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Distribution and Variation in the Starch Content of Sago Palms (*Metroxylon sagu* Rottb.) at Different Growth Stages

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Abstract Sago palms of the similar growth stage on shallow peat vary in length, circumference and weight of trunk. From the time of planting, a sago palm remains in the rosette stage for about 5.5 years before trunks are formed. Flower initiation occurs at 12.5 years and mature fruits are completely shed in 14.5 years.

The average content of dry starch increases with maturation until flowering. At the younger stages, starch is mainly found at the lower portion of the trunk, indicating the progressive accumulation of starch from the base to the top of the trunk. The maximum starch content, i.e. 18–20%, is observed between the full trunk growth stage (just before the emergence of inflorescence structure) and flowering stage. Thereafter, the starch content decreases sharply to 4–6% at the final stage.

In contrast to normal fruiting palms, mature-fruiting palms which produced little or no fruits because of abnormal or damaged inflorescence, retain the majority of the starch in the trunks. This demonstrates that most starch in the trunk is mobilised for fruit development at the end of its life span.

The maximum starch yield per unit time is found between the full trunk growth and flowering stages. For the maximum economic return and the promotion of growth of successor palms, harvesting should be carried out the full trunk growth stage.

Key words: Sago palm, Starch content, Starch distribution, Growth stage

異なる生長段階におけるサゴヤシの澱粉含有量の分布と変異

要　約　泥炭層の薄い泥炭地に生育するサゴヤシは同一の生長段階にあっても，幹の高さ，周径，重量とも変動がみられる．植栽時点から幹が形成されるまでの約 5.5 年間は，ロゼッタ段階にとどまっており，開花は 12.5 年で始まり，果実が完全に脱落するまでには 14.5 年かかる．

澱粉の平均乾燥重量は，開花期まで成熟するにつれて増大する．比較的早い生長段階では澱粉は主として幹の下部に集中するが，このことは澱粉の集積が幹の基部から頂部に移行することを示している．18～20% という最大の澱粉量は，幹の最大生長段階(花序形成の直前)と開花段階のあいだでみられる．その後は澱粉量は急速に減少し，最終段階では 4～6% になる．

正常に結実したヤシと対照的に，花序の異常あるいは損傷のためにまったくあるいはごくわずかしか結実しなかったヤシでは，澱粉の大半は幹の中に保持される．このことは，幹の中のほとんどの澱粉は，生長の最終段階である果実の発達のために移送されることを示している．

時間あたりの澱粉生成量が最大になるのも，幹の最大生長段階と開花段階のあいだにある．経済的にみて最大の収量を得ることと，次世代のヤシの生長を促進させるためには，収穫は最大生長段階でなされるべきである．

キーワード　サゴヤシ，澱粉含有量，澱粉の分布，生長段階

Introduction

Throughout the growth cycle of sago palm, the following twelve stages are known by the local sago farmers in Sarawak: rosette, trunk formation, early trunk growth (two stages), mid trunk growth, late trunk growth, full trunk growth, bolting, flowering, young fruiting, mature fruiting, and dying stages. Sago palms are normally harvested between the full trunk growth stage and flowering stage for processing. However, depending on the need for cash by farmers and permissiblity of weather conditions for transportation of sago logs, they may be harvested at a slightly younger or older stage. Palms harvested too much younger or older usually provide lower prices. This is because experienced sago processing factory owners can judge quite accurately from the appearance of the trunk that these palms contain little starch. However, there is still a dearth of scientific information in the following matters:

(a) How much starch is contained in young palms and whether these young palms can be harvested to get an early return;

(b) How starch distribution is in palms at different stages of growth, from the trunk formation to dying stages;

(c) How re-distribution of starch is in the trunk as it approaches the end of its life span.

