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Sago Root Studies in Peat Soil of Sarawak

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Abstract The sago palms (*Metroxylon sagu*) grow more slowly and take longer period to mature on peat soils than on mineral soils. Based on the two field experiments at Sungai Talau Peat Research Station, Sarawak, Malaysia, this article aimed to compare the root biomass distributions in tropical peat soils in relation to peat thickness and shoot growth, and to provide ecological information on sago growth. In experiment 1, sago root biomass was measured by taking soil blocks to a depth of 40 cm from the deep peat soil and from the alluvial mineral soil. Total fine root biomass of sago ($d \leqq 5$ mm) was larger in the alluvial soil (11.4 t/ha) than in the deep peat soil (4.7 t/ha), which contradicts the previous data on sago. The patterns of vertical distribution of roots in each diameter (= d) class were similar between the two soil types; the large roots ($d > 5$ mm) were distributed below 10 cm in depth and more than half of them concentrated in 20–30 cm layer, whereas fine roots ($d \leqq 2$ mm) and intermediate roots ($2 < d \leqq 5$ mm) allocated more than 60% and 55%, respectively, in 0–20 cm layer. The sago root distribution was not affected by the existence of other tree roots or large woody debris. In experiment 2, roots and shoots of one year sago palms were investigated. Both in deep and shallow peat soils, the shoot growths of the sample palms did not much differ and the roots extended below 1 m in depth only after about one year. Total numbers of first-order roots from the stump were larger in the shallow peat. But the difference became small when roots growing upward were excluded. The diameters of first-order roots were not significantly different. Collectively, total fine root biomass was smaller in the deep peat soil where sago palms grow slowly than in the alluvial mineral soil, and the pattern of vertical distribution of sago roots of three diameter classes (mentioned above) were similar between the two soil types.

Key words: Fine root, Root biomass, Root diameter, Root distribution, Sago palm, Tropical peat soil

サラワクの泥炭土壌におけるサゴヤシの根の研究

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要　約　熱帯の泥炭低湿地に生育するサゴヤシの根についての 2 種類の実験をマレーシアのサラワク州において行った．実験の目的は，サゴヤシの成長が異なると見られる 2 種類の土壌，すなわち泥炭土と沖積鉱質土におけるサゴヤシ根量とその分布のちがいを明らかにすることである．実験 1 では，サゴヤシ植栽地で約 8 年生のサゴヤシの幹の根元付近，そこから約 1 m あるいは 2 m 離れた地点で土壌ブロックを深さ 40 cm まで掘り出し，根量を調べた．サゴヤシ根を直径と分岐により，分岐の密な直径 2 mm 以下と，分岐の疎な 5 mm 以上，中間的な 2 mm から 5 mm, の 3 種類に分けて定量した．直径 5 mm 以下の細根現存量は泥炭層の厚い泥炭土壌，沖積鉱質土壌でそれぞれ，4.7, 11.4 t/ha と差がみられた．これらは森林における値の範囲の 5～10 t/ha とそれほど変わらなかった．成長のよい沖積鉱質土壌で細根量が多いという今回の結果はこれまでのサゴヤシや針葉樹の結果と異なっており，土壌サンプリングの深さや根の分岐特性のちがいが一因と考えられたが，今後さらに調査する必要がある．サゴヤシ根量の深さ 40 cm までの土壌中の垂直分布は 2 種類の土壌で同様であり，直径 2 mm 以下の根と直径 2 mm から 5 mm の根は表層の深さ 0～20 cm にそれぞれ

