 34.30%, 20.56%, 12.55% and 10.75% respectively. The value of principal components has both positive and negative values where positive value indicates that the relationship between the characters are closer, while the negative value indicates that the relationship between the characters are farther, making it desirable for the next breeding program. Based on these characters, selection will be initiated for developing a new breeding program.

Critical examination of table 4.16 revealed that the first principal component (PC1) explained 34.30% of the total variation. Characters like fruit weight (0.931), pulp weight (0.889), weight of peel (0.827), fruit peel thickness (0.698), bunch weight (0.661), pseudostem height (0.477), leaf blade width (0.457), leaf blade length (0.321), pulp:peel ratio (0.219) and number of fingers/hand (0.170) showed positive loadings explaining the maximum variance in the first principal component (PC1). Negative loading was observed in petiole length (-0.573) and number of hands/bunch (-0.037). The second principal component (PC2) described 20.56% of the variation and reflected significant positive loadings of girth size (0.800), pseudostem height (0.621),

number of fingers/hand (0.566), number of hands/bunch (0.558), leaf blade length (0.517), petiole length (0.459), pupl:peel ratio (0.341), bunch weight (0.266) and leaf blade width (0.218). Negative loadings were noted in number of suckers (-0.800), weight of peel (-0.299), fruit peel thickness (-0.268), fruit weight (-0.153) and pulp weight (-0.077). Chang *et al*. (2018) reported that the first two principal components accounted for maximum variations in *Musa* genotypes of Taiwan which was in accordance with the present findings. Asare *et al.* (2011) and Babu *et al.* (2016) also reported the first two principal components accounting maximum for total variation in cassava.

The third principal component (PC3) contributed to 12.55% of total variance and characterized positively by number of hands/bunch (0.666), number of fingers/hand (0.640), bunch weight (0.547), number of suckers (0.396), girth size (0.396) and pulp:peel ratio (0.141). Negative association was observed in petiole length (-0.375), leaf blade width (-0.263), weight of peel (-0.221), pseudostem height (-0.203), fruit weight (-0.142), pulp weight (-0.096), fruit peel thickness (-0.077) and leaf blade length (-0.073). The fourth principal component (PC3) contributed 10.75 % of total variation. It has positive association with fruit peel thickness (0.520), weight of peel (0.230), leaf blade length (0.469), pseudostem height ().221), number of fingers/hand (0.083), petiole length (0.086), girth size (0.071) and bunch weight (0.001). Negative association was observed in pulp:peel ratio (-0.811), pulp weight (-0.398), fruit weight (-0.220) and leaf blade width (-0.090).

Table 4.16 Principal component analysis

	PC1	PC2	PC3	PC4
Eigen value	4.802	2.879	1.758	1.506
Percentage of variance	34.302	20.563	12.557	10.758
Cumulative percentage of variance	34.302	54.864	67.422	78.180
No. of sucker	0.005	-0.800	0.396	0.071
Girth size	0.005	0.800	0.396	0.071
Pseudostem height	0.477	0.621	-0.203	0.221
Leaf blade length	0.321	0.517	-0.073	0.469
Leaf blade width	0.457	0.218	-0.263	-0.090
Petiole length	-0.573	0.459	-0.375	0.086
Bunch weight	0.661	0.266	0.547	0.001
No. of hands/bunch	-0.037	0.558	0.666	0.170
No. of fingers/hand	0.170	0.566	0.640	0.083
Fruit weight	0.931	-0.153	-0.142	-0.220
Pulp weight	0.889	-0.077	-0.096	-0.398
Weight of peel	0.827	-0.299	-0.221	0.230
Fruit peel thickness	0.698	-0.268	-0.077	0.520
Pulp peel ratio	0.219	0.341	0.141	-0.811

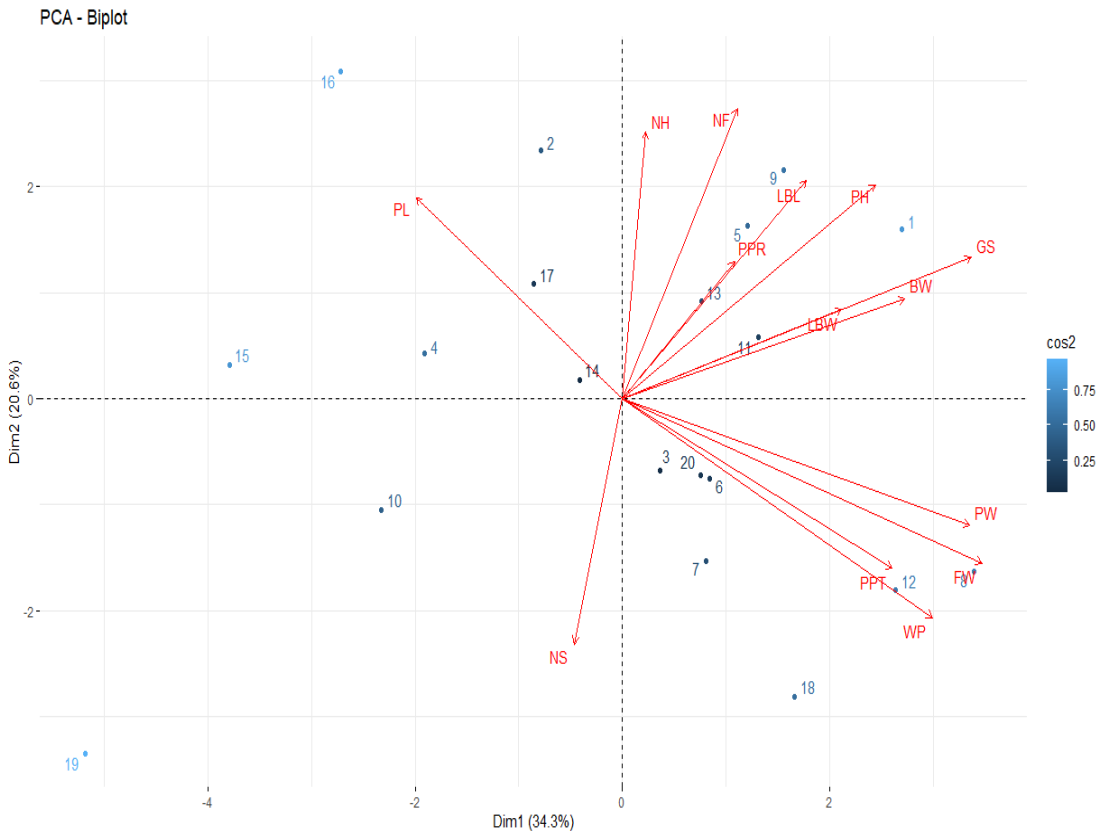


Figure 4.9 PCA Biplot depicting the first two principal components (54.864%)

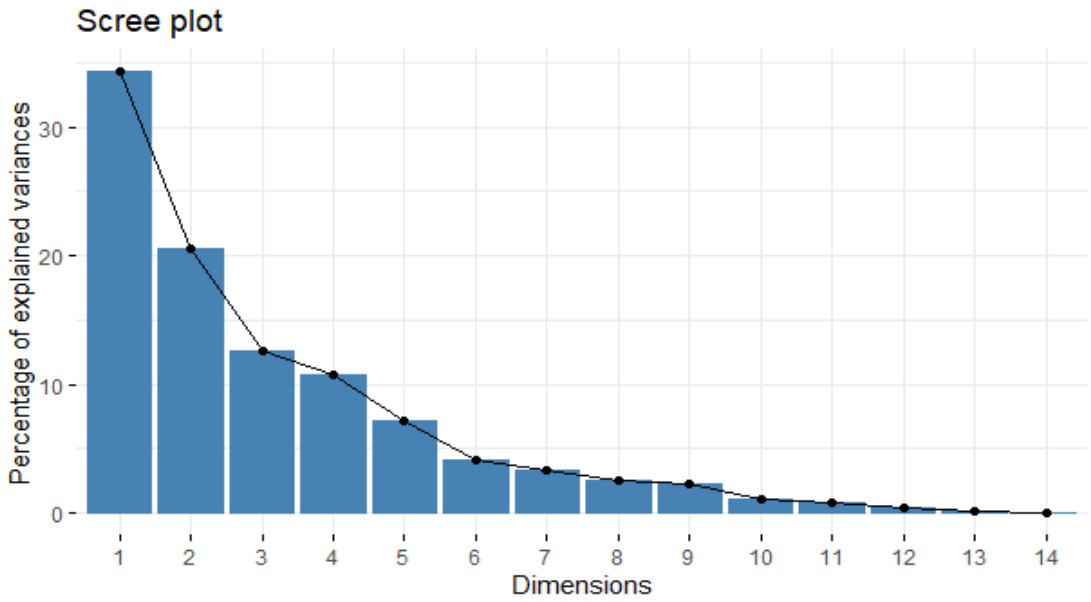


Figure 4.10 Scree plot depicting the cumulative percentage of variance

4.2 Experiment – 2

Ten banana genotypes were selected and evaluated for table purposes. Morphological characters of the banana fruits were determined based on IPGRI Descriptors for Banana (1996). Biochemical properties and mineral contents of the fruits were estimated. A sensory evaluation was conducted by a panel of experts to ascertain the suitability of the banana fruits for table purposes.

4.2.1 Fruit characters

The observation recorded on qualitative and quantitative fruit characters of different banana genotypes has been presented in table 4.17 and table 4.18 respectively.

4.2.1.1 Fruit shape

As given in table 4.17 genotypes Bhootmanohar, Kanthali, Lumungashe, Bharatmani, Kwetho and Meiteihei were found to have straight fruit shape. Chinichampa, Jahaji and Grand Naine recorded a slightly curved fruit shape and Nendran was the only genotype with fruit shape straight at the distal end.

4.2.1.2 Fruit apex

A variation was observed with respect to fruit apex (table 4.17). Bottlenecked fruit apex was observed in genotypes Chinichanpa, Bharatmani and Kwetho. Another three genotypes like Jahaji, Lumungashe and Grand Naine recorded a blunt tipped fruit apex. Pointed fruit apex was observed in genotype Bhootmanohar and Kanthali whereas Nendran was found to have lengthily pointed fruit apex and rounded fruit apex in Meiteihei.

4.2.1.3 Immature fruit peel colour

Immature fruit peel colour of various banana genotypes has been presented in table 4.17. It was observed that green was the dominant colour among all the genotypes. Green immature fruit peel colour was observed in

genotypes Bhootmanohar, Kanthali, Lumungashe, Kwetho and Meiteihei. Medium green was observed in Jahaji, Nendran and Grand Naine. Light green immature fruit peel colour was recorded in Chinichampa and Bharatmani.

4.2.1.4 Mature fruit peel colour

As evident from table 4.17, yellow colour of mature fruit peel was observed in genotypes Kanthali, Lumungashe, Bharatmani, Nendran and Meiteihei. Bright yellow colour was recorded in Chinichampa, Jahaji, Grand Naine and Kwetho. Only genotype Bhootmanohar recorded bright yellow with red tint mature fruit peel colour.

4.2.1.5 Pulp colour

Pulp colour of banana at maturity was recorded and presented in table 4.17. White was the dominant colour of pulp among the banana genotypes and was observed in genotypes Chinichampa, Kanthali, Lumungashe, Kwetho and Meiteihei. Orange yellow colour was observed in genotype Jahaji, Bharatmani and Nendran. Genotypes Bhootmanohar and Grand Naine possessed cream pulp colour.

4.2.1.6 Flesh texture

Flesh texture was recorded and grouped the banana genotype as firm and soft flesh texture (table 14.17). The banana genotypes that have firm flesh texture were Bhootmanohar, Kanthali, Lumungashe, Nendran and Kwetho. The remaining genotypes were grouped as soft flesh texture banana.

4.2.1.7 Presence of seed

Seeds were not detected among all the banana genotypes under study. The banana fruits are fleshy berry and developed parthenocarpically in most of the choicest varieties. The failure for seed development in banana fruit was attributed to be governed by a number of complex factors, although the fruits

enlarge and developed as vegetative parthenocarpy from the ovarian wall with the stimulus of inherent hormones synthesized in the ovary (Chattopadhay, 1996).

Table 4.17 Qualitative fruit characters of banana genotypes

Genotypes	Fruit shape	Fruit apex	Immature fruit peel colour	Mature fruit peel colour	Pulp colour	Flesh texture	Presence of seed
Bhootmanohar	Straight	Pointed	Green	Bright yellow with red tint	Cream	Firm	Not detected
Chinichampa	Slightly curved	Bottlenecked	Light green	Bright yellow	White	Soft	Not detected
Jahaji	Sightly curved	Blunt tipped	Medium green	Bright yellow	Orange yellow	Soft	Not detected
Kanthali	Straight	Pointed	Green	Yellow	White	Firm	Not detected
Lumungashe	Straight	Blunt tipped	Green	Yellow	White	Firm	Not detected
Bharatmani	Straight	Bottlenecked	Light green	Yellow	Orange yellow	Soft	Not detected
Nendran	Straight at the distal end	Lengthily pointed	Medium green	Yellow	Orange yellow	Firm	Not detected
Grand Naine	Slightly curved	Blunt tipped	Medium green	Bright yellow	Cream	Soft	Not detected
Kwetho	Straight	Bottlenecked	Green	Bright yellow	White	Soft	Not detected
Meiteihei	Straight	Rounded	Green	Yellow	white	Firm	Not detected

4.2.1.8 Bunch weight (kg)

The data with regards to bunch weight has been presented in table 4.18. The bunch weight was recorded in the range of 6.16 to 17.95kg where the maximum bunch was recorded in Grand Naine (17.95kg) followed by Chinichampa (16.55kg) which was at par with Bhootmanohar (15.95kg). The minimum bunch weight was observed in Meiteihei (6.16kg) followed by Nendran (6.25kg) and Kanthali (6.86kg). A similar finding was recorded by Rajeevan and Molunakumaran (1993) where significant variation in bunch weight in the main crop and first ratoon crop among the twenty four accession of Palayankodan banana. In a study by Babu (2001) it was noted that agro-climate and genetic variation are important factors that affect bunch weight. Bunch weight is an important character that has direct impact on yield. It is also a known fact that bunch weight is closely correlated with number of hands, number of fingers and weight of fingers.