Review of Literature

Variations in starch yield in sago palms at selected growth stages have been reported by Sim and Ahmed (1978) and Sim and Lim (1987). They believe that the best time for felling ranges from flowering stage to fruiting stage. Also, Johnson and Raymond (1956) reported that for maximum sago production, palms are best harvested after flowering and before fruit development. Lim (1991) found that the starch content is highest at the flowering stage although the starch yield does not differ from the inflorescence emerging stage to the flowering stage. Flach (1973) and Flach et al. (1989) reported that in Batu Pahat, Johore of Peninsular Malaysia, palms are harvested before flower initiation at about eight years after planting.

Sim and Ahmed (1978) revealed that starch was generally accumulated from the base upwards. The highest starch concentration is found between 1.5–6 m from the base and the lowest at the top of the trunk as it is probably used for flower and fruit development. Kraalingen (1984) also reported that starch appears to accumulate from the base upwards in young palms. He found that at flower initiation, starch appears to travel upwards to settle anew at the top of the trunk. In Papua New Guinea, some local populations remove the flower buds to retain the starch in the trunk for later harvesting (Barrau 1959). Lim (1991) found that the starch content from maximum vegetative to mature fruit stage is, in general, evenly distributed along the trunk except for the last part where the starch content decreased. The highest content is found at the base of the palm and the lowest at 1–2 m below the crown. Johnson and Raymond (1956) and Cecil et al. (1982) also reported likewise.

The above conclusions were drawn from investigations made only on a part of the growth stages. Systematic investigation on the pattern of starch accumulation or mobilization over a complete range of the trunk development stages has not been fully investigated.

Materials and Methods

Plant materials

To minimise variability in growth due to differences in soil type and other factors, sago palms of the spineless cultivar were selected from a cultivated and properly maintained garden near Kampung Teh, Dalat. These palms were planted from suckers in 1978 on shallow peat (about 30 cm in depth) overlying clay subsoil. They were apparently healthy in growth. The actual ages of palms in the dying and mature fruiting stages were known from the planting dates. The ages of other palms were estimated based on the farmers' memory, experience and comparison with growth stages of the nearby palms, ages of which were known. Of the 12 growth stages described, only the later 10 stages that possess visible trunks were chosen for this study (Table 1).

Table 1 Known stages of growth and development of sago palm in Sarawak

Development stage	Estimated age from planting (yr)	Local name	Duration of trunk growth (yr)	Growth description
1	1–5.5	sulur	0	Rosette stage to the start of trunk formation; Sucker-like young palm without visible trunk.
2	5.5	angkat burid	0	Start of trunk formation; A transition between rosette and trunk growth; Short trunks are found upon removal of dead sheaths at the base of the palm at ground level.
3	7	upong muda	1.5	Young trunk growth; Trunks are about 1–2 m in length.
4	8	upong tua	2.5	25% trunk growth; Trunks are about 2–5 m in length.
5	9	bibang	3.5	50% trunk growth; Trunks are about 4–7 m in length.
6	10	pelawai	4.5	75% trunk growth; Trunks are about 6–8 m in length.
7	11.5	pelawai manit	6	Full trunk growth; Full growth of harvestable trunk (7–14 m) Leaves become erect and small at the palm terminal; Appearance of whitish colouration on the stalks of these fronds.
8	12	bubul	6.5	Bolting; Appearance of torpedo shaped flowering structure at the palm terminal; Elongation of the trunk at the top of the crown and frond reduction to bract-like structures.
9	12.5	angau muda	7	Flowering; Well-developed flowering structure with primary, secondary and tertiary flowering axes spreading out at the terminal; Flowers are in the pre- or post-anthesis stage.
10	13	angau muda (same as stage 9)	7.5	Young fruiting; Fruits are about 20–30 mm in diameter; Endosperms of the seeds (if any) are still soft and small; Most fronds are still intact and presumably functional.
11	14	angau tua	8.5	Mature fruiting; Fruits are mature, 30–40 mm in diameter; Seeds (if any) are well developed with dark-brown seed coat and bony endosperms; Most fronds are in senescent stage.
12	14.5	mugun	9	Dying stage; Most fruits have been shed and all fronds are in senescent stage.

