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Morphological Characteristics and Potential of Sago (*Metroxylon* spp.) in Lingga Regency, Riau Islands, Indonesia

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Abstract

Sago (Metroxylon) is one of the local food species with development potential. Lingga Regency is one of the potential locations for sago development. However, no research on the morphological characteristics and production of sago in Lingga Regency has been conducted. The purpose of this research is to determine the morphological characteristics and production of sago in Lingga Regency. This study's sago plants came from six sago-producing villages. Before and after the sago trees were harvested, morphological characteristics and production were observed, with random sampling at each research site. Field observations on the potential of sago stands were conducted at the study site using the transect method with a single plot. Based on morphological characters there are two types of sago in Lingga: spiny and thornless sago. The morphological characteristics and sago production vary greatly between research sites. Sago stands have a production potential ranging from 3.37 to 14.55 tons ha^{-1}. Because they have a starch content of more than 200 kg stem^{-1}, the majority of sago accessions in Lingga are superior accessions with the potential to be further developed. Superior sago comes from the villages of Musai, Pekaka, Keton, and Teluk.

Keyword: *accession, diversification, local food, Metroxylon, starch, yield*

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Introduction

Food diversification is one alternative to achieve national food security (Pudjihastuti et al., 2019). The development of local food commodities needs to be carried out in order to meet the demand for food commodities, including the development of sago, sugar palm, gadung and other local food commodities. One of the potential local food commodities to be developed is sago. Sago (*Metroxylon* spp.) is a palm species native to Southeast Asia, particularly Indonesia, Papua New Guinea, Malaysia and the Philippines (Naim et al., 2016). Sago is a strategic commodity to overcome a country's food insecurity and increase the welfare of farming communities and local income (Pue et al., 2018; Murod et al., 2019). Indonesia has an area of 5.5 million ha of sago palm spread over Papua, Maluku Islands, Sulawesi, Kalimantan, Sumatera, and Java (Djoefrie et al., 2014). Based on data from Ditjenbun (2017), the area of sago managed by smallholders and private plantations is 219,978 ha with sago starch production of 489,643 tons. Sago plants in natural habitats produce sago starch production which varies between 200 kg tree^{-1} (Ahmad et al., 2016), 143.87–402.09 kg tree^{-1} (Pratama et al., 2018), and 275 kg tree^{-1} (Nurulhaq et al., 2022).

Sago contains carbohydrates that can be processed into sugar and bioethanol so that it has the potential to achieve food and energy security for the nation's future (Hayati et al., 2014). Indonesia is the largest sago starch producing country in the world which produces 585.093 tons year^{-1} (Ahmad, 2014). Sago starch can be used to make sago flour. The chemical composition of sago starch consists mostly of carbohydrates, as well as wheat flour, tapioca starch, and rice flour. This allows sago starch to be used as an ingredient for making biscuits, noodles and other food products that are widely accepted and recognized by the public such as brownies or cakes (Putri et al., 2019). Other parts of the sago tree can be used as material for roofs, house floors, animal feed, production of sago caterpillars, and plaiting (Ditjenbun, 2019). Sago has a carbohydrate content of 94 g 100 g^{-1}, so it is able to overcome the problem of national food shortages while reducing dependence on rice and wheat

(Auliah, 2012). Sago is an industrial raw material with various uses, such as the adhesive industry, caramel industry, liquid sugar industry, household use industry, and the cake and food industry (Bintoro et al., 2010). Based on this, the development of sago potential can support national and household food security, as well as strengthen family incomes and open up job opportunities for people in rural areas.

Sago starch production is influenced by environmental factors, namely climate, soil fertility, and hydrological class (Rembon et al., 2014). Farming communities distinguish each accession of sago based on morphological characteristics, namely the presence of thorns, thorn pattern, stem shape and height, and starch quality and production (Pratama et al., 2018). In general, sago is divided into two groups based on morphological characteristics, namely spiny and thornless sago (Pasolon, 2015). It can be found in lower swampy land flooded by water, where other plants are unable to thrive due to a lack of a canal or nourished land. Sago is one of the world's oldest plant families (Abd-Aziz, 2002).

Lingga Regency is an area that has a large diversity of local food potential. One of the main potentials of Lingga Regency is sago with a plantation area of 3,449 ha with a total production of 2,618 tons year^{-1} (Pemda Lingga, 2016). This makes sago very prospective if it is developed as a food estate in Lingga Regency. Research related to the morphological characteristics and production of sago has been carried out in several locations, such as Aimas District, Sorong (Ahmad et al., 2016), Mioko, Mimika (Pratama et al., 2018), and Haripau, Mimika (Nurulhad et al., 2022). However, no research on the morphological characteristics and production of sago in Lingga Regency has been conducted. This study aims to identify the morphological characteristics and production of sago in Lingga Regency, Riau Islands. Information related to the morphological characteristics and production of sago is expected to be used as advice and input to the farming community, industry, and local government in developing the potential of sago in Lingga Regency.

Methods

Time and location This study was conducted from June to August 2022 in Lingga Regency, Riau Islands, Indonesia (Figure 1). Astronomically, Lingga Regency is located between N0°20' and S0°40', and between E104°–105°. In terms of geographic position, Lingga Regency has boundaries as follows: North - Batam City and North Natuna Sea; South - Bangka Sea and Berhala Sea; West - Indragiri Hilir Sea; East - North Natuna Sea. Lingga Regency has tropical and wet seasons with a variation of rainfall average of 261.7 mm for the year 2022. It means that Lingga Regency has a high rate of rainfall. While May, June, and December have the highest rank in the number of rainy days. The average temperature of Lingga Regency in 2022 was 24.1 °C, whereas the average of its relative humidity was 86% (BPS Lingga, 2022).

