

# Vegetative Morphology and Starch Production Among Sago Plants (*Metroxylon* spp.) in Kepulauan Meranti District, Riau, Indonesia

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## Abstract

Sago (*Metroxylon* spp.) is the world's highest starch producer that have high productivity. Sago starch, however, is still underutilized compared to other starch. Sago can produce dry starch of 20-40 ton per ha per year. Indonesia has the largest sago area in the world with more than 90% of the world's total sago area. Sago have high species diversity and not all of them have the same starch-producing capability. This research was conducted to gather information on the morphological characters and starch production potentials of several types of sago in Meranti Islands Regency, Riau Province, Indonesia, especially in Bandul, Mengkirau, Tanjung Peranap, and Bagan Melibur. Three different types of sago in Kepulauan Meranti Regency, Riau, has been identified, namely Beremban, Meranti and Sangka. The morphology and starch production of different types of sago vary depending on environmental conditions, including soil types. Beremban Sago collected from Bandul Village were found to have the highest starch content, therefore it has potentials to be developed for starch production in Indonesia.

Keywords: sago plant types, diversity, starch production

## Introduction

Sago (*Metroxylon* spp.) is a carbohydrate-producing species that has high productivity and potentials for development in Indonesia. Sago trees can produce dry starch of as much as 20-40 tons.ha<sup>-1</sup> per year (Bintoro et al., 2010). Indonesia has the largest sago area in the world comprising more than 90% of the world's total sago area. Of the 5.5 million ha of sago area in Indonesia, 90% is located in Papua (4.7 million ha) and West Papua (510,000 ha) and 10% in another Indonesia areas (Bintoro et al., 2014). Sago can grow in marginal area, therefore sago production

has been expanded from areas with high soil water levels into into artificially drained peat areas for large-scale sago plantations (Azhar et al., 2020).

Sago starch can be used for various purposes, including as staple food, raw material for flavoring, liquid sugar, ethanol, animal feed and other industrial raw materials (Bintoro et al., 2016). Compared to maize and potato starch, sago starch is relatively underutilized (Zhu, 2020). Each sago trunk can produce 200-400 kg of dry starch (Bintoro et al., 2010). Sago starch production can be maximized for reducing sugar imports by using liquid sugar as an alternative. Data from the Central Statistics Agency (Badan Pusat Statistik, BPS) show that the highest sugar imports in Indonesia occurred in 2013 at 3.3 million tons (BPS, 2015).

Despite high species diversity of sago, especially in the areas of Papua and West Papua, there are only a limited research on identification of sago accessions (Dewi et al., 2016). The Papua Province is the center of origin of the sago (Abbas et al., 2010). Sago trunk usually is 8-10 m in height, 30-40 cm in diameter with 1-2 cm bark thickness (Bintoro et al., 2014). Flach (1977) stated that sago in South Sulawesi grows 8.4-10.3 strands per year, whereas according to Yamamoto et al. (2006) leaf growth in Papua could reach 5.8-7.0 strands per year, or 0.48-0.86 leaf per month. Sago leaves will be drying out at harvest. Generally, sago trees is classified into two types, those that have thorns and those that do not have thorns. Thorny sago is characterized by a smaller stem diameter compared to sago that do not have thorns. The number of tillers in each clump in thorny sago is higher than those of non-thorny sago. The thorns grow on the trunk, leaf bones and rachis.

Research on sago morphological characteristics is important to evaluate sago diversity and to understand different characters of sago accessions. In this study the morphology and production potential

of several types of sago in Kepulauan Meranti Regency, Riau were investigated to provide more information on resolving the taxonomy of *Metroxylon* and to develop sago as alternative source of sugar. The purpose of the research is to gather information about morphological characters and to determine the production potentials of several types of sago in Kepulauan Meranti Regency, Riau.

## Materials and Methods

### Sampling and Plant Identification

Samples of sago palm that morphologically look different were obtained from four villages located in the Meranti Islands Districts, Riau Province, Indonesia. The areas have tropical conditions with temperatures ranging from 21-35°C. The four villages include Bandul and Mengkirau of the Tasik Putri Puyu District, Tanjung Peranap of the Tebing Tinggi Barat District, and Bagan Melibur of the Merbau District. Sago samples were cut down from each village. Except for Bandul where sago grows on mineral soil, the rest of the sago in the other three villages grow on organosol or peat soil.

