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

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ABSTRACT

A new competition in the production of biofuel and food has occurred in recent years, prompting the need for developing and utilizing new plant resources. Sago palm (*Metroxylon sagu* Rottb.) and related species in the genus *Metroxylon*, which can store a large amount of starch in the trunk and grow under severe environmental conditions, are considered potential starch resources for not only food production but also ethanol production. However, even sago palm, an elite species among starch-producing palms, grows under semi-domesticated or natural conditions, creating many problems in its use. Systematic, ecological, physiological, agronomic, and economic studies should be carried out to improve this and other similar species. In this paper, recent research progress is reviewed. Large variations in morphological characteristics and palm size existed among 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. Two key parameters were closely related to the soil profile, indicating natural fertility. On the other hand, the genetic distance of sago palms 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 a comparatively long period. The salt resistance of sago palm might be due to salt avoidance that mechanically restricts an excess of Na distribution from the roots to leaflets. The Na influx might be disturbed by the endodermal cells of the roots, even with 342mM (2.0%) NaCl concentration. Sago palm tolerated severely low pH conditions, such as pH 3.6 in the growth media, for at least five months and maintained a low Al^{3+} concentration in the plant tissues. Sago palm was considered to have a high tolerance to Al with Al-exclusion ability. Moreover, the growth of sago palm was stimulated when $AlCl_3$ was added to the growth media along with 10ppm Al. This physiological information on the growth of sago palm and its response to environmental stresses will be valuable for investigating concrete strategies to introduce new plant resources to barren lands with sterile soil and improve the economy in places with low productivity.

Keywords: *Al-exclusion ability, genetic variation, Metroxylon sagu, salt resistance, starch*

I. Introduction

A new competition between biofuel production and food production has occurred in recent years in light of social problems, such as the exhaustion of fossil energy and a world population that increases by 200,000 per day. Various plants have attracted considerable attention as reproducible resources to ensure sufficient biomass for producing alternative energy, such as bioethanol or biodiesel. However, the total area of arable lands worldwide has increased slowly in the past decade and is near the limit. According to FAOSTAT, the world's agricultural area is almost same as it was in 1995. The productivity of major crops seems to have peaked in 2006. The amount of cereals produced per capita reached a maximum in 1987 and has since decreased. Considering these facts, areas of poor productivity or barren lands with sterile soil should be utilized for producing economic plants to ensure even larger amounts of biomass to cover the increasing demands for both food and energy sources. Also, the development, improvement, and utilization of new plant resources are needed to secure sufficient amounts as food and biofuel sources, so that production of both will not result in competition.

Metroxylon palms [sago palm (*M. sagu* Rottb.) and related species] can store a large amount of starch in their trunks. The trunk of the sago palm, the elite species among starch-producing palms, has a starch storage capacity of approximately 300kg (dry wt.) (Ehara 2006). Sago palm has long been cultivated as a food similar to bananas and taro (Barrau 1959, Takamura 1990). This palm species is a carbohydrate resource and is one of the oldest crops used by human beings since ancient times (Takamura 1990). The importance of sago palm as a staple food has not changed in some areas, such as Siberut Island in western Sumatra, the eastern archipelago of Indonesia; Maluku, Papua, and western Melanesia; Papua New Guinea. Sago palm also is an important staple food in other places in Southeast Asia and in areas inhabited by the Melanesian people (Ehara et al. 2000). Its carbohydrate (starch) can be processed into various basic raw materials for human and animal consumption, and also provides an industrial energy source. *Metroxylon* palms, especially sago palm, are considered a potential starch resource for not only food production but also ethanol production.

