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Assessment of Morphological Attributes of Sago Palm Accessions of Aimas, Sorong, West Papua, Indonesia

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Abstract

Sago palm has the highest starch content compared to the other source of carbohydrate crops such as cereal and tuberous crops. Sago palm can produce about 200-400 kg per trunk after 7 to 10 years. This research aimed to characterize several sago palm accessions in Aimas, Sorong District, West Papua Province, Indonesia. Eight sago palm accessions were studied, Waruwo, Wasulagi, Wasenan, Wayuluk, Wagelik, Wanegles, Wawun and Wafabala. Among these accessions, there were many differences based on trunk morphological characteristics which includes trunk height, diameter, circumference, and bark thickness, leaf number, length of rachis, length of petiole, and spine. Five accessions with potential yield of more than 200 kg dry starch per sago trunk are Waruwo, Wasulagi, Wasenan, Wayuluk and Wagelik. Stem morphological characters affect palm sago production, because the starch is located in the pith of the stem.

Keywords: starch, eastern Indonesia, Metroxylon sago

Introduction

Indonesia ranks number 4 in the list of countries by population, i.e. 272 million people in 2019, which means Indonesia needs a high amount of foods every year, particularly rice. Indonesian import of rice has been consistently high, which was 1400 MT in 2019 (USDA, undated). One of the solutions for food security is food diversification and promoting alternative of staple foods to Indonesian people, thus reducing dependency on rice.

Sago in Indonesia has not been used optimally and its processing is still conducted traditionally by smallholder plantation. By now, several companies have begun to work on sago but has not resulted in significant productivity improvement. High starch potential of sago can be utilized as source of carbohydrate. Sago may produce 20 to 40 ton. ha^{-1} starch, which is higher than other carbohydrate-producing crops (Bintoro et al., 2007; Jong et al., 2006; Bintoro et al., 2010). Therefore, sago has high potential as local food source alternative.

Sago can also be used as raw material to produce liquid sugar. The production of sugar from sago starch is superior over other alternatives as it is easier and has a lower cost of production. A kilogram of dry sago starch can produce 1 liter of liquid sugar (Pratama 2015). A well-managed sago production can yield 25 tons of dry starch per hectare per year, equal to sugarcane production and higher than cassava and potato (10 to 15 ton per hectare per year) (Bintoro et al., 2010).

Papua and West Papua are the regions with the highest sago population in the world and also contain a very high sago genetic diversity. Abbas et al. (2010) stated that Papua is the center of origin of the sago palm. Sago has different accessions and names in different regions (Dewi, 2015). Those accessions can be differentiated by morphological characteristics such as shoot color, size, density, hardness, spine position, leaf rachis color, trunk diameter, height, and starch color (Bintoro, 2008).

A morphological diversity marker is the initial step that can be observed directly based on a secondary characteristic, such as: trunk height, trunk girth, leaf shape, and leaf color. The potential of using a morphological diversity as a tool to conduct genetic characterization had been known to include morphological, cytological, and molecular markers (Aktrinisia, 2010).

Identification of sago accessions was conducted to identify sago accessions with high starch production. Moreover, information about genetic diversity is vital in conserving the germplasms and for the genetic wealth of a country. This research objective is to study the morphology and production potentials of several sago accessions in the Aimas District, Sorong Regency, West Papua Province.

Materials and Methods

This research was conducted from August to December 2016 in Aimas District, Sorong Regency, West Papua Province, Indonesia. Direct observation was conducted on selected plant samples. The observation on morphological characteristics was conducted before the plants were cut down. Sampling was conducted by randomly selecting each sago accession. Sample plants were sago palm that has met harvesting criteria i.e. generative stage (at flower initiation stage). Besides primary data, secondary data was also collected on weather related data including rainfall, temperature, and humidity.

Observation and recording was conducted on hydrological condition, altitude and coordinates of the sago plantation. Morphological characters that were recorded include trunk (length, diameter, girth, bark thickness). Trunk length was measured on the harvested plants from the base of the trunk above ground to the lowest leaf using measuring tape. Trunk diameter was measured in three points, base, middle and tip using measuring tape. Trunk diameter was observed after the plant was cut.

The circumference of the trunk was measured at 1 m above ground using a measuring tape. The thickness of the bark was measured manually using caliper at the base, the middle, and the tip of the trunk. Bark is the part of the stem from the outer surface to the border of the pith.

Leaf observations included leaf color that was observed visually on the mother plant and tillers by matching the color with Royal Horticultural Society (RHS) color chart 2015. Number of leaves was observed by counting leaf rachis on mother plants. Leaflet length and width were observed on mother plants by measuring fully opened, second leaf from the tip. Leaflets observed had matured or reached maximum growth (30 – 40 % space from petiole).

