SAGO PALM 28: 12 − 21 (2020)

Growth Characteristics and Starch Productivity of Sago Palm (*Metroxylon sagu* Rottb.) Grown in Pontianak, West Kalimantan, Indonesia

Yoshinori Yamamoto[1,*], Isamu Yanagidate[1], Tetsushi Yoshida[1], Hardaning Pranamuda[2], Yusuf Sigit Ahmed Fauzan[2], Urai Edi Suryadi[3], Yuliati Indrayani[3], Akira Miyazaki[1], and Nardiman Haska[2]

[1]Faculty of Agriculture, Kochi University, Nankoku, Kochi 783-8502, Japan

[2]Agency for the Assessment and Application of Technology (BPPT), Biothech Center, MH. Thamrin No. 8, Jakarta 10340, Indonesia,

[3]Faculty of Forestry, Tanjungpura University, Pontianak, Kalimantan Barat 78124, Indonesia

*Corresponding author: yamayosi@kochi-u.ac.jp

Abstract: Growth characteristics and starch productivities of the sago palms growing in Pontianak, West Kalimantan, Indonesia were investigated. Sago palms were growing along the tributaries of the Kapuas River in semi-cultivated/cultivated states. There were two folk varieties, Bemban and Buntal (hereafter referred to as varieties), both of which are non-spiny types; the characteristics of the varieties were distinguished in features such as their suckering ability, crown angles, and trunk length and diameter. Both varieties were estimated to be 10-12 years from harvest. As a result of a sampling survey at the appropriate harvest stage (bolting to flowering stage), Bemban was significantly superior to Buntal in trunk length, leaflet length, width and area, and leaf area. There were no significant differences between the varieties in dry matter, total sugar, and starch percentages in the pith. Moreover, a varietal difference was also not observed in the pith dry weight; therefore, there was no significant difference in starch content (yield), although the starch content of Bemban (326kg) was slightly higher than that of Buntal (278kg). There were no differences between the two varieties in the macronutrient contents in the leaflet and pith except for the Mg content in the leaflet. We concluded from these results that the two varieties of sago palms growing in Pontianak were not significantly different in starch and macronutrient contents in pith, although some growth characteristics were significantly different.

Keywords: Folk variety, Leaf characteristics, Macronutrients, Sago palm, Starch productivity, Trunk characteristics

Introduction

Much research has been conducted on the growth characteristics and starch productivities of sago palms growing in Muka and Dalat, Malaysia, Sarawak (Sim and Ahmed, 1978; Flach and Schuiling, 1991; Kueh et al., 1991; Jong, 1995; Yamamoto et al., 2003a, 2003b, 2003c; Ming et al., 2018). Sago palm plantations have been developed in this area on a large scale, and sago palm starch has been produced commercially for a long time (Yamamoto, 1998). On the other hand, there are few studies on sago palms in Kalimantan, including West Kalimantan, which is adjacent to Sarawak. Flach (1997) stated that the area of sago palms in a semi-cultivated/cultivated state in Kalimantan is 20,000 ha. Regarding the sago palm area of West Kalimantan, Rasyad and Wasito (1986) reported 1,576 ha, and Saitoh et al. (2008) reported that approximately 5,000 ha of sago palm forests spread along the Kapuas River. Saitoh et al. (2008) reported that three types of sago palm grew along the Kapuas River. However, the morphological and growth characteristics as well as the starch productivity of sago palm varieties have not been clarified.

With this background, the purpose of this study was to clarify the growth characteristics and starch productivities of sago palm varieties growing in Pontianak, West Kalimantan, Indonesia.

Materials and Methods

1. Interview survey

We conducted an interview survey on the types of sago palm (varieties), and their morphological and growth characteristics, starch productivities, cultivation, and uses with sago palm growers in Ambangah Village (about 35km southwest of Pontianak) along the Ambangah River (which is a tributary of the Kapuas River), near Pontianak, West Kalimantan, Indonesia in August 2007 (Fig. 1).