The genus *Metroxylon* spreads from Southeast Asia to Micronesia and Melanesia. It is divided into two sec-

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tions: *Metroxylon* (*Eumetroxylon*) and *Coelococcus* (Beccari 1918, Rauwerdink 1986). *M. sagu* Rottb. is the only species in section *Metroxylon* (*Eumetroxylon*), although the monophyly of this section remains uncertain. It is distributed across Southeast Asia (Thailand, Malaysia, Indonesia, Philippines) and northwestern Melanesia (Papua New Guinea and the Solomon Islands). Five species are recognized within the *Coelococcus* section, representing the eastern half of the *Metroxylon* distribution. One species is found in Micronesia, and the other four species are spread across Melanesia and Polynesia from Vanuatu to Fiji and Samoa (McClatchey 1999). Palms of the Coelococcus group also produce sago starch that is extracted from the pith of the 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. was used at Moen in Micronesia until the 1940s, and *M. warburgii* was used at Gaua in Vanuatu until at least the 1950s (Ehara et al. 2003b). At Malakula in Vanuatu, *M. warburgii* is sometimes used as an emergency food. 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 a highly important bioresource for not only sustainable agriculture but also rural development in swampy areas of the tropics. However, *Metroxylon* palms, including sago palm, are recognized as unexploited or underexploited plants because this species has been harvested from natural forests and/or has been semi-cultivated with very simple maintenance. Information on systematic, ecological, physiological, and agronomic characteristics of the sago palm is still limited. Since 1994, our 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 freshwater areas but also brackish water areas near the coast. Therefore, they 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 regarding the mechanism of salt tolerance in sago palm. It is usually very difficult to get uniform plant materials because of the low germination percentage of sago palm seeds and the large variation in days needed for germination (sometimes longer than one year). These factors may be the main reasons no experimental information exists on the ecological and physiological growth response regarding salt tolerance in sago palm. Recently, Ehara et al. (1998, 2001) developed a procedure to improve and accelerate germination of sago palm seeds for getting new planting materials. The Na^+ and K^+ concentrations of different plant parts under NaCl treatment were investigated to study absorption and distribution of Na^+ and K^+ in sago palm and related species (Ehara et al. 2006a, 2007, 2008a, 2008b).

As described above, sago palm grows in peaty soil that generally contains highly exchangeable Al. Aluminum, as $Al^{3+,}$ usually inhibits the root growth and nutrient uptake of various plant species under acidic conditions. However, several plant species are known to have enhanced growth with the application of Al (Osaki et al. 1997). Sago palm is also considered to be Al-tolerant. Even so, there are few studies on Al-induced changes on the growth responses of sago palm. Recently, a study to investigate the effect of Al under low pH concentration on the growth and aluminum distribution in the roots of sago palm has been done (Anugoolprasert et al. 2012).

Considering the social background and specific characteristics of sago palm, an efficient use of carbohydrates from sago palm and related species is currently anticipated, followed by a predicted increase in the development and utilization of land in swampy areas. The establishment of a concrete system for stable, 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 the results from recent researches, potency of sago palm as a carbohydrate resource for strengthening food security is discussed.

II. Growth Characteristics and Genetic Variation

A. Starch yield, yield component, and growth environment

A large variation in the starch yield of sago palm was found. The 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). A minimum of 28 kg was obtained from spineless Rumbia from north Sulawesi and a maximum of 712 kg from spiny Ihur at Seram. The starch yield can be determined from the weight of the dry matter (DM) and starch content of the pith, and a positive correlation between the two factors exists (Fig. 1). However, the partial correlation coefficient was higher between the starch yield and the weight of the dry-matter pith (0.995, $P<0.001$) than it was between the starch yield and the starch content of the pith (0.735, $P<0.001$). Thus, the multiple-regression analysis between dry-matter pith yield and related plant characteristics was conducted to investigate their effects on dry-matter pith yield.

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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.

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 the pith and trunk length. In the previous report (Ehara et al. 2000), it was shown that DBH and dry-matter content of the pith were the key parameters in estimating the dry-matter pith yield for sago palm grown in the eastern archipelago of Indonesia. Our current result is in partial agreement with the previous result, although the contribution of trunk length to dry-matter pith yield was significant in sago palms including larger number of samples collected from a wider area.