Research design This study's data was gathered through vegetation analysis and field observations. A vegetation analysis was performed to gather information on potential sago populations at the study site. Potential sago populations

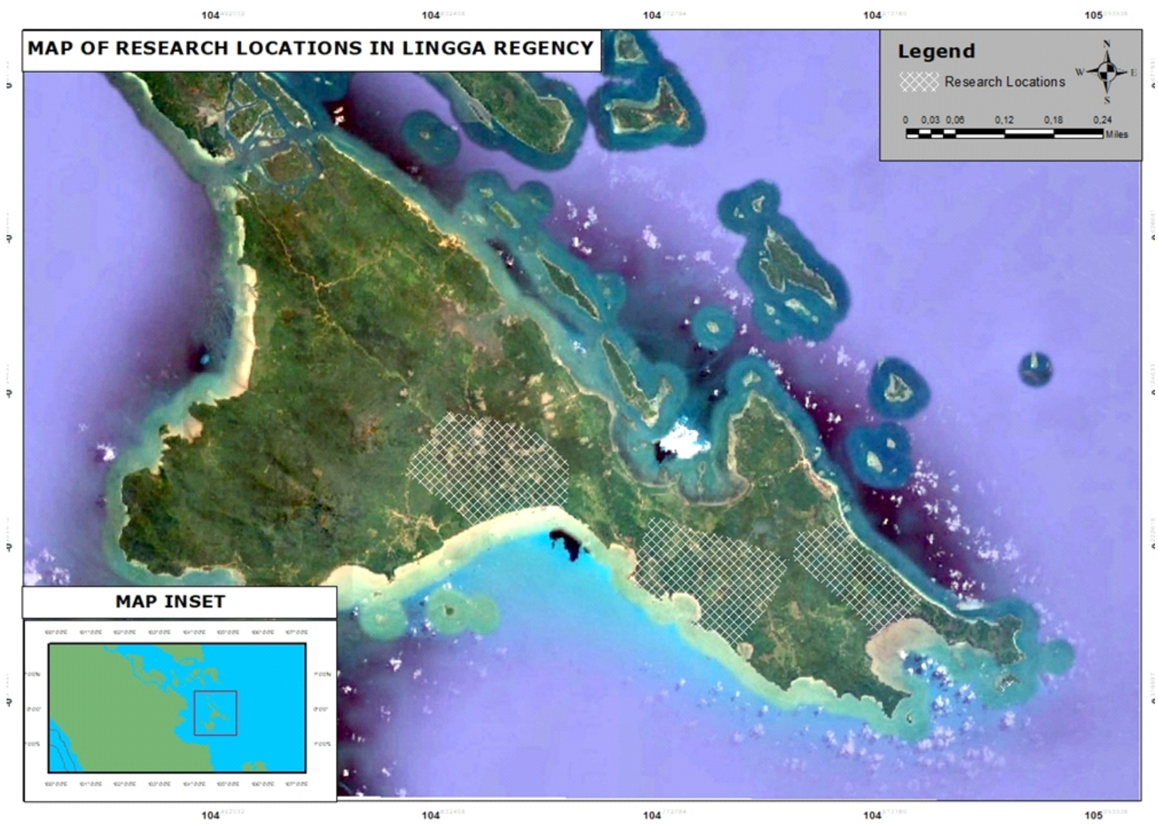

Figure 1 Map of research locations.

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Scientific Article
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were analyzed using observation plots measuring 50×50 m^2 with a plot area of 1 ha. Random sampling was used to observe morphological characteristics and sago production before and after the trees were harvested at each research site. Plant samples are collected from plants that have met the harvest requirements (in the generative phase or at the time of flower initiation). The research design proposed by Nakamura (2005) was adjusted in this study.

Data collection and data analysis The sago plants observed in this study came from six sago-producing villages. The parameters observed were morphological characters and sago potential. Morphological traits and sago quality were the observed parameters.

These morphological characters include 1) stem length, measured on the harvested tree from the base to the lowest leaf midrib (frond-free stem); 2) diameter of the stem, measured at the base, middle, and end of the stem using a measuring tape; 3) the thickness of the bark was measured using a tape measure at several points at the base, middle, and end of the stem; 4) the number of leaves, calculated based on the number of green leaf midribs; 5) leaf color, observed using the Royal Horticultural Society Color Chart 2015 (RHS); 6) the number of leaflets was counted on the left and right sides of the leaf bones (rachis); 7) the length of the leaflets, measured on the number two leaf from the shoot. The leaflets observed were leaflets in the middle of the rachis on both sides; 8) the width of the leaflets, measured on the leaf of the parent plant, namely on the number two leaf from the shoot. The leaflets observed were leaflets in the middle of the rachis on both sides; 9) the leaf area was measured based on the illustration made by Nakamura et al. (2005) which is presented in Figure 2. The leaf area is calculated using the formula stated by Nakamura et al. (2005) as shown in Equation *[1]*.

$$S_{(e)} = 0.785 \times L_{leaflet} \times W_{leaflet} \qquad [1]$$

note: S(e) = area of leaflet, $L_{leaflet}$ = length of leaflet, $W_{leaflet}$ = width of leaflet

