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Starch Productivity of Sago Palm in Indonesia

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Abstract: About 95% of the total sago forest is dispersed in East Indonesia (Kalimantan, Sulawesi, Maluku, and Papua), in which many sago palm varieties are differentiated, and the productivity of sago starch is markedly higher than in West Indonesia (Sumatra and Java). The distribution, genetic diversity, and starch-production potential of sago palm in Indonesia were investigated in 2001-2007. The non-swamp land on Tebing Tinggi Island, a sub-district of Riau, is divided by canals into 50-hectare blocks, and the water table is regulated at 20-50 cm below the surface. Sago suckers, nursed on floating rafts in canals, are planted at a square spacing of 10 m. In Aceh Besar, about 50 hectares of sago palm forest is spread along the river. In Pontianak, West Kalimantan, about 5,000 hectares of sago palm forest is spread along the Kapuas River. The starch-processing factories along the river produce 25-500 tons of dry or wet starch per month. Palopo, South Sulawesi, has about 1,000 hectares of sago palm natural forest. In Maluku province, 30,000 hectares of natural forests is distributed unevenly in the swampy area of each island. The Sentani sub-district of Papua has about 4,000-5,000 hectares of sago palm natural forest. In Papua, sixty types of sago palm have been collected from the natural forest. The phenotypic characteristics were compared, and two varieties, Yepha (spineless) and Phara (spiny), have been recommended for starch production. The starch yield per trunk was highest in Papua (835 kg), followed by Maluku (582 kg), South Sulawesi (373 kg), and Riau (225 kg), and lowest in Aceh Besar (135 kg) and West Kalimantan (100 kg). The starch yield of 835 kg per trunk is the highest ever observed. The starch content of pith highly correlated with bulk density of the pith and dry-matter ratio.
Key words: Bulk density of pith, Indonesia, Maluku, Papua, Sago palm (*Metroxylon sagu*), Starch production.

インドネシアにおけるサゴヤシのデンプン生産性―スマトラ，西カリマンタン，南スラウェシ，マルク，パプアにおける調査事例―

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要旨: インドネシアにおけるサゴヤシ林の約95% がインドネシア東部（カリマンタン，スラウェシ，マルク，パプア）に分布しており，この地域で多くの変種が分化したと考えられている．この地域のサゴヤシ林ではインドネシア西部（スマトラ，ジャワ）に比べてデンプン生産性が著しく高いことが知られている．そこで，インドネシアにおけるサゴヤシの分布と遺伝的多様性，デンプン生産性を2001年から2007年にかけて調査した．リャウのトゥビンティインギ島では商業的プランテーション栽培が行われ，水路によって50 haずつに区画された圃場に水上栽培した吸枝が10 m間隔（正方形植）で移植されていた．調査を行ったアチェ州アチェベサールでは，約50 ha，西カリマンタン州のポンティアナでは約5,000 ha，南スラウェシ州のパロポでは約1,000 haのサゴヤシ自然林が河川沿いに広がっていた。マルク州では各島々の沼沢地沿いに合計約30,000 haのサゴヤシ林を有していた．パプアのセンタニ（スンタニ）湖周辺には約4,000 − 5,000 haの自然林が広がり，州の農業試験場では自然林から60種類のサゴヤシ近縁種または変種を収集して表現形質や成長速度を比較していた．２種の変種Yepha（トゲなし），Phara（トゲあり）が推奨されていた．各調査地で可能な限り開花期に近い1-2個体（幹立ち後6-10年）を切り倒して調査した幹のデンプン収量はパプア（835kg）で最も高く，次いで マルク（582kg），南スラウェシ（373kg），リャウ（225kg）の順となり，アチェ（135kg）と西カリマンタン（100kg）では低かった．髄部デンプン含量は髄の比重および乾物率と密接な相関関係が認められた．

キーワード： インドネシア，サゴヤシ（*Metroxylon sagu*），髄部比重，デンプン生産，マルク，パプア．

Introduction

Sago palm (*Metroxylon sagu* Rottb.) occupies 2.6 million hectares of land in the world (Flach 1983). Most of it (2.4 million hectares) grows in Papua, Indonesia and Papua New Guinea as wild or natural forest, and these natural resources have been scarcely exploited. Sago palm has great potential as a source of food for the people living near the forest and as a raw material for food industries (Bintoro 2002). The distribution, genetic diversity, and starch-production potential of sago palm in Indonesia were investigated in 2001-2007. Yamamoto (2006) previously described the folk varieties of sago palm in Indonesia and observed a significant variation in palm starch yield of from 68 to 700 kg per tree (n=68) at seven locations in Indonesia and Malaysia. Although some research locations overlap and not many palms were sampled in comparison with Yamamoto’s report, we focused on the vertical profiles of the log weight and starch content of the trunk.

