Phylogeny of kemenyan (Styrax sp.) from North Sumatra based on morphological characters

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Abstract. Kemenyan is the most famous local tree species from North Sumatra. Kemenyan is known as rosin producer that very valuable for pharmaceutical, cosmetic, food preservatives and vernis. Based on its history, there were only two species of kemenyan those were kemenyan durame and toba, but in its the natural distribution we also found others species showing different characteristics with previously known ones. The objectives of this research will be: The objectives of this research were: (1). To determine the morphological diversity of kemenyan in North Sumatra and (2). To determine phylogeny clustering based on the morphological characters. Data was collected from direct observation and morphological characterization, based on purposive sampling technique to those samples trees at Pakpak Bharat, North Sumatra. Morphological characters were examined using descriptive analysis, phenotypic variability using standard deviation, and cluster analysis. The result showed that there was a difference between 4 species kemenyan (batak, minyak, durame and toba) according to 75 observed characters including flower, fruits, leaf, stem, bark, crown type, wood and the resin. Analysis and both quantitative and qualitative characters kemenyan clustered into two groups. In which, kemenyan toba separated with other clusters.

1. Introduction

Styrax is a genus of about 130 species of large shrubs or small trees in the family Styracaceae. The genus of Styrax known as benzoin rosin producer in the world and widespread but disjunctive distribution occurring in the Americas, eastern Asia, and the Mediterranean region [1]. However, different species of Styrax could also be found in some South East Asia countries such as Indonesia, Laos, Vietnam and Thailand. The province of North Sumatra was reported as the largest distribution site of kemenyan in Indonesia [2]. Although some experts suggest that these species are also found in South Sumatra and Papua, the accurate study about its existence has not yet been done.

The production of kemenyan in North Sumatra was 4,460 tons every year [3], which distributed to 5 districts: North Tapanuli, Humbang Hasundutan, Pakpak Bharat, Toba Samosir, and South Tapanuli. The existence of these species is important for forest communities in North Sumatra because it contributes 70-80% of farmers’ income.

The information about kemenyan species in Indonesia has not been determined yet, especially in North Sumatra. Previous research conducted by Jayusman [4] found two species that distributed in North Sumatra, i.e. kemenyan toba (Styrax sumatrana J.J.SM) and kemenyan durame (Styrax
Kemenyan bulu (Styrax parallele neurum) is also found in North Sumatra, but this species is rarely cultivated and has still not widely known until now. This species was referred by Steenis [5] as S. benzoin var hiliferum. In North Tapanuli farmer also found different species assumed as kemenyan dairi [6]. In Pakpak Bharat, based on farmer information there were kemenyan toba, kemenyan durame, kemenyan minyak and kemenyan batak, but there is no recent information about the species. Unclear information and community preference to cultivate only certain species (toba and durame) were the triggers to potential loss of species. The cultivation preference was chosen based on abundance of certain natural regeneration and limited knowledge of other species [7]. Comprehensive knowledge and database about kemenyan species could be a baseline in breeding activities in order to obtain superior characters and give easier guidance for farmer identification. The knowledge could also prevent species extinction due to species preferences. Therefore, we suggest specific study to differentiate the kemenyan species, particularly in North Sumatra.

Species identification of kemenyan could be done by morphological characterization. Morphological characterization played important role in systematic biology because despite of many approaches used to compile the classification system, all was originated from morphological characterization [8]. Morphological characterization was one activity to avoid gene erosion and also as a guide in the empowerment of genetic resources in plant breeding programs [9]. Therefore study about morphological diversity and phylogenetic of kemenyan species is needed to obtain precise information on the identity and species clustering in North Sumatra.

2. Materials dan Methods

2.1. Materials

Direct observation method using generative and vegetative morphological characterization measurements were used in this research. The vegetative character observation and measurement were done to habitus, stem, canopy, and leaf. The generative character observation was done to flower, petal, flower crown, fruit, and seed. We also observed the rosin character. The research was conducted at Pakpak Bharat district on North Sumatra due to the fact it has the largest local kemenyan species varieties compared to other districts.

The species studied were kemenyan batak, kemenyan durame, kemenyan bunga and kemenyan minyak. Identification and determination referred to Steenis [5] and Tjiorsoepomo [10]. The tools used for observation were a magnifier, razor blade, tweezers, knife, plant scissor, plastic bag, stationary, ruler, stereo microscope, petri dish and a book titled Munsell Colour for Plant Tissue for color identification.

