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Morphology and genetic variation of manau rattan (*Calamus manan,* Miq.) in Sumatra, Indonesia

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Abstract—Morphological and genetic variation of manau rattan (*Calamus manan*, Miq.) studies have been conducted in three provinces in Sumatra, Indonesia, i.e. in Bengkulu, in Jambi, and in West Sumatra Province. Distinctive variations such as the presence of vestigial flagellum and red colour of rachis, as opposed to no vestigial flagellum and the normal green colour of petiole and rachis, were noted in certain individuals in wild manau rattan populations, although the percentage was only 5–60%, depending on the sites. These variations, which were confirmed with isozyme analysis results, are based on 6 enzyme systems, i.e. PGD, PGI, MDH, IDH, PER and EST out of 10 systems analysed. The range of percentage of polymorphic loci was 66.67–76.67%. The highest genetic diversity (He = 0.34) was West Sumatra Province which was mainly contributed by the Siberut Island, followed by Jambi Province (He = 0.28). Based on a dendogram constructed, the relatedness and genetic distance between studied populations in Sumatra could also be determined.

Key words: Manau rattan; variation; morphology; genetic; isozyme; population.

INTRODUCTION

Indonesia, with 75–80% of the present world production, has targeted export earnings of about US$ 600 million from rattan in the near future [1]. Indonesia's total export of rattan product, however, has been decreasing each year due to the quality and availability of raw materials. Rattan collectors both in Sumatra and Kalimantan Islands purely depend on natural resources which have become low in terms of quantity and quality. Only rattan with low quality and grown in remote

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areas remained, as most of local communities do not plant rattan. A number of private companies have initiated to plant rattan but there has been an indication that there are some morphological variations as the seeds used might not be pure lines.

Among large-diameter rattans, *Calamus manan*, Miq., which is locally known as rotan manau with an average diameter around 3–4 cm, is preferable due to its cane quality which relates to the highest price [2]. This manau rattan is used for the frame of furniture and handicrafts. It is very flexible and after processing the colour of its skin is bright yellow to brownish with shiny brown nodes, which makes the product nice and interesting. Since 1985, due to over-exploitation, populations of this species have been decreasing dramatically. As a consequence, it is suspected that manau rattan canes sold in the market under the name of 'manau' might be a mixture of different taxa, resulting in variations in the quality of commercial canes. The manau rattan itself has been reported to be variable in size and colouration. As variations could affect the quality, assessing genetic variation to obtain a superior trait is of importance.

As high as 98% of manau rattan originated from wild populations in Sumatra. Canes collected from the cultivated ones were noted from surrounding Ulu Talo in South Bengkulu. Based on interview and communication with the local community and collectors conducted during field work in 2002, apparently since 1980, manau rattan has been cultivated in rubber or coffee plantations. The canes are sold in of 3.0–3.5-m-long units. Due to its solitary habit which is worsened by the fact that they are very rarely cultivated, and by over-exploitation and illegal cutting, the existence of the population is threatened, particularly populations around Rantau Gedang. Based on spot observation and discussion with a main supplier in the area, the population in this site is anticipated to disappear in 5 years, if there is no significant effort to manage the wild population.

In West Sumatra, supply of raw materials is mainly from wild populations in Siberut Island which are then sent to factories or exporters such as in Bengkulu where one manau rattan furniture factory is located. Manau rattan from Lubuk-pinang is sold through Padang, while that from Rantau Gedang is sold to Palembang. In Jambi, manau exploitation has been observed in Sei Sengak (101°58′E–20°14′S), a place where manau rattans are purchased from first-hand collectors by manau rattan merchants. About 120 pieces of manau (one piece is 3.5 m long) of 25–40 mm in diameter were harvested. The collectors only collected manau rattan, not other species of rattans, although there are other commercial rattans, such as semambu (*C. scipionum*), tebo-tebo (*C. ornatus*), sega (*C. caesius*), lilin (*C. javensis*) and semut (*Korthalsia sp*.). Manau rattans were most probably collected from the areas in the Kerinci Seblat National Park and in the area around Bukit Tiga Puluh National Park. Apparently manau rattans were supplied from Districts Merangin and Sarolangun. The first one is located in the border of the Kerinci Seblat National Park and the latter one is in the border of the Bukit Dua Belas National Park. Recent statistical data of non timber forest product [3] from Merangin suggest that manau production for years 2000–2001 was about 60 000 pieces per year. Other rattans which were also collected and sold are semambu, tebo-tebo, semut and balam. The manau has a grading system based on diameter which is determined locally, namely L for diameter 35–40 mm, M for diameter 30–34 mm, S for diameter 25–29 mm, SS for 20–24 mm and SK for diameter less than 19 mm, and AK for the cane at the very base of the plant, which was collected with its roots. This system which is commonly used in the provinces of West Sumatra and Jambi, was developed by local rattan industries. Based on observations in the field, manau rattan sold in the market seems to be sole manau as no mixture was found and the grading system seems to follow the determined one.