In addition, palms in stage 11 with abnormal (little or no) fruit development caused by damages to the inflorescence structures were also harvested for starch content determination. This was to find out whether removal or damage of flower buds would delay the loss of starch in over-mature palms.

Sampling

Depending on availability, three or more palms of each growth stage were felled just above ground level by a chainsaw. The length of the trunk was measured from the point of felling to the sheath base of the oldest living frond to represent the harvestable trunk. Trunk samples for starch content determination were taken from five evenly spaced sampling points along the trunk. The sample nearest to the base was named No. 1 and that closest to the crown, No. 5. This was to reflect the longitudinal distribution of starch and moisture from the base to the top of the trunk in each growth stage of uneven trunk length.

A disc of about 2 cm thick was cut out at each sampling point and put in a properly labelled polythene bag. The trunk was further cut into convenient lengths (if required) to determine the total weight of the harvestable trunk.

Starch extraction

From the sample discs collected, a segment of about 500 g was excised for analysis after measurement of the total weight. The remaining discs were saved for moisture determination. From the segment, the bark (about 10–12 mm thick) was separated from the pith by a chopping knife. The weight and volume of the bark and pith were determined by weighing and water displacement respectively. The bark was not used for starch extraction since it was too hard to process and contained little starch (Cecil, 1982).

The pith was chopped into about 1 cm^3 cubes and ground in a motorised grinder with an equal volume of water until it was well broken up. The content was then poured through a piece of bag-shaped nylon sieve (about 200 μm mesh size) placed on the top of a plastic pail. The starch was extracted by squeezing the nylon bag with the content in several washes of water until the liquid passing out of the nylon sieve became clear and no more starch could be squeezed out of the hampas; fibrous residue of rasped pith after starch was extracted. The filtrate collected was left to settle in a pre-weighed aluminium tray. After about 6 hours when the starch was settled at the bottom, excess water was decanted. The tray with the starch was dried in an oven at 68°C (sago palm starch gelatinises betwen 72–90°C) for 12 hours, following a procedure established at the Agricultural Research Centre, Sarawak. The weight of the dry starch was then determined immediately after removal from the oven to prevent the absorption of moisture from atmosphere.

Calculation

The starch content is expressed as the percentage of dry starch that can be extracted from a given weight of fresh sample. This enables easy estimation of the total dry starch yield of a palm once its fresh weight is known. The following formulae were used in this study:

$$[\text{Content of dry starch in sample}] = \frac{[\text{Weight of dry starch extracted from sample (g)}]}{[\text{weight of fresh sample (g)}]} \times 100\%$$

$$[\text{Estimated dry starch yield per palm}] = [\text{Total weigth of trunk (kg)}] \times [\text{Average content of dry starch from 5 samples in the trunk (\%)}]$$

$$[\text{Dry starch yield per unit time}] = \frac{[\text{Average yield of palm in a growth stage (kg)}]}{[\text{Time to reach the growth stage from planting (yr)}]}$$

