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Introduction of Sago Palm Seeds and Seedlings into Tanzania

Hiroshi EHARA[1], Hitoshi NAITO[2], Akwilin J. P. TARIMO[3],
Mochamad H. BINTORO[4] and Tomoki Y. TAKAMURA[5]

[1] Graduate School of Bioresources, Mie University, Kurimamachiya-cho, Tsu 514-8507, Japan
[2] College of Life Science, Kurashiki University of Science and The Arts, Nishinoura, Tsurajima-cho, Kurashiki 712-8505, Japan
[3] Faculty of Agriculture, Sokoine University of Agriculture, P.O.Box 3005, Morogoro, Tanzania
[4] Faculty of Agriculture, Bogor Agricultural University, Kampus IPB Darmaga, Bogor 16680, Indonesia
[5] Kyoto University Sago Palm Research Fund, Fushimi-ku, Kyoto 612-8436, Japan

タンザニアへのサゴヤシの種子および実生の導入

江原　宏[1]・内藤　整[2]・Akwilin J. P. TARIMO[3]・Mochamad H. BINTORO[4]・高村奉樹[5]

[1] 三重大学大学院生物資源学研究科
[2] 倉敷芸術科学大学生命科学部
[3] ソコイネ農業大学農学部
[4] ボゴール農科大学農学部
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Sago palm (*Metroxylon sagu* Rottb.), distributed in Southeast Asia and in areas inhabited by Melanesian people, grows in swampy, alluvial and peaty soils where almost no other crops can grow without drainage or soil improvement (Sato *et al*. 1979, Flach 1977, Jong 1995). This palm species stores a large amount of starch in the trunk, approximately 300 kg (dry wt.) per palm (Ehara 2006) and has long been cultivated like banana and taro (Barrau 1959, Takamura 1990). As a staple food, sago palm continues to be important in some areas of Southeast Asia and in areas inhabited by 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 for an industrial energy source. Sago palm is one of the most important crops for sustainable agriculture and for rural development in swampy areas of the tropics.

The possibility of transporting sago palm from its natural growing area to sites where sago palm is not distributed was reported by Takamura (1995). As precedents, sago palm seeds or suckers were introduced into Tanzania from Indonesia in 1995 and 2000 (Takamaura 1997, Takamura *et al*. 2001). Tanzania was selected for the introduction of sago palm because this country and Indonesia are at nearly the same latitude and have regionally similar tropical rainforest environmental conditions. In addition, a paddy field development project supported by Indonesian technical experts was conducted in the Mkindo area of Tanzania (Takamura *et al*. 2001). The suckers of sago palm introduced in 2000 were transplanted in a field, and some of them survived for several months until they were burned off (Takamura and Tarimo 2002). Thus, in 2003, we started a new sago palm introduction project in Tanzania using seeds or young seedlings according to an agreement signed by Bogor Agricultural University, Indonesia;

Sokoine University of Agriculture, Tanzania; and Kyoto University, Japan (Tarimo 2005). Mie University and Kurashiki University of Science and The Arts have joined the project since 2003 and have played leading roles in taking care of the plant materials and introducing them into Tanzania. Here, we report the process of introducing sago seeds and seedlings and their subsequent growth in Tanzania.

1. Materials collection and introduction process

Sago palm fruits were collected at the following times and sites in Indonesia: Manokwari, West Papua, September 2003 and February 2005; and the Sentani area (north shore of Lake Sentani) west of Jayapura, West Papua, November 2003. All the materials were collected by Bintoro and faculty members of Bogor Agricultural University (IPB) and were prepared at Mie University until they were introduced into Tanzania by Ehara and Naito.

(1) Introduction in 2003

The fruits that were collected in Manokwari in September 2003 germinated at IPB in Bogor, Indonesia. Each geminated fruit was planted in a small plastic pot (200 mL, no drainage hole) filled with vermiculite and Kimura B culture solution (Baba and Takahashi 1958) at full strength. The culture solution contained (mg/L) 48.2 $(NH_4)_2SO_4$, 15.9 K_2SO_4, 65.9 $MgSO_4$, 18.5 KNO_3, 59.9 $Ca(NO_3)_2$, 24.8 KH_2PO_4 and 3.5 Fe_2O_3. The plants were cultivated in an air-conditioned room at 30˚C and 75% relative humidity (12 hrs light). Three of the seedlings that germinated at IPB and 50 fruits collected in Sentani in November 2003 were introduced as hand-carried materials into Tanzania by air on 11 December 2003 (Plant Importation Permit: Ref. No. 00120/12/2003) via Amsterdam, Netherlands.