Fig 1. Map of West Kalimantan, Indonesia

2. Sampling survey

In August 2007, a survey was conducted in Ambangah Village described above (Fig. 1) . Two sago palm varieties (Bemban and Buntal) that were cultivated in the village were surveyed; three individuals of each variety at harvest stage (from bolting to flowering stage) were selected from farmers' sago palm gardens (*Kebun Sago*, in Indonesian). The sago palm gardens grew in mineral soil. Each individual was felled with an ax or a chainsaw, and the numbers of living leaves and leaf scars on the trunk were measured. The plant length and trunk length were measured from the cut portion of the trunk base to the tip of the top leaf and the node of the lowest living leaf, respectively. Since the surveyed individuals reached the growing stages after flower bud formation, leaf lengths were shortened from the lower leaves to the upper leaves (Yamamoto et al., 2014). Therefore, leaf characteristics−such as leaf length, number of leaflets, lengths, maximum widths, and SPAD values (SPAD-502, Minolta Co.) of the longest leaflets from right and left sides of the lowest leaves−were measured. SPAD values were measured at the center of leaflets. In addition, according to the method of Omori (2001), the leaf area was calculated as the longest leaflet length × its maximum width × the number of leaflets per leaf × 0.54, and the average leaflet area was calculated as the leaf area/the number of leaflets. Moreover, the middle parts of the longest leaflets on the right and left sides of each three leaves positioned at the 1st, the 8-10th, and the 16-18th from the base were sampled. The sampled middle parts of these leaflets were dried at about 80° C for two days and brought back to Japan, and further dried at 65° C for two days. On the other hand, the trunk was divided into four parts equal in length, and the diameter of each cut surface, including the base and top cut surfaces, was measured; discs of approximately three cm were cut out from the positions where the diameters were measured. The trunk was cut into short pieces (logs), and all logs were weighed with a 100 kg bar scale. Pith samples of approximately 50-100 g (0.1 g unit) were collected radially from the sampled discs with a portable electronic balance (HL-200, Kyoei Co.). The collected pith samples were dried at about 80° C for two days and brought back to Japan, where they were further dried at 65° C for two days, and then the dry weight was measured.

3. Macronutrient analysis of leaflet and pith

Leaflet and pith dry matter materials were pulverized to a fine powder of 100 mesh or less by the grinder (T1-100, SAMPLE MILL, CMY Co.), and 0.5 g samples were decomposed with sulfuric acid-hydrogen peroxide for the determination of macronutrients (N, P, K, Ca and Mg). Nitrogen (N) and phosphorous (P) were analyzed by the semi-micro Kjeldahl method and the colorimetric method (Murphy and Riley 1962), respectively. Potassium (K), calcium (Ca), and magnesium (Mg) were analyzed by atomic absorption spectrophotometer (AA-6800, Autosampler ASC-6100, Shimadzu Co.).

4. Total sugar and starch analyses (chemical method) of pith

From the pulverized pith dried materials described above, total sugar and starch were extracted using the method of Murayama et al. (1955). That is, 0.2 g of pith dry material was extracted with 80% hot alcohol three times for total sugar, and the residue was extracted with 4.6*N* perchloric acid for six times for starch. The glucose amounts of total sugar and starch were measured by the anthrone method, and the starch content was expressed as a value obtained by multiplying the glucose amount by 0.9. The starch content per plant (yield) was calculated as the trunk weight × 0.8 × the pith dry matter percentage × the starch percentage/10000, where 0.8 was the ratio of pith in the trunk weight (Yatsugi, 1977) and the pith dry matter and starch percentages were the average values of the five positions of discs.

5. Starch extraction from pith by electric blender

Two kg of the pith was sampled from the base, middle, and top of the trunk of the individual sampled plants. Each pith sample was cut into sections of 1-3 cm^3 and crushed several times with water using a commercial electric blender (1.5L) for 1.5-2 minutes. The crushed pith was double wrapped in 100-mesh cloth, and starch was extracted by squeezing with pouring water (Miyazaki et al., 2006). The supernatant was discarded after standing for about 30 minutes, and tap water was added to the precipitate and stirred to purify the precipitate through a double 100- mesh cloth. This purifying process of the precipitate was repeated three or four times. Then, the supernatant was removed and the precipitate (starch) was sun-dried and brought back to Japan. The starch was dried at 100° C for 12 hours and the dry starch weight was measured. The starch content was calculated by the fresh weight of the pith and the dry starch weight. Hereafter, this method is referred to as the blender extraction method.

6. Statistical analysis

Statistical analysis was performed on the obtained data using JMP (Version 7.0, SAS Institute).

Results

1. Interview survey

Sago palms grow in a semi-cultivated/cultivated state in an area approximately 500 m wide along the Ambangah River, a tributary of the Kapuas River. Sago palms were introduced to this area about 45 years ago (early 1960s). The habitat has mineral soil (silty loam-silty). Bemban and Buntal, two non-spiny types of sago palm varieties (although they have small spines along the midrib of leaflet in the rosette stage) are cultivated here (Table 1). Buntal's suckering

Table 1. The results of interview survey with the sago palm growers on the morphological and growth characteristics, starch productivity, and quality of the varieties grown in Ambangah village in Pontianak, West Kalimantan, Indonesia

