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Morphological and horticultural characteristics of some commercial banana (*Musa* spp.) cultivars of Kerala

Malikongwa Thatayaone*, Gomez Saji, Joseph Meagle, Netravati & Kuruvila Bintu

Department of Post Harvest Technology, Kerala Agricultural University, Thrissur 680 657, India

*Email: malikongwathati@gmail.com

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Abstract

Morphological and horticultural characteristics of six cultivars of banana fruits (*Musa spp.*) that are commercially grown in Kerala, belonging to different genomic groups *viz.* Nendran (AAB), Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (ABB) and Yangambi (KM-5) (AAA) were evaluated. The morphological traits were characterized using Banana Descriptors established by IPGRI (1996), from which 9 characters were selected for quantitative analysis. Horticultural characters on variables such as number of fruits per bunch, fruit length (cm), fruit pedicel length (mm), fruit pedicel width (mm), peel thickness (mm), pulp weight (g), fruit to peel ratio, fruit flesh firmness (cm^2kg^{-1}) were analysed and subjected to one way ANOVA to determine the significance (p=.05). The cultivar Nendran (AAB) exhibited large morphological and horticultural traits, particularly for the fruit length (22.07cm), pulp weight (89.20g) and peel weight (49.30g). The cultivar Karpooravalli (ABB) was smaller in terms of the fruit length (10.67 cm) and peel weight (9.65g), but had a large (4.81) fruit: pulp ratio compared to other cultivars studied. The present work reveals substantial morphological and horticultural variation among banana cultivars of different genomic groups, with an overlap of similarities and differences even in banana cultivars having the same genomic group.

Keywords

genomic group; cultivars; morphological characterization; horticultural characterization

Introduction

Banana (*Musa spp*.) is the second most important fruit crop of India, which belongs to the family Musaceae of the Zingiberales order. Banana is cultivated in the tropical and subtropical regions of the world. Banana fruits have high calorific value that is closely comparable to potatoes but are more easily digestible. The fruits are good sources of micronutrients and relatively cheap which make it affordable by many households worldwide (1). There are over a thousand banana cultivars or landraces recognized, which significantly contribute to commercial and nutritional value for millions of people around the world (2). Scientific and local names have been given to these species for identification to avoid confusion. Simmonds and Shepherd (3) developed a nomenclature system that is based on ploidy level and morphological characters to describe the edible cultivated bananas. Wild species of banana, *Musa acuminata* was designated as genotype AA and *Musa balbisiana* as BB, both being diploid species. Intra and inter-specific hybridi-

zation led to the development of edible, seedless cultivars of banana of different combinations of diploid, triploid and tetraploid genomes such as AA, AB, AAA, BBB, AAB, ABB and AAAB (4). These genomic constitutions have also led to a classification based on the mode of consumption where the dessert banana is dominated by 'A' genome and culinary bananas are dominated by the 'B' genome (5, 6). These genomic traits are also believed to impart distinctive quality to banana fruits such as colour and appearance, flavour (taste and aroma), texture and nutritional value, which are important in determining their suitability for a specific purpose. Banana is a premier fruit crop of Kerala, grown in an area of 52898.61 hectares with a production of 424948.07 tonnes (7). The State is blessed with diverse agroclimatic conditions with wide array of banana cultivars which cater to the local needs. In spite of its rich genetic diversity, very few banana cultivars are cultivated on a commercial scale (8). Important cultivars of commercial significance include Nendran (Plantain), Palayankodan (Poovan), Rasthali, Monthan, Red Banana, Njalipoovan, Karpooravalli, Robusta (5, 9). Despite a high genetic diversity of banana germplasm, there is a great need to address the morphological and horticultural characteristics that serve as medium for better quality parameters related to fruit identity and consumer preferences (8). There are few studies in the literature that compare morphological and horticultural traits of different genomic groups of banana. The objective of the present study is to evaluate and explore banana cultivars of different genomic groups in order to reveal their morphological and horticultural characteristics.