Leaflet area was counted using formula by Nakamura et al. (2005) as follows

$$S(e) = 0.785\ L\mathit{leaflet} \times W\mathit{leaflet}$$

Where
S(e) : leaflet area
L*leaflet* : leaflet length
W*leaflet* : leaflet width

Leaflets that were recorded are those that are fully opened on the left and right side of the rachis. Rachis length was measured on the fully opened leaf, at the part where leaflet emerges using a measuring tape. Petiole length was measured on fully a opened leaf, from the base of the petiole to the first leaflet. Petiole width was observed and measured at the base of the petiole. Spine observations included the presence or absence of the spine, space between two mature spines, space between row of spines, and longest spine length on each tiller with three replications using a caliper.

Sago leaf area (Figure 1) was calculated using following formula by Nakamura et al. (2009) as follows:

$$S_{leaf} = ab\ \pi/8 + ac/2$$

where
S_{leaf} : leaf area
a : rachis length
b : leaflet length on the left side (L_{CL}) + right side (L_{CR}) on the middle of the rachis (a/2)
c : leaflet length on the left side (L_{CL}) + right side (L_{CR}) on the base of the rachis (a/4)

Yield characteristics included starch production, starch color, starch percentage yield and chemical composition of the starch. Pith was taken from the trunk using a ring sample from which the volume was established (181.3 cm^3) on every 2-3 m. The obtained pith was crushed and placed in a container that had been filled with water. The pith was then crumpled to extract its starch. The extraction was repeated 3 times, each one using 200 ml of water. Water volume for crumpling the pith was the same amount for every repetition. The liquid was then deposited to get the starch. The obtained starch was then dried and weighed. Starch production per plant then was then calculated using the following formula:

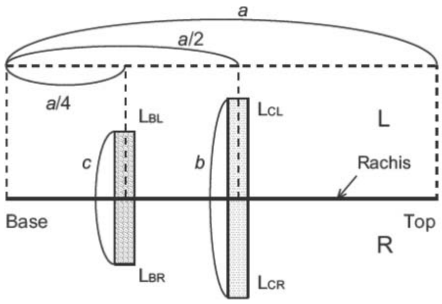

Figure 1. Illustration for measurement of sago leaf area (Nakamura et al., 2009)

Production per plant = trunk volume / sample volume] x dry starch weight

Trunk volume = πr^2 x length, with π= 3. 14 and r = radian of sago trunk

Dry starch weight was the average from sample plants. The percentage of yield was calculated with following formula:

Percentage yield = [dry starch weight from samples / pith weight] X 100%

The dry starch was then analyzed to determine the chemical composition of the starch. Chemical composition of the starch analyzed included water content, ash, carbohydrate, fat and protein (percentage unit). The analysis used was a proximate analysis referred to AOAC (2006).

Results and Discussion

Plant Habit

Sorong Regency is located at 00^0 33' 29'' south latitude and 130^0 42' 48''-132^0 13' 48'' east longitude. Based on its geographical location, Sorong Regency borders Raja Ampat Regency at its north and west, with South Sorong Regency at its south, and Manokwari at its east. The average temperature of Sorong Regency in 2015 was 24.40^0 C. The amount of rainy days in 2015 was 210 days with average humidity of 86.25%.

All of the sago accessions were obtained from one sago village, Aimas sago village. The total sago accessions observed were 8 accessions, Waruwo, Wasulagi, Wasenan, Wayuluk, Wagelik, Wanegles, Wawun and Wafabala. The altitude of the research location was 19 m above sea level (m asl). The research location had mineral soil, with a part of the location being dry land and another part being freshwater swampland 0-5 cm above land surface. Sago accessions in this area are all the sago type which bear fruit one time only and form a clump with tillers. The average amount of sago tillers of Aimas District varied with accessions. Wanegles accession had 7 tillers, Waruwo had 48, Wasulagi had 10, Wasnan had 35, Waluyuk had 29, Wagelik had 12, Wawun accession had 19 and Wafabala had 27.

Sago Morphological Characters

The sago trunk in Aimas District varies in trunk height, trunk diameter, trunk circumference and bark thickness (Table 1). The tallest trunk was found in Waruwo sago which was 17.75 m and the lowest was in Wafabala sago. The largest trunk diameter was found in Waruwo, Wayuluk and Wanegles which was 52.33 cm. The biggest trunk circumference was found in Waruwo and Wanegles accession which was 165 cm. The thickest bark was found in Wafabala accession of 1.09 cm.

