Morphophylogeny of Raru Producing Trees from Central Tapanuli-North Sumatra

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Abstract: Raru is the name for bark that produced by several genus of Dipterocarpaceae such as Cotylelobium, Shorea and Vatica. The raru bark known as important source for traditional medicine of diabetic and mixture of bataknese alkoholic drink called "tuak" for increasing the fermentation rate. The lack of natural regeneration and destructive illegal harvesting for wood and bark, decreased the population every year. Due to this condition, since 1998 this species classified on endangered (EN) based on IUCN Redlist. Previous research showed only one species was found in North Sumatra, but from local community information, there were three local species can be found in Central Tapanuli, those were raru songal, raru dahanon and raru pulut. The objective of our research were (1). To determine the morphological character of local raru species from Central Tapanuli and (2). To determine phylogeny clustering based on morphological characters. Morphological data was collected from direct observation and measurement of on vegetative part of raru trees (stem, canopy, and leaf). Morphological characters were examined using descriptive analysis, phenotypic variability using standard deviation, and cluster analyses. The result showed that there was a difference between three raru species according to 32 observed characters including leaf, stem, bark, crown type, wood and the rosin. Analysis and measurement both quantitative and qualitative characters clustered raru into two groups. In which, raru songal separated with other species.

1 INTRODUCTION

Raru is the name for bark produced by several genera of trees such as Cotylelobium, Shorea and Vatica. Raru is distributed in several locations in Indonesia, but only a few species can be found on the island of Sumatra, especially North Sumatra. Based on research conducted by Pasaribu (2007), raru in North Sumatra was identified as *Cotylelobium melanoxylon*. In North Sumatra, raru is scattered distributed in several locations of natural forests in Central Tapanuli, and Tanah Karo.

For local people in North Sumatra, the existence of raru is related to the production of traditional alcoholic beverages known as "tuak". Local people believe raru as a flavor enhancer for tuak and its bark may increases fermentation rate (Pasaribu & Setyawati, 2011). Besides being used as a mixture of tuak, raru is also used as a traditional medicine for the treatment of diabetes, malaria and stomach (Sorianegeara & Lemmens 1994; Idramsa et al. 2016). The barks of *raru* contain several compounds such as *ampelopsin* F., *isoampelopsin* F, ε-*viniferin*, *vaticanol* A, E, G, and *lyoniresinol* that are useful as antidiabetic medicines (Matsuda et al. 2009).

Although it has big potential as the source for medicinal raw material, the presence of raru in natural forests is also constrained due to low natural regeneration and destructive bark harvesting techniques. Destructive harvesting have been practicing in local people when they usually cut down the trees for tree bark harvesting. The timber considered as a residue and used for construction. The potential threat of raru has also been sounded by IUCN 1998 (Ashton 1998) with endangered status,

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meaning that there is a need for concrete effort to protected this species from extinction.

The results of our survey and interviews with the local community found that traditionally, local community identified three local raru species in the Central Tapanuli natural forest, namely raru dahanon, raru pulut and raru songal. Among them, raru dahanon is more preferred to be harvested by the community because it is believed to have the best quality. Even though there has been ambiguity in species classification and identification, information about the morphological characters of raru is currently still very limited. In other hand, morphological identification is an early taxonomic identification step to obtain basic scientific information for conservation efforts. Moreover, the preference for certain species of raru has caused the population to decline, it is feared that this condition will trigger a decrease in genetic potential. Based on these considerations, this research were conducted to determined the morphological character of local raru species from Central Tapanuli and phylogeny clustering based on morphological characters as a baseline data for further conservation effort of raru species in North Sumatra.

2 MATERIALS AND METHOD

2.1 Study Area

The research was conducted at Central Tapanuli district of North Sumatra (Figure 1). Bona Lumban forest known as one of raru bark producer in North Sumatra. Based on local people information, everyday kilo's of raru bark sold to other district for tuak mixture. Bona Lumban is a village located in Tukka District, Central Tapanuli Regency that covers area of 6,80 km^2 (BPS, 2016). Tapanuli Tengah Regency has the average temperature of 26,4 ^{0}C, with the highest may reach to 32,2 ^{0}C, while its lowest temperature is around 22,4 ^{0}C. The average of relative humidity is 82,50% and rainfall at around 12 mm/year. Forest in Bona Lumban village are located in two type land status, there are Protection Forest (Hutan Lindung/HL) and Area for Other Uses (Area Penggunaan Lain/APL).

