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Morphology and Starch Production Potential of Sago Palm Found in Village Haripau, East Mimika Subdistrict, Mimika, Papua Province, Indonesia

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Abstract

The largest sago palm (Metroxylon sagu Rottb.) growing area in the world (85%) is in Indonesia, and 95% of sago area in Indonesia is in Papua and West Papua. Field observation of accessions of sago palm was conducted at the sago growing area at Hiripau village. The aim of the study was to determine the diversity of sago palm accessions from Hiripau Village, and compare their morphology and starch production. Based on interview with the local farmers, the four accessions of sago palm dominated the Hiripau area are Nakowai, Mapartaro, Tuhai, and Korearipi. These accessions vary in the spine characteristics, features of the trunk, leaf, pith, and starch production. Sago Mapartaro leaves are the largest (23.56 m^2) and the leaflet areas are almost twice the size of the other accessions. Tuhai has the highest starch yield but it has high ash content resulting in low starch quality.

Keywords: sago variability, leaf spine, starch yield

Introduction

Sago palm (*Metroxylon* spp) belongs to the Arecaceae family; sago grows to form clumps with many suckers. The main part of the sago palm is the trunk that has accumulation of carbohydrates. Saitoh et al., (2008) reported, the production dry starch in one trunk reaches 835 kg. The leaves on sago palms are similar to those of other types of palms. The leaves are made up of leaflets that attached along the rachis. In some types of sago, there are spines attached to the midrib, leaflets, trunk whereas some types of sago are spineless.

Indonesia is the center of diversity for sago palm in the world (Abbas et al., 2010; Flach 1983; Bintoro et al., 2018). In Indonesia, sago can be found not only in Papua or Maluku island, but also in Sumatra, Borneo, Celebes (Sulawesi), and Java island. The sago palm in Indonesia comprise 85% of the sago worldwide, and 95% (5.2 million ha) of sago area in Indonesia is in Papua and West Papua (Bintoro et al., 2018). The morphological and genetic diversity in these regions is inferred to be high (Dewi et al., 2016) due to the crosses that occur naturally (Schuilling, 2009). According to Abbas (2018) Papua exhibited the largest genotype diversity in their population based on Wx gene markers, and Papua it is considered to be the center of sago palm genetic diversity in Indonesia.

The local people in Papua and West Papua have a simple method to classify sago. They differences based on shape (trunk shape, spine or spineless) and choose the best sago with the highest pith content based on local experience. Because sago grows as a natural stand, it is possible to have very high sago diversity due to cross-pollination (Pratama, 2018). Sago trees growing in a certain area could be from one or more species. Samples from each putative species (henceforth called ‘accessions’) are obtained and they represent the diversity of Sago in the area.

Dewi et al. (2016) reported the diversity in morphology of sago palm based on morphological characteristics such as shoots color, crown shape, trunk height, number of leaflets, existence of spine, starch content, pith and starch color. From these morphological characteristics, 12 accessions from the wild stand of sago palm in South Sorong District have been identified (Dewi et al., 2016). In addition, Limbongan (2007) reported sago diversity based on the presence of spines, plant height, stem circumference, and starch color.

Mimika District in Papua Province has an extensive growth of wild sago trees, i.e. 382,189 ha, and it has natural of sago stand. Currently there are limited studies on sago diversity in Indonesia and in the world. The objective of this study was to determine the diversity and production potential of sago (*Metroxylon* spp) in Hiripau village, East Mimika sub-district, Mimika District, Papua Province, Indonesia.

Materials and Methods

Field observations were conducted in the natural sago stand area of Hiripau village from July to September 2016. Data were collected through field observations and interviews with sago farmers. Each sago accession observed had entered the ready-to-cut (harvest) or ripe phase. The location of accessions were marked using Garmin GPS 64s series. Not all people in the Hiripau know about sago plants in the sago region. In general, people only recognize sago at their maturity phase (harvest time). There is a huge gap in the knowledge on sago between the older and younger generation of Hiripau, therefore only the older people (local term: *porapoka*) in the area were interviewed and particularly, the community leaders of the Hiripau people.

The accessions of sago were observed using the following parameters: 1) trunk (height, diameter of trunk at base (bottom), middle, and top, bark thickness); 2) leaf (number of leaves, number of leaflets, leaf area, width of leaflets, length of rachis, length and width of the petiole); 3) spine or spineless, spine spacing, spine pattern, length of spine); 4) leaf color, bark, and pith of each accession were also observed and determined using the Royal Horticulture Society Color Chart 2015; 5) sampling of the pith of each accession was carried out using a sample ring on three parts of the trunk (bottom, middle, and top).