Initial information on sago identity and types were obtained from the sago farmers. This type of identity is confirmed by Novariantio et al. (2014) which stated that sago that grows in Meranti Islands Regency consists of three accessions, namely duri sago, thornless sago (*sago bemban*), and sago sago (*sago sangka*). Research study sites were selected based on the abundance of sago trees in the four villages, where sago constitutes as the main source of livelihood for the community.

Samples for morphological identification were conducted at Desa Bandul, Mengkirau, Tanjung Peranap, and Bagan Melibur, Meranti Islands Regency, Riau Province. The sample sago trees were measured directly in the field. Starch production is calculated at the research location, then the

processed and dried starch sample is put into zip-locked bags to be analyzed for its composition at the Laboratory of the Center for Biological Resources and Biotechnology Research, Institute for Community Empowerment, Bogor Agricultural University.

### Data Collection and Analysis

Morphological characters and starch component analysis of the sago samples were conducted through physical measurements. Documentation, photos of specimens, and proximate analysis of sago starch were also conducted (Table 1). A list of the morphological characters of the vegetative parts of sago is presented in Table 1. Illustrations are provided to understand how some of these characters were measured (Figure 1). Specifically, the following characters were recorded in the different samples: stem (length, diameter, circumference, bark thickness and color), leaves (rachis length, number of leaves and leaflets, length and width of leaflets), and petiole (length and width). Production characters include starch production, starch recovery (rendemen), color of pith and color of starch, water content and starch components. Quantitative data on morphological parameters was analyzed using Microsoft Excel 2016.

## Results and Discussion

### Types of Sago Trees in the Study Areas

Three types of sago trees in Kepulauan Meranti Regency, Riau, has been identified. The three types of sago morphologically can be distinguished based on presence/absence and density of spines present on the vegetative organs of the tree. The three sago types are the Beremban sago (without spines), sago Meranti (spines densely distributed), and sago Sangka (spines sparsely distributed).

Sago Meranti is the most common type of sago in Meranti Islands Regency, Riau because it produces

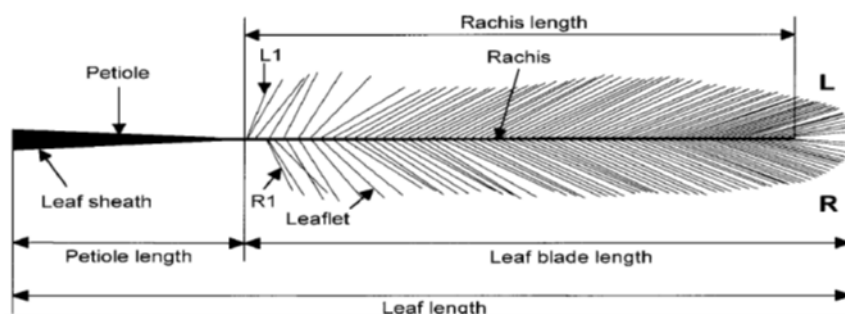


Figure 1. Illustration of sago leaves (Nakamura et al., 2004).

