SYSTEMATIC STUDY OF SELECTED GENUS GARCINIA L. BASED ON VEGETATIVE MORPHOLOGY

Azuan Bin Amron
Agrobiodiversity & Environment Research Centre
MARDI Headquarter, 43400, Serdang, Selangor, Malaysia
Email: azuan@mardi.gov.my

Maya Izar Binti Khaidizar
Agrobiodiversity & Environment Research Centre
MARDI Headquarter, 43400, Serdang, Selangor, Malaysia
Email: maya@mardi.gov.my,

Zulhairil Bin Ariffin
Agrobiodiversity & Environment Research Centre
MARDI Headquarter, 43400, Serdang, Selangor, Malaysia
Email: hairi@mardi.gov.my,

Rosliza Binti Jajuli
Agrobiodiversity & Environment Research Centre
MARDI Headquarter, 43400, Serdang, Selangor, Malaysia
Email: rosliza@mardi.gov.my,

Mohd Saifuddin Bin Ismail
Agrobiodiversity & Environment Research Centre
MARDI Headquarter, 43400, Serdang, Selangor, Malaysia
Email: msi@mardi.gov.my,

ABSTRACT

Garcinia has been described as a Guttiferae family which also known as Clusiaceae. A few different classification methods have been elaborated for Garcinia species. These approaches however are not really practical in field identification because of inconvenience of transportation and usage of necessary scientific instruments to and from the field. The objective of this study was to carry out comprehensive systematic survey of Garcinia species using vegetative morphological characters. Variabilities among 30 accessions from 12 selected species of Garcinia vegetative were studied using standard unweighted pair group method using averages (UPGMA). Principal component analysis (PCA) was used to analysed the diversity and to identify the optimum number of morphological traits which explain a high proportion of variability. Accessions similarity analyses were performed based on 23 vegetative morphological characters. The results suggest that the sampled accessions fall into five groups. Group 1 consist of 16 accessions which are from species G. atroviridis, G. cowa, G. parvifolia and G. prainiana. Group 2 consist of four accessions i.e. three from G. mangostana and one from G. nervosa. Group 3 represented by two accessions; G. bancana and G. griffithii. Group 4 consist of five accessions (two from G. dulcis and three from G. hombroniana) and group 5 consist of two accessions of G. forbesii and one accession of G. cambogiana. The principal component analysis (PCA) showed that eight of the 23 morphological traits were the most important components for explaining the grouping of accessions. The analysis determined leaf colour (below), canopy shape, leaf colour (above), leaf texture (below), leaf texture (above), leaf habit, leaf orientation and leaf apex/tip as the most important traits with a correlation of 89%. This finding provides important information to the Garcinia breeders that helps to optimize the selection of plant material to be used in breeding program. Vegetative morphological characteristics proved to be useful in systematic study of Garcinia.

Key words: Garcinia, vegetative morphology, systematic, numerical analysis

INTRODUCTION

Malaysia is rich in various fruit species which play an important role providing nutrition for local consumption and being an alternative source of income to farmers. These fruits are categorized as major, minor and rare or wild. Major fruits can be defined as producing fruits for commercial use. The fruits are cultivated in large acreages. According to Syauqi et. al (2010), at present only 16 species are classified in this group. Besides commercial fruits, many other fruit species are grouped under minor and rare fruit species. Many of the rare fruit species have great potential but they are under-exploited.

Home gardens or orchards constitute important agricultural systems and harbour many indigenous varieties, landraces and even some rare fruit species (Salma et al., 2006). However, our agrobiodiversity resources, particularly the rare and wild species of food crops, have not been fully studied and very little is known on their actual distribution and potential use (Sharif, 2006). Some species are near extinction even before they are documented. In view of this, MARDI has carried out surveys on the distribution, genetic diversity and undertaking the socio-economic studies on rare fruit species including Garcinia.

Garcinia family has approximately 300 species spreading across several parts of the world from South America, Africa, Madagascar to Southeast Asia. Garcinia has been described as a Guttiferae family which also known as Clusiaceae (Stevens, 2001).