Materials and Methods

The study was carried out in the Department of Post Harvest Technology, College of Agriculture, Vellanikkara, located in Thrissur district of Kerala between the period of December 2020 to March 2021 using the six banana (*Musa spp.*) cultivars of different genomic groups *viz*. Nendran (AAB), Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (AAA) and Yangambi (KM-5) (AAA). The genomic groups were determined using the nomenclature scheme for edible cultivated bananas, which is based on ploidy level and morphological characters devised by Simmonds and Shepherd (3). The fruits of the respective cultivars were collected from Banana Research Station, located at Kannara in Thrissur district of Kerala where they were grown under uniform conditions as per Package of Practices recommendations of the Kerala Agricultural University (10).

Morphological fruit characterisation

Fruit samples were taken from mid-hand and youngest hand of the bunch at ripe and full yellow stage of banana. The fruit morphological characterisation was conducted according to the Descriptors for Banana by IPGRI (11). Morphological descriptors of 25 characters evaluated include the fruit position, number of fruits, fruit length, fruit shape, transverse section of fruit, fruit apex, remains of flower relicts at fruit apex, fruit pedicel length, fruit pedicel width, pedicel surface, fusion of pedicels, immature fruit peel colour, mature fruit peel colour, fruit peel thickness, adherence of the fruit to the peel, cracks in fruit peel, pulp in fruit, pulp colour before maturity, pulp colour at maturity, fruit fall from hands, flesh texture, predominant taste, presence of seed with source of pollen, seed surface and seed shape. The fruit peel colour was virtually matched against the Royal Horticultural Society (RHS) colour chart at immature and mature fruit stage (12).

Horticultural characters

The horticultural characters of the fruit were also evaluated which include number of fruits per bunch, fruit length, fruit pedicel length, fruit pedicel width, fruit peel thickness, fruit pulp weight, fruit peel weight, fruit to peel ratio and fruit flesh firmness. The number of fruits observed on the mid-hand of the bunch was physically counted on each plant at time of harvest. The fruit length, fruit pedicel length, fruit pedicel width and fruit peel thickness were recorded using a digital vernier caliper. The fruit pulp weight and fruit peel weight were measured using a balance scale, and fruit to peel ratio was calculated using the values from these two measurements. The fruit flesh firmness was determined on the equatorial region of each fruit after removing the skin by using a hand held pressure tester (Model F 001 and F 327, Effigy, Italy) fitted with 8mm probe.

Data analysis

The experiment was laid out in a completely randomised design with three replications and presented as means in one way ANOVA to examine the significant differences using Web Based Agricultural Statistics Software Package (WASP) for analysis. Duncan's multiple range test was used for the comparison of means at 95% confidence level (p=.05). Qualitative analysis of fruit characters were quantified using unweighed scoring method and subsequently subjected to clustering analysis using SPSS version 20 windows (IBM SPSS Inc.,Chicago,IL) software, using Euclidean distances and presented as a two dimensional dendrogram.

Results and Discussion

Morphological characteristics

There were differences on the morphological characteristics among the six selected banana cultivars of different genomic groups that are commercially cultivated in Kerala (Table 1). Nendran (AAB) had the lowest number of individual fruits per bunch, which were perpendicular to the stalk but large in terms of fruit size, fruit pedicel length, and pedicel width. The fruit peel was thick, medium green in colour and turned yellow with maturity. The fruit pulp of Nendran (AAB) was light orange yellow at immature stage, which upon ripening changed to an attractive orange yellow colour with a firm pulp that has a sweet taste. Due to its large, sweet and firm pulp, the fruit is popular for both dessert and culinary purposes. The present study conforms to the findings of other authors who described fruits of AAB genomic group as large with thick peel and firm

Table 1: Morphological characteristics of some commercial banana cultivars of Kerala