Table 1. Morphological characters to differentiate types of sago in Indonesia

Component	Morphological/ chemical character	Method of data collection
Stem	Length	Measured on trees that were cut down; measurement from base of the stem at the ground to the midrib of the lowest leaf
	Diameter	Measured on trees that were cut down; measured from the base, middle and end of the stem
	Circumference	Measured on tree trunk located one meter above the ground
	Bark thickness	Measured on the bark which is the outer surface of the stem until it reaches the pith; measured from the points on the base, middle and end of the stem
	Color	Visual comparison with colors from the Royal Horticultural Society Color Chart
Leaves	Length of rachis	Measured in mature leaves, specifically leaf number 2 after spear-head; measured from the base of the midrib where the leaflets attach to the end of the midrib (Figure 1)
	Length of leaves	Measured in mature leaves
	Number of leaves	Mature leaves from harvested trees; determined by counting the number of green leaf midribs
	Number of leaflets	Mature leaves from the parent tree (leaf number 2 after spear leaf); counted the leaflets located in the middle of the leaf (midrib), right and left sides of the leaf bone (there is no such word as leaf bone, please use a different terminology)
	Length of leaflets Width of leaflets	Mature leaves from the parent tree, usually leaves number two from the top; involved leaflets that had reached maximum growth (30-40% from the leaf base)
Petiole	Length	Mature leaves of the parent plant, usually leaves number two after the spear leaves; length measured from the base of the midrib to the first leaf of the leaflet; width measured at the base of the midrib (Figure 1)
	Width	
Starch	Starch production per stem	Calculated using volume comparison and calculated based on formula by Bintoro et al. (2017): $\text{Starch production per stem} = (a \times c) / b$ <p>where a is the stem volume, b is the sample volume, c is the dry starch weight (average of the samples collected).                      Stem volume was calculated using the formula: <math>\text{Stem volume} = \pi r^2 \times \text{heights}</math>, where <math>\pi = 3.14</math>; r = sago stem fingers</p>
	Starch recovery	Calculated using the formula proposed by Bintoro et al. (2017) as follows: $\text{Rendemen} = a / b \times 100 \%$ where a =dry starch weights of sample; b = pith weight.
	Dried starch and pith color	Recorded using the Royal Horticultural Society Color Chart
	Water content in starch	Calculated using the formula proposed by Bintoro et al. (2017) as follows: $\text{Water content} = \frac{BB-BK}{BB} \times 100 \%$ Here BB refers to wet starch weight and BK means dry weight of starch.
	Starch composition	Dry starch composition was analyzed using proximate analysis (AOAC, 2006)

more seedlings than the other types of sago. Moreover, people sell sago in the form of *tual* (part of sago stem) and Sago Meranti is very suitable for cultivation. Beremban Sago has larger and taller stem than sago Meranti, but the number of seedlings it produces is low at around 3-5 each, that is why the local community is not interested in planting it. Sago Sangka is not often found in Meranti Islands Regency, Riau because it is a rare species. Thus, it is difficult to obtain sago Sangka seedlings and local farmers are not interested in cultivating it. In this study, we refer to Sangka 1 sago as a young sago that is still in its growth stage whereas Sangka 2 is a mature tree that has reached harvest stage.

### Vegetative Morphology

Between the two more common sago identified by the farmers, Beremban sago was found to be the tallest, have the greatest plant stem diameter and bark thickness compared to the Meranti sago (Figure 2). The Beremban sago trunk is theoretically larger because it produces fewer seedlings, resulting in

less competition for water absorption and nutrients. Due to a smaller population size of Beremban sago, photosynthesis is likely to be more optimal. Between the young and old Sangka sago (Sangka 1 and Sangka 2, respectively), Sangka 2 was the tallest, has the largest stem diameter and thickest bark. The age of these two plants is a significant factor in determining sago morphology.

The average number of leaf among the different types of Sago did not show too much variation. However, the number of leaflets was significantly lowest in Sangka 2 which was the oldest tree sampled in this study. Unlike Sangka 1, which was a young Sago that is still in its active vegetative growth, Sangka 2 was an older plant, therefore they have started producing starch, instead of growing new leaflets (Figure 3).

When it comes to length of leaves and rachis between the two common sago groups, Beremban sago was found to have longer leaves and rachis compared to Meranti. Between the two Sangka trees, Sangka 1 showed longer leaves and rachis. This can be

