SAGO PALM 14: 59 − 64 (2006)

Growth Performance of Sago Palms (*Metroxylon sagu* Rottb.) in Peat of Different Depth and Soil Water Table

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Abstract The sago palm is one of the highest yielding perennial starch crops in the world. Starch is accumulated progressively in the trunk and each palm is capable of producing about 200kg of dry starch. Because of the continuous production of off-shoots to replenish the harvested palm, the economic life of sago palm is theoretically perpetual. It is one of the very few crops that are highly tolerant to low pH and can be cultivated on peat and sulphidic soils.

The growth of sago palms on deep peat without maintenance and added nutrient is far inferior as compared to those grown under shallow peat and mineral soils. The soil water pH of the three studied gardens are between 3.8 to 4.6, slightly higher than the normal range of 3.2 to 4.0 found in Sarawak.

Under minimal drainage and maintenance on deep peat, about 20% of the 10-15 year-old sago palms produced trunks but none attained maturity. They possess 6-10 fronds and their trunk lengths and diameters are 1-4 m and 41 cm respectively.

On deep peat with seasonal flooding, less than 10% of the sago palms produced trunks at 8 years after planting. In contrast, over 80% of sago palms on shallow peat produced trunks at 5-6 years after planting and possess a crown size of 12-15 fronds. They attained maturity at 10-11 years, with trunk lengths and diameter of about 8 m and 45 cm respectively.

泥炭層の厚さと地下水位がサゴ生育に与える影響

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サゴヤシはデンプン生産量の高い永年生の作物である．1本のサゴヤシから約200kgのデンプン（乾燥重量）が幹に蓄積し，サッカーを利用することによって永続的に生産が可能である．サゴヤシはまた，低pH耐性があるため，泥炭や硫酸酸性土壌で生育可能である．無施肥，栽培管理なしの条件で厚い泥炭土壌で生育したサゴヤシは泥炭層がうすい土壌で生育したサゴヤシに比較して生育が劣る．そこで，本実験では3圃場において泥炭層の厚さと地下水位がサゴヤシの生育に与える影響について検討した．供試した3圃場の土壌pHは3.8～4.6であり，サラワクの一般的な値（pH3,2～4.0）よりやや高かった．

最低限の排水と栽培管理を行った厚い泥炭層では，移植後10～15年のサゴヤシのうち20%が幹立ちをしていたが，成熟期までは達していなかった．このサゴヤシは6～10枚の葉を持ち，幹の高さは

1～4m，胸高直径は41cmであった．

排水しない厚い泥炭土壌では，移植後8年で幹立ちをしているサゴヤシは10%以下であった．一方，泥炭層が薄い土壌で生育した移植後5～6年のサゴヤシは80%以上が幹立ちをし，12～15枚の葉が認められた．これらのサゴヤシは10～11年で高さ8m，胸高直径45cm程度となり，成熟した．

INTRODUCTION

In good sago palm smallholders on mineral soils with minimal maintenance and without fertilizer application, a starch production rate of about 10 tons per hectare per year has been reported (Jong, 2000). Under intensive cultivation, Flach (1984) estimated a starch yield of 25 tons/ha/yr at Batu Pahat, Malaysia. As such, it is one of the highest known starch-producing crops in the world.

The sago palm is tillering and perennial in nature, with a theoretically perpetual economic life. Given the right attention and development, this crop can increase in yield and could become one of the most important sources of starch in the tropics. It is also one of the very few crops that can be found growing on natural peat soils without appropriate soil amendments (Tie, personal communication) all over Southeast Asia.

In the Sarawak State of Malaysia, peat refers to soils with greater than 50 cm of organic matter at the top 100 cm and in which the organic soil material contains at least 35% of organic matter (Tie, 1982). The soil is classified as shallow peat if the organic layer is between 0.5 and 1.5 m and as deep peat if the organic layer exceeds 1.5 m in depth. The peat soil is normally low in pH.

It has been generally reported that sago palms cultivated on natural deep peat with minimal maintenance require 12-17 years to attain maturity (flowering) but those on mineral soils require only about 8-12 years (Jong, 1988; Jong and Flach, 1995; Tie *et al*., 1987; Yamaguchi *et al*., 1997); however, after 10 years of cultivation, no trunk formation was observed, particularly in sago palms cultivated in deep peat in Sarawak (Fong *et al*., 2005). To further understand the above, a comparative study was conducted to assess the growth performance of sago palms on acidic peat with known cultivation history and practices.