Garcinia is a dioecious evergreen trees or shrubs with yellow or white resinous latex. Leaves of the plant usually opposite, simple, entire without stipules. Trunks are straight, tapering to the top of the conical crown and the branches arranged in alternating pairs. Garcinia's flowers often bright and showy with variously arranged, can be clustered or axillary (Verheiji & Coronel, 1992).

The mangosteen (*Garcinia mangostana* L.) is a promising fruit of Southeast Asia and has been hailed as the queen of tropical fruits because of its instant visual and taste appeal. Apart from mangosteen, the most cultivated species are *G. prainiana* (cerapu), *G. atroviridis* (asam gelugor), *G. cowa* (kandis), *G. forbesii* (rose-kandis), *G. hombroniana* (beruas) and *G. dulcis* (mundu). In Malaysia, although the distribution and variation of mangosteen had already been studied; however, the wild relatives of these crops' species have been neglected. In view of this, MARDI has carried out survey on the distribution, genetic diversity and undertaking socio-economic study on Garcinia species. There were seven Garcinia species found throughout the country. Sabah had the highest number of species, followed by Kelantan, Terengganu, Pahang, Perak, Kedah and Johore. Selangor, Negeri Sembilan and Malacca recorded the lowest species number. Similarly, Sabah has the highest diversity followed by Pahang and Perak. Mangosteen and asam gelugor were two common species cultivated in all states. Aroi-aroi was found to be cultivated only in Sabah. As for cerapu, states like Pahang and Kelantan recorded highest number of the species compare to Terengganu, Sabah, Kedah, Perak and Johore. However, mundu and beruas registered very low number throughout the country (Azuan, 2008). From a survey on the distribution and genetic diversity of *G. atroviridis* throughout the country, Azuan (2010) found the variation in fruit characters among the accessions based on the morphological traits. There was also diversity in fruit, vegetative and floral characters of *G. prainiana* recorded by Azuan (2015). However, classification and divergence between these species never been done and it is important to do it as it can help to optimize the selection of plant materials to be used in the breeding program.

On the other hands, a few different classification methods have been elaborated for *Garcinia* species. Jones (1980) proposed to classify *Garcinia* into 14 sections based on morphological and pollen characters. Rismita (2000) used molecular methods in classifying *Garcinia*. Similarly, Nazre (2006) classified *Garcinia* used molecular methods and reduces the number of species from 43 to 16 with five varieties. Phylogenetic study also done by Yapwatannaphun (2004) to test the theory on the origin of mangosteen based on Richards (1990). On the other hand, Sweeney (2007) emphasised the importance of floral characteristics in classifying *Garcinia* species. These approaches however are not really practical in field identification because of inconvenience of transportation and usage of necessary scientific instruments to and from the field.

The objective of this study was to carry out comprehensive systematic survey of *Garcinia* species using vegetative morphological characters.

MATERIALS AND METHODS

Plant material

A total of 30 accessions from 12 species of Garcinia were collected from various states in Malaysia such as Perak, Negeri Sembilan, Kedah, Terengganu, Kelantan, Selangor, Pahang and Sabah. The species code and locality are presented in Table 1 below.

Data analysis

Data for 23 vegetative characteristics (qualitative and quantitative) were recorded for each species. The accessions were characterized using morphological traits described in Descriptors for Mangosteen (*Garcinia mangostana*) (IPGRI, 2003). The characters states in Table 2 below.

The cluster analysis was performed with computer programme Ntsys-pc version 2.11 (Rohlf, 1993). The relationship among Garcinia species were evaluated using unweighted pair group method using averages (UPGMA) (Sneath and Sokal, 1973).

Principal component analysis (PCA) was used to analyze the diversity and to identify the optimum number of morphological traits which explain a high proportion of variability. This was performed using the Minitab 17 statistical software. The Scree plot was used to display Eigenvalues and number of morphological traits in PCA.