The objectives of the study were to investigate morphological and genetic variation of manau rattan in wild populations in three provinces in Sumatra Island, Indonesia whether (1) the morphological characters are consistent in the studied populations; (2) there is any correlation between morphological characters and the growth rate of the stem; (3) there is any correlation between morphological characters and isozyme markers. Selection among variations observed will contribute to the improvement of manau towards a higher quality for trade and for sustainable development in the future.

MATERIALS AND METHODS

Field sampling

Sites of field sampling were as follows:

- Jambi Province: five locations were visited (a) Serestra II, a plantation established by PT. INHUTANI V, a semi estate company, in Sei Belanti; (b) in forest watershed area of Sei Merangin, Desa Masurai; (c) Sei Tembesi in Merangin District; (d) Desa Rantau Gedang in Batang Hari District; and (e) Desa Lambansigatal in Sorolangun District.
- Bengkulu Province: 4 populations in 4 sites Desa Sukaraja, Desa Dusun Baru, Desa Tumbuan and Desa Lubuk Pinang were studied. The first three sites are located in Bengkulu Selatan District while the last one is located in Bengkulu Utara District.
- West Sumatra Province: 4 populations in 2 sites in Pasaman District (i.e. Desa Tanjung Sepakat Mudik and Desa Pematang Panjang) and 2 sites in Mentawai Island District (i.e. Desa Sikabaluan and Desa Sigapokna) which are located on Siberut Island.

For the observation of stem growth in the future, individuals in Sumatra have been tagged. For this purpose, every first opened leaf (O-1) of studied individuals was marked with a tag. The length of the stem growth was measured from the mouth O-1 leaf sheath of the previous observation to the mouth O-1 in the next observation. The measurement equipment is either a manual roll meter or pole meter. In addition, an aluminium sectional ladder was used when necessary. Stem, leaf sheath and fruit

