Silicon Uptake and Phytolith Formation in Sago Palm (Metroxylon sagu Rottb.) (Advance Report)

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Silicon (Si) is a beneficial element for plants and present in soil solution as $Si(OH)_4$ (Currie and Perry, 2007) and alleviates the toxic effects caused by the stresses of heavy metals (for example manganese), salts and drought. Plants can take up Si with a radial and passive transport from the external solution (Mitani and Ma, 2005). Si dissolved from rocks and minerals in soil is transported to rice root surface by mass flow and reach the xylem through two kinds of transporters of Si (Ma and Yamaji, 2006). The complex of Si and protein might be moved to organs to form phytolith (biogenic silica plant microfossil, plant opal). There are few reports of phytolith formation in sago palm.

Keywords: excess, globular echinate, phytolith, silicon, toxic

Materials and Methods

Soil: Soil samples were taken from the sago experimental field of Pangasugan, Leyte, Philippines in 2000, air-dried and sieved by the 2 mm mesh sieve for chemical analysis. Total Si was determined by an X-ray fluorescence analyzer.

Sago palm leaf and seed: Sago leaf and seed samples of the third leaf from the apical were collected from the sago experimental field of Pangasugan, Leyte, Philippines in 2000, air-dried. Sago palm leaf and seed samples were oxidized with 30 % hydrogen peroxide (H_2O_2) at 80 °C, sieved with a 0.045 mm sieve and washed with tap water three times. The phytoliths from sago palm leaf and seed on a slide glass were observed under a microscope. The presence of phytolith was recorded according to International Code for Phytolith Nomenclature 1.0.

Results and Discussion

Phytoliths in sago palm leaf and seed: Silicon uptake resulted in the formation of phytoliths. Globular echinate phytoliths (Madella et al., 2005) in leaf and seed of sago palm were observed under a microscope (Fig. 1).

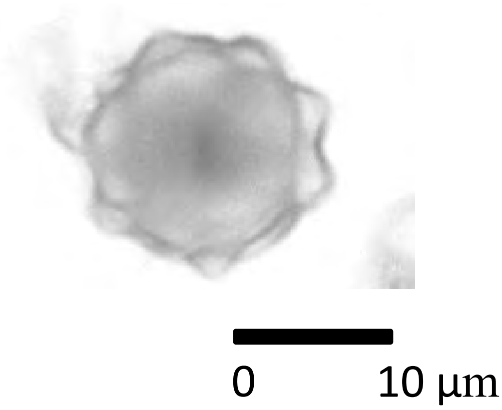

Fig. 1. Phytolith of sago palm under a microscope

Silicon uptake by sago palm resulted in the accumulation and formation of phytolith in leaf and seed of sago palm. Bowdery (2014) reported the glolular echinate form of phytolith from *Metroxylon sagu* to compare and classify the vegetation in the remote southern oceanic island of Rapa Nui (Easter Island) and concluded that *Metroxylon sagu* was present from 1425 to 1634. The presence of phytoliths in sago palm leaves indicate the potential alleviation of salinity and heavy metal stresses such as manganese. The effects of Si in leaves on salinity tolerance and inhibiting Mn uptake have been reported in rice (Ma et al. 2001). Thus, the further investigation of Si dynamics in sago palm could elucidate the underlying mechanism of high tolerance to abiotic stresses.

References

Bowdery, D. 2014 An enigma revisited: identification of palm phytoliths extracted from the 1983 Rapa Nui, Aano Kao2 core. Veget Hist Archaeobot, DOI 10.1007/s00334-014-0503-x

Currie, H. A. and C. C. Perry, 2007 Silica in plants: Biological, biochemical and chemical studies. Annals of Botany 100: 1383–1389

Guerriero, G., J-F. Hausman and S. Legay 2016 Silicon and the plant exteracellular matrix. Frontiers in Plant Science 7: 1-8

Ma, J. F., Y. Miyake and E. Takahashi 2001 Silicon as a beneficial element for crop plants. In Silicon in Agriculture, Ed. Datnoff, L.E., G.H. Snyder, and G.H. Korndorfer. P.17-39. Elsevier Science, Amsterdam.

Ma, J. F. and N. Yamaji 2006 Silicon uptake and accumulation in higher plants. Trends in Plant Science 11: 392-397

Madella, M., A. Alexandre and T. Ball 2005 International Code for Phytolith Nomenclature 1.0. Annals of Botany 96: 253–260

Mitani, N. and J. F. Ma 2005 Uptake system of silicon in different plant species. Journal of Experimental Botany 56: 1255–1261

Germination of Sago Palm Seeds Treated with Different Preparation Methods

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Introduction

Sago palm (*Metroxylon sagu* Rottb.) can be propagated from both off shoots (suckers) and seeds. The germination rate of sago palm seed can be changed by the preparation before seeding. In this study, the effects of fruit size and physical treatment on germination were investigated in the sago pilot farm in Kendari, Indonesia.