Sl. No.	Character	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi (KM-5) (AAA)
1	Fruit position	Perpendicular to the stalk	Perpendicular to the stalk	Curved upward	Curved towards the stalk	Parallel to the stalk	Curved towards the stalk
2	Number of fruits on the mid-hand	≤12	13-16	13-16	13-16	13-16	13-16
3	Fruit length (cm)	21-25	≤15	≤15	≤15	16-20	≤15
4	Fruit shape	Straight at the distal end	Straight in distal end	Slightly curved	Slightly curved	Slightly curved	Slightly curved
5	Transverse section of fruit	Pronounced ridges	Rounded	Rounded	Slightly ridged	Slightly ridged	Rounded
6	Fruit apex	Lengthily pointed	Lengthily pointed	Bottlenecked	Bottle necked	Blunt tipped	Bottlenecked
7	Remains of flower relicts at fruit apex	Base of the style prominent	Without any floral relicts	Base of style prominent	Base of the style prominent	Persistent style	Persistent style
8	Fruit pedicel length (mm)	≥21	≤10	11-20	≥21	11-20	11-20
9	Fruit pedicel width (mm)	>10	>10	5-10	5-10	>10	>10
10	Pedicel surface	Hairless	Hairless	Hairless	Hairless	Hairless	Hairless
11	Fusion of pedicels	No visible sign of fusion	No visible sign of fusion	No visible sign of fusion	No visible sign of fusion	No visible sign of fusion	No visible sign of fusion
12	Immature fruit peel colour	Medium green	Medium green	Ashy green	Light green	Medium green	Light yellowish green
13	Mature fruit peel colour	Yellow	Yellow	Yellow with ashy tint	Yellow	Bright yellow	Yellow
14	Fruit peel thickness (mm)	Three or more	Two or less	Two or less	Two or less	Three or more	Two or less
15	Adherence of the fruit to the peel	Fruit peel easily	Fruit peels easily	Fruit peels easily	Fruit peels easily	Fruit peels easily	Fruit peels easily
16	Cracks in fruit peel	Without cracks	Without cracks	Without cracks	Without cracks	Without cracks	Without cracks
17	Pulp in fruit	With pulp	With pulp	With pulp	With pulp	With pulp	With pulp
18	Pulp colour before maturity	Light orange yellow	Cream	Cream	White	Cream	Cream
19	Pulp colour at maturity	Orange yellow	Cream	Cream	White	Cream	Cream
20	Fruit fall from hands	Persistent	Deciduous	Persistent	Persistent	Deciduous	Persistent
21	Flesh texture	Firm	Firm	Firm	Firm	Soft	Soft
22	Predominant taste	Sweet (like Cavendish)	Sweet and acidic	Mild, slightly tasty or tasteless	Sweet (like Cavendish)	Sweet (like Cavendish)	Sweet(like Cavendish)
23	Presence of seed with source of pollen	ND	ND	ND	ND	ND	ND
24	Seed surface	ND	ND	ND	ND	ND	ND
25	Seed shape	ND	ND	ND	ND	ND	ND

textured pulp (6, 13). Grand Naine (AAA) was smaller in terms of size than Nendran (AAB), but was observed to be larger than other cultivars of different genomic groups selected for this study. A medium green peel was observed on Grand Naine at immature stage which upon ripening turned bright yellow with a cream coloured, soft and sweet pulp. This cultivar is a favourite dessert banana and due to its soft pulp, puree can be obtained by mashing the fruit using a fork (14).

Although Yangambi (KM-5) (AAA) belongs to the same genomic group as Grand Naine, several differences with respect to the morphological traits were observed (Table 1). Yangambi (KM-5) fruits were found to be small with light yellowish green coloured peel at immature stage which upon maturity turned yellow, with a soft, cream coloured pulp. Within the AAA genomic group, there were differences with regard to orientation, compactness and shape; therefore further grouping into subgroups have been done (15). The differences between Yangambi (KM-5) and Grand Naine can be attributed to the different subgroups within the same genomic group. Yangambi (KM-5) is characterized as a small fruited banana that belongs to Ibota subgroup while in the case of Grand Naine, the fruit size is relatively large and it belongs to the Cavendish subgroup (16). Karpoorvalli (ABB), a triploid banana cultivar, had a distinct character of having a peel that was ashy green which upon ripening turned yellow with an ashy tint and a pulp that was firm, cream coloured and fell under the predominant taste group of mild, slightly tasty and tasteless according to the descriptors of banana (11).The present study revealed two diploid banana cultivars being small in size but having differences in terms of the peel and pulp colour, as well as the taste. Pisang Lilin (AA) had a medium

