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Bananas and Their Wild Relatives in Pandeglang, Indonesia

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ABSTRACT

Pandeglang is one of the banana producer regencies of Banten, Indonesia, that produce 924 tons per year. However, information regarding the diversity of banana germplasm in this region is unavailable. This study explored districts Cadasari, Banjar, Jiput, Labuan, and Menes. Morphological characters were noted and used to identify the cultivars, subspecies, or varieties. In total, 22 accessions were collected from 22 collection sites. Based on morphological characters, we described 14 banana accessions of 10 cultivars, three accessions of wild *Musa acuminata* and one of *Musa balbisiana*. Considering its genome composition, five genome types we described among these banana cultivars, i.e., AA (divided into AA and AA wild), BB, AAA, AAB, and ABB. In this study, we did a principal component analysis and saw that AA wild and AAB were clearly separated, but the other genome types were clustered partially or included in one cluster. Our study expands the information on banana diversity in Indonesia. Further study on the potential of this banana germplasm to be used as a genetic resource to find resistance to banana diseases is needed.

1. Introduction

Banana (*Musa* spp.) is one of the most popular fruits and is favored by people around the globe, with production exceeding 125 million tons per year (FAO 2020). As the center of origin and diversity (Simmonds 1962; Perrier *et al.* 2011), Indonesia is number six after India, China, Filipina, Ecuador, and Brazil in production, with about 7 million tons per year (FAO 2020). In Indonesia, this fruit is part of daily life for food and income but also part of the culture (Kennedy 2009; Hapsari *et al.* 2017).

Among 70 banana species (Häkkinen 2013), *Musa acuminata* (genome A) and *M. balbisiana* (genome B) are the primary ancestors of banana cultivars that from their intra- and inter-hybridization resulted in various genome compositions from AA, AB, AAA, AAB, ABB, and AAAB bananas (Simmonds 1962; Heslop-Harrison 2011). The exact number of cultivars is unclear, but at least 1,000 banana cultivars with diverse morphological characters were recorded (Ruas *et al.* 2017).

The study of bananas in Indonesia began in the 1900s, as recorded in the Herbarium Bogoriense (Hotta 1989). Later in 1991, Nasution described 15 varieties of wild *M. acuminata*. Recently, surveys of bananas in Indonesia continued to progress. For example, Sutanto *et al.* (2016) reported banana diversity in eastern Indonesia, Hastuti *et al.* (2019) recorded new wild *M. acuminata* in Sulawesi, Sunandar (2017) and Sunandar and Kurniawan (2020) reported the presence of *M. balbisiana*, the distribution of *M. borneensis* and *M. campestris* in Kalimantan. Genetic diversity based on molecular study also has been reported. Poerba and Ahmad (2010) used RAPD and ISSR to distinguish genetic variability among 18 banana cultivars. The same markers were also helpful in assessing genetic diversity among wild *M. acuminata* (Poerba *et al.* 2019). Genetic diversity of *M. balbisiana* has been reported based on RAPD and AFLP markers (Poerba and Ahmad 2013; Ahmad *et al.* 2014). So far, still limited information about genetic diversity for each province or region in Indonesia.

Banten is one province as a center of banana production in Indonesia that contributed 3.82% of national banana production after East Java, Lampung, West Java, and Central Java (www.pertanian.go.id, accessed in 2021). Banten consists of four cities, i.e., Serang, Cilegon, Tangerang, and South Tangerang, and four regencies, i.e., Serang, Pandeglang, Lebak,

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and Tangerang. Pandeglang is the largest banana producer among those cities and regencies, producing 924 tons annually. However, information regarding the diversity of banana germplasm in Pandeglang is scarce (Pandeglang Regency Horticulture Office 2019, personal communication). Banana germplasm information is essential for management and genetic improvement. In this study, we reported the diversity of banana cultivars and wild relatives in Pandeglang and described its morphological characteristics.

2. Materials and Methods

2.1. Study Areas

Sampling exploration was conducted from January to July 2021. Five collection sites, including Cadasari, Banjar, Jiput, Labuan, and Menes located in Pandeglang. These locations were the largest banana producer area in Pandeglang (BPS 2020). Banana was collected from farmers' garden, forest, and abandoned area using a purposive sampling method

2.2. Characterization

We observed banana accessions at the fruiting stage. Morphological characters and the coordinates (GPS) were recorded at the sampling location. Photos of plant habitus, leaves, male bud, flower, fruit, and the bunch were taken for further characterization based on the Banana Descriptor (IPGRI 1996). The morphological characterization of wild bananas was based on Nasution (1991). Later, the morphological data was used to build a key identification of cultivars and wild banana relatives.

The genetic constitution or genome types of collected accessions were determined by a scoring system based on 15 characters of *Musa acuminata* Colla and *Musa balbisiana* Colla by Simmonds and Shepherd (1955). Furthermore, PCA (Principal Component Analysis) analysis was carried out to see the grouping of each cultivar, variety, and subspecies based on morphological characteristics using Clustvis (Metsalu and Vilo 2015).

3. Results

In this study, we found cultivars and wild banana relatives. All banana cultivars were found on a homestead. Meanwhile, wild bananas are found weedy in the village and riverside. Twenty-two accessions were collected from 22 collection sites (Figure 1). Based on morphological characters, we described 14 banana accessions consisting of 10 accessions of cultivars, three accessions of wild *M. acuminata* and one *M. balbisiana* (Table 1). Based on the morphology scoring system for *M. acuminata* and *M. balbisiana*, we described four genome types among these banana cultivars, i.e., AA, AAA, AAB, and ABB (Table 2). Two cultivar types include genome AA, i.e., "Pisang Oli" and "Pisang Mas". Three cultivar

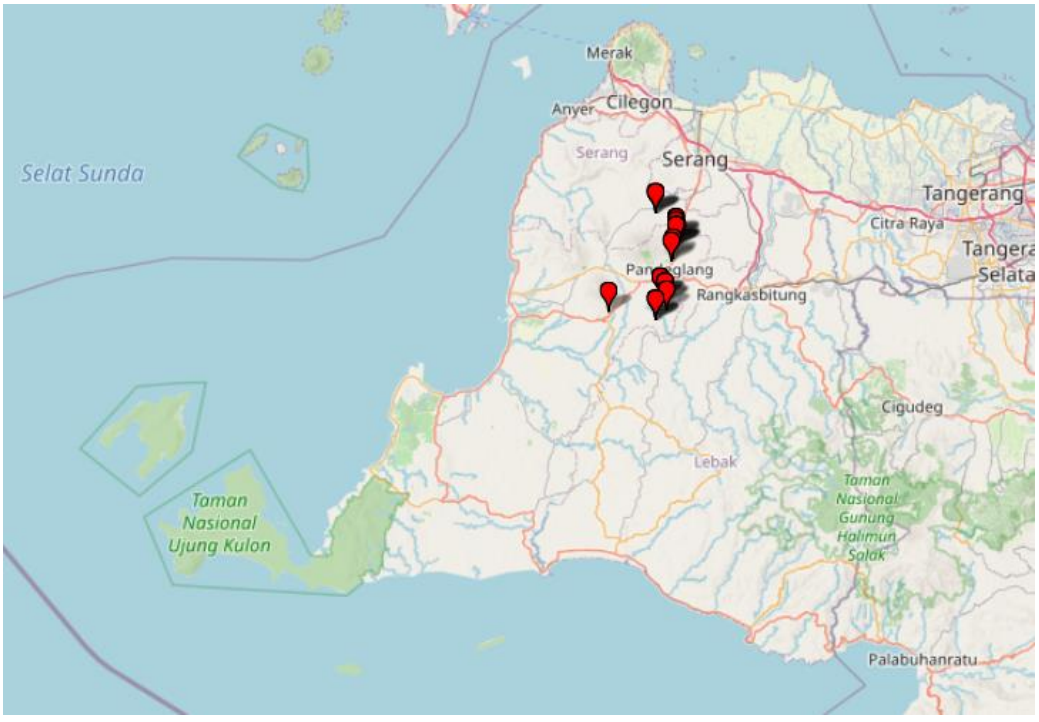

Figure 1. Collection site of the banana exploration in Pandeglang. The map was retrieved from gpsvisualizer.com

Table 1. Accession collected and collection site of the banana exploration in Pandeglang

Accession	Local name	Synonym	Type	Subgroup	Scientific name	Biology	Collection site		
							District, village	Latitude	Longitude
Ca2	Ketan	Pisang Oli	1	NA	*Musa* AA "Pisang Oli"	Cultivar	Cadasari, Cadasari	-6.25917	106.11972
Ba1	Ketan	Pisang Oli	1	NA	*Musa* AA "Pisang Oli"	Cultivar	Banjar, Cibodas	-6.38389	106.10250
Ba3	Raja Nangka	Pisang Oli	1	NA	*Musa* AA "Pisang Oli"	Cultivar	Banjar, Citalahab	-6.37111	106.10000
Me4	Ketan	Pisang Oli	1	NA	*Musa* AA "Pisang Oli"	Cultivar	Menes, Ramaya	-6.21306	106.08506
Ba2	Muli	Pisang Lampung	2	Sucrier	*Musa* AA (Sucrier subgrup) "Muli"	Cultivar	Banjar, Citalahab	-6.37111	106.10000
Ca7	Pulo	-	3	NA	*Musa* AAA "Pisang Pulo"	Cultivar	Cadasari, Cigadung	-6.27128	106.12078
Ca1	Raja Garing	Pisang Papan	4	NA	*Musa* AAA "Pisang Papan	Cultivar	Cadasari, NA	-6.26233	106.12006
Ba4	Ambon	Ambon Kuning	5	Gros Mitchel	*Musa* AAA (Gros Michele subgroup) "Ambon"	Cultivar	Banjar, Banjar	-6.36056	106.09222
Ca3	Raja Nangka	Pisang Nangka	6	Pisang Nangka	*Musa* AAB (Pisang Nangka subgrup) "Pisang Nangka"	Cultivar	Cadasari, Cadasari	-6.25917	106.11972
Ca4	Tanduk	-	7	Plantain	*Musa* AAB (Plantain subgrup) "Pisang Tanduk"	Cultivar	Cadasari, Cigadung	-6.27128	106.12078
Ba5	Tanduk	-	7	Plantain	*Musa* AAB (Plantain subgrup) "Pisang Tanduk"	Cultivar	Banjar, Banjar	-6.36056	106.09222
Me5	Tanduk	-	7	Plantain	*Musa* AAB (Plantain subgrup) "Pisang Tanduk"	Cultivar	Menes, Ramaya	-6.21306	106.08506
Ca6	Kepok Siem/Apu	Pisang Siem, Cau Bedong	8	NA	*Musa* ABB (Pisang Awak Subgrup) "Cau Bedong	Cultivar	Cadasari, Cigadung	-6.27128	106.12078
Me2	Kepok Siem	Pisang Siem, Cau Bedong	8	NA	*Musa* ABB (Pisang Awak Subgrup) "Cau Bedong	Cultivar	Menes, Tegalwangi	-6.39889	106.08501