Materials and Methods

The experiments are conducted at the sago plot farm in the campus of Halu Oleo University in Kendari, Indonesia. The fruits of sago palm were collected from 3 trees in Abelisawah, South Konawe. Hundred fruits were washed with tap water and dried for one night.

Expt.1 Sixty fruits were divided into three plots as 20 fruits in each plot. The fruits were put individually in a small plastic pot filled with soil. The seeding conditions were as follows, plot A: whole fruit without any treatment, plot B: top of fruit [a portion of seed coat tissues (sarcotesta and pericarp above embryo) corresponded to 1/3 in surface area of fruit] was cut, and C: seed without sarcotesta and pericarp (clean seed). Germination count was made for 50days after seeding.

Expt.2. Three sago palm trees (No.1, No.2, No.3) were selected, and 40 fruits were collected from tree No.2 tree, and 20 fruits were collected from tree No.1 and No.3. The tree No.2 had comparatively larger fruits rather than tree No. 1 and No. 3. The fruits from tree No. 2 were divided into two groups, which are large plot and middle plots by the size. The fruits from tree No.1 and No.3 were named small plot. The size (major and minor diameter with height) and weight of fruits were measured, and their pericarp and sarcotesta were removed. The clean seed without seed coat tissues were sown after measuring the size and weight of seed. Germination count was made every two days.

Results and Discussion

Expt. 1. During the experiment for 50 days, 20% of whole fruits (A), 45% of cut fruits (B) and 55% of clean seeds (C) germinated (Fig.1, 2, 3). Although first germination was observed at day 17, it was in plot C. Germination rate of the cut fruits (B) was higher than that of the whole fruits (A). The reason was considered to attributed smooth water absorption in the cut fruits. The difference in germination rate of the cut fruits and clean seeds was small after day 30.

Expt. 2. The weight of fruit in large plot, middle plot, and small plot was 48.9 g, 35.4 g, and 25.1 g, respectively (Table 1). The descending order in size of the seed weight was same as that of the fruits. At day 20, germination rate in the small plot was 35% while that of the large plot and middle plot was 10% and 15% (Fig.4). The smaller seeds tended to germinate comparatively early rather than the larger and middle size of seeds. However, at 50 day, there was no relationship between the seed size and germination rate.

As described above, it was found that physical treatment to fruits will have influence on seed germination. However, the relationship between fruit or seed size and germinability was not clear.

Table 1. Fruit and weight of seeds used in experiment 2

Item	Large plot	Middle plot	Small plot
Fruit weight (g)	48.9 ± 4.2	35.4 ± 3.9	25.1 ± 3.5
Seed weight (g)	11.6 ± 1.1	10.5 ± 1.2	7.9 ± 0.6

Mean ± S.D. (n=20)