Variety	Spine	Suckering ability	Clump extension	Angle of leaf crown	Trunk		Starch	
					length	diameter	yield	quality
Bemban	-	2	1	2	1	2	nd	nd
Buntal	-	1	2	1	2	1	nd	nd

Note) 1 indicates higher, wider, and thicker in the characteristics than 2. nd: not different.

ability is superior to that of Bemban. In Bemban, suckers stand farther away from the mother plant than do those of Buntal. The angle of the crown is wider in Buntal than in Bemban. The trunk is thinner and longer in Bemban than in Buntal. There is no clear difference in yield and starch quality (Table 1). Propagation depends on the planting of suckers, but it takes only around two years to form trunks because large suckers of more than 5 kg are transplanted after being nursed in a water pond for about one month until the emergences of new roots and a leaf. However, it takes four to five years to form trunks for suckers generated directly from the mother plant. The trunks of both varieties grow about 1 m per year, and Buntal and Bemban reach the flower bud formation stage at approximately 6 and 8 years after trunk formation, respectively. The planting density of suckers is 5 m × 5 m, and they are hardly managed after planting. Plants that have reached harvest stage (flower bud formation to flowering) are cut down with a chainsaw and cut into logs 1-2 m long and transported to the starch extraction site. The sago starch is collected by crushing the pith with a rotary crusher (rasper), and the starch is extracted by stamping the rasped pith on mesh sheets with water. The starch is sold to the Sagu Sari Factory at the mouth of the Kapuas River as wet starch, Rp. 700 and dry starch, Rp. 2100 per kg.

Sago starch is not eaten as a staple food but is partly used as a material for making cakes such as *Sago Lempeng* and *Kue Sago*.

2. Sampling survey

1) Growth characteristics

Table 2 shows the growth characteristics of both varieties. Owners of sago gardens estimated that the ages of sampled plants were approximately 12 years for both varieties. Plant lengths were not significantly different ($p<0.05$, unless otherwise noted, significance levels are the same below) between the two varieties; they were 18.6 m and 16.4 m for Bemban and Buntal, respectively. Similarly, there was no significant difference in the number of leaf scars between the two varieties. The number of surviving leaves was not significantly different between the two varieties, but the coefficient of variation (CV) was 29.3%, which was significantly higher than other characteristics. This was probably because one individual of Bemban showed a very small number of surviving leaves, nine leaves. However, since the number of leaf scars in the individual was high, there was no clear difference between the two varieties in the total number of leaf scars (a) and living leaves (b) (a + b), showing 81 and 77 for Bemban and Buntal, respectively, and the coefficient of variation was low, 7.8%. Since all plants were at the same growth stage, the number of leaves developed until flower bud formation after trunk formation was considered to be the same between the two varieties.

On the other hand, the trunk length in Bemban (9.6 m) was significantly longer than that in Buntal (7.4 m) (Table 2). Although the trunk diameter for Bemban (44.5 cm) was slightly thinner than that of

Table 2. Growth characteristics of sago palm varieties at harvest grown in Ambangah Village in Pontianak, West Kalimantan, Indonesia

Variety	Estimated palm age (yrs)	Plant length (m)	No. of leaf scars (a)	No. of leaves (b)	a+b	Trunk Length (m)	Trunk Diameter (cm)	Trunk Weight (kg)	Trunk Volume (m^3)
Bemban	12.0	18.6	59.7	21.3	81.0	9.6	44.5	1146	1.49
Buntal	11.8	16.4	56.0	21.0	77.0	7.4	46.9	1009	1.27
Average	11.9	17.7	58.1	21.2	79.3	8.6	45.5	1087	1.40
SD	0.2	2.4	7.3	6.2	6.2	1.3	2.4	124	0.20
CV(%)	1.7	13.7	12.6	29.3	7.8	15.1	5.3	11.4	14.1
Tukey's-test	*ns*	*ns*	*ns*	*ns*	*ns*	*	*ns*	*ns*	*ns*

ns and *: not significant and significant at $p<0.05$, respectively.

Buntal (46.9 cm), the difference between the two varieties was not significant. Neither was the trunk weight significantly different between the two varieties, ranging from 905 to 1294 kg, with an average of 1146 kg for Bemban and 1009 kg for Buntal.

2) Leaf characteristics

The leaf length of both varieties was about 9 m, and the number of leaflets was around 145; no significant differences were observed in these characteristics (Table 3). On the other hand, the longest leaflet length and its maximum width were 158 cm and 10.8 cm for Bemban, respectively, and 151 cm and 9.6 cm for Buntal, respectively. Significant differences at $p<0.01$ and $p<0.05$, respectively, were observed between the two varieties. The SPAD values of both varieties were about 65, and no significant difference was observed. As a result, the average leaflet area and leaf area were 1701 cm^2 and 25.1 m^2 for Bemban, respectively, which were significantly larger than those for Buntal, 1450 cm^2 and 20.6 m^2, respectively.

