Characterization of Six Varieties of Banana (*Musa paradisiaca* L.) Grown in Sarpang Dzongkhag

Chinta Mani Dhimal[v] Tulsi Gurung[w] Ngawang[v]

ABSTRACT

Twelve local banana (Musa paradisaica L.) varieties are popularly cultivated in Sarpang Dzongkhag but lack proper information on their characters. Therefore, evaluation on their morphological and compositional characters of six commonly grown varieties was conducted in Hilley and Shompangkhag geog under Sarpang. The purpose of the study was to identify morphological and compositional characters that have relationship and differences among six banana varieties. Using quantitative characters, through cluster analysis, they were grouped into four. Significant difference was observed in pseudo-stem height, pseudo-stem 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.

Keywords: *Morphological; Characterization; Compositional; Quantitative; Qualitative*

1. Introduction

Banana belongs to genus *Musa* under the family Musaceae which are grouped into five sections such as; Emusa, Australimusa, Calimusa, Rhodochlamys, and Incertaesedis based on the basic chromosome numbers, arrangement and orientation of flowers in inflorescence (UNCST 2007). Jesus et al (2009), Nakasone & Paull (2004) & Ploetz et al (2007) mentioned that most of the cultivated bananas (*Musa paradisiacal* L.) belong to Emusa section and are the inter specific cross between *Musa acuminate* Colla (A genome) and *Musa balbisiana* Colla (B genome). Simmonds & Shepherd (1955) used taxonomic scoring method to classify the edible bananas and to confirm on their evolution. Stover & Simmonds (1987) mentioned that *Musa* genus has 30 - 40 species. Simmonds & Shepherd (1955) stated that the cultivated banana (*Musa paradisiacal* L.) which originated primarily in Indo-Malaysia is a natural hybrid and differs from wild ones. It is cultivated in more than 130 countries throughout the tropical and subtropical regions (Gibert et al 2009) with estimated world production of about 106.54 million tons from an area of 5.16 million hectares in 2011 (FAO 2013).

[v] Corresponding author: *cmdhimal@moaf.gov.bt* (Chinta Mani Dhima), Agriculture Research and Development Center, DoA, Samtenling.
[w] College of Natural Resources, Royal University of Bhutan, Lobesa: Punakha

Honfo et al 2011, found that the children and mother in Nigeria and Cameroon eat bananas and plantains as boiled, fried, porridge, roasted paste and ripe. In Uganda the daily consumption of banana exceeds 1.6 kilograms per person, ranking highest in the world which provides more than 25% of carbohydrate requirement (Asten & Staver 2012). It contains 70% water, 27% carbohydrates, 0.5% crude fibre, 0.3% fat and 1.2% protein (Bal 1997). The physicochemical properties of banana are being influenced by environmental factors especially altitude. However, dry matter content is more stable than other chemical properties such as bunch and pulp weight (Gibert et al 2009). In cool climate, the fruits are smaller and fewer suckers are developed. Kumar et al (2005) mentioned that the quality of fruit and yield of banana varieties are affected by agro climatic condition and altitude.

Oliveira et al (2007) found considerable amount of ashes (composed of potassium, calcium and silicium salts) in all the morphological parts. Selvamani et al (2009) mentioned that carbohydrate is the principal component of green bananas which changes during ripening process. Soltani et al (2010) found that pH decreased from ripening stage one till three, then increased until stage seven. However stage six is an optimum stage for fruit consumption as it is the full ripening stage and delicious to eat. Forster et al (2003) from their study on distribution of nutrient inside the pulp found that ash and protein concentration was higher in the central part of pulp than on external part. In Spain, paediatricians recommend to avoid central part of pulp while feeding to children due to its difficulty in digestion. The nutrients in food required by body for maintenance, growth and other functions are provided from dry matter portion of food. Therefore, food formulations are prepared based on the dry matter content of food materials since nutrient requirement is on dry nutrient basis (Mertensa et al (n.d.).

In Bhutan they are grown mostly on small and semi- commercial scale. They are commonly cultivated in almost all the Dzongkhags except Bumthang, Gasa, Thimphu, and Paro. At national level, the annual production was 1,434 ton in 2004 (DoA 2004) which increased to 2,208 ton in 2010 (DoA 2010). However the leading Dzongkhags in terms of production are Sarpang and Samtse with 511 ton and 439 ton respectively (DoA 2010). From the same source it was found that the banana production in Hilley and Shompangkha geogs (study area) was 3 ton each in 2004 which increased to 15.12 ton and 214.19 ton respectively in 2010.

Many local varieties of banana are grown such as; *Chinichampa, Dhusrey, Jhaji,* (Council of RNR Research 2005) *Gheukola, Tinkesrey* and *Jhappari*without much knowledge on morphological and compositional characters. The only distinguishing methods at present are based on the farmers' information and physical appearance of the fruits. It is crucial to develop information on morphological characteristics on the available varieties and their yield potential which is important in income generation as well as nutritional benefits to farmers (Khampa 2012). Minimum studies have been conducted on their characters in Bhutan and limited information available on varietal characteristics. Only two varieties which were released as of now by National Seed Centre in 2002 are *Jhaji* and *Chinichampa* (DoA 2010). The aim of the present study was to identify and evaluate the relationship and differences on

morphological and compositional characters among six different varieties of cultivated desert banana *(Musa paradisaica* L).

2. Materials and Methods

2.1. Study area

The evaluation was done in Hilley and Shompangkha geogs under Sarpang Dzongkhag which are the leading producer of banana (DoA 2010). Similar to the characterization study conducted by Gibert et al (2009) on the consumption pattern and preferred varieties. Six varieties that are commonly cultivated were selected for characterization. These are *Jhaji, Ghewkola, Chinichampa, Jhappari, Tinkesrey* and *Dhusrey*. As per UPOV (2010) and IPGRI (1996), characterization should be done by raising germplasm block and preferably during 2nd and 3rd cropping cycle. However, due to the non-existence of germplasm block in Bhutan, evaluation was done by randomly selecting the plants in the farmers' field (*in situ)* in two geogs with matured fruits.

2.2. Sampling procedure

For attaining precision level of 0.10%, minimum number of one tree with six to ten fruits per tree is sufficient for most characters in avocado (Ledesma 1987). Mattos et al (2010) conducted agronomical and molecular characterization of banana using five plants per variety in a germplasm. In this study, four plants per variety were drawn for observation.

2.3. Qualitative characterization

Twenty qualitative characters were used for six plant parts such as three characteristics for pseudostem, one for leaf, five for inflorescence, two for bract, two for male flower and seven for fruits. For leaf habit, observation was made from a distance of 20 to 25 meters from the tree from all sides while dwarfism was observed through close view on petiole base. Sap colour was observed by puncturing the pseudostem and allowing sap to ooze out. Petiole margin was observed at the point where the petiole and pseudostem meet.