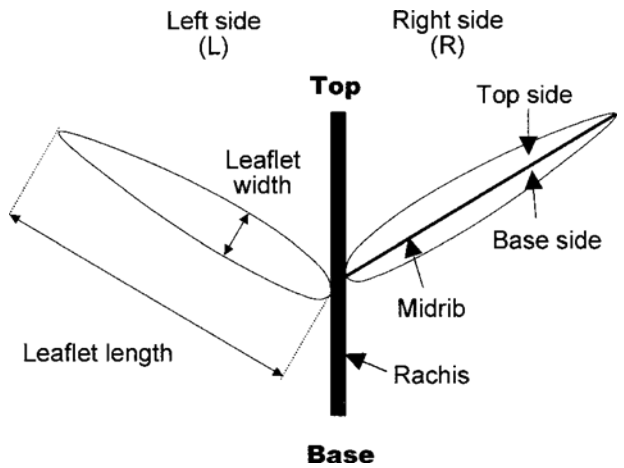

Figure 2 Illustration of leaflet area measurement (Nakamura et al., 2005).

10) leaf area, calculated on leaf number two from above. Illustration of sago leaves and the parameters measured are shown in Figure 3. The area of sago leaves is calculated based on the formula stated by Nakamura et al. (2009), as shown in Equation *[2]*.

$$S_{(leaf)} = \mathrm{ab}\,{}^{\pi}/_{8} + {}^{\mathrm{ac}}/_{2} \qquad [2]$$

note: S_{leaf} = leaf area, a = length of rachis, b = length of the left leaflet (LCL) + right (LCR) in the middle of the rachis (a/2), c = length of the left leaflet (LBL) + right (LBR) at from the base of the rachis (a/4); 11) the length of the rachis was measured from the base of the midrib where the leaflets attach to the tip of the midrib. Petiole length, measured from the base of the midrib to the first leaflet. The width of the petiole, measured at the base of the midrib (Figure 4); and 12) the distance between rows of thorns, measured at the base of the midrib in three replications. In the tillering phase, the distance between the rows of spines was measured on the leaf petiole in three replicates. The longest thorn was measured on the petiole of the tiller by measuring the longest thorn three times.

These sago potential include 1) data collection on the potential of sago stands was carried out by field observation at the study site using the transect method with a single plot measuring 50×50 m^2 (Figure 5); 2) starch production, measured by volume ratio. The pith was taken from the stem using a ring sample (volume 0.000154 m^3) at the base, middle, and tip of the stem. The sago pith obtained is then grated to extract the starch, then the starch is dried. Starch production $tree^{-1}$ is calculated using the formula as shown in Equation *[3]*; 3) starch color, observed using the Royal Horticultural Society Color Chart 2015 (RHS); and 4) the starch yield is calculated using the formula as shown in Equation *[4]*.

$$\text{Starch production} = \frac{\text{stem volume}}{\text{sample volume}} \times \text{weight of dry starch sample} \qquad [3]$$

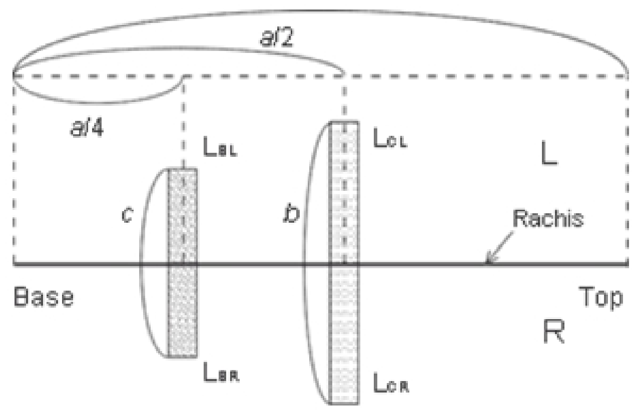

Figure 3 Illustration of leaf area measurement (Nakamura et al., 2009).

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note: *s*tem volume = $\pi r^2 \times h$

$$\text{Starch yield} = \frac{\text{weight of dry starch sample}}{\text{weight of pith}} \times 100\% \qquad [4]$$

Results and Discussion

Morphological characters The Lingga community calls sago species by several local names, including *sagu, rumbia*, and *merie*. The Lingga community recognizes two species of sago, namely spiny sago (*sagu*) and thornless sago (*bemban*) (Figure 6). Based on research conducted by Al Qodri and Wawan (2015) also Gemilang et al. (2019) that people in Lingga recognize two species of sago, namely spiny and thornless sago.

The location of the *dusun sagu* in Lingga Regency is a non-permanently inundated swamp land with a puddle height ranging from 0–10 cm above ground level. Haryanto and Pangloli (1992) stated that the optimal growing place for sago growth is in soils that contain a lot of minerals and organic matter, and fresh water areas but the roots of sago palms are not submerged in water and are not often affected by tidal water. All sago accessions in the study area were hapaxanthic sago, i.e. growth would stop (die) after the sago blossoms and bear fruit and the starch content decreased when the sago had flowered (Ahmad et al., 2016; Dewi et al., 2016). The following is a sago tree that has passed through maturity (Figure 6).

Sago at the research location is the result of planting during the time of Sultan Mahmud Riayat Syah. Currently, the sago area has become a sago forest with no plant cultivation activities, so its growth is not controlled. This is evidenced that many are found in one sago clump, there is only one mature tree that is ready to harvest and has a very close number of tillers in the growth phase of seedlings and saplings (weaning).