3) Starch productivity

The dry matter percentages in pith of both varieties were 47%, showing no significant difference (Table 4). The pith dry weight was relatively higher in Bemban than in Buntal, although there was no significant difference between Bemban (435 kg) and Buntal (381 kg). The starch percentages of Bemban (74.9%) and Buntal (73.0%) were almost the same. The starch content was 326 kg for Bemban and 278 kg for Buntal. No significant difference was observed in the starch content between the two varieties, but the content was about 50 kg higher in Bemban than in Buntal. The total sugar content of both varieties was in the range of 4-5% with no significant difference.

Fig. 2 shows the starch percentages by trunk position. Starch percentages were in the range of 70-75% at any trunk position, and there was no clear difference depending on the trunk position, although

Table 3. Leaf characteristics of sago palm varieties at harvest grown in Ambangah Village in Pontianak, West Kalimantan, Indonesia

Variety	Leaf length (m)	No. of leaflets	Longest leaflet length (cm)	Longest leaflet max. width (cm)	SPAD	Average leaflet area (cm^2)	Leaf area (m^2 leaf^{-1})
Bemban#	9.0	148	158	10.8	65.0	1701	25.1
Buntal	8.7	142	151	9.6	65.9	1450	20.6
Average	8.8	144	154	10.1	65.5	1551	22.4
SD	0.6	5.3	3.9	0.7	3.4	147	2.6
CV(%)	7.0	3.6	2.6	6.9	5.2	9.4	11.7
Tukey's-test	ns	ns	**	*	ns	*	*

Measured on the lowest living leaves for each sampled palm. #One of the sampled palms was excluded from the measurements of the characteristics because the number of leaves was too small and the lowest leaf length was too short as compared with the other sampled palms. ns, * , and ** : not significant and significant at $p<0.05$, and significant at $p<0.01$, respectively.

Table 4. Starch contents and related characteristics of sago palm varieties at harvest grown in Ambangah Village in Pontianak, West Kalimantan, Indonesia

Variety	Pith DM (%)	Pith DW (kg)	Total sugar (%)	Starch (%)	Starch content (kg)
Bemban	47.4	435	5.2	74.9	326
Buntal	47.3	381	4.0	73.0	278
Average	47.3	408	4.6	73.9	302
SD	0.9	52.0	0.9	2.3	46.6
CV (%)	1.8	12.8	20.5	3.1	15.4
Tukey's-test	*ns*	*ns*	*ns*	*ns*	*ns*

ns and *: not significant and significant at $p<0.05$, respectively.

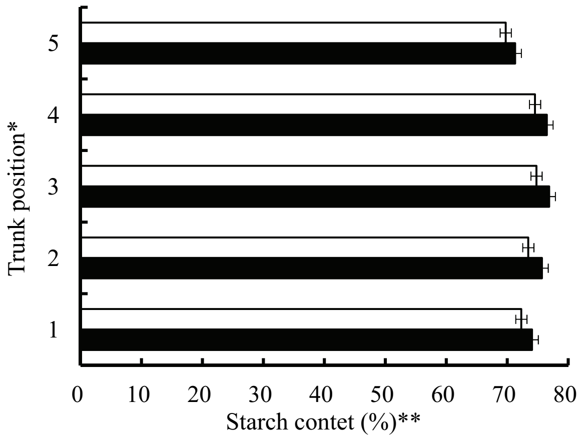

Fig 2. Positional differences of starch percentages in the pith of sago palm varieties at harvest grown in Ambangah Village in Pontianak, West Kalimantan, Indonesia
■Bemban, □Buntal.
*: Base (1) - Top (5) of trunk. **: Average of 3 plants.
Note) Ranges at the top of bars indicate standard errors.

the middle position showed a slightly higher value than those of the top and base positions.

4) Macronutrients in leaflet and pith

Table 5 shows the macronutrient contents of the leaflet and pith. In both varieties, the macronutrient contents were higher in the order of N>K>Ca>Mg>P in the leaflet and K>N>Ca>Mg>P in the pith. There were no significant differences in the macronutrient contents except for the Mg content in the leaflet. The Mg content in the leaflet was significantly higher in Bemban than in Buntal. Comparing the contents in the leaflet and the pith, the content of any nutrient was leaflet>pith, but the difference in N was particularly large. In addition, the coefficient of variation of Ca content was highest in both leaflet and pith.