Table 1. Continued

Accession	Local name	Synonym	Type	Subgroup	Scientific name	Biology	Collection site		
							District, village	Latitude	Longitude
Ba6	Kepok Besar	Pisang Kepok	9	Saba	*Musa* ABB (Saba subgrup) "Pisang Kepok"	Cultivar	Banjar, Gunung Putri	-6.36292	106.09297
Me3	Raja Buluh	Pisang Raja	10	Pisang Raja	*Musa* AAB (Pisang Raja Subgrup) "Pisang Raja	Cultivar	Menes, Ramaya	-6.21306	106.08506
Me1	Cau Kole	-	11	-	*Musa acuminata* subsp. *malaccensis*	Wild	Menes, Tegalwangi	-6.39889	1 06.08501
Me6	Cau Kole	-	12	-	*Musa acuminata* var. *breviformis*	Wild	Menes, Tegalwangi	-6.39889	106.08501
Pa1	Cau Kole	-	12	-	*Musa* acuminata var. *breviformis*	Wild	Pandeglang, Cikondang	-6.29806	106.11111
Pa2	Cau Kole	-	13	-	*Musa acuminata* var. *zebrina*	Wild	Pandeglang, Cikon-dang	-6.29222	106.11389
Sa1	Pisang Batu	Pisang Klutuk	14	-	*Musa balbisiana*	Wild	Saketi, Kadu Dampit	-6.38639	106.00278
Ca5	Pisang Batu	Pisang Klutuk	14	-	*Musa balbisiana*	Wild	Cadasari, NA	-6.27122	106.12139

Table 2. Morphology scoring based on Simmonds and Shepherd (1955)

Accession	Banana	Synonym	Type	Characters															Score	Genome
				Pseudostem colour	Petiole canal	Peduncle	Pedicles	Ovules	Bract shoulder	Bract curling	Bracts shape	Bract apex	Bract colour	Colour fading	Bract scars	Free tepal of male flower	Male flower colour	Stigma colour		
Ca2	Ketan	Pisang Oli	1	1	1	1	1	1	1	1	1	1	2	2	1	2	1	2	19	AA
Ba1	Ketan	Pisang Oli	1	1	1	1	1	1	1	1	1	1	2	2	1	2	1	2	19	AA
Ba3	Nangka	Pisang Oli	1	1	1	1	1	1	1	1	1	1	2	2	1	2	1	2	19	AA
Me4	Ketan	Pisang Oli	1	1	1	1	1	1	1	1	1	1	2	2	1	2	1	2	19	AA
Ba2	Mas Muli	Pisang Lampung	2	1	3	1	1	1	1	1	1	1	2	2	1	1	1	1	19	AA
Ca7	Pulo	-	3	1	4	2	1	1	1	1	1	1	2	2	1	1	1	1	21	AAA
Ca1	Raja Garing	Pisang Papan	4	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	17	AAA
Ba4	Ambon	Ambon Kuning	5	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	16	AAA
Ca3	Nangka	Pisang Nangka	6	2	1	2	2	5	1	1	1	3	3	4	1	2	2	2	32	AAB
Ba5	Tanduk	-	7	4	3	5	2	1	3	3	3	3	3	3	3	3	3	3	45	AAB
Ca4	Tanduk	-	7	5	3	2	3	1	3	3	3	3	3	3	3	3	3	3	44	AAB
Me5	Tanduk	-	7	5	4	2	3	1	3	3	3	3	3	3	3	3	3	3	45	AAB
Ca6	Siem	Pisang Siem, Cau Bedong	8	4	5	4	5	5	4	2	3	4	4	5	3	4	5	5	62	ABB

Table 2. Continued

Accession	Banana	Synonym	Type	Characters															Score	Genome
				Pseudostem colour	Petiole canal	Peduncle	Pedicles	Ovules	Bract shoulder	Bract curling	Bracts shape	Bract apex	Bract colour	Colour fading	Bract scars	Free tepal of male flower	Male flower colour	Stigma colour		
Me2	Siem	Pisang Siem, Cau Bedong	8	4	5	4	5	5	4	2	3	4	4	5	3	4	5	5	62	ABB
Ba6	Kepok Besar	Pisang Kepok	9	4	5	4	5	5	4	2	3	4	4	5	3	4	5	5	62	ABB
Me3	Raja/Raja Buluh	Pisang Raja	10	2	4	3	3	2	2	5	3	4	3	5	2	2	2	2	44	AAB
Me1	*Musa acuminata* subsp. *malaccensis*	-	11	1	1	1	1	1	1	1	1	2	1	2	1	1	1	1	17	AA
Me6	*Musa acuminata* var. *breviformis*	-	12	1	1	1	1	1	1	1	1	2	1	2	1	1	2	1	18	AA
Pa1	*Musa acuminata* var.*breviformis*	-	12	1	1	1	1	1	1	1	1	2	1	2	1	1	1	1	17	AA
Pa2	*Musa acuminata* var. *zebrina*	-	13	1	1	1	1	1	1	1	1	2	1	2	1	1	2	1	18	AA
Ca5	*Musa balbisiana*	Pisang Klutuk	14	5	5	5	5	5	5	5	4	5	5	4	5	4	4	4	70	BB
Sa1	*Musa balbisiana*	Pisang Klutuk	14	5	5	5	5	5	5	5	5	5	5	5	5	4	4	4	72	BB

types are described as AAA, i.e., "Pisang Pulo", "Pisang Papan" and "Ambon Kuning". Two cultivar types are described as AAB, i.e., "Pisang Nangka", "Pisang Tanduk", and "Pisang Raja". Two cultivar types are described as ABB, i.e., "Pisang Siem", and "Pisang Kepok".

Among described banana species in this study, we identified key traits to develop a key identification of bananas in Pandeglang as presented below:

1. a. The fruit filled with seed.. 2
   b. The fruit is seedless.. 5
2. a. Its ovules have two regular rows in each loculus.. 3
   b. Its ovules have four irregular rows in each loculus.. *Musa balbisiana*
3. a. The leaves are reddish with some blotches.............................. *Musa acuminata* var. zebrina
   b. The leaves are green or light green.................. 4
4. a. The male bud color is red or reddish....................................... *Musa acuminata* subsp. malaccensis
   b. Male bud is purple.................... *Musa acuminata* var. breviformis
5. a. The male bud is not present after the last hand of female flower.. "Pisang Tanduk"
   b. Male bud is present after the last hand of female flower 6
6. a. Style remains in the mature fruit...... "Pisang Oli"
   b. Without any floral relic.. 7
7. a. Fruit position is perpendicular to stalk............. 8
   b. Fruit is curved, parallel, or pendant to the stl.. 11
8. a. Petiole canal of the leaf number three before the flower is open or straight...................................... 9
   b.Petiole canal of the leaf number three before the flower is curved inward.. 10
9. a.Fruit is rounded with bottleneck tip ...."Pisang Mas"
   b. Fruit with blunt-tipped ...."Pisang Papan"
10. a. The compound tepal of male flower with strong red-purple pigmentation ...."Pisang Kepok"
    b. The compound tepal of male flower with light red-purple pigmentation .... "Kepok Siem"

11. a. Neutral/male flower persistent.."Pisang Raja"
    b. Neutral/male flower falling..... 12
12. a. The bunch is falling vertically ..... "Pisang Ambon"
    b. The bunch is at the angle..... 13
13. a. The fruit shape is straight....."Pisang Pulo"
    b. The fruit is curved..... "Pisang Nangka"

More detailed descriptions and photos of observed bananas are presented in Supplementary 1 and 2, respectively.

In one case, we found that more than one local name in one banana cultivar, such as "Ketan" and "Raja Nangka", to revere "Pisang Oli", meanwhile "Kepok Siem" and "Kepok Apu" to revere "Pisang Siem". Besides, one local name can revere different bananas in other villages, such as "Raja Nangka" that in Citalahab village revere "Pisang Oli", but in Cadasari village revere "Pisang Nangka".

"Pisang Oli" was the most common banana type cultivar in Pandeglang, found in four villages, followed by "Tanduk" in three villages and "Pisang Raja" in two villages. Other banana cultivars are only found in one village each. People commonly planted banana cultivars for their consumption and cash.

We found two wild banana species, *M. acuminata*, and *M. balbisiana*. These bananas are categorized as wild banana because it produces a seed that dominates the fruit content. *M. acuminata* was grown on the riverside or in an abandoned village area. In contrast, *M. balbisiana*, known as "Pisang Klutuk" or "Pisang Batu", was found on a homestead or in the farming area.

Seventy-six morphological characters were characterized (Supplementary 2) and used PCA to see the clustering (Figure 2). Only AA wild was clustered separately; meanwhile, other genomes types clusters were intersected or mixed with other genome types. Genome ABB and BB were clustered together. Two accessions of the AAA genome, "Pisang Ambon Kuning" and "Pisang Papan", were included in the cluster AA genome, but one AAA banana, "Pisang Pulo", was separated.

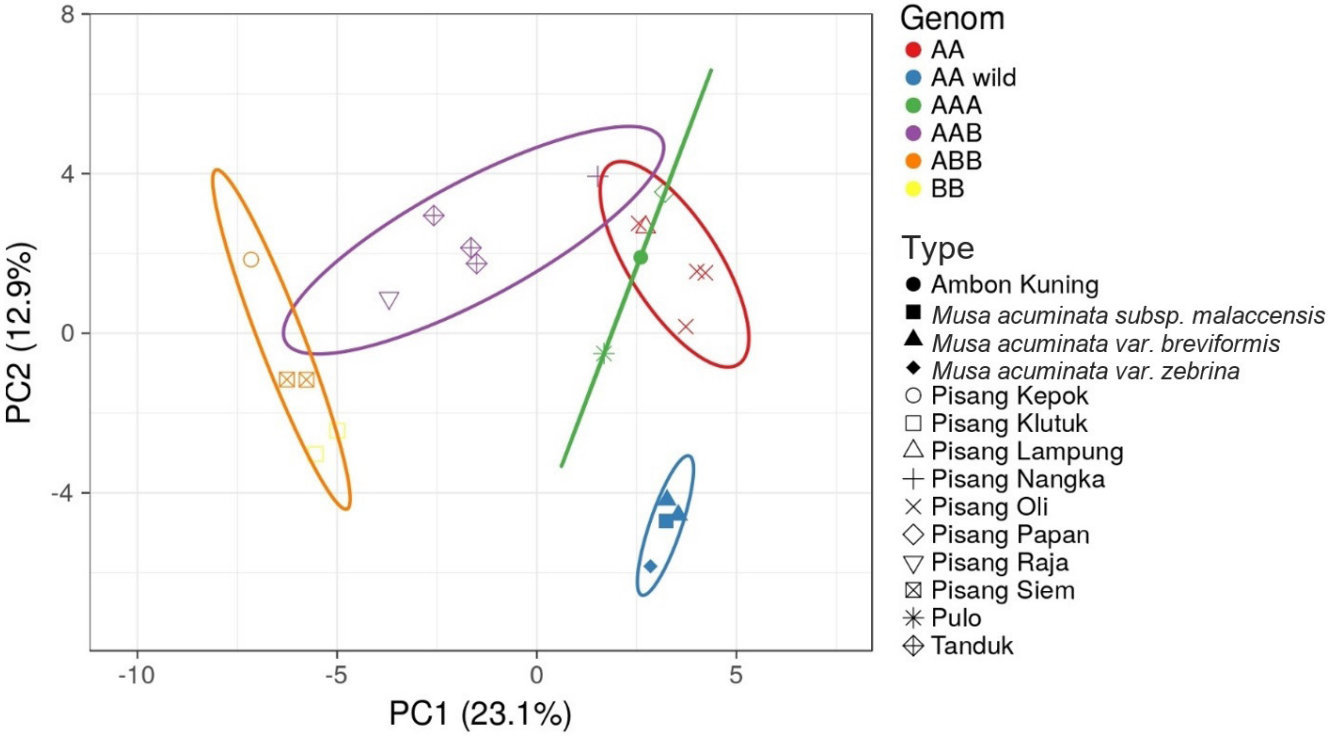

Figure 2. Principal component analysis of bananas in Pandeglang, Banten based on morphological characters

4. Discussion

Wild bananas *M. acuminata* and *M. balbisiana* are the wild relatives of banana cultivars (Simmonds Shepherd 1955; Simmonds 1962). The presence of these bananas in Pandeglang shows that wild banana relatives coexist with banana cultivars. *M. acuminata* in Pandeglang is present on the riverside and abandoned field in the village and grows as a weed that people do not plant. Wild bananas are not planted by people, and based on haplotypes analysis of four functional genes, ADH, G3PDH, IDH, CAT, and GBSS, indicated that *M. acuminata* subspecies are distributed specifically in geographic regions that indicate their specific origin (Volkaert 2011). Hence, we believe that *M. acuminata* in Pandeglang is native to this area. On the other hand, a different story for *M. balbisiana* or "Pisang Klutuk" is that people plant it for leaves (Hapsari *et al.* 2017). However, the presence of banana cultivars such as "Pisang Awak" (ABB), "Pome" (AAB), "Silk" (AAB), and "Mysore" (AAB) support the hypothesis that *M. balbisiana* indicated native from western Indonesia (Volkaert 2018). Therefore, those cultivars are the product of hybridization involving haplotypes of *M. acuminata* var. zebrina native to Java Island with *M. balbisiana*. The latter was previously considered native in Asia mainland and the Philippines (Perrier *et al.* 2011).