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

The starch content of pith is one of the components of starch yield. Previously, a positive relationship was reported between starch content of the pith and stomatal density on the abaxial side of the leaflets of sago palm grown in the eastern archipelago of Indonesia (Ehara et al. 1995). At that time, the stomatal density on the abaxial side of leaflets correlated positively with exchangeable Ca in the soil. In the current analysis, the relationship between stomatal density on the abaxial side of the leaflets and the starch content of the pith was positive (Fig. 4).

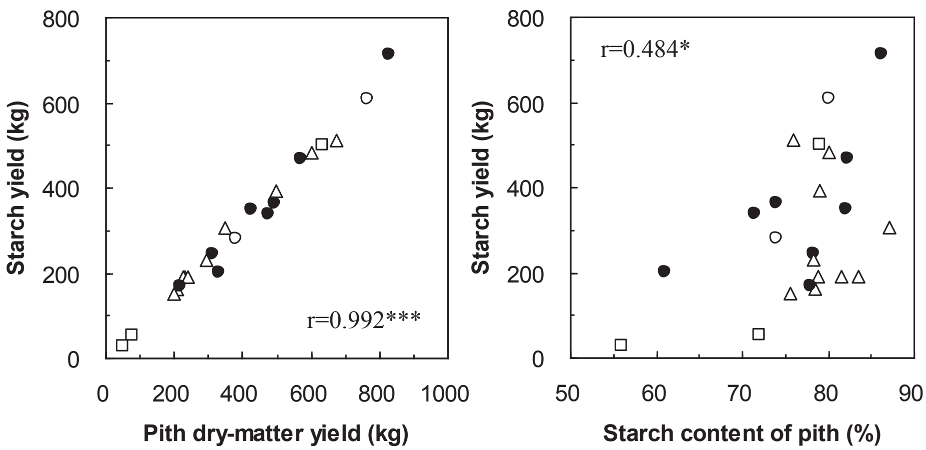

Fig. 1. Relationship between starch yield and dry-matter pith yield or starch content in pith (from Ehara et al. 2006b). △, spineless and weak black band; □, spineless and brown band; ○, spineless and no band; ●, spiny.

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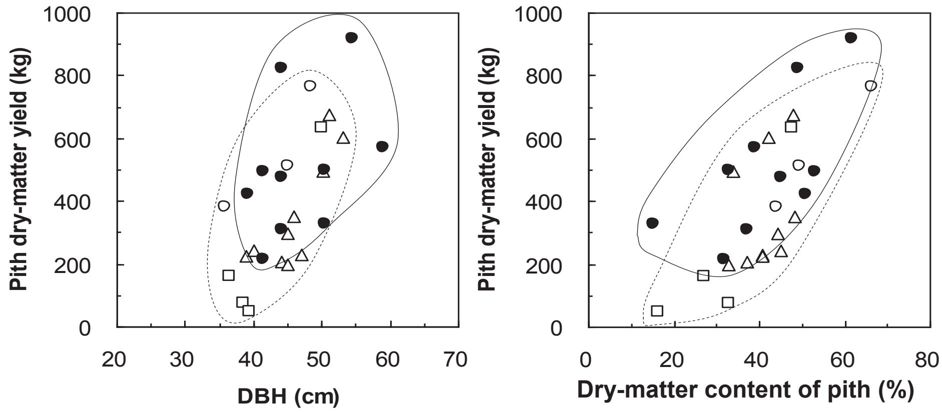

Fig. 2. Relationship between dry-matter pith yield and DBH or dry-matter content of pith (from Ehara et al. 2006b). Symbols are the same as those in Fig. 1.

The relationship between exchangeable Ca in soil and the stomatal density on the abaxial side of leaflets was positive in sago palm grown at geographically nearby areas, but it was not distinct on the whole.