green peel that turned yellow upon ripening with a firm, cream coloured pulp that was sweet and acidic. The sweet and acidic characteristic flavour of Pisang Lilin is most valued among supermarket processed products (14). Njalipoovan (AB) was the only variety that had equal ploidy levels of A and B characterized as a small sized banana of light green peel that turned yellow upon maturity and had a white coloured, firm flesh with a sweet taste. The white flesh of Njalipoovan is often confused with cultivars from 'Silk' subgroup of AAB genomic group but has poor keeping qualities due to its thin peel (9, 17). The triploids had superior fruit qualities when compared to the diploids. It is reported that with an increase in ploidy level there is an increase in the chromosome number of banana fruit which causes an increase in the quality parameters such as its adaptability to the environment (18). The overall findings reveal that although the anatomy, physiology and the development of banana cultivars was the same, there were differences in the morphological traits of bananas even within the same genomic group as observed between 'AAA' group Grand Naine and Yangambi (KM-5) (Plate I, Plate II, Plate III). Therefore, further characterization based on subgroup is essential to differentiate the banana cultivars.

Horticultural characteristics

Table 2 presents the results for horticultural characteristics of banana (*Musa spp*.) cultivars of different genomic group harvested at fully ripe stage. Significant differences were observed between the banana cultivars for all horticultural characteristics except the number of fruits per bunch. The fruit length was 22.07cm in Nendran (AAB) and 19.01cm in Grand Naine (AAA), where no significant difference in fruit length among these two triploid cultivars was recorded. The fruit length was 10.67cm in Karpooravalli (ABB), which was significantly different from Pisang Lilin (AA) (14.03cm), Njalipoovan (AB) (12.17cm) and Yangambi (AAA) (14.67cm).

Similar studies done using 26 accessions of banana revealed significant difference in the fruit length, where a range of 6.87-18.67cm was recorded. The cultivars having maximum fruit length had higher levels of ploidy which is believed to be impacted by an increase in the size of cell nuclei which subsequently results in increased size of the plant tissues (19, 20). The present study revealed that diploids Pisang Lilin (AA) and Njalipoovan (AB) were small fruited, while the triploids Nendran (AAB) and Grand Naine (AAA) had the maximum fruit size. However, this was not the case with other triploid cultivars like Yangambi (AAA) and Karpooravalli (ABB) which had small sized fruits. Although the level of ploidy can be used to characterize banana, difficulties could be encountered to identify the similarities and differences in banana varieties. Therefore, other methods of identification such as unweighed paired group method using mean arithmetic (UPGMA), DNA markers (RAPD and ISSR) are recommended (16, 20).