2.2. Methods

Living plant specimens were taken both for generative (flowers, fruits, and seeds) and vegetative (roots, stems, leaves) organs. Direct observation and measurement were conducted into detailed specific part of the specimen. The quantitative and qualitative data of morphological characters observed were transformed into binary score data and formed into data matrix using Microsoft Excel program. The data matrix was used to analyze sample clustering based on SAHN (Sequential Agglomerative Hierarchical and Nested Clustering) using UPGMA (Unweighted Pair Group Method Using Average) method with NTSYS PC program to obtain phylogenetic dendrogram. The results were compared descriptively.

3. Results and Discussion

3.1. Morphological Characters

Similar observation to leaf, stem, flower, fruit, seed and rosin characters showed morphological differences of all four kemenyan species. The morphological observation result of rosin, generative and vegetative part is presented in Table 1.
Kemenyan’s canopy consisted of monopodial branching with orthotropic branching and continuous branch position. All four kemenyan have rounded shaped canopies with variations in size and height, light branching, clear bole 4.5-7.8 cm. The canopy of kemenyan batak tended to be wider (4.4 m) but also the shortest compared to kemenyan minyak, durame and toba. Kemenyan had a

| No | Part         | Characters | Batak    | Minyak   | Durame   | Toba/Bunga |
|----|--------------|------------|----------|----------|----------|------------|
| 1  | Canopy      | a. Canopy shape | rounded  | rounded  | rounded  | rounded    |
|    |              | b. Canopy width | 4.4 m    | 3.10 m   | 3.7 m    | 2.94 m     |
|    |              | c. Canopy height | 11 m     | 24.1 m   | 15.6 m   | 12.6 m     |
| 2  | Leaf        | a. Leaf shape | elliptical | lanceolate | lanceolate | Lanceolate |
|    |              | b. Leaf margin | entire | entire | entire | entire |
|    |              | c. Leaf tip shape | acuminate | acuminate | acuminate | acuminate |
|    |              | d. Leaf base shape | obtuse | obtuse | obtuse | obtuse |
|    |              | e. Leaf area | 47.48 cm | 25.60 cm | 46.28 cm | 22.63 cm |
|    |              | f. Lamina length | 10.7 | 10 | 12.8 cm | acute |
|    |              | g. Number of lamina | 14 | 12 | 16 | 16 |
|    |              | h. Upper surface color | green | dark green6/2.5YG | Green | 4/8.5YG |
|    |              | i. Lower surface color | whitist green | silvery white7/4 | whitist | whitist |
|    |              | j. Leaf arrangement | alternate | alternate | alternate | alternate |
|    |              | k. Venation | pinnate | pinnate | pinnate | pinnate |
|    |              | l. Leaf surface | smooth | smooth | smooth | smooth |
|    |              | m. Leaf composition | simple | simple | simple | simple |
|    |              | n. Leaf bud | naked bud | naked bud | naked bud | naked bud |
| 3  | Stem        | a. Stem shape | cylindrical | cylindrical | cylindrical | cylindrical |
|    |              | b. Outer bark color | reddish yellow | reddish brown | reddish brown | reddish yellow |
|    |              | c. Inner bark color | yellow | yellow | yellow | yellow |
|    |              | d. Bark thickness | 0.6 cm | 0.6 cm | 1 cm | 0.5 cm |
|    |              | e. Wood color | creamy white | creamy white | creamy white | creamy white |
|    |              | f. Clear bole | 4.3 m | 7.7 m | 7.8 m | 7.4 m |
|    |              | g. Diameter | 17.1 cm | 28.7 cm | 50 cm | 16.3 cm |
|    |              | h. Stem character | monopodal | monopodal | monopodal | monopodal |
|    |              | i. Branch construction | orthotropic | orthotropic | orthotropic | orthotropic |
|    |              | j. Branch position | continuous | continuous | continuous | continuous |
| 4  | Flower      | a. Flower position | axillary | axillary | axillary | axillary |
|    |              | b. Number of petal | 4.5 | 4.5 | 4.5 | 4.5 |
|    |              | c. Flower color | white | white | white | white |
|    |              | d. Number of stamen | 10 | 8-10 | 10 | 10 |
|    |              | e. Stalk color | green | Green | Green | Green |
| 5  | Fruit       | a. Fruit shape | flat round | flat round | flat round | oval round |
|    |              | b. Fruit color | deeply green | deeply green | green | green |
|    |              | c. Skin thickness | 0.4 cm | 0.4 cm | 0.4 cm | 0.5 cm |
|    |              | d. Fruit length | 1.9 | 2.6 cm | 3.2 | 2.8 |
|    |              | e. Fruit width | 2.3 | 2.9 cm | 2.4 | 2.5 |
| 6  | Seed        | a. Seed shape | flat round | flat round | flat round | round |
|    |              | b. Length | 1.2 | 1.7 cm | 1.2 cm | 1.6 cm |
|    |              | c. Width | 1.5 | 2 cm | 1.5 cm | 1.5 cm |
|    |              | d. Seed color | brownish yellow | brownish yellow | brownish white | brownish white |
| 7  | Rosin       | a. Rosin color | Creamy white | yellowish white | yellow | Creamy white |
|    |              | b. Rosin scent | scented | resin | aromatic | Aromatic |
|    |              | c. Rosin type | hard | soft/liquid | soft/liquid | Crystal/hard |
cylindrical stem with up to 7.8 meters branch-free bole and monopodial branching. The bark was chapped and grooved; the outer bark was yellow in colour. The colour of inner bark varied from reddish yellow to reddish brown. Bark thickness varied between 0.5-1 cm.