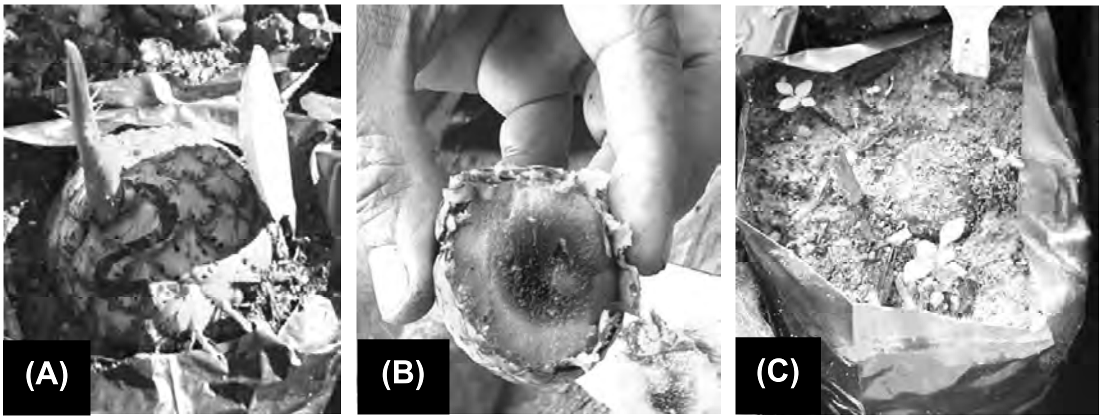

Fig.1. Germinated plants
(A) whole fruit,
(B) cut fruit,
(C) clean seed

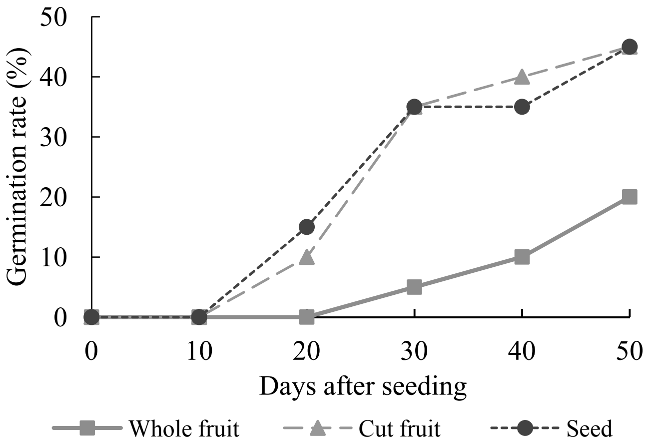

Fig. 3. Change in germination with different preparations

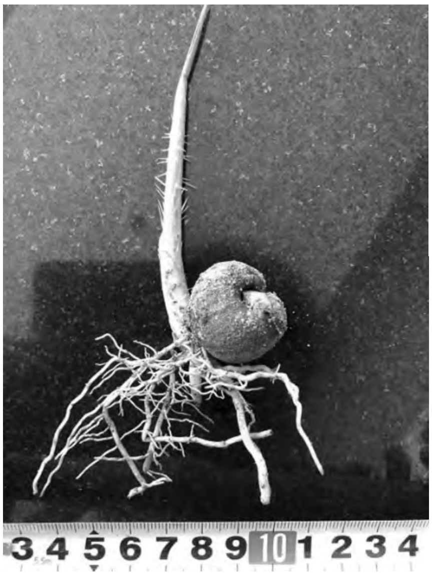

Fig.2. Sago palm seedling at the 2nd-leaf stage.

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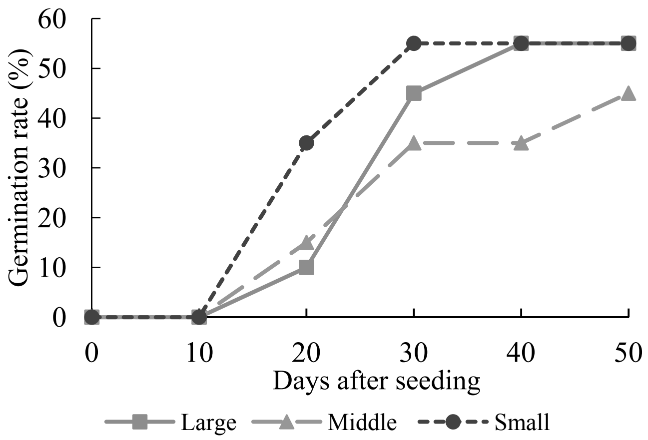

Fig. 4. Change in germination of seeds from different size of fruits

Comparison of Seedling Growth of Sago Palm under Different Fertilizer Application

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Introduction Sago palm (*Metroxylon sagu*) is the most promising species in the family Arecaceae as carbohydrate resource. In the former study, it was reported that the application of fertilizer accelerated the accumulation of dry matter in suckers rather than in mother palm in peat land. However, information about the growth and physiological response to chemical fertilizer is still limited because sago palm will be harvested from semi-cultivated stands or natural stands in many cases. In this study, the fundamentals of growth characteristics and its related nutrient acqisition under different fertilizer application were examined.

Materials and Methods The experiment was conducted in Nagoya University, Japan for 4 months from June to October 2018. Two-year-old seedlings grown individually in a pot (8L) were used. Four different plots are set as follows, Z plot: no fertilizer applied, NPK plot: 8.8g N, 8.8g P_2O_5, 5.9g K_2O per m^2 in each month NK plot: 8.8 g N, 5.9 g K_2O per m^2 in each month, and PK plot: 8.8 g P_2O_5, 5.9 g K_2O per m^2 in each month. Plant growth were measured every week such as, plant length, number of leaves per plant, number of leaflets per leaf, number of dead leaves and newly emerged leaves. Total leaflet area per plant was measured eighteen weeks after treatment using the portable leaf area meter, Li-3000C (LiCor Inc., USA). SPAD-502Plus (KONICA MINOLTA, Japan) was used to measure SPAD value. The chlorophyll content of the leaflets was determined by using the spectrophotometer. Photosynthetic rate, stomatal conductance and transpiration rate were measured from 10:00 - 11:00 after the 9th week of the beginning of treatment using the portable photosynthesis system, Li-6400XT (LiCor Inc., USA). The dry matter of leaf, petiole (from the top to 5th leaf) and the 3 types of roots (main, secondary and fine roots) were weighed and digested by Kjeldahl digestion method using H_2SO_4 and H_2O_2. Nitrogen content was analyzed by Kjeldahl distillation method, and phosphate content was analyzed by ammonium molybdate method. Potassium content in same part of the plants was analyzed by the method of ion chromatography with a conductivity detector (CDD-6A, SHIMADZU, Japan). Statistical differences among the mean values of NPK, NK, and PK treatments were determined by Tukey's studentized range test (HSD).