The number of ready-to-cut tree leaves from all accessions did not vary much, with an average of 13 leaves

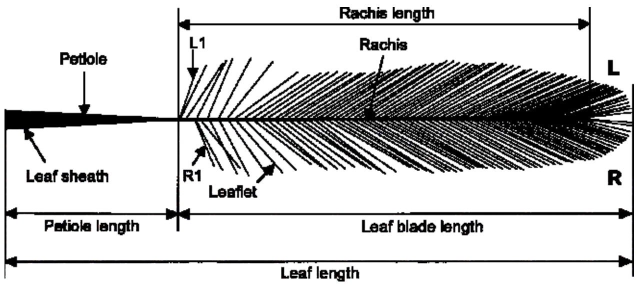

Figure 4 Illustration of sago leaf (Nakamura et al., 2004).

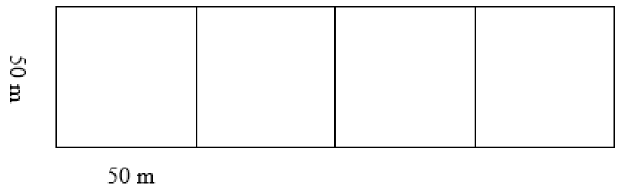

Figure 5 Observation plot design.

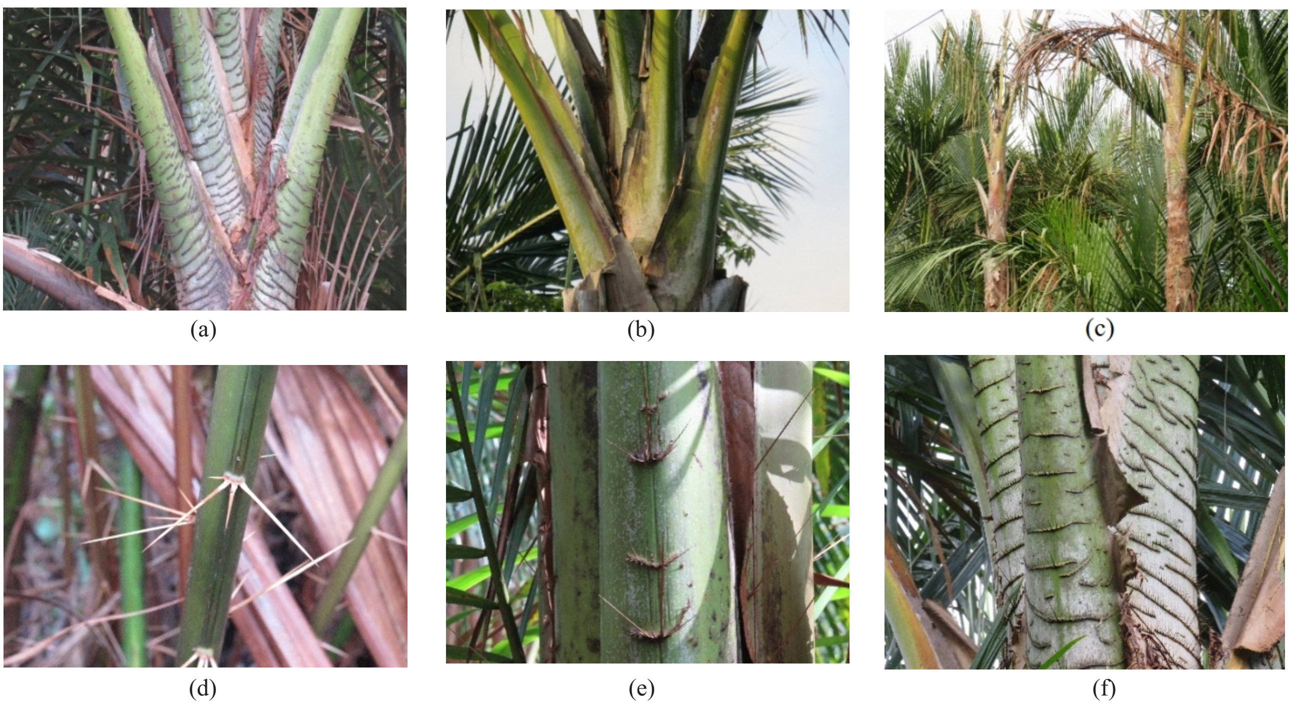

Figure 6 (a) spiny sago species; (b) thornless sago species; (c) a sago tree that has passed through ripening; (d) thorns on seedling; (e) thorns on sapling; (f) thorns on tree.

(Table 1). Sago from Pekaka Village had the highest number of leaves while sago from Keton Village had the least number of leaves. The number of leaflets on the right and left sides were different for each sago tree found in each research location. The difference in the number of leaflets ranges from 1 to 3 strands. The sago palms in the villages of Nerekeh, Panggak Laut, Musai, and Teluk have a higher number of left leaflets, while the sago palms in Pekaka and Keton villages have a higher number of right leaf buds. Leaf length, rachis length, and petiole width did not vary much, while the petiole length varied from 70 cm to the longest 149 cm.

Sago plants that grow in optimal habitats will have 24 leaves in one stem, and every month one new leaf will appear accompanied by the death of one of the oldest leaves (Flach & Schuiling, 1989; Flach, 1997). The size of sago leaves that grow in optimal habitats will have almost the same size in one stem. Optimal habitat will also affect the emergence of spear leaves (Flach & Schuiling, 1989). The average number of sago leaves varies greatly based on several previous studies, including Sentani (Papua) as many as 22.8 strands (Limbongan 2007), Meranti Islands (Riau) as many as 21.57 strands (Novarianto et al., 2014), Mimika (Papua) 17.71 strands (Ahmad et al., 2016), South Sorong (West Papua) 14 strands (Dewi et al., 2016), Indragiri Hulu (Riau) 16.98 strands (Novarianto et al., 2020), and Biak Numfor (Papua) as many as 22 strands (Mustamu et al., 2021). In addition to this, the number of leaves of sago is also influenced by the diameter of the stem, the larger the diameter of the stem, the more number of leaves (Flach & Schuiling, 1989; Flach, 1997).