Kemenyan had simple leaf in alternate arrangement, 12-16 pinnate laminas, smooth leaf surface. Kemenyan bunga, minyak and durame had lanceted leaves, but kemenyan batak had ovatus leaves. The leaf had entire margin, acuminate tip and obtuse base. The upper surface was moderate yellow green to deep yellow green. The lower surface colour was varied from silvery white to white. The fruit of kemenyan durame was flat round to oval in shape, hard shell, color from pale green (6/10) to green (8/6). The skin thickness was varied from 0.4 cm-0.5 cm. The diameter was varied from 1.9-3.2 cm. The fruit of kemenyan minyak had the largest size and it tended to have flat round in shape compared to other species. The seed was round to flat round, diameter 1.2-1.7 cm and the color varied from brownish yellow to pitch black. Kemenyan had compound flower. The flower was inflorescence and composed of 5-12 florets. It was axilary flower with 4-5 petals, the color varied from creamy white (9/4 YR) to white (9/6 YR). There were 8-10 stamens and the flower stalk was green (7/4).

Rosin was commonly used by farmers to identify kemenyan types in North Sumatra. The observation of rosin characteristics showed that kemenyan minyak had different color than other types (yellowish white). The rosin of kemenyan minyak was liquid, while kemenyan batak and bunga were hard.

3.2. Phylogeny of kemenyan in North Sumatra
Phylogeny could be used to estimate the degree of similarity between species or population, in contrast to the diversity coefficients which was used to estimate the degree of inter species differences or population on chosen characters. From this relationship, we can conclude that species with far relatedness distance have higher level of diversity and lower level of uniformity. This relatedness in kemenyan species is shown in phylogenetic dendrogram (figure 1).

![Dendrogram kemenyan](image)

Figure 1. Relatedness between kemenyan species

The phylogenetic dendrogram that determined using dissimilarity index according to morphological characters, showed that kemenyan durame and kemenyan minyak were clustered in a small group with genetic distance 0.44, this cluster later joined with kemenyan batak in a larger group and had genetic distance as 0.49. Kemenyan toba was separated from the others and had genetic distance 0.64. We concluded that kemenyan durame and kemenyan minyak had the highest
relatedness level and the largest morphological character uniformity, but lower diversity compared to kemenyan toba and kemenyan minyak.

However, the difference in character determination could result in different dendrogram pattern and classification model due to the difference of concept review and subjectivity between observers, although in general the characters are still similar. The more characters are analyzed, the higher a character’s ability as distinguishing characteristic, then the ability to know relatedness level is more obvious [11]. Therefore, we suggest further study with the help of molecular markers to ensure species identification.

4. Conclusions
Phylogenetic relationship based to morphological characteristics on four types of kemenyan showed that kemenyan minyak, durame and batak formed into a cluster according to kemenyan characteristic similarities of stem, leaf, flower, fruit, seed, canopy and rosin. Kemenyan toba was separated from the others due to its characteristic differences, in particular rosin characteristic, outer and inner bark color, the number of stamens and fruit size.

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