MATERIALS AND METHODS

Three sago farms at Mukah, Sarawak, were selected for the current study between November 2004 and January 2005:

(a) Sago palms established between 1989 and 1994 in deep peat with minimal drainage. Although canals were dug, the water table remained high throughout the year owing to poor water discharge outlets.

(b) Sago palms planted in 1995-1996 in deep peat with seasonal flooding. The field was often flooded up to over 1 m during the rainy season, from November to early March. The sago palms were partially submerged during the flood, and the entire area was flooded at the time of the research.

(c) Sago palms cultivated in shallow peat in 1985-1992 without any artificial drainage system. The soil water table was around 10 cm below the soil surface at the time of the study. Flooding was only transient during or after a heavy downpour. Minimal maintenance, such as weeding and removal of excess offshoots, was carried out in all three sago gardens. No fertilizer was applied throughout the entire cultivation period.

Growth data, such as crown size, percentage of trunk-producing palms, trunk length, and trunk diameter at 1 m above ground level were collected from all the sago palms in three replicated 50 x 50 m blocks in each of the selected gardens (about 6,000ha). The trunk height was measured by a calibrated extendable aluminum pole from the ground

Table 1 A summary of growth data on sago palms cultivated in deep and shallow peat with different water tables

Field condition	pH(H_2O)	Approx. palm age (year)	Number of palms sampled	No. of fronds in crown	% of trunk formation	Trunk length (m)	Trunk diameter of trunking palm at 1m from base (cm)	Water table from soil surface (cm)
Deep peat Min. drainage*	3.9 (0.11)	10 - 15	53	7.3 (0.23)	18.3 (11.7)	2.25 (0.61)	39.9 (1.69)	- 8.3 (5.9)
Deep peat Seasonal flood	4.4 (0.01)	8 - 9	39	6.8 (0.24)	3.5 (4.1)	1.65 (0.92)	40.0 (2.83)	+ 43 (22.2)
Shallow peat Non drainage**	4.1 (0.06)	9 - 12	64	12.7 (0.12)	83.7 (5.1)	7.43 (2.61)	43.9 (1.07)	- 9.2 (6.2)

Note: The values in parentheses denote standard deviation; +indicates above the soil surface; -indicates below the surface
The average and SD were calculated on the basis of the average and SD of the replications
*: "min. drainage" means that the sago garden is minimally drained
**: "non drainage" means no drainage system is present

surface to the leaf-base of the oldest living frond.

Four pH measurements and soil water tables each were taken at approximately 10 m from the corner of each plot. The pH was determined with a portable pH meter (Shindengen, KS501). In non-flooded fields, a hole was dug to below the soil water table for pH and soil water table measurements. In flooded fields, water samples were collected above the soil surface, and their pH was measured directly. The depth of the flood water was also measured directly.

Photo 1: 15 year old palms on deep peat with minimal maintenance

RESULTS

The study was conducted in the middle of rainy season, when the soil water table was higher than normal. The results of this study are summarized in Table 1. In the three sites studied, the pH of the soil water was around 3.8 to 4.6. The highest pH values of between 4.3 and 4.6 were found in a flooded field where there was moving surface water.

Under minimal drainage in deep peat, about 20% of the sago palms produced trunks, but none attained maturity at 10-15 years after these palms were transplanted to the field. They possessed 6-10 living fronds, and signs of necrosis and desiccation were observed at the older fronds. In general, the leaflets were pale green and non-lustrous, and the frond stalks were yellowish-green and dull (Photo 1). The trunk lengths of the leader palms varied from 1 to 4 m, and there were very few follower (that developed from off-shoots produced by the leader) palms attaining the trunk formation stage. The diameters were small, averaging 41 cm at 1 m above ground level and tapering gradually towards the upper part of each trunk.