Table 1: Species code for samples and the locations

Species	Code	Locality
G. atroviridis 1	GAVS1	Parit, Perak
G. atroviridis 2	GAVS2	Yan, Kedah
G. atroviridis 3	GAVS3	Kuala Kurau, Perak
G. atroviridis 4	GAVS4	Bukit Gantang,Perak
G. atroviridis 5	GAVS5	Kuala Pilah, N.Sembilan
G. atroviridis 6	GAVS6	Bukit Gantang, Perak
G. atroviridis 7	GAVS7	Pendang, Kedah
G. mangostana1	GMST1	Yan, Kedah
G. mangostana2	GMST2	Bukit Tangga, Kedah
G. mangostana3	GMST3	Gemencih, N. Sembilan
G. nervosa	GNVS	Tasik Kenyir, Terengganu
G. dulcis 1	GDLC1	MARDI Bkt Tangga,Kedah
G. dulcis 2	GDLC2	Kuala Krai, Kelantan
G. bancana	GBCN	Plot C, MARDI,Serdang
G. griffithii	GGFI	Hulu Terengganu
G. parvifolia	GPVL	Plot C, MARDI, Serdang
G. forbesii 1	GFBS1	Papar, Sabah
G. forbesii 2	GFBS2	Plot C, MARDI, Serdang
G. cambogiana	GCMB	Plot C, MARDI, Serdang
G. hombroniana 1	GHMB1	Kemaman, Terengganu
G. hombroniana 2	GHMB2	Hulu Terengganu
G. hombroniana 3	GHMB3	Tumpat,Kelantan
G. prainiana 1	GPRN1	Bachok, Kelantan
G. prainiana 2	GPRN2	Temerloh, Pahang
G. prainiana 3	GPRN3	Machang, Kelantan
G. prainiana 4	GPRN4	Kuala Pilah, N.Sembilan
G. prainiana 5	GPRN5	Kuala Lipis, Pahang
G. prainiana 6	GPRN6	Kuala Lipis, Pahang
G. cowa 1	GCOW1	Kuala Krai, Kelantan
G. cowa 2	GCOW2	Papar, Sabah