Table 2 Growth data of sago palms for this study

Development stage	Estimated age (yr) from planting	Duration of trunk growth (yr)	Palm No.	Trunk ht. (cm)	Trunk wt. (kg)	Trunk circumference 1 m a.g.l (cm)	Trunk vol (m^3)
3. young trunk growth	7	1.5	1	179	253	148	0.31
			2	157	187	141	0.25
			3	185	253	150	0.33
4. 25% trunk growth	8	2.5	1	295	566	167	0.87
			2	500	406	119	0.56
			3	410	394	127	0.79
			4	479	664	144	0.79
5. 50% trunk growth	9	3.5	1	550	573	137	0.82
			2	700	744	135	1.01
			3	595	580	123	0.72
6. 75% trunk growth	10	4.5	1	745	940	146	1.26
			2	677	942	147	1.16
			3	800	938	155	1.53
7. Full trunk growth	11.5	6	1	800	1062	153	1.49
			2	840	1087	160	1.71
			3	740	973	155	1.41
8. Bolting	12	6.5	1	825	1169	162	1.72
			2	733	1124	140	1.14
			3	741	1123	160	1.51
9. Young flowering	12.5	7	1	660	901	160	1.34
			2	767	1058	152	1.41
			3	741	1088	160	1.50
			4	969	1349	153	1.80
10. Young fruiting	13	7.5	1	560	730	163	1.18
			2	487	600	146	0.83
			3	802	1123	152	1.47
			4	700	603	135	1.01
11. Mature fruiting	14	8.5	1	720	791	146	1.22
			2	530	573	160	1.08
			3	535	519	145	0.89
12. Dying	14.5	9	1	770	681	157	1.51
			2	682	709	140	1.06
			3	807	935	145	1.34
			4	470	352	138	0.71

Analysis of variance was done by PC-STAT developed by Georgia University, USA and Statpal II (version 5) programmes for microcomputers.

Results

Growth data and estimated age of palms at different growth stages

Trunk length and weight varied considerably within each growth stage and among different ones but generally increased with age and reached a maximum at the full trunk growth stage, at age of 11.5 years after planting from suckers (Table 2).

However, overlaps in the lengths and weights of trunks were common especially after the 8th year of planting; some younger palms were observed to possess longer trunks and more weights than older ones.

The trunk circumference measured at 1 m a.g.l. also showed considerable variation especially among the different growth stages.

Variation in starch content along the trunk at each growth stage

The starch content of the pith at five sampling points along the trunk varied significantly in palms of stages 5, 6, 7, 8 and 10 (Table 3, Fig. 1). For

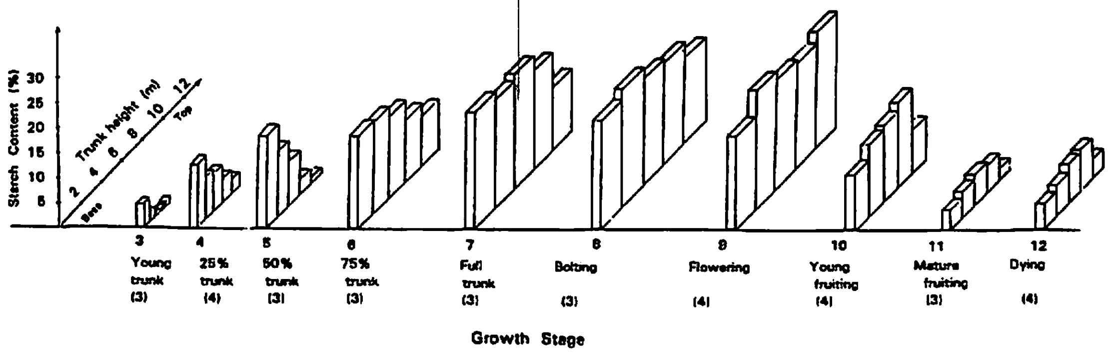

Fig. 1. The distribution of starch content along five evenly spaced positions in the trunk of sago palms. Note the increase in starch content from the base to the top as maturity of the palm advances and the movement of starch from the base to the top at flowering. The palm trunks in the late stages of growth are shorter because they are the leader palms (explained in Discusion). The number in brackets indicates the averaged number of investigated palms.