Sago palms cultivated in deep peat with seasonal flooding, which normally occurs from November to March each year, had less than 10% of trunk formation rate at 8-9 years after planting. The majority of the palms remained at the rosette stage, with palm heights varying from 2 to 4 m (Photo 2). In the trunk-producing palms, the trunks were small and tapering at the upper end. Premature desiccation of older fronds and fracture at the base of dead fronds were common.

In contrast to the above, trunk production was observed in over 80% of the studied sago palms in shallow peat. According to the owner of the farm,

Photo 2: 9-year old palm on deep peat under seasonal flooding

these palms started to form trunks at 5-6 years after field planting. They possessed 9-15 living fronds that were more lustrous and greenish, and they attained maturity (initiation of flowering) at 10 to 11 years, with trunk lengths and diameters of about 8 m and 45 cm, respectively. Although one of the gardens was established in 1985, there were no palms older than 12 years because mature palms were regularly harvested. More follower palms were produced than those grown in deep peat, forming a larger cluster with 2-3 palms in the trunk production stage at varying trunk heights (Photo 3).

Photo 3: A 11-year old palm on shallow peat

DISCUSSION

The peat in Sarawak was mostly correlated to *typic*, *fluvaquentic*, or *terric tropofibrists* of the USDA soil taxonomy or to *dystric histosols* of the FAO/UNESCO's system. The aqueous soil pH of peat in Sarawak had normally been reported to be between 3.2 and 4.0 (Deloitte & Touche, 1992). Deep peat was extremely low in macro- and micro-nutrients (Fong *et al*., 2005). It also had a high C/N ratio and a high CEC (Table 2).

The pH values of 3.8-4.6 were higher than the normal pH of 3.2 to 4.0 commonly encountered in the Sarawak peat, probably due to the rainy season, when soil water movement is enhanced. There was no significant difference between the soil water pH in deep and shallow peat. The variations in pH within and among the sampled plots were rather small at the time of the research.

Table 2 Chemical Properties of Peat in Sarwak

Properties		Topsoil (0-25 cm)	Subsoil (50-100cm)
pH(H_2O)		3.7	3.8
Organic Carbon	(g kg^{-1})	411	438
Total N	(g kg^{-1})	15.8	12.5
Exch. Ca	(cmol kg^{-1})	5.68	4.2
Exch. Mg	(cmol kg^{-1})	4.55	4.19
Exch. K	(cmol kg^{-1})	0.41	0.18
Exch. Na	(cmol kg^{-1})	0.65	0.65
CEC	(cmol kg^{-1})	70.8	66.4
Available P	(mg kg^{-1})	79	9
Total P	(mg kg^{-1})	401	149
Total Ca	(mg kg^{-1})	1468	457
Total Mg	(mg kg^{-1})	526	373
Total K	(mg kg^{-1})	283	143
Available Cu	(mg kg^{-1})	0.14	0.16
Available Zn	(mg kg^{-1})	0.96	0.52
Available Mn	(mg kg^{-1})	5	2
Available Fe	(mg kg^{-1})	10	2

Source: Deloitte & Touche*et al.,* 1992

Despite the low pH in shallow peat at the farmers' field, sago palms grow rather vigorously in the absence of added nutrients, regular maintenance, and lime application. In the selected gardens in shallow peat soil, the palms were rather heavily shaded either by adjacent sago palms or other unidentified tree species. Sago palms were mainly at the late trunk growth stages, with relatively few younger follower palms and suckers.

Healthy growth of sago palms is commonly observed on mineral sulphidic soils of extremely low pH in Batu Pahat and Rampangi Research Station (on acid-sulphate soil) in Malaysia (Jong, personal observations). Healthy growth of traditionally cultivated sago palms is also found in abundance along the acidic coastal soils of Riau in Indonesia. These facts reflect that the sago palm is a crop that is highly tolerant to low pH and well adapted to the extraction of nutrient requirements from growth media under acidic soil conditions. In shallow peat soil, nutrients are made available from the underlying mineral sub-soils to sustain the rather good growth of the sago palms.