Table 2: The vegetative characters and character states used in the study

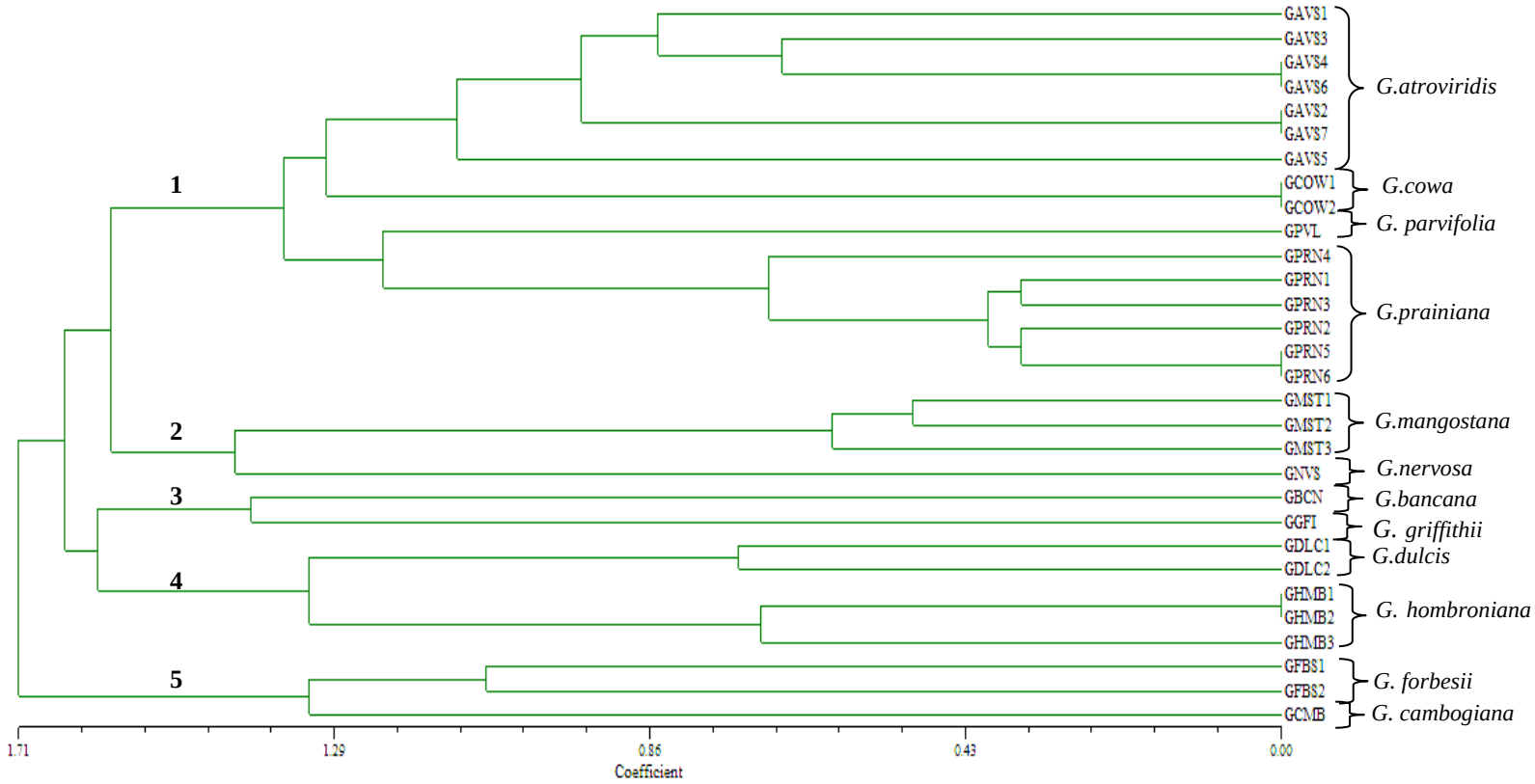
Code	Characters	Characters states							
		1	2	3	4	5	6	7	8
CH01	Leaf length (cm)	CH01 ≤ 10	10 < CH01 ≤ 20	20 < CH01 < 30	CH01 ≥ 30				
CH02	Leaf width (cm)	CH02 ≤ 5	5cm < CH02 <10	CH02 ≥ 10					
CH03	Leaf shape	Elliptic	Lanceolate	Oblong	Ovate	Obovate	Cabbagy leathery		
CH04	Leaf margin	Entire smooth	Entire slightly wavy	Wavy					
CH05	Leaf arrangement	Opposite	Deccussate						
CH06	Leaf orientation	Horizontal	Horizontal droopy	Droopy	Uphold				
CH07	Leaf habit	Flat	Slightly folded	Folded					
CH08	Leaf apex/tip	Acuminate	Acute	Obtuse	Blunt	Rounded	Cuspidate	Ermaginate	
CH09	Leaf base	Cuneate	Tapered	Acute	Subcordate	Rounded	Cordate	Attenuate	Cordate
CH10	Waxiness on leaf	Waxy	Slightly waxy						
CH11	Leaf texture above	Smooth	Glabrous	Undulated	Hairy	Leathery	Slight undulated		
CH12	Leaf texture below	Glabrous	Smooth						
CH13	Leaf colour above	Green	Dark green	Light green					
CH14	Leaf colour below	Green	Light green	Yellowish	Greyish green	Dark green			
CH15	Leaf shoot colour	Red	Light green	Yellowish	Greyish	Reddish/brown	Pinkish		
CH16	Petiole length (cm)	CH17 ≤ 0.5	0.5 < CH17 ≤ 1	1 < CH01 ≤ 1.5	1.5 < CH01 < 2	CH01 ≥ 2			
CH17	Tree vigour	Low	Medium	High					
CH18	Canopy dia. (m)	CH19 ≤ 2	2 < CH19 ≤ 4	4 < CH19 ≤ 6	6 < CH19 ≤ 8	8 < CH19 < 10	CH19 ≥ 10		
CH19	Canopy shape	Conical	Oblong	Dome	Oval	Pyramidal	Irregular		
CH20	Branching density	Dense	Medium	Low					
CH21	Branching pattern	Erect	Semi erect	Horizontal	Droopy				
CH22	Trunk surface	Rough	Fissured	Flaky	Smooth	Lenticellate			
CH23	Bark colour	Greyish	Brown	Yellowish brown	Dark brown	Greenish/brown	Light brown		