The starch production and morphological characteristics of sago palm, including density, height, and plant diameter, vary with accession and environmental factors. Trunk diameter is the characteristic that significantly affected starch production (Dewi, 2015). Sago trunk was the storage for sago starch, the heavier and taller the trunk, the more starch they contain. The height of the superior sago trunk in Sentani Papua ranges from 4-15.2 m (Limbongan, 2007). Ibrahim and Gunawan (2015) also stated that sago trees can grow taller on drier land.

The thickness of the bark is not considered by the locals in harvesting sago because in general the sago bark in Aimas District is not too hard and is thin,

Table 1. Trunk character of several sago accession in Aimas District, Sorong Regency, West Papua

Accession	Trunk height (m)	Diameter (cm)	Circumference (cm)	Bark thickness (cm)
Waruwo	17.75	52.33	165.00	1.51
Wasulagi	13.51	47.83	126.00	1.41
Wasenan	14.5	52.33	160.00	1.12
Wayuluk	15.37	52.00	150.00	1.47
Wagelik	15.71	52.33	158.00	1.90
Wanegles	13.70	36.33	165.00	1.21
Wawun	9.01	48.00	137.00	1.74
Wafabala	13.37	39.33	124.00	1.08
Average	14.12	47.57	48.13	1.43
Standard deviation	2.53	6.35	16.93	0.29
Coefficient of variation (%)	18.89	16.14	13.66	26.86

making it easier to cut down. Sago bark is related to the amount of starch production per trunk, the thinner the bark, the higher the starch production. Akmar (2001) stated that sago bark made up 17.4% of the total weight of sago. According to Idral et al. (2012) the amount of bark and sago *dregs*, i.e. the rest of pith after starch has been extracted, were approximately 26% and 14% of the total weight of sago trunk, respectively. Sago bark and dregs were ligno-cellulose material which was mostly composed of cellulose, hemicellulose, and lignin.

Based on the diversity of sago leaves in Aimas District, the variations were not too high (Table 2). The lowest number of leaves was found in Wayuluk and Wafabala with 14 leaves, while the highest number of leaves was in Waruwo and Wawun with 18 leaves. The most important part in the formation of sago starch was the leaves as the place for photosynthesis. Good growth and development of leaves would affect the growth and development of other organs such as the trunk, bark and pith, so that the formation of starch can be optimal. Starch production was very dependent on the age of the tree and the number of leaves that were formed because during rapid growth 2 leaves could be formed per month while at the time of starch accumulation only one leaf emerged per month (Novarianto, 2013).

In general, all leaves on these sago accessions were classified as parallel or straight-veined leaves with tapered leaf tips and elongated (lanceolate) leaf shapes. The leaves were also an identifier of sago trees that could be harvested. Another criteria of harvesting is the emergence of shoots that are more upright, and leaf rachis are cleaner than younger leaves.

Table 2 showed that the highest number of right and left leaflets were Wawun accessions of 91 and 95. Each individual sago plant has leaflets that can reach 150 strands (Botanri et al., 2011). Nakamura et al. (2004) added that the number of left leaflets was 1-5 more than the right leaflet and the left leaflet was the bottom leaflet.

The length of sago leaves varied from 3.22 to 8 m and petiole length was 35.5 to 60 cm. Leaf length varied depending on the type of accessions, but the leaf tends to be shorter near the tip due to a reduction in the length of petiole and rachis (Yamamoto et al. 2014). The lowest leaf area was 5.39 m^2 in Wasenan sago accession, while the highest was 24.18 m^2 in Wagelik sago accession. The size of the sago leaves affected the absorption of sunlight, higher surface area results in higher absorption of sunlight that can be used for photosynthesis. Furthermore, sago leaves can also function to capture carbon emissions and as oxygen providers (Hariyanto and Siswari, 2011).

Based on sago characteristics that were observed (Table 3), there were seven sago accessions with spine and one spineless accession. The biggest space between spine rows was found in Wagelik (6.5 cm). The biggest space between spine rows on the tiller and the longest spine length found in Wawun which were 5.34 cm and 11.06 cm, respectively. Wawun accessions are found on both dry and swamp land, while spineless accession tend to be found only on swamp land. According to Irawan and Sukania

Table 2. Leaf characteristic of several sago accession in Aimas District, Sorong Regency, West Papua

Accession	Number of leaf	Number of right leaflet	Number of left leaflet	Length (m)	Petiole length (cm)	Petiole width (cm)	Leaf area (cm^2)	Leaflet area (cm^2)
Waruwo	18	84	84	5.76	45.00	14.00	15.00	1.20
Wasulagi	16	91	86	6.83	48.00	12.00	15.51	1.19
Wasenan	17	51	52	3.22	35.50	11.50	5.39	0.64
Wayuluk	14	92	85	6.52	55.00	9.00	16.44	1.30
Wagelik	16	86	80	8.00	44.00	18.00	24.18	2.17
Wanegles	17	80	81	5.42	36.00	10.00	13.34	1.49
Wawun	18	91	95	6.14	60.00	15.50	13.29	1.37
Wafabala	14	81	82	6.60	50.00	19.50	16.83	1.20
Average	16.25	82	80.63	6.06	46.69	13.69	14.61	1.29
Standard deviation	1.58	13.35	12.47	1.39	8.52	3.76	52.05	0.52
Coefficient of variation (%)	9.73	16.28	15.46	22.88	18.26	27.47	1.25	1.26