In contrast to the palms in shallow peat, sago palms established in deep peat under minimal drainage and seasonal flooding conditions were retarded in growth, as reflected from the rather consistently small crowns and low trunk formation rates, even after more than 10 years. Large variations were noted in the percentage of palms that were able to produce trunks and the lengths of the trunk produced. The long juvenile phase in excess of 15 years is in agreement with those reported by Jong (1988), Jong and Flach (1995), Tie *et al*. (1987), and Yamaguchi *et al*. (1997). The late maturity, small crown size, poor trunk production capability, and other symptoms of retarded growth are more likely caused by the lack of the required nutrients in the deep peat strata (Table 2) and water-logged conditions rather than by the low pH *per se*.

The lack of added nutrients (Fong *et al*., 2005) and regular maintenance resulted in slow initial sago palm establishment and subsequent poor growth in deep peat. Under such unfavorable conditions, the palms are eventually overtaken by undesirable trees and weeds.

Sago palm growth in deep peat may be improved by nutrient addition, water table regulation, and scheduled weeding, as reflected from a commercial sago palm plantation in deep peat at Riau, Indonesia (Photo 4, Jong, 2000). Although the sites and the compositions of peat in Riau and Mukah are different, the findings indicate that proper cultivation and management practices are essential for improved sago palm growth in deep peat.

Photo 4: 7-year old palms at a commercial sago plantation on deep peat.

Seasonal flooding impedes further growth and development of sago palms, as reflected from the extremely low trunk production rate in palms of 8 to 9 years old. At the Sipik region of Papua New Guinea (Haatjens, 1968), most of the natural sago palms under constantly flooded conditions are unable to produce trunks. Flooding is likely to cause various undesirable physiological changes (Kozlowski, 1984), thereby retarding the growth of these sago palms. Nonetheless, flood-induced death in sago palm is unknown, as aerial roots are produced under prolonged flooding conditions.

The sago palm is a special crop that is highly tolerant to low pH and seasonal flooding. With appropriate soil improvements, such as drainage and fertilizer applications, waste peat swamps and sulphidic soils in the tropics can be utilized for sustainable sago palm production.

REFERENCES

Deloitte & Touche, Talisman Land Resource Consultants, and ARA Consulting Group Inc. 1992 Sarawak Agricultural Perspective Plan: Agricultural Development Project. Background Paper No. 13. State Planning Unit, Sarawak.

Flach, M. 1984 The Sago Palm. FAO Food Production and Protection Paper 47 AGPC/MISC/80. Food and Agriculture Organization of the United Nations (Rome) 85p.

Fong S. S., A. J. Khan, M. Mohamed and A. M. Mohamed 2005 The relationship between soil characteristics and the growth of sago palm (*Metroxylon sagu*). Sago Palm 13: 17-25.

Haantjens, H. A. 1968 Lands of the Wewak-lower Sepik Area, Papua New Guinea; Commonw. Scient. Indus. Res. Org., Land Res. Ser. No. 22 (Canberra) pp149.

Jong, F. S. 1988 A preliminary report on the performance of sago palms in Sungai Talau Deep Peat Station. Proceeding of the 24th Annual Research Officers Conference, Dept. of Agriculture, Sarawak 175-183.

Jong, F. S. and M. Flach 1995 The sustainability of sago palm (*Metroxylon* spp.) cultivation in deep peat in Sarawak. Sago Palm 3: 13-20.

Jong, F. S. 2000 Sago Production in the Tebing Tinggi Sub-District, Riau, Indonesia *In*: Sago 2000. Sustainable utilization of sago palm as an alternate source of food and materials for agro-industry in the Third Millennium. H. M. H. Bintoro *et al*. eds. (Bogor, Indonesia) 86-93.

Kozlowski, T. T. and S. G. Pallardy 1984 Effect of flooding on water, carbohydrate, and mineral relations. *In* Flooding and Plant growth. Kozlowski T.T. ed. Academic Press 356p.

Tie, Y. L., J. H. Osman and H. S. Kueh 1987 Performance of sago (*M. sagu*) in deep peat. Proceeding of the 24th Annual Research Officers Conference, Dept. of Agriculture, Sarawak 105-116.

Tie, Y. L. 1982 Soil classification in Sarawak. Tech. Paper No. 6, Soils Div., DOA, Sarawak.

Yamaguchi, C., M. Okazaki, T. Kaneko, K. Yonebayashi and A. H. Halim 1997 Comparative studies on sago palm growth in deep and shallow peat soils in Sarawak. Sago Palm 5: 1-9.