Materials and Methods

A field survey, including a questionnaire survey and interviews with the farmers and employees of the sago-starch factory, was carried out at the six research locations: Tebing Tinggi, sub-district of Riau; Pontianak District of West Kalimantan; Sentani sub-district of Papua; Palopo, Luwu District of South Sulawesi Aceh Besar, Aceh Province of Sumatora; and Maluku Province, from 1991 to 1997. At each location, one or two sago palm trees were cut down, and the trunks were cut into logs 50 or 100 cm long. After the measurement of trunk and pith diameters, 100 mL of pith was sampled using a stainless cylinder every 50 cm from the base to the top of the trunk. All samples were weighed and oven-dried at 80°C for over 48 hours and then reweighed. The samples were ground in a mill, and the starch content was determined with a Food Analysis Kit (J.K. International Co., Ltd.); the starches in sample solution were hydrolyzed by amyloglucosidase, and D-glucose was enzymatically determined with hexokinase and glucose-6-phosphate dehydrogenase. The yield of starch from the trunk was shown as a sum of the amount of starch in each log (the pith volume multiplied by the pith starch content).

Results and Discussion

1. Sago palm cultivation in Tebing Tinggi sub-district of Riau (Jong 2006)

The cultivation area of sago palm doubled, and starch production increased 2.5 times during the 1990s' exporting for sales in Cirebon, West Java. P.T. National Timber & Forest Products (PTNT) began establishing a 20,000-hectare commercial plantation (Fig. 1A) on Tebing Tinggi Island with deep peat soil in 1996. The scale and management techniques were reported previously (Jong 2001, 2006). Over 12,000 hectares of land has been planted, at a rate of 2,000 hectares per year. The non-swamp land was divided by canals into blocks of 50 hectares, and the water table was regulated at 20-50 cm below the surface. An unknown spiny folk variety has been used, and suckers nursed on floating rafts in canals were planted in the field at a square spacing of 10 m. After weeding, fertilizing, and sucker thinning, one sucker is allowed to develop further at a desired interval of 18 months. Modernized processing factories are now under construction.

Yamamoto et al. (2007) reported that the efficiency of sago starch extraction using the traditional method was about 50% in Tebing Tinggi Island. This indicates that if modernized factories are introduced into this area, the efficiency and starch production are expected to double.

2. Utilization of natural forest of sago palm in Pontianak District of West Kalimantan

About 5,000 hectares of sago palm forests is spread along the Kapuas River (Fig. 1B). All grow naturally, in contrast with that in Sarawaku, Malaysia, where the sago palm plantation area is expanding. Major varieties are Bemban (higher starch yield), Buntal, and Pulut, and these varieties are spineless. We were not able to find sago palm just before anthesis, which has the highest starch content. Many sago palm trees were harvested far before flowering, when the trunk shows the highest starch content, in order to receive cash under the shortage of log supply. The thick trunk (300-350 kg per 10 m) is obtained from the sago palm grown inland, but the thin trunk (100-200 kg per 10 m) is obtained from the sago palm grown near the river.

The small-, medium- (Fig. 1C), and large-scale factories along the river have respective starch production capacities of 20-25 t, 40-60 t, and 500 t per month (potentially 2,000 t). Rotating raspers were used to extract starch. The starch was recovered by sedimentation, and dry starch was obtained by sun drying. Dry starch was processed into rice noodles sold for 1,350 Rupiah per kilogram (Dec. 2002). The large-scale factory refined the wet starch, which was bought from the small factory for 600 Rupiah per kg, to dry starch, which was sold for 1,700 Rupiah to a Java company (Dec. 2002).