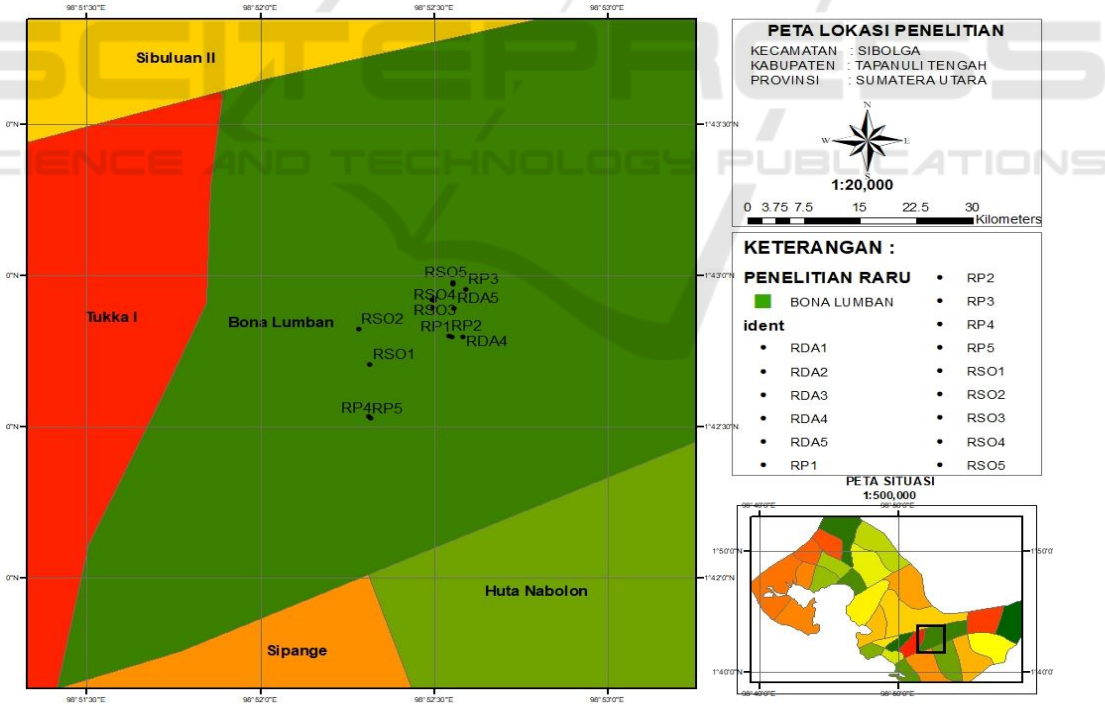


Figure 1: Location of Bona Lumban sub-district, Central Tapanuli district the sampling sites of Raru.

2.2 Procedure

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

canopy, leaves, stems. We also observed the rosin character. The species studied were local raru namely raru pulut, raru songal and raru dahanon. Identification and determination referred to Tjitrosoepomo (1990). The tools used for observation were a magnifier, razor blade, tweezers knife, plant scissor, plastic bag, stationary, ruler and a book titled Munsell Colour for Plant Tissue for color identification.

2.3 Data Analysis

Living plant speciments were taken from vegetative (roots, stems, leaves) organs. Direct observation and measurement were conducted into detailed specific part of the speciment. 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 Hirearchical 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 RESULT AND DISCUSSION

3.1 Morphological Description

The material of morphological identification of this research was originated from vegetative organ due to the limitation of generative organ speciement. Vegetative organ was less considered for taxonomical identification compared to flower character (Cronquist, 1968). But the vegetative speciment also have been used for morphological identification by previous researcher like leaf thickness and midvein morphology and plant habit. In this research, the crown, leaf, stem (vegetative organ) and rosin character were used for differentiate local raru species.

3.1.1 Crown

The tree crown composed by some structural organ, determining the magnitude of light capture (Sterck et al. 2001) and ability to shade the neighboring trees (Lang et al. 2010). The shape of a tree crown depends on the features of stems, namely the angle at which they ramify from the main trunk and their length (Tomlinson et al 2014), as well as the thickness of particular branches and twigs, that is corresponding with stiffness. Crown characteristics develop and change during ontogeny by the structural response of each species to different environments (Valladares and Niinemets 2007)

Raru is a large tree, spreading and evergreen tree. The observation of three local raru leaf shows that there are several characters that have similarities and some characters that can be used as differentiators of raru species (Table 1).

Table 1: Canopy character of raru songal, raru dahanon, and raru pulut.