(2) Introduction in 2005

The fruits collected in Sentani were treated physically for germination according to the procedure of Ehara *et al*. (1998, 2001). The seed coat tissues (pericarp and sarcotesta) of the fruits were removed and sowed (soaked) in 100 mL water per seed. The soaking seeds were kept in a dark air-conditioned room at 30˚C, and the water was renewed every day. The germinated seeds were planted in plastic pots filled with vermiculite and water, and 20 of the young seedlings were transported to Tanzania by air as hand-carried materials on 7 March 2005 (11 days after sowing; there was variation in days until germination) (Plant Importation Permit: Ref. No. 0164/03/2005) via Zurich, Switzerland.

2. Cultivation in pots

All the materials were accepted at the Department

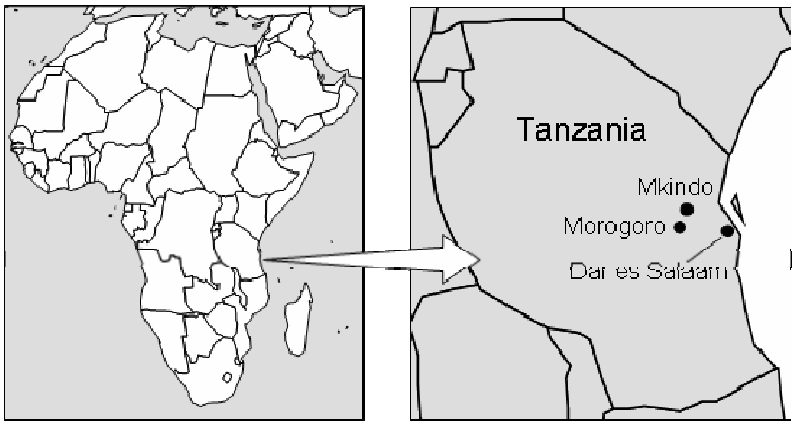

Fig. 1. Introduction site in Tanzania.

Table 1. Daily maximum and minimum air temperature, solar radiation, precipitation and evaporation for the 2003-04 growing season in Morogoro, Tanzania.

	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.	Sept.	Oct.	Nov.	Mean
Max. Temp. (°C)	34.4	32.9	31.2	31.2	29.7	29.1	26.7	28.4	29.3	30.7	30.7	32.5	30.6
Min. Temp. (°C)	21.4	22.2	21.6	21.7	20.9	17.4	16.4	15.4	16.5	17.7	19.6	20.9	19.3
Radiation (MJ/m^2)	21.5	20.1	19.3	19.0	16.1	15.8	15.8	17.0	15.9	12.9	19.5	20.5	17.8
Precipitation (mm)	52.2	157	120	187	219	12.9	2.6	4.2	2.6	2.5	49.7	58.7	72.4
Evaporation (mm)	8.1	6.3	5.2	4.7	3.4	3.5	3.5	4.1	5.0	5.6	6.2	6.5	5.2

Table 2. Soil properties in the experimental field at SUA.

Parameter	Site A	Site B	Site C
pH (H_2O)	7.01	6.93	6.50
pH (KCl)	5.60	5.67	5.26
Total N (g/kg)	1.50	2.40	1.50
Organic C (%)	1.39	1.86	1.71
Olsen P (mg/kg)	16.5	3.60	4.70
Exchangeable Ca ($cmol_c$/kg)	6.03	7.02	5.58
Exchangeable Mg ($cmol_c$/kg)	4.14	4.53	4.02
Exchangeable K ($cmol_c$/kg)	2.66	2.66	1.53
Exchangeable Na ($cmol_c$/kg)	0.56	0.59	0.61
CEC ($cmol_c$/kg)	19.8	20.2	15.2

Soil at sites A and B was used for cultivation in pots.
Site C was the planting site located in the Horticulture Unit.

of Crop Science and Production, Faculty of Agriculture, Sokoine University of Agriculture (SUA) in Morogoro, Tanzania (Fig. 1). Weather information for Morogoro is shown in Table 1.

(1) Materials introduced in 2003

a) Seedlings

The three young seedlings introduced into Tanzania in December 2003 were at the 6th leaf stage and were placed under 95% shade in a net house for one day. Then they were transplanted individually into 20 L plastic pots filled with water-saturated soil and placed under 85% shade in a vinyl house. Table 2 shows the properties of the soil used. CAN (calcium, ammonium, nitrate: N = 20%) was applied at a rate of 1.4 g per pot. Initially, these pots had no drainage holes, which resulted in suspended growth 2 or 3 months after transplantation; thus, the pots were drilled at the bottom to allow for water drainage. Top dressing was applied irregularly according to changes in leaflet color.