RESULTS AND DISCUSSIONS

From the study, Garcinia is an underutilized fruit tree, were cultivated in the home gardens, orchards or along the road sides in all states in Malaysia. Garcinia accessions collected and characterized from several states such as Perak (Parit, Batu Kurau, Bukit Gantang), Kedah (Yan, Pendang, Bukit Tangga), Negeri Sembilan (Kuala Pilah, Gemencih), Terengganu (Tasik Kenyir, Hulu Terengganu, Kemaman), Kelantan (Kuala Krai, Tumpat, Bachok, Machang), Selangor (Serdang), Pahang (Termeloh, Kuala Lipis) and Sabah (Papar). A total of 12 Garcinia species were found cultivated or semi cultivated in the home gardens or orchards in the locations. These species were G. atroviridis (7 accessions), G. mangostana (3 accessions), G. nervosa (1 accession), G. dulcis (2 accessions), G. bancana (1 accession), G. griffithii (1 accession), G. parvifolia (1 accession), G. forbesii (2 accessions), G. cambogiana (1 accession), G. hombroniana (3 accessions), G. prainiana (6 accessions) and G. cowa (2 accessions)
Leaf characters were examined for quantitative data including leaf length, leaf width, petiole length and canopy diameter. The range of data recorded for each characteristic varies between 1-10 per characters. Morphological observations showed variations on leaf shape, leaf margin, leaf arrangement, leaf orientation, leaf habit, leaf apex/tip, leaf base, waxiness on leaf, leaf texture above, leaf texture below, leaf colour above, leaf colour below, leaf shoot colour, tree vigour, canopy shape, branching density, branching pattern, trunk surface, bark colour.

The dendrogram (Figure1) separates the 30 accessions of Garcinia species into five groups. There is very clear separation of the accessions according to their species. Group 1, which is the largest in number, consist of 16 accessions which are from species G. atroviridis, G. cowa, G. parvifolia and G. prainiana. This group possesses almost same size leaf and acute leaf tip shape. Group 2 consist of four accessions i.e three from G. mangostana and one from G. nervosa. The grouping of these accessions based on their slightly undulated leaf. Group 3 only represented by two accessions; G. bancana and G. griffithii. They are distinguished by having greyish bark colour. Group 4 which consist by five accessions (two from G. dulcis and three from G. hombroniana) are distinguished by having more than 2cm petiole length. Group 5 consist of two accessions of G. forbesii and one accession of G. cambogiana. Canopy shape (oblong), canopy diameter and also trunk surface (fissured) are very similar in these three accessions. Vegetative morphological characteristics proved to be useful in systematic study of Garcinia. Nevertheless, vegetative morphological characters can be used to construct species identification keys to identify Garcinia species in the field.

Figure 1: The UPGMA dendrogram of 30 accessions Garcinia species inferred by 23 vegetative morphological characters



The principal component analysis (PCA) showed that eight of the 23 morphological traits were the most important components for explaining the grouping of accessions (Figure 2). To identify these eight most important traits, a subset regression analysis was performed. The analysis determined leaf colour (below), canopy shape, leaf colour (above), leaf texture (below), leaf texture (above), leaf habit, leaf orientation and leaf apex/tip as the most important traits with a correlation of 89% (Table 3). Together, the first eight principal components accounted for 89% of the total variance.

Figure 2: Scree plot of principal component analysis (PCA) showing the number of leaf morphological traits and their importance for grouping accessions into Garcinia gene pools.