The carbohydrate content of sago starch and analysis of chemical composition of sago starch was conducted at the Food Technology Laboratory IPB Bogor using the AOAC method (2006).

All data obtained were expressed in average. Standard deviation and coefficient of diversity were calculated using Minitab 16.

Results and Discussion

General Environment

Natural sago stand area in Hiripau village is located at an altitude of 10-26 meter above sea level. The area is semi-permanently flooded. The sago area is adjacent to the big river (Wania River) that in the rainy season, the water overflows and floods the sago growing area. The area has a gley type mineral soil with a top layer rich in organic matter from the decomposition of dead leaves and plants. The surface of the soil is also covered with mud deposits from the Wania River overflow and in steady conditions ranging from 0-15 cm.

In general, the sago trees in Hiripau village are naturally found in wetlands; this ecology seems to be optimal for sago. According to Muhidin et al. (2016a) sago grows better in wetlands than in dry land. Sago area in Hiripau village is located in lowland areas. Sago grown in the lowlands more quickly produce flowers compared to those grown in the highlands. Sago grown on the plateau has a longer vegetative phase (Muhidin et al., 2016b), so sago that grow in the lowlands, such the village of Hiripau, can be harvested earlier compared to sago growing on the highlands.

The vegetation in Hiripau village is heterogeneous, consisting of various types of timber trees in various stages of development (mature trees and seedlings), bamboo, and palm trees, but forest areas are dominated by sago stands that form clusters. The humidity in the sago area is between 72% -81% with the air temperature of 27.6 to 31.6^{0}C.

Local Community Interview

Based on field observations and interviews, four local accessions of sago are recognized by the local community. The accessions of sago were given local names as follows: Nakowai, Mapartaro, Tuhai, and Korearipi. Of the four accessions, one of them is unbounded sago (Korearipi). During the field observation, flowering sago accessions were rarely observed. This is because the harvesting of sago had been conducted before the sago plants started flowering.

Morphology of Sago Accessions

The trunk condition of each accession varies. Generally, the accessions (except for Tuhai) have dead stump that attaches to the surface of the chief plant trunk (Figure 1). The size of the trunk (height, diameter) also varies. Nakowai has a high trunk, whereas Mapartaro has large and short trunks (Table 1).

Nakowai and Mapartaro are the most accessible accessions in the sago forest in Hiripau. Both are spine accessions with almost identical features. The striking difference of both accessions is the size of the trunk. Hiripau people recognize Nakowai with its tall trunk, while Mapartaro is characterized with a large but short trunk.

The Hiripau people recognize the accessions of sago based on whether they have spine or are spineless. The spine accessions are differentiated by size and trunk shape. The visible features of the trunk is the basis for the people of Hiripau village to distinguish sago accession (Figure 2).

The number of leaflets do not vary among the four accessions. Mapartaro has the longest rachis but shorter petiole size compared to the other accessions. The number of leaflets on the left and right sides of the leaves of each accession varies. In Nakowai, Mapartaro, Tuhai and Korearipi there are more leaflets on the left side than the right side of the leaves. Mapartaro has the largest lea and leaflet size compared to the other accessions (Table 3).

Table 1. Characteristic of trunks of the four sago accessions in Hiripau village.

Accession	Height (m)	Diameter (cm)	Bark thickness (cm)	Trunk circumference (cm)
Nakowai	12.28	45.60	1.54	140.00
Mapartaro	7.90	54.30	1.54	55.00
Tuhai	11.80	45.60	1.65	125.00
Korearipi	13.20	40.30	1.90	120.00
Average	11.30	46.45	1.66	135.00
Standard deviation	2.43	5.80	0.17	15.81
Diversity coefficient (%)	20.69	12.48	10.15	11.71

Nakowai is 12.28 m tall while Mapartaro is only 7.9 m. However, the diameter and circumference of the Mapartaro rod is greater than that of Nakowai, Tuhai and Korearipi. Mapartaro also has along the trunk. Tuhai has a unique trunk shape with the seedling growing in the middle of the trunk so that the rods are seen in a continuous manner.