The number of leaflets that grow on rachis is not the same, this is in accordance with Nakamura et al. (2004) who stated that the number of leaflets on the right and left rachis is different. Based on the results of the study, it was found that the accessions of sago Nerekeh, Panggak Laut, Musai, Keton had more left-sided leaflets, while Pekaka and Teluk accessions had more right-side leaflets. Nakamura et al. (2004) in their research found that the number of leaflets on the left side of the rachis was more than on the right side.

The length of sago leaves found at the research site ranged from 4.1 m to 6.6 m. Flach (1997) stated that the length of sago leaves ranges from 58 m and there are 100–190 leaflets, each leaflet has an average length of 150 cm and a width of up to 10 cm. The number of sago leaf buds at the study site ranged from 81 to 146 strands with an average length of 135.67–147 cm. The difference in the length of sago leaves is due to differences in sago growing habitat and nutrient content in the soil. This is in accordance with Gardner et al. (1985) who stated that the nutrient (nitrogen) is very influential on leaf expansion, especially on the width and area of plant leaves.

Sago has elliptical leaflets, so that the length of the leaflets on the ½ and ¼ rachis are not the same. The length of the leaflets on the right and left sides of the rachis were not the same, both in the ½ and ¼ rachis. Some accessions of sago palm had leaves on the longer right side and some had leaves on the longer left side (Table 1). The width of the leaflets is quite varied, ranging from 5.9 cm to 12.5 cm. The sago plant with the widest leaflets came from Nerekeh, while the sago plant with the narrowest leaflet came from Pekaka. The area of the leaflets is calculated from the longest and widest leaflets (the middle of the rachis). Leaf area is an area calculation based on all the leaflets in one leaf. The Musai accession had the widest leaf area and the Pekaka accession had the smallest.

The sago found at the research site was spiny and thornless sago species. Thorns are one of the easiest morphological characters to distinguish sago species. Spiny sago accessions have the same shape and arrangement of spines. The spines on sago palms are still tight and long, but as they get older and enter the generative phase, the spines will become shorter and thinner (Figure 6).

The thorns that grow form a pattern and are arranged in rows, although there are thorns that grow outside the row, they are smaller and shorter in size. The length of the longest spine of the smallest tiller was 5 cm and the largest was 16 cm

Table 1 Leaf and leaflet characters of various accessions of sago in Lingga Regency

Parameters		Nerekeh	Panggak Laut	Musai	Pekaka	Keton	Teluk
Total of leaves (strands)		14	13	12	15	11	14
Total of leaflets (strands)	Right	59	72	62	42	46	54
	Left	61	74	63	39	44	55
Leaf length (m)		6.30	6.30	6.60	4.10	4.80	6.00
Rachis length (m)		4.90	5.56	5.20	2.80	3.60	4.10
Petiole (cm)	Length	95	70	70	85	76	149
	Wide	15.30	14.00	19.00	17.00	16.00	16.00
Leaflet length in ¼ rachis (cm)	Right	130	137	146	125	145	131
	Left	141	148	157	106	147	125
Leaflet length in ½ rachis (cm)	Right	154	145	160	128	140	138
	Left	180	148	172	117	147	128
Leaflet width in ½ rachis (cm)	Right	12	11	9	6.5	6	10.5
	Left	12.5	12	9.2	5.9	6.5	9
Leaflet area (cm^2)		1608.47	1323.12	1186.29	597.50	704.73	1020.89
Leaf area (m^2)		13.07	14.32	14.66	5.93	9.33	9.53

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(Table 2). The distance between rows of thorns on sago saplings was the widest in the Panggak Laut sago accession, which was 8.7 cm. The distance between rows of thorns will be shorter as the sago palm grows older. The arrangement of thorns in the tiller growth phase showed an almost uniform arrangement and pattern, while in adult plants the thorns at the base of the midrib showed a diverse arrangement and pattern (Figure 6).

The color of the bark of sago stems found at the study site was moderate reddish brown, greyish reddish orange, and moderate reddish orange (Figure 7). The color of the sago pith obtained at the study site showed various color variations (Table 3). The Nerekeh pith was pale yellowish pink, the Panggak Laut pith was dark greyish yellow, the Musai pith was yellowish grey, the Pekaka pith was pale yellow grey, the Keton pith was pinkish white, and the Teluk pith was bluish white. The color variations indicated that there were differences in the level of polyphenol oxidase (PPO) activity in each pith. This is in accordance with Konuma et al. (2012) who stated that the brown color of sago pith indicates a very high level of PPO activity in starch samples. PPO plays a major role in the development of brown pigment in plants (Selvarajan et al., 2018). Polyphenol compounds found in the sago pith and followed by polyphenol oxidase action can produce a negative effect on the color of sago starch (Karim et al., 2008).

Sago leaves have a midrib, petiole, and leaflets. The sago petiole found at the study site came in a variety of colors (Table 4). The petiole color of the seedling phase was moderate reddish orange in the Nerekeh accession, dark reddish orange in the Panggak Laut accession, and moderate red in the Musai, Pekaka, Keton, and Teluk accessions. The color of the petiole in the tree phase varied more than in the seedling phase, with accessions of Nerekeh and Keton being strong yellow green, Panggak Laut being brilliant yellowish green, Musai being moderate yellow green, Pekaka being vivid yellowish green, and Teluk being light yellow green.

