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Potency of Sago Palm as Carbohydrate Resource for Strengthening Food Security Program

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ABSTRACT

A new competition between biofuel production and food production has occurred in recent years, therefore the development of some new plant resources and their utilization are needed. Sago palm and related species that can store a large amount of starch in the trunk and can grow under severe environmental conditions are considered to be potential starch resources for not only food production but also ethanol production. However, even sago palm, an elite species among the starch producing palms, grows under semi-domesicated or natural condition and there are many problems to utilize it. Thus, the systematic, ecological, physiological, agronomic and economic studies should be carried out for improvement of these species. Here, the recent research progress is reviewed. Large variation in morphological characteristics and palm size existed among the folk varieties of sago palm, and the difference in pith dry-matter yield was mainly attributable to trunk diameter and dry-matter content of the pith. The two key parameters were closely related with soil profile indicating natural fertility. On the other hand, the genetic distance of sago palm individuals grown in the Malay Archipelago was considered to be related to geographical distribution. The genetic variation was small in the western area and large in the eastern area. Sago palm tolerated up to 171mM (1.0%) NaCl concentration in the growth media for comparatively long period. The salt resistance of sago palm might be due to salt avoidance to mechanically restrict an excess of Na distribution from the roots to leaflets. The Na influx might be disturbed by the endodermal cells of roots even under 342mM (2.0%) NaCl condition. Sago palm tolerated severe low pH condition such at pH 3.6 in the growth media for 5 months at least and maintained a low Al^{3+} concentration in the plant tissues. Sago palm was considered to have a high tolerance to Al with the Al exclusion ability. Moreover, the growth of sago palm was stimulated when $AlCl_3$ was added into the growth media with 10ppm Al. These physiological information on the growth response of sago palm to environmental stresses will be valuable for investigating concrete strategies to introduce new plant resources to barren lands with sterile soil and produce economic plants from poor productivity lands.

Key words: acid soil, biofuel, genetic variation, *Metroxylon*, salt stress, starch

INTRODUCTION

A new competition between biofuel production and food production has occurred in recent years under the social background such as the urgent problem of the exhaustion of fossil energy and the increase in world population with higher rate as 200,000 per day. Reflecting this situation, various plants have attracted considerable attention as reproduceable resources to ensure sufficient biomass for producing alternative energy, that is, bioethanol or biodiesel. However, the increase in total area of arable lands all over the world is very slow in this decade near to the limit, and the world agriculture area is almost same after 1995 according to FAOSTAT. The productivity of major crops looks to have peak already in 2006. The production amount of cereals per head was maximum in 1987 and had been decreasing after that. Considering these facts, the poor productivity lands or barren lands with sterile soil are also should be utilized for producing economic plants to ensure even larger amount of biomass covering the increase in demands for both food resource and/or energy source. Thus, the development and/or improvement of some new plant resources and their utilization are needed as one of the strategies to secure sufficient amount of biomass for producing foods and biofuel sources that will not compete with food production.

Metroxylon palms [sago palm (*M. sagu* Rottb.) and related species] can store a large amount of starch in the trunk. The total amount of starch storage in a trunk is approximately 300 kg (dry wt.) in case of sago palm, the elite species among the starch producing palms (Ehara, 2006). Sago palm has long been cultivated as food like

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banana and taro (Barrau, 1959, Takamura, 1990). This palm species is a carbohydrate resource and is one of the oldest crops that has been used by human being since ancient times, similar to banana and taro (Takamura, 1990). The importance of sago palm as a staple food has not changed in some areas such as Siberut Island in west Sumatra, the eastern archipelago of Indonesia: Maluku and Papua, and western Melanesia: Papua New Guinea. As a staple food, the sago palm continues to be important in some areas of Southeast Asia and in areas inhabited by the Melanesian people (Ehara *et al*., 2000). The carbohydrate (starch) can be further processed into various basic raw materials for human and animal consumption, as well as an industrial energy source. *Metroxylon* palms, especially sago palm is considered to be potential starch resource for not only food production but also ethanol production.

The genus *Metroxylon* spreads from Southeast Asia to Micronesia and Melanesia and it is divided into two sections, that is, *Metroxylon* (*Eumetroxylon*) and *Coelococcus* (Beccari 1918, Rauwerdink 1986). *M. sagu* Rottb. is the only species in section *Metroxylon* (*Eumetroxylon*: although monophyly of this section remains uncertain) and is distributed in Southeast Asia (Thailand, Malaysia, Indonesia, Philippines), and north-western Melanesia (Papua New Guinea and the Solomon Islands). Five species are recognised within section *Coelococcus* that represents the eastern half of the distribution of the genus *Metroxylon*: one species in Micronesia and the other four species in Melanesia and Polynesia, from Vanuatu to Fiji and Samoa (McClatchey, 1999). Palms of the section *Coelococcus* also produce sago, i.e. starch extracted from the pith of the palm trunk. McClathcey (1998) reported that people on Rotuma in Fiji consume sago produced from *M. warburugii* (F. Heim) Becc. In other areas, *Metroxylon* palms had been used occasionally, for instance *M. amicarum* (H. Wendl.) Becc. at Moen in Micronesia until the 1940s or *M. warburgii* at Gaua in Vanuatu until the 1950s at least (Ehara *et al*., 2003b). At Malakula in Vanuatu, *M. warburgii* is sometimes used as an emergency food. Contrarily, Indo-Fijian people often harvest *M. vitiense* (H. Wendl.) H. Wendl. ex Benth. & Hook. f. to the apical bud together with the very young leaf sheathes and leaves, and they use the palm-cabbage for cooking.