4.2.1.9 Number of hands/bunch

The data pertaining to number of hands/bunch has been presented in table 4.18. A critical examination of the data clearly revealed significant variation in number of hands/bunch. It was observed in the range of 6.33 to 14.00. Highest number of hands/bunch was recorded in Chinichampa (14.00) followed by Lumungashe (11.33) and Grand Naine (10.33). Genotypes like Bhootmanohar (9.33), Jahaji (9.00), Kanthali (9.00) and Bharatmani (9.00) are statistically at par. Lowest number of hands/bunch was recorded in Nendran (6.33) followed by Meiteihei (7.67) and Kwetho (8.00). A similar finding was recorded by Rajeevan and Molunakumaran (1993) where significant variation in number of hands in the main crop and first ratoon crop among the twenty four accession of Palayankodan banana. The variation in number of hands in banana may be due to the relative water content where it helps in better translocation of photosynthates to fingers for better filling. In a study by Murali

et al. (2005) on yield and yield parameters of banana under the effect of soil moisture stress at different stages of growth revealed that highest fruit yield was obtained under no stress followed by stress at fruiting stage. A similar observation was reported by Surendar *et al*. (2013) while studying the effect of water deficit on relationship between yield and physiological attributes of banana cultivars and hybrids reported that water deficit cause reduction in number of hands per bunch.

4.2.1.10 Number of fingers/hand

As evident from the data presented in table 4.18, there was significant variation in number of fingers/hand. The number of fingers/hand was recorded in the range of 7.25 to 17.00. The maximum number of fingers/hand was observed in genotype Chinichampa (17.00) followed by Bharatmani (15.75), Grand Naine (15.36) and Kwetho (13.75) which was at par with Bhootmanohar (13.37). The minimum number of fingers/hand was recorded in Nendran (7.25) trailed by Meiteihei (8.89) and Kanthali (11.52). A similar finding was recorded by Rajeevan and Molunakumaran (1993) where significant variation in number of fingers in the main crop and first ratoon crop among the twenty four accession of Palayankodan banana. The variation in number of fingers in banana bunch may be due to the relative water content where it helps in better translocation of photosynthates to fingers for better filling. In a study by Murali *et al*. (2005) on yield and yield parameters of banana under the effect of soil moisture stress at different stages of growth revealed that highest fruit yield was obtained under no stress followed by stress at fruiting stage.

4.2.1.11 Fruit weight (g)

The result presented in table 4.18 revealed significant variations in fruit weight where it was recorded in the range of 65.21g to 162.55g. The maximum fruit weight was recorded in Grand Naine (162.55g) followed by Nendran

(152.87g) and Bhootmanohar (141.30g). Minimum fruit weight was observed in Kanthali (65.21g) which was statistically similar to Chinichampa (65.89g) followed by Meiteihei (76.92g) which was also statistically at par with Jahaji (77.48g). It is to be noted that the ultimate size attained by each finger is a function of conditions prevailing after flower initiation and is determined by soil fertility, moisture availability, temperature, leaf number and area during bunch development and stage of maturity at harvest. Variation in fruit weight was reported by Sunilkumar (1997), Mattos *et al*. (2010a) and Smith *et al*. (2014) which were in confirmation with the present study. Baker and Davis (1951) asserted that variation in fruit size may due to the difference in characters of the pericarp like cell size and intercellular space in different tissues of the fruit which contribute to increase in length, breadth and thickness of the fruits. Crane and Brown (1950) also mentioned that the increase in fruit size, weight and other parameters are due to accumulation of carbohydrates in fruit. The growth of fruit size in the later stage was due to osmotic accumulation of food substance and water (Combe, 1960).

4.2.1.12 Pulp weight (g)

Pulp weight of the fruit was recorded after complete removal of the peel and the weight was expressed in gram. The data obtained with regard to pulp weight has been presented in table 4.18. The pulp weight was recorded in the range of 45.39g to 117.31g and the maximum pulp weight was observed in Nendran (117.31g) followed by Grand Naine (107.00g) and Bhootmanohar (106.12g). Although Grand Naine has more fruit weight than Nendran but due its thick peel lower pulp weight was observed. The minimum pulp weight was recorded in Kanthali (45.39g) which was similar to Chinichampa (46.57g) followed by Meiteihei (52.78g) and Jahaji (57.45g). Geneotypes like Lumungashe (62.45g) and Kwetho (64.05g) were statistically at par.

4.2.1.13 Fruit peel thickness (mm)

The data pertaining to fruit peel thickness has been presented in table 4.18. The fruit peel thickness was recorded in the range of 1.47 to 4.73 mm. The maximum value for fruit peel thickness was recorded in Grand Naine (4.73 mm) followed by Jahaji (3.73 mm) and Bharatmani (3.33 mm) which was at par with Lumungashe (3.20 mm). The minimum fruit peel thickness was observed in Chinichampa (1.47 mm) followed by kanthali (2.10 mm) and Meiteihei (2.23 mm). Genotypes like Lumungashe (3.20 mm) and Bharatmani (3.33 mm) were statistically similar. Also no significant variation was recorded between genotype Nendran (2.63 mm) and Kwetho (2.77 mm). Borges *et al.* (2019) revealed that peel thickness decreases during the fruit ripening. The findings by Aquino *et al*. (2017) accurately summed up that decrease in fruit peel thickness can be attributed to the migration of water from peel to the pulp because of the osmotic gradient due to the increase of the sugar contents in the pulp in relation to the peel.

Table 4.18 Quantitative Fruit characters of banana genotypes

Treatments	Bunch weight (kg)	No. of hands/bunch	No. of fingers/hand	Fruit weight (g)	Pulp weight (g)	Fruit peel thickness (mm)
Bhootmanohar	15.95^{g}	9.33^{bcd}	13.37^{d}	141.30^{f}	106.12^{f}	2.57^{de}
Chinichampa	16.55^{g}	14.00^{e}	17.00^{f}	65.89^{a}	46.57^{a}	1.47^{g}
Jahaji	13.49^{e}	9.00^{bcd}	13.00^{cd}	77.48^{b}	57.45^{c}	3.73^{b}
Kanthali	6.86^{b}	9.00^{bcd}	11.52^{c}	65.21^{a}	45.39^{a}	2.10^{f}
Lumungashe	15.26^{f}	11.33^{d}	12.63^{cd}	96.60^{d}	62.45^{d}	3.20^{c}
Bharatmani	8.65^{d}	9.00^{bcd}	15.75^{ef}	111.23^{e}	76.89^{e}	3.33^{c}
Nendran	6.25^{ab}	6.33^{a}	7.25^{a}	152.87^{g}	117.31^{h}	2.63^{d}
Grand Naine	17.95^{h}	10.33^{cd}	15.36^{e}	162.55^{h}	107.00^{g}	4.73^{a}
Kwetho	7.61^{c}	8.00^{abc}	13.75^{d}	89.00^{c}	64.05^{d}	2.77^{d}
Meiteihei	6.16^{a}	7.67^{ab}	8.89^{b}	76.92^{b}	52.78^{b}	2.23^{ef}
Range	6.16-17.95	6.33-14	7.25-17	65.21-162.55	45.39-117.31	1.47-4.73
SE(m)±	0.21	0.69	0.54	1.05	0.87	0.11
CD (0.05)	0.64	2.04	1.61	3.13	2.58	0.33

*Means with different superscript letters within column are significantly different from each other by Duncan Multiple Range Test (p = 0.05)

4.2.2 Biochemical observations

The ripened banana samples were evaluated for various biochemical characteristics and the results have been presented in table 4.19.

4.2.2.1 Total soluble solids – TSS (^{o}B)

The data with regards to total soluble solids (TSS) of banana genotypes has been presented in table 4.19 and demonstrated graphically in figure 4.11. It was recorded in the range of 15.78 to 24.39 where the maximum TSS was found in Bhootmanohar (24.39) followed by Grand Naine (22.33) which was at par with Chinichampa (22.23), Jahaji (21.88) and Kanthali (21.69). The minimum TSS was recorded in Lumungashe (15.78) which was similar to Meiteihei (16.03) followed by Bharatmani (17.20) and Nendran (18.31).

TSS is an important attribute of fruits that can serve as a useful index in the determination of fruit maturity and ripeness. The TSS of fruit pulp gives a rough idea of the sweetness because it includes all types of soluble solids. As reported by Lu (2004), TSS is an important quality attribute for many fresh fruits during ripening. . In a study by Siji and Nandini (2017), TSS content of Kanthali, Nendran and Robusta were recorded at 23.90^{0}B, 22.00^{0}B and 20.30^{0}B respectively. Variation in TSS content was reported by many researchers. Cano *et al*. (1997) evaluated two Spanish and one Latin-American banana and outline TSS in the range of 16.30 to 24.56^{0}B. Mattos *et al*. (2010b) reported that among 26 accession of banana the mean total TSS content was 19.48^{0}B with a range of 14.60^{0}B to 25.70^{0}B. A study by Sandipkumar and Shanmuga (2015) revealed that the magnitude of increase in total soluble solids in banana is dependent on cultivar.

4.2.2.2 Acidity (%)

As presented in table 4.19 and graphically in figure 4.12, varietal differences in terms of titrable acidity were observed to be statistically

significant. Data shows significant variation in different genotypes for titrable acidity within the range of 0.40-0.72%. The genotype Bhootmanohar was found to be least acidic (0.40%) when compared to other genotypes and was followed by Lumungashe (0.41%) and Kwetho (0.43%). Highest acidity content was recorded in Chinichampa (0.72%) followed by Nendran (0.53%) and Meiteihei (0.51%). According to Sadler and Murphy (2010), titrable acidity is a measured for the determination of total acid content present in a food. Sugar gives only sweetness but along with this acidity in different ratio contribute to a fine and characteristics taste of a particular fruit. In fruits, acidity decreases with ripening of fruits though it is a genetical character of individual variety. Cano *et al*. (1997) and Uma *et al*. (2006) have also observed the variation in acidity content in pulp of banana. High total titrable acidity is a desirable feature for the processing industry (Godoy, 2010; Aurore *et al*., 2009), which emphasize the suitability of Chinichampa for processing industry. In a comparative study, Sreedevi and Suma (2015) revealed that acidity content of inorganically cultivated Palayankodan was higher when compared to organically cultivated Palayankodan.

4.2.2.3 Total sugar (%)

The data pertaining to total sugar of banana genotypes has been presented in table 4.19 and figure 4.13. There was high variation in the composition of total sugar levels and it was recorded in the range of 9.21 to 16.20% where the maximum total sugar content was found in Grand Naine (16.20%) followed by Jahaji (15.64%), Nendran (15.25%) and Bhootmanohar (15.00%). Lowest total sugar content was recorded in Chinichampa (9.21%) followed by Kwetho (9.46%), Kanthali (10.10%) and Bharatmani (11.50%). In contrary to the present findings Godoy *et al.* (2016) reported a total sugar values between the range of 17.41 and 18.70 g glucose/100g among eight varieties of banana. A variation in total sugar content in banana has been

reported by Cano *et al*. (1997). One of the emminent changes that occur during ripening of banana pulp is the hydrolysis of starch into sugar and its subsequent accumulation (Lal *et al*., 1974). A similar finding has been reported by Tapre and Jain (2012) in advanced maturity stages of banana.

4.2.2.4 Reducing sugars (%)

The observation recorded for reducing sugars of banana genotypes has been presented in table 4.19 and graphically in figure 4.14. The result revealed reducing sugar in the range of 5.43 to 8.20%. Meiteihei (8.20%) genotype has the highest reducing sugar levels although it did not differ statistically from the Bhootmanohar (8.00%) genotype followed by Nendran (7.82%) and Jahaji (7.15%). The minimum reducing sugar levels were recorded in Kwetho (5.43%) followed by Kanthali (5.61%), Chinichampa (5.78%) and Lumungashe (6.00%). The genotypes Grand Naine (6.28%) and Bharatmani (6.30 %) were statistically at par. Presence of reducing sugars has significant impact to banana cultivators since they are involved in reactions of non-enzymatic darkening during processing (Oetterer and Sarmento, 2006).