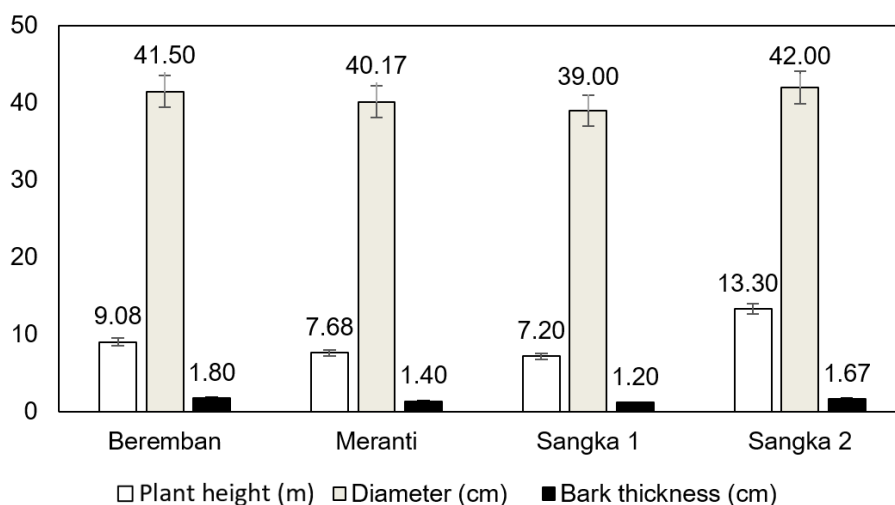


Figure 2. Size of Beremban, Meranti and Sangka sago trees in Kepulauan Meranti District.

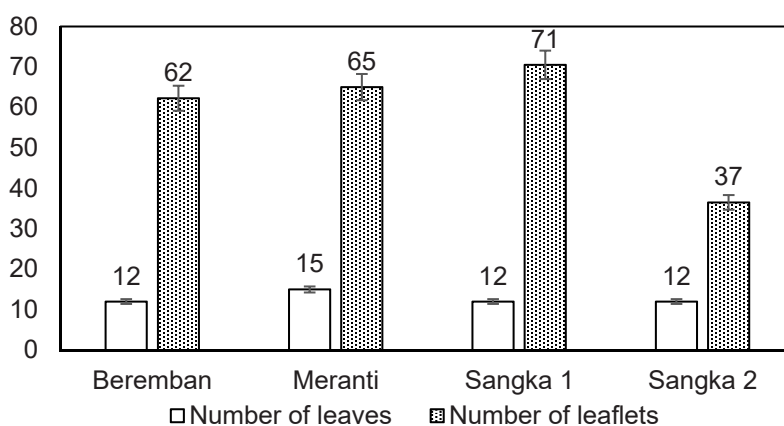


Figure 3. Number of leaves and leaflets found on various types of sago plants in Kepulauan Meranti District

attributed to the younger age of Sangka 1 where leaf length continuously increased and the small leaves had not fallen off, while old longer leaves in the older Sangka 2 would usually fall. Sago usually form one leaf every month and it is estimated that their leaves can last for an average age of 18 months before they age and fall (Flach, 1983).

In terms of petiole length between the common Sago groups, Beremban Sago had longer petioles than Meranti Sago (Figure 5). Additionally, between the Sangka, the younger Sangka 1 had longer petioles compared to the older Sangka 2. The longer petioles in Beremban and Sangka 1 are due to the age of these plants when they were cut down during sampling. Both trees were relatively younger than the Meranti and Sangka 2. Plant developmental stages are significant factors in photosynthates partitioning. Petioles are generally shorter in older sago trees because of the energy produced was distributed to starch production instead of growth.

*Starch Production and Composition*

The highest dry starch production among sago trees was recorded from Beremban Sago (318.64 kg per trunk) from Bandul Village, whereas the lowest was

from Beremban sago from Bagan Melibur Village (81.65 kg per trunk) (Table 2). The high starch production for Beremban sago in Bandul Village can be due to the mineral soil type on which it was grown. Whereas, the low starch production of Beremban sago from Bagan Melibur Village can be attributed to the peat soil of the area. The effect of soil on starch production can be further observed when looking at the dry starch production of Meranti Sago. Higher dry starch was produced by the trees collected from Bandul Village compared to those that were sampled from the other villages that had peat soil. The production of dry starch in Sangka sago varied with plant age; the older Sangka 2 had a higher dry starch produced compared to the younger Sangka 1. Sangka 1 was 8-years-old when harvested, therefore it had not entered its optimal harvest age. Sangka 2 was sampled at its harvest age (Figure 6). Sago trees are usually ready to be harvested when they are 10-12 years-old, i.e. when their starch content are at their maximum (Bintoro et al., 2010).

