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Research Article

Starch distribution in sago palm (*Metroxylon* spp) trunk in East Luwu Regency

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ABSTRACT

Sago is a starch-producing palm plant often found in marshland or peatland utilized by the community as food. East Luwu Regency is one of the areas where sago plants can be found. The purpose of this study was to determine sago starch distribution on the trunk of sago plants. The research methods used were interviews with farmers as key informants (qualitative) and direct observation of sago plants (quantitative). This study used 18 sago plant samples from two types of sago accessions, namely Uwwu accessions and Battang accessions, obtained from 3 sub-districts: Wotu, Kalaena, and Mangkutana. Sago morphological characteristics observed include plant height, trunk diameter, trunk circumference, pith weight, and dry starch weight. The circumference and diameter of the sago trunk varied among the lower, middle, and upper parts. The results showed that in Battang in Kalaena 3, the middle had a smaller diameter and trunk circumference compared to the lower and upper trunk but had the largest dry starch weight of 29.45 g, compared to the lower trunk (25.21 g) and the upper trunk (22.43 g). The environment is a factor that significantly influences the size of trunk circumference, trunk diameter, and starch content in sago plant trunk.

Keywords: accession; Battang; pith; qualitative; starch; Uwwu

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INTRODUCTION

Indonesia is country that has a sago area of around 5,539,637 million hectares (Bintoro et al., 2021). Papua and West Papua provinces have the largest distribution of sago in Indonesia. The distribution of sago in Indonesia is quite extensive, not only in Papua and West Papua but also on the islands of Sulawesi, Sumatra, Kalimantanand Java.

Sago (*Metroxylon* spp.) is a carbohydrate-producing plant that comes from trunk. Sago has long been a staple food in Eastern Indonesia (Ehara, 2018). Sago grows a lot in swampy areas and riverbanks (Nursalam, 2015) and can adapt to marginal soils where other cash crops cannot grow. Sago has many advantages, such as alternative raw materials for various types of animal feed, sources of biomass raw materials, bioethanol, and biodegradable plastics (Hoque et al., 2013; Kumar & Manivannan, 2015; Bukhari et al., 2017; Tiro et al., 2018). Sago product diversification can provide many food alternatives improve quality and capacity to maintain food security (Suyastri, 2018). Besides the economic benefits, sago is also environmentally beneficial (Bantacut, 2014). According to Syahza et al. (2021), sago cultivation is an effective land fire prevention strategy because plants need sufficient water to maintain wetlands.

Sago has excellent potential to fulfill food needs in Indonesia and population growth but has yet to become a priority commodity (Trisia et al., 2016). Sago consumer preferences can provide information in conducting sago marketing strategies and as an indicator of market demand for sago products (Helviani et al., 2018). It is also a strategic commodity in overcoming a country's food insecurity (Pue et al., 2018). Sago plant development is very important. Besides having many benefits, sago plants can grow with high environmental tolerance. The high potential of sago starch allows sago plants to become one for national food diversification. Until now, sago has been one of the largest sources of carbohydrates in the world because it produces 200-400 kg of dry starch per trunk.

Sago is a C3 plant that can live on marginal lands such as peatlands, swamps, and flooded soils. Anugoolprasert et al. (2014) stated that sago could grow at pH 3.6-5.7. Generally, sago grows naturally and develops into a sago forest combined with other plants. Sago's palms dominate stable sago forest vegetation (Botanri et al., 2011).

South Sulawesi Province has three districts as centers of sago commodities (Hayati et al., 2014), namely Luwu District, covering 3,598 ha; North Luwu District, covering 1,789 Ha; and East Luwu District, covering 1,050 ha. People's lives in Tana Luwu (Luwu Regency, Palopo City, North Luwu Regency, and East Luwu Regency) must be kept from the sago plant. In addition to being a food source, sago supports family economic resources and most people in coastal areas. People in Tana Luwu widely produce various types of food from sago.

Sago is harvested when the starch content in the trunk has reached its maximum. Ruamba and Sumule (2020) reported that sago is best harvested when it enters the ripening phase, characterized by the shortening of the top leaves and the appearance of flower initiation. The composition and distribution of sago starch are different in each growth phase. Starch accumulation begins during the vegetative period and increases significantly toward the generative period (flower initiation). The starch in the trunk at the end of the vegetative phase is estimated at 260 kg/m^3 while the average starch content during the generative phase is estimated at 230-240 kg/m^3 (Schuiling, 2009). This study aimed to determine the distribution and the highest starch content in sago plant trunks in 3 sub-districts in East Luwu Regency.

