Jurnal Biologi Indonesia 9(1): 39-49 (2013)

Phenetic Analysis of *Gossypium* Species (Malvaceae) from Indonesia (Analisa Fenotipe dari Spesies *Gossypium* (Malvaceae) dari Indonesia)

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Memasukkan: November 2012, **Diterima;** Maret 2013

ABSTRACT

This research was aimed to revise the species of *Gossypium* in Indonesia with statistical analysis of morphological characteristics. Three species of *Gossypium* were recognized based on phenetic analyses (cluster analysis-UPGMA and ordination-Principle Component Analysis) using 20 morphological characters and 18 samples of *Gossypium arboreum, G. barbadense*, and *G. hirsutum*. Based on these analyses, two varieties were differentiated under *G. arboreum* (var. *arboreum* and var. *acuminatum*). The data set used for the analysis was robust in separating the samples used in the analysis into discrete groups and cluster analysis-UPGMA and ordination-PCA were powerful tools for the allocation of those samples into identifiable groups.

Keywords: Phenetic analysis, *Gossypium*, Principal Component Analysis, UPGMA

ABSTRAK

Penelitian ini ditujukan untuk merevisi jenis-jenis kapas yang ada di Indonesia, apakah jenis-jenis tersebut dapat dikenali secara statistika dengan mengggunakan karakter morfologi sebanyak mungkin. Tiga jenis kapas (*Gossypium*) dari Indonesia dikenali berdasarkan analisis fenetika (analisis kluster-UPGMA dan ordinasi-Principle Component Analysis) dengan menggunakan 20 karakter morfologi dan 18 spesimen herbarium perwakilan. Ketiga jenis-jenis tersebut adalah *Gossypium arboreum, G. barbadense*, dan *G. hirsutum*. Dari analisis fenetika, dua varietas dikenali di bawah jenis *G. arboreum* (var. *arboreum* dan var. *acuminatum*). Data set yang dipergunakan untuk analisis fenetika sudah sangat baik untuk memisahkan ke-18 contoh tersebut menjadi kelompok-kelompok yang dapat dikenali. Selain itu, analisis kluster-UPGMA dan ordinasi-PCA, pada penelitian ini merupakan alat yang sangat cocok untuk memisahkan contoh-contoh tersebut menjadi kelompok-kelompok yang dapat di identifikasi.

Kata kunci: Analisis fenetika, *Gossypium*, *Principal Component Analysis*, *UPGMA*

INTRODUCTION

Gossypium is an important genus as several of its species are the source of cotton, an economically important fibre. It is one of the 50 genera in the cotton family (Malvaceae) (Purseglove 1979). Based on Fryxell (1965), there are ca. 32 species of *Gossypium* worldwide. However, with increased studies and further fieldwork, 50 species have been recognized (Zhao *et al*. 1998, Wendel & Cronn 2002).

Based on Purseglove (1979), *Gossypium* is divided into three general groups: lintless cotton, Old World cotton and New World cotton. Lintless wild cotton is classified into six sections (*Sturtiana*, *Erioxyla*, *Klotzschiana*, *Thurberana*, *Anomala*, and *Stocksiana*). Old World cotton and New World cotton has only one section each, sections *Herbacea* and *Hirsuta,* respectively. The origin of *Gossypium arboreum* and *G. herbaceum* is from the Old world (Asia, Africa, and Europe), *G. barbadense* and *G. hirsutum* are from the New World (the Americas). In addition, Wendel and Albert (1992) stated that *G. arboreum* and *G. herbaceum* have 26 chromosomes (2n), in contrast *G. barbadense* and *G. hirsutum* have 52 (4n). The genome designation of *G. barbadense* and *G. hir-*

sutum is AD, A derived from Africa and D from the Americas (Purseglove 1979; Wendel & Cronn 2002). The genome designation of *G. arboreum* is symbolized by A2 indicating that the species was originally from India (i.e., the Old World), in contrast to *G. hirsutum* and *G. barbadense* which are symbolized by (AD)1 and (AD)2, respectively.

Waalkes (1966) in his work 'Malvaceae in Malesia' (Indonesia, Malaysia, Brunei Darussalam, Singapore, the Philippines, and Papua New Guinea), stated that there were three species of cotton from this region based on few morphological features.

Brown (1938) and Purseglove (1979) recorded that four cotton species have been cultivated in Indonesia (*G. herbaceum, G. arboreum, G. barbadense,* and *G. hirsutum*). *Gossypium arboreum* has six races based primarily on their origin. For instance, 'indicum' is from India; 'burmanicum' is from North East of India to Burma, and then extending to East Hindia including Indonesia; 'cernuum is from Garo hill in Assam India; 'sinense' is from China, Korea, and Japan; 'bangalense' is from East Bengal (Bangladesh) to Assam, and 'soudanense' is from India and then extending to Africa from Sudan to West Africa (Purseglove 1979). Seven races of *G. hirsutum* have been recognized: 'palmeri', 'morilli', 'richmondi', 'yucatanense', 'marie-galante', 'punctatum', and 'latifolium'. The first four are from along the coastline of Central America, 'punctatum is from Central America (Mexico Gulf from Yucatan to Florida and Bahama), and 'latifolium is from Central America (Purseglove, 1979). The third species is *G. barbadense* and it has two races. The first race is 'brasiliense' from the tropical eastern part of South American (the eastern part of Brazil) and the second is 'darwinii' which is endemic to the Galapagos Islands (Purseglove 1979).