The color of sago leaflets varied in all sago accessions, as did the growth rate of seedlings and trees. The sago palm

Table 2 Distance and length of thorns of various accessions of sago in Lingga Regency

Location	The existence of thorns	Distance between rows of thorns (cm)		Longest thorn on the saplings (cm)
		Trees	Seedlings	
Nerekeh	Yes	4.3	5.8	5
Panggak Laut	Yes	4.0	8.7	8
Musai	Yes	4.0	6.7	16
Pekaka	Yes	5.0	7.1	11
Keton	Yes	3.3	5.0	10
Teluk	No	0	0	0

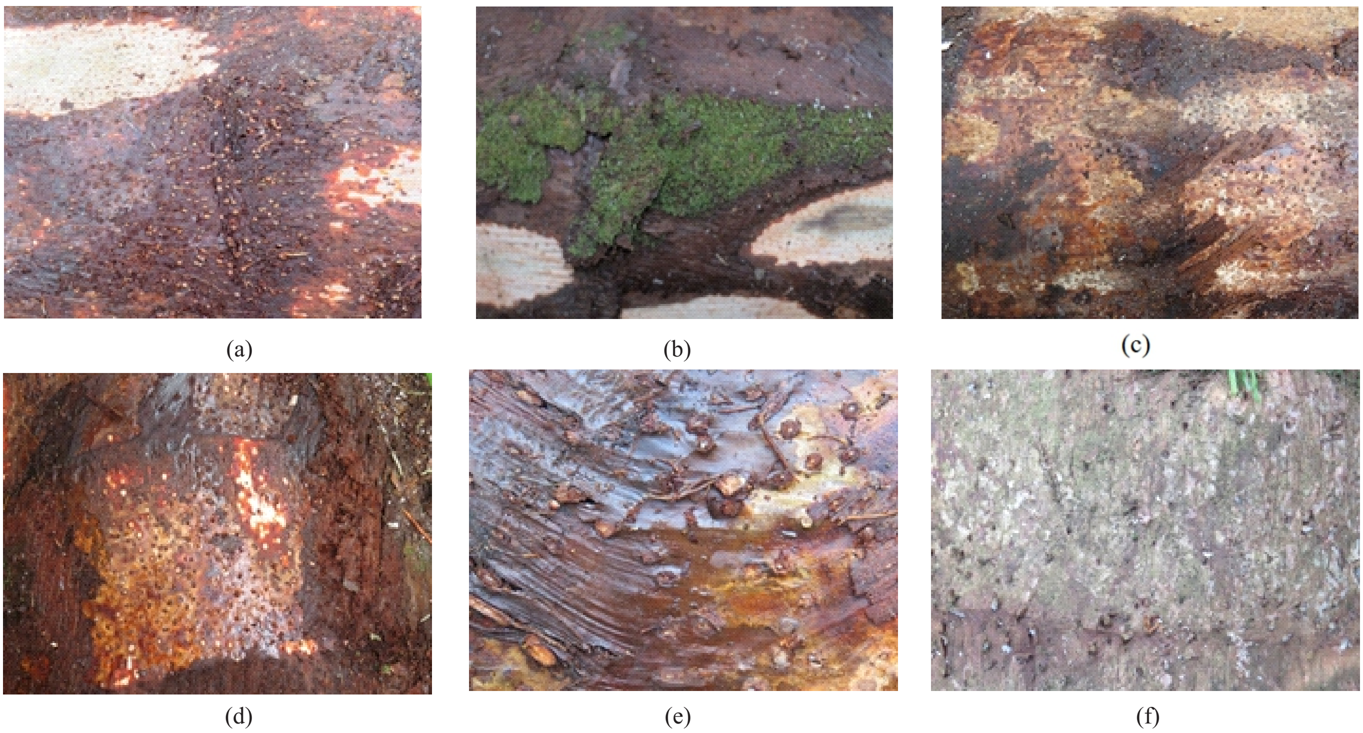

Figure 7 Variations in color of sago bark: a) Nerekeh; b) Panggak Laut; c) Musai; d) Pekaka; e) Keton; f) Teluk.

Jurnal Manajemen Hutan Tropika, *29*(1), 11–21, April 2023
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Table 3 Characteristics of bark and pith color of various accessions of sago in Lingga Regency

Location	Bark	Pith
Nerekeh	175A	27D
Panggak Laut	176C	199D
Musai	175D	156A
Pekaka	177A	194D
Keton	175A	NN155B
Teluk	174D	NN155A

