

## Notes on Discriminating Morphological Characters for Generic and Sectional Classification of Musaceae in Thailand

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### ABSTRACT

Morphological characters have been used effectively in classification of the banana family, Musaceae. Most taxonomic features are qualitative characters which require experience in evaluation and are subjected to individual opinions. On the other hand, though not many, quantitative characters can be directly measured on sites or from photographs. The objective of this study was to evaluate efficiency of these quantitative features in the classification of the banana family in Thailand. A total of 16 quantitative morphological characters of 143 accessions from 10 native taxa and one introduced *Musella* species were assessed. All quantitative data were evaluated by box-plot analysis, principal component analysis and discriminant analysis. It was found that the quantitative data are useful in the classification at the generic level in Musaceae and at the sectional level of *Musa*. All three genera can be distinguished by pseudostem height, number of sucker plants and fruit pedicel length. At sectional level, number of fruit rows on mid hand can separate the sections *Rhodoclamys* and *Callimusa* from *Musa* and leaf blade length can differentiate *Rhodoclamys* from *Callimusa*. Interestingly, fruit pedicel length and fruit apex length which were used in *Musa acuminata* descriptors at subspecific level were not significantly different in this study.

**Keywords:** Characterization, Morphometrics, Musaceae, Numerical Taxonomy, Phenetic analysis

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Musaceae, the banana family, distributed mainly in tropical regions especially in Southeast Asia [1] and Thailand is at its centers of distribution area. While 78 accepted species name have been described worldwide [2], 18 banana names were listed in Thailand, among which only seven are native species [3] including newly found, *Musa siamensis* [4], *M. serpentina* [5] and *M. nanensis* [6].

Numerical analysis has lately been applied in taxonomic studies of several plant taxa, e.g. Fabaceae [7], Alliaceae [8], Poaceae [9], Iridaceae [10], and Rosaceae [11] as morphometrics provided accurately measurable information for these classifications. In banana, there have been a few studies using the numerical taxonomy in different ranks including genera, sections, species and subspecies [12-14]. Meanwhile, banana morphological descriptors were compiled for cultivar characterization and selections of germplasm for breeding [13, 15]. Though several of these descriptors were quantitative, most of the characters used in wild banana classifications were qualitative [3, 16-17]. In Thailand, Chomchalow and Silayoi [18], followed Simmonds and Shepherd [19], classified 58 banana cultivars in Thailand into eight groups based on 15 qualitative characters and genome designation. Our preliminary results suggested that both qualitative and quantitative characters could be applied for the classification of Thai banana species (unpublished data). Following up those previous works, in this study, we have selected and evaluated efficiency of the quantitative morphological characters in taxonomic ranking of the banana family found in Thailand focusing on genera and sections.

## Materials and Methods

### Specimen collection

A total of 143 accessions, 14 taxa, from three genera in Musaceae, including 10 native species and one introduced *Musella* species, were collected in Thailand from natural habitats by Swangpol and Somana (pers. comm.) during 2005-2018 (Table 1). Accession information included accession numbers, collectors, dates and places of collections, specific, subspecific and local names. Of each accession, one third-to-fifth leaf was collected and preserved as dry specimens; inflorescence and fruits were preserved in 70% ethanol with 1% glycerol as in-spirit specimens. Leaf base, middle portion of a leaf and leaf apex were kept. Male bud and fruits from mid hand were collected as in-spirited specimens.

Photographs of each accession were always taken with standard color chart [15] and a scale. Parts included in the photograph collection of each accession were clump, leaf base, blade underside and cross section of petiole showing canal, fruit bunch and inflorescence, male bud and bract, male flowers, fruit hand, fruits, X- and L-sections of fruits. All specimens were deposited at Suan Luang Rama IX Herbarium, Bangkok. Drawings, if applicable, were done and accompanied the specimen sheets.