Character	R.Songal	R. dahanon	R. pulut
a. Canopy shape	Rounded	Rounded	Rounded
b. Canopy width	8.40 m	5.58 m	5.30 m
c. Canopy height	14.60 m	12.80 m	13.40 m

All three of local raru have rounded crown (globase) shape with variations in size and height and light branching. The canopy of raru songal tended to be wider (8.4 m) and also the heighest compared to pulut and dahanon. Large crown up to 10 m in diameter (Figure 2).

3.1.2 Stem

Raru have straight and cylindrical stem with monopodial branching architecture with spreading branches that have orthotropic branching type and continuous stem character. Raru songal was 40.8 m in height with bole brancheless was 26.2 m, higher than raru dahanon and raru pulut (Table 2).

The bark was chapped and rough for raru songal and smooth for the other with the thickness varied between 0.3-0.7 cm. The outer bark of raru dahanon and pulut have have pinkish white color (7.5 YR 8/2) and technically easier for debarking compared to songal, raru songal has a very light shade of brown (7.5 YR 9/2) color and rather difficult for debarked (Figure 3). On the other hand, the inner bark color raru songal has a light shade of orange (7.5 YR 8/4), raru dahanon has medium light shade of orange (7.5 YR 7/6), while raru pulut has medium light shade of brown (7.5 YR 8/6).

Raru songal showed 7.5 YR 8/8 wood color, while raru dahanon and raru pulut has pinkish wood color (7.5 YR 8/4). Interview with local community found out that the wood can be widely used as raw materials for construction, barn or coop building. Concerning its wider used, raru have been known to have good quality timber by local community. Martawijaya *et al.* (1989) stated that raru or giam (*Cotylelobium melanoxylon)* have high wood density

(a) (b) (c)

Figure 2: Canopies of Raru (a) Raru songal, (b) raru dahanon, (c) raru pulut.

class which is varied between 0.83-1.15. Raru timber has also high durability and strengh those can be used for houses, especially for house pole and foundation. According to Muslich (2006) *C. Melanoxylon* 's timber is grouped into class II of hardness category. Information on wood quality of three local raru in North Sumatra still limited, so further research still need to support comprehensive data. But based on morphological feature of wood, raru songal have high similarity with *C. melanoxylon* description according to Pasaribu (2010).

Table 2: Stem characters of raru songal, raru dahanon, and raru pulut.

Character	R. songal	R. dahanon	R. pulut
Stem shape	cylindrical	cylindrical	cylindrical
Outer bark color	7,5 YR 9/2	7,5 YR 8/2	7,5 YR 8/2
Inner bark color	7,5 YR 8/4	7,5 YR 7/6	7,5 YR 8/6
Bark thickness	0.7	0.3	0.3
Branch architecture	monopodial	monopodial	monopodial
Branch structure	orthotropic	orthotropic	orthotropic
Stem character	continuous	continuous	continuous
Bole branchless	26.2	17.7	18.4
Tree height	40.8	30.5	31.8
Diameter (cm)	31.92	18.32	19.7
Wood color	7.5 YR 8/8	7.5 YR 8/4	7.5 YR 8/4
Bark rough	rough	smooth	smooth

3.1.3 Leaves

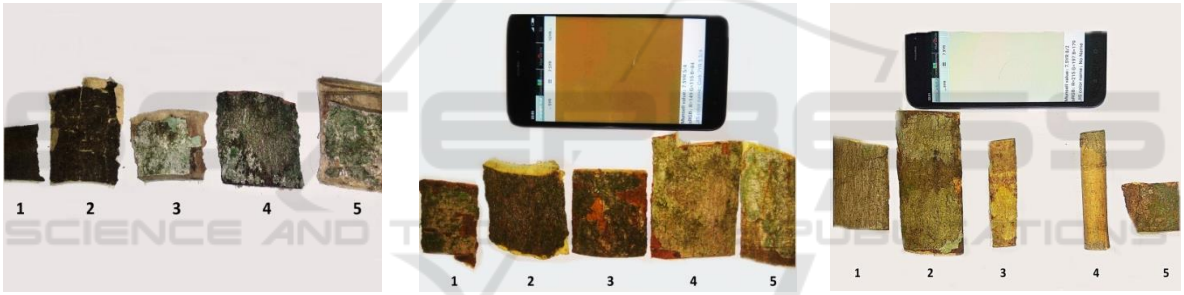
Leaf physiological and morphological traits are known to reflect the strategies of both resource uptake and resource use eficiency (Reich *et al.* 1999), and thus, these traits are expected to impact plant growth rates. The leaves morphology also has been used to differentiate and compare tropical rain forests species (Bongers and Popma, 1990; Medina et al., 1990). Foliar venation patterns, although very important for the taxonomic and phylogenetic considerations, have largely remained neglected.