Sago palm and related species grow in swampy, alluvial and peaty soils where almost no other major crops can grow without drainage or soil improvement (Sato *et al*., 1979, Jong, 1995). Sago palm is one of the most important bioresources for not only sustainable agriculture but also rural development in swampy areas of the tropics. However, *Metroxylon* palms, even sago palm is recognised as an unexploited or underexploited plant because this species has been harvested from natural forests and/or has been semi-cultivated under very simple maintenance. Information on systematic, ecological, physiological, agronomic characteristics of the sago palm is still limited. Since 1994, my sago research group has conducted field surveys to clarify the variations in starch yield in connection with environmental influences and genetic factors.

Metroxylon palms are distributed in not only fresh water areas but also in brackish water areas near the coast; and so are considered to be salt tolerant (Yamamoto, 1996). Flach (1977) reported that saline water treatment up to EC 6 to 7 mmho/cm did not affect leaf emergence in sago palm. However, few studies exist of the mechanism of salt tolerance in sago palm. It is usually very difficult to get uniform plant materials because of low germination percentage of sago palm seeds and large variation in days for germination, sometimes longer than one year needed, which may be main reasons why there is no experimentally further information of ecological and physiological growth response regarding salt tolerance in sago palm. Recently, Ehara *et al*. (1998, 2001) have developed a procedure how to improve and accelerate germination of sago palm seeds for getting new planting materials. Then, the Na^+ and K^+ concentrations of different plant parts under NaCl treatment to study absorption and distribution of Na^+ and K^+ in sago palm and related species were investigated (Ehara *et al*. 2006a, 2007, 2008a, 2008b).

As described above, sago palm grows in peaty soil that generally contains a high exchangeable Al. Aluminum, as Al^{3+}, usually inhibits the root growth and nutrient uptake of various plant species under acid condition. However, several plant species are known to be enhanced their growth by the application of Al (Osaki *et al*., 1997). Sago palm is also considered to be tolerant to Al. Even so, there are few studies on the Al-induced changes on growth responses of sago palm. Recently, the aim of study to investigate the effect of Al under low pH concentration on the growth and aluminum distribution in roots of sago palm has been done (Anugoolprasert *et al*., 2008, 2009).

Considering social background and specific characteristics of sago palm, an efficient use of carbohydrate from sago palm and related species is currently expected, followed by an anticipated increase in utilization from the view point of land development in swampy areas. The establishment of a concrete system for a stable and sustainable production is a pressing demand to enhance the further use of sago palm. This article provides a brief review of the research progress and feature prospects of promoting sago palm production and utilization. Based on such results from recent researches, potency of sago palm as carbohydrate resource for strengthening food security is discussed in this article.

POTENCY OF SAGO PALM

Starch yield, yield component and growth environment

A large variation in the starch yield of sago palm was found and its coefficient of variance among 22 folk varieties including two to three replications taken from Sumatra to Maluku in Indonesia was 56.5% (Ehara *et al*., 2006b). The minimum of 28 kg was obtained in spineless Rumbia from north Sulawesi and the maximum of 712 kg in spiny Ihur at Seram. The starch yield can be determined from the weight of dry-matter (DM) and starch content of pith. The starch yield is positively correlated with the weight of dry-matter and the starch content of pith (Figure 1). However, the partial correlation coefficient was higher between starch yield and the weight of pith dry-matter (0.995, P<0.001) than between starch yield and starch content of pith (0.735, P<0.001). Thus the multiple regression analysis between pith dry-matter yield and related plant characters was conducted to investigate the effect of the difference in plant characteristics on pith dry-matter yield.

Table 1 shows the result of a multiple regression analysis by using three selected parameters. The standard partial regression coefficient was highest in the diameter at breast height (DBH) followed by dry matter content of pith and trunk length. In the previous report (Ehara *et al*., 2000), it was shown that DBH and dry matter content of pith were the key parameters to estimate the pith dry-matter yield for sago palms grown in eastern archipelago of Indonesia. Our current result is in partial agreement with the previous result, while the contribution of trunk length to pith dry-matter yield was not small in sago palms including larger number of samples collected from wider areas.