3. Extraction of starch by electric blender

Table 6 shows the starch contents of pith at different positions of the trunk and the average starch content per pith fresh weight (dry starch percentage to pith fresh weight) by blender extraction and chemical methods. In the blender extraction method, the average starch content in the pith was 27.9% for Bemban and 27.1% for Buntal, and no significant difference was found, as in the chemical method. The average starch contents of both varieties by the blender extraction method and the chemical method were 27.5% (Bemban) and 34.1% (Buntal). The content was significantly (*p<0.001*) lower with the blender extraction method than with the chemical method, irrespective of the trunk positions. The starch contents of the top and base with the blender extraction method were 25.5% and 26.2%, respectively, which tended to be about 5% lower than that of the middle. This tendency was the same in the results of the chemical method, and the starch content was higher in the order of middle>base>top, and about 3 to 6% lower at the base and top than in the middle. In addition, a highly significant (*p<0.001*) positive correlation was observed between the starch content with the chemical method and that with the blender extraction method, and the contents using the blender method were about 80% of those when using the chemical method represented by the slope of the regression equation (Fig. 3).

Table 5. Contents of macronutrients in the leaflet and pith of sago palm varieties at harvest grown in Ambangah Village in Pontianak, West Kalimantan, Indonesia

Variety	Part	N	P	K	Ca	Mg
				(g/kg)		
Bemban	Leaflet	13.7	0.78	6.5	2.09	1.87
Buntal	Leaflet	14.4	0.83	7.8	1.90	1.33
Average		14.1	0.80	7.2	1.99	1.60
SD		0.76	0.03	1.32	0.66	0.36
CV (%)		5.4	3.8	18.5	33.1	22.4
Tukey's-test		*ns*	*ns*	*ns*	*ns*	*
Bemban	Pith	2.21	0.36	4.94	1.28	0.90
Buntal	Pith	2.04	0.38	5.66	1.69	0.77
Average		2.12	0.37	5.30	1.49	0.83
SD		0.21	0.05	1.31	0.62	0.16
CV (%)		9.9	13.5	24.7	42.0	19.7
Tukey's-test		*ns*	*ns*	*ns*	*ns*	*ns*

ns and *: not significant and significant at *p<0.05*, respectively.

Table 6. Comparison of starch contents (dry starch percentage to fresh pith weight) of sago palm pith at different positions using the blender method and the chemical method

Method	Variety	Trunk position (starch, %)			
		Base	Middle	Top	Average
Chemical	Bemban	33.2	36.5	34.2	34.6
	Buntal	33.5	36.4	30.8	33.6
Blender	Bemban	25.8	31.7	26.4	27.9
	Buntal	26.6	30.1	24.6	27.1
Method	*Chemical*	*33.4 a*	*36.4 a*	*32.5 a*	*34.1 a*
	Blender	*26.2 b*	*30.9 b*	*25.5 b*	*27.5 b*
	(M/C, %)	*(78.4)*	*(84.9)*	*(78.5)*	*(80.6)*
Variety	*Bemban*	*29.5 A*	*34.1 A*	*30.3 A*	*31.3 A*
	Buntal	*30.1 A*	*33.2 A*	*27.7 A*	*30.3 A*
Method (M)		***	***	***	***
Variety (V)		ns	ns	ns	ns
M × V		ns	ns	ns	ns

ns and ***: not significant at $p<0.05$ and significant at $p<0.001$, respectively. Numerals followed by the same letter within each column do not differ at $p<0.001$ by Tukey's test.

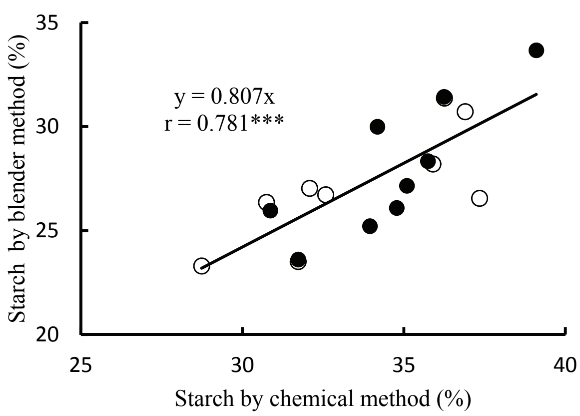

Fig 3. Relationship between starch contents using the blender method and the chemical method
●Bemban, ○Buntal.
***: significant at $p<0.001$.