60% 以上と 55% 以上が分布し，一方直径 5 mm 以上の根は深さ 10 cm より深い土層，特に 20～30 cm に 50 % 以上が存在した．サゴヤシの根の分布は他樹種の根や粗大木質有機物の存在により影響を受けていなかった．実験 2 では，約 1 年生の若いサゴヤシを，泥炭層の厚い泥炭土壌と泥炭層の薄い泥炭土壌で 3 本ずつ地上部・地下部ともに調査した．根の最大深さは両地点で少なくとも 1 m に達していると推察された．根株から分岐している 1 次根に関して，サゴヤシ 1 株あたりの全体の本数は泥炭層の薄い泥炭土壌の方が多かったが，上向きに伸長している根を除くと差は小さくなった．1 次根の直径では土壌間の差はなかった．以上から深い泥炭土壌と沖積鉱質土壌では上述の 3 つの直径階の根の垂直分布パターンは同様であったものの，根の量全体で比べると成長が遅いとされる前者の方でより少ない傾向にあることが示唆された．
キーワード　サゴヤシ，熱帯泥炭土壌，根の直径，根のバイオマス，根の分布

Introduction

There has been little information about the woody root distribution belowground in the tropical peat swamp forests. The fine root biomass reported for a variety of forest ecosystems markedly differs, for instance from 220.5 t/ha in a mangrove forest in Thailand (Komiyama and Ogino 1984) to 5–10 t/ha in temperate and tropical forests (Santantonio et al. 1977). Some reports indicated that less fine root biomass of conifers occurred in high productivity sites (Vogt et al.1987, Kasuya and Shimada 1996). On peat soils the palm appears to grow more slowly than on mineral soils (Flach and Schuiling 1989), and the palms growing on deep peats needed longer period to mature than those on mineral soils (Kueh et al. 1991). Do those palms on deep peats have more or less fine root biomass than those on mineral soils? Based on experimental works in sago plantations on peat soil of Sarawak, Malaysia, this study aimed to compare the root biomass distributions in tropical peat soils in relation to peat thickness and shoot growth and to provide ecological information on sago growth indispensable for sustainable land use of reclaimed areas in the tropical peat land.

Materials and Methods

Study site

The samplings for sago root biomass study were conducted in two research sites. The one was in Sungai Talau Peat Research Station located in the coastal area of Dalat, Sarawak, where there were many sago plantations for the experiment on deep peat soils (the depth of the peat was at least 1 m). Detailed description of soils at the Station is given in Yamaguchi et al. (1994). The other was in a farmer's garden with alluvial soil in Dalat, about 1 km away from the Station. The levels of water table at the time of measurement were -0.18 m and -0.10 m in the deep peat and the alluvial soil, respectively. Tie et al. (1991) showed that of total sago areas in Sarawak, organic soils and alluvial soils constituted 62% and 38%, respectively. Within the group of organic soils, deep organic soils with more than 150 cm (in depth) of organic soil materials formed 38% of total sago areas in Sarawak, while shallow organic soils with 50–150 cm formed 24%.

Root biomass study of sago palm

To investigate the distribution of sago palm roots, soil blocks were sampled at the distance of 0.4, 1.4 and 2.4 m in the deep peat and 0.3, 1.3 and 2.3 m in the alluvial soil from the center of the sago palm trunk, which had been estimated about eight years old. The blocks sampled were 405– 638 cm^2 in area at the ground surface and 40 cm in depth. Each block was divided into layers 10 cm in depth, put into plastic bags separately and brought back to the laboratory. Air-dried roots in the soil samples were obtained by washing the soil block over the sieve (0.5 mm mesh) in tap water, and divided into three diameter classes using caliper, based on the morphology and branching pattern: 1) smaller than 2 mm in diameter with many laterals including fibrous roots; 2) 2–5 mm with thick cortical tissues and intermediate branching; and 3) larger than 5 mm with few branching. Karizumi (1979) reported that several Palmae species had first-, second-, and third-order roots and their maximum diameter ranged from 5 to 20 mm. In this study, the distinction between live and dead roots was done by the following criteria. The roots of light yellow to brownish color were classified into 'live' and those of gray to black color were 'dead'. This judgment was applied only to large (d > 5 mm) and intermediate (2 < d ≦ 5 mm) roots since it was difficult to find the dead fine roots (d ≦ 2 mm) which might be mixed up in the surrounding peat.