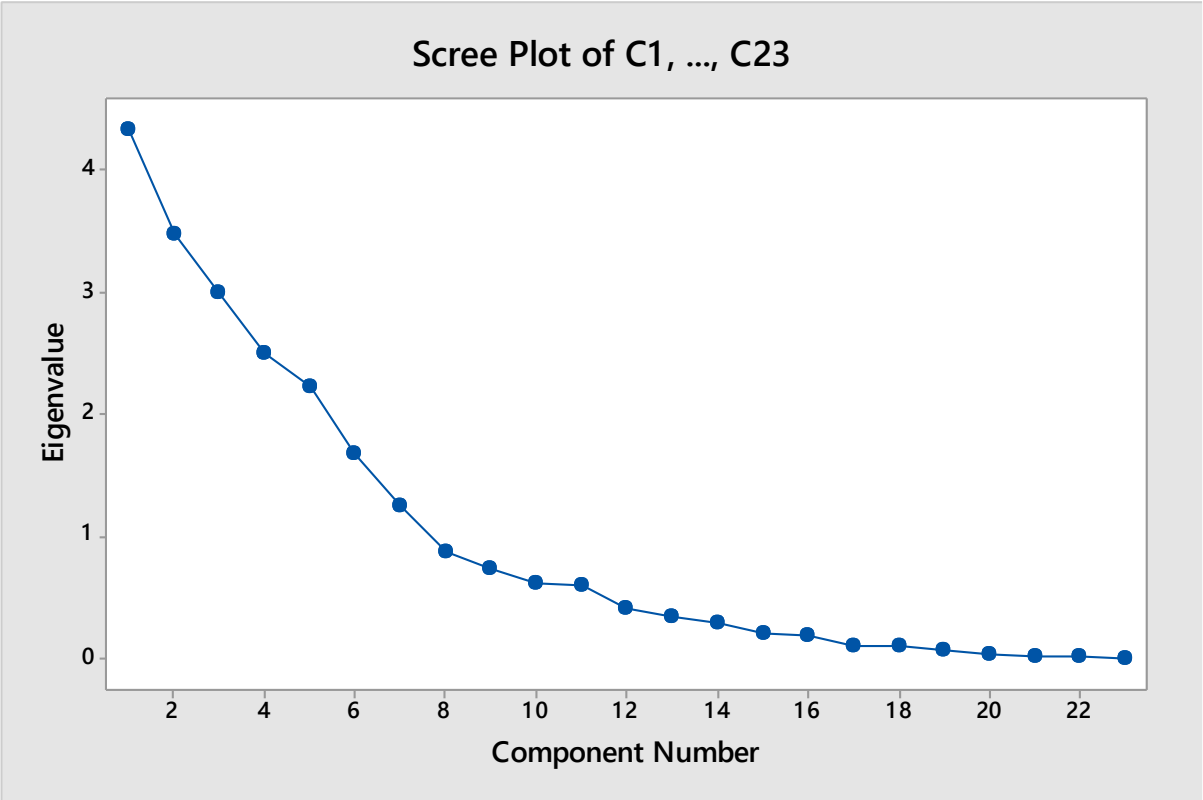


Table 3: Eigen analysis of the Correlation Matrix

Eigenvalue	4.3261	3.4776	2.9912	2.4941	2.2317	1.678	1.2482	0.8753	0.7369	0.6147
Proportion	0.188	0.151	0.13	0.108	0.097	0.073	0.054	0.038	0.032	0.027
Cumulative	0.188	0.339	0.469	0.578	0.675	0.748	0.802	0.84	0.872	0.899

CONCLUSIONS

Selected Garcinia species characterized with 23 vegetative morphological characters were suggest that the sampled accessions fall into five groups. There is very clear separation of the accessions according to their species. Vegetative morphological characteristics proved to be useful in systematic study of Garcinia. Nevertheless, vegetative morphological characters can be used to construct species identification keys to identify Garcinia species in the field. The PCA showed that eight of the 23 morphological traits were the most important components for explaining the grouping of accessions. This finding provides important information to the Garcinia breeders that helps to optimize the selection of plant material to be used in breeding program. However, since the number of samples for each species either in the home garden or forest is small at each site, therefore, in order to capture enough genetic variability for classification it requires to select many home gardens and large areas of forest reserves. It is recommended to intensify the cluster and PCA analysis of the Garcinia species in other than vegetative characters such as fruits and flowers in order to obtain comprehensive data pertaining to diversity and classification.

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