Results and Discussion The increment of plant length was less than 20 cm for 18 weeks during the treatment in all of the plots, and there was no significant difference also in the relative plant-length increase increment among the three plots, NPK, NK and KP. Leaflet number per leaf and relative leaf-number increase were same level in the three fertilization plots, however, the number of emerged leaves was high in the NPK and NK plots compared with the PK plot. There was no distinct difference in dry matter weight of most part except for petiole among the NPK, NK and PK plots. Specific leaf area (SLA) that is ratio of area to dry matter weight of leaflet was significantly higher in NPK and NK plots than PK plot. These results showed that the leaf morphogenesis in sago palm seedlings was influenced by the application of nitrogen fertilizer. Significant improvement of SPAD value, chlorophyll *a*, chlorophyll *b*, and carotenoids were observed in the NPK and NK plots, and photosynthetic rate, stomatal conductance and transpiration rate were also improved with the application of nitrogen fertilizer.

Nitrogen content in each part of the plant was tended to be high in the NPK and NK plots and the difference in phosphate content in plant parts was similar with that in nitrogen content except for the root. Although there was no distinctive difference in the leaf, it tended to be high with fertilization in the petiole and root compared with the Z plot.

In this experiment, it was revealed that sago palm seedlings started to respond to the nitrogen fertilizer within 2 to 3 months, and improved chlorophyll content in the leaflet and leaflet morphogenesis greatly. Furthermore, it enhanced the traits related to the photosynthetic activity. However, the effects of phosphate fertilizer were limited, which suggested that phosphate uptake would be influenced by the nitrogen content in the plant. The effect of potassium application on sago palm growth and related physiological features was still unclear, and clarification of the influence of potassium on palm growth and physiology is further subject.

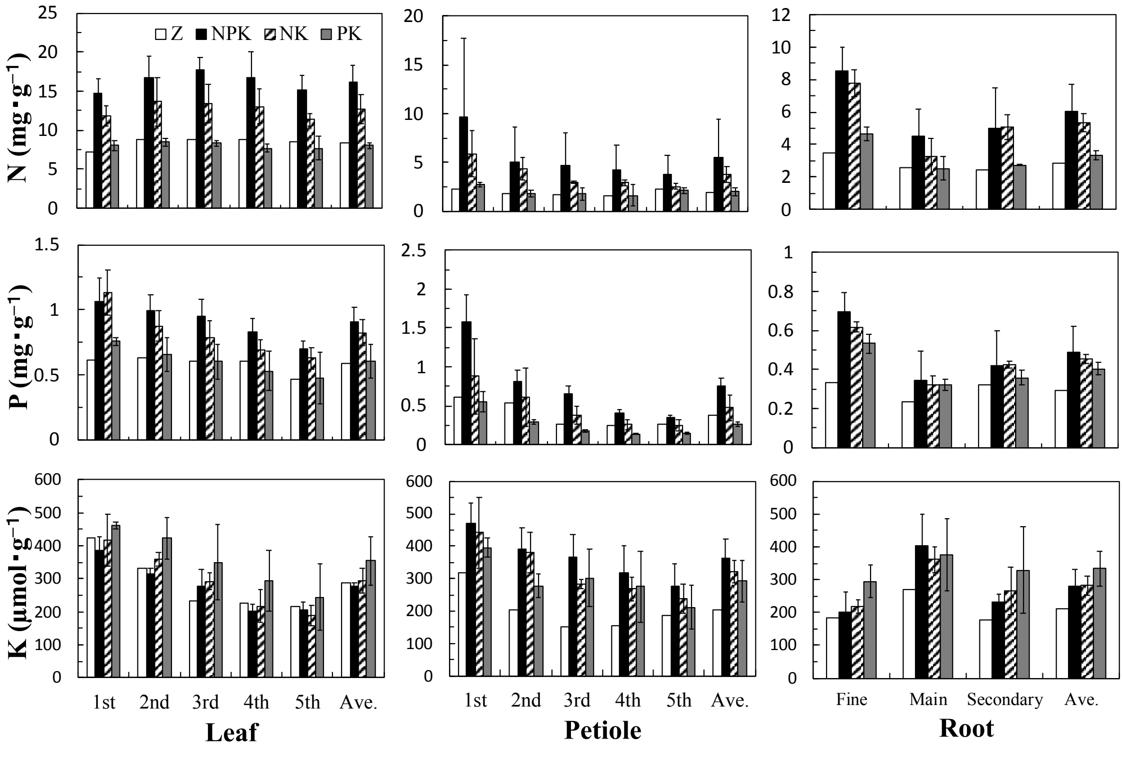

Fig.1. N, P and K concentrations in the leaf, petiole at different leaf positions and different type of roots. The vertical lines indicate the SD (n=3 in NPK, NK, PK)

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Metroxylon Palms in Guadalcanal, Solomon Islands