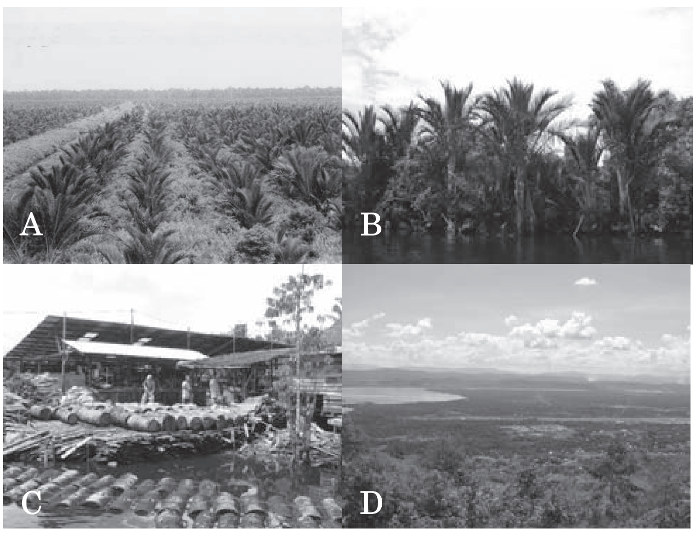

Fig. 1. Photos of sago palm utilization in Indonesia.
A: Commercial sago palm plantation in Riau.
B: Sago forest along Kapuas River in West Kalimantan.
C: Medium-size starch processing factory.
D: Sago forest around Sentani Lake in Papua.

Fig. 2. Photos of sago palm and processing.
E: Upper part of sago palm trunk (Para) cut down at Sentani sub-District containing 835 kg of starch.
F: Traditional starch extraction procedure in Papua
G: Sago starch is the staple food in Papua (Papeda).

Fig. 3. Recommended sago palm varieties, Yepha (left) and Para (right), at the collection field of the Institute for Assessment of Agricultural Technology in the Sentani sub-District of Papua.

3. Utilization of natural forest of sago palm in Sentani sub-district of Papua

Even today, wet sago starch is the staple food (Papeda, Fig. 2G) for the people living near the swampy area. In Papua, about 80% of the total food consumed is imported from another region. There are about 4,000-5,000 hectares of natural sago palm forests around the Sentani Lake (Fig. 1D). According to the production statistics of Papua in 2002, the harvested area, starch production (probably wet), and yield were 255 hectares, 6,375 tons, and 25 tons per hectare, respectively. This yield record of sago palm is as high as that of cassava in India (26.3 tons per hectare) on a fresh-tuber-weight basis (FAO 2007). The Institute for Assessment of Agricultural Technology in the Sentani sub-District of Papua collected 60 types of sago palm germplasm from the natural forest of Papua, and their phenotypic characteristics have been compared (Limbongan 2007, Bintoro 2008). Two types are recommended for starch production, i.e., Yepha (spineless, Fig. 3, left) and Para (spiny, Fig. 3, right). Each variety has two ecotypes, which produce white and red starches called Yepha Hongleu and Yepha Hongsay, and Para Hongleu (Fig. 2E) and Para Hongsay, respectively. Wet sago starch is sold for 1,000-1,500 Rupiah per kilogram at the market (Dec. 2003). A rotating rasper is used for crushing the pith, but it is washed and the starch extracted by hand by women (Fig. 2F).

4. Utilization of natural forest of sago palm in Aceh Besar

In Aceh Besar, with about 100 hectares of sago palm (unknown spineless folk variety) forest spread around the swampy area (Fig. 4H), sago palm was used as animal feed and was often distributed near the house for the utilization of leaflets and petioles for the roof. We visited Aceh in Dec. 2005, when the damage from the tsunami disaster on Dec. 26, 2004, still remained.

5. Utilization of natural forest of sago palm in South Sulawesi

Near Palopo, Luwu District of South Sulawesi, about 1,000 hectares of sago palm natural forest (spineless variety, Molat, Fig. 4I) is spread in the swampy area along the Teluk Bone Bay. The natural sago forest has been rapidly replaced by rice paddy field. Wet sago starch was sold at 1,000-1,500 Rupiah per kilogram at the rural market (Dec. 2004). Sago starch is eaten as a traditional staple food (Kapurung), prepared like papeda. Bagea, a sweet cookie made from sago starch, was also sold at the city market.

Fig. 4. Sago palm forest and photos related to sago palm in Indonesia
H: Natural sago palm forest in Aceh Besar.
I: Natural sago palm forest was made up of mostly Molat variety in South Sulawesi.
J: Provincial government supports the sago settlement sharing the 30 hectares of sago palm forest in Ambon.
K: The monument of the sago palm near the church in West Serum.