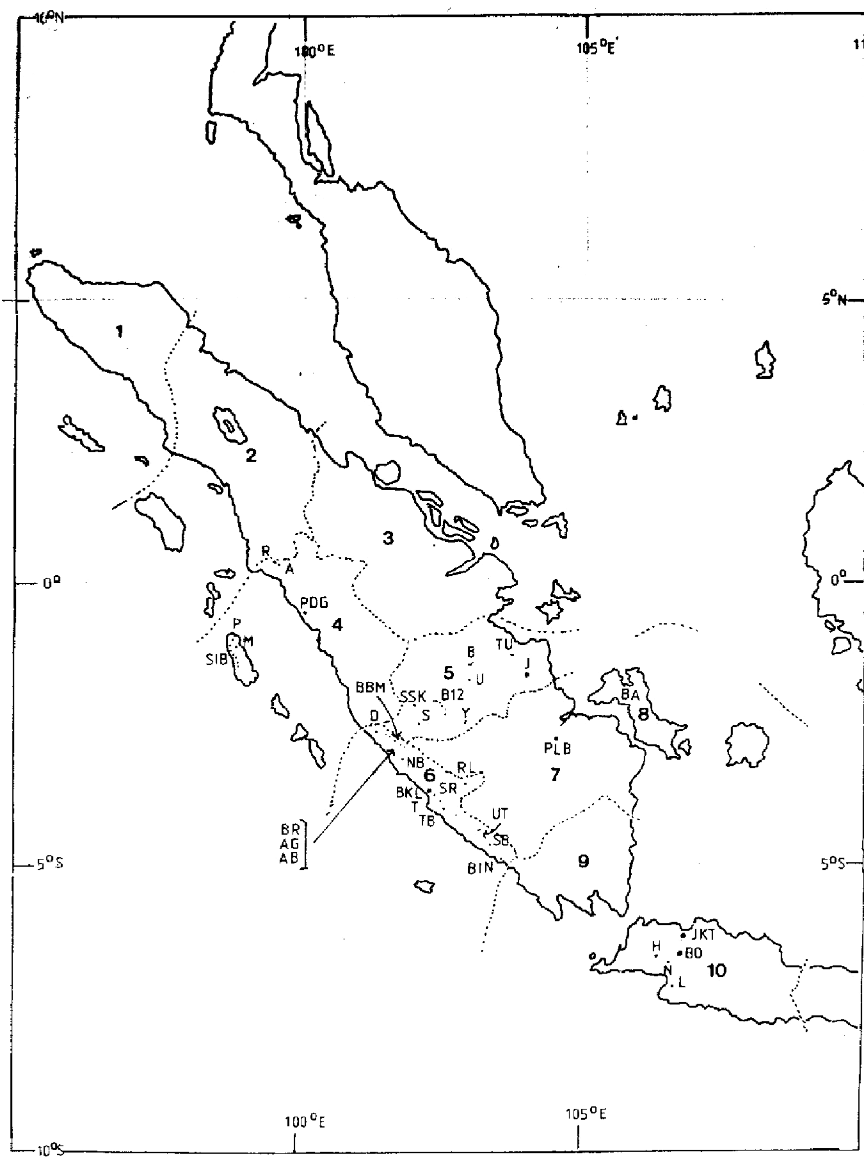

Figure 1. Map of the studied sites and distribution localities of wild manau population. Province: 1, Aceh; 2, North Sumatra; 3, Riau; 4, West Sumatra; 5, Jambi; 6, Bengkulu; 7, South Sumatra; 8, Bangka-Belitung; 9, Lampung; 10, West Java. Localities: A = Aek Nabirong, AB = Air Seblat, AG = Air Segalan, B = Sei Belanti, BA = Bangka Island, BBM = Bukit Barisan Mountains, BIN = Bintuhan, BO = Bogor, BR = Mt. Berekah, B12 = Bukit Duabelas Mountains, D = Lubukpinang, H = Haurbentes, J = Jambi, JKT = Jakarta, L = Lengkong, M = Sikabaluan, N = Nannggung, NB = North Bengkulu, P = Sigapokna, PDG = Padang, PLB = Palembang, R = Ranah Batahan, RL = Rejang Lebomg, S = Muara Siau, SB = South Bengkulu, SIB = West Siberut, SR = Sukaraja, SSK = Sei Sengak, T = Tais, TB = Tumbuan, TU = Tungkal Ulu, U = Rantau Gedang, UT = Ulu Talo, Y = Lamban Segatal.

diameter were measured using a digimatic caliper. Spines arrangement in the leaf sheath, form of leaflets, and ligule in the growing phase were observed directly in the field and through herbarium specimens. Specimens observed were both from the existing specimens in the Herbarium Bogoriense and new collections from the field. In addition, both a conventional and a digital camera were used to compile the field data. Herbarium specimens were made from studied localities when necessary.

The only wild manau populations in Jambi Province encountered so far were in Sei Belanti, Mersam Subdistrict, Batanghari District and in Sei Sengak, Muara Siau Subdistrict, Merangin District. Distribution of individuals in the populations was mapped. In the first observation, the size of population has been measured through seven plots which had been made through cruising line transects from 200 m to 10 000 m long by 40 m wide (20 m wide on each side of the line). The number of individuals in each plot was recorded. Because the localities of the wild population were not accessible during this study due to a long way, a hard and rough walk of three to seven days from the nearest village, the method of mapping in the following observation was modified. Localities of wild manau rattan population were only recorded from information gathered from the rattan collectors, extrapolation of the raw manau rattan product, secondary data from local Forestry Offices and from existing herbarium specimen in the Herbarium Bogoriense, Bogor, West Java. Localities of wild manau population were mapped using maps of Bengkulu Province [4], Jambi Province [5] and Sumatra [6] for populations in West Sumatra. Approximate latitude and longitude were measured manually in the map when the use of a GPS was not possible. In the field, the Trimble Scout Master GPS and the Garmin GPS 40 were used to locate the studied localities.

For genetic variation studies, four leaflets of each first opened leaf of related individual were collected. The mark code of the leaflet samples for isozyme analysis is the same one for the stem growth observation, namely T for Tais, TB for Tumbuan and so on (Table 1 and Fig. 1).

Observations on the provenance of the manau rattan namely on the stem length, diameter, growth and other vegetations, as well as generative morphological characters have been conducted in three provinces in Sumatra four sites each in Jambi Province, Bengkulu and West Sumatra Provinces including Siberut Island. Locations and plots were noted using local work plan map, compass, altimeter, trimble scout GPS, roll meter and red plastic string of 0.5 mm diameter. The length of stem and diameter, or plant height were measured by manual, roll meter, caliper, as well as with a haga meter.