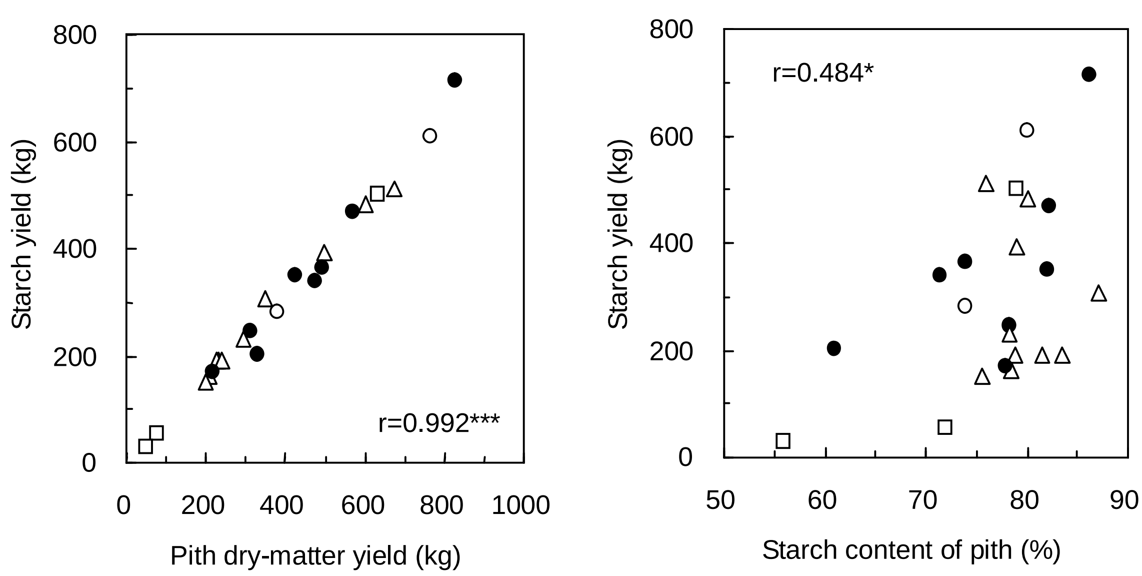

Figure 1. Relationship between starch yield and pith dry-matter yield or starch content in pith (from Ehara *et al*., 2006b). r , spineless and weak black band; ¨ , spineless and brown band; ¡ , spineless and no band; ˜ , spiny

Table 1. Result of multiple regression analysis (from Ehara *et al*., 2006b)

Variable	Partial regression coefficient	Standard partial regression coefficient	P	Partial correlation coefficient	Simple correlation coefficient
Trunk length	36.457	0.430	<0.001**	0.809	0.589
DBH	20.509	0.531	<0.001**	0.869	0.627
DM content of pith	9.039	0.569	<0.001**	0.828	0.694
Constant term	-1433.830		<0.001**		

Multiple correlation coefficient: 0.955, P<0.001

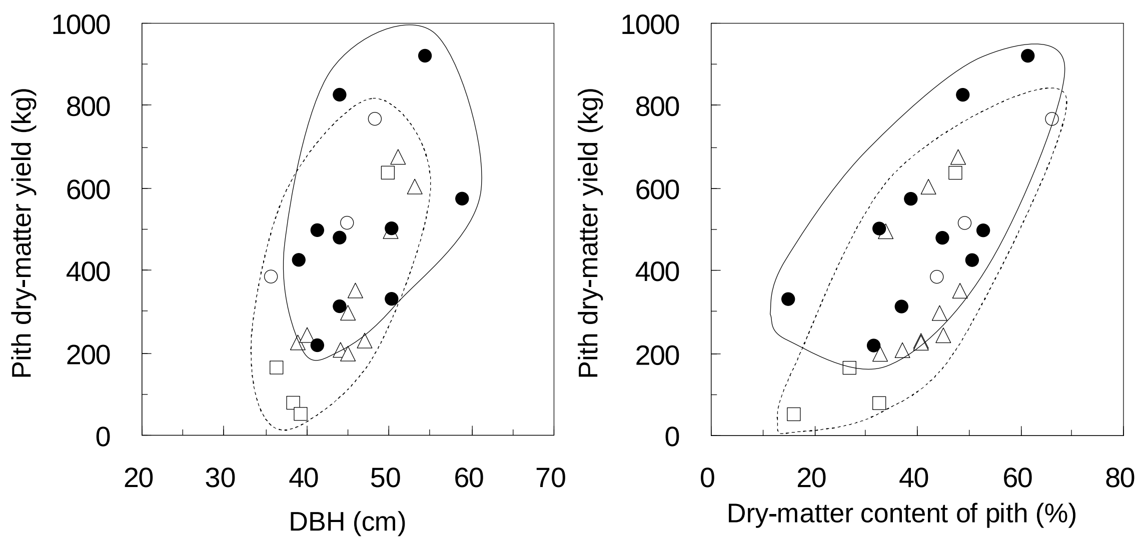

Figure 2. Relationship between pith dry-matter yield and DBH or dry-matter content of pith (from Ehara *et al.*, 2006b). Symbols are the same as those in Figure 1

Figure 2 shows the relationship between DBH and pith dry-matter yield. There was no apparent association between morphological characters and DBH. However spiny types showed, if anything, larger DBH and pith dry-matter yield than the spineless types. The relationship between trunk diameter and pith dry-matter yield was in almost the same trend with that between DBH and pith DM yield. The relationship between dry-matter content of pith and pith dry-matter yield is also shown in Figure 3. A rough tendency is that the pith dry-matter yield was higher in spiny types than spineless types with the same dry-matter content of pith. This tendency was attributed to the differences in DBH and trunk length between spiny and spineless types. There was a large variation in soil environment and DBH was positively correlated with pH (KCl) (Figure 3). However, other key parameters relating to pith DM yield did not have distinct relationship with any soil parameters.

The starch content of pith is one of the components of starch yield. Previously, a positive relationship between starch content of pith and stomatal density on the abaxial side of leaflet in sago palms grown in eastern archipelago of Indonesia was reported (Ehara *et al.*, 1995). At that time, the stomatal density on abaxial side of leaflet was positively correlated with exchangeable Ca in soil. In the current analysis, the relationship between stomatal density on abaxial side of leaflet and starch content of pith was positive (Figure 4). The relationship between exchangeable Ca in soil and stomatal density on abaxial side of leaflet was positive in sago palms grown at geographically nearby areas, but it was not distinct on the whole.