B. Genetic variation

As described above, the starch yield of sago palm may be influenced by the soil environment. However, to determine limiting factors of the starch yield, genetic diversity of this species and similarities to 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 palm was conducted. A total of 77 PCR products were scored from all the primers. Out of these 77 products, five were shared by all the populations, and 72 were polymorphic among 38 populations. A dendrogram constructed by the UPGMA method is shown in Fig. 4. From this dendrogram based on the RAPD data, two main groups were found. Group A included two subgroups. The cluster of subgroup A1 consisted mainly of populations in the western area of the Malay Archipelago: nine populations from Johor on the Malay Peninsula, 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. Subgroup A2 consisted of three populations from southeast Sulawesi and two populations from Mindanao in the Philippines. The cluster of group B consisted of 12 populations from the eastern area of the Malay Archipelago, specifically, eight populations from Seram and four populations from Ambon in the Maluku Islands (the Moluccas) of Indonesia. Six populations from Seram (Tuni 1, 2, 3; Molat 1, 2; Ihur) formed subgroup B1 and the other two populations from Seram (Makanaru 1, 2) and four populations from Ambon (Makanaru 3, 4; Tuni 4, 5) formed subgroup B2. Wakar, a population from PNG, appeared outside the two main groups in the dendrogram. It was considered, therefore, that the genetic distance of sago palm was related to geographical distribution.

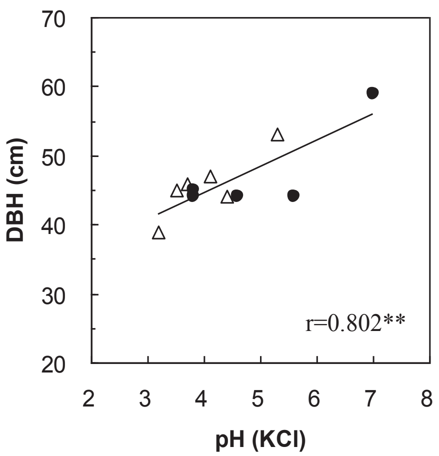

Fig. 3. Relationship between soil pH and DBH (from Ehara et al. 2006b). Symbols are the same as those in Fig. 1.

In a previous report, six populations in subgroup B2 of the dendogram appeared to be closely related to three populations from southeast Sulawesi (Runggumanu 1, 2; Rui) and two populations from Mindanao (Saksak; Lumbio) (Ehara et al. 2003a). In the current report, the populations in subgroup B2 were considered to be closer to the populations from Seram (Tuni 1, 2, 3; Molat 1, 2; Ihur in sub-group B1). From these results, the closer relationship between geographical distribution and genetic distance of sago palm in the Malay Archipelago became apparent. However, an exception was noted in