Tables 3 and 4 show the size of a sago palm plant grown in a pot for 15 months (data collected on 10 March 2005). The plant height was 157.0 cm, and the SPAD value indicating the chlorophyll concentration of each leaflet was 66.6. This plant had about 12 fully expanded leaves for about 15 months (14 leaves appeared for 15 months), considering the number of leaflets of each leaf on the observation date. According to Flach (1997), sago palms carry approximately 24 leaves or fronds (perhaps at the bole formation stage and/or the inflorescence stage), and each month one new frond appears out of the growing point when the oldest one dies. Flach stated that the average number of leaves formed per month at the rosette stage is two; however, our findings in other experiments indicate that the number may be nearly one to less than two. The rate of leaf emergence was 0.9 leaf per month in the current observation. Considering the growth cycle of sago palm (Flach 1997), the growth process, especially the plant height, of the sago palm in a pot at SUA seemed to be good.

Table 3. Number of leaflets at different leaf positions of sago palms introduced in 2003 (Morogoro, 10 March 2005).

Plant introduced as seedling			Plants introduced as fruits	
Sample leaf position[1)]	Leaflet number (remark)		Leaf position	Leaflet number[2)]
1st (7)	9		4th	2.0 ± 0
2nd(8)	10	(Dead)	5th	2.5 ± 1.1
3rd (9)	11		6th	4.3 ± 2.0
4th (10)	14		7th	7.6 ± 1.8
5th (11)	16		8th	10.5 ± 2.2
6th (12)	18		9th	13.8 ± 2.5
7th (13)	22		10th	16.3 ± 2.3
8th (14)	24		11th	19.1 ± 1.9
9th (15)	27		12th	21.7 ± 1.9
10th (16)	29		13th	23.0 ± 2.0
11th (17)	31		14th	24.5 ± 2.1
12th (18)	34	(Expanded)		
13th (19)	41	(Expanding)		
14th (20)		(Emerging)		

1) The positions of sample leaves were from the bottom. Numerals in the parentheses indicate estimated leaf position.
2) Mean values with S.D. of eight plants.

Table 4. Plant size of sago palms introduced in 2003 (Morogoro, 10 March 2005).

Parameter	Plant introduced as seedling	Plants introduced as fruits
Plant height (cm)	157.0	99.5 ± 10.7
Plant length (cm)	165.5	110.8 ± 10.1
SPAD	66.6	65.7 ± 4.4

Data of plants introduced as fruits are mean values with S.D. of eight plants.

b) Fruits

The size of fruits introduced into Tanzania in December 2003 was 36.71 – 42.34 mm in longer equatorial diameter, 34.64 – 40.52 mm in shorter equatorial diameter, 38.42 – 46.19 mm in polar length and 23.2 – 34.1 g in fresh weight. The fruits were treated physically for germination following the above-mentioned procedure for 3 months from the day after introduction (Fig. 2). Seed size was 21.66 – 27.23 mm in longer equatorial diameter, 20.48 – 26.61

Fig. 2. Seed preparation for germination test. The seed coat tissues (pericarp and sarcotesta) were removed from the fruits introduced on 11 December 2003.

mm in shorter equatorial diameter, 15.64 – 23.08 mm in polar length and 5.3 – 13.1 g in fresh weight.

Germination was observed from 3 days after sowing in water and the number of germinated seeds was 2, 2 and 1 after the 4, 5 and 6 days, respectively. However, after that, germination was not observed until 20 February 2004, and the germinated seeds stopped growing during the incubation period. The ungerminated seeds were left in a basin containing muddy slurry for further observation. Five seeds had germinated by 20 April, another one by 28 April, another by 1 May and another by 25 May 2004, with respective germination periods of 138, 146, 149 and 173 days. The germinated seeds were planted individually in small plastic pots (200 mL) that had small drainage holes in the bottom. Cocas growth media (seed coat tissues of coco palm broken into small pieces) were used as the culture media, and water was supplied every day. The eight seedlings were cultivated under 95% shade in a net house until the 5th leaf stage (three leaves that had expanded leaflets) and then were transplanted, each in a 20 L plastic pot (Fig. 3). The transplant dates were 16 July to 8 September 2004. The cultivation and placement of these eight seedlings were done according to the above-mentioned procedure.

Fig. 3. Sago palm introduced into Tanzania on 11 December 2003 and grown for 15 months (right end, 10 March 2005). The other plants were introduced as fruits and germinated at SUA.

The germination percentage was low in the current trial, even in cases in which the seed coat tissues were removed. In the other trial at Mie University using sago palm seeds that were collected at the same time as the seeds introduced into Tanzania, the germination percentage was 88% at 36 days after sowing under the same conditions.