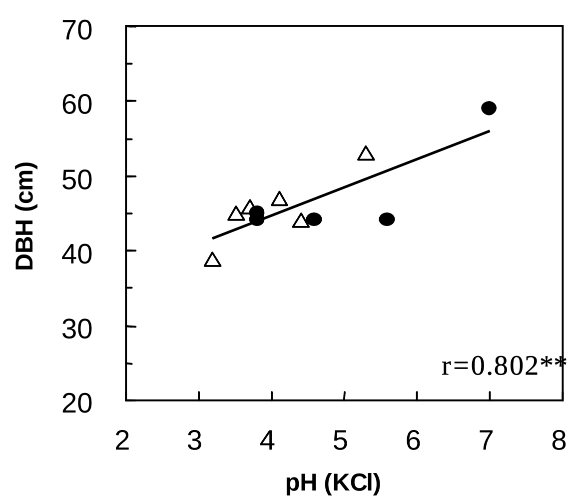

Figure 3. Relationship between soil pH and DBH (from Ehara *et al.*, 2006b). Symbols are the same as those in Figure 1

Genetic variation

As described above, the starch yield of sago palm may be influenced by soil environment. However, to determine limiting factors of the starch yield, genetic diversity of this species and similarities of local varieties growing at different areas should be investigated (Ehara *et al.*, 2003a). An RAPD analysis to estimate geographical and genetic relationships among various types of sago palms was thus conducted. A total of 77 PCR products were scored from all the primers. Out of 77 products, five were shared by all the populations, and 72 were polymorphic among the 38 populations. The dendrogram constructed by the

UPGMA method is shown in Figure 6. From the dendrogram based on RAPD data, two main groups were found. Group A included two sub-groups, and sub-group A1 consisted of nine populations from Johor on the Malay Peninsular, eight populations from Sumatra and the surrounding islands, one population from West Java and two populations from Roe (Roe 1, 2) in Southeast Sulawesi, Indonesia, and sub-group A2 consisted of three populations from Southeast Sulawesi in Indonesia and two populations from Mindanao in the Philippines. The cluster of sub-group A1 mainly consisted of the populations occurring in the western area of the Malay Archipelago. The cluster of group B consisted of 12 populations from the eastern area of the Malay Archipelago, i.e. eight populations from Seram and four populations from Ambon in the Maluku Islands (the Moluccas), Indonesia. Six populations from Seram (Tuni 1, 2, 3; Molat 1, 2; Ihur) formed sub-group B1 and the other two populations from Seram (Makanaru 1, 2) and four populations from Ambon (Makanaru 3, 4; Tuni 4, 5) formed sub-group B2. Wakar, a population from PNG, appeared outside the two main groups in the dendrogram. It was therefore considered that the genetic distance of sago palms was related to geographical distribution.