Table 3. Spine characteristic of several sago accessions in Aimas District, Sorong Regency, West Papua

Accession	Space between spine rows (mother plant) (cm)	Space between spine rows (tiller) (cm)	Longest spine length (tiller)
Waruwo	5.48	3.43	8.74
Wasulagi	0.00	0.00	0.00
Wasenan	5.00	3.97	4.36
Wayuluk	4.59	4.92	4.12
Wagelik	6.50	5.23	2.35
Wanegles	2.52	4.14	2.79
Wawun	5.63	5.34	11.06
Wafabala	4.23	4.01	4.34
Average	4.85	4.43	5.40
Standard deviation	1.27	0.73	3.24
Coefficient of variation (%)	26.09	16.41	60.07

(2015), based on spines that were emerged from petiole surface, sago can be categorized as sago with spine and spineless sago.

Starch percentage yield of all accessions were between 25% and 50%. Water content was between 29% and 72% (Table 4). The lowest dry starch weight was found in Wawun accession with 110.69 kg/ trunk. The highest percentage yield was in Wasenan accession with 361.51 kg per trunk which also gives the highest dry starch potential per sago tree.

Coefficient of variation value of dry starch weight was 39.72%. According to Tenda and Miftahorrachman (2015), coefficient of variation value between 20 – 50% was considered quite high for selection process of mother plant of sugar palm tree based on its sap yield character. Production character was an important characteristic that was affected by genetic and environmental factors, thus production characteristics should be correlated with other morphological characters.

Average fat content of eight sago accession was 0.27%. The lowest protein content found in Wasulagi accession was 0.26% and the highest in Wafabala was 1.49%. Sago is considered to have low fat content (Table 5).

Proximate analysis results showed there were statistically no difference among accessions (Table 5). Sago starch water content did not vary with an average value of 13.69%. Polyana et al. (2008) stated that sago starch water content between 12.53 to 12.96% was suitable as commercial starch. Ash content of 8 sago accessions was between 0.56 – 1.45%. Ash content shows the residue of inorganic minerals from food source. Ash content was affected by several factors such as species, soil nutrient content, plant maturity, climate, growing condition, and harvest age of the sago (Adisti, 2016). The location where sago grew in Aimas District was water-

Table 4. Production characters of several sago accession in Aimas District, Sorong Regency, West Papua

Accession	Percentage yield (%)	Water content (%)	Dry starch weight (kg per trunk)
Waruwo	40.53	60.20	289.21
Wasulagi	43.80	57.33	248.54
Wasenan	43.38	70.33	361.51
Wayuluk	39.51	45.83	211.84
Wagelik	25.52	71.27	215.72
Wanegles	49.01	45.87	128.54
Wawun	37.24	29.80	110.69
Wafabala	41.29	54.00	149.30
Average	40.04	54.33	214.42
Standard deviation	6.83	13.80	85.17
Coefficient of variation (%)	17.06	25.39	39.72

Table 5. Proximate analysis result of sago starch from several sago accession in Aimas District, Sorong Regency, West Papua

Accession	Water content (%)	Ash (%)	Fat (%)	Protein (%)	Carbohydrate (%)
Waruwo	13.72	1.25	0.14	0.33	84.56
Wasulagi	13.46	1.38	0.12	0.26	84.78
Wasnan	13.66	1.15	0.36	1.02	83.81
Wayuluk	13.9	0.84	0.21	0.42	84.63
Wagelik	13.89	0.56	0.22	0.41	84.92
Wanegles	13.61	0.74	0.38	0.42	84.85
Wawun	13.79	1.45	0.16	0.59	84.01
Wafabala	13.43	0.58	0.55	1.49	83.95
Average	13.69	0.99	0.27	0.62	84.44

logged, making the soil anaerobic. The longer sago grows in a water-logged condition, the more starch metabolized into inorganic matter causing higher ash content.

Conclusion

Sago accessions in Aimas District have different morphological characters and production. Based on starch production, there were five accessions with dry starch production of above 200 kg per trunk when they harvested at flower initiation stage. Morphological characteristics particularly trunk height, diameter, and bark thickness, affected production potentials as starch is stored inside the pith.

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