4.2.2.5 Shelf life (Day)

The data pertaining to shelf life as recorded by counting the number of days until the fruit starts spoilage has been presented in table 4.18. The maximum shelf life has been recorded in Meiteihei (8.00 day) followed by Bhootmanohar (7.00 day) and Chinichampa (6.00 day) which was similar to Lumungashe (6.00 day) and Nendran (6.00 day). Minimum shelf life was recorded in Grand Naine (3.00 day) followed by Jahaji (4.00 day) which was similar to Bharatmani (4.00 day). The shelf life in fruits is associated with rate of respiration. The rate of respiration is slow in fruits stored at lower temperatures than in those stored at room temperature (Gane, 1936). This can be attributed to a slow-down in physiological processes within the fruit at lower temperatures. Early senescence was observed in fruits stored at room

temperature as the temperature was high and rate of the physiological processes was probably faster. Desai and Deshpande (1975) reported similar findings with various storage temperatures in banana.

4.2.2.6 TSS/Acid ratio

The data with regards to TSS/acid ratio has been presented in table 4.19. It was recorded in the range of 30.88 to 60.98 where the maximum TSS/acid ratio was found in Bhootmanohar (60.98) followed by Kanthali (49.30), Grand Naine (47.51) and Kwetho (46.88). Minimum TSS/acid ratio was recorded in Chinichampa (30.88) followed by Meiteihei (31.43) and Bharatmani (34.40) which was similar to Nendran (34.55). The TSS/Acid ratio index provides information on fruit flavour.

4.2.2.7 Crude protein (g/100g)

Examining table 4.19 and figure 4.15, there was a significant difference in protein concentration of the banana genotypes. The protein content of the genotypes ranged from 0.62 to 1.24 g/100g. The highest protein content was observed in Grand Naine (1.24 g/100g) tailed by Jahaji (1.14 g/100g), Chinichampa (1.10 g/100g) and Nendran (1.04 g/100g) while Bharatmani (0.62 g/100g) had the lowest value of protein concentration followed by Lumungashe (0.73 g/100g) and Kwetho (0.84 g/100g) which was similar to Meiteihei (0.84 g/100g). In a similar findings, the protein concentration of eight banana genotypes of Kerala range between 0.91 g/100g to 1.37 g/100g as reported by Siji and Nandini (2017). Climacteric fruits such as bananas have high protein content when they are mature. Fruit maturation and ripening is associated with increase in ethylene production. It is assumed that ethylene regulates the expression of genes involved in the maturation due to increased levels of protein in banana pulp tissue which is in line with the maturity of the fruit (Dominguez-Puigjaner *et al.*, 1992). The amount of amino acids required by the body is supplied by protein.

4.2.2.8 Total carotene (mg/100g)

A wide variation of total carotene concentration was found in the pulp of banana genotypes ranging from 2.68 mg/100g in white fleshed Meiteihei to 4.20 mg/100g in orange fleshed Bharatmani (Table 4.19, figure 4.16 and plate 20). The maximum total carotene content was recorded in Bharatmani (4.20 mg/100g) which was statistically equal to Nendran (4.05 mg/100g) followed by Grand Naine (3.82 mg/100g) and Jahaji (3.62 mg/100g). Meanwhile, Chinichampa (3.57 mg/100g) and Kwetho (3.48 mg/100g) were statistically at par. Lowest total carotene content was recorded in Meiteihei (2.68 mg/100g) followed by Lumungashe (2.79 mg/100g) and Bhootmanohar (3.01 mg/100g). Many researchers have reported about variation in total carotenoids content in banana pulp in their studies (Arora *et al*., 2008; Fungo and Pillay 2013; Borges *et al*., 2014). The banana flesh colour intensity indicates the carotenoid concentration. Orange flesh coloration recorded greater carotenoid concentration in the present study. A similar finding has been reported by Englberger *et al*. (2003a, 2003b), Amorim *et al*. (2009), Davey *et al*. (2009) and Newilah *et al.* (2008) in their studies.

Table 4.19 Performance on fruit quality of different banana genotypes

Treatments	TSS (^{0}Brix)	Acidity (%)	Total Sugar (%)	Reducing Sugar (%)	Shelf Life (Day)	TSS/Acid ratio	Crude protein (g/100g)	Total carotene (mg/100g)
Bhootmanohar	24.39^{f}	0.40^{a}	15.00^{ef}	8.00^{fg}	7.00^{e}	60.98^{g}	0.91^{bcd}	3.01^{b}
Chinichampa	22.23^{e}	0.72^{g}	9.21^{a}	5.78^{bc}	6.00^{d}	30.88^{a}	1.10^{de}	3.57^{d}
Jahaji	21.88^{e}	0.49^{de}	15.64^{fg}	7.15^{e}	4.00^{b}	44.65^{d}	1.14^{de}	3.64^{de}
Kanthali	21.69^{e}	0.44^{c}	10.10^{b}	5.61^{ab}	5.00^{c}	49.30^{f}	0.97^{cd}	3.24^{c}
Lumungashe	15.78^{a}	0.41^{ab}	13.82^{d}	6.00^{c}	6.00^{d}	38.49^{c}	0.73^{ab}	2.79^{a}
Bharatmani	17.20^{b}	0.50^{e}	11.50^{c}	6.30^{d}	4.00^{b}	34.40^{b}	0.62^{a}	4.20^{f}
Nendran	18.31^{c}	0.53^{f}	15.25^{f}	7.82^{f}	6.00^{d}	34.55^{b}	1.04^{cde}	4.05^{f}
Grand Naine	22.33^{e}	0.47^{d}	16.20^{g}	6.28^{d}	3.00^{a}	47.51^{ef}	1.24^{e}	3.82^{e}
Kwetho	20.16^{d}	0.43^{bc}	9.46^{ab}	5.43^{a}	5.00^{c}	46.88^{e}	0.84^{bc}	3.48^{d}
Meiteihei	16.03^{a}	0.51^{ef}	14.37^{de}	8.20^{g}	8.00^{f}	31.43^{a}	0.85^{bc}	2.68^{a}
Range	15.78-24.39	0.40-0.53	9.21-16.20	5.43-8.20	3-8	30.88-60.98	0.62-1.30	2.68-4.20
SE(m)±	0.35	0.01	0.25	0.10	0.14	0.70	0.07	0.07
CD (0.05)	1.03	0.02	0.75	0.29	0.41	2.09	0.21	0.20

*Means with different superscript letters within column are significantly different from each other by Duncan Multiple Range Test (p = 0.05)

G-6
Bharatmani

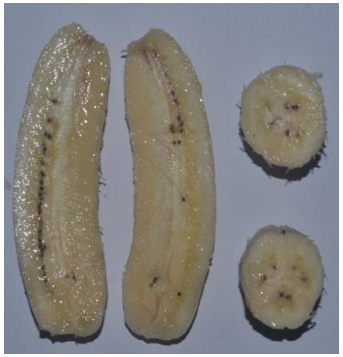
G-7
Nendran

G-8
Grand Naine

G-3
Jahaji

G-2
Chinichampa

G-9
Kwetho



G-4
Kanthali

G-1
Bhootmanohar

G-5
Lumungashe

G-10
Meiteihei

Plate 20. Tranverse section of banana fruit depicting the colour intensity of the pulp

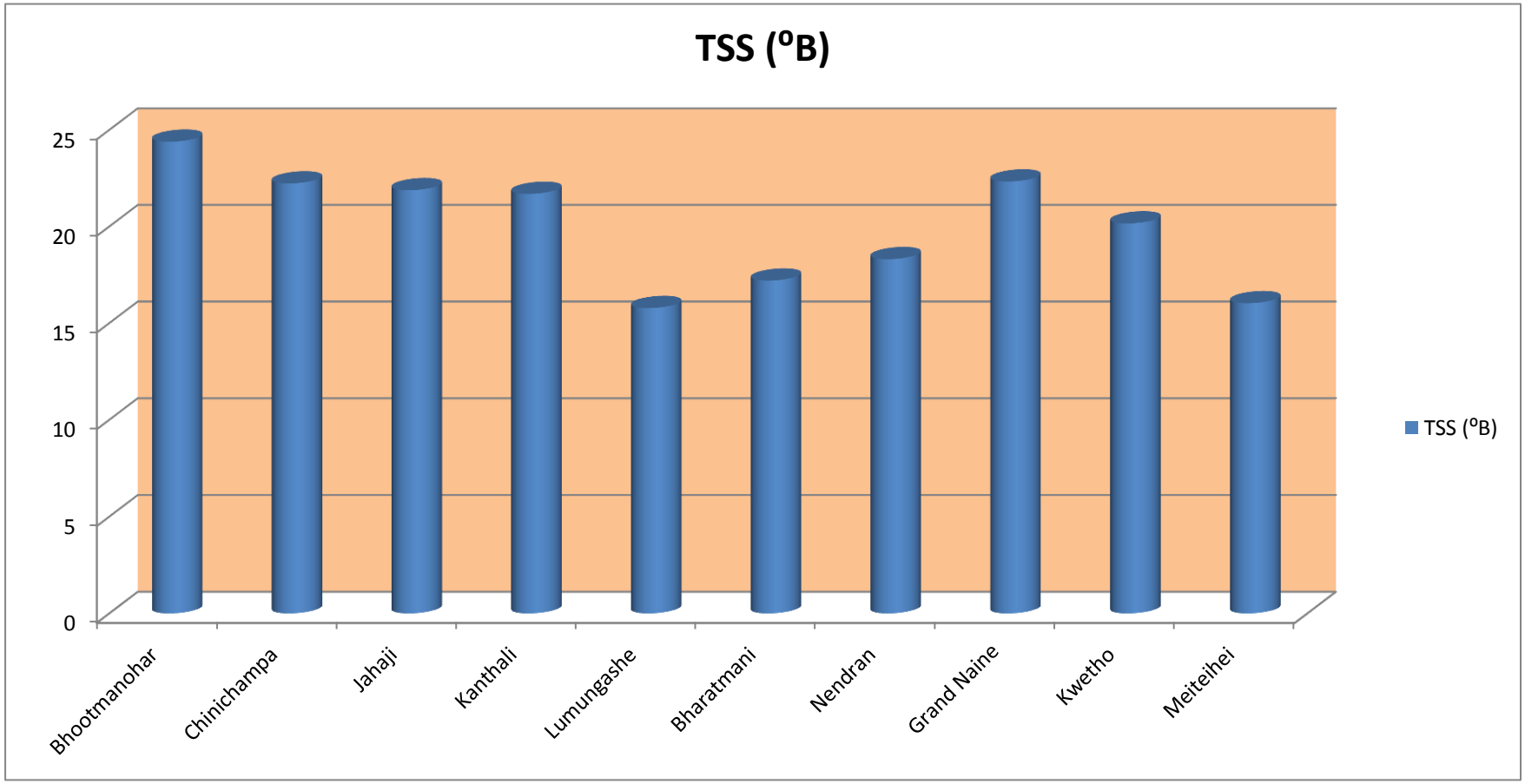


Figure 4.11 Performance of various genotypes of banana on TSS (^{0}B)

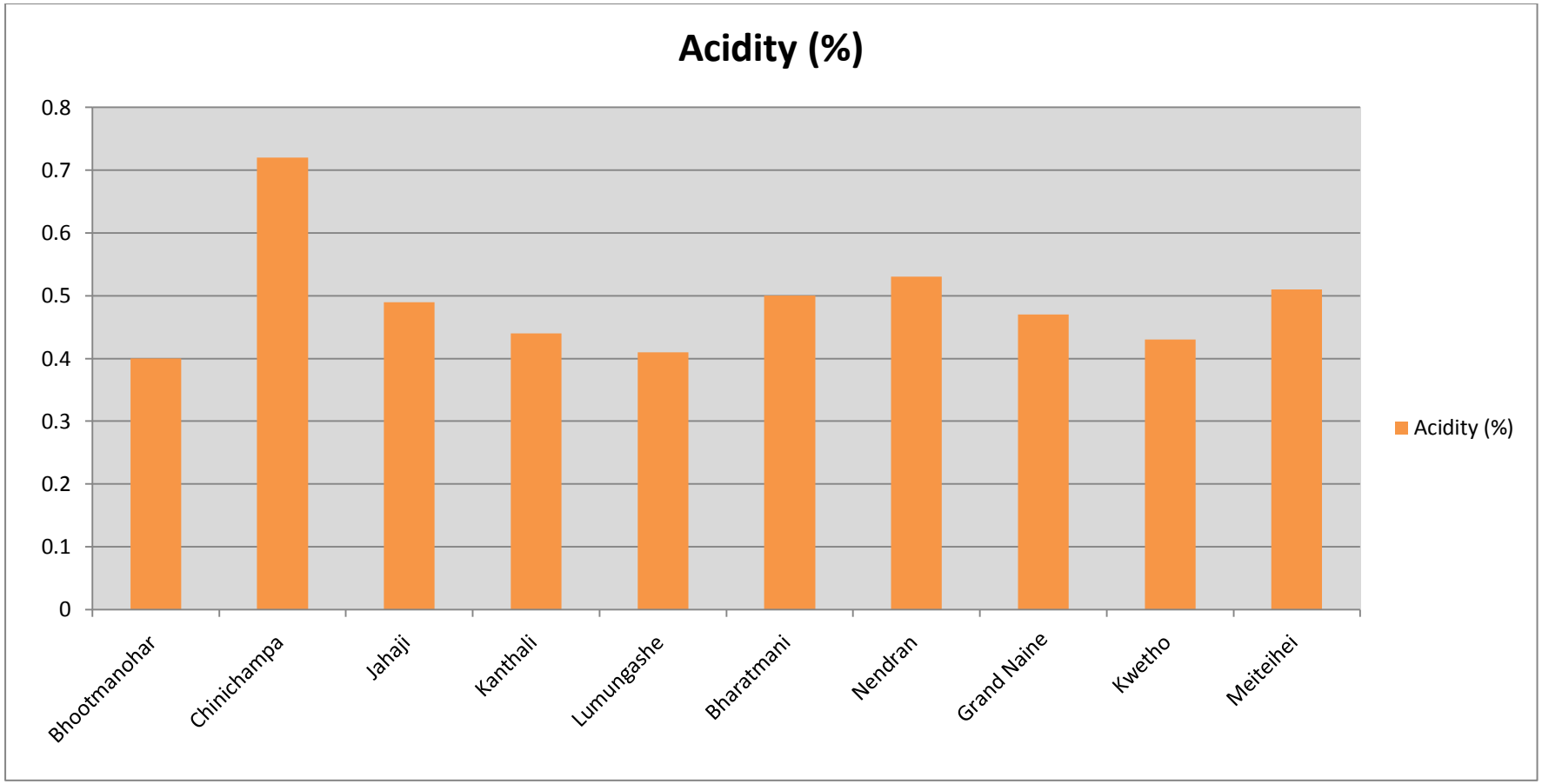


Figure 4.12 Performance of various genotypes of banana on acidity (%)