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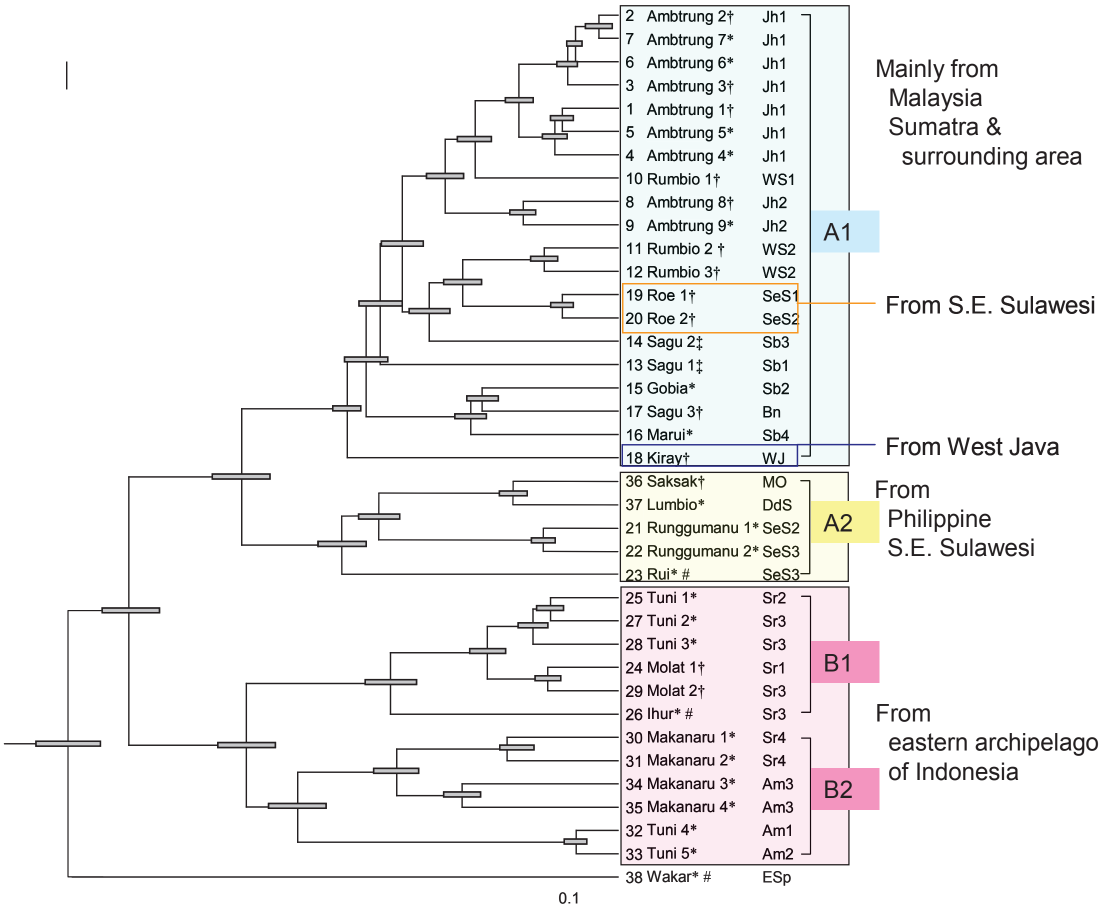

Fig. 4. UPGMA dendrogram based on RAPD data (from Ehara et al. 2003a). *, spiny; †, weak black band; ‡, brown band; #, reddish pith color. ■, SE.

Roe from southeast Sulawesi. It currently cannot be explained how Roe appeared in the cluster of subgroup A1. Sometimes suckers (offshoots) of sago palm were presented as gifts for the birth of a baby in southeast Sulawesi as a way of 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. Both natural dispersal and historical plant migration should be considered when investigating the similarities of sago palm growing at different sites.

Each cluster included both spineless and spiny sago palm populations. The dissimilarity between the two populations 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 Peninsula was apparently small 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 was also observed in seedlings produced from seeds of spineless sago palm. Jong (1995) reported the opposite case, with both spiny and spineless seedlings growing 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 palm grown in the eastern area of the Malay Archipelago may be arranged genetically into four groups (B1, B2, A2, and A1 in the current report).

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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 subgroup B2. Three populations, Rui from southeast Sulawesi; Ihur from Seram in the Maluku Islands, Indonesia; and Wakar from PNG, showed reddish pith color and occurred in subgroup 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 color showed a clear relationship with genetic distance in the present study.

C. Resistance against environmental stress

Growth response and ion concentrations in different plant parts of sago palm were investigated regarding salt resistance. Seedlings were 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). A 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; therefore, it was considered that sago palm tolerated up to 171mM for comparatively long periods (Ehara et al. 2006a).