MATERIALS AND METHODS

The research was conducted from January to August 2022. The studies were implemented in three sub-districts of East Luwu Regency: Wotu, Kalaena, and MangkutanaThe tools included machetes, digital scales, circumference meters, ring samples, chainsaws, ropes, crowbars, cameras, blenders, tea sieves, and verniers.

The materials used in this study were two types of sago accessions (Uwwu accessions and Battang accessions) repeated three times in each of the three sub-districts, so 18 samples of sago plants from three sub-districts were obtained. This research was conducted by surveying farmers and sago plantation owners who are familiar with the accessions and distribution of sago in East Luwu Regency as key informants. A plot of 50 m x 50 m (2,500 m^2) was made at each sample location, containing six samples to be observed. Sago plants selected were those that had entered the harvest maturity phase.

Observations were made at the habitat where sago plants grow in three sub-districts. Sago plants were selected and cut for morphological analysisMorphological characters were collected by direct observation through measurement (quantitative data) and photographing (qualitative data) on the trunk of cut-down sago plants. trunk length was measured using a tape measure on the felled sago trees from the base of the trunk to the lowest leaf midrib. Trunk diameter was measured using a meter in three parts: the bottom, middle, and top of the felled sago trunk. The trunk circumference was measured using tape on the felled sago at the bottom, middle, and top. The thickness of the bark was measured manually with a meter at several points at the bottom, middle, and of the trunk. The bark is the trunk’s outer surface until it reaches the pith. The pith collection was carried out at the bottom, middle, and top of the sago trunk using a sample ring with a radius (r) of 0.036 m and a height of 0.04 m. Dry starch weight was determined by weighing the pith and smoothing it with a blender with the same volume of water (200 ml) repeated three times. The smooth pith was squeezed and filtered to extract starch. The deposition process was carried out for one night; after the starch had settled, it dried for 4-6 hours (not exposed to direct sunlight). Starch was then weighed to determine the dry starch weight in sago trunks. The quantitative data were analyzed using Microsoft Excel 2010 software.

RESULTS AND DISCUSSION

Sago is a plant from a palmaceous tribe that is often found in swampy or peaty soils. As one of the plants that provide carbohydrate food, sago starch is widely used to make liquid sugar, alcohol, and eco-friendly plastics (Heryani & Silitonga, 2017). Sago starch productivity is essential improving its management. One of a plant's morphologies that are often observed to see the characteristics of sago is plant height and trunk diameter. According to Adawiyah and Dirgantoro (2019), sago plant height ranges from ground to flower base ranges from 10 to 15 meters, while trunk diameter ranges from 35 to 50 cm.

People in East Luwu Regency distinguish Uwwu accessions and Battang accessions by looking at the presence or absence of moss growing on sago plant trunks. Morphological traits might not only be influenced by genetic factors but also by environmental factors. Extreme environmental conditions can even change plant behavior. There are several very dense sago clumps in the research location. High air humidity triggers moss and ferns to grow on old fronds attached to sago trunks. Uwwu accessions have a trunk that is not smooth (there are fragments of fronds) and is generally mossy.

In contrast, the Battang accessions do not have frond scars and are not mossy, so they look smooth (Figure 1). Sago distribution in East Luwu Regency is found in three locations, namely Wotu, Kalena, and Mangkutana. Several sago plants were found in each location, and only three plants of each accession type per sub-district were further analyzed to determine the sago plant's morphological characteristics for each tree.

Sago can be commercially harvested at least eight years of age. Starch is stored in the trunk's parenchyma (pith), which is gradually filled from the base to the top. After the fruit has been fully formed, the starch content in the trunk decreases, while the generative phase of the sago plant occurs with the formation of flowers and fruit. The starch storage phase during the generative phase lasts about three years. The total life span of a sago tree ranges from 11-23 years.

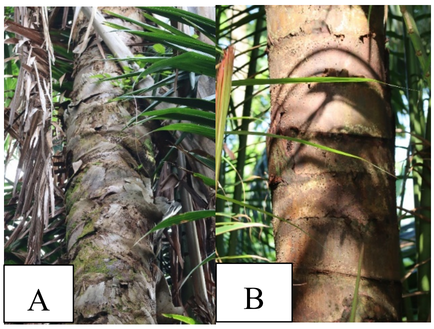

Figure 1. Condition of sago trunk ; (A) Uwwu sago, (B) Battang sago.