**Table 1** List of Musaceae species in this study.

Taxa Number	Genera/Section	Species	Subspecies	No. of Accession	Note
1	<i>Ensete</i>	<i>E. glaucum</i> (Roxb.) Cheesman		3	
2	<i>Ensete</i>	<i>E. superbum</i> (Roxb.) Cheesman		3	
3	<i>Musa/Musa</i>	<i>M. acuminata</i> Colla	<i>siamea</i>	41	
4	<i>Musa/Musa</i>	<i>M. acuminata</i> Colla	<i>malaccensis</i>	23	
5	<i>Musa/Musa</i>	<i>M. acuminata</i> Colla	subsp.1	17	New subsp.
6	<i>Musa/Musa</i>	<i>M. acuminata</i> Colla	subsp.2	4	New record
7	<i>Musa/Musa</i>	<i>M. balbisiana</i> Colla		20	
8	<i>Musa/Musa</i>	<i>M. itinerans</i> Cheesman		3	
9	<i>Musa/Musa</i>	<i>M. serpentina</i> Swangpol & Somana		3	
10	<i>Musa/Musa</i>	<i>M. nanensis</i> Swanpol & Traiperm		3	
11	<i>Musa/Musa</i>	<i>Musa</i> sp.1		6	New record
12	<i>Musa/Rhodoclamys</i>	<i>M. rubra</i> Wall. ex. Kurz		9	
13	<i>Musa/Callimusa</i>	<i>M. gracilis</i> Holttum		5	
14	<i>Musella</i>	<i>Musella lasiocarpa</i> (Franch.) C.Y. Wu		3	Exotic
Total				143	

### Data collection and analyses

A total of 16 quantitative morphological characters of vegetative and reproductive structures modified from previous literature [2, 13, 15] were assessed; characters were measured and recorded both in the fields and from photographs (Table 2).

### Box-plot Analysis

Data were analyzed and box-plots were created in PASW Statistics for Windows version 18 [20]. Significant characters were considered by graphically depicting groups and subsequently confirmed with principal component analysis and discriminant analysis.

### Principal Component Analysis (PCA) and Discriminant Analysis (DA)

Both PCA and DA were performed in PAST version 3.18 [21]. PCA was employed to infer any data structures, e.g. groups of accessions while DA was used to determine character(s) that maximize a priori grouping. For the latter, the priori groups of accessions were genera and sections of Musaceae.

**Table 2** Quantitative morphological characters used in this study.

Vegetative characters		Reproductive characters	
<b>Pseudostem</b>	Pseudostem height	<b>Bunch</b>	Peduncle length
	Number of sucker plants		Rachis diameter
<b>Leaf</b>	Petiole length		Scar elevation
	Leaf blade length	<b>Male bud</b>	Male bud length
	Leaf blade width		Male bud width
			Male bud base-to-shoulder length
		<b>Fruit and seed</b>	Number of fruits on mid hand
			Fruit pedicel length
			Fruit length
			Fruit width
			Fruit apex length

## Results

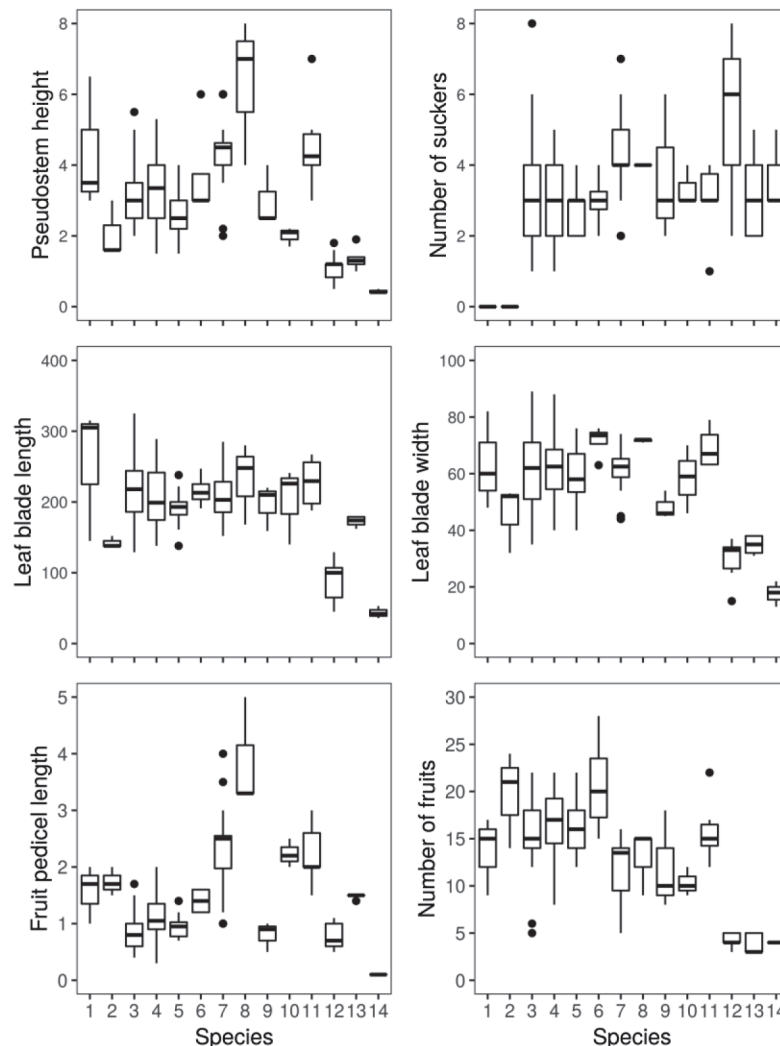
Most quantitative characters in box-plot analysis as shown in Fig. 1, except rachis diameter and fruit apex length (data not shown), can be used to classify accessions into either *Ensete* or *Musella*, though *Musa* cannot be sorted out. *Ensete* does not have sucker plants while *Musa* and *Musella* have more than one. Scar elevation (data not shown) and fruit pedicel length separated the genus *Musella* from *Ensete* and *Musa*. However, leaf blade length and width of *M. rubra* are aligned to those of *Musella*. Number of fruits on mid hand of *M. rubra* and *M. gracilis* also have the comparable number with *Musella*.