The Na^+ concentration increased in almost all the parts and at all the leaf positions in 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 (Fig. 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 the same as those found in the previous study (Ehara et al. 2006a). Although the K^+ concentration decreased in the roots during the NaCl treatment, it did not decrease in the leaflets and petiole (Fig. 6). At some leaf positions, the K^+ concentrations were higher in the treated plants than in the control plants. The K^+ concentration in the petiole tended to be higher at higher leaf positions than at lower leaf positions, especially in the treated plants, which was same tendency exhibited in our previous finding (Ehara et al. 2006a). In some species, plant growth is not affected when the K^+ concentration is maintained under NaCl treatment (Greenway 1962a, 1962b, Greenway et al. 1965, Munns et al. 1983, Jeschke et al. 1985, Yeo and Flowers 1986). In the current experiment, K^+ concentrations in the top part did not decrease, regardless of the leaf position. 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 tended to increase rather than have no effect. Although new leaf emergence was delayed slightly with the NaCl treatment, senescence of the lower leaf did not advance. In *Metroxylon* (*M. warburgii* (Heim) Becc. of section *Coelococcus* in genus *Metroxylon*), senescence of the lower leaf advanced with

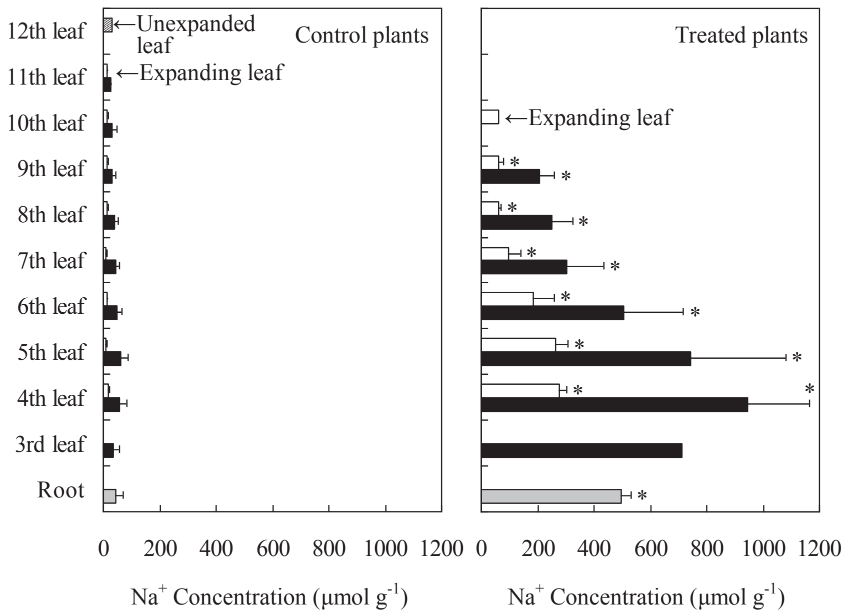

Fig. 5. Na^+ concentration in roots and leaflets and petiole at different leaf positions under NaCl treatment (from Ehara et al. 2008a). *: significant difference.

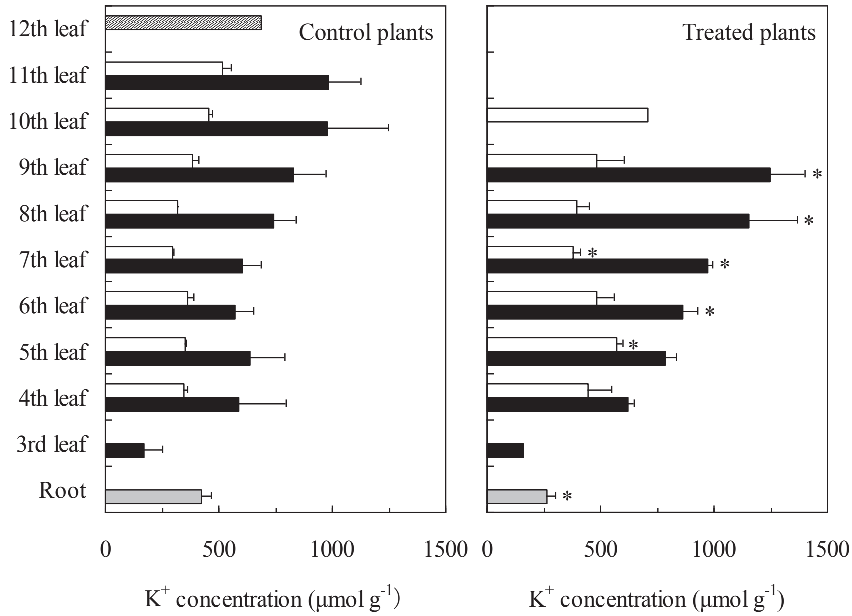

Fig. 6. K^+ concentration in roots, leaflets, and petioles at different leaf positions under NaCl treatment (from Ehara et al. 2008a). Bars and symbols are the same as those in Fig. 5.