Indonesia is the center of origin of the banana and the place of banana evolution that resulted in edible bananas (Simmonds 1962; Heslop-Harrison and Schwarzacher 2007). Hence, we should consider that the future of banana genetic improvement relies on this country's genetic diversity of banana cultivars and wild relatives. *M. acuminata* and *M. balbisiana* play a role in the presence of various genome compositions (Heslop-Harrison and Schwarzacher 2007). In Indonesia, wild *M. acuminata* varieties and subspecies were described by Nasution (1991), but *M. balbisiana* in Indonesia was not yet reported. Two common *M. balbisiana* that are found in Indonesia is "Pisang Klutuk" with the green pseudostem and "Pisang Klutuk Wulung" with the black-purple pseudostem (Ahmad *et al.* 2014). Poerba *et al.* (2019) used RAPD and ISSR markers and reported that the genetic diversity of wild *M. acuminata* varieties is wide among those. In contrast, the genetic diversity of *M. balbisiana* is relatively narrow (Poerba and Ahmad 2013; Ahmad *et al.* 2014).

Based on the main morphological characters, we provided key identification of each group of bananas found in Pandeglang. In our key identification, 11 of 15 characters are related to generative organs. In general, key characteristics among banana cultivars and wild relatives were related to the generative organ, such as fruit and flower characters. Among 51 minimum highly discriminating characters in Banana Descriptors (IPGRI 1996), 36 are related to the bunch, flower, and fruit. In Bahasa, the name of banana varieties might refer to the fruit's shape, color, and taste. For example, the "Pisang Tanduk" shape is like a horn or "tanduk" in Bahasa Indonesia (Valmayor *et al.* 2000). Another example is "Pisang Mas," which has bright yellow colors like gold (gold means "Mas" in Javanese), and "Pisang Madu" ("Madu" means honey) for one of the sweetest sucrier bananas (Poerba *et al.* 2018). However, in other aspects, vegetative characteristics of leave habit and color may help determine or estimate the ploidy level and subspecies, respectively. Poerba *et al.* (2017) described that the "Pisang Rejang" tetraploid has a dropping leave habit compared to the diploid plant. *M. acuminata* ssp. zebrina and var. nakaii are distinct from other subspecies or varieties of their reddish leaves color (Nasution 1991). Wild *M. acuminata* seed shape is an important trait to distinguish among subspecies or varieties, such as flat seed with rough edges is revere to var. sumatrana, globular and smooth is revere to var. halabanensis, angular for other varieties and subspecies (Nasution 1991).

The local banana name in Pandeglang is sometimes confusing as one banana is called with more than one local name and vice versa. The variation of the local banana name for a cultivar is expected in Indonesia and other countries (Valmayor *et al.* 2000). To solve the problem of the confusing name of local bananas, banana researchers developed standardized banana grouping based on morphological characters and genetic information. In addition, they compiled known synonyms for all local names based on global collections (Ruas *et al.* 2017). Afterward, now we know subgroup Sucrier for sweet diploid cultivar (AA) such as "Pisang Mas", subgroup Cavendish for "Cavendish" (AAA) like bananas such as "Pisang Ambon Lumut" and "Grand Naine", subgroup Saba for ABB cooking banana alike "Kepok", and more (Ruas *et al.* 2017). In studying banana evolution, the local name may help trace the origin of the banana. More than 1,100

terms related to what people call bananas, and a few of them are essential to tracing the banana dispersal, such as muku, punti, quRatay, and baRat. These name distributions suggest the banana dispersal from the origin worldwide (Perrier *et al.* 2011).

In this study, we did PCA to see the association between grouping based on genome compassion and morphological characters. The PCA result separated AA and AAA cultivars into two groups. However, the AA and AAA were closed and could be integrated into one group. Only "Pulo" that separated but not that far. The general morphological characteristics of AA and AAA related to pseudostem appearance, leave, wax, sap, male flower, petiole, and male bud, 60 out of 76 characters, were similar. Due to this similarity level, these bananas were grouped. According to genome content, the difference between AA and AAA is the number of chromosome A derived from *M. acumianata*, so these bananas are one species of *M. acuminata*. BB and ABB bananas were together in one group because of the many similarities between these two bananas. In our observation, general morphological characters of BB and ABB bananas look-alike for pseudostem, male bud, bunch, and fruit. However, a few characters of ABB distinct from BB are seedless, and the leaf formation is dropping. This observation indicated that the two B genomes dominate one A genome in the ABB banana. Hence the morphological character is similar.

As part of Indonesia, the center of banana diversity, Pandeglang is essential as the genetic source for the banana improvement program. However, the banana in this region has never been screened for disease resistance or tolerance to abiotic stress. Based on our exploration, we found *M. acuminata* subsp. malaccensis that this subspecies is known as Fusarium wilt (FWB) resistant banana (D'Hont *et al.* 2012) and is observed to be resistant in their natural habitat in Sumatra (Maryani *et al.* 2019). Ahmad *et al.* (2020) reported that accession of subsp. malaccensis from Sumatra was resistant to FWB, and its selfing segregation population suggests that the resistance was associated with a region on the tip of chromosome 10. Maryani (2018) tested the most extensive diversity of FWB pathogens against subsp. malaccensis in the greenhouse, and none showed any symptoms. In addition, Subsp. malaccensis, var. zebrina, "Klutuk" and "Pisang Siem" were reported to be resistant to Black Sigatoka resistance (Kimunye *et al.* 2021) that these bananas found in Pandeglang. Hence, in the future, intensive genetic study for disease or abiotic stress is needed to discover the true potential of bananas from Pandeglang Banten and Indonesia in general.

In conclusion, banana cultivars found in Pandeglang coexist with their wild relatives. Fourteen bananas were found in Pandeglang, divided into ten accessions of banana cultivars and four accessions of wild bananas. Among banana cultivars, five genetic constitutions were described, i.e., AA, BB, AAA, AAB, and ABB. Two wild relatives were found, i.e., *M. acuminata* and *M. balbisiana* in PCA, the *M. acuminata* clearly separated, but the *M. balbisiana* clustered together with ABB banana.

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Supplementary Materials

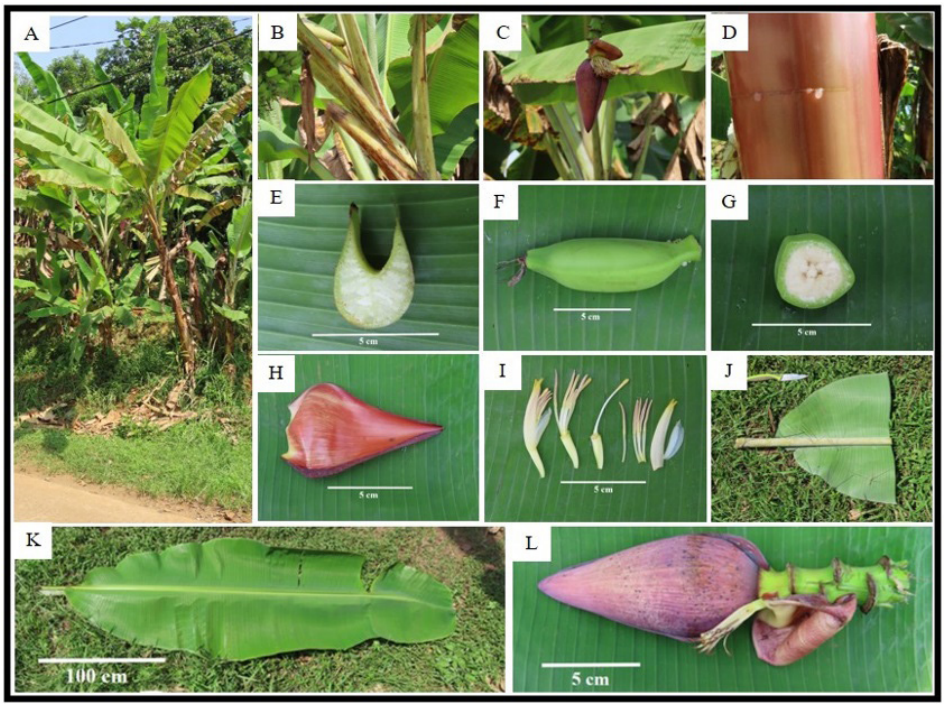

Figure 3. *Musa* AA (Sucrier subgroup) "Muli", characters; (A) Habitus, (B) blotches at the petiole base, (C) bractea curling, (D) sap, (E) petiole canal leaf III, (F) fruit, (G) transverse section of fruit, (H) braktea, (I) flower, (J) shape of leaf blade base, (K) Color of upper leaf surface, and (L) male bud. Scale bars in (E-J) and (L) equal 5 cm, scale bar in (K) equal 100 cm

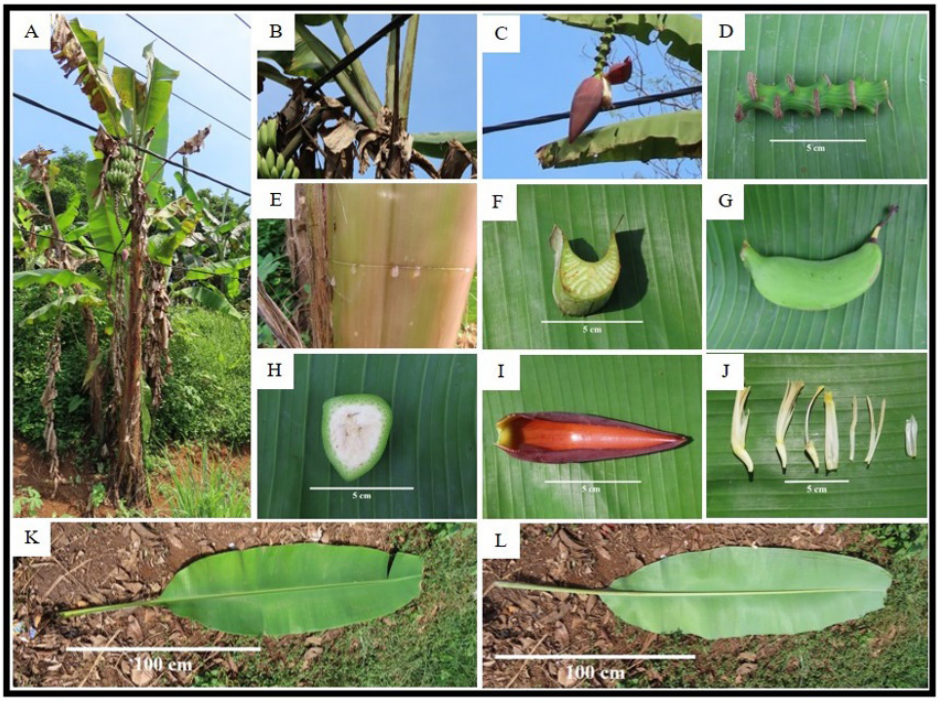

Figure 4. *Musa* AAB (Pisang Nangka subgroup) "Pisang Nangka" characters (Ba3); (A) Habitus, (B) blotches at the petiole base, (C) bractea curling, (D) bractea scar, (E) sap, (F) petiole canal leaf III, (G) fruit, (H) transverse section of fruit, (I) braktea, (J) flower, (K) color of leaf upper surface, and (L) color of leaf lower surface. Scale bars in (D-J) equal 5 cm, scale bars in (K) and (L) equal 100 cm