Raru had simple leaf in alternate arrangement, 31-46 pinnate laminas, grablous leaf surface. The leaf had entire margin, acuminate tip and obtuse-acute base. Young leaves, twig, outer stipules, bud and raceme densely shortly powdery grey tomentose, fugaceous on leaf and midrib, so on twigs, persistent on racemes. Leaves 5-10 by 2-6 cm, eliptical-lanceolate. Stipules to 3 mm long, small, linear, caducous.

Raru dahanon and raru pulut have a lanceolate leaf shape, it is contrast to raru songal which has an elliptical leaf shape. Raru dahanon and raru pulut have the same leaf color as on the upper surface spesifically dark yellow green color (5GY 4/4) and the lower surface color is olive green (5GY 4/4) while the upper surface color of raru songal is green (3/3) and the lower surface of Raru songal is dark olive green (GY 3/4). Based on the leaf character, raru dahanon and pulut have similarity with *C. lanceolatum*.

(a) (b) (c)

Figure 3: Stems of Raru (a) Raru songal, (b) raru dahanon, (c) raru pulut.

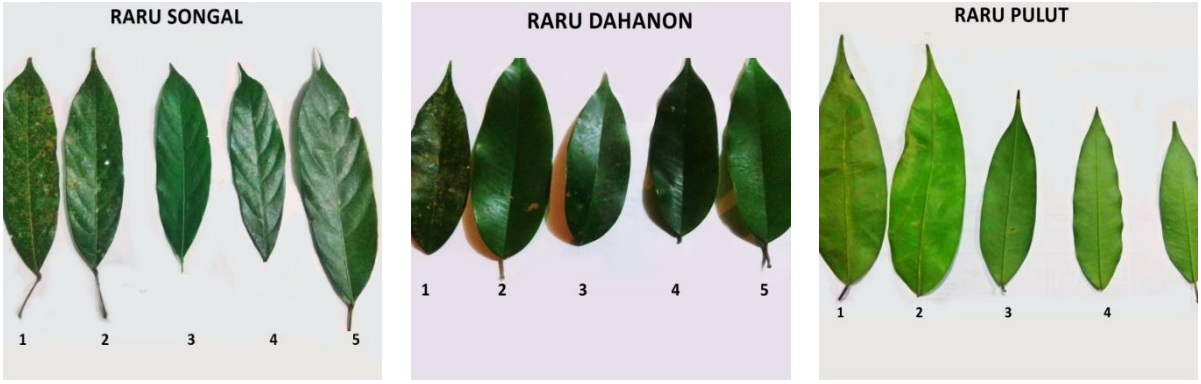


(a) (b) (c)

Figure 4: Raru Barks (a) Raru songal, (b) raru dahanon, (c) raru pulut.

Table 3: Leaves characters of raru songal, raru dahanon, and raru pulut.

Character	R. songal	R. dahanon	R. pulut
Leaf shape	Elliptical	Lanceolate	Lanceolate
Leaf margin	Entire	Entire	Entire
Leaf tip shape	Acuminate	Acuminate	Acuminate
Leaf base shape	Acute	Obtuse	Obtuse
Leaf area (cm^2)	51.55	44.6	38.4
Lamina length (cm)	13.38	15.26	15.5
Number of lamina	31	46	43
Upper surface color	5GY 3/3	5GY 3/6	5GY 3/6
Lower surface color	5GY ¾	5GY 4/4	5GY 4/4
Leaf arrangement	Alternate	Alternate	Alternate
Veination	Pinnate	Pinnate	Pinnate
Leaf surface	Grablous	Grablous	Grablous
Leaf composition	Simple	Simple	Simple
Leaf bud	naked bud	naked bud	naked bud



(a) (b) (c)

Figure 5: Leaves of Raru (a) Raru songal, (b) raru dahanon, (c) raru pulut.

3.1.4 Rosin

Rosin can be used to distinguish different raru species in North Sumatra. Our observation of rosin characteristics showed that raru songal had different scent and rosin type compared to others (Table 4). The rosin of raru dahanon and pulut were hard, while songal was soft.

Table 4: Leaves characters of raru songal, raru dahanon, and raru pulut.

