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The Sustainability of Sago Palm (*Metroxylon sagu*) Cultivation on Deep Peat in Sarawak

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Abstract About 62% of the sago palms (*Metroxylon sagu*) in Sarawak are cultivated traditionally on peat. Fertilizer is not used and management is at a minimum. On deep peat only 15–20 trunks per ha per year are harvested as compared to 25–40 on mineral soils. Under such traditional and low density cultivation, the starch yield per trunk is comparable to those grown on mineral soils. However, the time to reach maturity is about 12–15 years as compared to 8–10 years on mineral soils. The total starch yield per unit area and time is thus significantly lower.

Under intensive cultivation with other traditional practices, sago palm growth on deep peat is expected to be slow. It takes about 6 years to start trunk formation and at least 12 years to maturity as compared to respectively 4.5 years and 10 years on mineral soils. Premature desiccation of fronds occurs resulting in small palm crowns of about 10 fronds and sometimes even less. They have a total leaf area of about 90 m^2 as compared to 220 m^2 for those grown on mineral soils. The trunk volume is about 37% smaller. Preliminary investigation on starch yield per trunk of similar growth stages on deep peat shows that it is only 23% of that on mineral soils.

As deep peat soils are being used for intensive cultivation of sago palm, the problem of fertilizer application should be solved first. If this problem can be solved, yields may be expected up to 200 kg dry starch per ha per year. Attention should also be paid to nursery practices, sucker regulation, spacing, control of pests, diseases and weeds, improvement of planting material and other as yet unknown factors.

Key words: Deep peat, Nutrient uptake, Sago palm, Starch yield

サラワクの泥炭層におけるサゴヤシ (*Metroxylon sagu*) 栽培の持続性

要約 サラワクにおけるサゴヤシ (*Metroxylon sagu*) の 62%は，伝統的に泥炭土壌で栽培されてきた．肥料は用いず，最小限の管理がおこなわれている．深い泥炭土壌では 1 ha あたり年間 15–20 本の幹が収穫されるが，これは無機質土壌での 25–40 本より少ない．幹あたりの澱粉の収量は変わらないものの，成熟するまでの期間は無機質土壌で 8–10 年なのに対し泥炭土壌では 12–15 年である．この 2 つの理由から，泥炭土壌でのサゴ澱粉の収量はかなり少ないことになる．

伝統的な方法に基づいて集約的な栽培を行っても，泥炭土壌における幹形成の開始までの期間と成熟までの期間はそれぞれ約 6 年と約 12 年以上であり，ミネラルに富んだ土壌での 4.5 年と 10 年よりはるかに長い．泥炭土壌では成熟前の乾燥により葉冠が小さく 10 本かそれ以下の葉柄しかつけず，葉の全表面積が約 90 m^2 となり無機質土壌での 220 m^2 より小さくなる．また，幹の体積も約 37 %小さい．予備的な調査結果では，泥炭土壌と無機質土壌での類似した生長段階の幹あたりの澱粉収量は前者で後者のわずか 23 %であった．

深い泥炭層をもつ土壌がサゴヤシ栽培に利用されようとしているが，施肥に伴う問題をまず解決しなければならない．これがうまくいけば，年間に 1 ha あたり乾重量で 200 kg の澱粉の収穫が期待できる．さらに，苗床をつくること，側枝の調整，間引き，病虫害やサゴ甲虫の防御，植えつける道具の改良など，まだよく知られていない点にも注意を払わ

なくてはならない.

キーワード　泥炭層，養分吸収，サゴヤシ，澱粉収量

Introduction

The sago palm is once flowering (hapaxantic) and tillering (soboliferous) perennially. It is mainly propagated vegetatively from suckers (tillers) although seeds are sometimes used. The growth of sago palm can roughly be divided into two broad stages, viz., the rosette stage without trunk growth and the later stage with trunk growth. In Sarawak, a full-grown sago palm has a trunk of 7–12 m in length, 40–60 cm in diameter and about 1 tonne in fresh weight. Starch is accumulated progressively from the base to the top of the trunks, starting as soon as the trunks are formed. About 200 kg of moisture-free starch is produced from each trunk just before flower initiation, the normal harvesting time of the palm.

