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The Biology And Molecular Studies Of Ceiba Pentandra (L.) Gaertn.: A Review

Fadilla Hefzi* and Mansyurdin

Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Andalas. Jl. Univ Andalas, Kampus Limau Manis, Padang 25163, West Sumatra, Indonesia

*Corresponding author: fadilahefzi@gmail.com

Abstract – Ceiba pentandra (L.) Gaertn. of the family Malvaceae is an essential multi-purpose tree known as kapok or silk-cotton. The characteristics, taxonomy, distribution, reproductive biology, and molecular studies of C. pentandra are updated in this review. Biological and molecular studies can be used to help the description, identification, and conservation of this species. Google Scholar and PubMed were used to gather information for this review. The selection of articles in the literature was based more on topics than on the coverage period, although higher priority was accorded to more recent references. Further research on the molecular and genetic structure of C. pentandra in several other areas was suggested.

Keywords – kapok, Malvaceae, mixed-mating system, silk-cotton

I. INTRODUCTION

Ceiba pentandra (L.) Gaertn. of the family Malvaceae, commonly called the kapok or silk tree, has the most extensive distribution in South and Central America, the Caribbean, and West Africa [1, 2]. The wood is used to make coffins, dugout canoes, drums, plywood, household items, and drums [3, 4]. The fiber, commonly called kapok, is used for stuffing cushions, pillows, and mattresses. It is also used as an insulation material, an absorbent material, and a tinder. The gum is eaten to relieve stomach upset, whereas the leaves and fruits are used as a laxative, and an infusion from the leaf is used for colic treatment in both men and livestock [4]. Because of its myriad uses, kapok has been recommended frequently for agroforestry projects in rural areas [5]

Biological *characteristics*, such as morphological characteristics, are the fundamental characteristics used to help the description and identification of plants in the taxonomy field [6]. This character still has limitations and tends to be subjective. Therefore, molecular studies are required to support plant species identification [7]. Furthermore, molecular information has implications for the management of the genetic resources of *C. pentandra,* and management of the species has a high risk on its sustainable utilization and conservation [8].

Previous reviews have reported the biology and industrial potentials of *C. pentandra* [9, 10]. In this review, we concentrate on biological and molecular studies of *C. pentandra,* as well as future studies that will provide comprehensive data that may be useful for identifying and conserving this species.

II. RESEARCH METHODS

This study used Systematic Literature Review (SLR) method. SLR have strict requirements for search strategy and selecting articles for inclusion in the review [11]. Sources for this review from Google Scholar and PubMed. The literature articles were selected based on their relevance to the review topics. More recent references were given a higher priority. This review discusses the characteristics, *taxonomy*, distribution, reproductive biology, and molecular studies of *C. pentandra*.

III. Results And Discussion

Characteristics

C. pentandra is an emergent tropical forest tree species that grow fast and can reach a height of 15-60 m [12]. The tree has grayish bark that may or may not have protruding large spines. Older trees produce buttress roots from the trunk [13]. Main branches are arranged verticillate, spreading horizontally, commonly in threes, to form a crown with a pagoda-like shape. The leaves are palmately compound, or digitate, with a long petiole, each bearing 5-8 leaflets that are lanceolate, acuminate, and have a slightly serrated margin. Flowers are bisexual, creamy white, 5-merous, clustered on the branchlets, and have a milky fragrance. Fruits are pendulous, elongated capsules borne in clusters, many-seeded, green when young, and brown when fully matured. Seeds are almost globose, 4–6 mm in diameter, glabrous, dark brown or black, and embedded in copious white or grayish fibers (Fig. 1) [14]