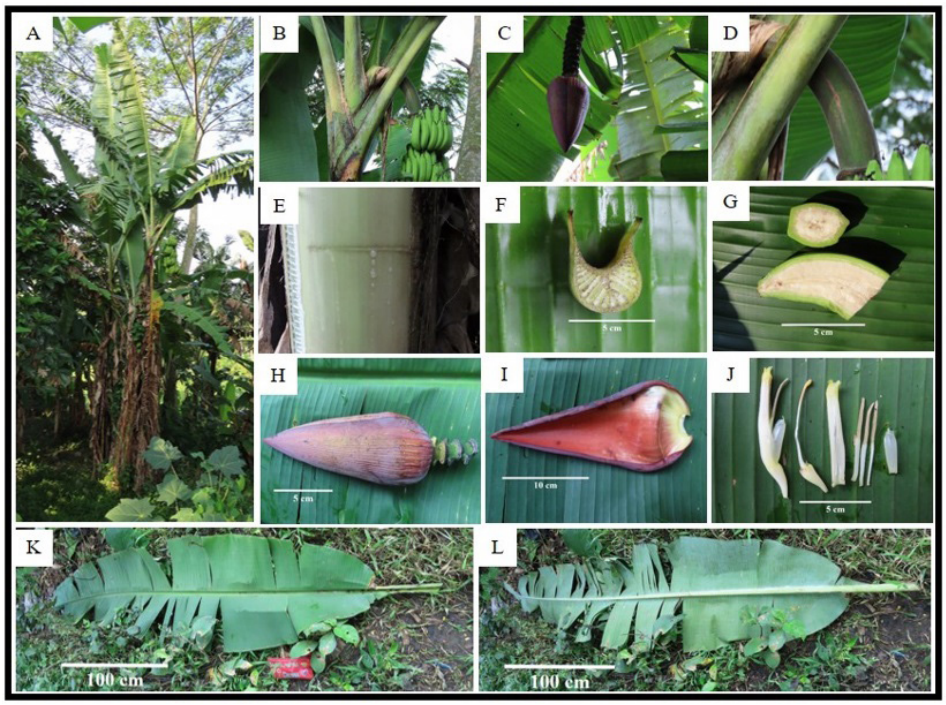

Figure 5. *Musa* AAA (Gros Michele subgroup) "Ambon" characters (Ba4); (A) Habitus, (B) blotches at the petiole base, (C) braktea curling, (D) peduncle, (E) sap, (F) petiole canal leaf III, (G) transverse section of fruit, (H) male bud, (I) braktea, (J) flower, (K) color of leaf upper surface, and (L) color of leaf lower surface. Scale bars in (F), (G), (H), and (J) equal 5 cm, a scale bar in (I) equal 10 cm, and scale bars in (K) and (L) equal 100 cm

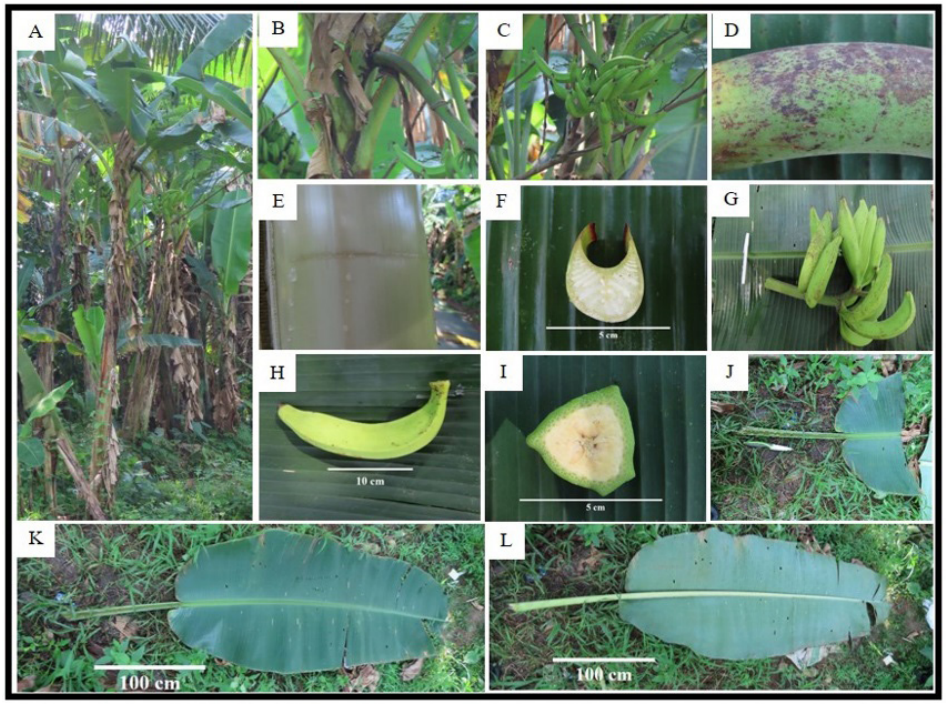

Figure 6. *Musa* AAB (Plantain subgroup) "Pisang Tanduk" characters (Ba5); (A) Habitus, (B) blotches at the petiole base, (C) bunch position, (D) peduncle, (E) sap, (F) petiole canal leaf III, (G) bunch, (H) fruits, (I) transverse section of fruit, (J) shape of leaf blade base, (K) color of upper leaf surface, and (L) color of leaf lower surface. Scale bars in (F) and (I) equal 5 cm, a scale bar in (H) equal 10 cm, and scale bars in (K) and (L) equal 100 cm

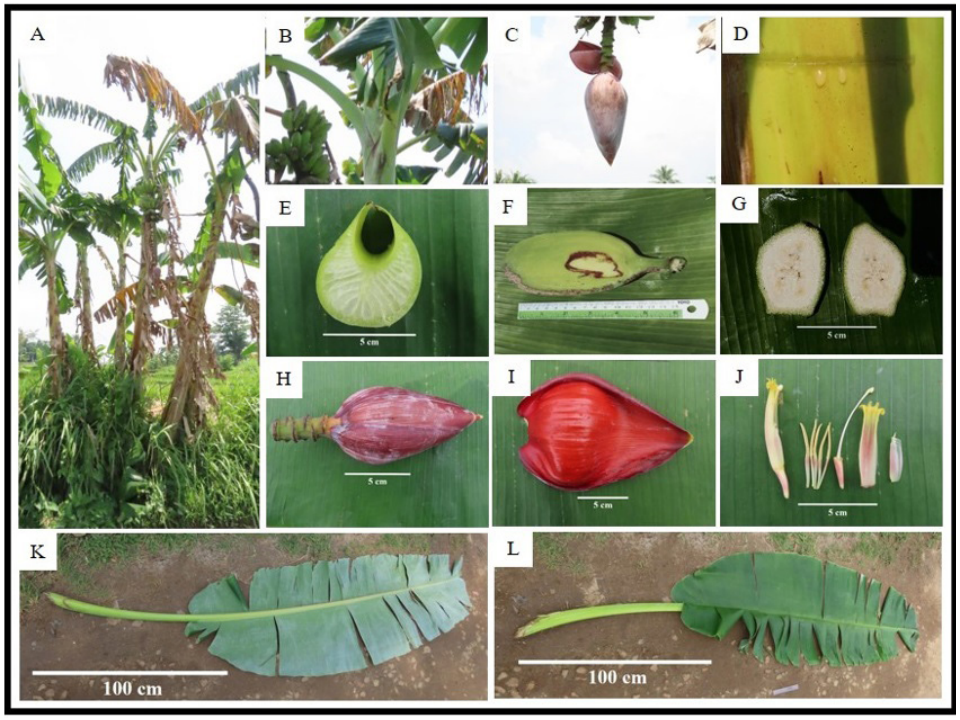

Figure 7. *Musa* ABB (Saba subgroup) "Pisang Kepok" characters (B6); (A) Habitus, (B) blotches at the petiole base, (C) braktea curling, (D) sap, (E) petiole canal leaf III, (F) fruit, (G) transverse section of fruit, (H) male bud, (I) braktea, (J) flower, (K) color of leaf upper surface, and (L) color of leaf lower surface. Scale bars in (E), (G-J) equal 5 cm, and scale bars in (K) and (L) equal 100 cm

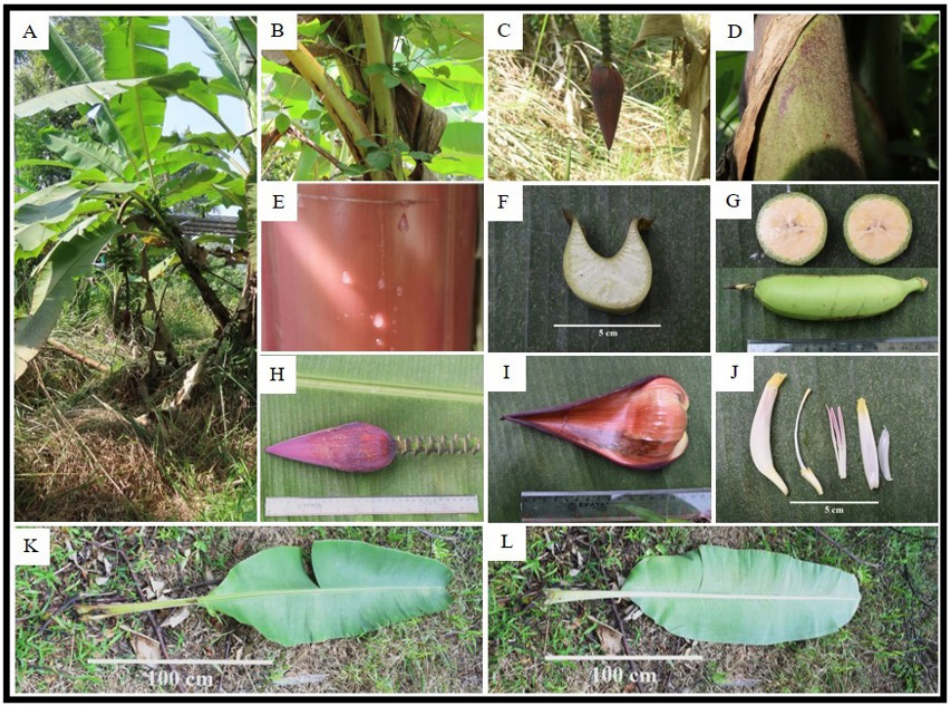

Figure 8. *Musa* AAB (Pisang Raja Subgrup) "Pisang Raja" characters (Ca1); (A) Habitus, (B) blotches at the petiole base, (C) bractea curling, (D) peduncle, (E) sap, (F) petiole canal leaf III, (G) fruit and transverse section of fruit, (H) male bud, (I) braktea, (J) flower, (K) color of leaf upper surface, and (L) color of leaf lower surface. Scale bars in (F) and (J) equal 5 cm, and scale bars in (K) and (L) equal 100 cm