Therefore, it is concluded that all species occurring in Indonesia are not native. These were introduced and cultivated, and then escaped, becoming naturalized, and then adapted to secondary forests and open areas. Herbarium specimens observed at Herbarium Bogoriense showed that there were three species of *Gossypium* collected from Sumatra, Java, Kalimantan, Nusa Tenggara, Sulawesi, Maluku, and West New Guinea.

The most wildly distributed species in Indonesia is *G. barbadense* (Figure 1). Waalkes (1966) stated that this plant was introduced to Indonesia as an agriculture plants by merchants or missionaries and its cultivation was limited to the local house industry. The wide distribution of *G. barbadense* might have occurred due to the tolerance of the species to tropical climates.

In contrast to *G. barbadense*, *G. arboreum* var. *obtusifolium* (Figure 1) has a more sporadic distribution. The origin of this species was hypothesized to have been in India from where it spread to Burma, Indonesia, and the Philippines. The variety *obtusifolium* has been cultivated for hundreds of years and was commonly grown to produce cotton thread, especially in South Sumatra, Java, Sunda Islands, Sulawesi, and Maluku. It is unknown who took this variety to Indonesia.

Gossypium hirsutum is widely distributed in Java, and it can also be found in South and South East Sulawesi, Tanimbar, Lombok, Flores, and South Sumatra. Based on Harland in Purseglove (1979), the wild from of *G. hirsutum* occurs in the North East of Brazil and it spread to Polynesia from South America carried by the ocean currents. However, Waalkes (1966) stated that this species was introduced into most tropical countries of the Old World (Palembang, Java, North Borneo, the Philippines, possibly Moluccas) from the North and Central America not due to any geological events. This introduction was intended to be done in Indonesia, North Borneo, and the Philippines for experimental purposes.

It is not unexpected that the distribution of this species is restricted. Waalkes (1966) mentioned that this species had been cultivated in

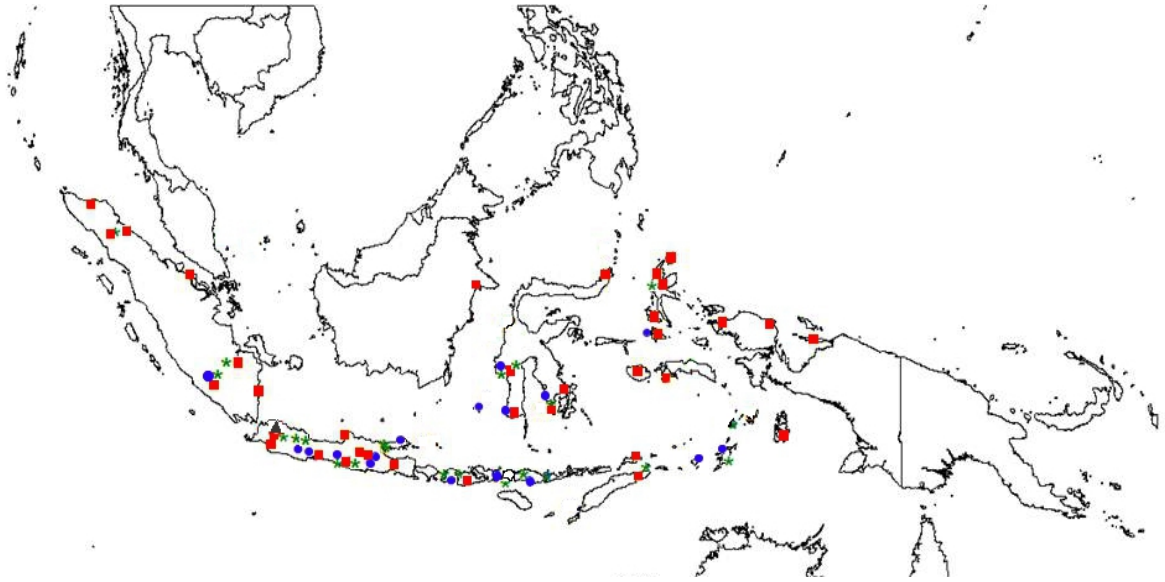

Figure 1. Distribution map of *Gossypium* species in Indonesia, ■ *Gossypium barbadense*, ● *Gossypium hirsutum*, **Gossypium arboreum* var. *obtusifolium*, ▲ *Gossypium arboreum* var. *arboreum*.