The Mapartaro leaves are the largest (23.56 m^2) compared to the other accessions. The leaf and the leaflet areas of Mapartaro are almost twice the size of the other accessions. The area of the leaves is influenced by the length of the rachis. The longer rachis will contain more leaflets in the midrib making the leaves more capacious. Although there are more leaflets on the left than the right side (Table 2) the width of the leaflets on the right side is broader than the leaflets on the left side of the rachis (Table 3). The difference in the number of leaflets on the left and right sides of the rachis is due to the sinistrorse phyllotaxis in sago plants (Nakamura and Goto 2015). Sinistrorse phyllotaxis can be seen by looking at the direction of the leaf arrangement. If the direction of the leaf composition is counter-clockwise, it is called sinistrorse, and if it is clockwise it is called dextrorse. Another difference in the morphology of the leaves is the presence of a white band on the back of Korearipi leaves (Figure 3). The white band extends from the

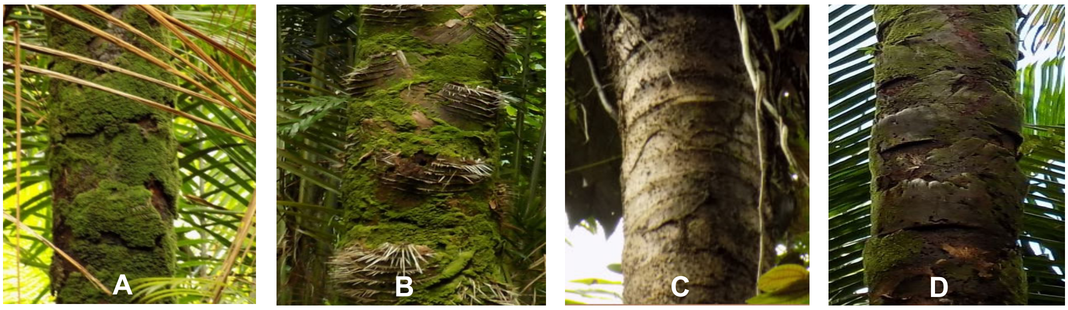

Figure 1. Trunk variations: Nakowai (A), Mapartaro (B), Tuhai (C), and Korearipi (D)

The sago accessions from Hiripau village do not vary in leaf shapes; Korearipi has a white band in the middle of the midrib (leaf bone) in the back. The number of leaves at the harvest stage among the four accessions is at 14-22 (Table 2). The number of leaves of the four accessions ranged from 14-18 midribs, which is consistent with Schuiling (2009) that sago in the adult vegetative phase has the average number of leaf of 14 to 22 per tree. Sago tree begins to initiate flowers at the harvest stage. The new leaves that grow will be smaller in size with short rachis and the number of leaflets is also fewer than the previous phase.

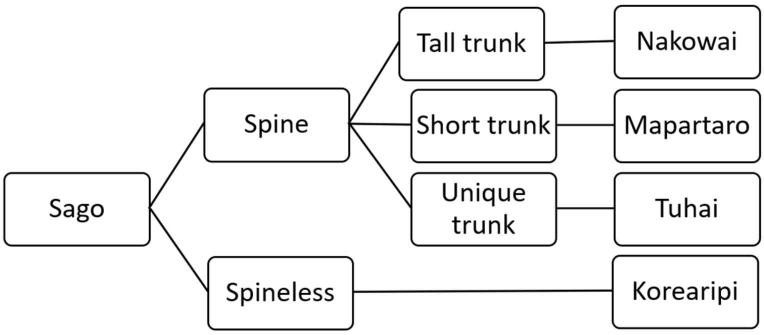

Figure 2. Hiripau method to distinguish sago accessions

Table 2. Leaf characteristics of sago accessions in Hiripau village

Accession	Leaf number	Leaflet number		Leaf length (cm)	Rachis length (m)	Petiole length (cm)
		Adaxial-left side	Adaxial-right side			
Nakowai	14.00	74.00	79.00	6.90	5.07	183.00
Mapartaro	14.00	85.00	88.00	8.80	8.01	79.00
Korearipi	17.00	85.00	88.00	6.72	5.67	105.00
Tuhai	18.00	72.00	75.00	6.22	4.99	123.00
Average	15.75	79.00	82.50	7.16	5.94	122.50
Standard deviation	2.06	6.98	6.56	1.13	1.42	44.19
Diversity coefficient (%)	13.06	8.83	7.95	15.79	23.86	36.08

Table 3. Leaf area and leaflet area of sago accessions at Hiripau village.