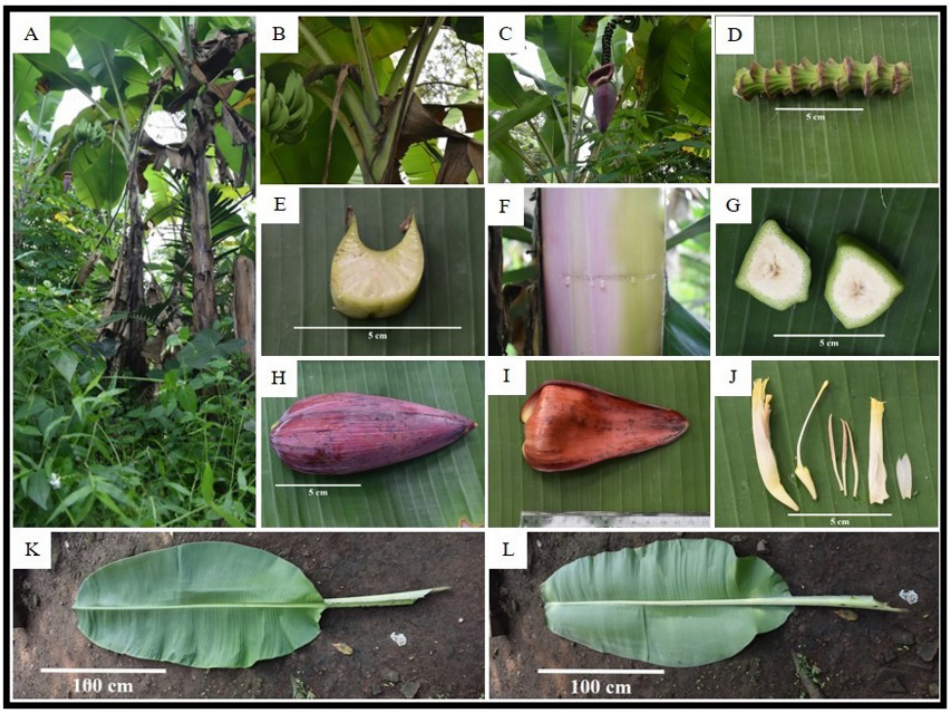

Figure 9. *Musa* AAB (Pisang Nangka subgroup) "Pisang Nangka" characters (Ca3); (A) Habitus, (B) blotches at the petiole base, (C) braktea curling, (D) bractea scar, (E) petiole canal leaf III, (F) sap, (G) transverse section of fruit, (H) male bud, (I) bractea, (J) flower, (K) color of leaf upper surface; and (L) color of leaf lower surface. Scale bars in (E), (G), (H), and (J) equal 5 cm, and scale bars in (K) and (L) equal 100 cm

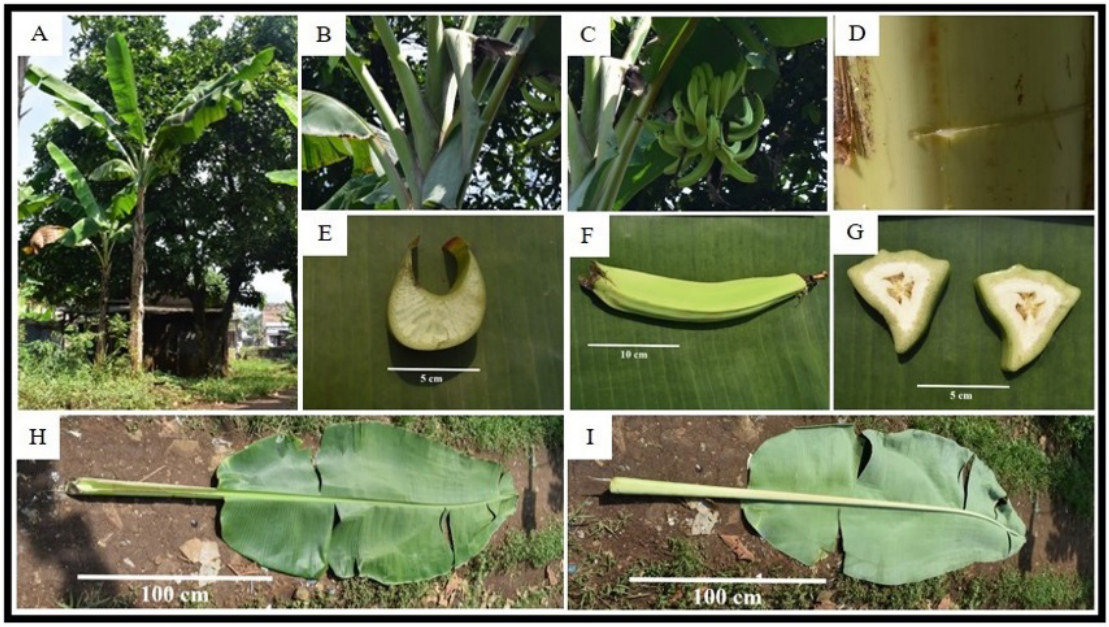

Figure 10. *Musa* AAB (Plansubgroupbgrup) "Pisang Tanduk" characters (Ca4); (A) Habitus, (B) blotches at the petiole base; (C) bunch position, (D) sap, (E) petiole canal leaf III, (F) fruit, (G) transverse section of fruit, (H) color of upper leaf surface, and (I) color of leaf lower surface. Scale bars in (E-G) equal 5 cm, and scale bars in (H) and (I) equal 100 cm

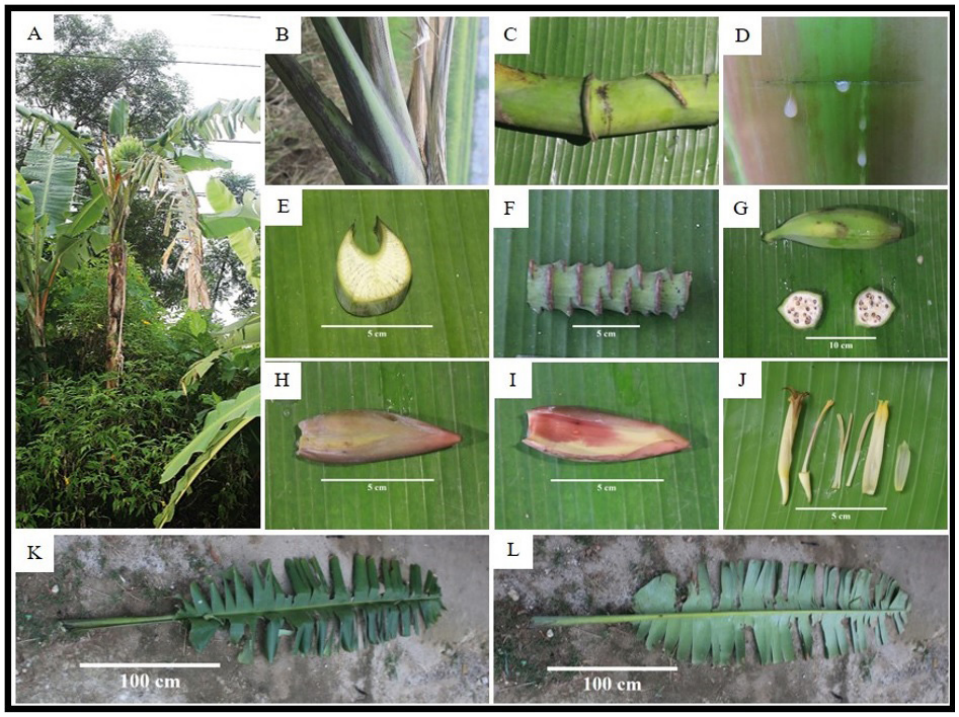

Figure 11. *Musa balbisiana* characters (Ca5); (A) Habitus, (B) blotches at the petiole base, (C) peduncle, (D) sap, (E) petiole canal leaf III, (F) bractea scar, (G) fruit and transverse section of fruit, (H-I) bractea, (J) flower, (K) color of leaf upper surface, and (L) color of leaf lower surface. Scale bars in (E-J) equal 5 cm, and scale bars in (K) and (L) equal 100 cm

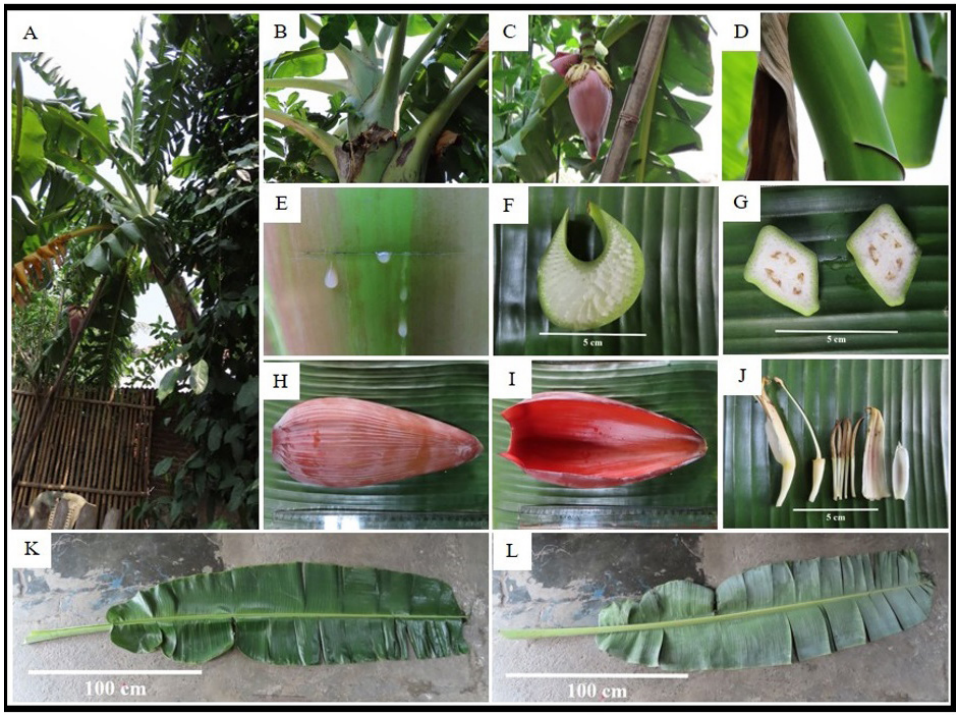

Figure 12. *Musa* ABB (Pisang Awak Subgrup) "Cau Bedong" characters (Ca6); (A) Habitus, (B) blotches at the petiole base, (C) bractea curling, (D) peduncle, (E) sap, (F) petiole canal leaf III, (G) transverse section of fruit, (H) male bud, (I) bractea, (J) flower, (K) color of leaf upper surface; and (L) color of leaf lower surface. Scale bars in (F), (G), and (J) equal 5 cm, and scale bars in (K) and (L) equal 100 cm