Table 1. Four groups recognized initially based on their overall morphological appearances

Taxa recognized from their overall morphological appearance	Morphological distinction initially recognized	Distribution
'Arboreum'	Leaf palmate with the tips of the leaf lobes acute, indumentum of short stellate and single long soft hairs, epicalyx is fused at the base	Jakarta
'Barbadense'	Leaf palmate with the tips of the leaf lobes acute, indumentum of short stellate hairs, epicalyx is free at the base	Sumatra, Java, Kangean, Kalimantan, Sulawesi, Sumbawa, Maluku, Halmahera, and Irian Jaya
'Hirsutum'	Leaf palmate with the tips of the leaf lobes shortly acute, indumentum of short stellate hairs, epicalyx is free at the base	Sumatra, Java, Kangean, Lombok, Sumbawa, Flores, Tanimbar, Sulawesi, and Kapoposang
'Obtusifolium'	Leaf palmate with the tip of the leaf lobes obtuse, indumentum of short stellate and single long soft hairs, epicalyx is fused at the base	Sumatra, Java, Madura, Sumba, Flores, Sulawesi, Ternate, and Tanimbar

Central and North America of which this species then was introduced to the Old World including Indonesia, perhaps by the English or the Dutch because the local names of this species was 'Dutch Cotton' and 'English Cotton'. *Gossypium hirsutum* was cultured in several places in Indonesia without satisfaction.

Based on herbarium specimens, *G. arboreum* var. *arboreum* was only recorded from Jakarta (Figure 1C). Waalkes (1966) stated that the plant was not cultivated any longer , however they still could be found as garden plants.

This research was mainly aimed at revising the *Gossypium* species occurring in Indonesia and to determine whether they could be recognized statistically using numerous morphological characteristics. Morphological data were analyzed using cluster analysis and factor analysis. Description of the species and their distribution were detailed as far as possible.

MATERIALS AND METHODS

On hundred and forty herbarium specimens deposited at the Herbarium Bogoriense were studied. The specimens were separated into piles based on their similarities and differences. Four groups were recognized initially based on their overall appearance (Table 1). Eighteen out of 140 specimens were chosen to represent those four groups. Twenty morphological characteristics from each representative specimen were recorded and coded numerically. Morphological characteristics used in the phenetic analyses are presented in Appendix 1. The complete data set (Appendix 2) was analyzed using UPGMA (Unweighted Pair Group Method with Arithmetic Average) cluster analysis by Sneath and Sokal (1973) and ordination using Principle Component Analysis (PCA) (Pearson, 1901). Standardization using Milligan and Cooper's technique (1988) was implemented in the data to provide equal weight for each morphological character before the data set was analyzed. Cluster analysis using Euclidean distance and equal weight linkage method (UPGMA) and PCA were generated using the program PC-ORD (McCune and Grace 2002) including identifying the important characters placing the sampled specimens into groups.

RESULTS

Cluster Analysis and Principal Component Analysis

Cluster analysis (Figure 2) shows that the four groups initially recognized were clearly separated into four clustered at the 50% cutting point (differences). At the 75% differences, the four prior groups could not be separated. Only two groups were recognized at 25% differences 'Barbadense-Hirsutum' and 'Obtusifolium-Arboreum'

A similar pattern was shown in the ordination analysis using PCA (Principal Component Analysis, Figure 3). 'Barbadense' was widely separated from 'Obtusifolium' and 'Arboreum', as well as 'Hirsutum'. The gap between 'Barbadense' and 'Hirsutum' was wider than between 'Obtusifolium' and 'Arboreum'. However, the distance between 'Arboreum' and 'Obtusifolium' was relatively closer compared to the distance between these two groups with 'Barbadense' and 'Hirsutum. Therefore, 'Obtusifolium' and

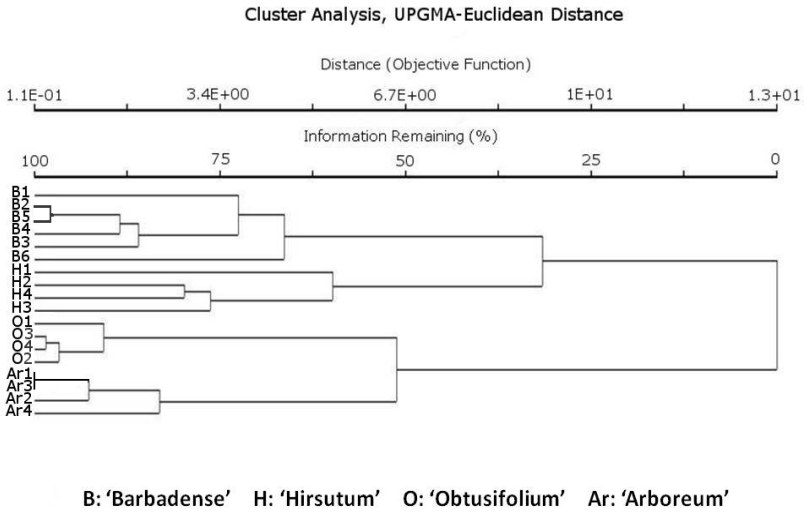

Figure 2. Cluster Analysis of *Gossypium* using Euclidean Distance and UPGMA

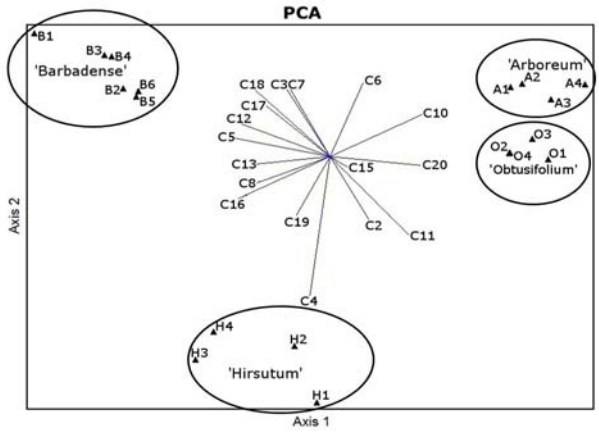

Figure 3. Principal Component Analysis of species of *Gossypium* from Indonesia (Cs are quantitative morphological characteristics used to separate taxa displayed into two dimension).