Production of starch is affected by water content in the pith, and consequently the yield. The lower the water content, the higher the yield. Among all Sago plants sampled, Meranti sago from Tanjung Peranap Village had the lowest water content (37.04%) and therefore

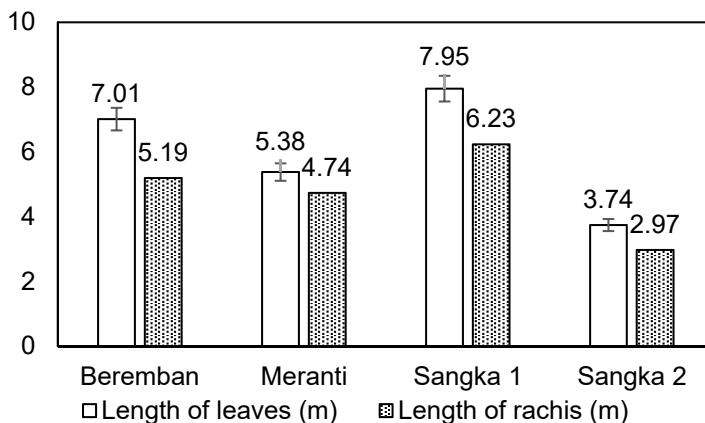


Figure 4. Length of leaves and rachis in various types of sago in Kepulauan Meranti District.

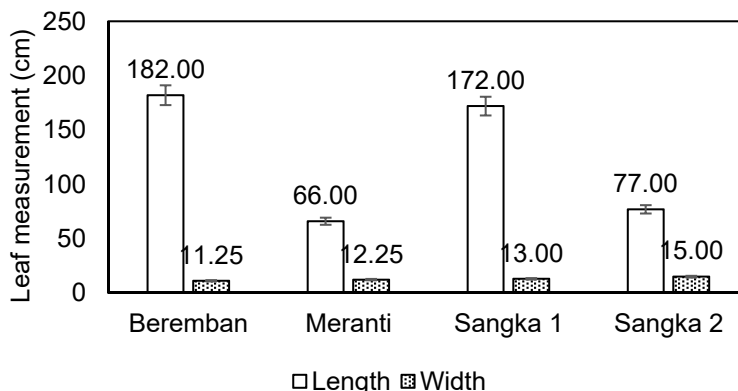


Figure 5. Size of petioles (length, width) among various types of Sago plant in Kepulauan Meranti District.

Table 2. Starch production of different types of sago in Kepulauan Meranti District

Village	Type	Water content (%)	Yield (%)	Dry starch production (kg per trunk)
Bandul	Beremban	42.80	18.88	318.64
	Meranti	42.36	21.53	174.49
Mengkirau	Beremban	47.01	15.20	112.06
	Meranti	47.05	17.41	118.08
Tanjung Peranap	Beremban	40.84	17.67	109.58
	Meranti	37.04	25.64	127.31
Bagan Melibur	Beremban	51.77	14.69	81.65
	Meranti	50.78	14.42	105.01
	Sangka 1	49.59	14.55	82.12
	Sangka 2	49.12	17.63	232.51
Average		45.84	17.76	146.14
Standard deviation		4.84	3.58	75.72
Coefficient of diversity (%)		10.56	20.14	51.82

the highest yield (25.64%). On the other hand, Meranti sago from Bagan Melibur Village had the highest water content (50.78%) and consequently, the lowest yield (14.42%). This is influenced by the temperature and the starch drying process. Surlianto et al. (2015) stated that the water content is highly influenced by temperature and the length of the drying time.

Starch production, which seems to be related to the trunk morphology, is affected by both genetic (intrinsic) and environmental (extrinsic) conditions (Dewi et al., 2016). Sago trees that have a long, circular, and large trunk diameter will usually have high starch production. Sago starch production is positively correlated with stem weight and starch content in the stem ( $r = 0.9$ ; Ehara, 2009), and according to Flach (1997) stem circumference is more important in influencing pith, thus starch production, in the sago trunk compared to stem length.

When sago starch from the different plant types were analyzed for their composition, it was found that Meranti sago from Tanjung Peranap Village (15.95%) and Beremban sago from Bandul Village (13.95%) had the highest water content. These water content exceeded the SNI limit (Indonesian National Standard) for sago starch of 13% (BSN, 2008). The lowest water content was recorded from Sangka 2 (9.68%) from Bagan Melibur Village (Table 3). In terms of ash content, Beremban Sago from Bandul Village had the highest ash content of 0.56%, Beremban Sago from Tanjung Peranap Village had the lowest ash content of 0.09%. Jading et al. (2011) stated that the average ash content produced from three drying methods can be at 0.20-0.24%. The level of sago ash from Bandul Village exceeded the maximum SNI limit, which is 0.5% (BSN, 2008). High levels of ash in food ingredients reduce the quality of the foods.