Nendran (AAB) had the longest fruit pedicel length of

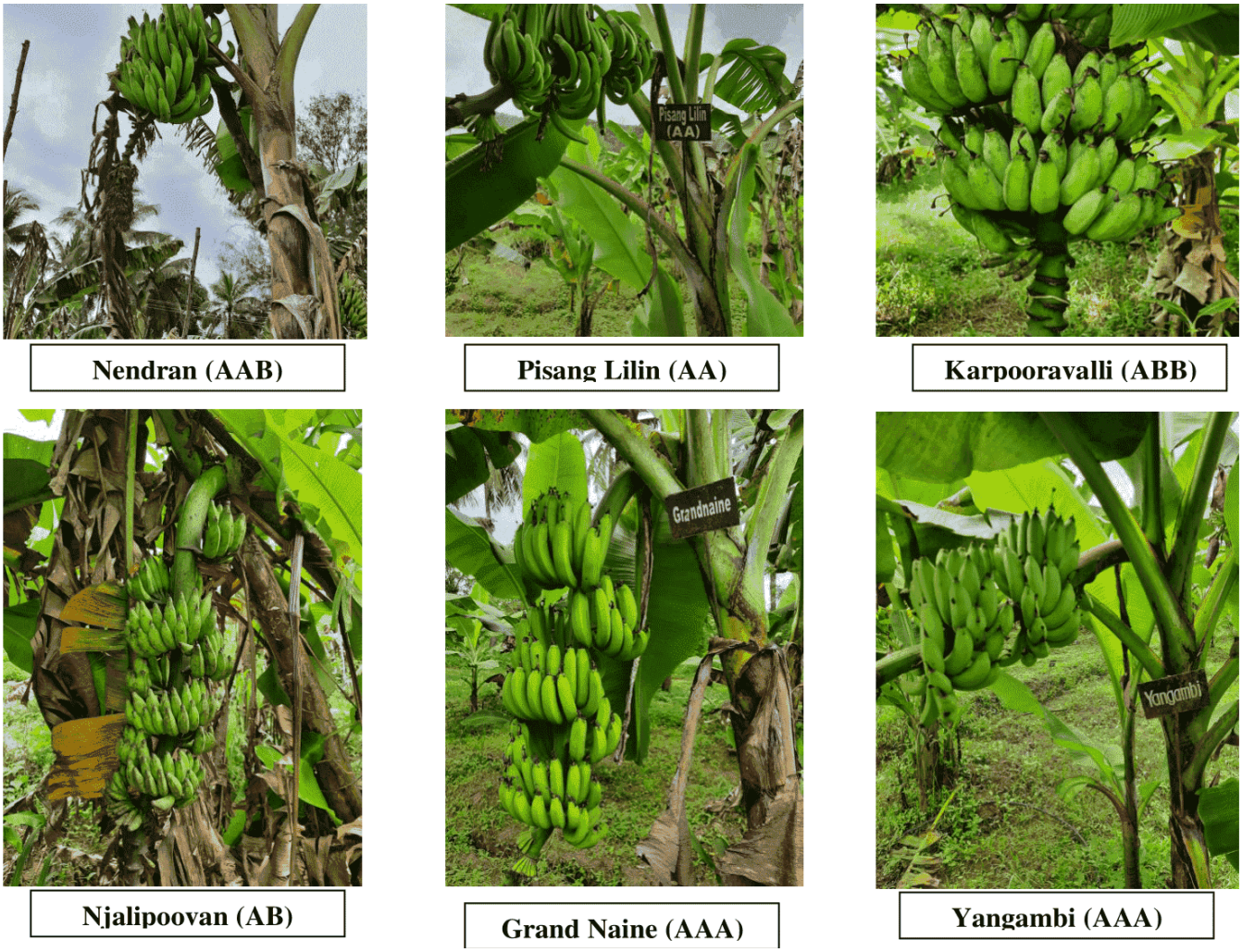

Plate I: Arrangement of fruit around the stalk in some commercial banana (Musa spp.) cultivars of Kerala.

Plate II: Unripe fruits of some commercial banana (Musa spp.) cultivars of Kerala .

28.54cm that was not significantly different from that of Njalipoovan (AB), which had 26.00cm. Karpooravalli (ABB) had the shortest pedicel (7.97cm), followed by Njalipoovan (AB) (9.57cm). Among the cultivars of AAB and AB genomes, there is an overlap of horticultural characters which can result in difficulties in distinct differentiation among these genomes (21). The triploid banana cultivars had higher values in terms of peel thickness, with the exception of Karpooravalli (ABB), while lower values were recorded in the diploid varieties. The present study revealed that the triploids such as Nendran (AAB), Grand Naine (AAA) and Yangambi (AAA) had better storage and transportation qualities than diploids due to their thicker peel. The study also revealed that although Nendran (AAB) had the highest fruit pulp and peel weight, the pulp in fruit was lower compared to other cultivars, as indicated by the low fruit pulp: peel ratio (1.8). Karpooravalli (ABB) had the highest values of fruit pulp (4.81), indicating that the major part of the fruit is pulp.

One of the series of physiological changes during fruit ripening is fruit softening which is a consequence of changes in the composition of cell wall pectic substances (22). Data for fruit firmness presented in Table 2 revealed significant difference among banana fruits of different genomic groups. Njalipoovan (AB) and Nendran (AAB) had the highest values for fruit firmness which were at 0.09cm^{2}kg^{-1} and 0.08cm^{2}kg^{-1}, respectively. The lowest values for fruit flesh firmness were recorded in triploid cultivars of the same genomic groups *i.e.,* Grand Naine (AAA) and Yangambi (AAA) which had the same values of 0.04cm^2 kg^{-1}. Cultivars with 'B' genome such as AAB have the highest level of lignins (catechins and chlorogenic acids) and are firm like cooking bananas while that of AAA genome group contains lower levels of phenylpropanoid (essential components for cell wall structures); hence they are softer and are used for dessert purposes (23,24).