'Arboreum' were relatively more similar to each other.

Cs are quantitative morphological characteristics that were important to group taxa used into cluster of taxa identified from the cluster analysis. Figure 3 shows that 'Barbadense' (B1, B2, B3, B4, B5, and B6) was separated from the other groups mainly based on characters 3 (C3: lobe shape in the leaf blade), 5 (C5: lobe shape), 7 (C7: the number of leaf midrib), 12 (C12: Corolla length), 17(C17: pedicel length), and 18 (C18: stamina column length). 'Hirsutum' was distinct from the others by character 4 (C4: number of lobes in the leaf blade). 'Obtusifolium' and 'Arboreum' were separated from each other by character 3 (the shape of leaf lobes in the leaf blade).

DISCUSSION

'Obtusifolium' and 'Arboreum' are clustered into one clade at 50% cutting point (Figure 2). However, 'Barbadense' and 'Hirsutum' distinctly formed two separate clusters. At 75% cutting point, B1 (Barbadense-1) was separated from B2, B3, and B4. Similar pattern also occurred in 'Hirsutum'. H1 (Hirsutum-1) was separated from H2, H3, and H4. However, 'Arboreum' and 'Obtusifolium' were separated clearly at this point. At 25% cutting point 'Barbadense-Hirsutum' had to be lumped together into groups. This finding did not support the initial recognized groups that hypothesized 'Barbadense' and 'Hirsutum' were two separate groups. In addition, the separation of 'Obtusifolium' and 'Arboreum' was not supported by this analysis. Thus, at 50% cutting point, the classification proposed by Bossum Walkes (1966) was supported.

Figure 3 shows that characters 6 (C6: length:width leaf lobes), 10 (C10: single long soft hairs), 11 (C11: soft stellate hairs), 20 (diameter:length fruit), and 15 (length:width epicalyx) were used to separate 'Arboreum' and 'Obtusifolium' from 'Hirsutum' and 'Barbadense'. Character 15 (length: width epicalyx) did not clearly separate these two because the range of the ratio between length and width of epicalyx based on the data collected initially was in between 1.15 to 1.43 for 'Obtusifolium' and 1.3-1.53 for 'Arboreum'. Character number 10, 11, and 20 (C10, C11, C20) (Figure 3) were important characters to cluster 'Arboreum' and 'Obtusifolium into groups. Character 10 (C10) was the presence of single long soft hair on the stem, C11 was the presence of short stellate hairs, and C20 was ratio between diameter and length of the fruit. However, character 6 (length:width lobes) was significant to separate 'Arboreum' from 'Obtusifolium'.

Four groups were separated clearly. However, the distance between 'Obtusifolium' and 'Arboreum' was not as widely separated as between these two to 'Hirsutum' and 'Barbadense'. 'Hirsutum' and 'Barbadense' were separated distincly from each other as well as from 'Arboreum-Obtusifolium' to 'Hirsutum' or 'Barbadense'. The gap between taxa indicates the differences among them, the larger the gap is the more different their morphological appearance. Therefore, 'Hirsutum' and 'Barbadense' are two separate groups that can be identify quantitatively instead of intuitively

recognized using few morphological characteristics. Although 'Arboreum' and 'Obtusifolium' were separated clearly, however the distance between them were relatively closer compared to the others. Thus, these two groups could not be identified as two different groups. This finding is supported by the traditional taxonomic delimitation of the four taxa. 'Barbadense' and 'Hirsutum' are two different species *G. barbadense* and *G. hirsutum*, while 'Arboreum' and 'Obtusifolium' comprise the species *G. arboreum* with two varieties, *abroreum* and *obtusifolium*.

Therefore, cluster analysis employing Euclidean distance and UPGMA linkage method and Principal Component Analysis using data set collected were robust in identifying the species of *Gossypium* occurring in Indonesia. Choosing proper morphological characteristics is also important for this method to be able to determine groups. Three species were recognized from these analyses, i.e., *G. barbadense*, *G. hirsutum*, and *G. arboreum* (as var. *arboreum* and var. *obtusifolium*). The taxonomy of the genus *Gossypium* in Indonesia is presented in the following section.

Taxonomic treatment of *Gossypium* from Indonesia

Three species were recognized in the morphometric analyses of *Gossypium* in Indonesia. They are *G. barbadense*, *G. hirsutum*, and *G. arboreum*. The recognition of the species is presented as an identification key and the description of each species of *Gossypium* occurring in Indonesia. Two varieties can be recognized under *G. arboreum*. The characters used and their character states (C1-20) are presented in Appendix 1.