Discussion

Two varieties, Bemban and Buntal, were cultivated along the Ambangah River, a tributary of the lower Kapuas River in West Kalimantan. Saitoh et al. (2008) reported that there were three major sago palm varieties along the Kapuas River in Pontianak : Bemban, Buntal, and Pulut. However, they did not report the characteristics of each variety. According to the interview results of this research, Bemban and Buntal were presumed to belong to early-flowering varieties because they were harvested at 10-12 years after sucker emergence/planting, following the categorization of the earliness of flowering of sago palms by Yamamoto et al. (2020). Gusmayanti and Maherawanti (2011) reported that these varieties reach the harvest stage in 8-10 years. Both varieties were non-spiny types and were distinguished by local sago growers by characteristics such as their suckering ability, the extent of their clump, the angle of their trunk crowns, the length and thickness of their trunks, etc. (Table 1). The years from sucker emergence to trunk formation were 4-5 years in both varieties, which was almost the same length of time as for varieties of around Lake Sentani, Papua, Indonesia, which is included in the sago palm's area of origin, and those of Sarawak, Malaysia (Yamamoto et al., 2003a; 2020).

It is estimated that the sago palm was introduced to this area about 45 years ago and cultivation began. Gusmayanti and Maherawanti (2011) reported that sago palm cultivation in West Kalimantan, including Ambangah Village, dates back more than 30 years. In addition, they reported that the average sago palm cultivation area in West Kalimantan was about 1.5 ha, and suckers were planted at distances of 3-10 m. In Ambangah Village, transplanted suckers take only about two years from planting to trunk formation because large suckers weighing more than 5 kg are transplanted after being nursed in a pond (for about 1 month) to generate new roots and a new leaf (planting density: 5m × 5m). This duration was earlier than the 4-6 years previously reported in mineral soil (Yamamoto et al., 2003c, 2010, 2020). The fertile soil in this area, located at the lower reaches of the Kapuas River, as well as the large nursed suckers might have caused the earlier trunk formation. Cultivation management after sucker planting was hardly carried out (Gusmayanti and Maherawanti, 2011).

Large differences in leaf area and trunk length were found between both varieties, and these characteristics of Bemban were significantly superior to those of Buntal; however, there was no significant difference in trunk diameter between both varieties (Tables 2 and 3). These results were consistent with results of the interview, which showed that Bemban has a longer and thinner trunk than Buntal. The trunk weights of the surveyed individuals of both varieties were in the range of 900-1300 kg, and the trunk weight tended to be equivalent to that of the sago palm of Muka, Sarawak (Jong, 1995) or slightly heavier (Yamamoto et al., 2003a, 2003c).

On the other hand, regarding starch productivity, there were no significant differences between the two varieties in the dry matter, starch, and total sugar percentages in the pith related to starch productivity (Table 4). These values were in the same range as those reported so far (Yamamoto et al., 2003a, 2010, 2020); however, the starch percentages were significantly different and several percentages higher than those of the sago palms in Muka, Sarawak, Malaysia. The starch percentage in the trunk was higher in the middle than those in the top and base, but the difference between varieties was small (Fig. 2). This result was consistent with the result of Yamamoto et al. (2003a). A significant difference in the starch content was not observed between the two varieties, but Bemban had a longer trunk than Buntal, resulting in heavier pith weight, and its starch contents, 272-380 kg (average 326 kg), were higher than those of Buntal, 250-306 kg (average 278 kg). The starch contents of both varieties were superior to those of the previously reported sago palms in Muka, Sarawak (Yamamoto et al., 2003a, 2003c).

The starch content of sago palm in remote areas was crushed and easily measured without using chemicals using a commercially available electric blender. The crushed pith was squeezed through a double 100-mesh cloth with water, and the precipitated starch was removed. As a result, it was clarified that about 80% of starch chemically analyzed can be recovered by this method, regardless of trunk positions (Table 6). Therefore, this method was considered effective as a simple method for measuring starch content in remote areas where electricity is available. Miyazaki et al. (2006) reported that the efficiency of extracting starch from sago palms grown in Jayapura, Papua, by the blender extraction method was about 80% of the starch amount chemically analyzed. The extraction efficiency in this survey showed similar values. The starch extraction efficiencies using traditional methods, such as using an ax-like tool or a grater to pulverize the pith were reported to be 44% (Schuiling, 2009) and 48% (Yamamoto et al., 2007), respectively. As compared to these traditional methods, the blender extraction method was considered to have the advantage of 30-35% higher extraction efficiency, as well as simplicity and reduction of investigation time.