2.4. Quantitative characterization

Eleven quantitative characters were used for four plant parts such two characteristics for pseudostem, three for leaf, two for peduncle and four for fruit. Pseudostem height was recorded from the base of pseudostem to the point of peduncle emergence using measuring tape. Pseudostem diameter was measured at 0.3 meters above the ground by making cross sectional cut as per UPOV, 2010 guidelines. For leaf blade length, third leaf from the bunch emergence was taken and measured from extreme end point of midrib till the blade ends on petiole. Width was measured at the maximum point. Petiole length was measured on the same leaf from lamina till pseudostem. Length of peduncle was measured on the inner part from leaf crown to the first hand of fruit using measuring tape. The width of peduncle was measured using vernier caliper (15 centimeter long, Bristol) at the midpoint of peduncle.

Middle hands from each bunch were taken to find the number of fingers per hand as per the method used by Gibert et al (2009). The length of fruit was measured using vernier caliper on the internal arc of the fruit excluding pedicel of matured fruit. The bunch weight per plant was measured at fruit maturity immediately after harvest using electronic digital weighing

balance (30 kg capacity) by removing peduncle above the first hand and rachis below the last hand. As studied by Muchui et al (2010), fingers were weighed by selecting four fruits from middle hand at matured stage along with the pedicel immediately after harvest using electronic digital weighing balance (model: AND EK - 610i) with maximum weight limit of 600 gram.

2.5. Compositional characterization

Gibert et al (2009), evaluated for characters such as; dry matter content, pH, ash content, total nitrogen content, soluble sugars, total sugars, starch content and minerals (Potassium, calcium, magnesium and sodium) from the fruit pulp. In this study, due to lack of lab test facilities only five characters (pH, Total Soluble Sugar, dry matter content, ash content, and protein content) were analyzed in College of Natural Resources (CNR) laboratory.

From each bunch, three ripened fingers from middle hand were selected for lab analysis Fruit pulp pH was determined using pH meter. TSS was determined using digital refractometer (GMK - 701AC, G - WON) and cross checked with hand held refractometer. This was performed as per the procedure followed by Muchui et al 2010, who used Atago hand held refractometer. Proximate analysis was performed as per the study conducted by Ramli et al (2010) for determining dry matter and ash content. Ash content was determined as per the chemical composition analysis byOliveira et al (2007). Protein content was determined by Kjeldahl method as mentioned by McDonald (1977).

2.6. Data Analysis

The data was entered into Microsoft Excel 2007 spread sheet and the statistical analysis was done using Statistical Package for Social Science (SPSS) 16.0 version. Both for quantitative and compositional characters descriptive statistics were computed. Non parametric test was done to analyze the differences in characters using Kruskal-Wallis and chi square value at 0.05 significant level. Cluster analysis was done by Ward method of dendogram and assessed at squared Euclidean distance of five. Relationship on the characters among varieties was done by Bivariate Spearman correlation. For qualitative characters frequency table was constructed.

3. Results and Discussions

3.1. Quantitative characters

Using quantitative characters, cluster analysis was done by Ward method of dendogram and assessed at squared Euclidean distance of five (Figure 1). *Jhaji* and *Dhusrey* were in separate groups while *Chinichampa* and *Jhappari* were similar in their characteristics and the *Gewkola* and *Tinkesrey* were similar. The result indicated that there were some differences and similarities in quantitative morphological characters among six varieties. Mattos et al (2010) found that there were significant differences in agronomical and morphological characters among 26 banana varieties studied. Therefore, their finding was used for banana breeding and developing into triploid and tetraploid hybrids along with better agronomic traits.

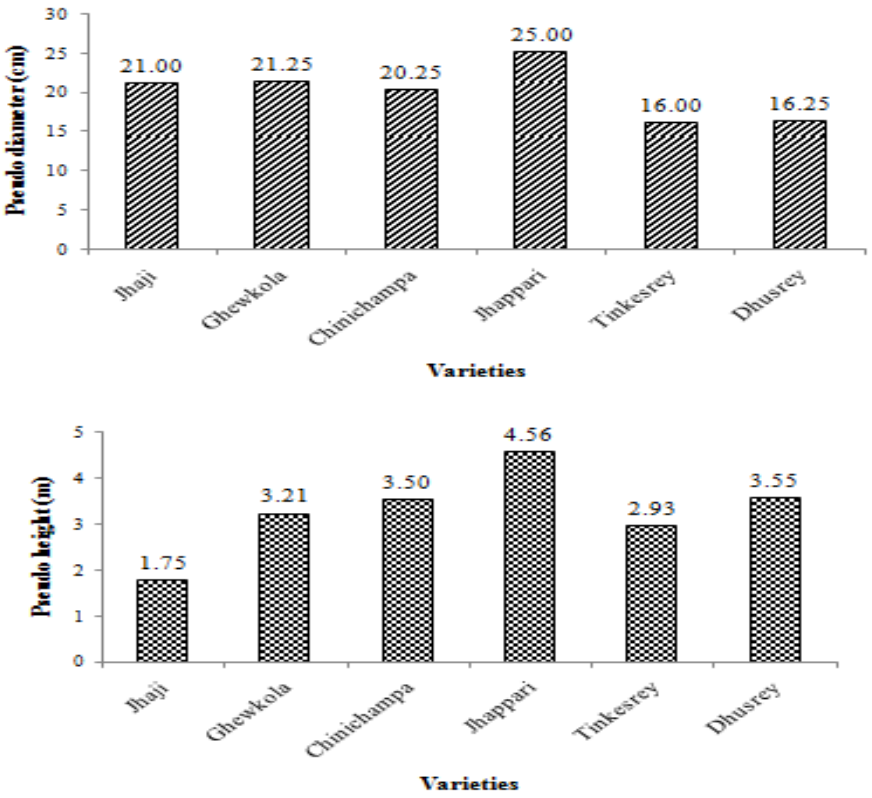

Figure 5. Mean of pseudostem diameter (above) and height (below)

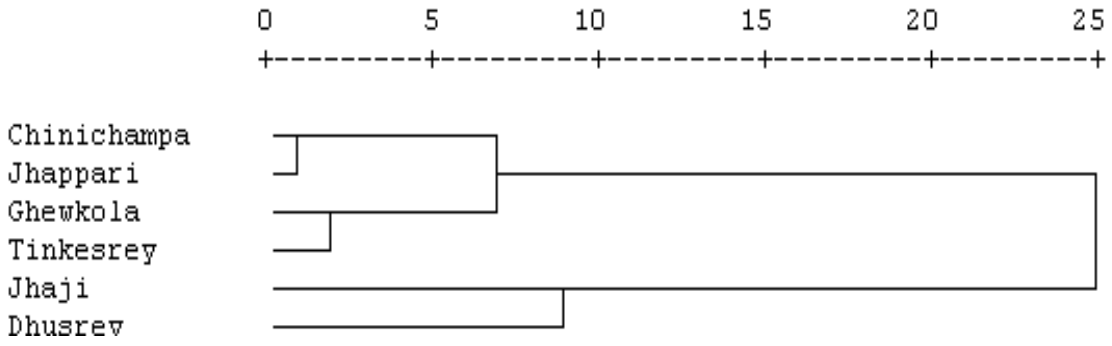

Figure 6. Dendogram based on general quantitative characters

3.1.1. Pseudo-stem characters

Kruskal-Wallis test showed that there was significant difference on the height of pseudostem among six varieties, $H(5) = 14.256$, $p = .05$. The maximum mean pseudostem height was in *Jhappari* and minimum in *Jhaji* (Figure 2). Pseudostem diameter was significantly different among varieties $H(5) = 12.10$, $p = .05$. The maximum pseudostem diameter was observed in *Jhappari* and minimum in *Tinkesrey* (Figure 2). The difference in pseudostem height and

diameter may be due to the differences in growing micro environment, climatic conditions, management and varietal characteristics. Ara et al (2011) found significant variation in pseudostem height and diameter among three varieties. The authors also concluded that the differences was due to edaphic, climatic and management factors.