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Introduction

The genus *Metroxylon* is divided into two sections, *Metroxylon (Eumetroxylon)* and *Coelococcus*. *Metroxylon sagu* Rottb. (sago palm) is the only species in the section *Metroxylon*. There are four species in the section *Coelococcus*. *M.* salomonense (Warb.) Becc. (Solomon sago palm) is distributed in the Solomon Islands, Papua New Guinea (PNG) and Vanuatu, and its habitat is geographycally near to that of sago palm in comparison with the other *Coelococcus* spp. Starch yield of Solomon sago palm is comparatively high next to sago palm. In Solomon Islands, both of Solomon sago palm and sago palm exist, the study on their distribution and characteristics relating to starch production will be valuable for inventory study of sago resources. We report here on the summary of our field research conducted on the Island of Guadalcanal, Solomon Islands last year.

Research Sites and Plant Materials

A field survey was made at two sites, east and west of Honiara on Guadalcanal, Solomon Islands on 18 and 19 September 2018. *M. sagu* was harvested in inland swamp of Malango area (9°29′3″S, 160°4′58″E), and *M. salomonense* was harvested in Kakambona area close to north coast (9°25′23″S, 159°54′11″E). One palm each of two species were used to measure plant length, trunk length, diameter of trunk and some other agronomic parameters. Three part of trunk (top, middle and bottom parts) in *M. sagu* and two parts (middle and bottom) in *M. salomonense* were cut into a disk. The disk sample was cut into a triangular-prism-shape pith of which the apex was the center of the disk after removing the bark. The pith sample was used for determining bulk density, pith dry-matter yield, starch yield with sugar content.

Results and Discussion

Morphological characteristics of palm samples are shown in Table 1. The harvested *M. sagu* had an inflorescence with immature fruits (2 to 3cm diameter) and its size in trunk diameter and trunk length was 45cm and 11.4m. This tree was considered to be moderate size as adult sago palm at bearing stage. On the other hand, the harvested *M. solomonense* that was 44cm in diameter was considered to be small considering our former experience in Vanuatu and PNG. Although plant length of the *M. salomonense* harvested in this survey was 14.3m, its trunk was short with 3.8m in length. Regardless of its short trunk, this *M. salomonense* tree was at flowering stage and ready to be harvested. Considering the number of leaf scars as 19 and green leaves as 14 with supposing leaf emergence interval as 1 to 1.5 month, the duration from trunk formation to flowering stage was estimated around 3 to 4 years, which was considered remarkable early among *Metroxylon* species. The reason of estimated early development of growth phase was obscure whether it would depend on genetic factor(s) or environmental factor(s). Plant length of *M. salomonese* in this survey was small, though its inflorescence was comparatively long as 6.8m rather than that of *M. sagu* (2.7m). However, the inflorescence length of *M. salomonense* on Guadalcanal was smaller than that in Vanuatu (9.6m) (Ehara et al. 2003). Rachillae (3rd branches) of the inflorescence were pendulous and about 20cm, which were typical characteristics of *M. salomonense*.

Table 1 Stage and morphological characteristics of *Metroxylon* palms in Guadalcanal, Solomon Islands.

	Stage	Total length (m)	Trunk length (m)	DBH (cm)	Average diameter (cm)	Inflorescence length (m)	1st branch		2nd branch		3rd branch	
							No.	length (cm)	No.	length (cm)	No.	length (cm)
M.sagu	Bearing	16.09	11.37	45	44.5 (n=12)	2.70	22	201.7 (n=3)	20.9 (n=8)	41.1 (n=9)	8.8 (n=9)	9.4 (n=66)
M.salomonense	Flowering	14.29	3.75	44	41.4 (n=4)	6.76	28	195 (n=3)	11.7 (n=12)	26.6 (n=9)	7.2 (n=9)	19.8 (n=62)

Table 2. Starch yield and related characters of *Metroxylon* palms in Guadalcanal, Solomon Islands.

		Pith dry matter percentage (%)	Pith starch content (%)	Starch density (g/cm^3)	Starch yield (kg/plant)	Sugar content (mg/g)
M.sagu	*Top*	49.6	73.8	0.337		33.5
	Mid	50.2	77.7	0.328		28.1
	Bot	44.9	69.4	0.253		26.9
	AVE	48.3	73.6	0.306	493.2	29.5
M.salomonense	Mid	23.3	30.3	0.058		118.0
	Bot	31.7	26.9	0.073		124.4
	AVE	27.5	28.6	0.066	30.0	121.2

Starch yield depended on chemical analysis was 493kg/plant and its related pith dry-matter percentage was 48.3% and starch content in pith was 73.6% in *M. sagu*. These data were almost same level with those in sago palm grown in Maluku, Indonesia (Yamamoto et al. 2008). *M. salomonense* showed 30kg/plant dry starch, which was low because of shorter trunk length as 3.8m, low pith-dry matter percentage as 27.5% and low starch content in pith as 28.6%. Besides, total sugar content in pith was high as 12% even after inflorescence appearance in *M. salomonense*. Sago palm has been used as a roofing material (leaflet) and a material of handicraft such as pendant top and ornament(seed) also in Solomon Islands.