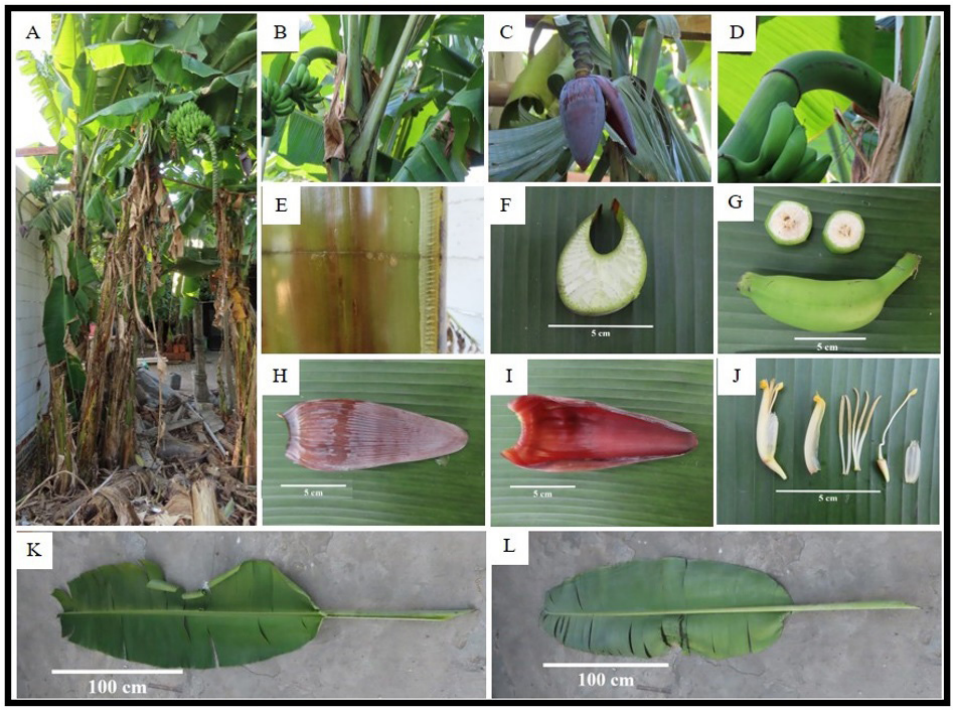

Figure 13. *Musa* AAA "Pisang Pulo" characters. (A) Habitus, (B) blotches at the petiole base, (C) bractea curling, (D) peduncle, (E) sap, (F) petiole canal leaf III, (G) fruit and transverse section of fruit, (H-I) braktea, (J) flower, (K) color of leaf upper surface, and (L) color of leaf lower surface. Scale bars in (F-J) equal 5 cm, and scale bars in (K) and (L) equal 100 cm

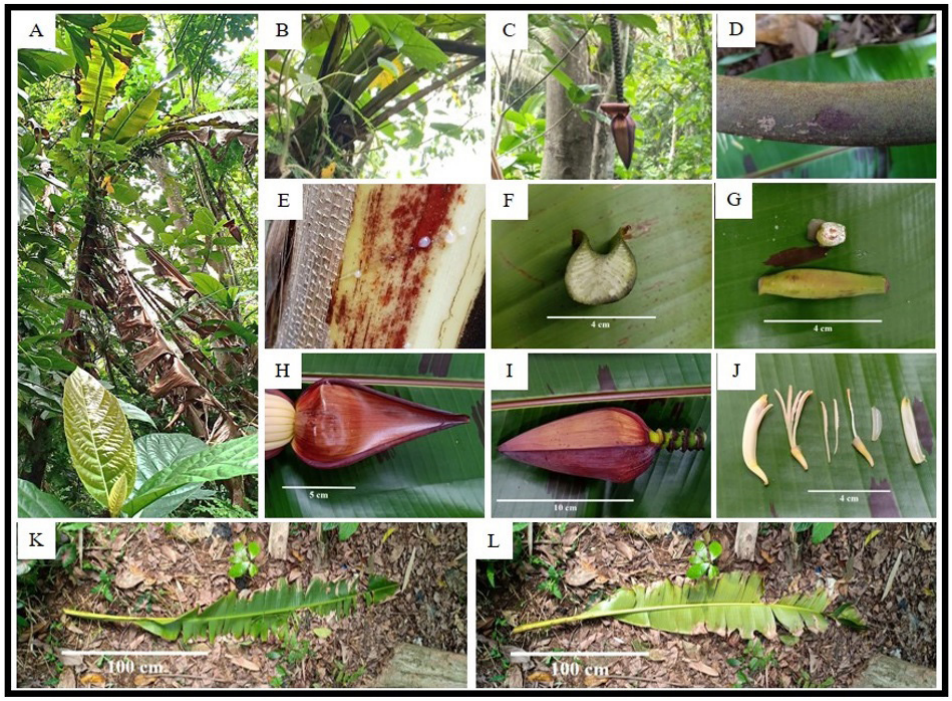

Figure 14. *Musa acuminata* characters (Me1); (A) Habitus, (B) blotches at the petiole base, (C) gulungan braktea, (D) peduncle, (E) sap, (F) petiole canal leaf III, (G) fruit and transverse section of fruit, (H) braktea, (I) male bud, (J) flower, (K) color of leaf upper surface, and (L) color of leaf lower surface. Scale bars in (F), (G), (H), and (J) equal 5 cm, a scale bar in I equal 10 cm, and scale bars in (K) and (L) equal 100 cm

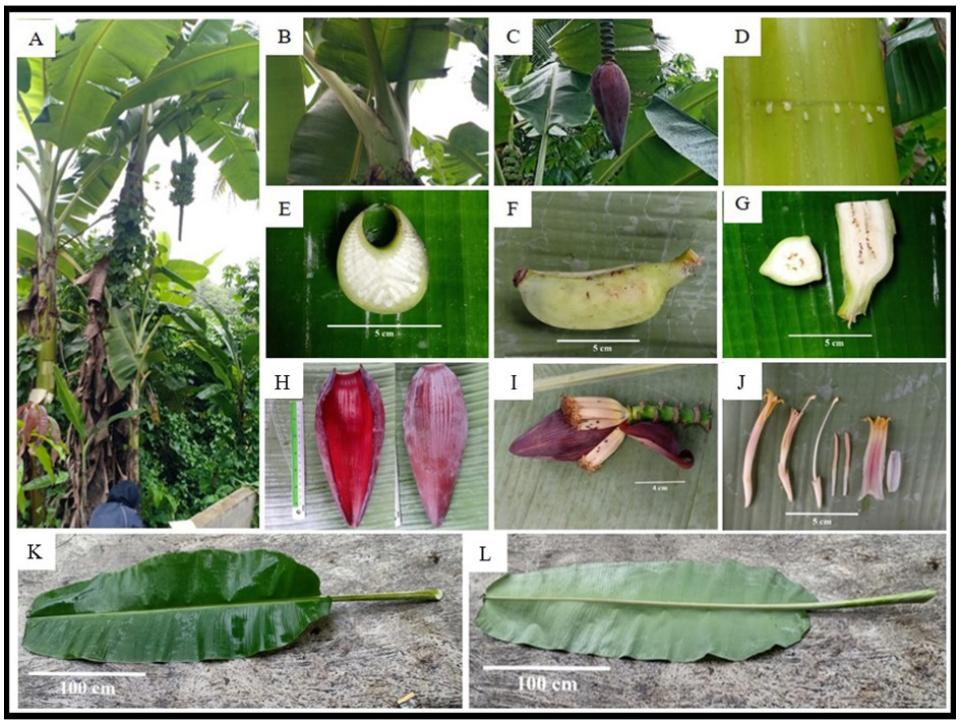

Figure 15. *Musa* ABB var. siem character (Me2); (A) Habitus, (B) blotches at the petiole base, (C) bractea curling, (D) sap, (E) petiole canal leaf III, (F) fruit, (G) transverse section of fruit, (H) braktea, (I) male bud, (J) flower, (K) color of leaf upper surface, and (L) color of leaf lower surface. Scale bars in (E), (F), (G), (I), and (J) equal 5 cm, and scale bars in (K) and (L) equal 100 cm

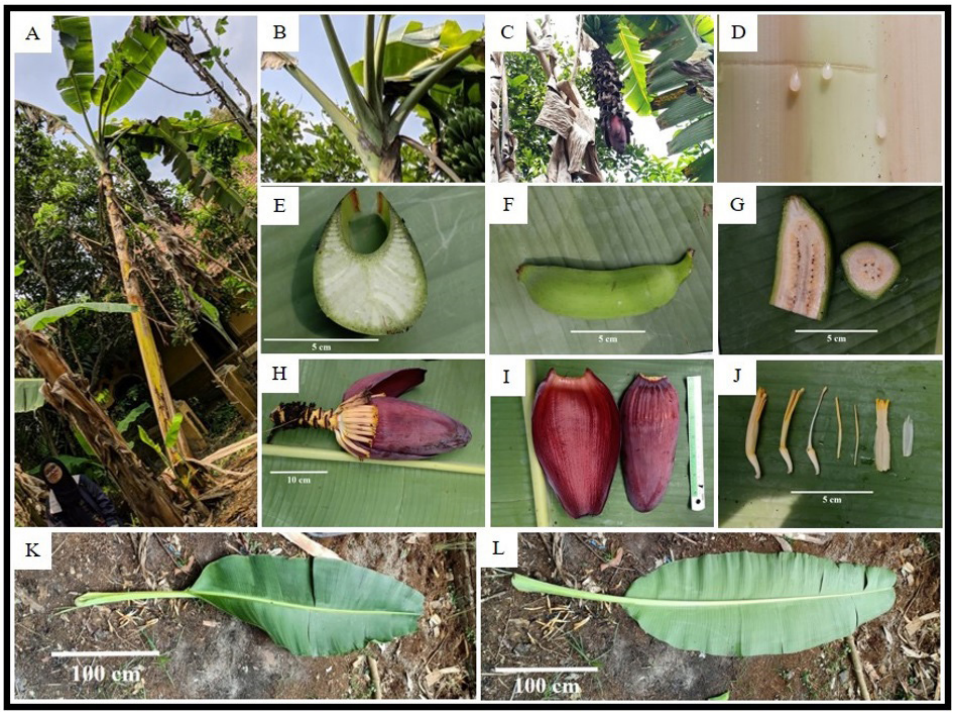

Figure 16. *Musa* AAB (Pisang Raja Subgrup) "Pisang Raja" characters (Me3); (A) Habitus, (B) blotches at the petiole base, (C) braktea curling, (D) sap, (E) petiole canal leaf III, (F) fruit, (G) transverse section of fruit, (H) male bud, (I) bractea, (J) flower, (K) color of leaf upper surface, and (L) color of leaf lower surface. Scale bars in (E), (F), (G), (I), and (J) equal 5 cm, and scale bars in (K) and (L) equal 100 cm