Root study of young sago palm

In order to investigate the pattern of root development of sago palm, root systems of about one year old plants were taken from the soil columns (50 cm × 50 cm × 40 cm) that included the trunk at the center, after measurement of the aboveground parameters such as height and number of fronds. Three sample palms were selected from the deep peat site at the Station and from the shallow peat site in a farmer's garden adjacent to the Station, respectively. The soil blocks were excavated by using a chain saw and a long knife. During the excavation, some roots growing downward were traced with hand to examine how deep the roots extended. Both in the deep and in the shallow peat soils, however, it was difficult to take the root tips which lay below 1 m in depth. The root samples attached to the stump were brought back to the laboratory and then the number and the diameter of the first-order roots from the stump were measured.

Results and Discussion

Root biomass study of sago palm

Fine root biomass of sago (d < 5 mm) was 4.7 t/ha and 11.4 t/ha in the deep peat and alluvial soil, respectively (Fig. 1), both of which were slightly out of range of 5–10 t/ha in temperate and tropical forest ecosystems (Santantonio et al. 1977). It should be noted here that only roots in surface soil 40 cm in depth were recovered. The shoot growth was similar in both sites; the diameter of the trunk at the ground level was 56.1 and 54.5 cm and the palm height was 14.2 and 12.9 m for the sago grown in the deep peat and alluvial soil, respectively. Yamaguchi et al. (1994) reported from the growth measurement at the Station that the sago palms on deep peat soils grew more slowly than those on shallow peat soils and alluvial soils. In this respect, those palms selected as a sample were rather an unusual case, and at the stand level the sago palms on alluvial mineral soils grow faster than on deep peat soils. The reverse relationship between fine root biomass and productivity was observed in some temperate coniferous forests; smaller fine root biomass was found in high productivity sites (Keyes and Grier 1981; Kasuya and Shimada 1996). In this sago palm study, however, smaller fine root biomass was found in low productivity sites. It has still been unknown whether this inconsistency resulted from species or site difference. Tie et al. (1987) found that sago palms grown on infertile peats have a much denser and extensive rooting system so that a larger volume of soil materials is exploited. This study dealt only with surface soil 40 cm in depth, and sampling depth may considerably affect the results. Since palm roots have relatively simple branching system (Karizumi 1979), it can be speculated that even fine root of sago might play some role in supporting the shoot system, which suggests that fine root biomass may increase in proportion to the shoot growth.

When the rooting density (g/dm^3) was examined in relation to distance from the center of the sago trunk, more root biomass was distributed in the alluvial soil with decreasing distance to the center of the trunk, but this tendency was not obvious in the deep peat. Though there was no replicate of soil samples in this study, other sago root biomass measurements at the Station (Jong F. S.: unpublished data) support the present result in the alluvial soil; comparing the 50 × 50 × 20 cm soil blocks at 50 cm intervals from the sago trunk, it was found that the nearer to the trunk, the more sago root biomass there was, and that soil layer 0–40 cm in depth contained 81 and 87% of sago root within soil layer 0–80 cm in depth in the 3 and 8 year old sago plantation fields, respectively. To generalize the horizontal and vertical distribution of sago root biomass, further research such as sampling soil materials in various directions of the same sago trunk should be conducted.