In Wasakiki village, eastern part of Guadalcanal, distribution of *M. warburgii* (Vanuatu sago palm) was observed. According to villagers there, *M. warburgii* was introduced from Santa Cruz Islands. From this survey, it was cleared that the largest diversity of species in the genus *Metroxylon* is found in Solomon Islands.

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References

Ehara, H. et al. 2003 Agronomic features of *Metroxylon* palms growing on Gaua in the Banks Islands, Vanuatu. SAGO PALM 11: 14–17.

Yamamoto, Y. et al. 2008 Sago palm and its utilization in Ambon and Seram Islands, Maluku Province, Indonesia. Abstracts of the 17th conference of Japanese Society of Sago Palm Studies, p17-22.

Impact of High Soil Water Levels on Sago Palm's Nutrient Uptake and Photosynthesis

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Introduction The issue of peat restoration has attracted attention in the islands of Southeast Asia in recent years. Peatland restoration aims to restore the function of peatland as a water absorption area and maintaining carbon content by preventing the occurrence large amounts of carbon emissions caused by peat fire. Therefore, it is very important to keep the peat soils wet. In terms of agronomy, this is not beneficial especially for plantation crops. Sago palm (*Metroxylon sagu* Rottb.) is distributed also in peatland close to tidal area in the islands of Southeast Asia and expected to be highly utilized for the current issue of peat restoration. In this study, sago palm's growth performance with nutrient uptake and photosynthetic rate was investigated under high soil water levels.

Materials and Methods This experiment was conducted from August 2018 to March 2019. Three-year-old sago palm seedlings were grown individually in 29L pot (39.8cm × 37.6cm) filled with commercial black soil. Three different conditions were applied to the seedlings regarding soil water level treatment as follows, normal water application as a control: water including nutrients was supplied from a hole of bottom of pot put into a plastic container, 50% and 80% soil water levels were the percentage of the height of pot which was similarly with the control pots put in the plastic container. Fifty percent strength of Kimura B culture solution was supplied with approximately 3cm depth for the control and depth corresponding to 50 and 80% of pot height for the 50 and 80% plots in the plastic container. The soil in the control pots was kept at 30% order of moist condition. Twice a week the culture solution was changed. Sago palm's photosynthetic performance was evaluated using Li-Cor 6400XT (LiCor, USA) and photosynthesis yield analyzer (MINI-PAM, Walz, Effeltrich, Germany) after 30 minutes dark adaptation. Leaf greenness was observed using SPAD-502 (KONICA MINOLTA, Japan. Leaflet area was measured using Li-3000C (LiCor, USA). All leaflets and petioles emerged during the experiment were digested by Kjeldahl method using H_2SO_4 and H_2O_2. The extracts were used for N, P and K analysis. Nitrogen content was measured by Kjeldahl distillation method. Phosphate concentration was determined by ammonium molybdate method and the absorbance was measured at 710 nm wavelength using a spectrophotometry (UV-1800 Shimadzu, Japan). Potassium content was analyzed using Flame Photometers.

Results and Discussion Sago seedlings were able to show good adaptation in high and continuous soil water levels tested. The fresh and dry matter weights of leaf and petiole were higher in high wail water than control plants. The trend of growth performance such as leaflet area and plant height of higher water treatments was larger rather than normal soil water condition (control). Under high soil water condition, sago palm tended to absorb much nutrients as we found that N, P and K concentrations in leaflets and petioles in high soil water conditions trended higher than control, however, there was no significant difference among the three treatments. There was no interference with photosynthetic performance in both high soil water conditions. Light harvesting system in PSII also was not affected by high water soil water treatments. Stable chlorophyll fluorescence parameters indicated that there was no deterioration in photosynthetic performance under the two high soil water levels.

Although sago palm naturally grows in tidal conditions as well with appropriate water circulation, continuous high soil water levels also will allow its high growth performance and high nutrient uptake compared with those in normal soil water condition. However, further evaluation on non-structural carbohydrate content is needed to investigate whether sago palm growing under high soil water level will be able to utilize photosynthate efficiently for maintaining own plant body and stimulate morphological growth with appropriate dry matter and starch production.