3.1.2. Leaf characters

Kruskal-Wallis test showed that there was highly significant difference on the leaf blade length of banana among six varieties, $H(5) = 15.47$, $p = .01$while Leaf blade width was significantly different among the varieties $H(5) = 13.68$, $p = .05$.

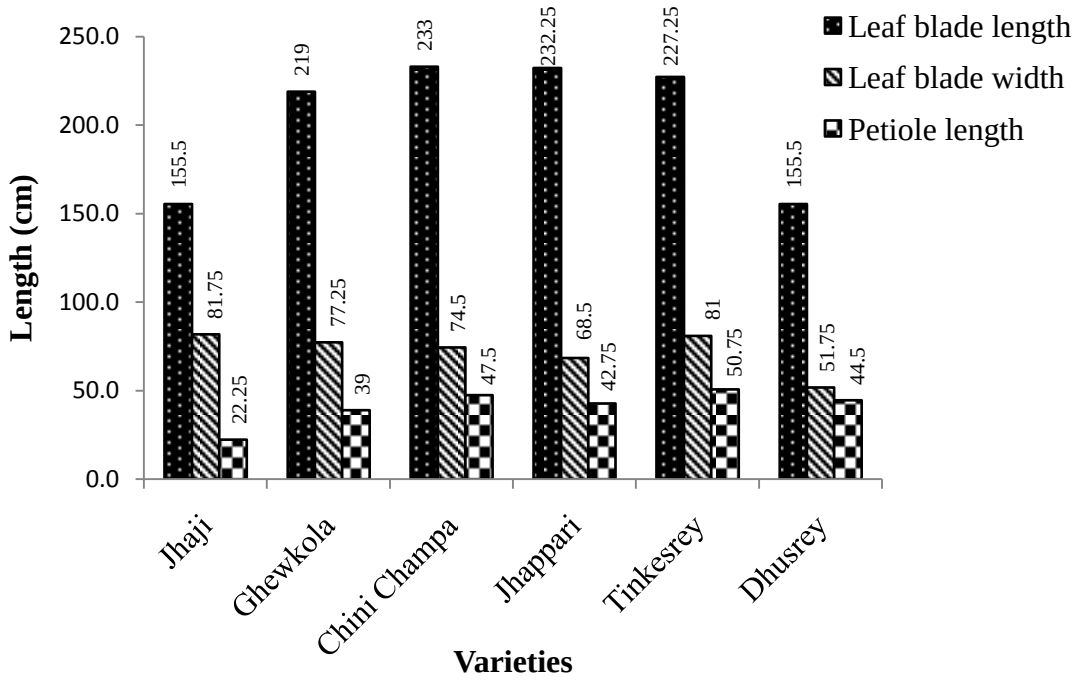

Figure 3**.** Mean of leaf blade length, width and petiole length

There was significant difference on petiole length among six varieties, $H(5) = 14.90$, $p = .05$. Ara et al (2011) from their study concluded that the differences in length and width of leaf and petiole length were due to the diversity of climatic conditions, season and varieties. Therefore, the significant differences found from this study revealed the same conclusion. The maximum mean leaf blade length was observed in *Chinichampa* with 233 cm while minimum was 155.5 cm in *Jhaji* and *Dhusrey*. The maximum mean leaf blade width was observed in *Jhaji* (81.75 cm) and minimum in *Dhusre*y (51.75 cm). With respect to petiole length the longest petiole was 50.75 cm in *Tinkesrey* and minimum in *Jhaji* with 22.25 cm (Figure 3).

3.1.3. Peduncle characters

From Kruskal-Wallis test no significant difference was found among six banana varieties on peduncle length while highly significant difference was observed on peduncle width among the varieties, $H(5) = 15.50$, $p = .01$. The maximum mean peduncle length was recorded in *Dhusrey* with 52.50 cm (n=4) and minimum with 27 cm in *Jhaji* variety (Figure 4). With

regard to peduncle width the maximum mean was recorded as 6.22 cm (n=4) in *Jhaji* and *Jhappari* and minimum with 4.22 cm in *Dhusrey*. The result revealed that the length of peduncle can be of any length to hold the bunch on the tree. However the width is important according to the weight the bunch in order to hold and support on the tree. Therefore, there was no difference in peduncle length but had differences in width.

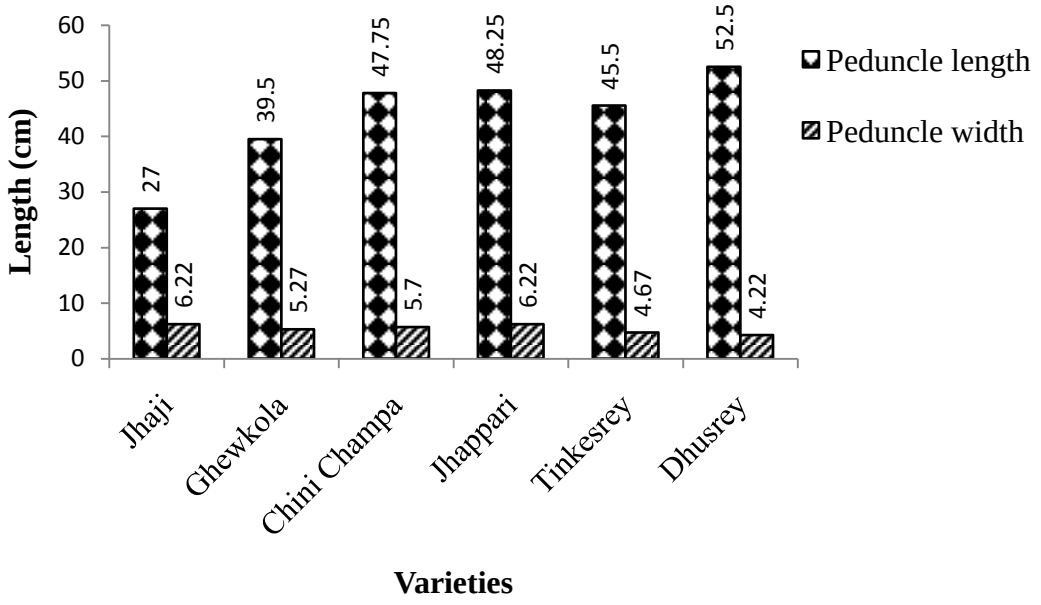

Figure 4. Mean of peduncle length and width

3.1.4. Fruit characters

Kruskal-Wallis test showed that there was highly significant difference on the number of fingers per hand $H(5) = 17.95$, $p = 0.01$, finger length $H(5) = 17.285$, $p = 0.01$ and finger weight $H(5) = 17.550$, $p = .01$ among six banana varieties. Arra et al (2011) concluded that there were differences in number of fingers per bunch, finger weight, length of fingers and bunch due to varieties and season. From the field study it was observed that number of fingers, weight of fingers and length were different based on the varieties. Kruskal- Wallis test showed no significant difference on bunch weight among varieties. In a study conducted by Bathan and Lantican (2010), it was found that yield of banana depends upon input utilization; types of cultivar planted and soil type. This study was also carried out in same area with similar soil type and other factors. Therefore, there was no difference in bunch weight among the six varieties which contributes to yield. The maximum number of fingers per hand was recorded in *Jhaji* (17.25) and minimum in *Dhusrey* (10) (Table 1). Fingers were longest in *Dhusrey* and shortest in *Ghewkola*. Maximum bunch weight was recorded in *Jhaji* and minimum in *Dhusrey* while finger weight was maximum in *Dhusrey* and minimum in *Chinichampa* (Table 1).