Identification Key of species of *Gossypium* from Indonesia

1a. Leaf palmate with 3 lobes and 5 lobes occasionally (C4) …… ……*G. hirsutum*

1b. Leaf palmate with 5 lobes and 3 lobes occasionally (C4) ……..... 2

2a. Tips of leaf lobes tapering (C5); size of corolla large, 56-78mm long (C12); staminal column 38-80mm long (C18), short stellate absence (C11) and long soft simple hairs (C10 ……...*G. barbadense*

2b. Tips of leaf lobes obtuse (C5); size of corolla medium, 24-41mm long, stamina column 8-19mm long (C18), short stellate (C11) and longsoft simple Hairs (10 ……..… *G. arboreum*

Gossypium Linn., Sp. Pl. 693. 1753 & Gen. Pl. ed. V. 309 1754; Benth. & Hook. f.; Gen. Pl. 1: 209. 1862; Schumann, in Engler and Prantl, Nat. Pflanzenfam. 3, 6: 51. 1890, Hutch., Gen. Fl. Pl. 2: 548. 1967; Fryxell, Rheedea 2(2): 108-165. 1992.

Type species: *Gossypium arboreum* Linn.

Shrubs, perennial shrubs, occasionally trees, almost all parts of the plant filled with black oil glands. Leaf blades palmate and lobulate, sometimes leaf margin entire with 3-5 veins. Flowers solitary, grown on the axillary sympodial inflorescences. Pedicel without nodes, nectary glands at the base of the epicalyx. Epicalyx 3, distinct and fused at the base, usually broadly cordate, entire, or terrate to deeply terrate. Calyx bowl shapes at the base. Corolla yellow. Staminal column is shorter than corolla, antheriferous throughout. Style single with 3-5 decurrent stigmatic lobes with 2 ovules slightly exceeds the stamina column. Capsule rounded to ovate, occasionally fusiformis to lanceolate, 3-5 loculed. Seeds ovate covered with densely hairy.

Gossypium barbadense Linn. Sp. Pl.2: 693. 1753.

Annual shrub or perennial, sometimes small tree. Branches are full of black spots. Leaves ovate to round, with 54-110mm length and 47-138mm width, palmate to lobed, 3-5 lobes, 11-70mm length and 7-48mm width; the tip of the lobes widely acute closed to obtuse; midribs 3-5, short stellate hairs; petiole 30-120mm. Bract linear to lanceolate, often falcate (sickle form), acute, 15-

38mm length and 2-30mm width. Pedicel is shorter than petiole, 12-27mm length. Epicalyx enclosed corolla and capsule, occasionally open, free at the based, cordate and tapering at the tip. Calyx campanulate, 7-13mm height. Corolla light yellow; petals obovate, 56-80mm long. Staminal column 38-80mm long. Capsule shortly ovate to rounded, with 24-60mm long and 15-26mm in diameter. Seeds 5-8 celled, ovate to rounded, 9-13mm long, 4-6mm in diameter, seed hairs white.

Specimen examined: Beguin 474, Sumatra: Afdeeling (district), Bengkalis, Selat Panjang. Lorzing, J.A. 12070, 23 Sept 1927, Sumatra: Sibolangit and surrounding (BO 0111699); Jaheri 330 (BO 0056603); Leg. Ign. sn., Culta in Hort. Bog. XV.J.B.XVII.3a (BO00117214, 00117215); Leg. Ign. sn., culta in Hort. Bog. XV. J. (AX), 7a (BO 1275309, 1275310); Leg. Ign. sn., culta in Hort. Bog. (BO 1404272, 1404273, 1404274).

Notes: Leaf palmate with the tips of the leaf lobes acute, size of corolla large, staminal column 38-80mm long. The significant difference between *G. barbadense* and *G. hirsutum* is in the shape of the tip leaf lobes.

Gossypium hirsutum Linn. Sp. Pl. 2: 975. 1763.

Annual shrub or perennial, 1-3m. Stem erect, stellate and long single hairs, and occasionally glabrous. Leaves ovate to round, with 41-98mm length and 43-105mm width, palmate to lobed, 3-5 lobes, 7-33mm length and 6-39mm width; short stellate hairs; the tip of the lobes widely acute closed to obtuse; midribs 3-5, short stellate hairs with simple long hairs; petiole 12-60mm. Bract ovate to lanceolate, 8-15mm length and 2-4mm width. Pedicel 5-30mm length. Epicalyx free, enclose partly corolla and capsule, cordate and tapering at the tip. Calyx campanulate, 6 -10mm height. Corolla yellow to white, juvenile flowers occasionally purple, rarely with purple spot at the center; petals obovate, 32-62mm long. Staminal column 18-32mm long. Capsule shortly ovate to rounded, with 20-33mm long and 10-15mm in diameter. Seeds 3-5 celled, ovate to rounded, 7-8mm long, 4-5mm in diameter, seed hairs white.

Specimen examined: Heyne 9. Cult. Hort. Museum Tuin BO (pertinent ad 0056679-0056681 or BO 56681 or BO1404271). Leg. Ign. sn. Sumatra: Muara Enim (BO 0056688, 0056689); Leg. Ign. sn., Maumere (BO 0056768); Leg Ign sn. Cultivated in Hort. Bot. Garden KV. KB. XXXIV.12 (BO-0111701).