PCA of 14 Musaceae taxa showed that the 16 quantitative characters can classify this family into three groups at the generic level, i.e. *Ensete*, *Musa* and *Musella* (Fig. 2). Five characters with highest correlation coefficient with principal component (PC) 1 included fruit pedicel length, number of fruit on mid hand, fruit length, fruit apex length and leaf blade length (data not shown), and separated *Musella* from the other two genera. Also, another five characters having highest correlation to PC2 were rachis diameter, fruit width, number of sucker plants, scar elevation and petiole length (data not shown), and divided *Musa* from *Musella* and *Ensete*.

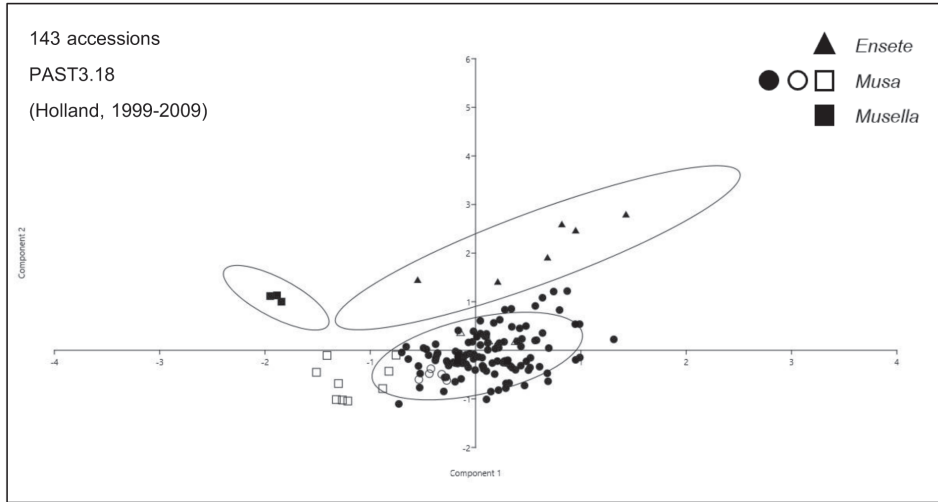
At the sectional level, 16 quantitative morphological characters also classified the genus *Musa* in Thailand into three groups, namely section *Callimusa*, *Rhodoclamys* and *Musa* (Fig. 3). The characters in PC1 were leaf blade length, rachis diameter, male bud length and width, fruit length, differentiate *Callimusa* from *Rhodoclamys-Musa*. Those in PC2 included peduncle length, fruit apex length, scar elevation, male bud base-to-shoulder and male bud width.

DA using all 16 quantitative characters also indicated that these characters were able to unambiguously classify all three genera (Fig. 4). Quantitative characters that were highly correlated to discriminant axis (DA) 1 were petiole length, leaf blade length, leaf blade width, peduncle length, and rachis diameter. DA2 contained petiole length, leaf blade length, leaf blade width, peduncle length and number of fruits on mid hand.