Table 1.Mean values of fruit characters

Varieties	Number of fingers/hand	Finger length [cm]	Bunch weight (kg)	Finger weight (gm)
Jhaji	17.25	11.22	15.48	88.75
Ghewkola	13.75	9.55	11	88.25
Chini Champa	16.25	7.725	13.13	45
Jhappari	14	10.22	12.05	65.75
Tinkesrey	13	12.07	9.92	120.5
Dhusrey	10	14.35	8.9	157.5

3.1.5. Correlation among quantitative characters

A bivariate spearman correlation coefficient was conducted among quantitative characters (Table 2). The reason for conducting correlation coefficient was to explore on which characters are well associated and useful for varietal selection (Putta et al (2013). Bunch weight was associated with pseudostem diameter (r = 0.49, p = 0.05) indicating that larger pseudostem diameter had more bunch weight. Bunch weight was highly associated with peduncle width (r = .64, p= 0.01) and number of fingers per hand (r = 0.73, p= 0.01). The results indicated that heavier bunch with wider peduncle had more number of fingers. O'Farrell (1987) concluded that the weight of bunch was due to the increase in number of fingers per bunch.

Pseudostem height was associated with length of leaf blade (r = 0.44, p= 0.05) and petiole length (r = 0.49, p= 0.05) whereas pseudostem height was highly associated with peduncle length (r =0.62, P= 0.01). The result revealed that higher the height, longer the leaf blade, petiole and peduncle. A study conducted by O'Farrell (1987) confirmed that **t**here was an increase in bunch weight (16.5 kg) with an increase in height of the pseudostem. Pseudostem diameter had highly significant correlation with peduncle width (r= .72, p= 0.01) and significant correlation with number of fingers per hand (r = 0.48, p= 0.05). This indicates that any change in pseudostem diameter will lead to change in width of peduncle. Leaf blade length was associated with leaf blade width (r=0.42, p= 0.05) and petiole length (r = 0.43, p= 0.05). The result revealed that leaf blade length was proportionate to leaf width and petiole. There was significant correlation between leaf blade width and peduncle width (r = 0.45, p= 0.05) and number of fingers per hand (r = 0.48, p=0.05). Petiole length was highly associated with peduncle length (r = .70, p= .01) indicating that longer the petiole longer the peduncle.

Negatively high association was observed between peduncle width and finger weight (r = -0.52, p=0.01) and positive association with number of fingers per hand (r = .81, p = .01). The result indicated that increase in peduncle width may not necessarily increase finger weight while increase number of fingers per hand. Fruit length was highly correlated with finger weight (r =0.68, p= 0.01) indicating that increase in fruit length increases finger weight. Negative correlation was observed between finger weight and number of fingers per hand (r = -0.63, p= 0.01). The results indicated that increase in finger weight decrease number of fingers per hand.

Table 2. Bivariate Spearman correlation among quantitative characters

Characters	BW	PH	PD	LBL	LBW	PTL	PUL	PUW	FL	FW	NFH
Bunch weight (BW)	1	-0.07	0.49*	-0.01	0.16	-0.15	-0.14	0.64**	-0.32	-0.37	0.73**
Pseudo height (PH)	24	1	0.35	0.44*	-0.32	0.49*	0.62**	0.05	0.00	-0.09	-0.28
Pseudo diameter (PD)	24	24	1	0.29	0.20	-0.18	0.06	0.72**	-0.37	-0.26	0.48*
Leaf blade length LBL)	24	24	24	1	0.42*	0.43*	0.34	0.3	-0.33	-0.4	0.1
Leafblade width(LBW)	24	24	24	24	1	-0.05	-0.35	0.45*	-0.05	-0.26	0.48*
Petiole length (PTL)	24	24	24	24	24	1	0.70**	-0.27	0.13	0.03	-0.27
Peduncle length (PUL)	24	24	24	24	24	24	1	-0.15	0.16	0.13	-0.26
Peduncle width (PUW)	24	24	24	24	24	24	24	1	-0.29	-0.52**	0.81**
Finger length (FL)	24	24	24	24	24	24	24	24	1	0.68**	-0.39
Finger weight (FW)	24	24	24	24	24	24	24	24	24	1	-0.63**
No. Finger/hand (NFH)	24	24	24	24	24	24	24	24	24	24	1

3.2. Compositional characters

Using compositional characters (pH, total soluble solids, dry matter content, ash content and protein content) cluster analysis was done by Ward method of dendogram and assessed at squared Euclidean distance of five (Figure 5). *Jhaji* was alone while other varieties were in one group.

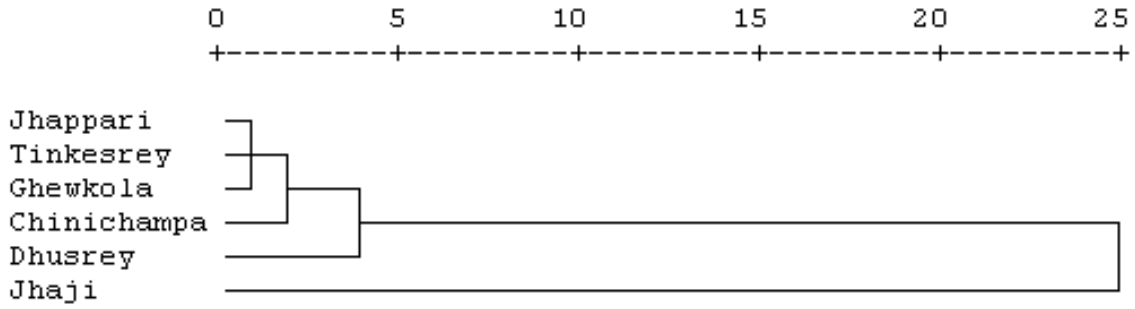

Figure 5. Dendogram based on general compositional characters

3.2.1. Pulp pH

Kruskal-Wallis test showed that there was highly significant difference in pulp pH among six banana varieties, $H(5) = 15.97$, $p = 0.01$. The maximum mean pH was recorded in *Jhaji* (5.04) and minimum in *Dhusrey* (4.08) (Figure 6). Banana pulp pH was recorded 5.02 at ripening stage one which decreased to 4.93 at seventh stage (Soltani et al 2010). In this study, pH was analyzed at full ripening stage and the findings were as per their study. Fruits with higher pH value have lower titratable acidity representing better fruit quality which is preferred by consumer and vice versa. Therefore *Jhaji* variety with high pH value indicates low titratable acid content and preference of consumers.