It is one of the important export crops in Sarawak, currently the fourth largest agricultural export earner with an export volume of 49,500 tonnes of dry flour (according to Sarawak Agricultural Statistics 1992). Sago export from Sarawak can be traced back to the early 19th century, soon after Singapore was founded in 1821 (Morris 1977). The sago industry has grown very slowly until the early 1980s. In the last decade, research and development in the cultivation and processing of the sago palm has been intensified. Great emphasis is now placed on the large scale cultivation of the crop. Establishment of a 7700-ha sago palm plantation on deep peat near Mukah is towards completion and another one near Oya is in good progress. Large areas are further planned for cultivation in the coming decade.

Large sago palm plantations have a favourable stabilizing effect on the climate. There is minimal soil run-off, probably comparable to a virgin forest and generates less silt than any other plantation crops. It also has a vegetation sponge effect and the surface roots of sago palms serve as silt traps (Flach 1977). The long-term and ancillary environmental benefits and ecological contributions of sago palms are strongly stressed by Stanton (1991). Sago palms can therefore be exploited without harmful effects on the existing ecological pattern and thus are really adapted to the hot humid tropical swamp (Sago 1972; Ong 1977; Paijmans 1980; Flach 1984).

Traditional Sago Palm Cultivation

An estimated 19,720 ha of sago palms are found in Sarawak (Tie et al. 1991). Sixty-two percent is located on organic soils of which 7,520 ha are on peats deeper than 150 cm of organic material (Tie et al. 1991). Sago palms are commonly cultivated on deep peat mainly because better mineral soils are required for other crops. Because of their ability to withstand inundation and temporary flooding, they are generally found on low lying mineral or peat soils where other crops are less suitable. Even though starch yield is low per unit time and area, the sago palm is one of the very few crops that can grow well on peat in its natural state without soil improvement.

In the main sago producing areas of Mukah and Dalat Districts, sago palms are almost exclusively cultivated on smallholder basis. Once the suckers are planted, maintenance is kept at a minimum, probably confined to a few rounds of weeding at the young stage. Fertilizers are rarely or not used at all. The palms are left to grow by themselves until harvest. Occasional weeding and removal of dead fronds may be carried out. Sucker growth is normally not regulated but it is left to grow freely and is usually suppressed under heavy natural shade.

Pests are mainly confined to the sago worms (*Rhynchophorus schach*). The grub is considered as a delicacy by many peoples and frequently collected before they have a chance to cause further damage. Diseases are hardly encountered and preventive measures of pest and diseases are usually not taken. This creates the situation that sago palms require no fertilizer and are relatively free from pest and diseases. Many sago palm gardens are very old and have been passed down for a number of generations. Frequently, fruit and other trees are found in the holdings. Missing points are seldom filled, resulting in a low plant density per area.

Under such a traditional production system, sago palm has been considered as the only crop capable of giving sustained economic returns on the peat swamps of Sarawak (Tie and Lim 1977). However, the trunk production on deep peat is estimated at 15–20 trunks per ha per year whereas those on mineral soils are estimated at 25–40. There is no significant difference between the trunk starch content in palms grown under the two soil types (Tie et al. 1991; Lim 1991). The duration of growth of sago palms to maturity on peat is about 12–15 years (Tie et al. 1987, 1991) as compared to 8–10 years on mineral soils (Johnson and Raymond 1956; Flach 1984). The total starch yield per unit time and area is thus significantly lower. This is far lower than properly managed palms in sago plantations at Batu Pahat, Johore, where over 100 trunks are harvested per ha per year (Flach 1984).

Intensive Sago Palm Cultivation on Deep Peat Compared to Traditional Cultivation on Mineral Soils

The growth performance of sago palms at high density planting is monitored in the Sungai Talau Deep Peat Station for sago palm research. The station has been established in 1982 and sago palms were planted at intervals of 9 m by 9 m. Each palm cluster is only given 0.35 kg N, 0.5 kg P_2O_5 and 0.9 kg K_2O per year in the form of ammonium sulphate, Christmas Island rock phosphate and muriate of potash, respectively.

Table 1 shows the growth performance of sago palms cultivated intensively on deep peat as compared with those on mineral soils. Palms of similar growth stages are compared to minimise variability due to differences in growth stages.

At the Sungai Talau Deep Peat Station, trunk formation of sago palms starts at about six years after planting from suckers. With the exception of two palms that reached flower initiation 12 years after planting, hundreds of others planted at the same time have not yet reached the same growth stage. Trunk formation is normally achieved in four to five years when palms are cultivated on mineral soils along the banks of the Oya River. They are harvested at or just before flower initiation, about 10 years after planting.