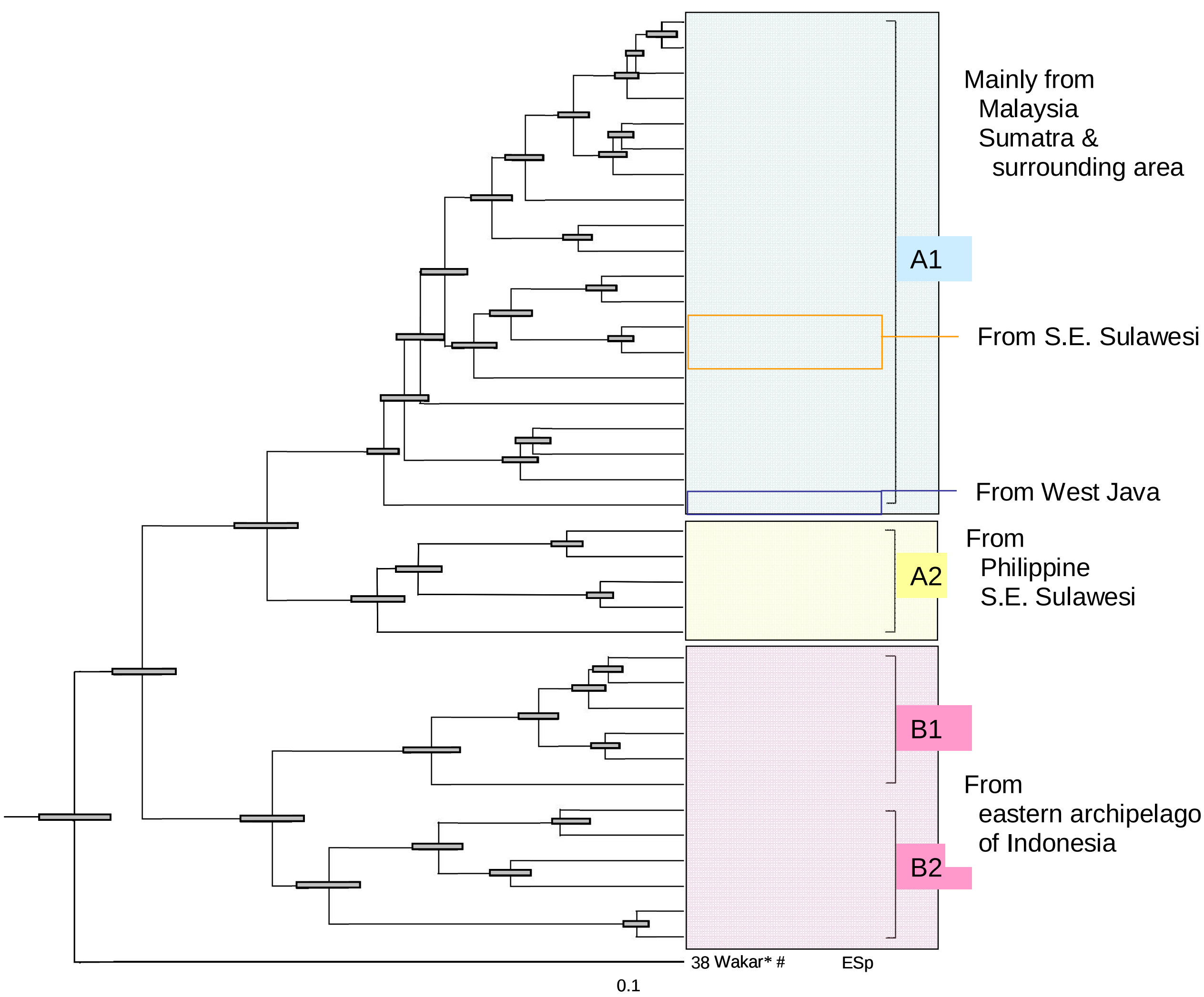

Figure 4. UPGMA dendrogram based on RAPD data
*, spiny; †, weak black band; ‡, brown band; #, reddish pith colour. ■, SE

In the previous report, six populations in sub-group B2 appeared to be closely related to three populations from Southeast Sulawesi (Runggumanu 1, 2; Rui) and two populations from Mindanao (Saksak; Lumbio) in the dendrogram (Ehara *et al.*, 2003a). In the present study, the populations in sub-group B2 were considered to be close to the populations from Seram (Tuni 1, 2, 3; Molat 1, 2; Ihur in sub-group B1) rather than the other populations. From the current result, the closer relationship between geographical distribution and genetic distance of sago palms in the Malay Archipelago became apparent. However an exception was noted in Roe from Southeast Sulawesi in Indonesia. It cannot be explained currently how Roe from Southeast Sulawesi appeared in the cluster of sub-group A1. Sometimes sucker (off shoot) of sago palm were presented as a gift for the birth of a baby in Southeast Sulawesi and this was aimed at providing a source of future income for the child. The distribution of sago palm could be influenced by not only natural factors but also some customs and cultural factors of inhabitants. It should be considered that both natural dispersal and historical plant migration to investigate the similarity of sago palms growing at different sites.

Each cluster included both spineless and spiny sago palm populations. The dissimilarity between the spineless population and the spiny population was not as large as that within different spineless populations or within different spiny populations. For instance, the dissimilarity between Ambtrung 2 (spineless) and Ambtrung 7 (spiny) from Johor on the Malay Peninsular was apparently small as compared to the other pairs of spineless or spiny populations. Consequently, the presence or absence of spines on the petiole and rachis was not considered to correspond with genetic distance. This result supports the proposal that spiny and spineless sago palms should be synonymous as *M. sagu* (Rauwerdink, 1986). Ehara *et al*. (1998) reported that spine emergence had also been observed in seedlings produced from seeds of spineless sago palm. Jong (1995) reported the opposite case that not only spiny seedlings but also spineless seedlings grew from seeds of spiny sago palm. Considering these results, some types of sago palm can be lumped as one species regardless of the presence or absence of spines in seedlings. Sago palms grown in the eastern area of the Malay Archipelago may be genetically grouped into four (e.g. B1, B2, A2 and A1 in the current report).

Moreover, two populations having a brown band on the back of the petiole and rachis (Sagu 1 and Sagu 2 from Siberut near West Sumatra in Indonesia) were included in sub-group B2. Three populations showing reddish pith colour, Rui from Southeast Sulawesi, Ihur from Seram in the Maluku Islands, Indonesia and Wakar from PNG occurred in sub-group B1, group A and outside the two main groups, respectively. However, neither the banding pattern at the back of the petiole and rachis, nor the pith colour showed a clear relationship with genetic distance in the present study.

Salt resistance

Growth response and ion concentrations in different plant parts of sago palm were investigated to make clear salt resistance. The seedlings are grown one each in a plastic pot filled with vermiculite and Kimura B culture solution containing (µM) 36.5 $(NH_4)_2SO_4$, 54.7 $MgSO_4$, 18.3 KNO_3, 36.5 $Ca(NO_3)_2$, 18.2 KH_2PO_4 and 3.9 FeO_3 (Baba and Takahashi 1958). The culture solution containing 85.5 to 342mM NaCl (corresponding to 0.5 to 2% NaCl) was used in the NaCl treatments for about one month. Transpiration rate did not decrease up to 171mM (1.0%) NaCl concentration in the growth, it was therefore considered that sago palm tolerated up to 171mM for comparatively long period (Ehara *et al*., 2006a).