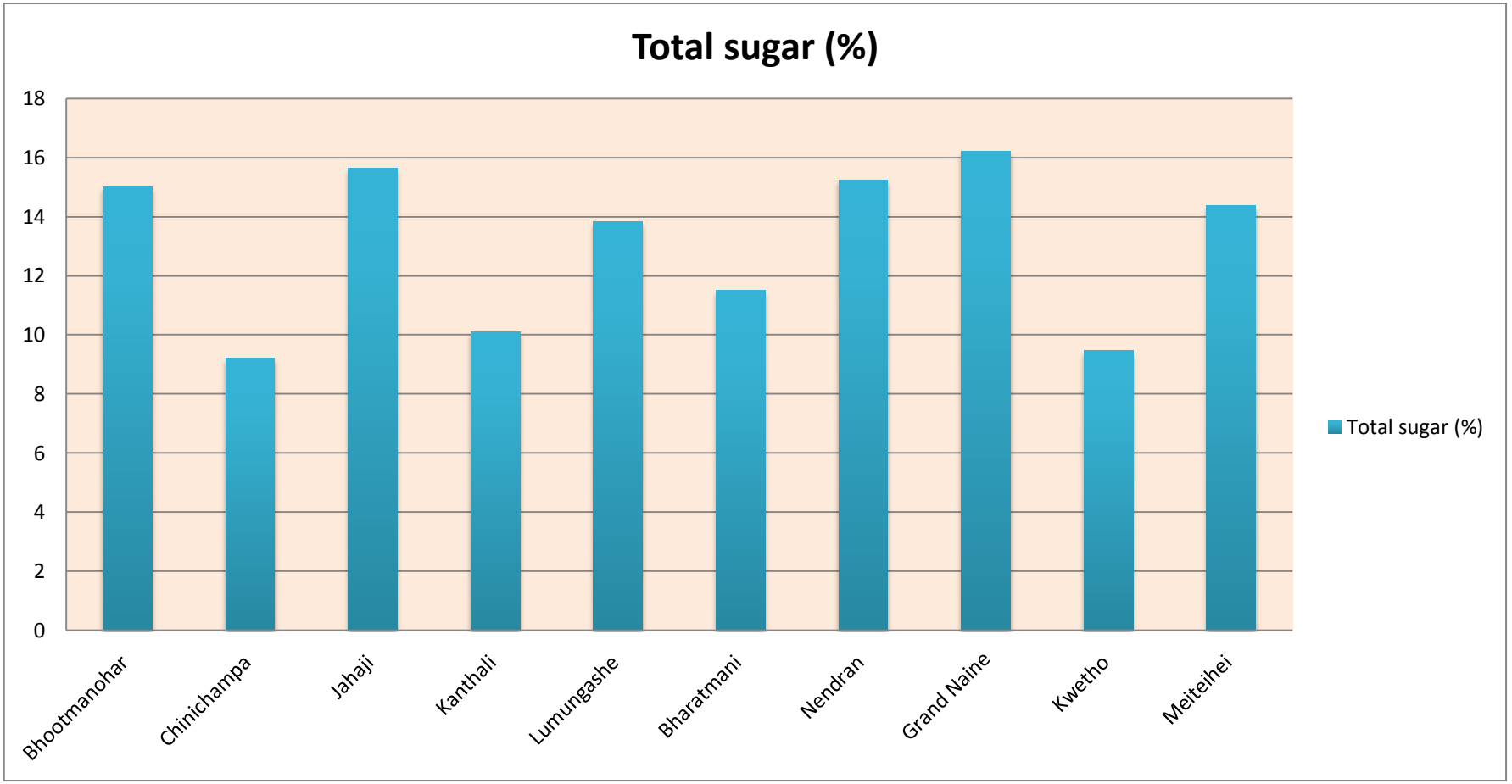


Figure 4.13 Performance of various genotypes of banana on total sugar (%)

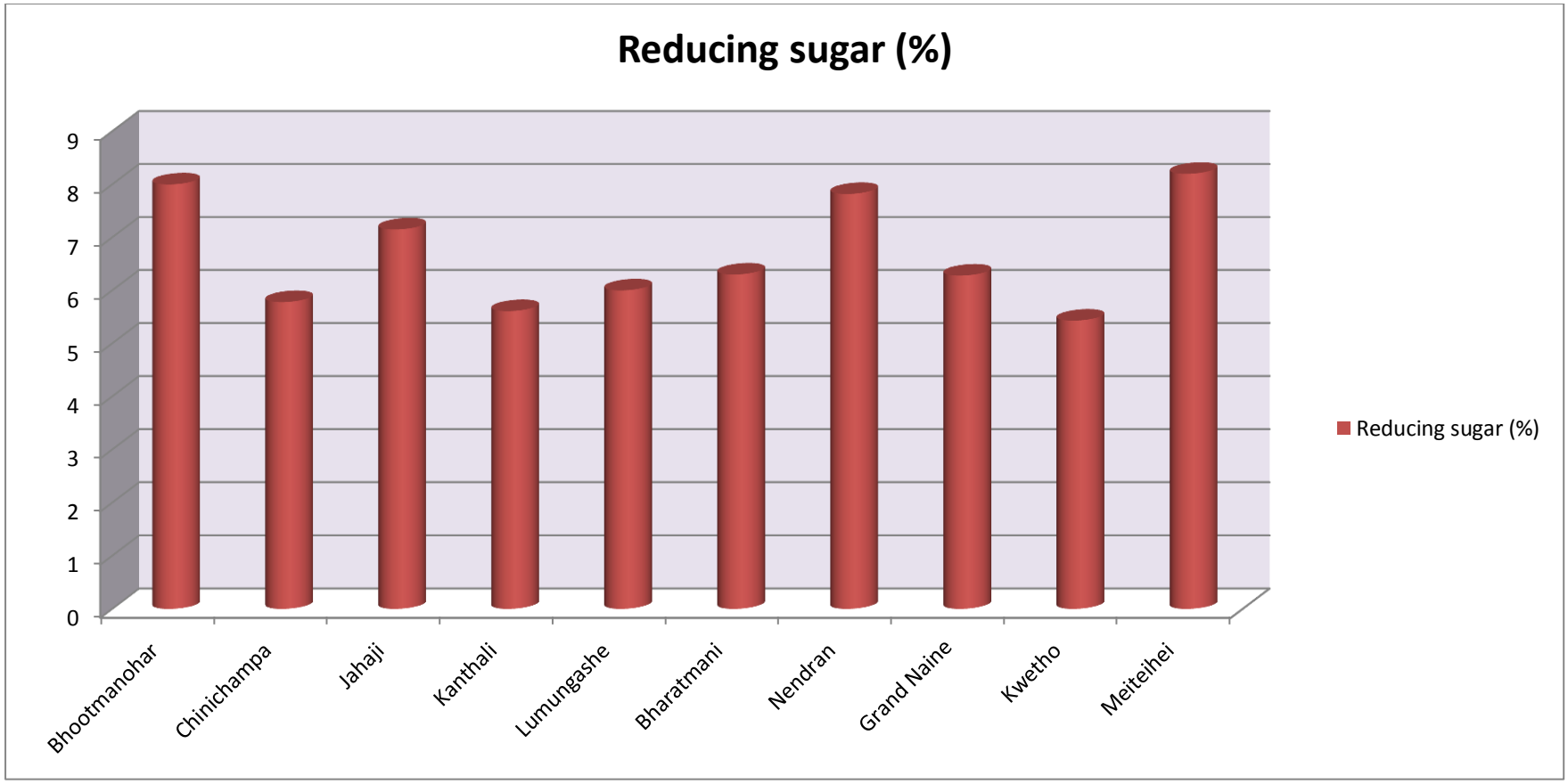


Figure 4.14 Performance of various genotypes of banana on reducing sugar (%)

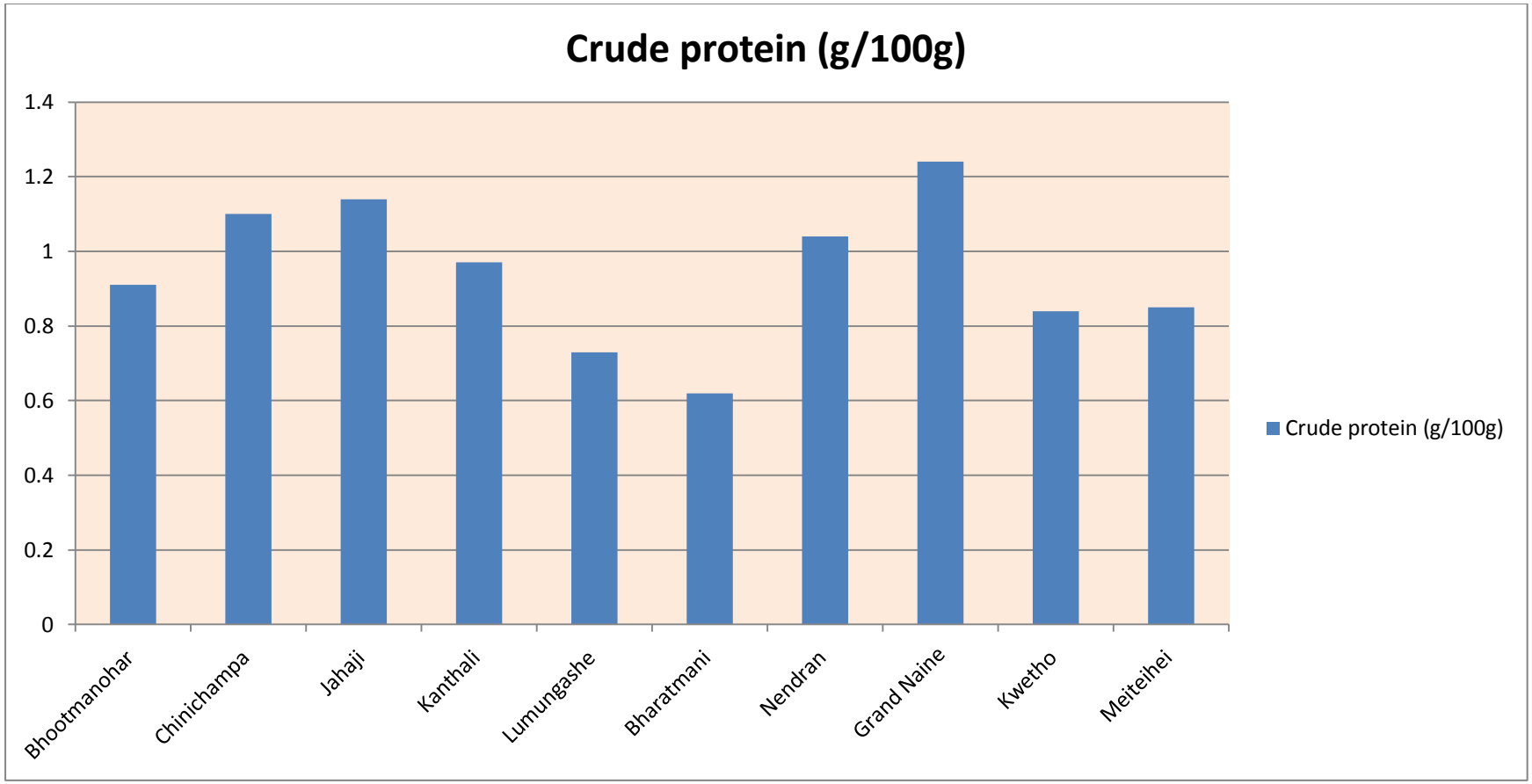


Figure 4.15 Performance of various genotypes of banana on crude protein (g/100g)