Cluster analysis

The cluster analysis based on the morphological characters among six banana cultivars of different genomic groups is shown in a dendrogram (Fig. 1). Major degree of similarities and differences among the six bananas of different genomic groups was revealed by the taxonomic distance. In the present study, the dissimilarity level was in the estimated range of 1 to 25. Three categories of clusters were observed among the banana cultivars, with one consisting of Karpooravalli (ABB), Njalipoovan (AB) and Yangambi (AAA) where a taxonomic distance of less than 2.5 per cent was observed. The second cluster was dominated by the group

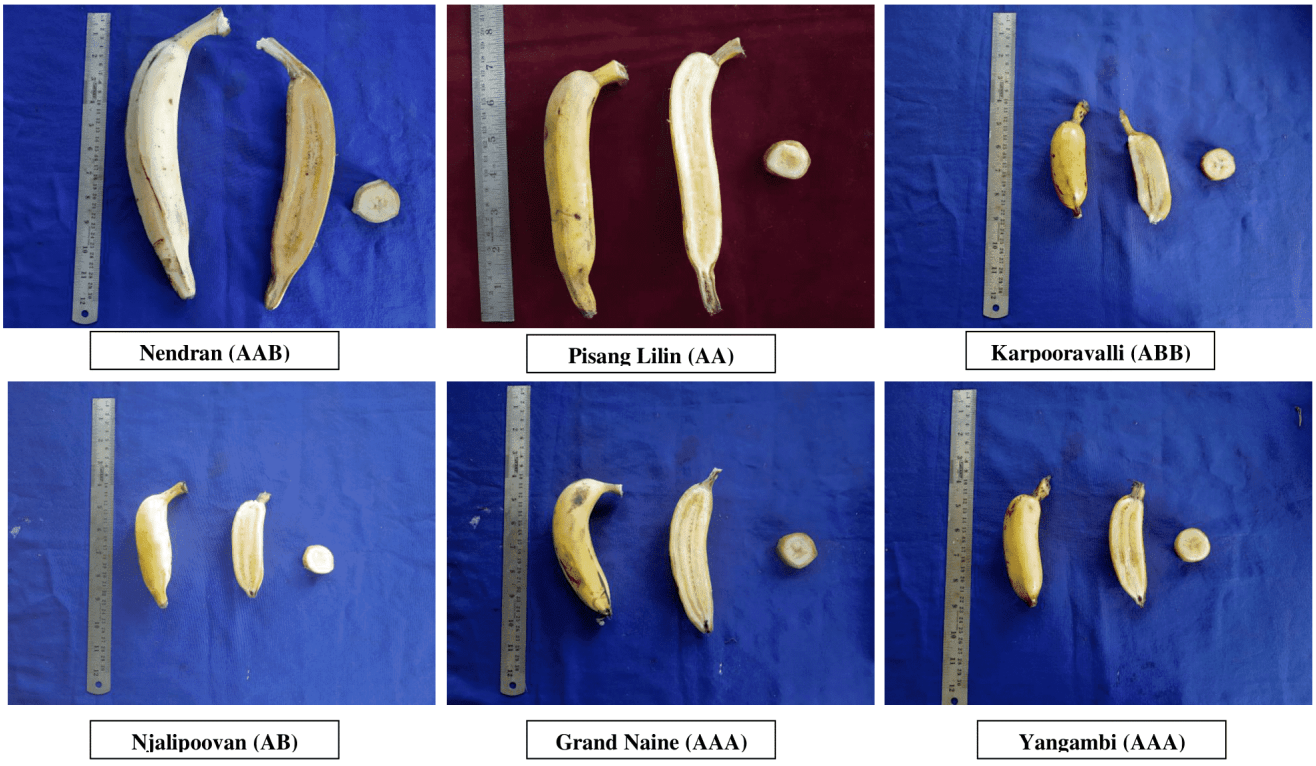

Plate III: Ripe fruit of some commercial banana (Musa spp.) cultivars of Kerala

having 'A' genome with all the banana cultivars mentioned above with the exception of Karpooravalli (ABB) and the addition of two banana cultivars, namely Grand Naine (AAA) and Pisang Lilin (AA). In this category of cluster, the taxonomic distance was observed to be higher, at estimated values of 12.50 per cent. The last category of cluster consisted of banana cultivars *viz.* Grand Naine (AAA), Pisang Lilin (AA) and Nendran (AAB) where the taxonomic distance of 25 per cent was recorded. Although Grand Naine (AAA) and Yangambi (KM-5) (AAA) were in the same genomic group, there was a huge difference between the two cultivars as shown by the taxonomic distance. Similar results of variations within the same genomic group were reported in the study where Muraru (AA) was different from other diploids of Sucrier (AA) and Banksii (AA) of the same group, but very similar to triploids Gros Michel (AAA) and Cavendish (AAA) of a different genomic group (25).