Proportions of live sago root biomass in three di-

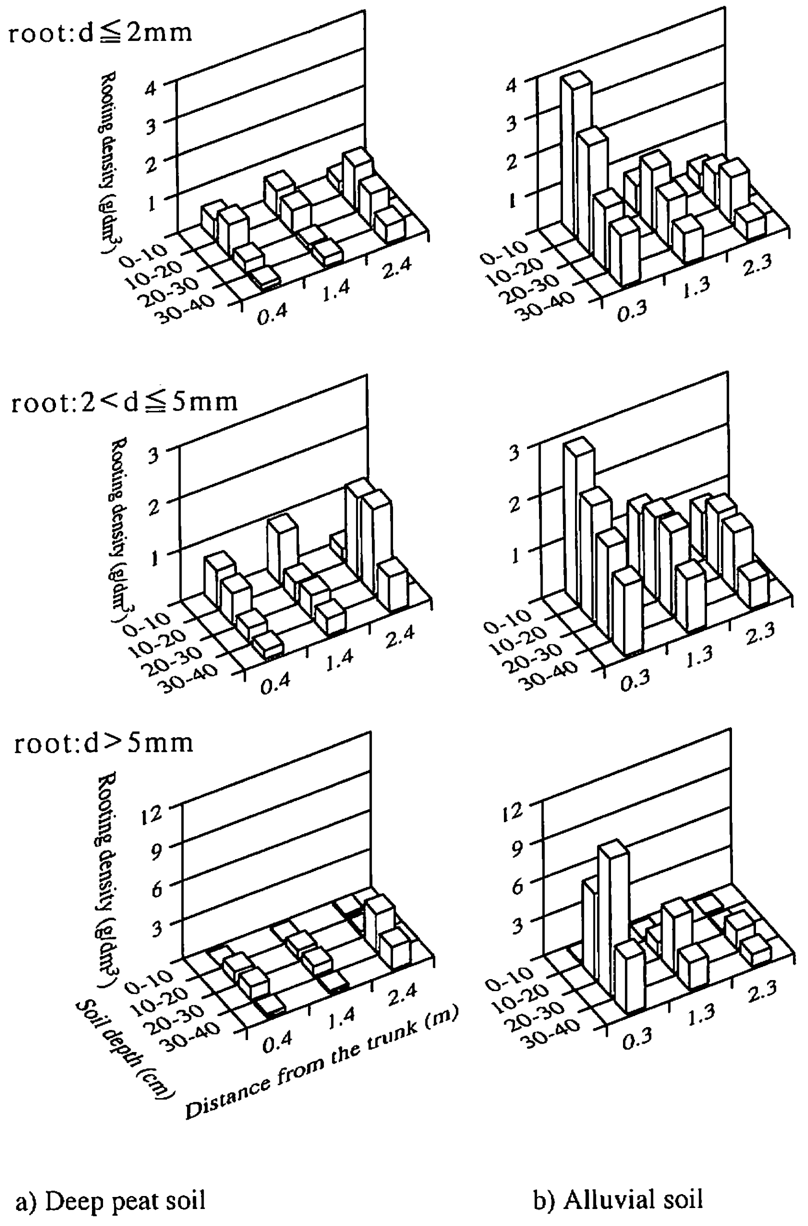


Fig. 1 Live sago root density of three diameter classes at different distances from the trunk in the deep peat soil and alluvial soil. d: diameter.

ameter classes were similar in the two soil types (Fig. 2). The proportion of the larger root ($d > 5$ mm) averaged 56% (ranging from 38 to 76%) in 20–40 cm soil layer, while less than 2% was in 0–10 cm layer in the alluvial soil. The fine root ($d \leqq 2$ mm) and intermediate root ($2 < d \leqq 5$ mm) concentrated in the surface soil layers, more than 60% and 55% distributed in 0–20 cm layer, respectively.

Table 1 summarizes biomass and proportions of live and dead sago roots ($d > 2$ mm) in different soil layers. The large roots were classified as dead in a higher proportion than the intermediate roots were, chiefly because decomposition was slower for large roots. The roots of other tree species (unidentified), mainly intermediate- and large-classes, were often found in surface layers, and rare below 10 cm in depth, in contrast with sago roots. These tree roots were judged to inhibit to a negligible extent the growth of sago roots. Large woody debris (more than 10 cm in diameter) existed in some samples of the 20–40 cm layers in the deep peat, but there was no sign of decreases in root biomass caused by the disturbance of these woody debris. Many sago roots penetrated the large woody debris which were difficult to break by hand (Fig. 3), suggesting that large woody debris did not particularly obstruct sago root elongation.

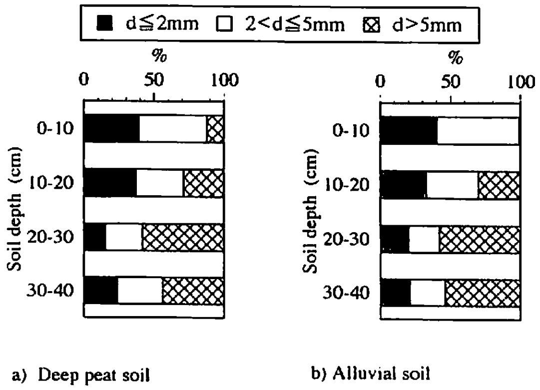


Fig. 2 Proportions of live sago roots in three diameter classes in the deep peat soil and alluvial soil layers. d: diameter.