Table 3 Starch content in sago palm pith at five sampling positions along the trunk

Sampling position	Starch content (%) at different growth stages									
	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Stage 8	Stage 9	Stage 10	Stage 11	Stage 12
1	5.06	13.91	19.93^{a}	19.77^{a}	25.01^{a}	23.43^{ab}	19.94	11.95^{bc}	4.50	5.69
2	1.88	9.12	13.82^{ab}	19.72^{a}	23.79^{a}	25.83^{a}	25.73	15.40^{ab}	5.74	7.24
3	0.78	8.32	9.20^{bc}	17.96^{ab}	25.19^{a}	22.81^{ab}	23.91	16.69^{ab}	6.95	8.50
4	0.49	5.29	2.93^{cd}	13.59^{ab}	21.51^{a}	22.33^{ab}	23.02	18.73^{a}	6.02	9.06
5	0.83	3.26	1.24^{d}	10.99^{b}	13.53^{b}	18.68^{b}	25.48	9.47^{a}	2.13	4.10
Mean	1.85	8.00	9.42	18.35	21.81	22.62	23.62	14.45	5.07	6.92
S.E. (dif)	3.12	5.03	3.07	3.79	3.35	2.22	2.93	2.69	3.93	3.79
C.V. (%)	211	89.2	39.96	28.35	18.8	12.04	17.60	26.4	101	77.5

* Note: Figures in the columns followed by different letters are significantly different at $p = 0.05$ by DMRT.

palms at the trunk of stages 3 and 4, higher starch content was found at the bottommost position even though the difference was not significant. At stages 5 to 7, the lower sections of the trunk had markedly higher starch content than the upper portions. In palms of growth stage 9, high starch content of 20–25% was found evenly distributed along the trunk. At stage 10, a sharp drop in starch content was observed in the topmost position. Starch content in the remaining four-fifth of the trunk showed a decreasing trend from the upper to the lower portion. At stages 11 and 12, low starch content was found evenly distributed along the whole trunk.

Starch yield per unit time at different growth stages

The mean starch content in the pith increased significantly from stages 3 to 6, and then plateaued off at a maximum content of 21.8 to 23.6% from stages 7 to 9 before decreasing sharply in stages 10 to 12. Young palms contained very little starch in the pitch and the highest starch content was found in palms in stage 9 (Table 4).

The highest yields were obtained in stages 7 to 9; although stage 9 contained slightly more starch than the other two stages, the difference was insignificant. The maximum yield per unit time also occurred at stages 7 to 9.

Comparison of starch yield in over-mature (stage 11) palms with normal and abnormal fruit development

Palms at stage 11 with normal fruit development contained an average of 4.16% of starch evenly distributed along the trunk. In contrast, palms at the same growth stage but with little or no fruit development contained an average of 19.9% starch, with slightly lower levels at the bottommost and topmost positions of the trunk (Table 5).

Discussion

Overall growth

Under optimal growth conditions, the age of sago palm can be predicted from the following equation (Flach and Schuiling, 1989):

Table 4 Starch yield of sago palms at different development stages

Development stage	3	4	5	6	7	8	9	10	11	12
Estimated age (yr)	7	8	9	10	11.5	12	12.5	13	14	14.5
Av. starch yield per palm (kg)	3.6^{d}	36.9^{de}	49.2^{cd}	128.7^{b}	203.4^{a}	216.6^{a}	219.4^{a}	93.1^{bc}	24.8^{de}	41.8^{de}
Yield/unit time (kg/yr)	0.52^{e}	4.62^{cd}	5.47^{cd}	12.87^{b}	17.69^{a}	18.04^{a}	17.55^{a}	7.16^{c}	1.77^{de}	2.88^{de}

Table 5 Comparison of starch content in mature palms (stage 11) with normal and abnormal fruit development

Sampling position		1	2	3	4	5	mean
Starch content (%)	normal fruit development	4.40	5.74	2.45	6.02	2.12	4.16
	Abnormal fruit development	18.97^{ab}	21.50^{a}	22.59^{a}	21.51^{a}	14.56^{b}	19.9

Note: Figures in the rows followed by different letters are significantly different at $p = 0.05$ by DMRT .

$$[\text{Age (yrs)}] = 4 \text{ (or 4.5)} + \frac{[\text{No. of internodes + no. of functional leaves}]}{12}$$

This is based on the estimate that palms grown from seeds take 4 to 4.5 years to form trunks and after that it is assumed that they produce an average of 12 fronds per year. However, under sub-optimal conditions, palms may remain in the rosette stage for more than nine years as observed in palms cultivated at high density in Sarawak. Thus, for the description of different growth stages, the physiological age would be more useful than the actual age or parameters such as palm height or trunk circumference. Flach (pers. com.) stipulated that the development stages could reflect the number of leaf scars present on the trunk and this subject deserves further investigation.