Determining the proper harvest time affects sago starch yield. Sago trunk harvest maturityrange inheight from 8-15 mand have a trunk circumference of ± 150 cm. Before the sago plants are cut down, farmers remove moss and sago saplings from the tree's base, which can obstruct the felling process. After the trees are cut down, pieces or sago tual form at 40-60 cm in length. The proces yields 15-28 tual per trunk. These pieces facilitate the mobilization of sago tual to transportation sites, which will be transported by car to work sites.

Table 1. Observations of the morphology of sago species from 18 trees for variable plant height and trunk diameter at the bottom, middle, and top.

Sago type	Bottom trunk diameter (cm)	Middle trunk diameter (cm)	Top trunk diameter (cm)
Battang in Wotu 1	52	53	58
Battang in Wotu 2	51	46	59
Battang in Wotu 3	45	41	62
Battang in Kalaena 1	51	69	57
Battang in Kalaena 2	50	59	58
Battang in Kalaena 3	57	54	60
Battang in Mangkutana 1	49	55	59
Battang in Mangkutana 2	48	64	67
Battang in Mangkutana 3	54	51	46
Uwwu in Wotu 1	58	69	64
Uwwu in Wotu 2	56	62	51
Uwwu in Wotu 3	56	62	59
Uwwu in Kalaena 1	50	63	61
Uwwu in Kalaena 2	52	58	50
Uwwu in Kalaena 3	54	60	51
Uwwu in Mangkutana 1	48	53	62
Uwwu in Mangkutana 2	48	51	62
Uwwu in Mangkutana 3	52	54	64

Parts of sago plants that were utilized to extract starch were the trunk. Sago trunk contain piths, which were shredded/ground, squeezed, and precipitated to get starch during harvesting. Observations of trunk diameter were made on three parts: the bottom, middle, and top of the sago plant trunk. Trunk diameters at the bottom, middle, and top differed in size. Battang accession in Wotu had a lower trunk diameter ranging from 45-52 cm, middle trunk 41-53 cm, and upper trunk 58-62 cm. The scion (top) diameter was larger than the lower and middle trunk diameters. Battang accession in Kalaena had a larger middle trunk diameter of 54-69 cm compared to a lower trunk (50-57 cm) and upper trunk diameter (57-60 cm), while Battang accession in Mangkutana had a similar trunk development as Battang accession in Wotu where upper trunk diameter was larger at 46-67 cm compared to the lower trunk diameter of 48-54 cm andmiddle trunk diameter of 51-64 cm.

Uwwu accession in Wotu had a bigger middle trunk diameter of 62-69 cm than the bottom trunk diameter of 56-58 cm and top trunk diameter of 51-64 cm. Similarly, the Uwwu accession in Kalaena had a larger middle trunk diameter (58-63 cm) when compared to the bottom trunk (50-54 cm) and top trunk (50-61 cm). However, unlike the Uwwu accession in Mangkutana, he top trunk diameter was larger (62-64 cm) than the bottom trunk diameter of 48-52 cm and the middle trunk diameter of 51-54 cm. According to Adawiyah and Dirgantoro (2019), in 3 locations in East Luwu Regency, the bottom trunk diameter is larger than the middle and top trunks of sago plants.

Trunk circumference

Sago trunk circumference shows measurements of sago trunk perimeters. Sago trunk circumference can be used to determine its starch content. A greater trunk circumference indicates a bigger starch content in the sago plant. Sago trunk circumference in East Luwu Regency is divided into three parts: bottom, middle, and top.

Battang accession in Wotu had a bottom trunk circumference of 127-143 cm, a middle trunk of 124-145 cm, and a larger top trunk circumference of 150-197 cm. In contrast, the Battang accession in Kalaena had a larger middle trunk circumference of 169-

214 cm compared to the bottom trunk circumference of 147-181 cm and the top trunk circumference of 176-184 cm. Battang accession in Mangkutana had a larger top trunk circumference of 141-181 cm than the bottom trunk circumference of 146-158 cm and a middle trunk circumference of 152-168 cm.

Table 2. Observations of the morphology of sago species from 18 trees for trunk circumference variables at the bottom, middle, and top.