3.2.2. Dry matter content

Kruskal-Wallis test showed that there was significant difference in pulp dry matter content among six banana varieties, $H(5) = 11.43$, $p = 0.05$. Maximum dry matter content was in *Dhusrey* (29.60%) and minimum in *Jhaji* (19.80%) (Figure 6). Gibert et al (2009) found the

differences in dry matter content among 23 varieties which ranged from 19.6 to 30.9 %. From their study they concluded that the dry matter content was due to the genotype and their interaction depending upon varieties. Therefore the result found from this study revealed that the differences in dry matter content were due to the varietal differences. Several studies have shown different dry matter content in different varieties and climatic conditions. Gibert et al (2009) from their study concluded that the difference in dry matter content in different banana varieties pulp was due to varieties and environmental effects especially related to altitude. Therefore, the differences observed from this study may be due to varietal characteristics. Mertensa et al (n.d.) stated that formulation of rations is prepared on dry matter basis as animal require specified amount of dry nutrient. The authors also mentioned that most of the food ingredients requirements are met from dry matter portion of food materials. Therefore higher dry matter provides more nutrients to the body. So, *Dhusrey* variety is preferred for more nutrient supplement due to its high dry matter content.

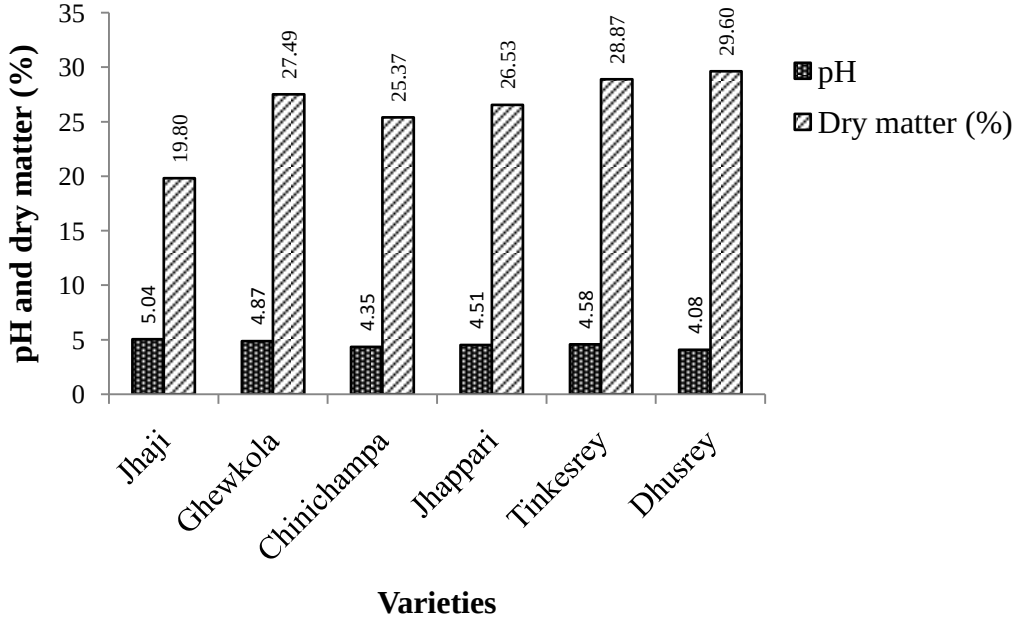

Figure 6. Mean of pH and dry matter of six varieties

3.2.3. TSS, ash and protein content

Kruskal-Wallis test showed that there was no significant difference in TSS, ash content and protein content among six banana varieties. Soltani et al (2010) from their study concluded that TSS of banana pulp increased till seventh ripening stage (21.9%) and declined further. The authors also mentioned that TSS indicates the amount of available sugar content in the pulp which indicates the sweetness of fruit. Mattos et al (2010) found mean TSS of 19.48 % with minimum of 14.60 % in Towoolle variety and maximum of 25.70 % in Teparod variety. In this study the maximum TSS was in Dhusrey (22.47%) and minimum in Jhaji (15.33%) (Figure 7). In this study, mean TSS is 19.24% which is lesser than their findings indicating that TSS was tested before sixth ripening stage (eating stage).At sixth stage (full ripe stage) the peel colour is all yellow, fresh and delicious to eat called as eating stage. At seventh ripening stage, the peel colour declines and have brown spots on the surface, sugar content

will be highest, and flesh becomes soft which is at declining phase. According to Fedha et al (2010) pumpkin fruit contained higher ash content than in seed indicating that mineral intake in the diet can be enhanced by eating pumpkin fruit. Oliveira et al (2007) found that considerable amount of ashes (composed of potassium, calcium and silicium salts) was found in all the morphological parts.

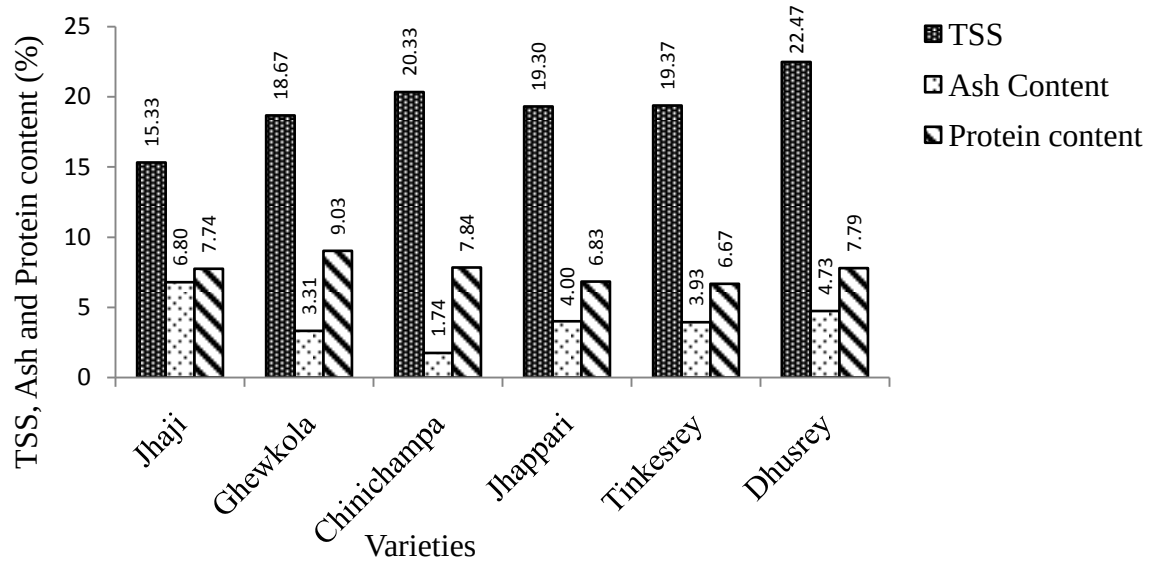

Figure 7. Mean of TSS, ash and protein content of six varieties

Gibert et al (2009) found ash content in desert banana as 2.3 to 4.3 % which varied between varieties. In contrary to it, this study found higher ash content indicating the consumption of fruit contribute better diet to human body. The maximum ash content was in *Jhaji* (6.80%) and minimum in *Chinichampa* (1.74%) (Figure 7).Therefore *Jhaji* variety is preferred variety for ash intake. Protein is good for children, lactating mothers and old people who need more proteins for growth, maintenance and repair of worn out tissues (Fedha et al 2010). Mahapatra et al (2010), found that the protein content was recorded as 2.2% which was lower than this study. This could be due to ripening stage, variety and climatic conditions. The authors also mentioned that protein content increases over ripening process depending upon genotype, variety, growing altitude and climate. Highest protein was found in *Ghewkola* (9.03%) and minimum in *Tinkesrey* (6.67%) (Figure 7). Therefore, protein intake can be enhanced by eating *Ghewkola* than other varieties.