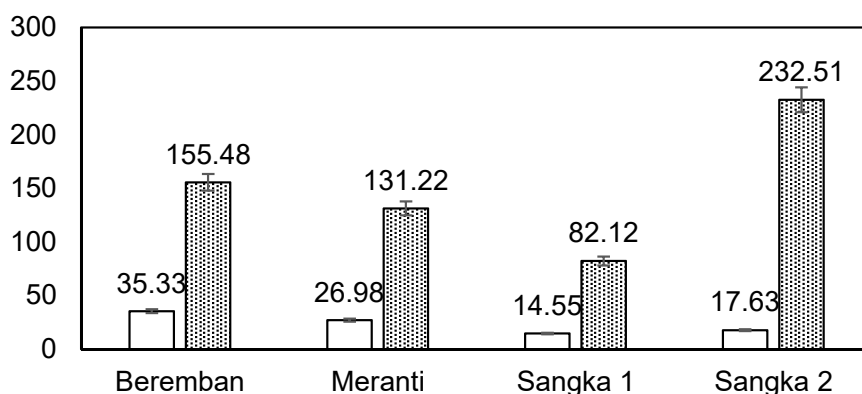


Figure 6. Starch production in various types of sago in Kepulauan Meranti District.



Table 3. Starch components from different types of sago in Kepulauan Meranti District

Village	Type	Content (%)				
		Water	Ash	Fat	Protein	Carbohydrate
Bandul	Beremban	13.95	0.56	0.23	0.93	84.34
	Meranti	12.68	0.28	0.21	1.25	85.59
Mengkirau	Beremban	10.45	0.30	0.20	0.58	88.48
	Meranti	11.05	0.19	0.17	0.75	87.86
Tanjung Peranap	Beremban	12.81	0.09	0.28	0.33	86.50
	Meranti	15.95	0.21	0.14	0.66	83.04
Bagan Melibur	Beremban	10.00	0.27	0.24	0.67	88.84
	Meranti	10.22	0.19	0.19	1.11	88.31
	Sangka 1	10.26	0.24	0.10	0.17	89.24
	Sangka 2	9.68	0.15	0.21	0.17	89.80
Average		11.70	0.25	0.19	0.66	87.20
Standard deviation		2.07	0.13	0.05	0.37	2.25
Coefficient of diversity (%)		17.69	51.96	25.82	55.82	2.58

The lowest fat content among the sago trees was recorded from Meranti sago obtained in Tanjung Peranap Village at 0.14% while the highest fat content was detected in Beremban sago from Tanjung Peranap Village at 0.28%. Sago fat is a type of vegetable fat (Hermanto et al., 2010). Previous study showed that the protein content of sago starch from trees in South Sorong and Sorong ranged from 0.01-0.07% (Adisti, 2016). In the current study, highest protein content was in Meranti sago from Bandul Village, i.e. 1.25%, whereas the lowest was in Sangka from Bagan Melibur village, i.e. 0.17%. The carbohydrate content of all sago trees were similar and ranged from 83.04-89.80%. The carbohydrates content of all the sago in this study exceeded the minimum limit minimum carbohydrate level set by SNI of 65% (BSN, 2008).

The variation of sago morphology reflect the interaction of various factors, including the evolutionary history of the species, geographic range and genetic diversity of this species. Further studies should be directed to understand the genetic diversity of sago in Indonesia, to identify the high yielding accessions with fast growth rate and adaptable to diverse environment.

## Conclusion

Three different types of sago in Kepulauan Meranti Regency, Riau, Indonesia, has been recorded, namely Beremban, Meranti and Sangka. These trees exhibit variations in their vegetative morphology, starch production and sago composition. Morphological measurements and starch component analysis showed that variations among the different types

of sago could be affected by the soil types. Based on starch production Beremban sago from Bandul Village has the highest production of 318.637 kg per trunk. Further research should be conducted to gain better understanding about the genetic diversity of sago, to identify superior sagos and develop them as the source of starch in Indonesia.

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