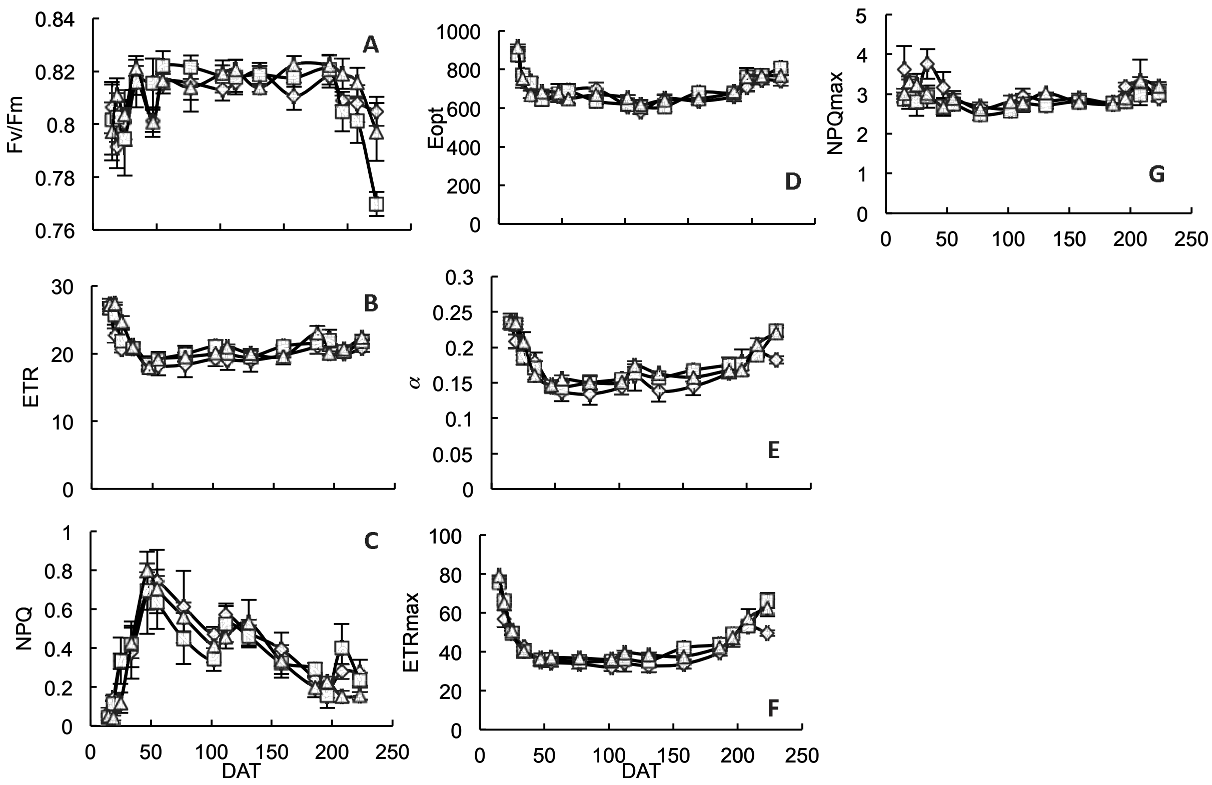

Fig. 1. Fv/Fm- maximum quantum yield PSII (A), ETR–electron transport rate (B), NPQ–non-photochemical quenching (C), Eopt-optimum irradiance (D), α–asymptotic photosynthetic efficiency (E), ETRmax–maximum electron transport rate (F) and NPQmax–maximum non-photochemical quenching (G) of sago palm seedlings growing under normal (◇), 50% (□) and 80% (△) soil water condition. Data corresponds to the mean value and standard error (n = 4)

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From Producers to Consumers: Distribution and utilization of sago starch in Surabaya, East Java, Indonesia

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Introduction A distribution channel is the set of steps a good or service from a producer that has to go through to reach the final consumer. A distribution channel shows a path traced in the direct or indirect transfer of a product as it moves from a producer to an ultimate consumer or industrial user. A number of studies have been conducted to determine the distribution channel and price transmission of agricultural products in Indonesia. However, to date, there is no empirical evidence of whether distribution channels and price transmission can be considered to be efficient for different actors in the sago starch distribution. This situation indicates the need for analyzing the distribution and utilization of sago starch in Surabaya as the main market destination in Indonesia.

Material and Methods The survey was conducted in January 2019 in Surabaya, East Java, Indonesia. 3 traditional markets (Wonokromo, Pabean and Blauran) and 1 cake shop were observed to identify sago starch utilization and their market linkages.

Results and Discussion For small and medium sago businesses, understanding the distribution management is the important way to maximize their profit. According to our investigation in traditional markets, 2 sago products were found: (1) dried sago and (2) roasted sago (Figure 1).