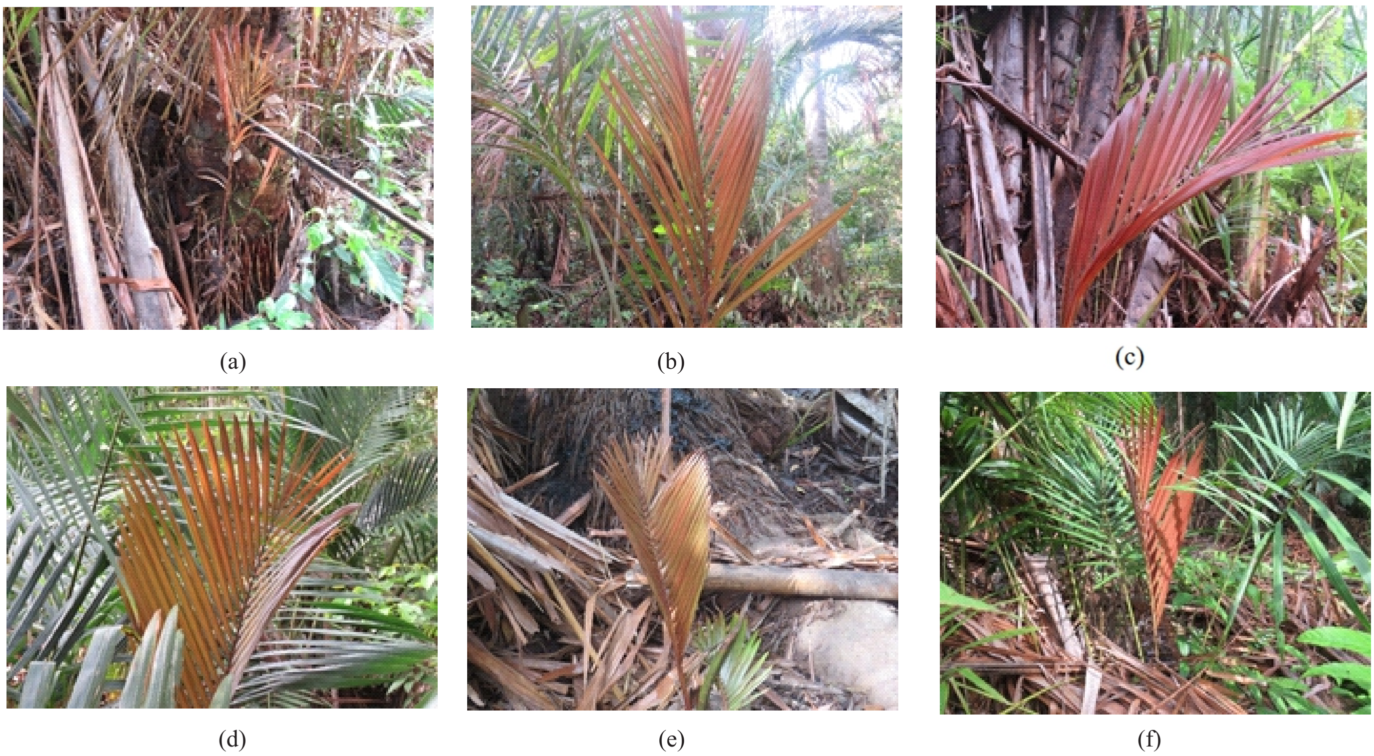
Note: 27D = pale yellowish pink; 156A = yellowish grey; N155A = pinkish white; NN155B = bluish white; 174D, 176C = greyish reddish orange; 175A, 177A = moderate reddish brown; 175D = moderate reddish orange; 194D = pale yellow grey; 199D = dark greyish yellow

leaflets will be moderate red during the seedling phase (Figure 8), and change into moderate green and deep yellowish green during the tree phase. In both the seedling and tree stages, the midrib on sago leaves had several color variations. The leaf midrib in the tillering phase of the Nerekeh accession was deep pink, the Panggak Laut accession was dark yellowish pink, the Musai, Pekaka, and Keton accessions were moderate red, and the Teluk accession was moderate reddish orange. The color of the midrib in the tree phase was moderate yellow green in accessions of Nerekeh, moderate green in accessions of Panggak Laut and Pekaka, moderate yellowish green in accession of Musai and Teluk, and dark greenish yellow in accession of Keton.

Table 4 Color characteristics of tree and sapling sago leaves in various accessions in Lingga Regency

Location	Trees			Saplings		
	Petiole	Leaflet	Midrib	Petiole	Leaflet	Midrib
Nerekeh	143C	141A	139C	178D	180B	180D
Panggak Laut	140B	135B	135B	178B	180B	181D
Musai	138B	135B	137D	180C	179A	180A
Pekaka	140A	135B	135B	179B	180B	180A
Keton	143B	135B	152D	181A	180B	180A
Teluk	145B	135B	137D	181B	179A	179C

Note: 135B = moderate green; 137D = moderate yellowish green; 138B, 139C = moderate yellow green; 140A = vivid yellowish green; 140B = brilliant yellowish green; 141A = deep yellowish green; 143B, 143C = strong yellow green; 145B = light yellow green; 152D = dark greenish yellow; 178B = dark reddish orange; 178D, 179C = moderate reddish orange; 179A, 179B, 180A, 180B, 180C, 181 A, 181B = moderate red; 180D = deep pink; 181D = dark yellowish pink



(a) (b) (c) (d) (e) (f)

Figure 8 Variations in the color of young leaf buds in sago seedlings: (a) Nerekeh; (b) Panggak Laut; (c) Musai; (d) Pekaka; (e) Keton; (f) Teluk.

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Potential of Sago The potential for sago stands in several villages in Lingga Regency was very diverse and showed a stable condition (Table 5). The density of the growth rate of seedlings ranged from 254–752 individuals ha^{-1}, saplings ranged from 113–408 individuals ha^{-1}, poles ranged from 97–220 individuals ha^{-1}, and trees ranged from 46–176 individuals ha^{-1}. The location with the highest individual density at the growth rate of seedlings, saplings, and trees was Keton Village, while the highest pole density was Teluk Village.