Character	R. songal	R. Dahanon	R. pulut
rosin color	N1	9/3	9/3
rosin scent	aromatic	-	
rosin type	soft	hard	hard-
rosin flow	clot	clot	clot

Wilujeng and Sambiak (2015) stated that '*melanoxylon*' refers to the heartwood character *melaanos* which means 'black' and *xylon* which means 'wood'. It has the similarity character to raru songal from in North Sumatra which has dark wood color and black rosin (N1). Raru has blackish brown wood color with are heavy weight, hardness, and resistant to termite attacks and decay (Yoza, 2015). Raru dahanon dan raru pulut have very pale yellow rosin color (2.5 Y 9/3). In accordance with the statement of Thomas (2010), *C. lanceolatum* has yellowish clear rosin, and it became agarwood resin-like when dried up.

3.2 Phylogeny based Morphological Characters

Although other important non-genetic processes (i.e. habitat fragmentation, pollution), genetic factors (i.e. mutation, linkage, inbreeding) also can contribute to species extinction (Loewe and Hill, 2010). That's why a better understanding of plant genetic diversity was very important for Raru as endangered species, to protected this species from extinction.

Determination of the dendogram of kinship between raru pulut, raru songal and raru dahanon by using disimilarity index based on morphological characters indicates that, the highest genetic distance (1.1331) was showed between population 1 and 2; 1 and 3, while the lowest genetic distance (0.2274) was showed between population 2 and 3 (Table 5). Raru dahanon and raru songal have a fairly small genetic. distance, then followed by raru songal which have different populations.

Table 5: Nei's (1973) genetic identity and genetic distance of 3 populations of Raru.

	Populasi		
	1	2	3
1	*	0.3220	0.3220
2	1.1331	*	0.7966
3	1.1331	0.2274	*

Dendrogram kinship between raru species was found that raru dahanon and raru pulut in one small group with a genetic distance of 0.20, then joined with raru songal in a larger group with a coefficient of 0.93. Dendrogram result showed a specific cluster in population groups, and show similarities between populations. Cluster analysis of kinship coefficient reveals the population structure and provides better insight in plant breeding in terms of genetic variation. According to Govindaraj et al. (2015), Diversity in plant genetic resources provides opportunity for plant breeders to develop new and improved cultivars with desirable characteristics.

(a) (b) (c)

Figure 6: Rosin of Raru (a) Raru songal, (b) raru dahanon, (c) raru pulut.

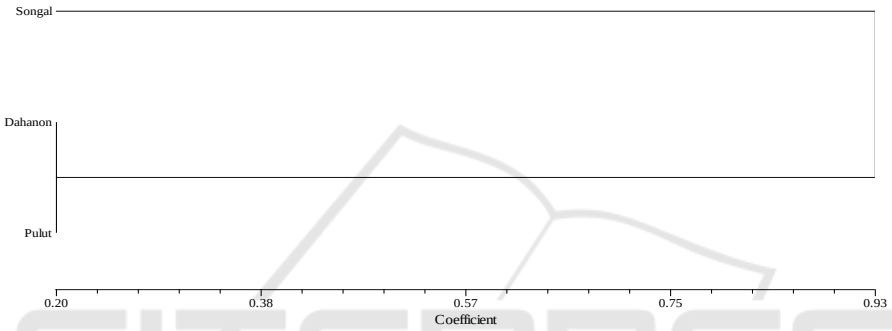


Figure 7: Dendrogram 3 populations of Raru from North Sumatera based on Nei's genetic distance.

Raru dahanon and raru pulut have very high similarities to morphological characteristics. Only several of morphological characteristic were different between raru dahanon and raru pulut such as, inner and outer bark color, and several morphological measurements such as leaf size, tree height, diameter, branch-free height, and number of lamina. It is suspected that raru pulut dan raru dahanon were the same species with a little different morphology. Plant growth and development influence by environmental factors that can cause anatomical modification and plant morphology. According to Falconer (1960) the diversity of appearance seen from a plant (phenotype) is a result of a combination of diversity due to influence of genetics and environment.

4 CONCLUSIONS

Our reserch point out that morphological character can be used for determined raru species in Central Tapanuli. Raru pulut, dahanon and songal can be determined by using leaf shape, wood colour and rosin character. Raru songal have higher dissimilarity character compared to dahanon and pulut.

Raru dahanon and raru pulut joined into a small group with a coefficient of 0.20, then formed a large group with raru songal and had a coefficient of 0.93.

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