The Na^+ concentration increased in almost all the parts and at all the leaf positions with the 342mM NaCl treatment (Ehara *et al*., 2008a). In the leaflets and petioles of the treated plants, the Na^+ concentrations were higher at lower leaf positions than at higher leaf positions (Figure 5). The difference in the Na^+ concentrations in both the leaflets and petiole between the control and treated plants was larger at lower leaf positions. These tendencies were same with those found in the previous study (Ehara *et al*., 2006a). Although the K^+ concentration decreased in the roots with the NaCl treatment, it did not decrease in the leaflets and petiole (Figure 6). At some leaf positions, the K^+ concentrations were higher in the treated plants rather than in the control plants. The K^+ concentration in the petiole was tended to be higher at higher leaf positions rather than at lower leaf positions especially in the treated plants, which was same tendency with our previous finding (Ehara *et al*., 2006a). In some species, plant growth is not affected when the K^+ concentration in plant is maintained under NaCl treatment (Greenway, 1962a, 1962b, Greenway *et al*., 1965, Munns *et al*., 1983, Jeschke *et al*., 1985, Yeo and Flowers 1986). The K^+ concentrations in the top part did not decrease regardless of the leaf position in the current experiment. It appears that Na^+ absorption clearly did not depress K^+ absorption and translocation to the leaves in sago palm even under the 342mM NaCl treatment and the K^+ distribution in the top part was more of the increase than no effect. Although new leaf emergence delayed slightly with the NaCl treatment, leaf senescence of lower leaf did not advanced in sago palm. In *Metroxylon* (*M. warburgii* (Heim) Becc. of section Coelococcus in genus *Metroxylon*, leaf senescence of lower leaf advanced with the same level NaCl treatment. Considering the current result on leaf senescence, there is a difference in growth response to NaCl stress between the species. Our previous and current results in sago palm strongly support the assumption that salt tolerance is related to the exclusion of K^+ by Na^+ absorption in the leaf blade (Greenway 1962a, 1962b, Munns *et al*., 1983, Jeschke *et al*., 1985, Yeo and Flowers, 1986). It has supposed that K^+ accumulation might be associated with osmotic adjustment in sago palm in the previous study (Ehara *et al.*, 2006a). Yoneda *et al.* (2006) also suggested that K^+ is important for osmotic adjustment under NaCl stress in sago palm. Considering these results, K^+ assumes the role of osmotic adjustment especially at higher leaf positions, that is, in most active leaves. To examine the water status of leaves under NaCl stress should be carried out for further studies.

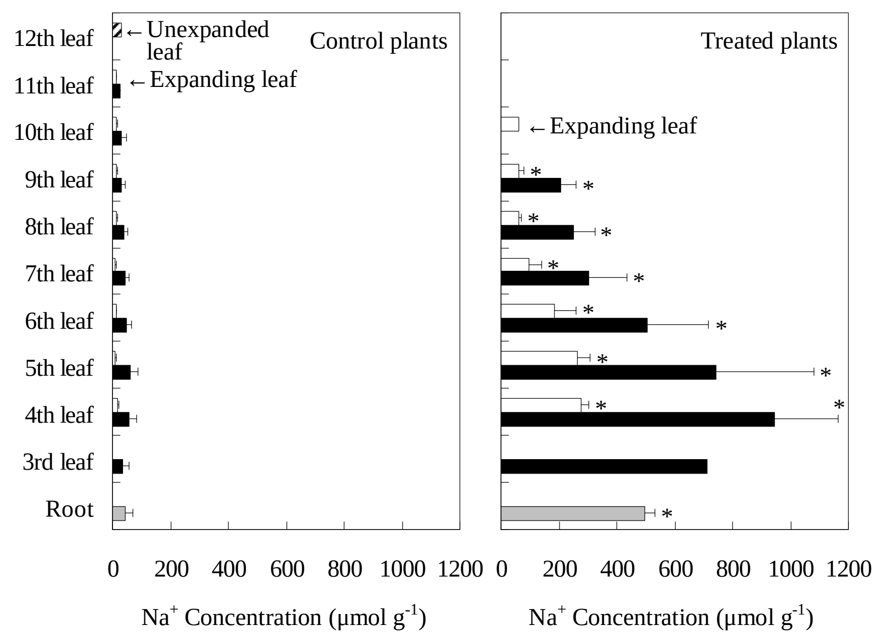

Figure 5. Na^+ concentration in roots and leaflets and petiole at different leaf positions under NaCl treatment (from Ehara *et al*., 2008a)

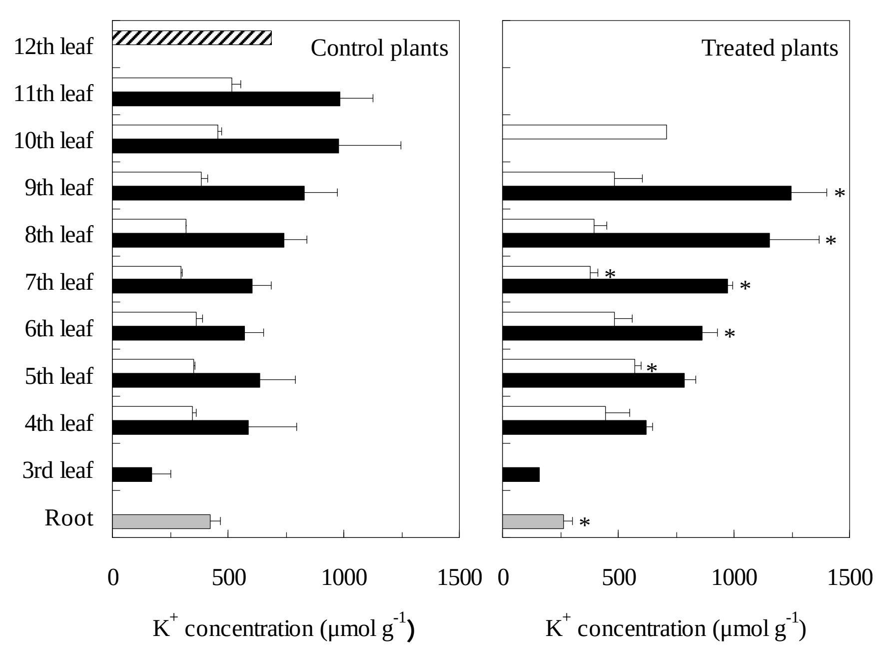

Figure 6. K^+ concentration in roots, leaflets and petioles at different leaf positions under NaCl treatment (from Ehara *et al*., 2008a). Bars and symbols are the same as those in Figure 5