Note: Leaf palmate with 3 lobes and 5 lobes occasionally. Leaf palmate with the tips of the leaf lobes shortly acute. The significant difference between *G. hirsutum* and *G. barbadense* is in the tips of the leaf lobes and the common number of leaf lobes. Staminal column of this species is much shorter than *G. barbadense*.

Gossypium arboreum Linn. Sp. Pl. 2: 693. 1753. Wight, Icon. Pl. Ind. Or. 1: t. 198. 1838; Mast. In Hook.f., Fl. Brit. India 1: 347. 1874; Hutch. & Ghose, Ind. J. Agri. Sc. 7: 233. 1937; Borss., Blumea 14: 12 1966; Abedin in Nasir & Ali (eds.), Fl. W. Pakistan 130: 30. 1979; Rao, Fl. Goa, Diu, Daman, Dadra & Nagarhaveli 1: 34. 1985; Paul & Nayar in Nayar et al. (eds), Fasc. Fl. India 19: 112. 1988; Fryxell, Rheedea 2(2): 146. 1992; Paul in Sharma & Sanjappa (eds.), Fl. India 3: 387. 1993.

Identification key of the varieties of *Gossypium arboreum* from Indonesia

1a. Leaf palmate with with ovate leaf lobes (C3), ratio between length and width of leaf lobes is between 0.8-0.95 (C6) ..... *var. obtusifolium*

1b. Leaf palmate with lanceolate leaf lobes (C3), ratio between length and width of leaf lobes is between 1.75-3.59 (C6)..... *var. arboreum* *Gossypium arboreum* var. *arboreum*

Annual shrub or perennial, 1-2m. Stem slim and erect, stellate and long single hairs, and occasionally glabrous. Leaves ovate to round, with 20-82mm length and 24-87mm width, palmate to

lobed, 3-5 lobes; 3-25mm length and 40-70mm width; the tip of the lobes widely acute, 9-54mm long, 3-16mm width; midribs 3-5, short stellate hairs with simple long hairs; Petiole 11-65mm. Bract linear to lanceolate, often falcate (sickle form), acute, 5-23mm length and 1-28mm width. Pedicel short, 18-25mm length. Epicalyx enclosed corolla and capsule, occasionally open, fused at the base, cordate and tapering at the tip. Calyx campanulate, 5-8mm height. Corolla yellow, occasionally purple with spotted purple in the centre, all red, or all purple; petals obovate, 25-45mm long. Staminal column 18-28mm long. Capsule shortly ovate to rounded, with 23-30mm long and 12-16mm in diameter. Seeds 5-8 celled, ovate to rounded, 6-9mm long, 4-6mm in diameter, seed hairs white.

Specimen examined: Heyne 4, Java, cultivated in Hort. Museum Tuin (BO 0056633, 0056634); Van Leeuwn, Dr. 4763, 7 Oct 1920, Kampung Bangkok (BO 57086 or BO 1424353); Leg. Ign. sn, 1 Oct 1952 (BO 0056631, 0056632); Leg Ign sn. 29 Sept 1925, cultivated at Bogor Bot. Garden, XV. KB. XXXVII.8 (B01758361 or BO111687).

Note: Leaf palmate with lanceolate leaf lobes and the tips of the leaf lobes acute, indumentum of short stellate and single long soft hairs, epicalyx is fused at the base. The significant difference between var. *arboreum* and var. *obtusifolium* is in the tips of the leaf lobes.

Gossypium arboreum var. *obtusifolium*

Annual shrub or perennial, 1-2m. Stem erect, stellate and long single hairs, and occasionally glabrous. Leaves ovate to round, with 30-58mm length and 40-70mm width, palmate to lobed, 3-5 lobes, 3-25mm length and 40-70mm width; the tip of the lobes widely acute closed to obtuse; midribs 3-5, short stellate hairs with simple long hairs; petiole 12-60mm. Bract linear to lanceolate, often falcate (sickle form), acute, 5-17mm length and 1-10mm width. Pedicel short, 6.5-12mm length. Epicalyx enclosed corolla and capsule, occasionally open, fused at the base, cordate and tapering at the tip. Calyx campanulate, 5-7mm height. Corolla yellow, occasionally purple with spotted purple in the centre, all red, or all purple; petals obovate, 20-40mm long. Staminal column 19-25mm long. Capsule shortly ovate to rounded, with 13-32mm long and 10-23mm in diameter. Seeds 5-8 celled, ovate to rounded, 5-11mm long, 3-7mm in diameter, seed hairs white.

Specimen examined: Leg. ign sn., Sumatra: Muara Enim (BO 0056739, 00567342¸ 00567343, 0056744); Leg. ign. sn., Sumatra: Muara Enim (BO 0056740, 0056741). Backer, C.A. 16881, Java: Cirebon (BO 1424359, 1424360); Leg ign sn., Sumatra: Muara Enim (BO 56739,42, 43, 44 or BO 1832529, 30, 31, 32).

Note: Leaf palmate with the tip of the leaf lobes obtuse, indumentum of short stellate and single long soft hairs, epicalyx is fused at the base. The difference between *G. arboreum* var. *arboreum* and *G. arboreum* var. *obtusifolium* is the tip shape of the leaf lobes.