Table 2: Horticultural characteristics of some commercial banana (*Musa spp.*) cultivars of Kerala

Cultivars	Number of fruits per bunch	Fruit length (cm)	Fruit pedicel length (mm)	Fruit pedicel width (mm)	Peel thickness (mm)	Pulp weight (g)	Peel weight (g)	Fruit to peel ratio	Fruit flesh firmness (cm^2kg^{-1})
Nendran	12.33	22.07^{a}	28.54^{a}	11.56^{a}	3.10^{a}	89.20^{a}	49.30^{a}	1.81^{d}	0.08^{a}
Pisang Lilin	11.67	14.03^{bc}	9.82^{c}	10.23^{ab}	1.45^{cd}	43.87^{de}	18.97^{c}	2.32^{c}	0.06^{b}
Karpoorvalli	15.67	10.67^{c}	16.41^{b}	7.97^{c}	1.17^{d}	46.50^{cd}	9.65^{d}	4.81^{a}	0.06^{b}
Njalipoovan	15.67	12.17^{bc}	26.00^{a}	9.57^{bc}	1.74^{cd}	33.03^{e}	9.60^{d}	3.41^{b}	0.09^{a}
Grand Naine	15.67	19.01^{a}	17.30^{b}	10.15^{ab}	2.56^{ab}	62.30^{b}	23.20^{b}	2.69^{c}	0.04^{c}
Yangambi	13.67	14.67^{bc}	17.58^{b}	10.90^{ab}	2.02^{bc}	55.89^{bc}	17.39^{c}	3.20^{b}	0.04^{c}
S.Em (±)	0.65	0.74	1.04	0.32	0.11	0.11	0.67	0.08	0.00
CD (0.05)	NS	3.96	5.53	1.70	0.61	11.16	3.57	0.45	0.02

Conclusion

The data presented in this present study reveal substantial morphological and horticultural variation among banana cultivars of different genomic groups, with an overlap of similarities and differences even in cultivars under the same genomic group. A number of morphological and horticultural characteristics such as fruit length, fruit pedicel length, fruit pedicel width, peel thickness and fruit pulp weight were large in Nendran (AAB) cultivar. Although cultivar Karpooravalli (ABB) exhibited smaller morphological and horticultural traits, it had a larger fruit: pulp weight ratio compared to other banana cultivars. Even though Yangambi (AAA) and Grand Naine (AAA) belonged to the same genomic group, major differences were observed on the morphological and horticultural traits between the two culti-