The contents of macronutrients in the leaflet and pith were higher in the order of N>K>Ca>Mg>P and K>N>Ca>Mg>P for Bemban and Buntal, respectively (Table 5). This order was consistent with previous reports (Sim and Ahmed, 1991; Falch and Schuiling, 1991 ; Yamamoto et al., 2003b, 2020). Except for the Mg content in the leaflet, there were no significant differences between the two varieties in the macronutrient contents of the leaflet and pith. As compared to sago palms grown in Mukah, Sarawak, leaflets had higher K contents (Sim and Ahmed, 1991; Flach and Schuiling, 1991), the N and K contents in the pith tended to be higher, and the Ca content tended to be lower than those of sago palms in Mukah (Flach and Schuiling, 1991; Yamamoto et al., 2003b). It was particularly noteworthy that the K contents in the leaflet and pith were higher than those of sago palms in the adjacent Sarawak, because it was reported that the K content in the leaflet promoted the translocation of photosynthetic products from the leaf to the starch reservoir (Tsuno and Fujise, 1965; Haedar et al., 1973), and the K content in the pith was noted for the activation of starch synthase (Marsher, 1986; Hara, 2001). Based on these facts, it was estimated that the significantly higher starch percentages in the pith of the sago palms in Pontianak as compared to those in Muka, Sarawak mentioned above, were closely related to the differences in the K contents in the leaflet and pith.

Acknowledgements

We express our sincere gratitude to Professor Saeri Sagiman, Faculty of Agriculture, Tanjungpura University, West Kalimantan, Indonesia, who gave us a great deal of support and assistance in our conducting of this research. In addition, we thank the local sago palm growers for their kind cooperation in interview surveys and the sample collections of sago palms. This study was supported by a JSPS KAKENHI Grant (Grant No. 18405019).

References

Flach, M. 1997 Sago palm, *Metroxylon sagu* Rottb (Promoting the Conservation and Uses of Underutilized and Neglected Crops, 13). International Genetic Resources Institute (Rome) pp. 85.

Flach, M. and D. L. Schuiling 1991 Growth and yield of sago palms in relation to their nutritional needs. *In*: Towards greater advancement of sago industry in the '90s (Proceedings of the Fourth International Sago Symposium) (Ng, T. Y., Y .L. Tie and H. S. Kueh eds.) Lee Ming Press (Kuching) 103-110.

Gusumayanti, E. and Maherawanti 2011 Sago palm cultivation practices in four sago producing villages in West Kalimantan. *In*: Proceeding of the 10th International sago symposium -Sago for food security, bio-energy, and industry, from research to market (Siregar, I.Z., T. Sudaryanto, H. Ehara, Suwardi, I. Lubis, and S. W. Ardie eds.) Bogor Agricultural University (Bogor) 48-49.

Haeder, H. E., K. Mengel and H. Forster 1973 The effect of potassium on translocation of photosynthates and yield pattern of potato plants. Journal of the Science of Food and Agriculture 24: 1479-1487.

Hara, T. 2001 Plant growth and nutrition system. *In*: Plant nutrition (Mori, S., T. Mae, and T. Yoneyama eds.) Buneido (Tokyo) 133-137. (in Japanese)

Jong, F.S. 1995 Research for the development of sago palm (*Metroxylon sagu* Rottb.) cultivation in Sarawak, Malaysia. Ph.D. thesis of Agricultural University, Wageningen, The Netherlands. pp. 139.

Kueh, H.S., Y.L. Tie, E. Robert, C.M. Ung and J. Hj. Osman 1991 The feasibility of plantation production of sago (*Metroxylon sagu* Rottb.) on an organic soil in Sarawak. *In*: Towards greater advancement of sago industry in the '90s (Proceedings of the Fourth International Sago Symposium) (Ng, T. Y., Y .L. Tie and H. S. Kueh eds.) Lee Ming Press (Kuching) 127-136.

Marsher, H. 1986 Mineral nutrition (Second edition). Academic Press (London) 285-312.

Ming, R. Y. C., Y. Sobeng, F. Zaini and N. Bursi 2018 Suitability of peat swamp areas for commercial production of sago palms: The Sarawak experience. *In*: Sago Palm –Multiple contributions to food security and sustainable livelihood– (Ehara, H., Y. Toyoda, and D.V. Johnson eds.). Springer Open (Singapore) 91-108.

Miyazaki, A., F.S. Jong, Petrus, Y. Yamamoto, T. Yoshida, Y.B. Pasolon, H. Matanubun, F.S. Rembon, and J. Limbongan 2006 Starch extraction in several sago palm varieties grown near Jayapura, Papua State, Indonesia. Proceedings of the 15th Conference of the Society of sago Palm Studies, 9-12. (in Japanese)

Murayama, N., M. Yoshino, M, Oshima, S. Tsukahara and Y. Kawarazaki 1955 Studies on the accumulation process of carbohydrates associated with growth of rice plant. Bulletin on the National Institute of Agricultural Sciences, Japan. Series B4: 123-166. (in Japanese with English summary)

Murphy, J. and J. P. Riley 1962 A modified single solution method for the determination of phosphate in natural waters. Analytica Chimica Acta 27:31-36.