Sago palms cultivated intensively on deep peat have a small number of fronds in the crown. In the first three years after planting, the average crown size or frond emergence rate is about 12–15 (Anonymous 1988–1992). The longevity of the fronds is about 12 months. From the fourth year, the rate of frond production and the crown size drop gradually to about 10 or even less. Premature desiccation of the lower fronds is present in all the palms. This is a clear sign of premature nutrient recycling from the older to the younger fronds due to shortage of supply. The average area of living fronds in a full-sized crown measured from two palms at The Sungai

Table 1 Comparison of sago palm growth under intensive cultivation on deep peat with traditional cultivation on mineral soils.

	Average time to form trunk (yrs)	Average time to maturity (yrs)	Frond no. in crown	Average leaf area of a full-sized crown (m^2)*	Average trunk volume (m^3)**	Average starch density in pith (g/cm3)**	Average starch yield per trunk (kg)**
Deep peat (intensive)	6	≥ 12	10	89	0.83	0.054	28.8
Mineral soil (traditional)	5	10	15	220	1.31	0.118	129.4

* The leaf area is determined from two palms grown in each location.

** Twelve palms each in the 75% trunk growth ("pelawai") stage are compared. The average trunk volume, starch density and yield will be higher in the full-trunk growth (mature) stage. The pith starch density is expressed as g dry starch per cm^3 of fresh pith.

Talau Station is 89 m². Sago palms cultivated traditionally on mineral soils normally have an initial crown size of 15–18 which later drops to and is maintained at about 15. The longevity has not been determined on mineral soils but is estimated to be about 15 months. The average area of living fronds measured from two full-sized crowns in palms grown on mineral soils is 220 m², more than twice of that on deep peat. Assessment of trunk size and starch yield was made on 12 palms in the 75%-trunk (locally called "pelawai") stage. The trunk volume of palms under intensive cultivation on deep peat is about 37% smaller than those grown on mineral soils. The smaller trunk volume is due mainly to the smaller trunk diameter and lesser height. The pith starch density is only 0.054 g/cm³ as compared to 0.118 g/cm³ in the palms grown on deep peat soils. The total starch yield per palm is only 29 kg, a merely 23% of that from a palm in similar growth stage on mineral soil. The much lower starch yield is largely due to the very much reduced leaf surfaces for photosynthesis.

Nutrient Uptake of Sago Palms

In most crops, the unproductive period can be shortened by the application of nutrients. The same should hold too for the sago palms. Based on the nutrient content analysis, the total estimated uptake of major nutrients in a sago palm trunk and a complete leaf is shown in Table 2. Based on this table, the total annual uptake of the major nutrients by a palm cluster with a mature and a few follower palms can be calculated (Table 3). The following practical assumptions have been made:

(a) A sago palm starts trunk formation at five years and the leader palm reaches maturity at 12 years after planting.

(b) Sucker growth is regulated to one in 18 months.

(c) Each mature palm has an average of 15 fronds and a full-sized crown is attained at the end of five years when trunk formation starts.

(d) All the fronds (naturally fallen or after harvesting) remain in the field so that nutrients are recycled upon decomposition.

At the end of 12 years when the leader palm attains maturity, the cluster consists of five trunks, each separated by 18 months in growth. Three trunkless suckers are also found at the same growth interval. At this stage, each palm cluster removes 5200, 1100, 6700, 11000 and 1600 grammes of N, P, K, Ca and Mg, respectively, from the soil. This is roughly equivalent to 12 kg urea, 8 kg rock phosphate, 14 kg muriate of potash and 48 kg of dolomite. These nutrients are mainly locked up in the palm cluster. When a trunk is harvested, the trunk containing 590 g N, 170 g P, 1700 g K, 860 g Ca and 350 g Mg will be removed. The palm crown with 15 fronds containing a total of 560 g N, 90 g P, 300 g

Table 2 Estimated nutrient contents in grammes of single trunk and single leaf (after Flach and Schuiling 1989)

Nutrient	In one trunk	In one leaf
N	590	37
P	170	6
K	1700	20
Ca	860	90
Mg	350	7

Table 3 Total estimated annual uptake of major nutrients (g) in the trunks and leaves of a sago palm cluster before harvesting of the mature leader palm

Time from planting (yrs)	N	P	K	Ca	Mg
0–1	30	10	20	70	10
1–2	60	10	30	140	10
2–3	190	30	100	470	40
3–4	310	50	170	740	60
4–5	360	60	200	880	70
5–6	470	90	450	1070	120
6–7	480	90	540	1050	140
7–8	530	110	670	1120	170
8–9	640	130	920	1300	220
9–10	650	140	1010	1290	240
10–11	690	150	1150	1360	260
11–12	800	180	1400	1550	320
Total	5200	1100	6700	11000	1600

K, 1350 g Ca and 110 g Mg will be returned to the field.