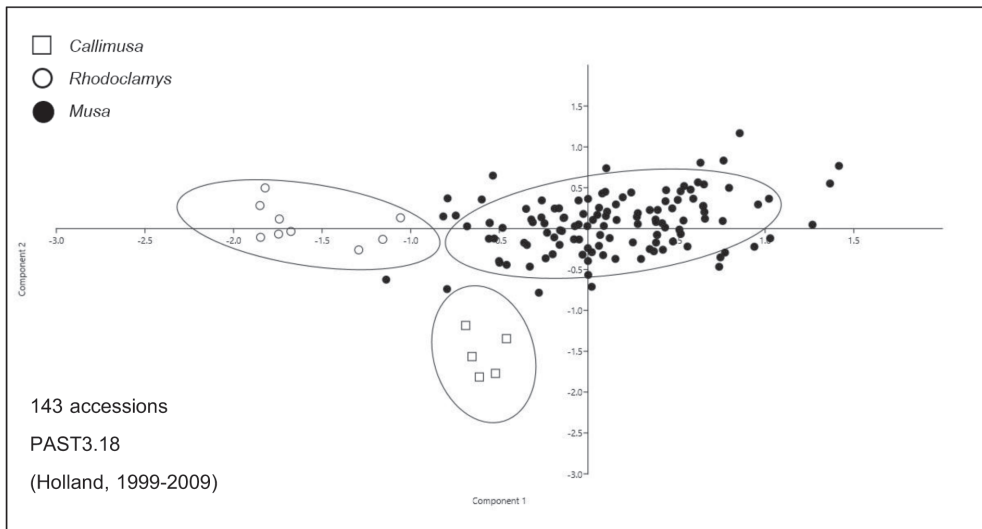
Also, for three *Musa* sections, DA based on these quantitative characters could clearly separate *Callimusa*, *Rhodoclamys* and *Musa* from each other (Fig. 5). Five characters with highly correlated to DA1 included petiole length, leaf blade length, leaf blade width, peduncle length and rachis diameter. The DA 2 contained petiole length, leaf blade length, leaf blade width, peduncle length and rachis diameter like in DA1.



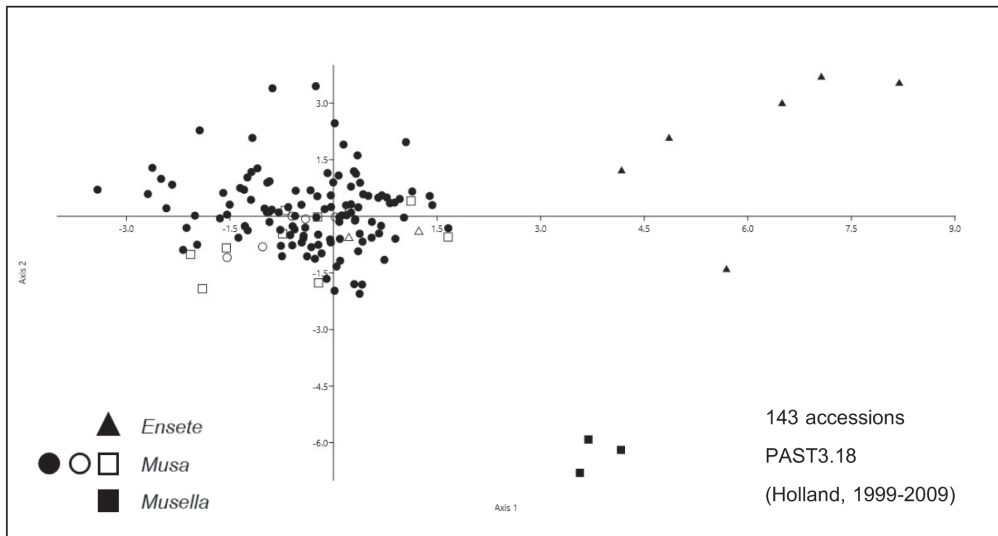
**Figure 1** Box-plot analysis of six quantitative morphological characters of 14 Musaceae taxa found in Thailand. Taxa names follow Table 1.



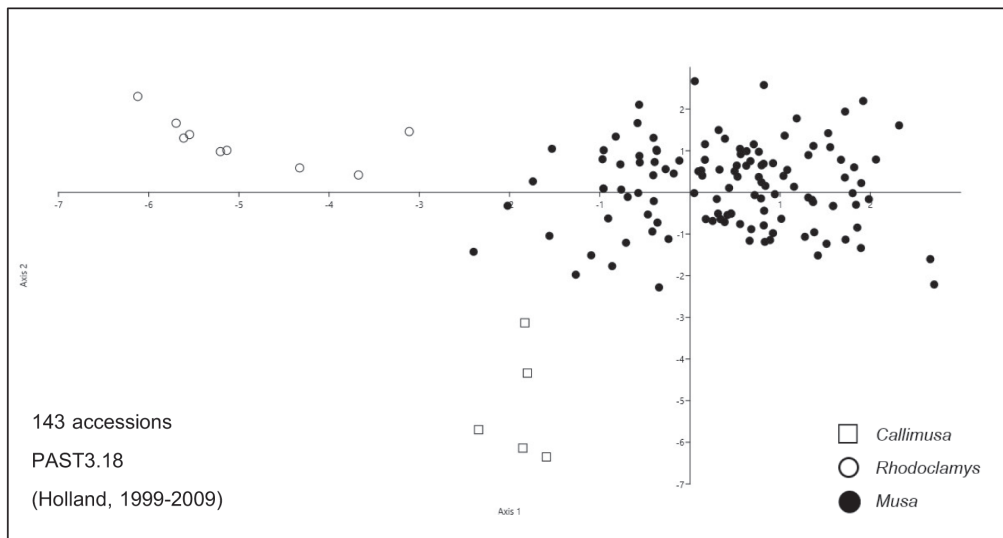
**Figure 2** Scatter plots of principal component analysis delineating the three genera of Musaceae.