6. Utilization of natural forest of sago palm in Maluk

In Maluku province, 30,000 hectares of natural forest is unevenly distributed in the swampy area of each island, and sago starch is rapidly being replaced as a main staple food (papeda) by rice. Sago lempen is a preserved food in the rural area of Maluku, made from sago starch baked in a square-shaped unglazed pan on the fire. In Ambon, the provincial government supports the sago settlement sharing the 30 hectares of sago palm forest (Fig. 4J), and the United Nations Industrial Development Organization (UNIDO) has been developing appropriate technology for purification of sago dry starch and making new snacks and sweets. In Eti village, West Serum, protestant missionaries help save people from starvation by teaching them how to extract the starch from the sago palm trunk (Fig. 4K). Although Yamamoto (2006) confirmed five varieties (Tuni, Ihur, Makanaru, Ikau, and Morat) in Ambon and Serum, we identified four varieties excepting Ikau and newly recognized one variety, Duri Rotan, which is probably the same as the Rotan introduced as a variety in Southeast Sulawesi by Yamamoto (2006).

7. Comparison of starch productivity among locations

The mean, maximum, and minimum daily temperatures were almost the same in the six locations, but the precipitation was lowest in Banda Aceh (Table 1). The length, thickness, and weight of sago palm trunk were greater in the decreasing order of Papua, Ambon, South Sulawesi, Riau, Aceh Besar, and West Kalimantan (Table 2). The starch yield per trunk was highest in Papua (835 kg), followed by

Table 1. Climate factors at the research locations.

Factor	Banda Aceh	Tebing Tinggi	Pontianak	Watam-pone*	Ambon	Jayapura
Mean Temp. (℃)	27.2	27.6	27.5	27.1	26.8	27.1
Max. Temp. (℃)	32.2	31.9	32.0	30.9	29.8	31.7
Min. Temp. (℃)	22.7	23.4	22.9	23.3	23.8	22.5
Pricipitation (mm)	1029	1762	2145	2003	1852	1853

Data sources are different by site and item (http://www.worldclimate.com/).
* : South Sulawesi.

Table 2. Comparisons of trunk weight, starch content, and starch yield of sago palm among six locations.

Location	Trunk		Pith		Starch content		Starch yield
	length (m)	weight (kg)	diameter (cm)	volume (L)	(DW%)	(g/L)	(kg)
Riau (Tebing tinggi island)	10.5	1059	37.5	1177	69.3	218	253
Papua (Jayapura)	11.5	2502	56.7	2917	72.9	280	834
West Kalimantan (Pontianak)	6.5	871	49.6	794	57.5	122	100
South Sulawesi (Palopo)	11.5	2035	48.0	2000	62.3	168	373
Aceh Besar (Malaka)	6.5	754	39.3	850	50.2	160	135
Ambon (Central Maruku)	18.0	2473	44.9	2859	68.3	198	582

Data was the mean of 1-3 sago palm trunk in each location.

Maruku (582 kg), South Sulawesi (373 kg), and Riau (253 kg), and lowest in Aceh Besar (135 kg) and West Kalimantan (100 kg). The starch yield of 835 kg per trunk was higher than the various assessments of yield (160-550 kg) in different locations (Oates 2002; Yamamoto 2006). As reported by Yamamoto (2006), the varietal diversity was wider, and the per-trunk starch yield higher, in the eastern part of Indonesia – especially in Papua, which is considered to be the centre of diversity of *M. sagu* – than in the western part of Indonesia.

The fresh weight of log (kg m^{-1}) was lightest at the top of the trunk and heaviest at three to five meters below the top in Riau, Ambon, South Sulawesi, and especially Papua (Fig. 5). However, it was heaviest near the base of the trunk in West Kalimantan and Aceh Besar, where the sampled palms were younger (6 or 8 years old) than in the other locations. The reason that the fresh weight of log near the top was two or three times heavier in Papua than in the other locations was not clear. The highest starch content was obtained near the base of the trunk in Riau, Aceh Besar, and West Kalimantan, from the upper part of the trunk in Ambon, South Sulawesi, and from a slightly higher portion of the trunk in Papua (Fig. 6). Shimoda et al. (1994) reported that starch content was highest at the base in the younger trunk, but at the middle of the trunk just before anthesis. The starch content of 313 g L^{-1} in Ambon and 310 g L^{-1} in Papua was higher than the 300 g L^{-1} reported by Flach and Schuiling (1989). The starch content of pith highly correlated with bulk density of the pith (Fig. 7) and dry-matter ratio (dry weight / fresh weight) (Table 3). This implies that the starch content is simply