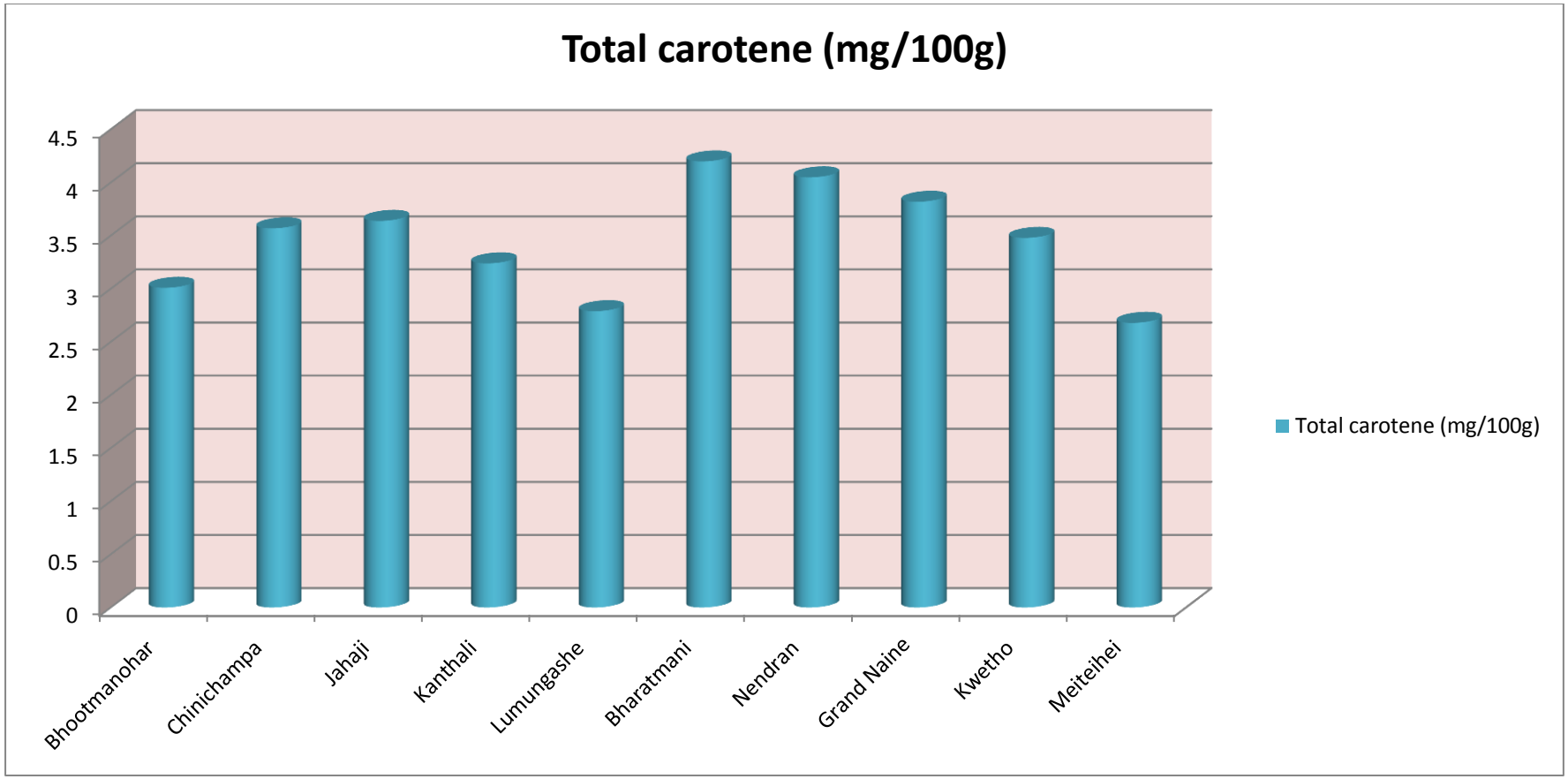


Figure 4.16 Performance of various genotypes of banana on total carotene (mg/100g)

4.2.3 Minerals content in pulp and peel of banana

The minerals content in both pulp and peel of banana genotypes were analyzed and the results have been presented in table 4.20.

4.2.3.1 Potassium (mg/100g)

The data obtained with regards to potassium content in banana pulp and peel has been presented in table 4.20 and figure 4.17. Total potassium content in the pulp was recorded in the range of 250.48 to 380.41 mg/100g. Maximum potassium content in pulp was obtained in Grand Naine (380.41 mg/100g) followed by Jahaji (360.19 mg/100g) and Bhootmanohar (302.84 mg/100g) which was at par with Kanthali (302.57 mg/100g) and Meiteihei (298.00 mg/100g). Lowest potassium content in pulp was recorded in Lumungashe (250.48 mg/100g) followed by Kwetho (265.73 mg/100g) which was similar to Chinichampa (270.00 mg/100g). Meanwhile the potassium content in peel was recorded in the range of 48.15 to 310.38 mg/100g. Maximum potassium content in peel was recorded in Jahaji (310.38 mg/100g) followed by Grand Naine (300.60 mg/100g) and Meiteihei (201.00 mg/100g) which was similar to Bhootmanohar (198.00 mg/100g). Lowest potassium content in peel was observed in Nendran (48.15 mg/100g) followed by Chinichampa (72.64 mg/100g) and Kanthali (127.95 mg/100g) which was similar to Kwetho (130.62 mg/100g). Genotypes Lumungashe (160.00 mg/100g) and Bharatmani (164.27 mg/100g) were also statistically at par.

Bananas are a rich source of mineral nutrients and it could serve as mineral element supplement in diet for both humans and animals (Morton, 1987; Stover and Simmonds, 1987). Potassium was found to be the most abundant element in all the genotypes under study where a similar finding has also been reported by Joachim *et al*. (2019) and Akinyoye (1991). High levels of potassium concentration in banana fruits are useful for people with cardiovascular compromised conditions (Daniells, 2003). Due to high

concentration of potassium in banana fruits, the peels of plantain and banana were also used as source of alkali in soap making (Debabandya, *et al.*, 2010). In a study by Smitha *et al*. (2015) in bananas grown in coastal belt of Karnataka, a significant variation in potassium concentration was reported and the highest potassium content was recorded in Cavendish (397.01 mg/100g) which was in accordance with the present findings. The variation in potassium content can be attributed to many factors such as sampling errors, difference in intercultural practices (Mayer, 1997), soil conditions including fertilizer application and storage (Sreedevi and Suma, 2015). Stage of fruits maturity and external environmental factors may also play a role in fluctuation of the nutrient content.

4.2.3.2 Boron (ppm)

The data pertaining to boron content in banana pulp and peel has been presented in table 4.20 and figure 4.18. The boron content in pulp was recorded in the range of 0.18 to 0.90 ppm. The maximum boron content in pulp was recorded in Jahaji (0.091 ppm) followed by Grand Naine (0.74 ppm), Bhootmanohar (0.61 ppm) and Kanthali (0.53 ppm) which was similar to Chinichampa (0.50 ppm) and Nendran (0.52 ppm). Lowest boron content in pulp was recorded in Bharatmani (0.18 ppm) followed by Lumungashe (0.26 ppm) and Kwetho (0.35 ppm). On the other hand, maximum boron content on peel was recorded in Jahaji (0.60 ppm) followed by Grand Naine (0.52 ppm), Bhootmanohar (0.45 ppm) and Chinichampa (0.39 ppm) which was similar to Nendran (0.38 ppm). The lowest boron content in peel was observed in Lumungashe (0.11 ppm) followed by Bharatmani (0.15 ppm) which was equal to Meiteihei (0.13 ppm) and Kanthali (0.28 ppm).

As evident from the data in table 4.20, low concentration of boron mineral was observed in both pulp and peel of banana fruits. Similar findings where low content of boron in various banana genotypes were reported by

Gates and Lehmann (1968), Monro *et al*. (1986), Chauhan *et al*. (1991) and Hardisson *et al*. (2001). Low concentration of boron in banana may be due to the fact that one-third of the cultivated soils in India are deficient in boron (Gupta *et al*., 2008). Availability of soil boron to plants is often related to the total boron content as well as other properties such as pH, $CaCO_3$ and organic matter contents, nutrient interactions, plant type or variety and environmental factors, which strongly influence the emergence of boron deficiency or toxicity in plants (Sakal *et al.*, 1996; Saha and Singh, 1997). Deficiencies of boron in Indian soils ranged from 2% in alluvial soils (Ustipsamments) of Gujarat to 68% in red soils (Calciorthhents, Haplustalfs) in Bihar, with a mean of 33% for the whole country (Singh, 1999; Singh 2006). A maximum occurrence of boron deficiency (54–86%) was recorded in Alfisol soils of Assam and West Bengal due to a decrease in water soluble boron with increase in rainfall (Sakal and Singh, 1995).

4.2.3.3 Iron (ppm)

The mean values of iron content in pulp and peel of banana genotypes were recorded and presented in table 4.20 and figure 4.19. The iron content in pulp of banana was in the range of 3.52 to 8.37 ppm. Maximum iron content in pulp of banana was recorded in Nendran (8.37 ppm) followed by Meiteihei (7.94 ppm) and Chinichampa (7.00 ppm). Genotypes Kanthali (5.43 ppm) and Bhootmanohar (5.32 ppm) were statistically at par. The lowest iron content in banana pulp was observed in Lumungashe (3.52 ppm) followed by Kwetho (4.03 ppm) which was similar to Bharatmani (4.16 ppm). In case of iron content in peel of banana it was recorded in the range of 1.00 to 7.00 ppm. The maximum iron content in peel was recorded in Nendran (7.00 ppm) followed by Meiteihei (5.83 ppm) and Chinichampa (5.00 ppm) which was similar to Grand Naine (4.92 ppm). The lowest iron content was recorded in Lumungashe

(1.00 ppm) followed by Bharatmani (2.17 ppm) and Kanthali (3.14 ppm) which was equal to Bhootmanohar (3.00 ppm).

Iron is an important component of hemoglobin and its deficiency can leads to anaemia. Increased catecholamine levels in children leading to abnormal behavior have been linked to iron deficiency and folic acid deficiency (Clark and Noudoost, 2014). The body requires iron, in particular hemoglobin and myoglobin for oxygen transport, protein synthesis and for forming heme enzymes including other iron-containing enzymes (Lieu *et al*., 2001). It is involved in the transport of oxygen from the lungs to the tissues (Gupta *et al.,* 2014). Iron has a recommended dietary allowance (RDA) of 18 mg (Alibabica *et al.,* 2016). The iron content in banana peel and pulp was quite low as indicated by the present study and similar findings has also been reported by Ogunlade *et al*. (2021) and Anhwange *et al.* (2009) for peel and Ogunlade *et al.* (2019) and Feming (1998) for pulp.

4.2.3.4 Zinc (ppm)

The data with regards to zinc content in pulp and peel of various banana genotypes has been presented in table 4.20 and illustrated graphically in figure 4.20. The zinc content in the pulp was in the range of 0.92 to 2.10 ppm. Maximum zinc content in pulp was recorded in Jahaji (2.10 ppm) followed by Chinichampa (1.90 ppm) which was at par with Nendran (1.85 ppm) and Grand Naine (1.71 ppm). Minimum zinc concentration was recorded in Lumungashe (0.92 ppm) followed by Bhootmanohar (1.00 ppm), Bharatmani (1.10 ppm) and Kwetho (1.30 ppm) which was similar to Meiteihei (1.36 ppm). On the other hand, the zinc content in peel was recorded in the range of 0.26 to 1.20 ppm. Maximum concentration of zinc in peel was observed in Chinichampa (1.20 ppm) followed by Grand Naine (1.00 ppm) and Jahaji (0.98 ppm). While the minimum zinc content in peel was detected in Bharatmani (0.26 ppm) followed

by Kwetho (0.36 ppm) and Lumungashe (0.49 ppm) which was similar to Bhootmanohar (0.52 ppm).

Zinc is an important trace element which functions in the body for cellular processes involving cerebral development, behavioral mechanisms and body repair especially regarding wound healing (Mlitan *et al*., 2014). Zinc also plays a key role in the regulation of insulin production of pancreatic tissues and glucose utilization by muscles and fat cells (Eleazu *et al*., 2013). It has recommended dietary allowance (RDA) of 4 to 14 mg. Zinc content in banana fruits was quite low as revealed by the present study and could suggest supplementation with zinc rich dietary options. In a similar manner, low zinc concentration was reported in Williams and Dwarf Brazilian banana cultivars (Wall, 2006). Mahesh *et al*. (2009) reported a low concentration of zinc in eleven banana cultivars from the Southern India which was in the range of 1.18 to 2.75 mg/kg. Mineral concentration of eleven banana fruits grown at different countries was reported by Fungo *et al*. (2007) where zinc content was recorded in the range of 0.04 to 0.74 mg/100g fresh weight.