Since the sago palms used in this study were selected from a cultivated garden with known background, the estimated age of the various growth stages was close to the actual age of these palms. The rosette stage of 5.5 years reported in this study agrees with the findings of the sago research work on deep peat by the Department of Agriculture, Sarawak (Anonymous,1991–93) but differed considerably from those stipulated by Flach and Schuiling (1989) for palms of three years and nine months in age under optimal growth conditions. This is normal in Sarawak as sago palms are observed to reach the harvestable stage at widely different ages. Depending on soil fertility and growth conditions, sago palms are estimated to attain maturity in 10.3 years on mineral soils and about 12.5 years on deep peat (Lim, 1991).

Variation and overlapping in the length, weight and circumference of the sago palm trunks within each growth stage and among different ones were common (Table 2). These were most likely due to environmental differences. In an open field, the first batches of sago (leader) palms to reach maturity generally have shorter trunks than the follower palms. This is probably due to the absence of overhead shading of the leader palm as compared to the followers which have to elongate under the umbrella of the leader in order to compete for sunlight. Under such a situation and upon harvesting of the leader palm, the followers would get more sunshine and hence be expected to increase in the circumference of the newly formed trunk thereafter.

Variation in starch content along the trunk at each growth stage

The progressive increase of starch content from the base to the upper portion of the trunk agrees with the reports of Sim and Ahmed (1978) and Kraalingen (1984). However, this finding cannot be directly compared with that of Lim (1991) who studied the total weight of starch in a one-metre log section rather than the percentage of starch. The trunk circumference of a sago palm along its entire length is variable, usually the biggest at the base and the smallest at the top. This difference has a great influence on the total starch yield in each log section. In the earlier studies, investigations were mainly carried out on palms from "late trunk formation" to "mature fruit" stages.

From stage 7 to 10, higher starch contents were generally found at progressively higher sampling positions from the base with a concurrent decrease at the bottommost position. This probably indicates the initiation of an upward mobilization of starch from the base to the upper portion of the trunk. The apparent upward movement of starch was also reported by Kraalingen (1984).

The sharp decline in starch content from stage 10 onward is interpreted as mobilization and conversion of starch into other forms of energy for flower and fruit development. The drastic decline in starch content at the topmost portion is probably due to its closeness to the developing fruits. Starch in this part of the trunk is converted into soluble forms ready to be mobilised to the sink. By stage 11, when the fruits are mature, only little starch is left unused which probably decays together with the trunk.

Mobilisation and utilization of the majority of starch in the trunk for flower and fruit development is strongly supported by comparison of starch contents in palms at stage 11 which had normal and abnormal fruit development. The latter contained an average of 19.9% dry starch in the trunk, with a lesser amount found at the topmost and bottommost sampling positions. This supports the report of Barrau (1959) that the Papuan New Guineans remove the flower buds to delay starch loss in flowering sago palms. In the absence of fruits, most of the starch remains immobilised and probably decays with the dying trunk later. This finding provides strong evidence to support the second theory of Kraalingen (1984) and speculation of Sim and Ahmed (1978), that starch is mobilised to the top for fruit development.