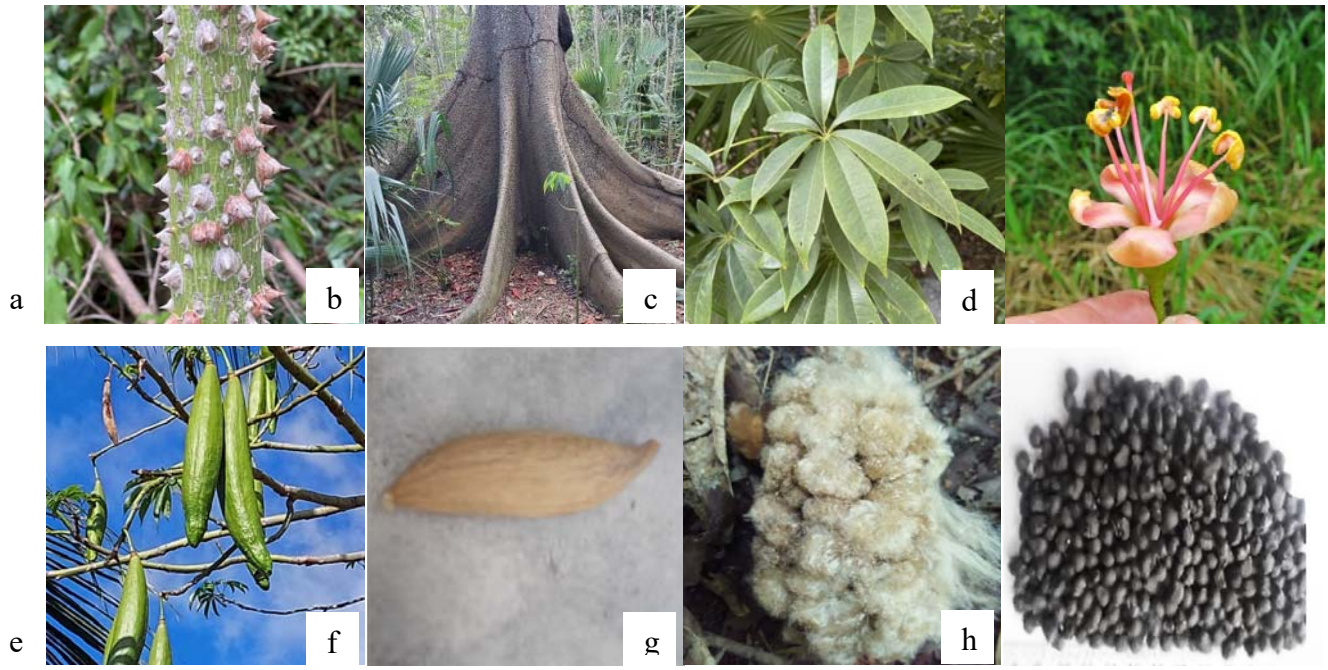

Fig. 1. Morphological character of *C. pentandra*, (a) trunk, (b) buttresses, (c) leaves, (d) flower, (e) young fruit, (f) ripe fruit, (g) fiber/kapok, (h) seeds

Taxonomy

The kapok tree *belongs* to the family Adansoniae of the Bombacaceae. In 1524, Oviedo stated its Caribbean name, *Ceyba* or *Seyba*, and Miller adopted this vernacular name as a generic name in 1739. Linnaeus gave it the name *Bombax pentandrum* when he was studying indica-material. The name is based on an illustration published in Rheede tot Draakenstein's Horti Malabarici [15]. In 1971, Gaertner division of the genus Bombax into *Bombax* and *Ceiba*, which accounts for the current botanical name *Ceiba pentandra* (L.) Gaertn. [16].

C. pentandra is one of nine species in the genus Ceiba, family Malvaceae subfamily Bombacoideae, which contains two Palaeotropical genera, *Adansonia* and Bombax, and seven Neotropical genera [1]. The species *C. pentandra* has at least four varieties: var. caribaea (DC.) Bakh., var. guineensis (Schumach. & Thonn.) H. G. Baker, var. pentandra, and var. indica Bakhuisen, which are morphologically only slightly different. Although slight morphological differences between these varieties have been reported [17], there have been no specific studies for the precise identification of these varieties in previous studies on the species.