4.2.3.5 Calcium (mg/100g)

The mean value of calcium content in pulp and peel of various banana genotypes has been presented in table 4.20 and graphically illustrated in figure 4.21. The calcium content in the pulp of banana was recorded in the range of 28.70 to 36.00 mg/100g. Maximum calcium content was recorded in Bhootmanohar (36.00 mg/100g) followed by Jahaji (35.74 mg/100g), Kanthali (34.41 mg/100g) and Grand Naine (33.93 mg/100g). The lowest calcium content was observed in Bharatmani (28.27 mg/100g) followed by Kwetho (29.89 mg/100g) which was at par with Nendran (30.26 mg/100g), Chinichampa (30.52 ppm) and Lumungashe (31.00 mg/100g). Calcium content in peel was recorded in the range of 11.25 to 25.50 mg/100g. Highest calcium content in peel was recorded in Grand Naine (25.50 mg/100g) followed by

Jahaji (20.64 mg/100g) and Bhootmanohar (17.28 mg/100g) which was equal to Kanthali (17.00 mg/100g). Lowest concentration of calcium was recorded in Bharatmani (11.58 mg/100g) which was statistically at par with Kwetho (12.00 mg/100g) and Chinichampa (12.51 mg/100g) followed by Nendran (13.79 mg/100g) which was similar to Lumungashe (14.30 mg/100g) and Meiteihei (15.10 mg/100g).

A moderate level of calcium content in both pulp and peel were observed in the present study making them useful calcium sources. Similar calcium levels has been reported by Wall (2006) and Oyeyinka and Afolayan (2019) in William cultivar of banana and other *Mus*a spp. respectively. It has also been reported that the calcium content of banana grown in the coastal belt of Karnataka was in a moderate range of 17.15 to 47.19 mg/100g fresh weight (Smitha *et al.*, 2015). On the contrary, a very low concentration of calcium in banana has also been reported by Siji and Nandani (2017) from selected varieties of banana from Kerala which was recorded in the range of 0.35 to 1.35 mg/100g. Calcium is an important mineral for optimal bone growth and development and for the heart, muscular and nervous system to function properly. It has a recommended dietary allowance (RDA) of 1000 mg for adults (Khan *et al*., 2011). Alteration in calcium flux can have adverse effects on insulin secretion which is a calcium dependent process (O'Connell, 2001).

4.2.3.6 Magnesium (ppm)

The estimated magnesium content in pulp and peel of banana has been presented in table 4.20 and displayed graphically in figure 4.22. The magnesium content in pulp was in the range of 101.93 to 320.00 ppm. The highest magnesium content was recorded in Jahaji (320.00 ppm) followed by Chinichampa (301.00 ppm) and Bhootmanohar (290.28 ppm). Low concentration of magnesium in pulp was recorded in Kanthali (101.93 ppm) which was at par with Bharatmani (108.51 ppm) and Nendran (110.02 ppm).

With regards to magnesium content in peel, it was detected in the range of 82.79 to 280.10 ppm. Highest content of magnesium in peel was recorded in Bhootmanohar (280.10 ppm) which was similar to Jahaji (275.61 ppm) followed by Chinichampa (243.00 ppm) and Meiteihei (150.52 ppm). Meanwhile, lowest magnesium content in peel was recorded in Kanthali (82.79 ppm) followed by Bharatmani (90.46 ppm) and Nendran (101.50 ppm) which was similar to Lumungashe (108.00 ppm).

Moderately quantifiable magnesium content was observed in the present study as evident from table 4.20 and figure 4.22. In a similar note Mahesh *et al.* (2009) reported a magnesium content of eleven banana cultivars from Southern India in the range of 095 to 590 mg/kg. Hassan *et al.* (2018) also reported mean magnesium content in peel of *Musa sapientium* to be at 44.50 mg/100g. A moderate level of magnesium concentration was also observed by Okareh *et al*. (2015) in ripened peel of plantain. Magnesium has a recommended dietary allowance (RDA) of 450 mg (Jahnen-Dechent and Ketteler, 2012) and is important for cardiac functioning and stemming the early phase of diabetes (Haq and Ullah, 2011), nerve impulse transmission, detoxification and bone and teeth structural strength (Kartika *et al*., 2011).

Table 4.20 Mineral content in pulp and peel of banana

Treatment	Potassium (mg/100g)		Boron (ppm)		Iron (ppm)		Zinc (ppm)		Calcium (mg/100g)		Magnesium (ppm)	
	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel
Bhootmanohar	302.84^{d}	198.00^{e}	0.61^{e}	0.45^{e}	5.32^{d}	3.00^{c}	1.00^{b}	0.52^{c}	36.00^{f}	17.28^{d}	290.28^{f}	280.10^{g}
Chinichampa	270.00^{b}	72.64^{b}	0.50^{d}	0.39^{d}	7.00^{f}	5.00^{e}	1.90^{g}	1.20^{i}	30.52^{b}	12.51^{a}	301.00^{g}	243.00^{f}
Jahaji	360.19^{e}	310.38^{g}	0.90^{g}	0.60^{g}	4.97^{c}	4.00^{d}	2.10^{h}	0.98^{g}	35.74^{ef}	20.64^{e}	320.00^{h}	275.61^{g}
Kanthali	302.57^{d}	127.95^{c}	0.53^{d}	0.28^{c}	5.43^{d}	3.14^{c}	1.63^{e}	0.65^{d}	34.41^{de}	17.00^{d}	101.93^{a}	82.79^{a}
Lumungashe	250.48^{a}	160.00^{d}	0.26^{b}	0.11^{a}	3.52^{a}	1.00^{a}	0.92^{a}	0.49^{c}	31.00^{b}	14.30^{b}	180.52^{d}	108.00^{c}
Bharatmani	287.42^{cd}	164.27^{d}	0.18^{a}	0.15^{b}	4.16^{b}	2.17^{b}	1.10^{c}	0.26^{a}	28.27^{a}	11.85^{a}	108.51^{a}	90.46^{b}
Nendran	278.26^{bc}	48.15^{a}	0.52^{d}	0.38^{d}	8.37^{h}	7.00^{g}	1.85^{g}	0.82^{f}	30.26^{b}	13.79^{b}	110.02^{a}	101.50^{c}
Grand Naine	380.41^{f}	300.60^{f}	0.74^{f}	0.52^{f}	6.24^{e}	4.92^{e}	1.71^{f}	1.00^{h}	33.93^{cd}	25.50^{f}	140.57^{b}	130.48^{d}
Kwetho	265.73^{b}	130.62^{c}	0.35^{c}	0.14^{cb}	4.03^{b}	2.31^{b}	1.30^{d}	0.36^{b}	29.89^{b}	12.00^{a}	156.75^{c}	124.00^{d}
Meiteihei	298.00^{d}	201.00^{e}	0.19^{a}	0.13^{b}	7.94^{g}	5.83^{f}	1.36^{d}	0.75^{e}	32.65^{c}	15.10^{c}	194.25^{e}	150.52^{e}
Range	250.48-380.41	48.15-310.38	0.18-0.90	0.11-0.60	3.52-8.37	1.00-7.00	0.92-2.10	0.26-1.20	28.27-36.00	11.85-25.50	101.93-320.00	82.79-280.10
SE(m)±	5.06	2.83	0.01	0.01	0.10	0.07	0.02	0.01	0.53	0.25	3.47	2.46
C.D (0.05)	15.05	7.08	0.03	0.02	0.31	0.21	0.07	0.04	1.58	0.76	10.31	7.31

*Means with different superscript letters within column are significantly different from each other by Duncan Multiple Range Test ($p = 0.05$)

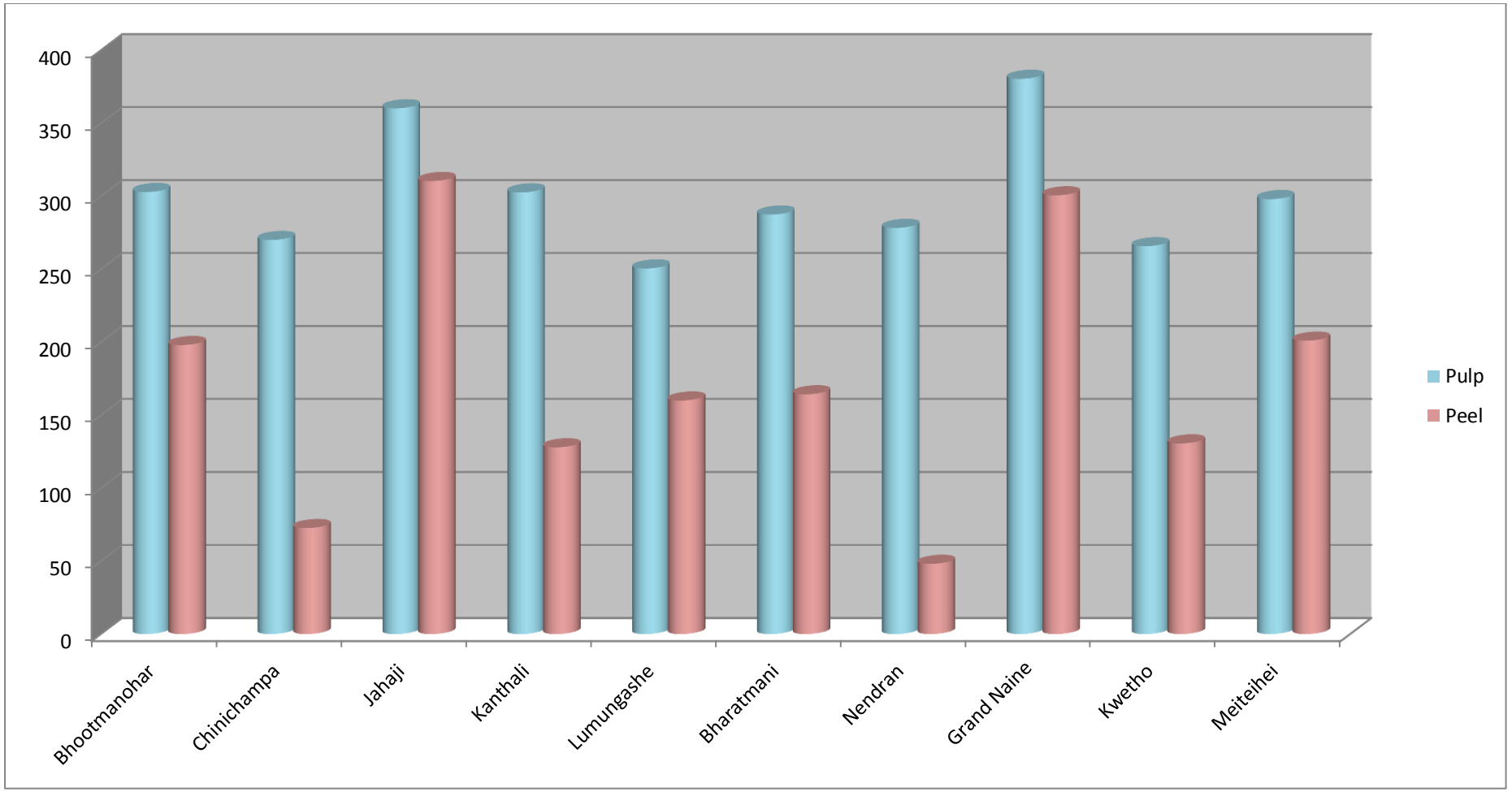


Figure 4.17 Concentration of potassium (mg/100g) mineral in pulp and peel of banana