3.3. Qualitative characterization

Twenty important qualitative morphological characters are reported through frequency distribution table (Table 3). Based on leaf habit, bananas were being grouped into three; *Jhaji* had erect, *Chinichampa* and *Jhappari* intermediate and *Ghewkola* and *Dhusrey* had drooping leaves. Based on dwarfism, only *Jhaji* was dwarf type with leaves strongly overlapping while the rest of the varieties were normal. With respect to sap colour, they were grouped into two; *Jhaji* and *Ghewkola* had watery sap while rest had milky. In terms of petiole margin, *Jhaji* and *Ghewkola* were winged while others were without wing along the petiole (Figure 8).

Considering bunch position they were grouped into three such as; group one included *Ghewkola* with bunch position at 45^{o} angle, group two included *Jhaji* and *Dhusrey* hanging vertically and group three included the *Chinichampa, Jhappari* and *Tinkesrey* positioned at an angle (Figure 9).

Figure 8. Petiole margin of six varieties (A = Jhaji, B = Ghewola, C= Chinichampa, D = Jhappari, E = Tinkesrey and F = Dhusrey)

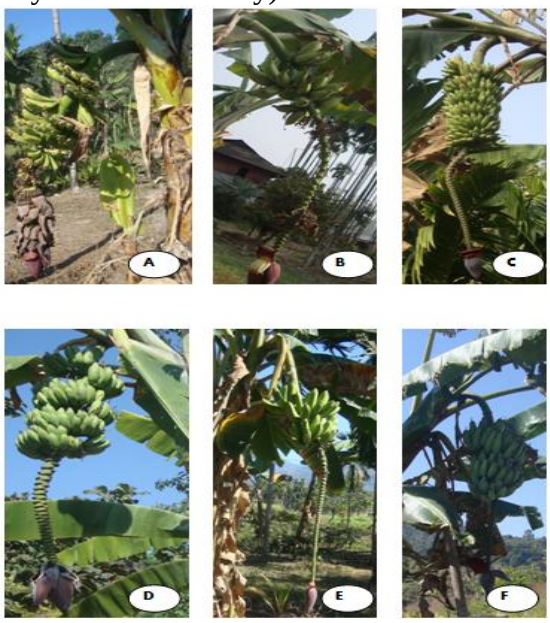

Figure 9. Petiole margin of six varieties (A = Jhaji, B= Ghewola, C= Chinichampa, D = Jhappari, E = Tinkesrey and F = Dhusrey)

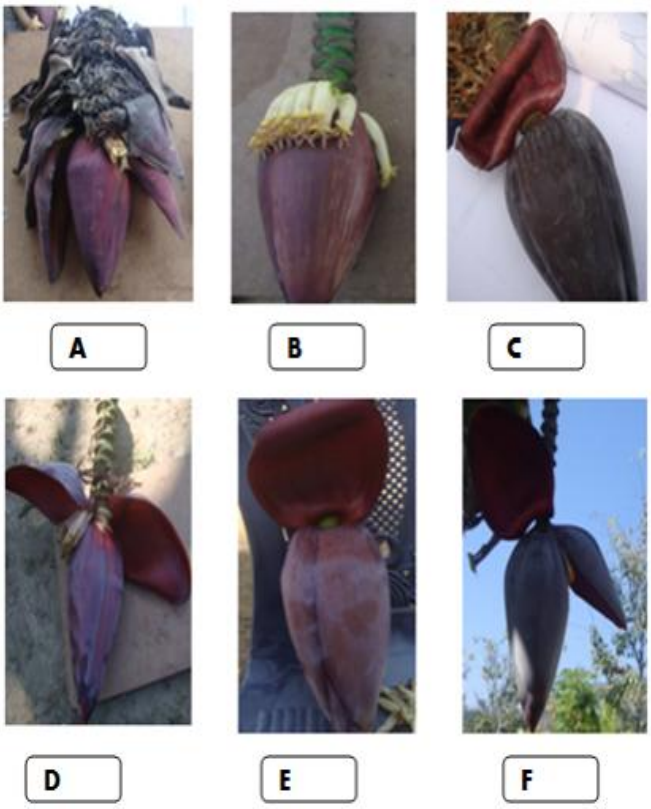

Figure 10. Male flower behaviour (A = Jhaji, B = Ghewkola, C = Chinichampa, D = Jhappari, E = Tinkesrey and F = Dhusrey)

Figure 11. Shape of style of six varieties

Two varieties (*Ghewkola and Chinichampa*) were in one group while others were in other based on rachis position. However, looking at rachis appearance those six varieties were grouped into three. Observing male bud, they were divided into two groups; Jhaji and *Ghewkola* had colour stripes on bracts while others did not have. Based on the bract behavior before falling, they were divided into two groups such as revolute (*Ghewkola, Chinichampa, Tinkesrey* and *Dhusrey*) and non revolute (*Jhaji* and *Jhappari*). Bananas were clearly

classified into three groups based on male flower behavior (falling before the bract, falling after the bract and neutral/male flowers persistent) (Table 3) (Figure 9). Observing the shape of style, they were grouped into two such as; curved at the base (*Chinichampa*) and straight (Figure 11).

Other characters such as fruit apex, remains of flower relics and peel crack were also studied as reflected in Table 3. General appearance of fingers of six varieties is in figure 12 and hands in Figure 13. These characters are useful for banana promotion through variety selection. Dwarf variety (*Jhaji*) can be selected in areas with strong wind to prevent lodging. *Jhappari* is recommended for those who prefer varieties with larger pseudostem for dual purpose (cattle feed and fruit). For longer transportation and storage, *Ghewkola* is preferred since its fingers remain attached with the hand for longer duration. Moreover its peel is stronger as compared to other although its pulp is soft inside. *Dhusrey* is not much preferred by consumers as its peel cracks and has poor presentation.