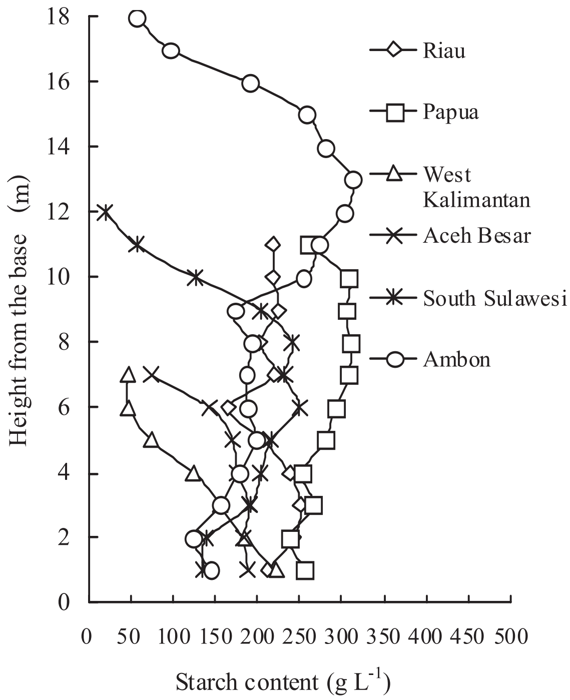

Fig. 6. Vertical profile of starch content of pith every one meter from the base of the sago palm trunk.

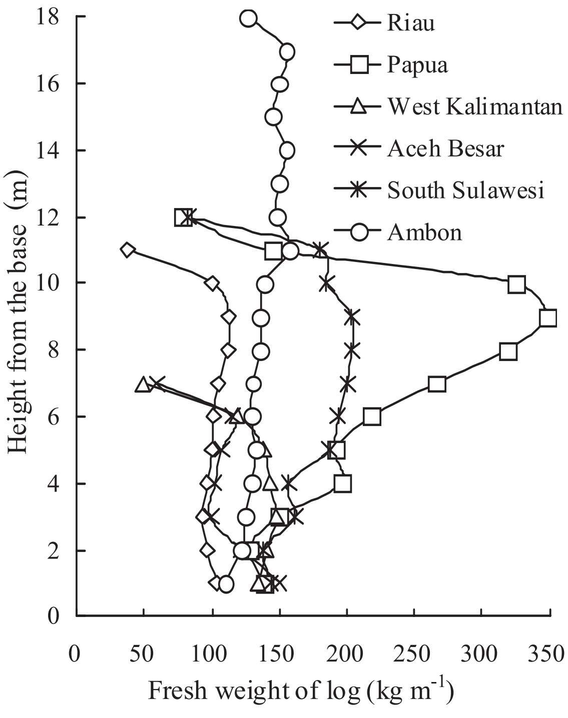

Fig. 5. Vertical profile of log weight every one meter from the base of the sago palm trunk.

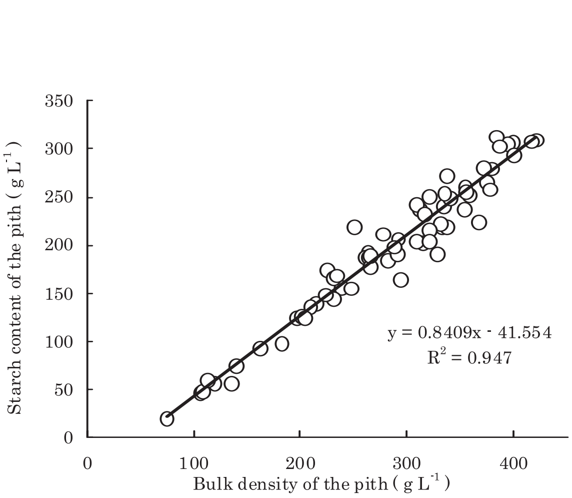

Fig. 7. The relationship between bulk density of the pith and starch content of sago palm at different heights of the trunk in six locations in Indonesia.

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