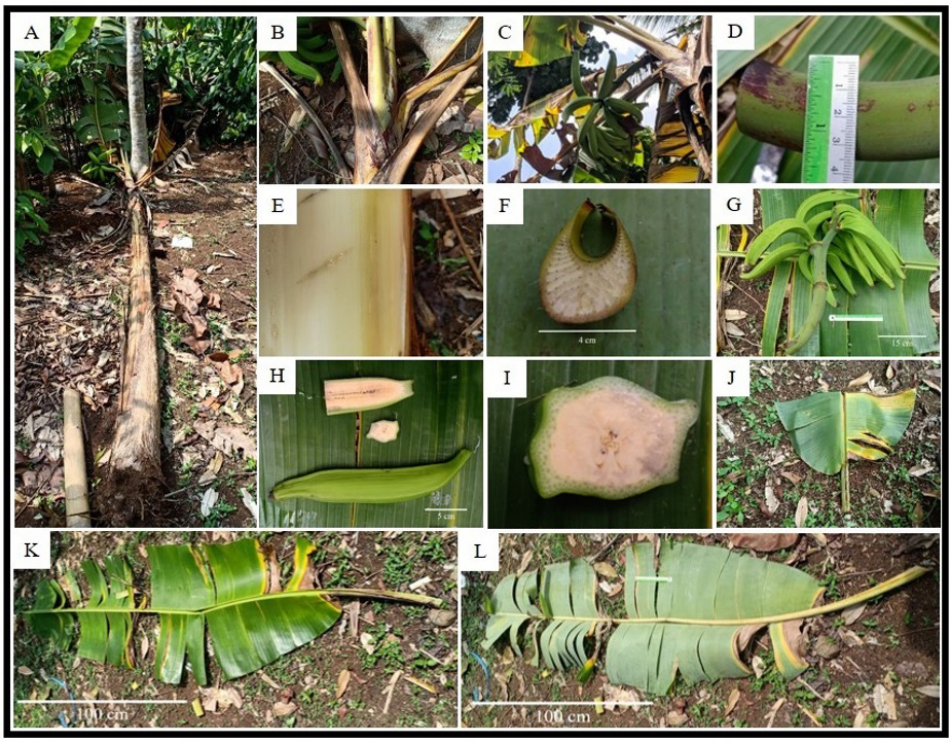

Figure 17. *Musa* AAB (Plantain subgroup) "Pisang Tanduk" characters (Me5); (A) Habitus, (B) blotches at the petiole base, (C) bunch position, (D) peduncle, (E) sap, (F) petiole canal leaf III, (G) bunch, (H) fruit, (I) transverse section of fruit, (J) shape of leaf blade base, (K) color of upper leaf surface; and (L) color of leaf lower surface. Scale bars in (F) and (H) equal 5 cm, and scale bars in (K) and (L) equal 100 cm

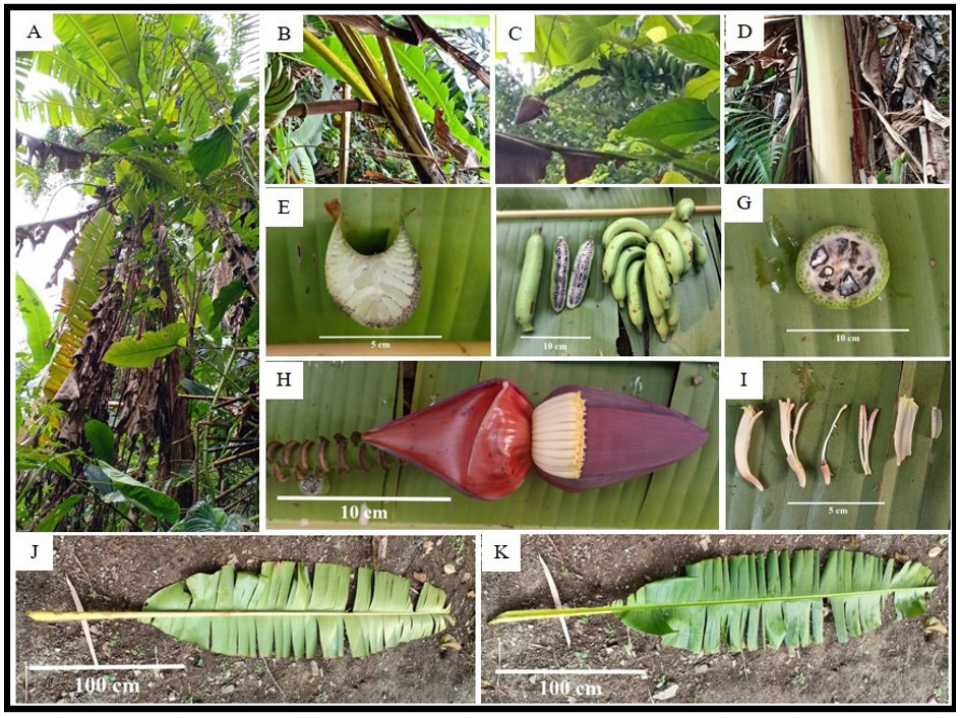

Figure 18. *Musa* acuminata characters (Me6); (A) Habitus, (B) blotches at the petiole base, (C) bractea curling, (D) pseudostem, (E) petiole canal leaf III, (F) fruits, (G) transverse section of fruit, (H) male bud, (I) flower, (J) color of leaf lower surface, and (L) color of the upper leaf surface. Scale bars in (E), (F), (G), and (I) equal 5 cm, a scale bar in (H) equal 10 cm, and scale bars in (J) and (K) equal 100 cm

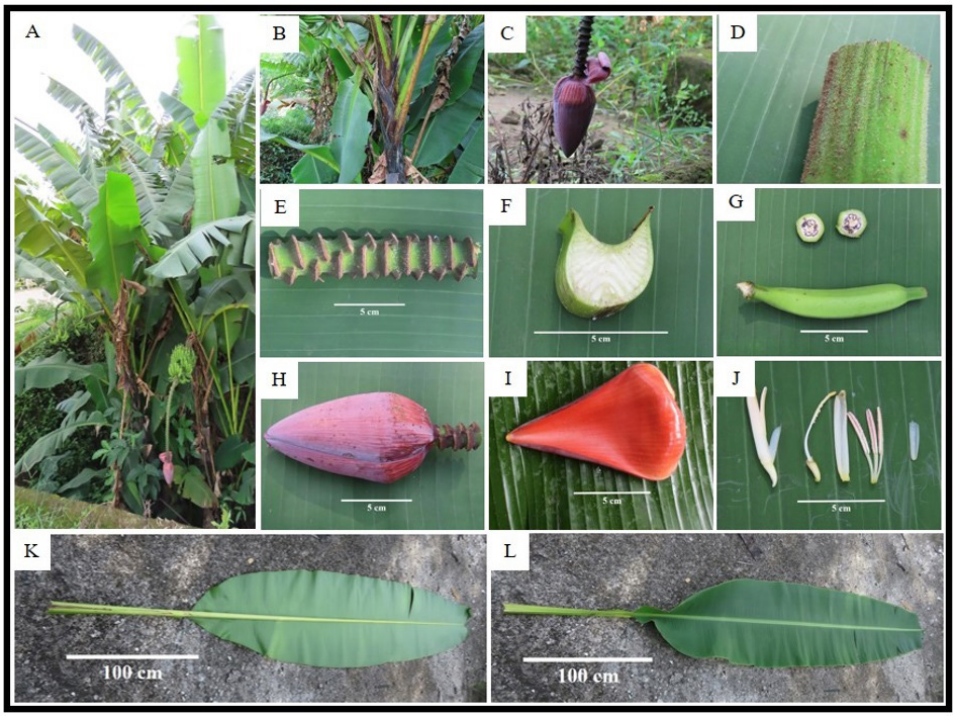

Figure 19. *Musa acuminata* characters (Pa1); (A) Habitus, (B) blotches at the petiole base, (C) bractea curling, (D) peduncle, (E) bractea scars, (F) petiole canal leaf III, (G) transverse section of fruit, (H) male bud, (I) bractea, (J) flower, (K) color of leaf lower surface, and (L) color of the upper leaf surface. Scale bars in (E-J) equal 5 cm, and scale bars in (K) and (L) equal 100 cm

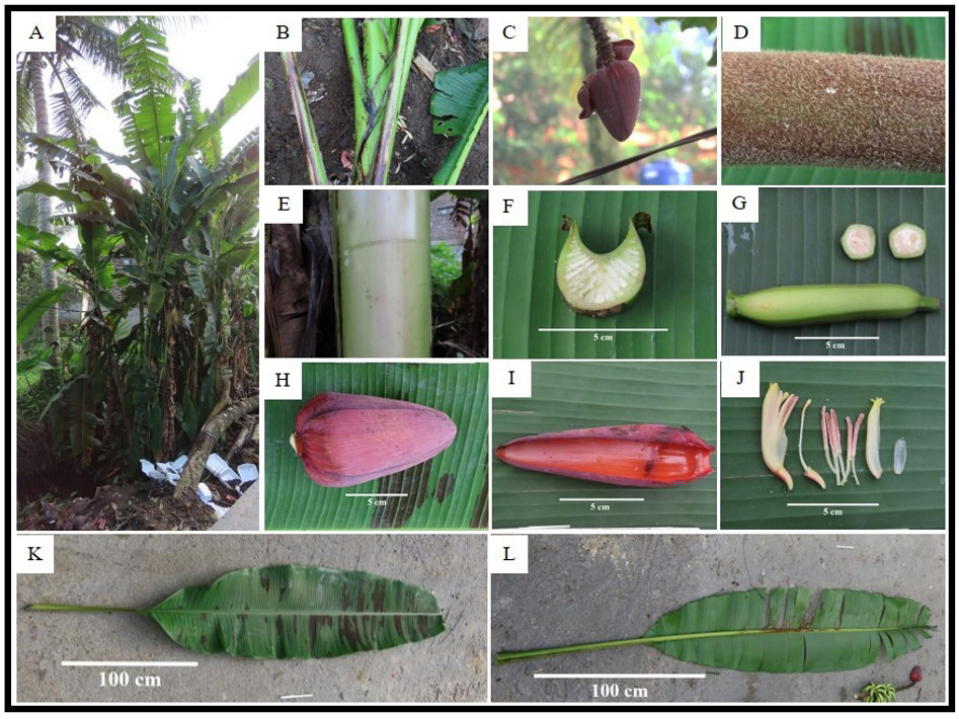

Figure 20. *Musa acuminata* var. zebrina characters (Pa2); (A) Habitus, (B) blotches at the petiole base, (C) bractea curling, (D) peduncle, (E) sap, (F) petiole canal leaf III, (G) fruit and transverse section of fruit, (H) male bud, (I) bractea, (J) flower, (K) color of upper leaf surface, and (L) color of leaf lower surface. Scale bars in (F-J) equal 5 cm, and scale bars in (K) and (L) equal 100 cm