Figure 12. Appearance of fingers of six Varieties

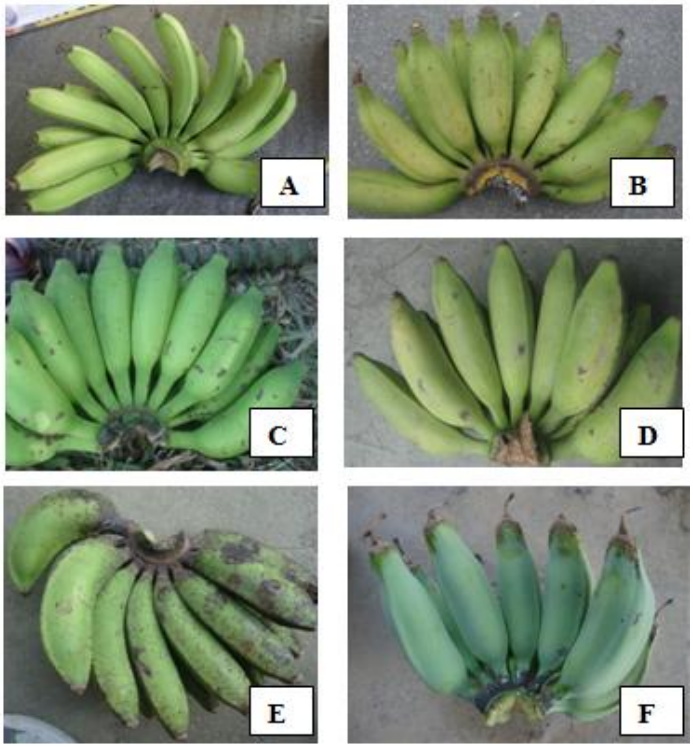

Figure 13. General appearance of hands of six varieties (A = Jhaji, B = Ghewkola, C = Chinichampa, D = Jhappari, E = Tinkesrey and F = Dhusrey)

Table 3. Frequency distribution of qualitative characters of six banana varieties

Descriptors	Characters	Varieties*	Frequency	%
Leaf habit	Erect	1	1	16.67
	Intermediate	3,4	2	33.33
	Drooping	5,6	2	33.33
Dwarfism	Normal	2,3,4,5,6	5	83.33
	Dwarf type	1	1	16.67
Sap colour	Watery	1,2	2	33.33
	Milky	3,4,5,6	4	66.67
Petiole margin	Winged and clasping the pseudostem	1,2		33.33
	Not winged and clasping the pseudostem	3,4,5,6	4	66.67
Bunch position	Hanging vertically	1,6	2	33.33
	Slightly angled	3,4,5	3	50.00
	Hanging at angle 45°	2	1	16.67
Bunch shape	Truncated cone shape	2,5	2	33.33
	Cylindrical	1,2,4,6	4	66.67
Bunch appearance	Lax	2,5	2	33.33
	Compact	1,4	2	33.33
	Very compact	3,6	2	33.33
Rachis position	Falling vertically	1,4,5,6	4	66.67
	With a curve	2,3	2	33.33
Rachis appearance	Bare	3,4,5,6	4	66.67
	Neutral flowers	2	1	16.67
	Neutral/male flowers and presence of withered bracts	1	1	16.67
Colour stripes on bract	Without discoloured lines (not ridges) on the external face	3,4,5,6	4	66.67
	With discoloured lines or stripes on the external face	1,2	2	33.33
Bract behavior before falling	Revolute	2,3,5,6	4	66.67
	Not revolute	1,4	2	33.33
Male flower behavior	Falling before the bract	3,4,5,6	4	66.67
	Falling after the bract	2	1	16.67
	Neutral / male flowers persistent	1	1	16.67
Style shape	Straight	1,2,4,5,6	5	83.33
	Curved at the base	3	1	16.67
Fruit position	Curved upward (obliquely, at a 45°angle upward)	1,3,4,5,6	4	66.67

	Perpendicular to the stalk	2	1	16.67
Fruit apex	Blunt-tipped	1,5	2	33.33
	Bottle-necked	2,3,4,6	4	66.67
Remains of flower relicts at fruit apex	Persistent style	6	1	16.67
	Base of the style prominent	1,2,3,4,5	5	83.33
Adherence of the fruit peel	Fruit peels easily	1,3,4,5,6	5	83.33
	Fruit does not peel easily	2	1	16.67
Cracks in fruit peel at maturity	Without cracks	1,2,3,4,5	5	83.33
	Cracked	6	1	16.67
Fruits fall from hands	Persistent	2	1	16.67
	Deciduous	1,3,4,5,6	5	83.33
Flesh texture	Firm	1,3,4,5,6	5	83.33
	Soft	2	1	16.67

Varieties*: 1.Jhaji**,** 2. Ghewkola**,** 3. Chinichampa**,** 4. Jhappari**,** 5. Tinkesrey**,** 6. Dhusrey

4. Conclusion

There were similarities and differences in morphological and compositional characters among six varieties of banana. Regarding pseudo-stem, flower and leaf appearance, all the varieties were similar. Through cluster analysis looking at general quantitative morphological characters, they were grouped into four. Generally, Jhaji had different characters in terms of chemical composition of fruit pulp while rests were similar. Jhappari had comparatively maximum pseudo-stem height and diameter while Jhaji was the shortest plant. Tinkesrey had the minimum pseudostem diameter among six varieties. The leaf blade length was similar while there was significant difference in leaf blade width and petiole length among varieties. Jhaji had maximum leaf blade width with shortest petiole. Dhusrey had minimum leaf blade width and Tinkesrey had longest petiole. Peduncle length was mostly similar but width was different among six varieties. Maximum peduncle width was in Jhaji while minimum in Dhusrey. There was significant difference in number of fingers per hand, finger length and finger weight but there was no difference in bunch weight among six varieties. Dhusrey had minimum number of fingers per hand with longest and heaviest fingers but minimum bunch weight. Jhaji had maximum number of fingers per hand with minimum finger weight. Shortest finger was in Ghewkola. Highest bunch weight was in Jhaji. Bunch weight was correlated with peduncle width and number of fingers per hand.

Compositional characterization showed that Jhaji was different from other varieties which had maximum pulp pH, minimum dry matter content and maximum ash content. Dhusrey was different from other varieties with minimum pulp pH, maximum dry matter content and maximum TSS. Highest protein was found in Ghewkola. Qualitative characters showed some variations and similarities among six banana varieties. Jhaji is dwarf type with erect leaves while Chinichampa and Jhappari had intermediate leaves and Ghewkola and Dhusrey with drooping leaves. Jhajiand Ghewkola had watery sap with winged petiole margin but others had milky sap without winged petiole margin. Bunch position was at 45^{o} angle in Ghewkola,

hanging vertically in Jhaji and Dhusrey and at an angle in Chinichampa and Chappari. Jhaji bear neutral or male flower with presence of withered bracts, ghewkola with neutral flowers and others have bare rachis. Jhaji and Ghewkola had colour stripes on bract while rest of the varieties did not have. The behaviour of bract before falling was non revolute in Jhaji and Jhappari while revolute in other varieties. Male flower remain neutral or persistent in Jhaji while male flowers fall after the bract in Ghewkola but fall before the bract fall in other varieties. Chinichampa had style with curved at the base. Ghewkola had fingers on the bunch at perpendicular to the stalk while rests were curved. Dhusrey had persistent style at the finger tip and cracked peel while others had prominent base of style without cracked peel. Fruit apexes were blunt tipped in Jhaji and Tinkesrey while rest had bottle neck type. For future studies characterization of wild bananas would contribute to diversification of genotype and species for future germplasm collection and breeding purposes. Study on physicochemical characters for different varieties in same location and same variety in different locations is essential.