CONCLUSION

Three species of *Gossypium* were recognized from phenetic analyses employing cluster analysis and ordination. Those are *G. arboreum, G. barbadense*, and *G. hirsutum*. Within *G. arboreum*, the two varieties *arboreum* and *obtusifolium,* were also identified from these analyses. Phenetic analyses are a powerful tool to delimit the species boundary of *Gossypium* species from Indonesia.

ACKNOWLEDGEMENT

The Author would like to thank Dr. Irawati for her support this project at the Herbarium Bogoriense, Botany Division, Research Centre for Biology. A thank you goes to Dr. Endang Tri

Margawati for her inputs in the scientific writing and Mr. Lyn Craven (CANB) for his comments to the manuscript.

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Appendix 1. Morphological characteristics used in the morphometric analysis of the species of *Gossypium* collected from Indonesia.

Vegetative characteristics of Leaves

C1). Leaf Margin
Palmate : 0 Lobed : 1
C2). Leaf length: Leaf width
C3). The lobes shape of leaf blade
Ovate : 0
Widely ovate : 1
Lanceolate : 2
C4). Number of lobes of leaf blade
5 occasionally 3 : 0
3 occasionally 5 : 1
C5). Lleaf lobes apex
Widely acute : 0
Shortly acute : 1
Tapering : 2
C6). Lobe length : Lobe width
C7). Number of leaf nerves of mature leaves
C8). Petiole length

Hair types

C9). Long soft simple hairs on leaf surface
Absent : 0 Present : 1
C10). Long soft hairs on stem surface
Absent : 0 Present : 1
C11). Soft stellate hairs on stem surface
Absent : 0 Present : 1

Generative morphological characteristics

Flowers

C12). Corolla length (mm)
C13). Calyx length (mm)
C14). Epicalyx shape
Dentate : 0
Sharply dentate : 1
C15). Epicalyx length : Epicalyx width
C16). Epicalyx
Fused at bottom : 0
Free at bottom : 1
C17). Pedicel length (mm)
C18). length of staminal column (mm)

Fruit

C19). Fruit length : Fruit diameter
C20). Fruit diameter : fruit length

Appendix 2. The complete data set of *Gossypium* species collected from Indonesia.

Characters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
'Barbadense'																				
BO-1275309-10	0	0.66577	2	0	2	1.1	5	84.3	0	0	0	77.5	10	1	1.2	1	22	80	1.61	?
BO-117214-15	0	0.84963	2	0	2	1.24	5	43	0	0	0	69	7	1	1.17	1	22.5	48	2.58	?
Jaheri 330 (BO-56603-04)	0	0.64415	2	0	2	1.33	5	62.8	0	0	0	56	8	1	1.15	1	31	38	1.92	0.44
Beguin 474	0	0.5692	2	0	2	1.72	5	57.3	0	0	0	64	9	1	1.43	1	20	50	2.21	0.46
J.A. Lorzing 12070 (BO-111699)	0	0.82945	2	0	2	1.58	5	55.3	0	0	0	66.33	8	1	1.3	1	16	52	2.6	0.5
BO-1404272, 73, 74	0	0.93408	2	0	2	1.295	5	41.3	0	0	0	69.5	13	1	1.63	1	16	48	1.6	0.48
Hirsutum																				
XV KB XXXIV 12	1	112.664	1	1	1	0.95	3	41.3	0	0	1	48	7	1	1.23	1	10	28	2.20	0.56
BO-56768	1	0.82819	1	1	1	0.8	4.5	44.75	0	0	1	38	6	1	1.36	1	11	18	2.08	0.52
BO-56679	1	0.69903	1	1	1	0.69	4.8	69.4	0	0	1	45.33	10	1	1.47	1	14	23	3.3	0.5
BO-56688, 89	1	0.98462	1	1	1	0.77	5	79.14	0	0	1	54.33	10	1	1.48	1	15.67	28.5	1.78	0.54
Obtusifolium																				
BO-56740-41	0	0.90291	0	0	0	0.8	5	38.5	1	1	1	31.33	5	0	1.43	0	8	25	2	0.69
BO-56739, 42, 43, 44	0	101.778	0	0	0	0.9	4.6	39.4	1	1	1	40.25	5	0	1.15	0	17.75	24.6	2	0.62
BO-56714, 15, 16	0	0.76014	0	0	0	0.89	4.2	22.8	1	1	1	39	5.5	0	1.37	0	19	25	2	0.71
Backer 16881	0	0.79365	0	0	0	0.95	4.5	47.25	1	1	1	37	8	0	1.23	0	13	18	1.88	0.69
Arboreum																				
Dr. Van Leeuwen 4763	0	0.80203	2	0	0	1.75	4.5	35.25	1	1	1	41	5	0	1.5	0	12	25	1.58	0.6
BO-56631, 32	0	0.88659	2	0	0	2.5	5	28.67	1	1	1	30.67	7	0	1.3	0	6.5	19.8	1.71	0.57
Heyne 4	0	0.90551	2	0	0	2.19	4.5	40.75	1	1	1	24	5	0	1.48	0	9.3	20	1.36	0.61
XV KB XXXVII.8	0	0.88889	2	0	0	3.59	4	14.25	1	1	1	34.33	5	0	1.53	0	10	24	1.95	0.7

Appendix 3. Exicata lists of specimens used

arb: *Gossypium arboreum* var. *arboreum*, obt: *Gossypium arboreum* var. *obtusifolium*, bar: *Gossypium barbadense*, hir: *Gossypium hirsutum*

Aet & Idjan 589 (BO 1763840, 1763841): bar; *Afriastini, J.J. 1591* (BO1763873): hir; *Anang 200* (BO 1758387): bar.