Field morphology of rattan was studied during the observation in the field by collecting specimen, making a plant line architecture, close observation to an object and through a distance using a conventional and digital camera.

The types of samples collected from the fields were samples for herbarium specimens, fruits for morphological and growth study, and leaf samples for isozyme analyses.

Table 1.
Sites, number of samples and tagged individuals in Sumatra

No.	Site	Code	Province	NS	Population size[a]	Habitat
1	Ranah Batahan	R	West Sumatra	50	800 in 4 ha	RTP
2	Aek Nabirong	A	West Sumatra	50	400 in 2 ha	MTG
3	Sigapokna	P	West Sumatra	50	800 in 4 ha	MTG
4	Sikabaluan	M	West Sumatra	50	1600 in 2 ha	MTG
5	Sei Belanti	B	Jambi	63	3200 in 8 ha	LOG
6	Rantau Gedang	U	Jambi	50	1600 in 4 ha	RTP
7	Muara Siau	S	Jambi	56	3200 in 8 ha	MTG
8	Lamban Segatal	Y	Jambi	31	1600 in 4 ha	MTG
9	Lubuk Pinang	D	Bengkulu	50	200 in 2 ha	MTG
10	Sukaraja	SR	Bengkulu	50	4000 in 10 ha	RTP
11	Tais[b]	T	Bengkulu	49	200 in 4 ha	FTG
12	Tumbuan	TB	Bengkulu	50	2000 in 5 ha	RTP

CD = code, NS = number of samples, HAB = Habitat, RTP = Rubber tree plantation, MTG = Mixed tree garden, LOF = Logged over forest, FTG = Fruit tree garden.

[a] Approximate number of individual and size of the land covered area in hectare.

[b] Samples from Tais were taken from two populations, i.e. from Dusun Baru (15 samples) and from Talang Saling (34 samples). The distance between Dusun Baru and Talang Saling is about 200 m.

Isozyme analysis

Sampling procedure. Sampling for isozyme analysis was conducted at the same time as the tagging of individuals for morphological and growth performance. The number of samples taken is presented in Table 1.

Isozyme analysis protocol. The extraction of isozymes from leaf samples was carried out by grinding them to powder in liquid nitrogen and extraction buffer was added prior to centrifugation at 15 000 rpm, 4°C for 15 min. The composition of extraction buffer used was the modification of that developed for *Shorea spp.* and other tropical forest tree such as *Scaphium macropodum* [7, 8]. Potato starch gel at the concentration of 13% was used and the condition of electrophoresis was one hour at 35 mA and followed by 5–6 h at 45 mA. Gel buffer used was histidine, pH 6.0. A modified procedure used for staining isozyme of several tropical forest trees [7] was applied. Enzyme systems stained were 10, i.e. PGI (phosphoglucoimerase), MDH (malate dehydrogenase), IDH (isocitrate dehydrogenase), SDH (shikimic dehydrogenase), ME (malic enzyme), 6-PGD (6-phosphogluconate dehydrogenase), EST (esterase), PER (peroxidase), PGM (phosphoglucomutase) and Aldo (aldolase). Out of these enzyme systems, only the best 6, i.e. PGI, MDH, IDH, PGM, 6-PGD and PER, were used for further analysis.

Data analysis using computer software. Data obtained were analysed using the POPGENE 1.0 [9] software programme was used to analyse isozyme results.

Beside genetic distance, the calculated genetic diversity parameter values were the number of alleles per locus, the effective number of alleles per locus, percentage of polymorphic loci, number of polymorphic loci, observed heterozygosity, expected heterozygosity, observed homozygosity, expected homozygosity, Nei's expected heterozygosity and Shanon's Information Index. The software programme was based on Nei's genetic distance which was used for constructing a dendogram. Genetic similarity index formula [10] was: $\mathrm{GS} = 2N_{\mathrm{ab}}/(N_{\mathrm{a}} + N_{\mathrm{b}})$, where N_{ab} is the number of isozyme bands in common between genotypes a and b, and N_{a} and N_{b} are the total number of isozyme bands observed for genotypes a and b, respectively. A dendogram was constructed based on genetic distance (1–GS) using the unweighted pair-group with arithmetical average (UPGMA).