If 100 clusters are established per ha, the nutrients taken up by the sago palms per ha just before the first harvesting are approximately 520 kg N, 110 kg P, 670 kg K, 1100 kg Ca and 160 kg Mg (roughly equivalent to 1150 kg urea, 760 kg rock phosphate, 1350 kg muriate of potash and 4800 kg of dolomite).

The removal of such large amounts of nutrients needs to be replenished to make sago palm cultivation sustainable. This is especially so in the inherently nutrient deficient peat soils (Table 4). The amount of nutrients taken up by the sago palms in each year should be returned annually. From the first harvest onwards (if the fronds are not removed), only the nutrients removed in the trunk needs to be replenished. To allow losses and fixation of fertilizer, somewhat greater amounts than those removed should be added. Under the extremely wet conditions in peat, the methods of fertilizer application need to be further investigated. Split applications during the months where the water table is below the soil surface may be appropriate.

Of equal importance is the micronutrient requirement for the growth of sago palms on peat. From coconut planting on deep peat (Bonneau et al. 1993), severe Cu deficiency with slight and temporary deficiency in Fe is experienced. Deficiency in B and Zn are not apparent. In different reports, Zn (Singh 1982) and Cu (Kanapathy 1978) deficiencies are common in oil palms established on peat.

A preliminary study at the Sungai Talau Station shows that the Cu level in the young sago palm fronds is extremely low, with several samples containing undetected amounts. The main symptom associated with extremely low Cu level is necrosis of the apex of the young fronds (including the just opened frond), starting from both margins and moving towards the tip and mid-rib of the leaflets (Fig. 1). Manganese level appears to be lower than from those grown on gleyed mineral soils. The levels of other micronutrients like Zn, B and Fe are apparently comparable or even higher than those in palms grown on mineral soils (Table 5). However, the critical levels of these elements in the sago palms are yet to be determined. Preliminary research in this field has been done by Sim and Ahmed (1991).

Table 4 Chemical propertities of major organic soils in Sarawak (after Tie and Lim 1977)

	Mean	Range
pH (1 : 2.5 H_2O)	3.40	3.1 –3.9
Loss on ignition (%)	95.4	82.7 –92.7
Organic carbon (%)	38.4	29.8 –49.2
Total Nitrogen (%)	1.44	1.1 –1.67
CEC (me/100 g)	106.4	76.2 –125.8
Exch. Ca (me/100 g)	2.62	0.71–5.20
Exch. K (me/100 g)	0.63	0.2 –1.25
Exch. Mg (me/100 g)	4.00	0.78–9.87
Ec (μ ohms/cm 25°C)	230	160 –322
Fe (ppm)	3	1 –8
Mn (ppm)	13	6 –15
Zn (ppm)	2.24	0.4 –4.45
Cu (ppm)	trace	trace
Al (ppm)	9	5 –14

Analytical methods were as follows:
Organic carbon: Walkley and Black wet oxidation method.
Total nitrogen: Semi-micro Kjeldahl distillation method.
Exch. cations: Leachimg soil with 1 N amm. acetate: Ca and Mg determined by atomic absorption, spectrometer; K determined by flame photometer.
Fe, Mn, Cu, Zn, Al: Extracted with Morgan's solution and determined by atomic absorption spectrometer.

Table 5 Comparison of micronutrients levels (ppm) in sago palms established intensively on deep peat with those on gleyed mineral soils (preliminary results from a mean of 10 samples: 0.35 kg N, 0.5 kg P_2O_5 and 0.9 kg K_2O per cluster per year are applied to the palms on deep peat)

	Zn	Cu	Fe	B	Mn
Gleyed mineral soil	22.1[b]	7.2[a]	103	10.6[b]	201[a]
Deep peat (Sungai Talau)	30.9[a]	1.0[b]	96	12.3[a]	151[b]

Note: Figures in the columns followed by different letters differ significantly at $p < 0.05$.

Fig. 1 Symptoms of suspected copper deficiency at the apex of leaflets in young sago palm grown on deep peat. Note the necrosis which begins from the margins just behind the tip of the leaflets.