Distribution

C. pentandra is a native species of tropical America and Asia's natural forests [18]. This species is also known as an endemic tree in the dry seasonally tropical forests of the Neotropics comprising Central America, Caribbean, and South America

[19]. Nowadays, *C. pentandra* have been introduced worlwide such as Indonesia, Malaysia, Central and South America, Mexico, Carribean, and West Africa (Fig. 2) [20]

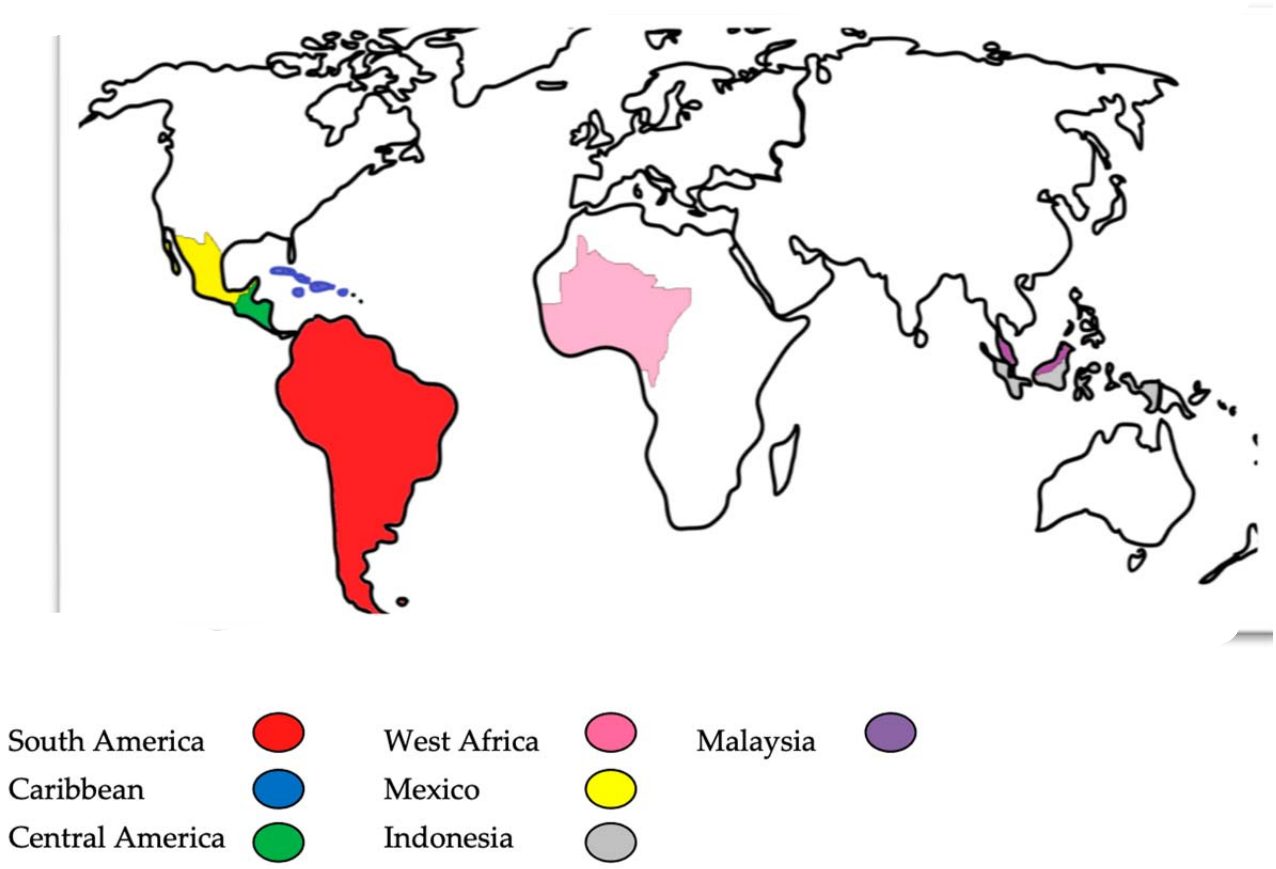

Fig. 2. Worldwide location of *C. pentandra*

Reproductive Biology

Several studies show that *C. pentandra* has a mixed mating system, with high rates of selfing in some populations [21, 22, 23]. Mixed mating is a mechanism where selfed and outcrossed seeds are present within populations or individuals of the same species [2]. When outcrossing rate of a species, or some of its populations is between $0.2 < tm < 0.8$, the species is considered to engage in mixed mating [24]. Selfing rates in mixed-mating species may be influenced by a variety of ecological factors, including population density, pollinator abundance, and pollinator efficiency [25]. On the other hand, outcrossing rates are related to limited outcross pollen availability due to changes in population density [26, 27], reduced pollinator activity [22], or effects of fragmentation [28].

The annual *reproductive* phenology of *C. pentandra* is irregular, with yearly variations in the frequency of flowering and fruiting, leading to high interindividual variation in the frequency of reproduction and reproductive success [12, 29, 30]. In Central America and Mexico, the annual reproductive season occurs in the dry season (January–April) and is highly synchronized within and among populations [29]. In Costa Rica, flowering occurs in January–February, and fruiting occurs from February–April [31].

Bats are the main pollinator of *C. pentandra* [32, 22]. Besides bats, in the Brazilian Amazon, insects also visit the flowers of *C. pentandra* both at night (moths) and during the day (bees and wasps) [12]. In Samoa, *C. pentandra* is pollinated by *Pteropus tonganus* [31]. In Guanacaste, *C. pentandra* received more visits by *Phyllotomus discolor* than *Glossophaga soricina* [32]. In India, three pteropodid bats *Cynopterus sphinx, Pteropus giganteus*, and *Rousettus leschenaulti* have been reported to be

pollinators *of C. pentandra* [33, 23]. Bats were more effective than other pollinators, such as insects, at pollinating the flowers of *C. pentandra* [23].