RESULTS AND DISCUSSION

Growth of manau rattan

In general, the stem at the base was 2 to 2.5 cm in diameter and gradually larger to the top up to 6 cm in diameter. Experience in Sikabaluan, Siberut Island, West Sumatra revealed that the stem diameter at the base could be much larger than 2 cm during cultivation and old leaf sheaths which cover the stem usually falls down as soon as the related leaves are getting older.

Although the measurement of tagged individuals in Sumatra could only be carried out once, results obtained based on a study in West Java in 2002 indicated that there might not be a correlation between the stem growth with regard to the stem length and stem diameter of the individual, the presence or absence of the vestigate, and whether the plant is male, female or sterile, as well as the number of opened leaves produced, soil type and average annual rainfall (unpublished data). The light expose to the manau rattan plant might have a correlation with the stem growth rate as it was reported by other investigators [11], however it can not be concluded yet from this observation.

Variation in morphology

Population of male plant in Lubukpinang, Ranah Batahan, Rantau Gedang, and Lamban Segatal in average was about 8% from the population. Most leaf sheaths have no vestigial flagellum or only less than 5% from the populations, however 60% of cultivated manau rattan population in Lubukpinang were bearing a vestigial flagellum (Fig. 2). This species character was not noted in related previous publications [1, 11–13].

The leaf sheath of the very young leaf was mostly rather whitish. The petiole of the young plants in the rosette stage was mostly longer than the rachis. At that stage, the petiole was up to 150 cm long while the rachis was up to 50 cm long. The petiole has been usually used by 'Suku Anak Dalam' or 'Kubu' (a traditional

Figure 2. Vestigate organ (arrow) of a certain manau rattan individual in Jambi Province, Sumatra.

people) for making arrows. Rachis of the sword and young leaves were mostly pale brown to green, but manau rattan from Jambi (namely Sei Belanti, Rantau Gedang, Lamban Segatal and Muara Siau) were mostly bright red (Fig. 3).

Spine arrangement on the leaf sheath when they were young in most cases was a combed-like structure, with large flat triangular spines of 3 to 4 cm long, and at the base up to 0.5 cm wide. The spine was usually dark greenish black, while that at the base was bright yellow. The comb consisted of 5 to 10 spines. The smaller spines were solitary and scattered along the sheath. When getting older the combed spines were much reduced in the number of combs and spines. Spine direction was mostly down wards, sometimes perpendicular and very rarely upwards. Figure 4a–4c shows spine arrangement variation.

Observation of variations in morphology in the younger stage may lead to a wrong identification especially if someone has not been specially trained as taxonomist. Two young plants of 1 m height with 2 cm in diameter of leaf sheath which grows slender and dwarf found in Sei Belanti, although it was thought as manau rattan by INHUTANI V's personnel, was suspected that it might not belong to this species during the first visit to Jambi. Further observation during the second visit, when they grew up further, it was confirmed that they belong to *C. axillaris*.

Young plants have hooded (*cucullatus*) leaflets, broadly ellips, arranged into five groups, each group consists of two divergence leaflets, underneath whitish, and no cirrus. When plant was getting older the leaflet arrangement became regular, flat, linear, pendulous, and the cirrus gradually developed longer. Ripe fruits from

Figure 3. Manau rattan in individual possessing red rachis in Jambi province, Sumatra.

Tais, Ranah Batahan and Aek Nabirong were mostly ellipsoid sometimes rounded (*globosus*). The aspect of morphological development of manau rattan has not been mentioned yet in any scientific publications.

Genetic variation

It was observed that isozyme variation patterns of Sumatran populations were much higher than that of West Java [14]. Results based on isozyme analysis also indicated that Sumatra populations are higher in terms of genetic diversity as shown by the expected heterozygosity (He) values, i.e. ranging between 0.25–0.34 (Table 2). These values were considered higher than other tropical forest species (He = 0.11–0.18) reviewed based on isozyme markers [15]. The result also indicated that the highest gene diversity (0.34) of studied populations in Sumatra was West Sumatra populations while the overall value of Sumatra (0.30) was lower due to low values of Bengkulu and Jambi population. This suggests that there is a tendency that the diversity of overall Sumatra will be reduced considering the threats faced to date and in the future. Therefore, an action plan to conserve manau population in Sumatra, especially the wild one, is an urgent action to be conducted.

Isozyme analyses extracted from rattan manau leaves revealed that there were more banding pattern variations in Sumatra than in West Java population. For

Figure 4. Variations in spine arrangement of manau rattan in Sumatra.