Two types of roots, large root (adventitious root) and small root (lateral root), are distinguished in root systems of sago palm (Nitta *et al*., 2002), thus the Na^+ concentration in both types of roots was investigated. The large root, that is adventitious root, is divided into the cortex and stele. Figure 7 shows the Na^+ concentration in different parts of the roots. The Na^+ increased with the NaCl treatment in the small root and both the cortex and stele of the large root. In the large root, the Na^+ and Cl^- concentrations were lower in the stele than in the cortex. The Na^+ concentration in the small root was same level with that in the stele of the large root, contrarily the Cl^- concentration in the small root was similar level with that in the cortex of the large root. According to Nitta *et al.* (2002), the adventitious roots whose primordial are formed just inside the epidermis in the stem, emerged from the stem surface and grow downward into soil, and the lateral roots whose primordial are formed on the adventitious roots or on the other lateral roots, grow not only downward and obliquely but also right above in soil. They reported that both large and small roots have the same internal structures containing epidermis, exodermis, suberized sclerenchyma cells, cortex and stele, with only differences in their size or cell numbers. The functions and roles of large and small roots seem to be different as follows: large roots seem to be a suitable structure for air conduction and transport of nutrition and water; the internal structure of small roots is suitable for air exchange and this root body is exposed in the air, the function of this roots seems mainly to be air transportation from the root to the shoot rather than transport of nutrition or water (Nitta *et al*., 2002). It is not clear about the function of the small root responding to the excess ions from the former information. However, the current results suggest that the physiological response to excess Cl^-, that is, exclusion ability, of the small root is not same with that to excess Na^+ (Ehara *et al.,* 2008a).

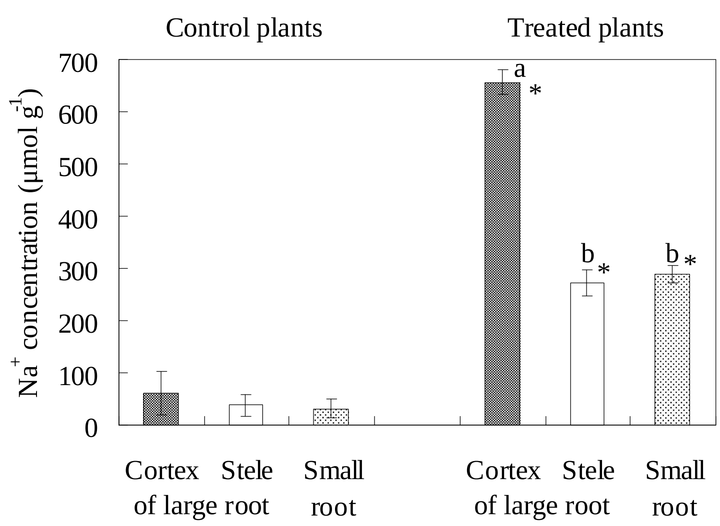

Figure 7. Na^+ concentration in different parts of the roots under NaCl treatment (from Ehata *et al*., 2008a). Vertical lines indicate the standard deviation (n=3). Different letters in the figure indicate significant differences in different parts within the treated plants at the 0.05 probability level, according to the Tukey-Kramer test. Asterisks indicate significant a difference in each part between the control and treated plants at the 0.05 probability level, according to the T-test

Figure 8 shows Na distribution from the cortex to stele in the large root of the treated plants by the X-ray micro-analysis. Na was detected more rich in the cortex rather than the stele (Ehara *et al*., 2008a). The highest distribution of Na was found at the inner region of the cortex near the stele. In this region, there is the endodermis that suberin or lignin develop (Casparian strip) in general (Ruddal, 1992). From only this finding, it is difficult to discuss in detail, though it was cleared at least that the region including the endodermis has a mechanism to trap some of over influx of Na into the large root. This mechanism will be very important to restrict translocation of Na^+ from root part to top parts under salt stress. Sago palm exhibits the mechanism to maintain low Na^+ concentration in the leaflets by storing Na^+ in the roots and petioles especially at lower leaf positions.

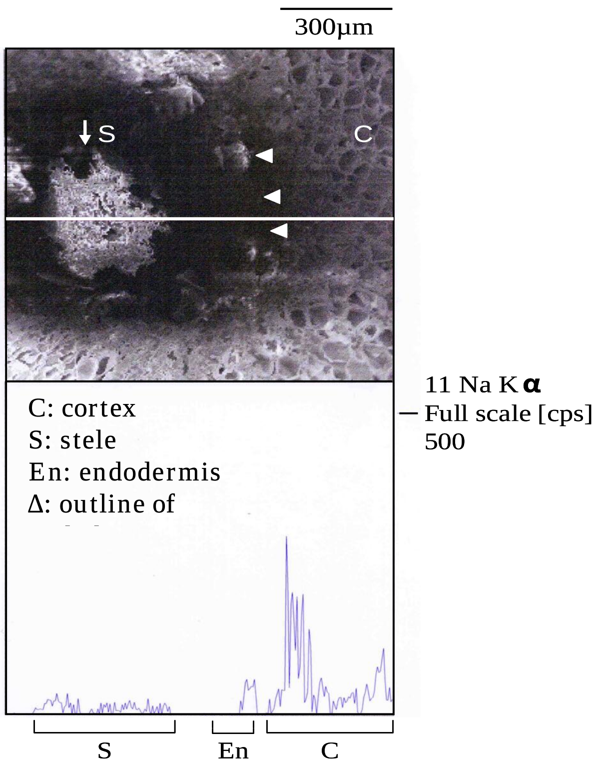

Figure 8. Electronmicrograph of transverse section of adventitious root in a treated plant and Na distribution by X-ray micro-analysis (from Ehara *et al*., 2008). The lower figure indicates Na distribution along the solid line in the upper electronmicrograph