Molecular Studies

During the last 20 years, there have been significant advances in the study of molecular plants. The full chloroplast and mitochondrial *genome* sequences and the genome of *Bombax ceiba* L. were published in 2018. Using these genomes, phylogenetic analysis showed that *B. ceiba* has a close relationship with the genus *Gossypium* [34, 35, 36]. The genomic data of 13 Malvaceae species was released in the database MaGenDB in 2020. This database may be helpful for comparing the genomes of different Malvaceae species [37].

Genetic information and molecular studies for *C. pentandra* are still limited. In 2003, microsatellite markers for *C. pentandra* were developed to study refined questions of mating systems, gene flow, family structure, and populations dynamics in the Brazilian Amazon [38]. In 2016, RAPD and ISSR markers were used to reveal the genetic relationship among the 36 genotypes of *C. pentandra* in Ghana. Therefore, the findings of this study are recommendable to all forestry stakeholders, especially those using *C. pentandra* as a major species in their plantation development [8]. In 2018, a study on the genetic diversity of *C. pentandra* in the Colombian seasonally dry tropical forest showed that most of the 12 locations studied had heterozygosity scores close to Hardy-Weinberg expectations. Based on this finding, the priority areas for the in-situ conservation of *C. pentandra* in the Colombian SDTF were identified [39].

Several *studies* have been conducted on the genetic bases regulating cotton fiber development [40]. The two transcription factor genes GhMML3 and GhMML4 from the MYB family have been identified as master regulators of cotton fiber initiation. *Theobroma cacao* L., *Durio zibethinus* Rumph. ex Murray and *Bombax ceiba* have all been shown to have these genes, which according to the evolutionary analysis of this gene family, are clustered in two Malvaceae-specific clades [41].

IV. Conclusion

C. pentandra (kapok) is a multipurpose tree planted in agroforestry and afforestation projects. Biological studies of *C. pentandra*, such as morphological character, *taxonomy*, reproductive biology, and molecular studies, were valuable tools to help describe, identify, conserve, and genetic resource information. The genetic information of *C. pentandra* is still limited. Therefore, more molecular and genetic studies in some areas were suggested.

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