Root study of young sago palms

Although the sample young sago palms at the two sites did not show much difference in shoot growth (Table 2), the palms in the shallow peat had a larger number of the first-order roots from the stump than those in the deep peat (80 and 57 on average, respectively) (Table 3). When the roots were classified into two types according to elongating directions, namely roots growing upward and downward (Fig. 4), the numbers of roots growing downward did not differ between the two sites. The larger proportion of the roots elongating upward was found in the shallow peat. This may be due to considerable volume of suckers and their horizontally long shape (Fig. 4).

Table 1 Live and dead sago root (d > 2 mm) biomass data (g/dm³) on the deep peat and the alluvial soil

Soil type and Diameter class (mm)	Soil depth (cm)	Position from the trunk											
		near				middle				far			
		live (g/dm³)	%	dead (g/dm³)	%	live (g/dm³)	%	dead (g/dm³)	%	live (g/dm³)	%	dead (g/dm³)	%
Alluvial	0–10	2.87	(87)	0.44	(13)	1.30	(85)	0.24	(15)	0.85	(88)	0.11	(12)
2 < d ≦ 5	10–20	2.25	(82)	0.48	(18)	1.56	(75)	0.51	(25)	1.19	(87)	0.18	(13)
	20–30	1.79	(92)	0.16	(8)	1.61	(86)	0.26	(14)	1.14	(83)	0.23	(17)
	30–40	1.38	(93)	0.11	(7)	1.04	(80)	0.25	(20)	0.55	(52)	0.51	(48)
Alluvial	0–10	0.13	(80)	0.03	(20)	0.02	(100)	0	(0)	0.01	(100)	0	(0)
d>5	10–20	6.62	(88)	0.93	(12)	1.02	(48)	1.08	(52)	0.17	(83)	0.04	(17)
	20–30	10.6	(80)	2.73	(20)	4.28	(67)	2.11	(33)	1.44	(46)	1.68	(54)
	30–40	4.28	(74)	1.53	(26)	2.12	(56)	1.69	(44)	0.93	(23)	3.03	(77)
Deep peat	0–10	0.72	(99.6)	0.003	(0.4)	0.98	(91)	0.09	(9)	0.22	(81)	0.05	(19)
2 < d ≦ 5	10–20	0.62	(86)	0.10	(14)	0.36	(90)	0.04	(10)	1.55	(97)	0.05	(3)
	20–30	0.27	(80)	0.07	(20)	0.45	(91)	0.05	(9)	1.66	(95)	0.09	(5)
	30–40	0.17	(88)	0.02	(12)	0.33	(97)	0.01	(3)	0.68	(89)	0.08	(11)
Deep peat	0–10	0	(—)	0	(—)	0.07	(82)	0.02	(18)	0.23	(73)	0.08	(27)
d > 5	10–20	0.84	(72)	0.33	(28)	0.65	(78)	0.18	(22)	0.25	(44)	0.31	(56)
	20–30	1.01	(71)	0.41	(29)	0.75	(79)	0.20	(21)	2.92	(94)	0.19	(6)
	30–40	0.26	(87)	0.04	(13)	0.22	(99)	0.002	(0.9)	1.74	(100)	0	(0)

Table 2 Characteristics of the young sago samples and their growing environment

Site	Sample No.	Age after planting (year)	Height (m)	No. of living fronds (dead)	No. of suckers	Level of water table (m)	Peat thickness (m)	Max. rooting depth (m)
Deep	1	1	1.9	4 (0)	1	− 0.1	> 1	> 0.7
peat	2	1	2.3	4 (0)	1	− 0.15	> 1	> 1.1
	3	1	2.2	5 (2)	0	− 0.1	> 1	> 0.9
Shallo	1	1	1.4	5 (1)	0	− 0.3	0.4	> 0.55
peat	2	1	1.8	7 (1)	0	− 0.35	0.35	> 1.05
	3	1	1.4	5 (0)	1	− 0.2	0.2	> 1.1