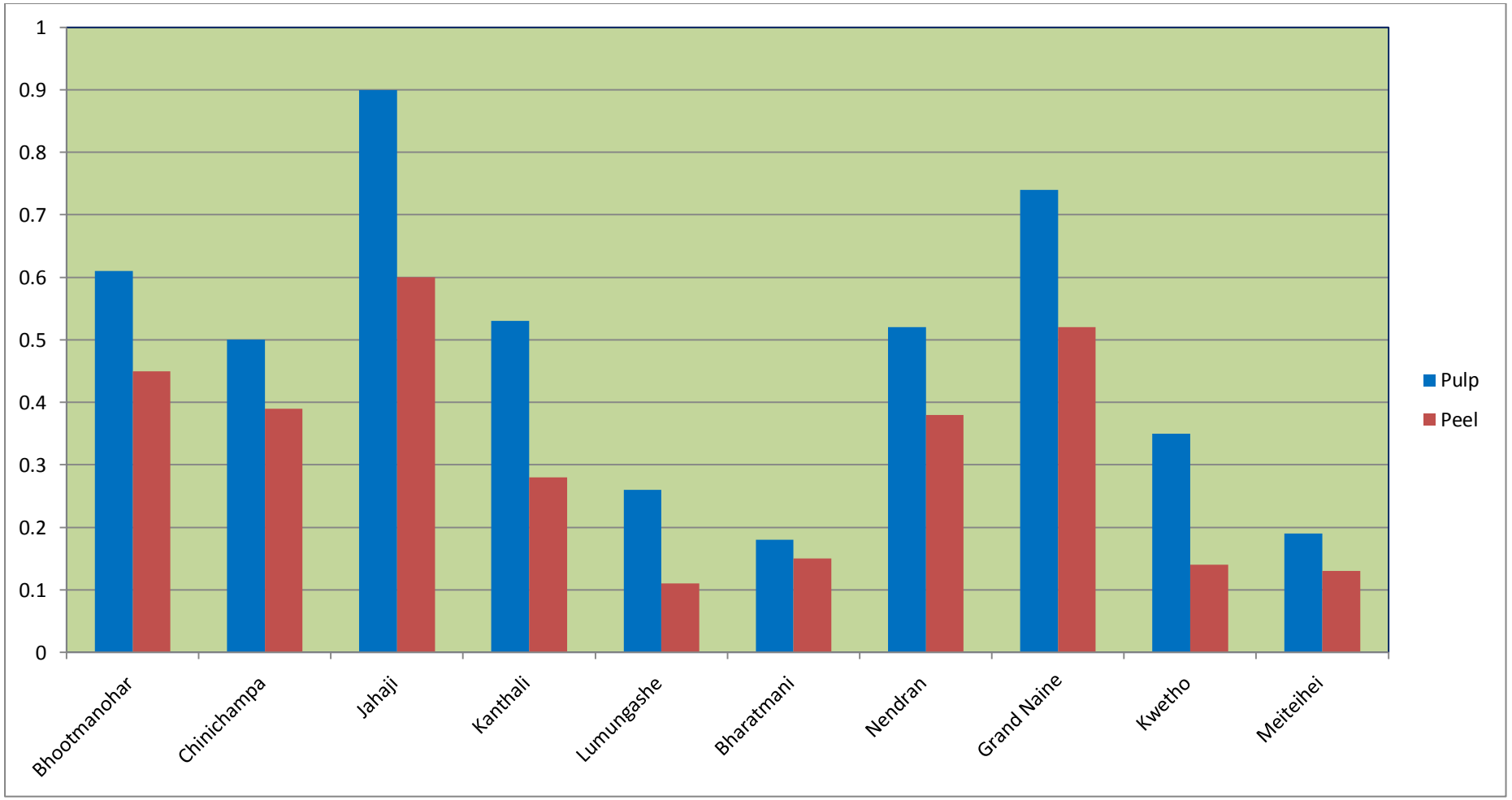


Figure 4.18 Concentration of boron (ppm) in pulp and peel of banana

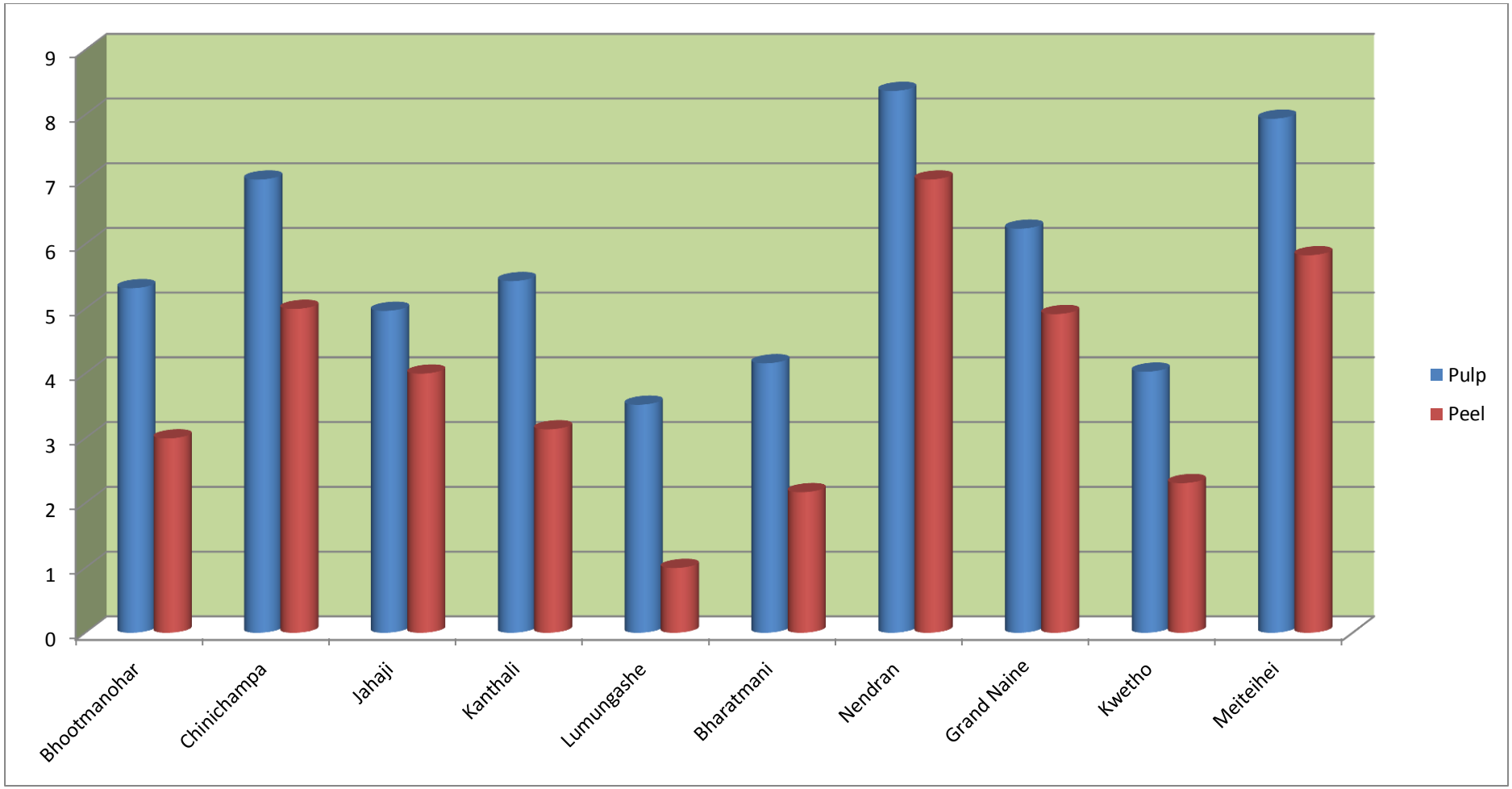


Figure 4.19 Concentration of iron (ppm) in pulp and peel of banana

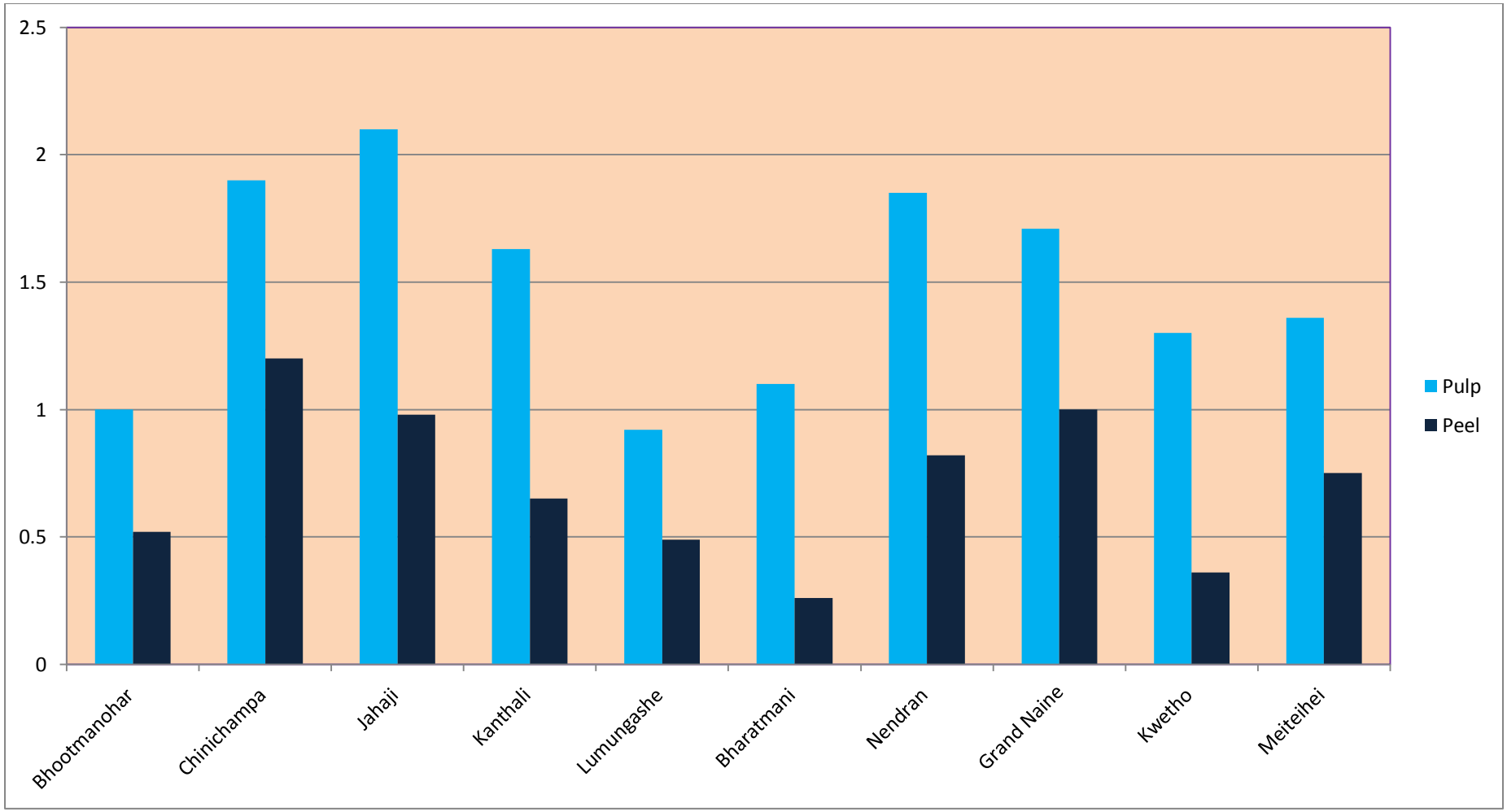


Figure 4.20 Concentration of zinc (ppm) in pulp and peel of banana

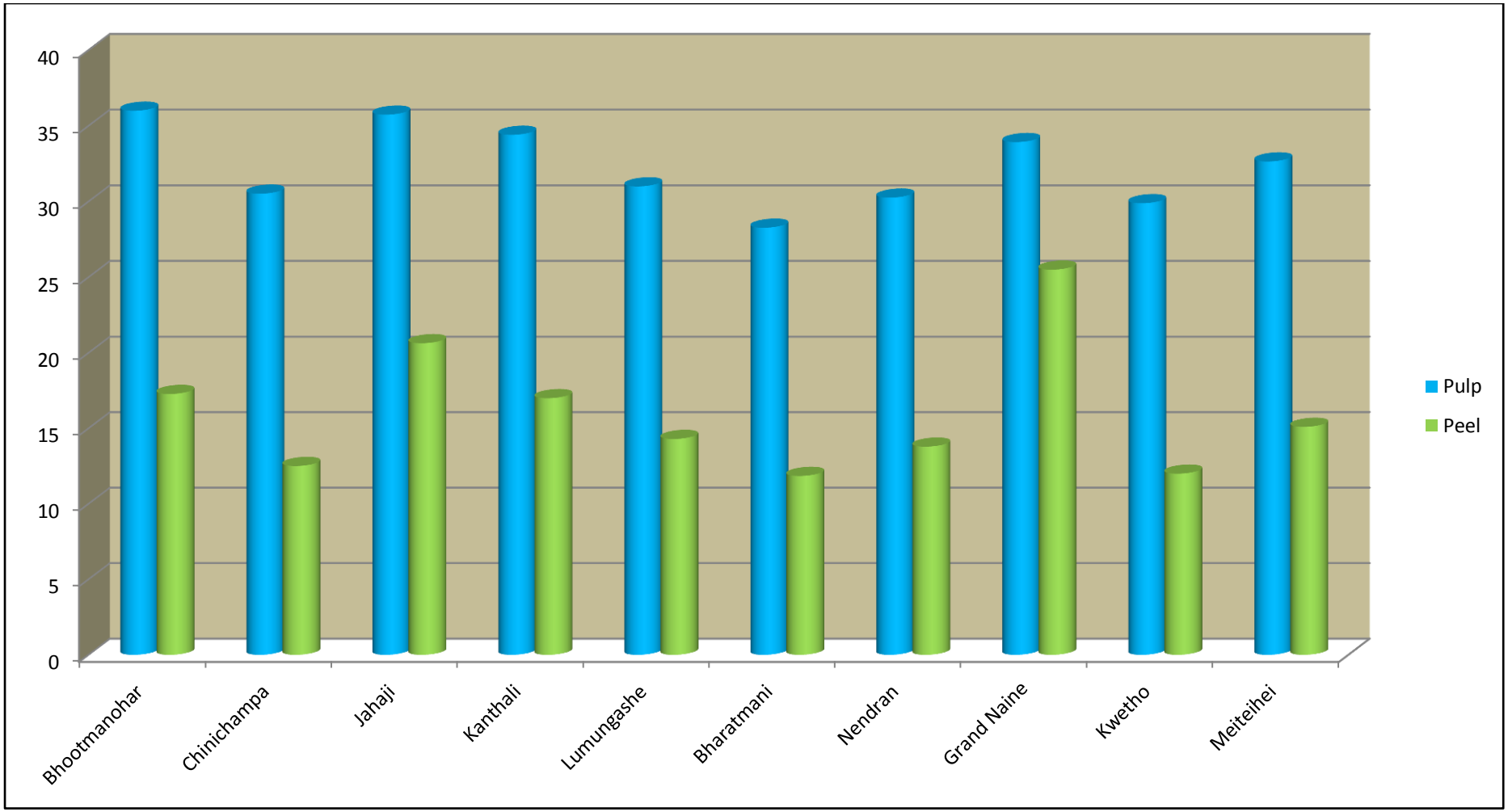


Figure 4.21 Concentration of calcium (mg/100g) in pulp and peel of banana

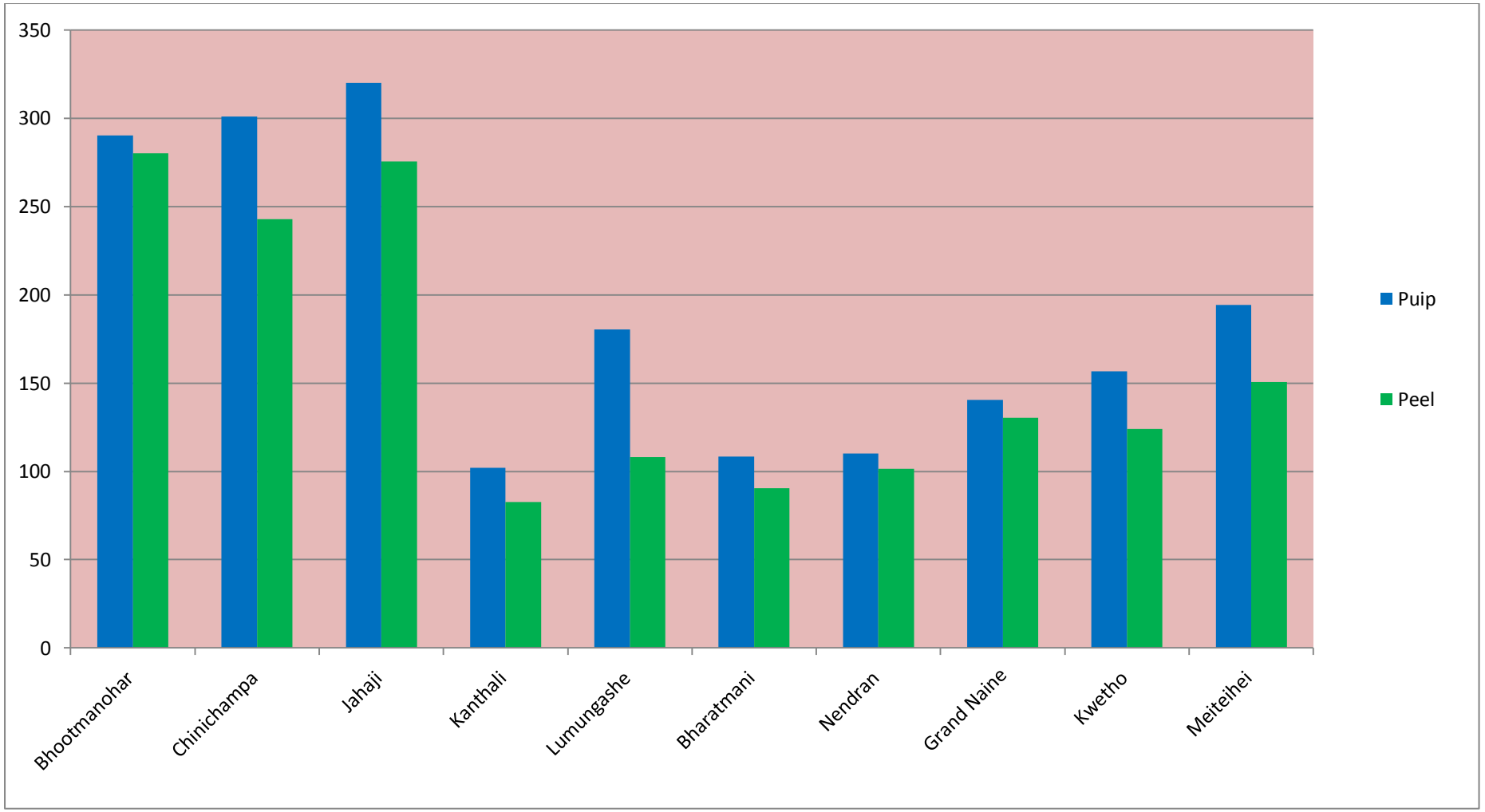


Figure 4.22 Concentration of magnesium (ppm) in pulp and peel of banana

4.2.4 Sensory evaluation

The consolidated information derived from the panelist has been presented in table 4.21. Based on the panelist findings it was observed that genotypes Grand Naine has the higest overall acceptability score of 4.15 based on five levels Hedonic Scale followed by followed by Jahaji (3.94) which was at par with Chinichampa (3.93) and Bhootmanohar (3.70). The lowest score was assigned to Meiteihei at 2.65.

The consumer's first selection criterion is the external appearance of the fruit and it is strongly influenced by the colour, which under a normal ripening process is mainly given by chlorophyll degradation and the appropriate carotenoid synthesis major lutein, α-carotene, and β-carotene (Wall, 2006). All the genotypes showed the characteristic yellow colour of ripening which has also been reported by Pelayo *et al.* (2003). The quality of fruits can be evaluated from flavor, textural and nutritional attributes. Flavor is a combination of the basic tastes (salty, sweet, sour and bitter), mouth feel and aroma (Meilgaard *et al.*, 1991). Perception of fruit and vegetable flavor is a composite of sensory responses resulting from compounds such as acids, sugars, volatiles and many other compounds. Texture is generally defined as the overall feeling that a food gives in the mouth and depends on biochemical components such as lipid content, cell wall content and composition, particle size and shape, moisture content and mechanical (Mattheius and Fellman, 1999). Climatic factors including rainfall, temperature and light intensity have a strong influence on the on plant growth and postharvest quality (Kader, 2002). Therefore the season and agro-ecological conditions in which plant grow will affect fruit quality attributes.

Table 4.21 Performances of banana genotypes on sensory evaluation

Treatments	Appearance	Flavour	Texture	Taste	Overall acceptability
Bhootmanohar	3.50^{abc}	3.20^{cde}	4.00^{a}	4.10^{a}	3.70^{ab}
Chinichampa	4.00^{ab}	3.92^{abc}	3.70^{ab}	4.08^{a}	3.93^{ab}
Jahaji	4.00^{ab}	4.00^{ab}	3.90^{a}	3.86^{a}	3.94^{ab}
Kanthali	2.30^{e}	2.90^{def}	3.32^{ab}	4.00^{a}	3.13^{cde}
Lumungashe	2.60^{de}	2.40^{f}	3.08^{ab}	2.98^{b}	$2.77d^{e}$
Bharatmani	3.40^{bcd}	3.56^{abcd}	3.26^{ab}	3.72^{a}	3.49^{cde}
Nendran	2.74^{cde}	3.22^{cde}	3.42^{ab}	2.76^{b}	3.04^{de}
Grand Naine	4.31^{a}	4.24^{a}	3.92^{a}	4.12^{a}	4.15^{a}
Kwetho	3.21^{bcd}	3.40^{bcd}	3.34^{ab}	2.78^{b}	3.18^{cd}
Meiteihei	3.25^{bcd}	2.54^{ef}	2.86^{b}	1.94^{c}	2.65^{e}
C.D (p= 0.05)	0.76	0.68	NS	0.60	0.43
SE(m)±	0.26	0.24	0.29	0.21	0.21

*Means with different superscript letters within column are significantly different from each other by Duncan Multiple Range Test (p = 0.05)

CHAPTER V

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

The present investigation entitled "Diversity mapping and database development of banana (*Musa* spp.) germplasm in Nagaland" was carried out at Department of Horticulture, at School of Agricultural Sciences and Rural Development, Medziphema, Nagaland University during the year 2019-20 & 2020-21. The experiment was conducted in the states of Nagaland covering five districts to estimate the genetic variability, correlation coefficient, path analysis, genetic divergence and principal component analysis. For estimating the physico-chemical properties and mineral content of the ten selected genotypes, an experiment was carried out in a randomized block design (RBD) with three replication and ten treatments (genotypes).

5.1 Summary

A survey and collection was conducted to collect the divergent clone of *Musa* spp. from various locations of Nagaland covering five revenue districts. Identification and morphological characterization of the collected germplasm was done using the Descriptor for Banana given by International Bureau of Plant Genetic Resource Institute. During the course of survey and exploration work, twenty banana genotypes were collected and were systematically characterized based on plant general appearance, flower and fruit characters. The collected germplasm were conserved *ex-situ* at instructional cum horticultural research farm, School of Agricultural Science and Rural Development, Mesdziphema Campus, Nagaland University.

The analysis of variance indicated that the mean sum of square due to genotypes were highly significant for all the quantitative characters. Significant means sum of square due to fruit yield and

attributing characters revealed existence of considerable variability in material studied for improvement of various traits.