Sago type	Bottom trunk circumference (cm)	Middle trunk circumference (cm)	Top trunk circumference (cm)
Battang in Wotu 1	143	145	150
Battang in Wotu 2	140	126	195
Battang in Wotu 3	127	124	197
Battang in Kalaena 1	156	214	176
Battang in Kalaena 2	147	178	176
Battang in Kalaena 3	181	169	184
Battang in Mangkutana 1	150	168	179
Battang in Mangkutana 2	146	163	181
Battang in Mangkutana 3	158	152	141
Uwwu in Wotu 1	166	197	171
Uwwu in Wotu 2	159	183	145
Uwwu in Wotu 3	157	171	165
Uwwu in Kalaena 1	157	195	191
Uwwu in Kalaena 2	158	163	152
Uwwu in Kalaena 3	159	164	153
Uwwu in Mangkutana 1	151	164	190
Uwwu in Mangkutana 2	138	150	190
Uwwu in Mangkutana 3	151	157	197

Uwwu accession in Wotu had a larger middle trunk circumference of 171-197 cm compared to the bottom (157-166 cm) and top (145-171 cm). Uwwu accession in Kalaena also likewise had a wider middle trunk circumference of 163-195 cm than the bottom (157-159 cm) and top (152-191 cm). While Uwwu accession in Mangkutana had a larger top trunk circumference (190-197 cm) compared to the bottom (138-151 cm) and midd trunk circumference (150-164 cm).

Pith weight

The pith is a part of the trunk that contains fiber and starch. Pith content can reach 75-83% of trunk weight but only has a small starch content of about 15-30%. Sago pith extraction results in sago starch that is utilized by society. A higher pith extracted may increase the sago starch content. Pith was taken on three parts of sago plant trunk using a sample ring, and each pith sample was weighed to determine its weight.

Battang accession in Wotu had pith weights thatwere not significantly different, but the bottom trunk had the heaviest pith (143.67-156.54 g) compared to the middle trunk (143.66-145.83 g), and the top trunk (142.26-147.94 g). The heaviest pith weight in Battang accession in Kalaena was found in the middle trunk (147.47-164.89 g) than in the bottom trunk (139.24-158.15 g) and top trunk (141.29-152.93 g). Battang accession in Mangkutanahad the largest pith weight in the middle trunk, which was 129.31-156.81 g compared to the bottom (139.24-146.39 g) and the top trunk (136.70-144.30 g).

Uwwu accession in Wotu has the heaviest pith weight in the lower trunk, which is 130.70-148.31 g, then the middle part 133.52-142.24 g and the upper part 139.12-145.18 g, as well as in Uwwu accession in Kalaena which has the heaviest pith weight in the lower trunk which is 146.31-163-27 compared to the middle part 142.24-146.18 g and the upper part 130.20-153.75 g. Uwwu accession in Mangkutana has the heaviest pith weight in the lower part, 134.00-158.51 g, as opposed to the middle part, which is 137.00-153.10 g, and the upper part, which is 123.00-145.89 g.

Table 3. Observations of the morphology of sago species from 18 trees for pith weight at the bottom, middle, and top.

Sago type	Pith weight of bottom trunk (g)	Pith weight of middle trunk (g)	Pith weight of top trunk (g)
Battang in Wotu 1	143.67	145.83	142.26
Battang in Wotu 2	156.54	143.66	147.94
Battang in Wotu 3	148.20	145.36	142.50
Battang in Kalaena 1	158.15	147.47	141.29
Battang in Kalaena 2	140.92	164.89	152.93
Battang in Kalaena 3	139.24	152.45	148.67
Battang in Mangkutana 1	144.61	156.81	144.30
Battang in Mangkutana 2	146.39	129.31	140.30
Battang in Mangkutana 3	150.18	159.20	136.70
Uwwu in Wotu 1	130.70	139.65	142.54
Uwwu in Wotu 2	137.29	133.52	139.12
Uwwu in Wotu 3	148.31	142.24	145.18
Uwwu in Kalaena 1	154.32	142.24	130.20
Uwwu in Kalaena 2	162.27	146.18	153.75
Uwwu in Kalaena 3	146.31	148.64	141.16
Uwwu in Mangkutana 1	158.51	153.10	145.89
Uwwu in Mangkutana 2	155.01	137.57	131.63
Uwwu in Mangkutana 3	134.00	137.00	123.00

Of these 18 sago plant pith samples collected in 3 sub-districts, the bottom pith was generally heavier than the middle and top piths. However, Battang accession in Kalaena and Mangkutana had the heaviest pith weight in the middle trunk. Thebottom trunks pithcontained more fibers than the middle and top trunk. Total starch in sago trunk is also regulated by light intensity absorbed by the leaves, which affects photosynthetic activity and the amount of assimilates (carbohydrates) produced by a plant (Manaroinsong et al., 2013). According to Huwae and Papilaya (2014), growing area of the sago influences carbohydrate content. The environment influences a variety of organic materials and minerals raised by breath roots, which will shape the composition of the carbohydrate content in sago to be higher.