the same level of 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). In the previous study, it was supposed that K^+ accumulation might be associated with osmotic adjustment in sago palm (Ehara et al. 2006a). Yoneda et al. (2006) also suggested that K^+ is important for osmotic adjustment under NaCl stress. Considering these results, K^+ assumes the role of osmotic adjustment, especially at higher leaf positions in most active leaves. Examination of the water status of leaves under NaCl stress should be carried out in further studies.

Two types of roots, large roots (adventitious roots) and small roots (lateral roots), are distinguished in the root systems of sago palm (Nitta et al. 2002), and the Na^+ concentration in both types of roots was investigated. The large root was divided into the cortex and stele. Fig. 7 shows the Na^+ concentration in different parts of the roots. Na^+ increased with the NaCl treatment in the small root as well as 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 the same as it was in the stele of the large root, but the Cl^- concentration in the small root was similar to that in the cortex of the large root. According to Nitta et al. (2002), the adventitious roots, whose primordia are formed just inside the epidermis in the stem, emerge from the stem surface and grow downward into the 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 the soil. Both large and small roots are reported to have the same internal structures containing epidermis, exodermis, suberized sclerenchyma cells, cortex, and stele, with differences only in their size or cell numbers. The functions and roles of large and small roots appear to be different. Large roots seem to be a suitable structure for air conduction and transportation of nutrition and water. The internal structure of small roots is suitable for air exchange, and the root body is exposed in the air; however, the function of these roots seems to be mainly for transporting air from the root to the shoot rather than transporting nutrition or water (Nitta et al. 2002). The former information is unclear about the function of the small root in response to excess ions. However, the current results suggest that the physiological response to excess Cl^-, that is, the exclusion ability of the small root, is not the same as it is to excess Na^+ (Ehara et al. 2008a).

As the result of Na distribution from the cortex to the stele in the large root of the treated plants as revealed by X-ray microanalysis, much more Na was detected in the cortex than in 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, the endodermis where suberin or lignin (Casparian strip) develops also in sago palm (Prathumyot and Ehara 2011). From only this finding, it is difficult to discuss the information in detail, although it is clear that the region including the endodermis has a mechanism to trap some of the over-influx of Na into the large root. This mechanism will be very important in restricting translocation of Na^+ from the root to the 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.

The growth parameters of sago palm seedlings grown at different pH conditions (pH 5.7, 4.5, 3.6, adjusted with 1.0N 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 among the three treatment plots (Anugoolprasert et al. 2012a). Next, the seedlings were planted in Wagner pots filled with vermiculite and Kimura B culture solution and grown at pH 3.6 that included different levels of AlCl3•6H2O corresponding to 0, 10, 20, 100, and 200 ppm Al (hereafter Al-0, Al-10, Al-20, Al-100, Al-200) (Anugoolprasert et al. 2012b). Weekly increments 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. The root system of Al-200 was apparently different from that of the Al-0 to Al-100 and the branched roots were stunted, brownish, and thick. The root dry weight was also less 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 the adventitious roots, while it tended to be higher in the cortex of adventitious roots (values ranged from 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 as Al-accumulators ($\geq$ 1,000 mg Kg^{-1} DM) or Al-excluders (< 1,000 mg Kg^{-1} DM), according to the Al concentrations in the plant tissues. Considering the result of Al^{3+} concentration in this study, sago palm is considered to have Al-exclusion ability under acidic conditions.