Accession	Leaf area (m^2)	Leaflet area (cm^2)	
		Adaxial-left side	Adaxial-right side
Nakowai	13.00	11.15	23.15
Mapartaro	23.56	16.35	36.00
Tuhai	12.13	10.32	10.60
Korearipi	13.23	9.71	10.77
Average	15.48	11.88	20.13
Standard deviation	5.41	3.04	12.11
Diversity coefficient (%)	34.95	25.54	60.13

petiole to the rachis on the back of the midrib. The band on the back of the midrib is found only in the spineless accessions. This feature has also been found in other spineless sago accessions in the eastern Indonesian archipelago (North Sulawesi and Maluku), one accession with a slightly black band (Roe) and three accessions with brown band (Tewasen / Rumbia, Beka bawes, Roku mamo) (Ehara et al., 2000). Based on research conducted by Ehara (2009), sago diversity in eastern Indonesia is genetically correlated to geographical distribution. Accessions found in the same location are most likely to be similar in morphology.

Figure 3. White band (black arrow) on the abaxial of Korearipi leaf midrib.

Spines are found only in three accessions: Nakowai, Mapartaro, and Tuhai. Spines were present on every single leaf midrib except during the harvest phase. The spines can be seen as traces or have been broken off in the leaf midrib during harvest phase (Figure 4). Spines in the midrib (petiole and rachis) of seedlings have different densities (Table 4). Spines are also present on the side of the mother plant and leaflets from the sucker.

The color of the mother plant leaves and leaflet can be described as green and yellow-green based on the RHS Color Chart 2015 (Table 5). The color of the sucker leaflet is more varied and can be described as green, yellow-green and grayed-purple. The color of the bark and pith are as follows: brown and greyed-purple for the bark, and white and orange-white for the pith.

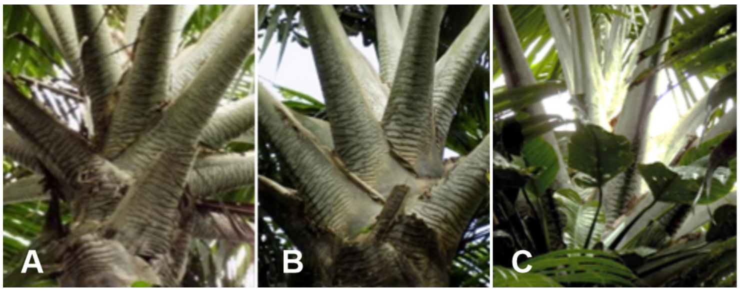

Figure 4. Variations of spine traces at adult phase of sago leaves: Nakowai (A), Mapartaro (B), Tuhai

The spines traces on the leaves at the Nakowai, and Mapartaro troughout the petiole to the mid of rachis, while the Tuhai spines traces is only at the base of petiole. The spine traces pattern of each accession varies both on the mother plant petiole and on the sucker. The spine on the sucker forms a scattered or random pattern (spotted) and surround the petioles (rimmed). The traces on the mother plant form regular pattern (straight) and random. Spines are present on both sides of each leaflet for all accessions, except Korearipi. In Mapartaro the spines of the dead leaves are still attached to the trunk (Figure 1B). Spines are also present on both sides of the leaflet and midrib of the leaves in the mother plant leaves and the sucker, except on Korearipi. The density of spines on the petiole and rachis in the sucker varies from 6-12 cm (Table 4). According to Novero et al., (2012), the appearance of spines in sago is epigenetic, which means that the spines in sago plants is controlled by genes, expression of which is caused by other factors, in addition to changes in basic DNA sequences. Environmental factors could influence the morphology of sago plants.

The green color of the leaves of the parent plant is similar to those of the leaflets and midrib leaves, as well as the bark and pith, whereas the color of the sucker leaflet svaries. In Mapartaro the leaves on the sucker is red purple while on the other accessions, the leaves look green or greenish yellow. The color of leaflets on new leaves is one of the sago characters that is easy to distinguish and can be used as a distinguishing characteristic because it is not influenced by the environment (Dewi et al., 2016). The leaflet color is one way for people in the South Sorong to differentiate the various accessions of sago palm. Sago pith color on sago spine accessions (Nakowai, Mapartaro and Tuhai) tends to be almost similar (Table 5). The pith of these accessions is white. Based on the Royal Horticulture Society (2015) the pith color of Nakowai is pale yellow green, while the accessions of Mapartaro and Tuhai are pure white. The pith color of the Korearipi is orange-white or yellowish pink. The color differences indicate the activity levels of polyphenol-oxidase on the pith of each accession. Konuma et al., (2012) reported that the brownish red color of starch and sago pith

Table 4. Variation in the spines on mother plants and sucker of different accessions of sago from Hiripau village.