Dry starch weight

The results showed that the bottom trunk in Batang accession in Wotu had the largest dry starch weight of 15.62-47.48 g, compared to the middle trunk (20.54-31.33 g) and the top s trunk (25.67-29.12 g). Similarly, Battang accession in Kalaenahad the largest dry starch weight found in the middle trunk (29.45-41.88 g) thanthe trunk (10.70-30.67 g) and bottom trunk (16.32-27.97 g). Battang accession in Mangkutana had the heaviest dry starch weight at the top trunk of 20.83-33.02 g, compared to the bottom trunk of 20.57-29.76 g and the middle trunk of 23.61-30.43 g.

Uwwu accession in Wotu had the highest dry starch weight in the middle trunk (20.08-34.51 g) compared to the bottom trunk (11.94-29.31 g) and the top trunk (15.42-32.26 g). Uwwu accession in Kalaena showed that the middle s trunks had the largest dry starch weight, 22.56-36.45 g, followed by the bottom trunk (14.59-24.14 g) and the top trunks (19.85-25.89 g). The Uwwu accession in Mangkutana had the maximum dry starch weight in the middle trunk (26.89-32.46 g) followed by the bottom trunk (18.06-26.45 g) and the top trunk (29.44-31.08 g). Flour chemical composition of sago starch mainly consists of carbohydrates uch as wheat flour, tapioca flour, and rice flour. This allows sago starch to make bread, biscuits, noodles, and other commonly established andrecognized foods by the community, such as brownies or cakes (Hajiana et al., 2017).

Table 4. Observations of the morphology of sago species from 18 trees for variable dry starch weight at the bottom, middle, and top

Sago type	Dry starch weight of bottom trunk (g)	Dry starch weight of middle trunk (g)	Dry starch weight of top trunk (g)
Battang in Wotu 1	15.62	20.54	27.87
Battang in Wotu 2	26.20	26.39	29.12
Battang in Wotu 3	47.48	31.33	25.67
Battang in Kalaena 1	27.97	36.24	10.70
Battang in Kalaena 2	16.32	41.88	30.67
Battang in Kalaena 3	25.21	29.45	22.43
Battang in Mangkutana 1	29.76	30.43	28.97
Battang in Mangkutana 2	28.43	30.21	33.02
Battang in Mangkutana 3	20.57	23.61	20.83
Uwwu in Wotu 1	28.07	34.51	15.42
Uwwu in Wotu 2	11.94	20.08	32.26
Uwwu in Wotu 3	29.31	30.03	28.35
Uwwu in Kalaena 1	24.14	22.56	22.17
Uwwu in Kalaena 2	20.77	36.45	25.89
Uwwu in Kalaena 3	14.59	27.16	19.85
Uwwu in Mangkutana 1	24.16	27.17	31.08
Uwwu in Mangkutana 2	18.06	26.89	29.44
Uwwu in Mangkutana 3	26.45	32.46	29.76

The dry starch weight of the sago trunk showed no significant difference between the Uwwu accessions and Battang accessions in three districts. The dry starch weight was distributed across the sago plant's bottom, middle, and top trunk. The trunk circumference and diameter of sago plants cannot determine that a wider circumference and diameter of the trunk contain more starch. As demonstrated in the Battang accession in Kalaena 3, the middle trunk had the biggest dry starch weight at 29.45 g, which was more than the bottom step (25.21 g) and the top trunk (22.43 g). The upper trunk circumference was 184 cm, which was greater than the bottom trunk (182 cm) and themiddle (169 cm).However, the largest dry starch weightwas found in the middle trunk at 29.45 gfollowed by the bottom trunk at 25.21 g and thetop trunk at 22.43 g. Differences in accession do not affect trunk circumference, trunk diameter, and starch content in sago plant trunk; rather, the environment in which sago is grown hasa major impact on the distribution of trunk starch contents.

CONCLUSIONS

East Luwu Regency is home to wo sago ccession types: the Uwwu accessions and the Battang accessions. The circumference and trunk diameter in the two accession types were diverse. The largest circumference and diameter were found in the sago plant's bottom, middle, and top trunk. The Battang accession in Kalaena 3 showed that the middle trunk had a smaller diameter and circumference than the middle and top trunks, but it contained the largest dry starch weight of 29.45 g, compared to the bottom trunk at 25.21 g and the top trunk at 22.43 g. The sago plant's dry starch weight cannot be Environmental factors greatly affect circumference size, trunk diameter, and starch content in sago plant trunks.

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