Table 2.
Genetic diversity values of Sumatra populations

No.	Parameter	B	J	WS	Overall Sumatra
1	Number of alleles per locus	1.76	1.79	1.77	1.83
2	Effective number of alleles per locus	1.45	1.47	1.63	1.51
3	Percentage of polymorphicloci	73.33	76.67	66.67	83.33
4	Number of polymorphic loci	22	23	20	25
5	Observed heterozygosity	0.41	0.41	0.52	0.43
6	Expected heterozygosity	0.25	0.28	0.34	0.30
7	Observed homozygosity	0.59	0.59	0.48	0.57
8	Expected homozygosity	0.75	0.72	0.66	0.70
9	Nei's expected heterozygosity	0.24	0.26	0.34	0.28
10	Shanon's information index	0.36	0.39	0.48	0.42

B = Bengkulu, J = Jambi, WS = West Sumatra.

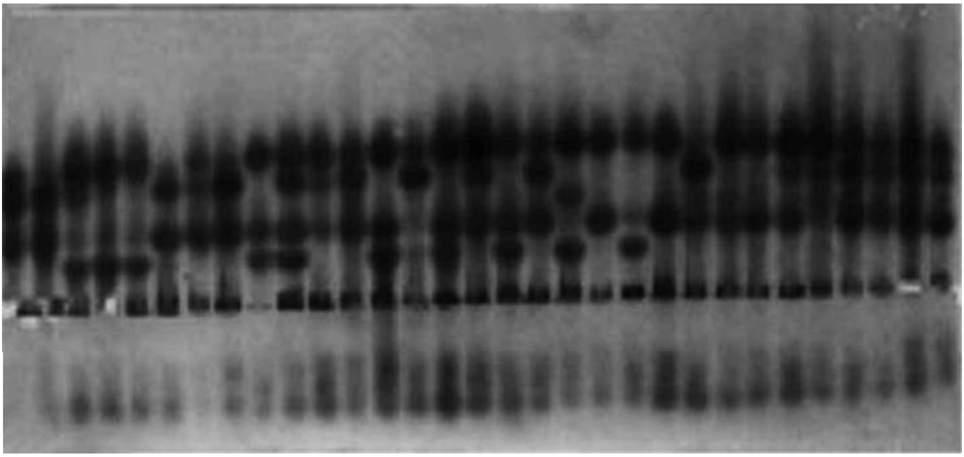

Figure 5. Stained gel electrophoresis of PER of manau rattan individuals in Jambi population.

example, banding pattern of MDH of Jambi population was 23 as compared to that of West Java populations, i.e. six [14]. Figure 5 shows the example of a gel of PER showing variations in isozyme banding pattern.

Isozyme analysis also confirmed morphological difference among samples during field visits. Checking in the field resulted that variations of isozyme pattern most likely correlated with morphological variations as some of these isozyme variations showed that those specific individuals possessed a vestigial flagellum organ or have red rachis.

A dendogram constructed based on 6 enzyme systems of Sumatra populations shows 2 major clusters. Cluster I consists of 3 subclusters, Cluster II only consists of one population, i.e. A (Subdistrict Pasaman, West Sumatra mainland). Subcluster 1 of cluster I is a group of Jambi populations, except SR and TB which are Bengkulu populations. Subcluster 2 consists of a mixture of 2 populations (M and P) of Siberut

Island of West Sumatra Province and one North Bengkulu population (DW) which is at the first cycle with S (Muara Siau, Jambi Province). This confirms that all wild populations forming one subcluster separated from the others (Fig. 6). Subcluster 3 consists of one population, i.e. T of Bengkulu Province. As wild manau in West Sumatra Province could only be found in Siberut Island, which is part of Mentawaian Archipelago, conservation needs to be carried out. Siberut Island has been reported as a unique ecosystem due to its geological and geographical conditions which consequently has several globally important endemic flora and fauna species.

Grouping of certain populations of Sumatra, i.e. the West Sumatra populations, is the same as that based on one enzyme system only such as IDH (data not shown) as two populations of Siberut Island (Sigapokna and Sikabaluan) are closely related but far apart from the other two populations of West Sumatra in the Sumatra mainland. This suggests that small islands have a more closed ecosystem than big islands. The physical condition of Siberut Island is highly fragile. Uneven natural spans and geological forms are constituted of young and muddy sediment. These conditions when combined with the high level of annual rainfall made the island vulnerable to erosion and soil infertility. More than 50% of the island area is considered to be very sensitive to land conversion. Consequently, if the island ecosystem where wild manau in West Sumatra Province could only be found is disturbed, the destruction rate will be faster with longer ecological recovery time. Conservation efforts, therefore, need to be carried out in the near future. The result also confirms that all wild populations forming one subcluster separated from the others (Fig. 6).