Table 3 Number of the first-order roots originating from the stump distinguished by elongating directions

Elongating direction	Deep peat			Shallow peat		
	No. 1	No. 2	No. 3	No. 1	No. 2	No. 3
downward	42	50	38	36	70	35
upward	14	14	12	31	37	32
total	56	64	50	67	107	67

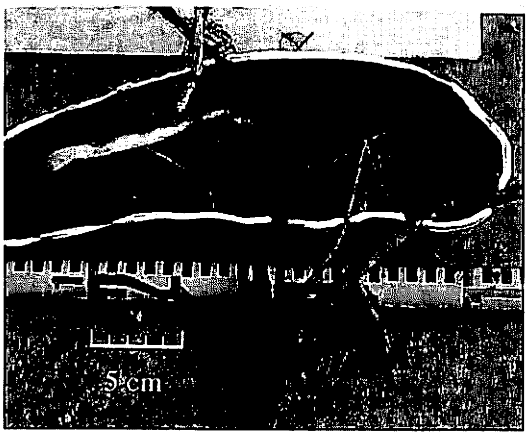


Fig. 3 Sago roots (light yellow color) penetrating the large woody debris (black-colored object in the middle).

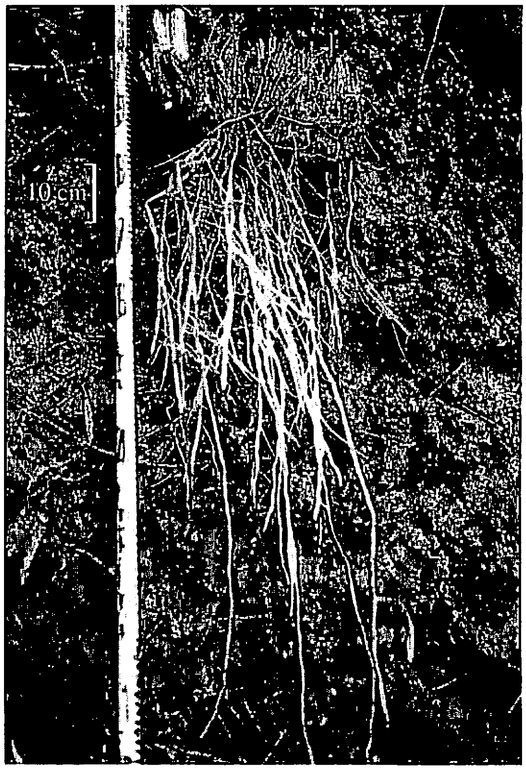
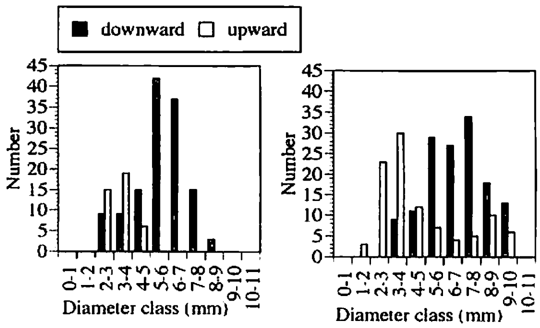


Fig. 4 Roots of 1 year old sago in the shallow peat soil (sample no. 3). Fronds were already severed.