Accession	Spine spacing of the mother plant (cm)	Spine spacing of the sucker (cm)	Length of the spine (cm)
Nakowai	4.54	12.11	4.81
Mapartaro	7.10	9.08	4.08
Tuhai	3.89	6.15	3.86
Average	5.18	9.11	4.25
Standard deviation	1.72	2.98	0.49
Diversity coefficient (%)	32.78	32.70	11.70

Table 5. Observation of leaf and leaflet color* of the sago plant accessions.

Accessions	Mother plant leaflet	Sucker leaflet	Bark	Mother plant leaves	Pith
Nakowai	NN137B	152A	200B	143B	155C
Mapartaro	143A	183A	185A	143A	N155D
Tuhai	137A	137A	200A	144A	N155C
Korearipi	144A	143A	200B	144A	159A

*Color code according to RHS2015, where 125-143 = *Green group;* 159 = *Orange-white group;* 144-154 = *Yellow-green group;* 183-N187 = *Greyed –purple group;* 155-NN155 = *White group;* 200-N200 = *Brown Group*

indicates high levels of polyphenol-oxidase activity. Differences in the color of the pith and starch indicate the differences in the type of sago growing in the ecosystem.

Starch Production

The average production of dry starch of sago accessions from Hiripau village was 174.83 kg per plant, with the lowest dry starch content coming from Nakowai and the highest from Tuhai (Table 6). The lowest yield of starch comes from Nakowai while the highest comes from Korearipi. The average water content of starch was 16.2%.

According to Dewi et al. (2016) the high production of sago starch is influenced by genetics and environment. Each accession has a different production of starch seen from the difference in the yield of each accession. The difference in yield is also influenced by the water content in the sago pith causing low yield of sago starch in the pith.

The fat, protein, and carbohydrate contents of the four accessions of sago from Hiripau village did not vary significantly. With regard to ash content in dry starch produced, Tuhai has the highest at 2.1%, indicating the presence of inorganic materials. Among the four accessions, only Nakowai has an ash content that is within the Indonesian National Standard (SNI = 0.5%). High ash levels determine the quality of food. The proportion of ash content in foods is influenced by several factors, such as plant species, soil nutrient state, plant maturity, climate, growing area, and age of sago cutting (Adisti, 2016). Based on research conducted by Konuma et al. (2012) sago that grows in waterlogged land, in acidic conditions, and areas with high concentration of sulfur, will produce starch with high ash content.

Table 6. Potential starch production of the four sago accessions from Hiripau village.

Accession	Rendemen (%)	Water content (%)	Starch production (kg per plant)
Nakowai	9.00	15.60	104.38
Mapartaro	12.00	15.70	116.47
Tuhai	20.00	17.70	275.04
Korearipi	23.00	15.60	203.45
Average	16.00	16.20	174.83
Standard deviation	6.58	1.03	80.10
Diversity coefficient (%)	41.14	6.41	45.79

Table 7. Chemical composition of sago starch among different accessions from Hiripau village

Accession	Ash content (%)	Fat (%)	Protein (%)	Carbohydrate (%)
Nakowai	0.23	0.16	0.52	83.10
Mapartaro	0.63	0.29	0.53	82.70
Tuhai	2.10	0.29	1.53	78.10
Korearipi	0.58	0.18	0.53	83.08
Average	0.89	0.23	0.78	81.75
Standard deviation	0.82	0.07	0.50	2.44
Diversity coefficient (%)	93.71	30.33	64.53	2.98

Conclusion

Four sago palm accessions in Hiripau have been identified by the local farmers, i.e. Nakowai, Mapartaro, Tuhai and Korearipi. The four sago accessions vary in the leaf, spine, and trunk morphology. The starch production can reach > 200 kg dry starch per trunk. Tuhai has the highest potential yield but had high ash content, indicating low starch quality.

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