III. Potency of Sago Palm

In review, the starch yield of sago palm may be affected by the growth environment, such as soil fertility in areas geographically near to where sago palm grows genetically. The genetic distance of sago palm populations growing in the Malay Archipelago is closely related to geographical distribution, and the presence or absence of spines on the petiole and rachis does not correspond with genetic distance. On the other hand, sago palm can grow under comparatively severe environmental conditions, such as coastal areas or acidic soil. This palm species is very useful to turn areas of poor productivity or barren lands with sterile soil into productive lands and can ensure even larger amounts of biomass to cover the increase in demand for both food resources and an energy source.

A high-level meeting on food security was held in Madrid. As a result, the conclusions of the 1996 World Food Summit were reaffirmed, as were the objectives

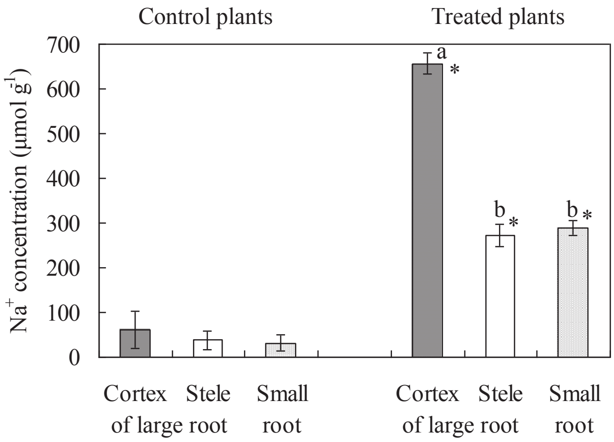

Fig. 7. Na^+ concentration in different parts of the roots under NaCl treatment (from Ehata et al. 2008a). Vertical lines indicate the standard deviation (n=3). Different letters indicate significant differences in various parts within the treated plants at a 0.05 probability level, according to the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

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confirmed by the World Food Summit five years later. Those objectives were to achieve food security for all through an ongoing effort to eradicate hunger in all countries, with an immediate view to reduce by half the number of undernourished people by no later than 2015 while maintaining their commitment to achieve the Millennium Development Goals (MDGs). The declaration of the high-level conference on World Food Security focused on the challenges of climate change and bioenergy and convened in Rome in June 2008. Participants indicated the urgent need to identify financing gaps and additional resources for existing anti-famine mechanisms, including food and nutrition assistance and social protection programs, and for supporting small-scale agriculture. They indicated the need to coordinate utilization of these resources. Moreover, they agreed that consultations should be open to the full range of stakeholders involved in agriculture, food security, and nutrition, including farming organizations, civil society organizations, women's organizations, the private sector, developing country governments, and both regional and international organizations.

Participants at the meeting on food security stated that our agronomic aims for sustainable agriculture and rural development are pressing needs and include the challenges of climate change and bioenergy. Sago palm is a perennial plant; therefore, the effect of climate change on its growth is considered lower compared with annual crops. Using chemical analysis, the starch content of sago palm pith is about 77% (Ehara et al. 2006b). When the starch is extracted by the traditional method, however, it is about 48%, 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, Sasaki et al. (2002) and Ohmi et al. (2004) have tried to make a plastic seat. The remaining starch in the extracted pith residue, which includes both starch and cellulose, can be converted into ethanol. At the present time, efficient extraction of the starch from the pith is difficult. However, if we use the starch extracted according to the simple, conventional way and utilize the extracted pith residue for producing biofuel, the utilization efficiency of sago palm as a regional resource is increased. Flach (1997) estimated the growth area of sago palm to be about 2.5 million hectares worldwide. Moreover, sago palm can grow in saline or acidic soil. The amount of peaty soil is estimated at 29 million hectares in Indonesia, Malaysia, and Thailand. It is expected that the recent research on the progress in the sago palm's growth response to environmental stresses can contribute for developing concrete strategies to introduce new plant resources into barren areas with sterile or poorly producing soil for use in biomass production.

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