**Figure 3** Scatter plots of principal component analysis delineating the three sections of the genus *Musa* i.e *Callimusa*, *Rhodoclamys* and *Musa*.



**Figure 4** Scatter plots of discriminant analysis delineating the three genera of Musaceae i.e *Ensete*, *Musa* and *Musella*.



**Figure 5** Scatter plots of principal component analysis delineating the three sections of the genus *Musa* i.e *Callimusa*, *Rhodoclamys* and *Musa*

## Discussion and Conclusion

For a long time, Musaceae has been reported as having two genera, *Musa* and *Ensete*. In 1889, Franchet [22] described new section of *Musa* as *Musella*. And In 1978, Li et al. [23] was raised it to a new genus. Though, several botanists disagreed [16, 24-25], though the plant characteristics show unique morphology differing from the other two genera including inflorescence terminal or axillary near base of pseudostem, male bud conical [26]. Most discriminating characters used to classify *Musella lasiocarpa* were based on qualitative morphological characters [16, 22-26].

In our study, the quantitative morphological analysis showed the differences between the three genera of *Musaceae*. *Musella* was distinguished from *Ensete* and *Musa* by the inflorescence characters; scar elevation less than 0.1 mm (data not shown) and fruit pedicel 0.1 cm in length. The result confirmed Li et al [23] to elevated *Musella lasiocarpa* as the new genus. That single pseudostem was used to separate *Ensete* from *Musa* can be modified into quantitative characters as number of suckers and still usable in generic classification. Also, pseudostem height which was a discriminating character between *Musella* and *Musa* used in previous literature [26] can be used in our study at the generic level. The identification key resulting from these numerical analyses is provided below.

### Key to genera of Musaceae in Thailand

- |   |                |
|---|----------------|
| 1. Sucker plant does not present                            | <i>Ensete</i>  |
| 1. Sucker plants present                                    |                |
| 2. Pseudostem height < 60 cm, fruit pedicel 1 mm. long      | <i>Musella</i> |
| 2. Pseudostem height > 60 cm, fruit pedicel over 1 mm. long | <i>Musa</i>    |

Quantitative morphological characters could be used in the banana classification also at the sectional level. *Musa* found in Thailand were separated into three sections, i.e. *Callimusa*, *Rhodoclamys* and *Musa*. Pseudostem height, leaf blade width and number of fruits on mid hand could be used as discriminating characters for these three sections in *Musa*. Sections *Callimusa* and *Rhodoclamys* have pseudostem not higher than 2 m, while pseudostem height of the section *Musa* is 2 to 8 m. *Rhodoclamys* has shorter leaf blade length, not over 130 cm, than *Callimusa* which has that at average 150-180 cm. From these results, we constructed key to sections as follow.



**Key to sections in *Musa***

- |  |                            |
|--|----------------------------|
| 1. Pseudostem < 2 m., number of fruits on mid hand up to 5 |                            |
| 2. Leaf blade up to 130 cm. long                           | Section <i>Rhodoclamys</i> |
| 2. Leaf blade 150-180 cm. long                             | Section <i>Callimusa</i>   |
| 1. Pseudostem > 2 m., number of fruits on mid hand 5-28    | Section <i>Musa</i>        |

Quantitative characters have been under-utilized as many plant taxonomists believe they are high variable due to continuous environmental changes. Our study, however, demonstrated that they can be employed as discriminating characters even at the generic and the sectional levels. It was found that pseudostem height, number of sucker plants and fruit pedicel length are able to discriminate the three genera in Musaceae, meanwhile, pseudostem height, leaf blade length, and number of fruits on mid hand can be used to classify the three sections of the *Musa* genus found in Thailand.

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