Kraalingen (1984) speculated that the lower starch content at the bottom portion of the trunk of flowering and fruiting palms might be due to the presence of more fibres and channels and higher demand by sucker development. Utilization of starch in this manner is rather insignificant as observed from the high starch content in over-mature palms without fruit development. Furthermore, suckers are continuously generated from the parent palm, even as early as the first year of planting, rather than sprouting in a pulse from maturing palms.

Variation in starch content at different growth stages

The highest starch content was found at stage 9 (flowering) although the difference between stages 7 to 9 was insignificant. This is in agreement with the report of Johnson and Raymond (1956) that maximum starch yield occurs after flowering but before fruit development. It also supports the findings of Sim and Lim (1987) and Lim (1991) that starch yield is the highest at these growth stages.

Starch content varied from 1.85 to 23.6% in the pith of sago palms at different growth stages. Harvestable palms at stages 7 to 9 normally contain 21 to 25% of dry starch in the pith, which would give a starch yield within the range of those reported by Sim and Ahmed (1978) and Sim and Lim (1987).

Starch yield and estimated yield per unit time

An average yield of above 200 kg per palm was obtained at stages 7 to 9. This is higher than that reported in Batu Pahat, Johore (Flach and Schuiling, 1989). The finding concurrs with that of Sim and Lim (1987) and Lim (1991), that starch yield is highest (but insignificantly different) among these three growth stages of one-year separation. For maximum starch yield, palms should be harvested during these stages.

The maximum yield per unit time is insignificant between stages 7 to 9. From an agronomic point of view, it will be advantageous to harvest palms at the full trunk growth (stage 7) as this will promote the growth of the follower palms by the reduction of competition for light and nutrients at an earlier time. On the other hand, flexibility enables the harvest of palms to be timed for periods of high prices within this time frame (Lim 1991).

Harvesting palms earlier than stage 7 will be wasteful as this is the time of most active starch accumulation and the yield per unit time is significantly lower. Fujii et al. (1986) reported that the smaller grain size of starch from young palms made it more difficult to settle in processing thus leading to poorer starch recovery and yield.

In this study, palms only attain stage 7, 11.5 years after planting. On mineral soils, palms can attain harvestable stage earlier as reported by Lim (1991), Flach (1973), and Flach and Schuiling (1989).

It is also evident that palms harvested at the fruiting or dying stage will give lower starch yield. However, most of the starch is retained in over-matured palms with damaged flowering structures. This implies that harvesting of sago palms can be delayed (if necessary) by removing the inflorescence during flower formation.

Conclusions

Starch is accumulated progressively from the base of the trunk upwards, initiating as early as the trunk formation stage. However, in the early stages of trunk development, the starch content is low and is mainly confined to the lower portion of the trunk.

From the full trunk development stage onward, the pith is filled with maximum mean starch content of 22%. The high content of starch remains rather constant throughout the whole length of the trunk until the flowering stage. Thereafter, the level of starch decreases sharply, with a more pronounced dip at the topmost and bottommost positions of the trunk. This has been interpreted as the mobilization of most of the starch for fruit development.

The mean starch content increases steadily from the trunk formation to the full trunk growth stage. The most active starch accumulation occurrs between the stages 5 to 7, at the rate of 75 to 80 kg per palm per year. Starch content is at its maximum of about 200 to 220 kg per palm from the full trunk development (stage 7) to flowering stage (stage 9). Once fruits are formed, the starch content drops rapidly at about 130 kg per palm per year from the flowering to fruit maturing period.

The total starch yield and estimated yield per unit time are highest between stages 7 and 9. However, palms are best harvested at full trunk growth to enable an early economic return and early reduction of competition for light and space with the follower palms.

In general, this study provides an understanding on the temporal and spatial distribution as well as the pattern of accumulation of starch along the entire length of the sago trunk. It also provides information on the variations of starch content in palms at different stages of trunk development. Evidence is also given on the mobilisation of starch for fruit development. An understanding on yield in relation to the corresponding development stages also enables the harvesting of a palm at the correct stage for maximum agronomic and economic returns.

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