Highest genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) was observed for bunch weight indicating selection for such characters would be more reliable to be used as selection for crop improvement. High degree of heritability estimates were obtained in case of fruit weight, pulp weight, girth size and weight of peel. High genetic advance were observed for leaf blade length and pulp weight indicating predominance of additive gene effect and possibilities of effective selection for the improvement of these characters.

In correlation studies, fruit weight had significant phenotypic correlation with pseudostem height and pulp peel ratio. Significant genotypic correlation with fruit weight was seen for girth size, petiole length and bunch weight.

Path coefficient analysis revealed that pulp weight and weight of peel were the most important trait affecting yield both at phenotypic and genotypic level.

Diversity analysis based on D^2 value grouped all the 20 genotypes into six clusters. Maximum number of genotypes were included in cluster I (8 genotypes) followed by cluster II (5 genotypes), cluster III include 4 genotypes and 1 genotypes each in cluster IV, V and VI.

In principal component analysis, the first four principal components contributed to 78.181 % of the total variation with proportionate contribution value of 34.302 %, 20.563 %, 12.557 % and 10.758 % respectively.

From the collected twenty banana genotypes, ten genotypes were selected and evaluated for table purpose based on grower's preference and market suitability. Morphological fruit characters were documented along with biochemical properties and nutrient content for the selected genotypes. Sensory evaluation was conducted by a panel of six judges.

Among the fruit characters, maximum bunch weight, fruit weight, weight of peel and fruit peel thickness was recorded in Grand Naine. Highest number of hands/bunch and number of fingers/hand were recorded in Chinichampa and Nendran has the maximum pulp weight.

The maximum total soluble solids, acidity, total sugar and reducing sugar were found in Bhootmanohar, Chinichampa, Grand Naine and Meiteihei respectively. Longest shelf life was found in Meiteihei and Bhootmanohar. Highest TSS/acid ratio, crude protein and total carotene were obtained in Bhootmanohar, Grand Naine and Bharatmani respectively.

Maximum concentration of boron, zinc and magnesium were obtained in the pulp of Jahaji. Grand Naine, Meiteihei and Bhootmanohar have the highest concentration of potassium, iron and calcium respectively. Potassium and boron content was found maximum in the peel of Jahaji. Iron, zinc, calcium and magnesium were found maximum in the peel of Nendran, Chinichampa, Grand Naine and Bhootmanohar respectively.

Based on five levels Hedonic Scale sensory evaluation the panelist preferred Grand Naine, Bhootmanohar, Jahaji and Chinichampa in most of the sensory attributes.

5.2 Conclusions

1. The states of Nagaland lie at a point where the Indian subcontinent meets the Southeast Asian countries where distinctive

concentration of banana diversity were known to occurred in semi-evergreen and sub-tropical forests of hill slopes. A survey and collection of banana germplasm was conducted from five districts of Nagaland and twenty banana genotypes were collected and maintained *ex-situ* at instructional cum horticultural research farm, NU;SASRD.

2. A wide spectrum of variability and diversity in context of taxonomical and morphological characters were noticed among the twenty genotypes in their natural population.

3. Highest genotypic coefficient of variation (GCV) and phenotypic coefficient of variation PCV) was observed in bunch weight while high heritability coupled with high genetic advance was observed for traits like bunch weight, pulp weight, weight of peel and fruit weight. Correlation studies revealed fruit weight had significant phenotypic correlation with pseudostem height and pulp peel ratio. Significant genotypic correlation with fruit weight was seen for girth size, petiole length and bunch weight. Path coefficient analysis revealed that pulp weight and weight of peel were the most important trait affecting yield both at phenotypic and genotypic level. The D^2 values recorded for twenty genotypes indicated appreciable amount of diversity among the genotypes with VI cluster. In principal component analysis, the first four principal components contributed to 78.180 % of the total variation.

4. Satisfactory amount of TSS, total sugar, reducing sugar, TSS/acid ratio, crude protein and total carotene were found in all the genotypes. Potassium mineral was found to be abundant in all the banana genotypes under study. Quantifiable amount of mineral nutrient were recorded in all the banana genotypes. In sensory evaluation, the panelist preferred Grand Naine, Bhootmanohar, Jahaji and Chinichampa to other genotypes.

5.3 Future line of work

- ❖ Advanced molecular techniques could be employed to identify duplicate genotypes for efficient management of banana germplasm and to tag important gene available in the germplasm through linkage to DNA markers.
- ❖ Next generation genome sequencing can be employed for promising cultivars.

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CHAPTER VI

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