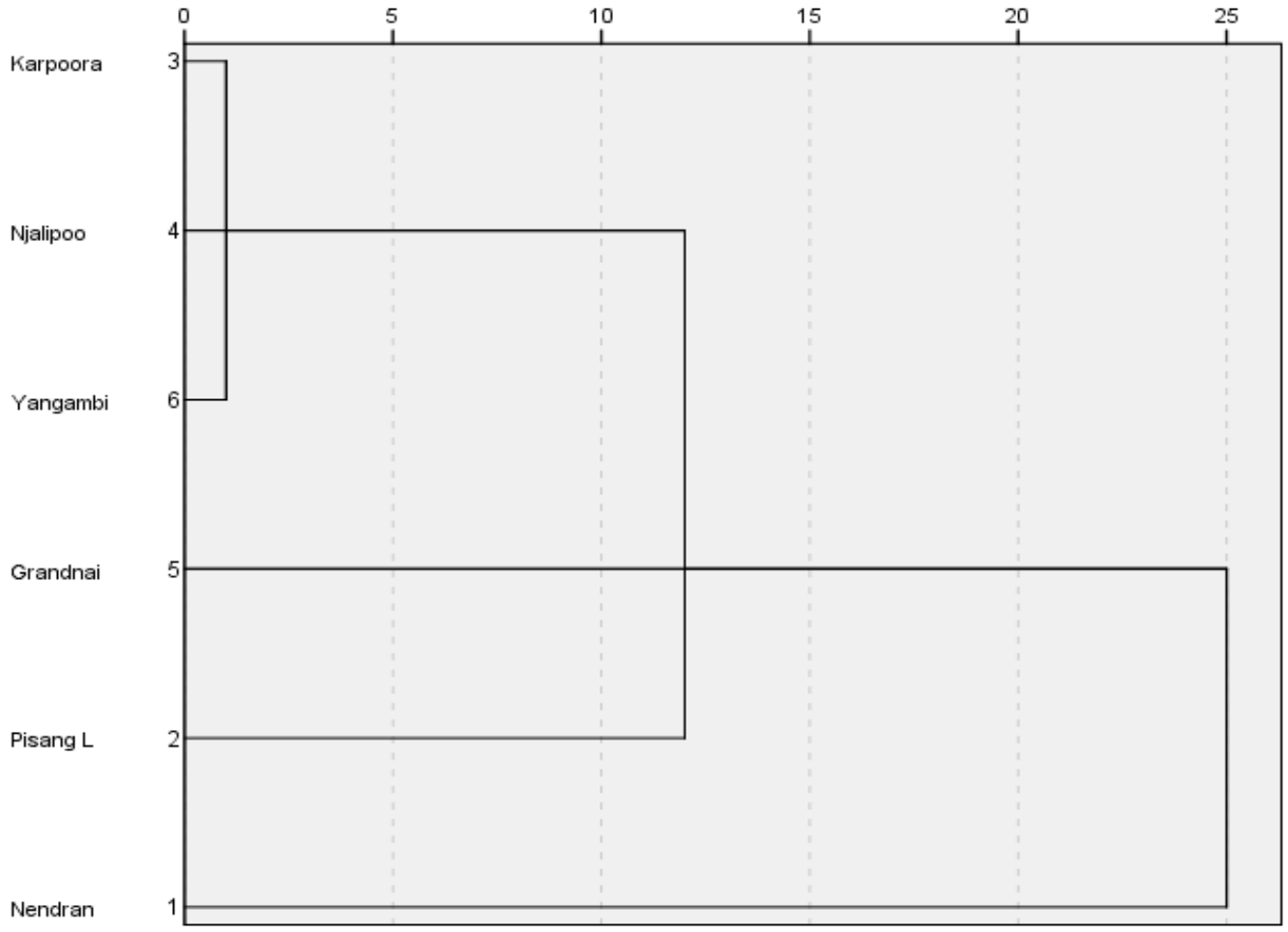

Fig. 1. Dendrogram showing clustering patterns of some commercial banana (*Musa* spp.) cultivars of Kerala based on the morphological descriptors [Karpora= Karpooravalli (AAB); Njalipoo= Njalipoovan (AB); Yangambi= Yangambi (KM-5) (AAA); Grandnai=Grand Naine; (AAA) Pisang L=Pisang Lilin (AA); Nendran=Nendran (AAB)].

vars. For the production of processed food like banana chips, Intermediate Moisture Fruit (IMF) *etc*, a large and firm fruit is more desirable which fits the traits described for Nendran (AAB).

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Authors contributions

The work was a part of PhD thesis of the first author which was supervised by second and third authors. All authors have read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None.

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