Analysis of each site of Sumatra populations carried out in 2001 resulted in a clear genetic relatedness between each populations. For example, Jambi consists of two main clusters with S population was separated from the others which might be due to the fact that it is considered unique among wild populations. Each of Bengkulu and West Sumatra populations were also grouped into two main clusters.

CONCLUSIONS

Variations in spine arrangement on the leaf sheath, presence or absence of vestigial flagellum, the development of leaves in young plants, colour variation of the young rachis and gross fruit development which have not been reported by previous researchers were observed in this study. However, up to now a temporary conclusion on morphological variation local populations is not significant yet.

Wild manau rattan populations have been located using longitude and latitude of the localities. In Bengkulu Province, they were found in the east of Bintuhan, Ulu Talo, and east of Lubukpinang along the Bukit Barisan Mounts to the south. In West Sumatra Province, it was mainly found in the west part of Siberut Island. In Jambi it was around Sei Sengak, Tungkal Ulu, and Bukit Dua Belas. It is anticipated, due to over exploitation, the population around Tungkal Ulu is becoming very limited at the moment.

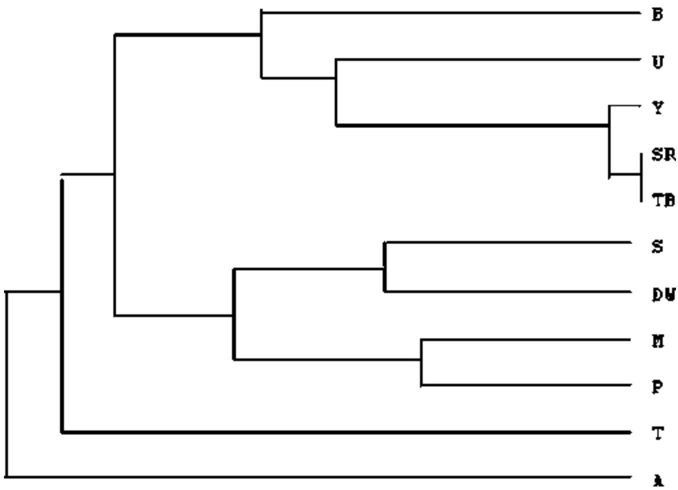

Figure 6. Dendogram constructed from six enzym systems (PER, EST, PGI, PGD, IDH, MDH) of Sumatran manau populations. B = Sei Belanti, Jambi; S = Muara Siau, Jambi; U = Rantau Gedang, Jambi; Y = Ds. Lamban Segatal, Jambi; SR = Ds. Sukaraja, South Bengkulu; T = Kp. Ds. Baru and Talang Saling, South Bengkulu; TB = Ds. Tumbuan, South Bengkulu; D = Ds. Lubung Pinang, North Bengkulu; A = Kp. Aek Nabirong, West Sumatra; M = Kp. Nanguang, Siberut, Mentawai Island District, West Sumatra; P = Ds. Sigapokna, Mentawai Island District, West Sumatra.

Genetic identity (above diagonal) and genetic distance (below diagonal) value in the table below based on Nei [10]

Populations	B	S	U	Y	SR	T	TB	DW	A	M	P
B	****	0.9037	0.9353	0.9186	0.9226	0.9019	0.9215	0.8980	0.8828	0.8867	0.8502
S	0.1013	****	0.9136	0.9157	0.9108	0.8801	0.9102	0.9494	0.9085	0.9410	0.9028
U	0.0668	0.0904	****	0.9371	0.9423	0.8935	0.9407	0.9145	0.9092	0.8995	0.8428
Y	0.0850	0.0881	0.0649	****	0.9922	0.8794	0.9944	0.9053	0.8783	0.8915	0.9032
SR	0.0806	0.0935	0.0595	0.0079	****	0.8882	0.9985	0.9070	0.8811	0.8869	0.9013
T	0.1033	0.1277	0.1126	0.1285	0.1186	****	0.8896	0.9266	0.8642	0.8771	0.8487
TB	0.0818	0.0941	0.0611	0.0056	0.0015	0.1170	****	0.9119	0.8787	0.8923	0.9022
DW	0.1075	0.0519	0.0894	0.0995	0.0976	0.0763	0.0922	****	0.8709	0.9427	0.8990
A	0.1247	0.0960	0.0952	0.1297	0.1266	0.1460	0.1293	0.1382	****	0.8575	0.8183
M	0.1203	0.0608	0.1059	0.1149	0.1201	0.1311	0.1139	0.0590	0.1538	****	0.9582
P	0.1623	0.1023	0.1711	0.1018	0.1039	0.1640	0.1029	0.1065	0.2006	0.0427	****