The mean diameters of the first-order roots (upward plus downward) were 5.1 ± 0.58 and 5.8 ± 0.62 mm in the deep and shallow peat, respectively (Fig. 5), with maximum diameter of 10 mm for downward elongated roots. In both sites, the average diameter of roots growing downward was larger than those upward by more than 40%. To sum up, total number of young sago palm roots in the shallow peat were larger than those in the deep peat, but the number of roots elongating downward and diameter of the first-order roots were not significantly different. These young sago roots extended so deeply (well below the water table at the time of measurement) that the maximum root could not taken of the



a) Deep peat b) Shallow peat

Fig. 5 Frequency distribution of the first-order sago roots classified by diameter in the deep and shallow peat soils. Roots growing upward and downward are shown separately.

sago palms one year and a few month old. Ray and Schweizer (1994) reported that in some coniferous plantation twenty years after planting, the maximum depths of fine roots were as small as 0.20–0.28 m (less than the water table) in deep blanket peat in Scotland. Thus the present observation is contrasting in that sago roots could grow well below the level of water table at the time of measurement (−0.35 to −0.10 m from the surface, see Table 1), only a few roots appeared on the soil profile 50 cm distant from the center of sago stem, and in that young sago palms extended their roots vertically rather than horizontally.

Conclusions

The preliminary experiments showed that in the sago palm plantation, total sago root biomass was larger in the alluvial soil than in the deep peat soil. The nearer to the center of the trunk, the more roots existed in the alluvial soil, though this tendency was not obvious in the deep peat soil. The pattern of vertical distribution of sago roots differed among the three root diameter classes, but were similar between the two soil types. Existence of either large woody debris or roots of other tree species did not seem to influence sago root biomass distribution. Young sago palms (about one year after planting) extended their roots at least below 1 m in depth. Total number of the first-order roots from the stump was larger in the shallow peat soil than in the deep peat soil. As far as roots growing downward was concerned, the numbers were not different between the two soil types.

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References

Flach, M. and Schuiling, D. L. 1989 Revival of an ancient starch crop: a review of the agronomy of the sago palm. Agroforestry Systems 7: 259–281.

Karizumi, N. 1979 Illustration of tree roots. Seibundo Shinkosha (Tokyo) pp. 1121. (in Japanese)

Kasuya, N. and Shimada, H. 1996 Change in the fine root biomass of Cryptomeria japonica in relation to position on a slope. Bull. Kyoto Pref. Univ. For. 40: 1–12. (in Japanese with English summary)

Keyes, M. R. and Grier, C. C. 1981 Above- and belowground net production in 40-year-old Douglas-fir stands on low and high productivity sites. Can. J. For. Res. 11: 599–605.

Kueh, H. S., Elone, R., Tie, Y. L., Ung, C. M. and Jaman, Hj. Osman 1991 The feasibility of plantation production of sago (Metroxylon sagu) on an organic soil in Sarawak. Proc. of the 4th International Sago Symposium, Kuching, Sarawak, Malaysia: 127–136.

Komiyama, A. and Ogino, K. 1984 Root biomass of a mangrove forest in the southern Thailand — Estimation by the trench method. Trans. 95th Meet. Jpn. For. Soc. 339–340. (in Japanese with English summary)

Ray, D. and Schweizer, S. 1994 A study of the oxygen regime and rooting depth in deep peat under plantations of Sitka spruce and lodgepole pine. Soil Use and Management 10: 129–136.

Santantonio, D., Hermann, R. K. and Overton, W. S.

1977 Root biomass studies in forest ecosystems. Pedobiologia 17: 1–31.

Tie, Y. L., Jaman, Hj. Osman and Kueh, H. S. 1987 Performance of sago (Metroxylon sagu) on deep peat. Proc. 24th Research Officer's Conf., Dept. of Agriculture, Sarawak: 105–118.

Tie, Y. L., Loi, K. S. and Kelvin, L. E. T. 1991 The geographical distribution of sago (Metroxylon spp.) and the dominant sago-growing soils in Sarawak. Proc. of the 4th International Sago Symposium, Kuching, Sarawak, Malaysia: 36–45.

Vogt, K. A., Vogt, D. J., Moore, E. E., Fatuga, B. A., Redlin, M. R. and Edmonds, R. L. 1987 Conifer and angiosperm fine-root biomass in relation to stand age and site productivity in Douglas-fir forests. J. of Ecol. 75: 857–870.

Yamaguchi, C., Okazaki, M. and Kaneko, T. 1994 Sago palm growing on tropical peat soil in Sarawak, with special reference to copper and zinc. Sago Palm 2: 21–30.