Accession	Ba1	Ba3	Ca2	Me4	Ba2	Ca7	Ca1	Ba4	Ca3	Ba5	Ca4	Me5	Ca6	Me2	Ba6	Me3	Me1	Me6	Pa1	Pa2	Ca5	Sa1
Genome	AA	AA	AA	AA	AA	AAA	AAA	AAA	AAB	AAB	AAB	AAB	ABB	ABB	ABB	AAB	AA wild	AA wild	AA wild	AA wild	BB	BB
Character / Type	Pisang oli	Pisang oli	Pisang oli	Pisang oli	Pisang Lampung	Pulo	Pisang papan	Ambon kuning	Pisang nangka	Tanduk	Tanduk	Tanduk	Pisang siem	Pisang siem	Pisang kepok	Pisang raja	*Musa acuminata* subsp. *malaccensis*	*Musa acuminata* var. *breviformis*	*Musa acuminata* var. *breviformis*	*Musa acuminata* var. *zebrina*	Pisang klutuk	Pisang klutuk
6.1.1 Leaf habit	1	1	1	1	2	2	3	2	2	2	2	2	3	3	3	2	1	1	1	1	1	1
6.2.1 Pseudostem height	2	2	1	2	2	3	1	3	2	3	3	3	3	3	2	3	3	3	3	2	3	3
6.2.2 Pseudostem aspect	1	1	1	2	2	1	2	2	1	2	2	2	3	3	3	2	1	1	1	1	2	2
6.2.3 Pseudostem color	4	1	3	5	5	1	5	6	1	1	1	1	4	4	1	1	3	3	3	5	3	3
6.2.6 Pigmentation of the underlying pseudostem	5	2	1	5	5	6	5	5	2	3	1	1	5	2	1	1	1	1	1	2	4	2
6.2.7 Sap color	1	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1	2	2	2	1	2	2
6.2.8 Wax on leaf sheaths	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1
6.2.8.1. Types of wax on leaf sheaths	2	3	2	1	2	2	2	2	2	3	3	3	3	3	3	3	2	2	2	1	4	3
6.3.1 Blotches at the petiole base	3	1	2	3	3	1	3	2	1	1	5	2	1	5	1	5	3	4	4	3	2	1
6.3.2 Blotches color	3	2	2	3	2	6	5	4	2	1	2	2	3	3	2	1	2	4	4	1	5	5
6.3.3 Petiole canal leaf III	1	2	1	1	2	3	1	2	2	3	3	4	4	4	5	3	2	2	2	2	4	4
6.3.5 Wing type	1	1	1	1	1	1	1	1	1	1	1	2	1	2	2	1	1	1	1	1	2	1
6.3.9 Leaf blade length [cm]	1	1	1	3	1	2	1	1	1	3	3	2	2	3	2	3	3	3	2	3	2	1
6.3.10 Leaf blade width [cm]	1	1	1	2	1	1	1	1	1	2	2	1	1	2	1	2	2	2	1	1	1	2
6.3.10.1 Leaf ratio	1	1	2	2	1	3	1	1	1	2	3	2	3	3	3	3	2	2	2	3	3	2
6.3.11 Petiole length [cm]	1	1	1	3	1	2	1	1	1	1	1	2	2	2	2	1	2	2	3	3	1	3
6.3.12 Color of upper leaf surface	2	1	1	2	1	1	1	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2
6.3.13 Appearance of upper leaf surface	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	2	1	1	1	2	1
6.3.14 Color of leaf lower surface	4	2	3	4	1	4	1	2	2	3	2	4	4	4	4	2	4	4	4	4	1	3
6.3.15 Appearance of leaf lower surface	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6.3.16 Wax on leaves	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6.3.16.1 Types of wax on leaves	2	3	2	2	1	2	2	2	3	4	3	3	4	4	4	3	1	1	1	1	4	4
6.3.17 Insertion point of leaf blades on petiole	1	1	1	1	2	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	2
6.3.18 Shape of the leaf blade base	3	3	3	3	2	3	3	3	3	1	1	1	1	1	1	1	3	3	3	3	3	1
6.3.20 Color of midrib dorsal surface	2	2	2	3	2	2	2	2	1	1	1	1	2	1	1	1	3	1	3	3	3	3
6.3.21 Color of midrib ventral surface	3	1	3	1	1	1	2	1	2	1	1	1	1	1	1	1	2	2	3	3	4	2
6.4.1 Peduncle length [cm]	2	2	2	2	1	2	3	2	2	2	2	1	3	2	2	2	1	1	3	3	1	3

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Accession	Ba1	Ba3	Ca2	Me4	Ba2	Ca7	Ca1	Ba4	Ca3	Ba5	Ca4	Me5	Ca6	Me2	Ba6	Me3	Me1	Me6	Pa1	Pa2	Ca5	Sa1
Genome	AA	AA	AA	AA	AA	AAA	AAA	AAA	AAB	AAB	AAB	AAB	ABB	ABB	ABB	AAB	AA wild	AA wild	AA wild	AA wild	BB	BB
Character / Type	Pisang oli	Pisang oli	Pisang oli	Pisang oli	Pisang Lampung	Pulo	Pisang papan	Ambon kuning	Pisang nangka	Tanduk	Tanduk	Tanduk	Pisang siem	Pisang siem	Pisang kepok	Pisang raja	*Musa acuminata* subsp. *malaccensis*	*Musa acuminata* var. *breviformis*	*Musa acuminata* var. *breviformis*	*Musa acuminata* var. *zebrina*	Pisang klutuk	Pisang klutuk
6.4.3 Peduncle width [cm]	2	1	1	2	2	1	2	2	1	2	1	1	2	2	2	1	1	1	1	2	2	2
6.4.4 Peduncle color	1	3	1	3	1	1	3	3	3	1	1	1	1	1	1	1	3	3	1	4	2	1
6.4.5 Peduncle hairiness	1	1	1	1	1	1	1	1	1	2	1	1	2	2	2	1	1	1	1	1	2	2
6.4.5.1 Level of peduncle hairiness	2	2	2	2	2	2	2	2	2	1	2	2	1	1	1	2	3	3	3	3	1	1
6.4.6 Bunch position	3	3	3	3	3	3	1	1	3	2	3	3	1	1	2	1	4	4	4	4	3	1
6.4.7 Bunch shape	1	1	1	1	1	1	3	1	1	5	5	5	1	1	2	1	1	1	1	1	1	1
6.4.8 Bunch appearance	1	1	1	1	1	1	1	2	1	1	1	1	2	2	2	2	1	1	1	1	2	1
6.4.10 Positioning of fruits on the crown	2	2	2	2	2	2	2	2	2	1	1	1	2	2	2	2	2	2	2	2	2	2
6.4.12 Rachis position	1	2	1	1	1	1	1	3	1	NA	NA	NA	1	1	1	1	1	1	1	1	1	1
6.4.15 Male bud shape	1	2	1	1	1	1	1	1	1	NA	NA	NA	1	1	4	3	1	1	1	1	3	1
6.5.1 Bract base shape	1	1	1	1	1	1	2	2	2	NA	NA	NA	1	3	2	1	2	2	2	2	3	1
6.5.2 Bract apex shape	2	2	2	2	2	1	2	2	4	NA	NA	NA	3	3	3	4	2	2	2	2	3	5
6.5.3 Bract imbrication	1	1	1	1	1	2	1	1	2	NA	NA	NA	3	2	2	3	1	1	1	2	1	3
6.5.4 Color of the bract external face	1	1	1	3	1	1	1	1	1	NA	NA	NA	3	1	3	3	4	5	5	5	4	1
6.5.5 Color of the bract internal face	1	1	1	1	1	2	1	3	1	NA	NA	NA	4	4	2	5	5	5	5	5	2	5
6.5.6 Color on the bract apex	2	2	2	2	2	2	2	2	1	NA	NA	NA	2	2	1	2	2	2	2	2	2	2
6.5.8 Bract scars on rachis	1	1	1	1	1	1	1	1	1	NA	NA	NA	1	1	1	1	1	1	1	1	1	2
6.5.9 Fading of color on bract base	1	1	1	1	1	1	1	1	1	NA	NA	NA	2	2	2	1	1	1	1	2	2	2
6.5.11 Male bract lifting	2	2	2	3	2	2	2	2	2	NA	NA	NA	2	1	2	3	1	1	1	2	2	2
6.5.12 Bract behaviour before falling	1	1	1	1	1	1	1	1	1	NA	NA	NA	1	1	1	2	1	1	1	1	2	2
6.5.13 Wax on the bract	1	1	1	1	1	1	1	1	1	NA	NA	NA	1	1	1	1	1	1	1	1	1	1
6.5.13.1 Level of wax on the bract	2	3	2	2	2	3	2	2	3	NA	NA	NA	4	3	4	3	2	2	2	2	4	4
6.6.2 Compound tepal basic color	1	2	2	1	2	1	1	1	2	NA	NA	NA	1	2	2	2	1	1	1	2	2	2
6.6.3 Compound tepal pigmentation	1	1	1	1	1	1	1	1	1	NA	NA	NA	3	3	3	1	1	1	1	1	3	3
6.6.4 Lobe color of compound tepal	1	1	1	1	1	1	1	1	1	NA	NA	NA	1	2	1	1	1	1	1	3	1	1
6.6.8 Free tepal appearance	1	1	1	1	1	1	1	1	1	NA	NA	NA	2	2	1	3	1	1	1	3	2	2

Continued

Accession	Ba1	Ba3	Ca2	Me4	Ba2	Ca7	Ca1	Ba4	Ca3	Ba5	Ca4	Me5	Ca6	Me2	Ba6	Me3	Me1	Me6	Pa1	Pa2	Ca5	Sa1
Genome	AA	AA	AA	AA	AA	AAA	AAA	AAA	AAB	AAB	AAB	AAB	ABB	ABB	ABB	AAB	AA wild	AA wild	AA wild	AA wild	BB	BB
Character / Type	Pisang oli	Pisang oli	Pisang oli	Pisang oli	Pisang Lampung	Pulo	Pisang papan	Ambon kuning	Pisang nangka	Tanduk	Tanduk	Tanduk	Pisang siem	Pisang siem	Pisang kepok	Pisang raja	*Musa acuminata* subsp. *malaccensis*	*Musa acuminata* var. *breviformis*	*Musa acuminata* var. *breviformis*	*Musa acuminata* var. *zebrina*	Pisang klutuk	Pisang klutuk
6.6.9 Free tepal apex development	1	2	2	1	1	1	3	1	1	NA	NA	NA	1	1	1	2	1	1	1	1	2	2
6.6.11 Anther exsertion	3	3	1	3	2	2	3	3	3	NA	NA	NA	3	3	3	3	2	2	2	2	2	2
6.6.13 Anther color	1	2	1	1	4	1	4	1	4	NA	NA	NA	4	4	1	2	2	2	2	2	2	2
6.6.16 Style basic color	2	1	2	2	1	1	1	1	1	NA	NA	NA	1	1	1	1	1	1	1	1	5	5
6.6.18 Style exsertion	3	3	2	3	3	2	3	3	3	NA	NA	NA	1	2	3	3	2	2	3	3	2	2
6.6.19 Style shape	1	1	1	1	1	3	1	1	1	NA	NA	NA	1	1	1	1	1	1	1	1	1	1
6.6.20 Stigma color	1	1	1	1	1	1	1	1	1	NA	NA	NA	3	3	2	2	2	2	2	2	2	2
6.6.21 Ovary shape	1	2	1	1	1	1	2	2	1	NA	NA	NA	1	1	1	2	2	2	2	2	1	1
6.6.22 Ovary basic color	1	2	2	1	2	2	2	1	2	NA	NA	NA	1	1	1	1	2	2	2	2	2	2
6.6.23 Ovary pigmentation	1	1	1	1	1	2	1	1	1	NA	NA	NA	1	2	2	1	1	1	1	2	1	1
6.6.24 Dominant color of male flower	1	2	2	1	2	2	1	1	2	NA	NA	NA	3	3	3	4	1	1	1	2	3	1
6.6.26 Arrangement of ovules	1	2	1	1	1	1	1	1	2	1	1	1	2	2	2	2	1	1	1	1	2	2
6.7.1 Fruit position	1	2	1	1	4	1	4	1	1	3	3	3	1	3	4	3	1	1	1	1	2	1
6.7.2 Number of fruits	1	2	1	1	2	3	2	1	1	1	2	1	2	2	2	2	2	2	2	2	2	3
6.7.3 Fruit length [cm]	1	1	1	1	1	1	1	1	1	3	3	3	1	1	1	1	1	1	1	1	2	1
6.7.4 Fruit shape (longitudinal curvature)	3	1	3	3	1	2	1	3	3	2	2	2	1	1	1	1	1	1	1	1	1	1
6.7.5 Transverse section of fruit	3	2	3	3	3	3	3	3	2	2	2	1	3	3	2	3	2	2	2	2	1	1
6.7.6 Fruit apex	3	1	3	3	4	4	1	3	1	2	1	2	3	3	5	3	4	4	4	4	3	3
6.7.7 Remains of flower relicts at the fruit apex	2	2	2	2	2	1	2	1	3	3	2	3	2	2	3	2	1	1	1	1	1	1
6.7.8 Fruit pedicel length [mm]	1	1	1	1	1	3	1	2	2	2	2	2	3	2	3	2	1	1	1	1	3	3
6.7.9 Fruit pedicel width [mm]	1	1	2	2	2	2	2	3	2	3	3	2	2	3	3	3	2	2	2	2	2	2
6.7.10 Pedicel surface	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	2
6.7.17 Pulp in fruit	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2