Shankar (2001) distinguished the state of the level of plant regeneration into several categories as follows: a) good category, if the number of seedlings is more than saplings and the number of saplings is more than trees (seedlings > saplings > trees); b) fair category, if the number of seedlings is more than the number of saplings and the number of saplings is approximately equal to the number of trees (seedlings > saplings < trees); c) poor category, if the species found is only at the sapling level, no seedlings are found (the number of saplings can be fewer, more, or equal to the number of trees); d) category none, if the species found are only at the tree level and species at the seedling and sapling level are not found; e) new category, if the species found are only at the seedling and sapling levels and no species at the tree level are found. The regeneration of sago at the research site was included in good and fair categories, because the number of seedlings found was more than the number of saplings, poles, and trees, and in some locations, it was found that the number of trees was more than the number of poles (Figure 9).

The study site's sago population also revealed a large number of sago tillers (Figure 10). This occurred due to insufficient sago plant sucker maintenance (transfer). As a sago palm grows, many suckers appear from the mother stem (Nabeya et al., 2015). When there are too many suckers, sago growth will be suboptimal. Thinning is one method of reducing pressure on sago plant growth. This is consistent with the claim made by Bintoro et al. (2016) that sucker thinning is essential for good sago growth and development. Suckers can be used for cultivation activities. Sago palm can be propagated mainly by suckers, which are branches from the base of the stem raised as seedlings (Sato et al., 1979).

Morphological characteristics of the tallest stem height were found in Keton Village with a height of 12.10 m, while the largest stem diameter was found in Nerekeh Village, which was 49.00 cm. The water content of sago starch at the study site ranged from 11.92–23.60%, while the yield of sago starch ranged from 14.81–32.17%. The potential for sago production in several villages in Lingga Regency is presented in Table 6.

The highest production of sago starch was found in Teluk Village, which was 288 kg stem^{-1}, while the lowest production of sago starch was found in Panggak Laut Village, which was 95.08 kg stem^{-1}. The sago palm produces a significant amount of starch, approximately 150–300 kg of dry starch per plant (Konuma, 2018). Several studies that have been carried out, showed that the average starch production varies greatly at each location, including Aimas District (Sorong) of 183.40 kg trees^{-1} (Ahmad et al., 2016), Mioko (Mimika) of 143.87–402.09 kg tree^{-1} (Pratama et al., 2018), and Haripau

Table 5 Potential population of sago in several villages in Lingga Regency

Location	Density (ind ha^{-1})			
	Seedling	Sapling	Pole	Tree
Nerekeh	461	214	164	65
Panggak laut	428	200	100	116
Musai	254	113	97	69
Pekaka	670	322	182	46
Keton	752	408	132	176
Teluk	680	204	220	104

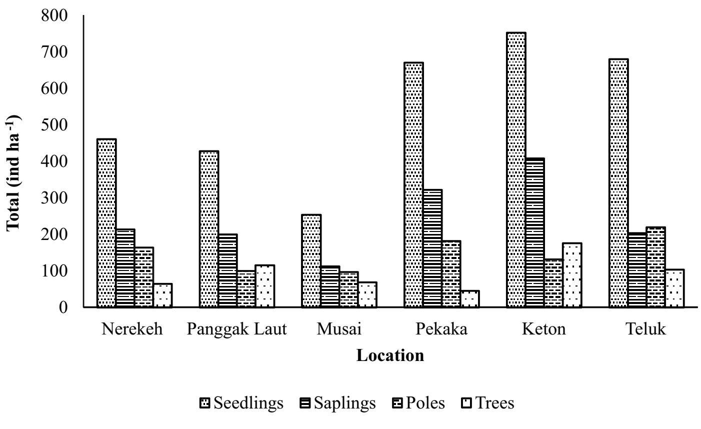

Figure 9 The density of sago stands at each growth stage.

Figure 10 The population of sago tillers is in excess condition.

Table 6 Sago production potential in several villages in Lingga Regency

Location	Height (m)	Diameter (cm)	Water content (%)	Yield (%)	Starch production (kg stem^{-1})	Trees ready to harvest (trees ha^{-1})	Production potential (ton ha^{-1})
Nerekeh	8.00	49.00	16.89	15.99	156.68	29	4.54
Panggak Laut	8.60	37.66	11.92	14.81	95.08	68	6.47
Musai	11.60	47.32	15.82	16.79	238.66	32	7.64
Pekaka	8.60	45.00	16.95	22.10	210.38	16	3.37
Keton	12.10	46.60	23.60	15.20	227.40	64	14.55
Teluk	9.50	41.34	12.96	32.17	288.64	28	8.08

(Mimika) 104.38–275.04 kg tree^{-1} (Nurulhaq et al., 2022). Starch production is influenced by several factors, including height, diameter, moisture content, and yield of sago stems. Ehara (2009) stated that sago starch production was positively correlated with stem weight. Accumulation of starch begins at the bottom of the stem and reaches a maximum in the middle until the top two-thirds of the stem is free from midrib (Schuiling, 2009).

Conclusion

In Lingga Regency, there are two types of sago: spiny sago and thornless sago (*bemban*). The morphological characteristics and sago production at the research sites vary greatly. The potential for sago stands is spread across several villages, including Nerekeh, Panggak Laut, Musai, Pekaka, Keton, and Teluk. Sago stands have a production potential ranging from 3.37 to 14.55 tons ha^{-1}. Because they have a starch content of more than 200 kg stem^{-1}, the majority of sago accessions in Lingga are superior accessions with the potential to be further developed. Superior sago comes from the villages of Musai, Pekaka, Keton, and Teluk.

Recommendation

The development of sago potential in Lingga Regency necessitates collaboration among multiple stakeholders, including local government and related agencies, universities, communities, and industry. The sago forest must be revitalized into a sago garden by transferring a large number of seeds in one clump. To predict kinship and genetics between accessions, more research on the genetic analysis of each sago accession in Lingga Regency is required.

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