Omori, K. 2001 Agro-physiological studies on sago palm (*Metroxylon sagu* Rottb.). Master's thesis for the Subtropical Agricultural Course 2000, Graduate School in Agricultural Science, Kochi Univ. pp. 118. (in Japanese)

Rasyad, S. and K. Wasito 1986 The potential of sago palm in Maluk (Indonesia). *In*: Sago-'85: Proceedings of the 3rd International Sago Symposium (Yamada, N. and K. Kainuma eds.) The Sago Palm Research Fund (Tokyo) 1-6.

Saitoh, K., M.H. Bintro, I. Ohe, F.S. Jong, J. Law and N. Sugiyama 2008 Starch productivity of sago palm in Indonesia. Sago Palm 16: 102-108.

Schuiling, D. L. 2009 Growth and development of true sago palm (*Metroxylon sagu* Rottöll) with special reference to accumulation of starch in the trunk. Ph.D. thesis of Agricultural University, Wageningen, The Netherlands. pp. 257.

Sim, E. S. and M. I. Ahmed 1978 Variation of flour yield in the sago palm. Malaysian Agricultural Journal 51: 351-358.

Sim, E. S. and M. I. Ahmed 1991 Leaf nutrient variation in sago palms. *In*: Towards greater advancement of sago industry in the '90s (Proceedings of the Fourth International Sago Symposium) (Ng, T. Y., Y .L. Tie and H. S. Kueh eds.) Lee Ming Press (Kuching) 94-102.

Tsuno, Y. and K. Fujise 1965. Studies on the dry matter production of the sweet potato VIII. The internal factors influence on photosynthetic activity of sweet potato leaf. Proceeding of Crop Science Society of Japan 33: 230-235.

Yamamoto, Y. 1998 Sago palm. Tropical Agriculture Series, Tropical Crop Manual No. 25, Tokyo: Association for International Cooperation of Agriculture and Forestry. pp.109. (in Japanese)

Yamamoto, Y., K. Omori, Y. Nitta, A. Miyazaki, F. S. Jong and T. Wenston 2007 Efficiency of starch extraction from the pith of sago palm: A case study of the traditional method in Tebing Tinggi Island, Riau, Indonesia. Sago Palm 15: 9-15.

Yamamoto, Y., K. Omori, Y. Nitta, K. Kakuda, Y. B. Pasolon, R. S. Gusti, A. Miyazaki and T. Yoshida 2014 Changes of leaf characters in sago palm (*Metroxylon sagu* Rottb.) after trunk formation. Tropical Agriculture and Development 58: 43-45.

Yamamoto, Y., F. S. Rembon, K. Omori, T. Yoshida, Y. Nitta, Y. B. Pasolon and A. Miyazaki 2010 Growth characteristics and starch productivity of sago palm (*Metroxylon sagu* Rottb.) in Southeast Sulawesi, Indonesia. Tropical Agriculture and Development 54: 1-8.

Yamamoto, Y., I. Yanagidate, A. Miyazaki, T. Yoshida, A. F. Irawan, Y. B. Pasolon, F. S. Jong, H. Matanubun, A. A. Arsy and J. Limnongan 2020 Growth characteristics and starch productivity of folk varieties of sago palm around Lake Sentani near Jayapura, Papua State, Indonesia. Tropical Agriculture and Development 64: 23-33.

Yamamoto, Y., T. Yoshida, Y. Goto, F. S. Jong and L. B. Hilary 2003a Starch accumulation process in the pith of sago palm (*Metroxylon sagu* Rottb.). Japanese Journal of Tropical Agriculture 47: 124-131. (in Japanese with English abstract)

Yamamoto, Y., T. Yoshida, Y. Goto, F. S. Jong and L. B. Hilary 2003b Changes in macroelement content in the pith of sago palm (*Metroxylon sagu* Rottb.) with palm age. Japanese Journal of Tropical Agriculture 47: 206-214. (in Japanese with English abstract)

Yamamoto, Y., T. Yoshida, Y. Goto, Y. Nitta, K. Kakuda, F. S. Jong, L. B. Hilary and H. Hassan 2003c Differences in growth and starch yield of sago palms (*Metroxylon sagu* Rottb.) among soil types in Sarawak, Malaysia. Japanese Journal of Tropical Agriculture 47: 250-259.

Yatsugi, T. 1977 Sago starch. *In*: Starch Science Handbook. (Nakamura, M. and S. Suzuki eds.) Asakura Syoten (Tokyo) 404-410 (in Japanese)