Acid Tolerance

The growth parameters of sago palm seedlings grown at different pH conditions (pH 5.7, 4.5, 3.6 adjusted with 1.0 N HCl) one each in a Wagner pot filled with vermiculite and Kimura B culture solution were investigated. There were no significant differences in any growth parameters be among the three treatment plots (Anugoolprasert *et al.,* 2008). Next, the seedlings were grown in a Wagner pot that filled with vermiculite and Kimura B culture solution at pH 3.6 including different level of $AlCl_3 \cdot 6H_2O$ corresponding in 0, 10, 20, 100 and 200 ppm Al (here after Al-0, Al-10, Al-20, Al-100, Al-200) (Anugoolprasert *et al.,* 2009). Weekly increment of plant length, total leaf area and dry matter weight were largest in Al-10, followed by Al-0, Al-20, Al-100 and Al-200 plots. The root system in Al-200 was apparently different from the other plots, which the branched roots were stunted, brownish and thick. The root dry weight was also smaller than the other plots. Consequently, the critical toxic level to inhibit sago palm growth was considered to be around 200 ppm Al in the media. The change in P, N, K^+, Ca^{2+} and Mg^{2+} concentrations with the Al treatments was moderate. The Al^{3+} concentration tended to be lower in the leaflets at higher leaf position and the stele of adventitious roots, while it tended to be higher in the cortex of adventitious roots (the values were in the range of 190 - 950 mg Kg^{-1} DM in all the plant parts even at Al-200). According to Chenery (1948), the thousands of plant species are classified (by the Al concentrations in the plant tissues) as Al-accumulators (≥ 1,000 mg Kg^{-1} DM) or Al excluders (< 1,000 mg Kg^{-1} DM). Considering the result of Al^{3+} concentration in this study, sago palm is considered to have the Al exclusion ability under acid condition.

As reviewed above, the starch yield of sago palm may be affected by growth environment such as soil fertility in geographically near areas where genetically near sago palms grow. The genetic distance of sago palm populations growing in the Malay Archipelago are closely related to geographical distribution, and the presence or absence of spines on the petiole and rachis do not correspond with genetic distance. On the other hand, sago palm can grow under comparatively severe environmental conditions such as costal area or acid soil. This palm species is very useful to turn over the poor productivity lands or barren lands with sterile soil as productive lands for ensuring even larger amount of biomass covering the increase in demands for both food resource and/or energy source.

The Madrid high-Level Meeting on Food Security for all reaffirmed the conclusions of the World Food Summit in 1996 and the objectives confirmed by the World Food Summit five years later, to achieve food security for all through an ongoing effort to eradicate hunger in all countries, with an immediate view to reducing by half the number of undernourished people by no later than 2015, as well as their commitment to achieving the Millennium Development Goals (MDGs). The Declaration of the High-Level Conference on World Food Security: the challenges of Climate Change and Bioenergy convened in Rome in June 2008. Participants also indicated the urgent need to identify financing gaps and the additional resources needed for existing anti-famine mechanisms, including for food and nutrition assistance and social protection programs, and for supporting smallholder agriculture. They indicated the need for arrangements to coordinate the utilization of these resources. Moreover, they agreed that the consultations should be open to the full range of stakeholders involved in agriculture, food security and nutrition (including farmers' organizations, civil society organizations, women's organizations, private sector, developing country governments, and both regional and international organisations).

As the high-level meeting on food security for all stated, our agronomic aims for sustainable agriculture and rural development are pressing needs, and of course, the challenges of climate change and bioenergy are included. Sago palm is perennial plant, therefore the effect of climate change on its growth is considered to be lower if coampared with annual crops. The starch content of pith of sago palm is about 77% from chemical analysis (Ehara *et al*., 2006b). However, it will be about 48% of chemical analysis when the starch is extracted by the traditional method, and the percentage of the extracted residue was 55.7% on a dry weight basis (Yamamoto *et al*., 2007). To utilize the extracted pith residue of sago palm, Sasaki *et al.* (2002) and Ohmi *et al.* (2004) have tried to make a plastic seat. Of course, the extracted pith residue including starch and cellulose can be converted remaining starch into ethanol. It seems to be not easy to improve extraction efficiency of starch from the pith in a short-term. If we use the starch extracted by the simple method according to the conventional way and utilize the extracted pith residue for producing the biofuel, the utilization efficiency of sago palm as regional resource. Flach (1997) estimated the growth area of sago palm to be about 2,500,000ha in the world. Moreover, sago palm can grow even at saline soil or acid soil. Peaty soil area is estimated at 29,000,000ha even in Indonesia, Malaysia and Thailand. It is expected that the recent research progress on the growth response of sago palm to environmental stresses can contribute for investigating concrete strategies to introduce new plant resources to barren lands with sterile soil and utilize even a part of poor productivity lands for biomass production.

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