References

Ara N, Basker M. K & Hossain M. F. 2011.Growth, yield and quality of banana (M*usa sapientum* L) influenced by different banana varities/lines and planting time. *Tropical Agricultural Research & Extension*.14(2).

Asten P. V & Staver C. 2012. Banana.Impacts of climate change on the agricultural and aquatic systems and natural resources within the CGIAR's mandate. CCAFS Working Paper 23.CGIAR.Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. Access on Available online at: www.ccafs.cgiar.org

Bal J. S. 1997. *Fruit growing*. New Delhi: Kalyani Publishers.

Bathan B.M. & Lantican F. A. 2010**.** Factors affecting yield performance of banana farms in Oriental Mindoro, Philippines. J. ISSAAS. 16 (1): 110 – 120.

Council of RNR Research. 2005. *Integrated agriculture technical guide book*.Department of Agriculture, Ministry of Agriculture and Forests. Thimphu, Bhutan.

DoA. 2004. *Agriculture statistics*.Department of Agriculture, Ministry of Agriculture and Forests, Royal Government of Bhutan.

DoA. 2010. *Agriculture statistics*.Department of Agriculture, Ministry of Agriculture and Forests, Royal Government of Bhutan.

DoA. 2010. *Fruits and Nuts Germplasm Inventory*.Department of Agriculture, Ministry of Agriculture and Forests, Royal Government of Bhutan.

FAO. 2013. FAO stat preliminary data.< http:// fao.org>.Accessed 8 May 2013.

Fedha M.S, Mwasaru M.A, Njoroge C. K, Ojijo N. O & Ouma G. O. 2010. Effect of drying on selected proximate composition of fresh and processed fruits and seeds of two pumpkin species. *Agriculture and biology journal of North America.*1(6): 1299-1302**.**

Forster M, Rodriguez E. R, Martin J. D & Romero C. D. 2003. Distribution of nutrients in edible banana pulp.Food Technol. Biotechnol.41 (2): 167 – 171.

Gibert O, Dufour D, Giraldo A, Sanchez T, Reynes M, Pain J. P, Gonzalez A, Fernandez A. & Diaz A. 2009. Differentiation between cooking bananas and desert bananas. 1. Morphological and compositional characterization of cultivated Colombian Musaceae (*Musa* sp.) in relation to consumer preferences. *Journal of agricultural and food chemistry*.57: 7857-7869. doi: 10.1021/jf901788x

Honfo F. G, Tenkouano A & Coulibaly O. 2011. Banana and plantain-based foods consumption by children and mothers in Cameroon and Southern Nigeria: A comparative study. *African Journal of Food Science*.5 (5): 287 – 291.

IPGRI. 1996. International Plant Genetic Resource Institute: Conduct test of description, uniformity and stability (DUS) and descriptor list of banana (*Musa* spp.)

Israel G. D. n.d. *Determining Sample Size.*University of Florida, IFAS Extension. PEOD6.

Jesus O.N, Ferreira C.F, Silva S. O, Camara T.R, Soares T.L. & Pestana K.N. 2009. Characterization of recommended banana cultivars using morphological and molecular descriptors.*Crop breeding and applied biotechnology*.9: 164-173.

Khampa. 2012. Morphological characterization of Asian pear and its production potential (Dessertation).College of Natural Resources, Lobesa Bhutan.

Kumar R., Rajan S & Singh A. 2005. Evaluation of plantain (*Musa X paradisiaca*) varieties under subtropics of north India.*Indian Journal of Agricultural Sciences*.75 (7): 422 – 4.

Ledesma D.R & Carpena A.L. 1987. Sampling techniques for measuring different fruit characters in avocado (*Perseaamericana* L.). *Philippine Journal of Crop Science*.12 (2): 87 -91.

Mahapatra D, Mishra S. & Sutar N. 2010. Banana and its by- product utilization: an overview. *Journal of Scientific & Industrial Research*.69: 323 – 329.

Mattos L. A, Amorim E. P, Amorim V. B. O, Cohen K. O, Ledo C. A. S & Silva S. O. 2010. Agronomical and molecular characterization of banana germplasm. Pesquisa Agropecuria Brasileira. 45 (2).

MCDonald C.E.1977. Methods of Protein Analysis and Variation in Protein Results.

Mertensa D. R, Boltonb K. & Jorgensenc M. n.d. Measure dry matter routinely on the farm and make rations more consistent. <http://www.uwex.edu/ces/crops/uwforage/DM_using_dehydrator_Final.pdf>. Accessed 11 May 2013

Muchui M.N, Njoroge C.K, Kahangi E.M. & Onyango C.A. 2010. Determination of Maturity Indices of Tissue Cultured Bananas (*Musa* spp.) 'Williams' and 'Grande Naine'. Acta Horticulturae, (ISHS). 879: 425 - 430.

Nakasone H.Y & Paull R.E. 2004. *Tropical fruits*. UK: CAB international.

O'farrel P. J. 1987. Effect of cutting height of the parent pseudo-stem on yield and time of production of the following sucker in banana. Scientia Horticulturae (Amsterdam). 2: 89 – 94.

Oliveira L, Cordeiro N, Evtuguin D. V, Torres I. C. & Silvestre A. D. J. 2007. Chemical composition of different morphological parts from 'Dwarf Cavendish' banana plant and their potential as a non-wood renewable source of natural products.Industrial crops and products.26 (2): 163 – 172.

Ploetz R.C, Kepler A. K, Daniells J. & Nelson S. C. 2007. *Banana and plantain- an overview with emphasis on Pacific islands cultivars.*Version 1.

Putta R, Jogloy S, Suriharn B, Wangsomnuk P. P, Kesmala T. & Patanothai A. 2013.Variations in morphological and agronomic traits among Jerusalem artichoke (Helianthus tuberosus L.) accessions. Genet Resour Crop Evol. 60: 731 -746.

Ramli S, Ismail N, Alkarkhi A.F.M. & Easa A.M. 2010. The Use of principal component and cluster analysis to differentiate banana peel flours based on their starch and dietary fibre components.Tropical Life Sciences Research.21(1): 91–100.

Selvamani P, Manivannan K. & Mohan R. J. 2009. Proximate Composition and Pasting Behavior of Starch from Indian Bananas (*Musa* Spp).Botany Research International **2 (2):** 103-106.

Simmonds N. W & Shepherd K. 1955. The taxonomy and origins of the cultivated bananas. *Journal of the Linnean Society of London, Botany*.**55:** 302–312. doi: 10.1111/j.1095-8339.1955.tb00015.

Soltani M, Alimardani R & Omid M. 2010. Comparison of Some Chromatic, Mechanical and Chemical Properties of Banana Fruit at Different Stages of Ripeness. *Modern Applied Science.***4 (7).**

Stover R.H. & Simmonds N.W. 1987. Bananas, Longman, London.

UPOV. 2010. International union for the protection of new varieties of plants: guidelines for the conduct of test for distinctness, uniformity and stability, banana (*Musa* spp.), Geneva.