(a)

(b)

Fig 1. (a) Dried sago in distributor, (b) *sagu kotak*/roasted sago found in Surabaya

A. Dried sago starch distribution

The distribution of dried sago in Surabaya can be classified into indirect distribution with market linkages from producer to the domestic trader. There is no linkage market between distributor to the exporter. The product is from Selat Panjang, Riau and distributes to Surabaya from Cirebon (Fig. 2). In Cirebon, the distributor price of dried sago for 1 sack (50 kg) is ¥ 2450 (¥ 49/kg). In the distributor/ agent in Surabaya, the price of dried sago is ¥ 2894 (¥ 58/kg). Meanwhile, in the retailer level, the dried sago is sold for ¥ 76/kg to the consumer. The consumer can buy dried sago directly to the distributor for dried sago in the small quantity (1 kg) for ¥ 69/kg. Due to the long chain between a producer to a consumer, the price of dried sago in Surabaya hikes over 55.1% until it reaches the consumers without any extra value addition. The price of the product is marked up to cover transportation, storage, and profit for distributor and retailers although there is weight loss during the shipment due to moisture content. The total weight of dried sago until Surabaya is only 90-98% of the original weight.

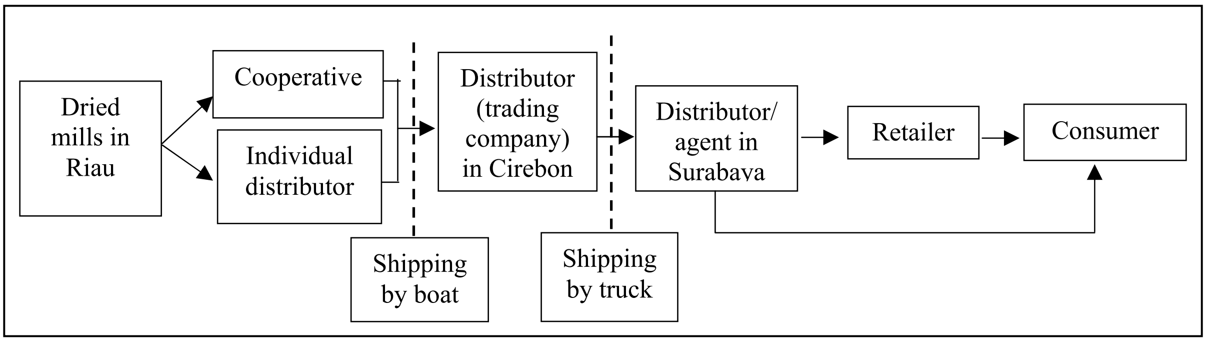

Fig 2. Dried sago distribution in Surabaya, East Java, Indonesia

B. *Sagu kotak*/ roasted sago distribution

Sagu kotak also has an indirect distribution from the distributor in Ambon to agent, wholesaler, and retailer in Surabaya (Fig. 3). At the distributor level, *sago kotak* is sold per sack (90 kg) between ¥ 10.283 – ¥ 10.969 (¥ 114 – ¥ 122/kg). The wholesalers sell the product between ¥ 11.654 - ¥ 11.997/sack (¥ 129 – ¥ 133/kg) to consumers. In the retailer level, the selling prices of *sago kotak* vary between ¥ 152 to ¥ 168/kg.

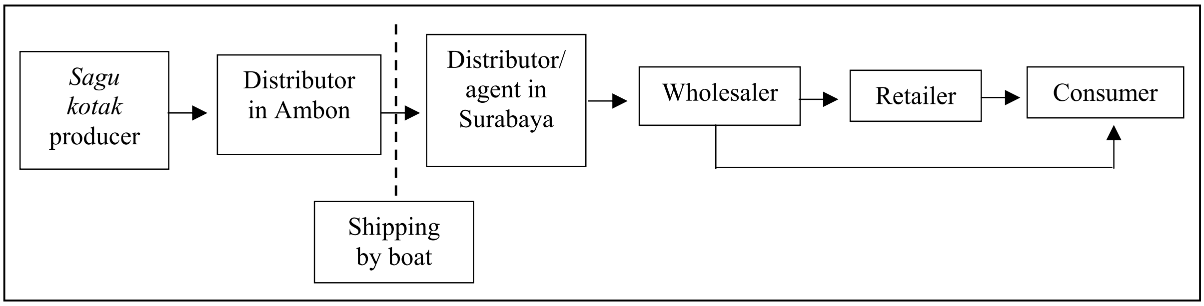

Fig 3. *Sagu kotak* distribution in Surabaya, East Java, Indonesia

C. *Bubur sagu*/ sago pudding

People in Surabaya utilize sago starch mainly for food. *Bubur sagu*/ sago pudding is considered as one of the famous foods in Surabaya. *Bubur sagu* is a sweet pudding made by boiling *sagu kotak* with water, sugar and serving it with coconut milk. It is sometimes added with other ingredients such as black glutinous rice, sweet potato, and mung bean called *bubur campur* (mix pudding). *Bubur sagu* is believed by local people to be able to relieve fever and sore throat. The price of bubur sagu in the traditional market is ¥ 46 meanwhile, in the cake shop, it is sold for ¥ 61. The distribution of *bubur sagu* can be classified into direct selling with market linkages from producer to consumer with additional online distribution. The demand for *sago kotak* highly increases, especially in Ramadhan and Eid al-Fitr.

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