Backer, C.A. sn (BO1423355, 1423356): arb, *917* (BO1832503, 1832504): obt, *2662* (BO1832508): obt, *15319* (BO1832509): obt, *15268* (BO1763860): hir, *15343* (BO1832534, 1832535): hir; *16881* (BO1424359, 1424360): obt, *17687* (BO1763851): hir, *20068* (BO1819488, 1819489): obt, *22418* (BO1763820): bar, *27286* (BO1763855): hir, *28584* (BO1763856, 1763857): hir, *27286* (BO1763856, 1763857): hir, *28584* (BO1763856, 1763857): hir, *35321* (BO1763819): bar, *35322* (BO 1758399): bar; *Beguin sn* (BO1832541): bar; *Binnendjk sn* (BO1404269): hir; *Bloembergen 3883* (BO1758359, 1758366): obt; *Boorsma* sn (BO 1763827): bar; *Botanische Sammlung 3285* (BO1758374): bar; *Bundle 336* (BO 1763839): bar; *Bünnemeijer, H.A.B. 10726* (BO1832520): bar, *11377* (BO1832519): bar; *Buwalda, P. 5535* (BO1758390): bar.

Cramer 141 (BO1832567): bar.

Dommers 3 (BO-): bar.

Egawa, S. no c (BO1404263): bar; *Elbert, J. 2906* (BO1758364): obt, *3365* (BO1763853): hir; *4295* (BO 1758365): obt.

Galoengi 503 (BO1763845): bar; *Gusdorf, H.A. sn* (BO1763822, 1763823): bar.

Halher D424 (BO1424365): obt; *Hassjark sn* (BO 1758345): obt; *Herbarium Koordersianum 197* (BO56618): bar; *Heyne 1* (BO1832511): hir; *3* (BO 1758355): obt, *4* (BO 1758340, 1758341): arb, *5* (BO1427919, 1758394): bar; *7* (BO1832523): obt, *8* (BO 1424364): obt, *9* (BO1404270, 1404271): hir, *11* (BO1763863, 1763864, 1763865): hir; *12* (BO1404283, 1404284, 1404285): bar; *16* (BO 1758350): obt, *17* (BO 1832524, 1758351, 1758352): obt, *sn* (BO1758353): obt, *sn* (BO1758354): obt, *sn* (BO1833307): bar; *Hidayat, A. 258* (BO00119746): hir; *Horst 8* (BO1832544): obt; *Huijsmans 83* (BO1763882): hir; *Hulstya, L. sn* (BO1758386): bar.

Iboet 214 (BO1832510): obt.

Jaheri 37 (BO1424351, 1424352): bar, *330* (BO1763807, 1763808): bar.

Kessler, P.K. 1293 (BO0018641): bar; *Koorders, S.H. 35121ß* : bar, *35655ß* (BO1832507): obt, *35831ß* (BO 1404264): bar.

Laudboun consulent sn (BO1832548, 1832549): obt, *sn* (BO1833306, 1832501, 1833312, 1832550, 1832551, 1832505): obt; *Leeuwen 1360* (BO 1832522): obt; *Letti 475b* (BO 1758346, 1758347): obt; *Lörzing, J.A. 1795* (BO1763838): bar, *12070* (BO1763821): bar, *16968* (BO1758357): obt.

Main 566 (BO1763836): bar; *Musset 228* (BO1758392, 1758393): bar.

Nedi 158 (BO 1758391): bar; *Noerkas 390* (BO 1758334, 1758348, 1758343, 1758342): obt.

Raap, H. 477 (BO1758397): bar; *Rachmat 363* (BO 1758349): obt, *126* (BO1832542, 1832543): hir, *777* (BO1832521): obt, *sn* (BO1763870, 1763871, 1763872): hir; *Robinson, C.B. 494* (BO 1758385): bar.

Saakov 86 (BO1763880): hir; *Scheffer 16* (BO1763862): hir.

Teysmann 5187 (BO1832502): obt, *sn* (BO1758360): obt, *sn* (BO1763825): bar, *sn* (BO1404282): hir, *sn* (BO1763876, 1763877, 1763878): hir; *Treub 475* (BO1760710, 1760707): obt.

Udjoeus, C. 437 (BO1427918): hir.

Van Borssum Waalkes 1710 (BO1763848, 1763849, 1763850): bar, *2558* (BO1763847): bar, 3202 (BO1758377): obt, *3126* (BO1758376): obt, *3119* (BO1763869): hir, *3211* (BO1832515): hir; *Van Steenis, C.G.G. J. 1783* (BO 1758398): bar.

Winckel, W.F. sn (BO1758373): bar.