It is, therefore, recommended that *in situ* conservation in the locations of wild manau found especially in Rantau Gedang and Tungkal Ulu in Jambi Province or *ex situ* conservation have to be established as it has been anticipated that it will be lost within 5 year period if such efforts are not made. In addition, *ex situ* conservation of wild manau especially that with distinctive superior characters such as fast growth since they were found at a higher frequency in Bengkulu Province, has to be made for both conservation and breeding purposes.

Isozyme analyses could indicate the presence of morphological variations which are related to important characters such as fast growing which is likely to have connection with the presence of a vestigial flagellum. Further analysis applying the same ecological condition and the range of age determined would be useful for a selection which contribute to breeding.

Isozyme analysis could be used to identify samples from wild and cultivated manau rattans and could distinguished those collected from different Provinces as they were forming a different clusters based on an UPGMA dendogram.

Although genetic diversity of manau rattan in studied populations in Sumatra is still considered high, preventive actions is of importance considering recent threats that are becoming more and more serious.

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REFERENCES

1. J. Dransfield and N. Manokaran (Eds), *Plant Resources of South-East Asia 6: Rattans*. Bogor, Wageningen (1994).
2. J. P. Mogea, Palm utilization and conservation in Indonesia, in: *Palms for Human Needs in Asia*, D. Johnson (Ed.), p. 37–73. Balkema, Rotterdam (1991).
3. Jambi Forest Service, Non Timber Forest Product of the Bengkulu Province in the year 2000 and 2001. Unpublished Intern Report, Jambi. Mimeographed, 2 p (2001).
4. Pembina Peraga, Peta Propinsi Bengkulu, 1 p, 110 × 70 cm (1992).
5. Karya Pembina Swajaya, Peta Propinsi Jambi, 1 p, 110 × 70 cm (1993).
6. Indo Prima Sarana, Peta Sumatra, 1 p, 110 × 70 cm (2001).
7. E. Sudarmonowati, N. S. Hartati and U. J. Siregar, Establishment of biochemical markers of *Shorea spp*-tropical rainforest species, *Annales Bogorienses n.s.* **5** (2), 1–14 (1998).
8. E. Sudarmonowati, N. S. Hartati, B. H. Narendra, A. Fahnidar, U. J. Siregar and T. J. B. Boyle, Assessing genetic diversity of two tropical tree species (*Scaphium macropodum* and *Fordia johorensis*) in Jambi Province, Sumatra using isozyme markers, *Annales Bogorienses n.s.* **6** (1), 13–26 (1999).
9. CIFOR, POPGENE version 1.0. Microsoft window-based software for population genetic analysis. A quick user guide, Interim Report of a joint project development by Forest Genetic Lab, University Alberta and Centre for International Forestry Research (1996).
10. M. Nei and W. H. Li, Mathematical model for studying genetic variations in terms of restriction endonucleases, *Proc. Natl. Acad. Sci.* USA **75**, 5269–5273 (1979).
11. W. Razali, W. Mohd, J. Dransfield and N. Manokaran (Eds), A guide to the cultivation of rattan, *Malayan Forest Record No. 35*. Kepong (1992).
12. A. bin Muhammad, *Calamus manan Miquel*, in: *Plant Resources of South East Asia 6: Rattans*, J. Dransfield and N. Manokaran (Eds), pp. 50–52. Bogor (1994).

13. A. Supriadi and O. Rachman, in: *Pemanfaatan Rotan Jawa Barat. Duta Rimba* 241/XXIV, pp. 26–28 (2000).
14. E. Sudarmonowati, N. S. Hartati, J. P. Mogea, L. T. Hong and V. R. Rao, Variation of cultivated rattan manau (*Calamus manan*) in West Java based on morphological appearance and isozyme pattern, in: *Proceedings of Indonesian Biotechnology Conference*, Yogyakarta, Indonesia (2001).
15. L. L. Hamrick, M. J. W. Godt and S. L. Sherman-Broyles, Factors influencing levels of genetic diversity in woody plant species, *New Forests* **6**, 95–124 (1992).