Other agronomic practices

Concurrent with adequate fertilizer application, proper agronomic practices should also be adopted to sustain sago palm cultivation on deep peat. The important practices are as follows:

(a) Nursery practices are important to increase the survival and enhance the establishment of suckers. (Jong and Kueh 1992). Freshly harvested suckers should be used for planting. The suckers of about 2–4 kg should be collected with a good portion of rhizome attached. They should be planted with the cut-end of the rhizome covered in the soil to prevent sago worm attack. Shading should be provided during the dry months. If delay in planting is unavoidable, the suckers (especially the cut-end) should be treated with a wide-spectrum fungicide and kept in a cool and moist place.

(b) In transplanting or direct planting to the field in peat, about 100 points per ha is recommended (Jong et al. 1994). The planting points should be cleared of debris so that the sago palm suckers are in contact with the soil rather than sitting on root masses. Deep planting should be avoided to minimise drowning during heavy rain. Planted suckers should be stacked to prevent them from leaning or washed away by temporary flooding. Gaps caused by mortality should be filled.

(c) Slash weeding around the suckers should be carried out twice a year during the early growth stage. This will reduce the competition of nutrient and space with weeds, enable easier accessibility and recycle nutrient from the slashed weeds.

(d) Suckers' growth should be regulated to one in every 18–24 months (Flach 1984). This promotes the formation and growth of trunks and reduces competition among suckers. It also provides a scheduled development of the follower palms to allow continuous and scheduled harvest. Removal of dead fronds is also essential to increase accessibility and aeration.

(e) Under intensive cultivation on deep peat, more pests are encountered (Megir and Jong 1991). Some of the more important ones are outlined below:

(e1) Termites (*Coptetermes* sp.). Because of the abundance of woody materials, termite attacks increase and can be a potentially serious pest. This is more common in the rainy season when the high water table forces the termite to colonise the sago palm clusters. They bore through the living tissues and encourage sago worm attacks through such injuries. They can be controlled by drenching with heptachlor.

(e2) Sago worms (*Rhynchophorus schach*). Sago worms are mainly found on palms with injuries caused by excessive pruning or by the colonisation of termites. Quite commonly found are attacks of the newly planted suckers in the nursery or in the field which they gain entry through the cut-end of the rhizome. Preventive measures include avoidance of injuries to the palms and covering or treating injuries with insecticides, mud or tar. The cut-ends of freshly extracted suckers should be covered in soil during planting.

(e3) Hispid beetles (*Botryonopa grandis*). The larvae are commonly found gnawing and damaging the young tissues at the centre of the crown. It can be controlled by target spraying or drenching with systemic insecticides.

(e4) Skipper butterflies (*Hidari irava*). Caterpillars of the skipper butterflies are occasionally found to almost completely eat up the leaf blades of an entire sago palm. It can pose a serious threat if not checked. This pest can be controlled by target spraying with common insecticides.

(e5) Wild pigs (*Sus scfora*) and monkeys (*Macaca* sp.). These mammalian pests can uproot newly planted palms. Wild pigs feed on the rhizomes whereas monkeys prefer eating the young shoots. Shooting and trapping are the current control measures taken.

(f) Harvesting should be done just before flower initiation (locally known as "pelawai manit" stage) although there is insignificant difference in yield from this stage to anthesis. This provides a maximum yield per unit area and allows the earlier reduction in competition to other developing suckers.

Conclusions

In Sarawak, the sago palm is one of the very few crops that can grow on the natural deep peat swamps with minimal drainage. By the cultivation of sago palms, it is possible to convert the vast areas of peat swamps into productive agricultural lands without sophisticated and expensive soil amendment such as drainage or compaction. Furthermore, sago palm is one of the most environmentally beneficial and ecologically sound crops. This couples with its high adaptability to the peat swamp conditions, making it the best choice among other crops for cultivation on deep peat.

Under a traditional cultivation system where fertilizer use and maintenance are minimal, the sago palm growth is slow and the yield is about 15–20 trunks (3–4 tonnes dry starch) per ha per year. In view of the large nutrient requirements of sago palms and the notoriously poor nutrient levels of peat soils, fertilizer application to replenish the nutrients extracted by the sago palms is inevitable to bring about sustainable yield. As with other crops, optimal yields can only be achieved with appropriate maintenance and nutrient inputs.

For intensive cultivation of sago palms on deep peat in Sarawak, the nutrient deficiency problems should be solved first. Then, proper agronomic practices, i.e. nursery, weeding, spacing, sucker regulation, pest and disease management, as well as correct harvesting practices should follow. If all these are properly adopted, the yield can be increased to about 14 tonnes of dry starch per ha per year. The immaturity period of the crop may well be shortened. If cultivation practices remain traditional, the crop yield will remain traditional too.

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