The plant sizes of sago palms grown in pots for 15 months are shown in Tables 3 and 4 (data collected on 10 March 2005). The average plant height was 99.5 cm, and the average SPAD value was 65.7. There was a large variation in the number of days before germination among these plants. The uppermost expanded leaf was the 12th to 14th. The plant that germinated earlier expanded 14 leaves for about 10 months and 3 weeks considering the number of leaflets of each leaf attached on the observation date (16 leaves appeared for less than 11 months). The average number of leaves formed per month was 1.5 in these plants. On the other hand, the standard deviation in plant height was 10.7 cm. The growth process of these young plants was considered to be quite good.

(2) Materials introduced in 2005

The 20 young seedlings introduced into Tanzania in March 2005 were transplanted in small plastic pots filled with cocas growth media 2 days after introduction following the above-mentioned procedure

Fig. 4. Sago palm seedlings introduced into Tanzania on 7 March 2005 (photographed on 9 March 2005). The young seedlings were about 2 weeks post-germination and were transplanted individually in a pot with cocas growth media.

Fig. 5. Transplanting of sago palm in the field of SUA (in front of the African Seed Health Center, 10 March 2005). This seedling was introduced into Tanzania on 11 December 2003. The seedling was transplanted individually into a hole 1 m in depth.

(Fig. 4). One seedling was lost during the planting process. The 19 transplanted seedlings were placed under 95% shade in a net house. They were re-transplanted, each in a 20 mL plastic pot, at the 6th leaf stage according to the above-mentioned procedure.

3. Cultivation in field

The plant materials cultivated in pots were re-transplanted in a field after precipitation conditions were considered.

(1) Plants introduced in 2003

The plants that were introduced as seedlings in December 2003 were re-transplanted in a field of the Horticulture Unit, Department of Crop Science and Production (in front of the African Seed Health Center) on 11th March 2005 (Fig. 5). Two of the other eight plants that were introduced as fruits in December 2003 and germinated at SUA were re-transplanted separately in the field of the Horticulture Unit (in front and side of the African Seed Health Center) at the same time (Fig. 6). The remaining six plants were re-transplanted at about 11.5 m intervals in a row in the field of the Horticulture Unit in April 2005 (Fig. 7).

(2) Plants introduced in 2005

The plants that were introduced as young seedlings

Fig. 6. Sago palm germinated at SUA by 20 April 2004 and transplanted in the field (in front of the African Seed Health Center) on 11 March 2005 (photographed on 7 November 2006).

Fig. 7. Sago palms germinated at SUA by 25 May 2004 and transplanted in the field (behind the African Seed Health Center) in April 2005 (photographed on 7 November 2006).

Fig. 8. Sago palms introduced on 7 March 2005 and transplanted in the field of the Crop Museum in May 2006 (photographed on 8 November 2006).

in March 2005 were re-transplanted at about 8 m intervals in a row in the field of the Crop Museum in May 2006 (Fig. 8).

Table 5 shows the growth in the field of the plants introduced in 2003 and 2005 (data collected on 8 November 2006). The height of the largest plant reached over 3 m, and that of the other plants introduced in 2003 was about 2 m. Plant heights varied, which was attributed to the difference in days before germination or damage from insects. The petioles or leaf sheaths of a few plants were damaged by rhinoceros beetles (*Oryctes* spp.), but the damage did not appear to be serious. There was a variation in the number of suckers, which may suggest the necessity of sucker control to promote earlier trunk formation.

All the sago palms introduced into Tanzania in 2003 and 2005 were the spiny type. The other germinated seeds were introduced in August 2006 from Jayapura, Indonesia. Some spiny palm seeds were provided by Dr. Nadirman Haska, Director of the Technology Center for the Assessment and Application of Biotechnology, Agency for the Assessment and Application of Technology (BPPT), Indonesia, at the 8th International Sago Symposium held in Jayapura, Indonesia on 4-6 August 2005. Some of these seeds had already germinated when the materials were introduced into Tazania. Sizes and other characteristics of these plants are given in Table 5. The plants were transplanted into the experimental field of the Department of Crop Science and Production on 9 November 2006. We introduced not only the spiny type but also the spineless type into Tanzania in 2006. However, because there was a different donor, information on the spineless type will be reported separately. In any case, sago palms have shown satisfactory growth since their introduction in the experimental field of SUA in Morogoro, Tazania. Thirty-nine sago palms grow on the African continent at the present time, and another 18 seedlings are awaiting transplantation in a vinyl house at SUA. We expect bole formation to begin in the first introduced palms next year at the earliest.

Table 5. Plant size of sago palms grown in the field at SUA (Morogoro, 8 November 2006).

Sample[1)]	Plant height (cm)	Canopy width (cm)	Green leaf number[2)]	Dead leaf number	Sucker number	Transplanting in field
A	210	290	16	3	4	Mar. 2005
B1	335	270	18	1	2	Mar. 2005
B2	239	280	11	3	6	Mar. 2005
C	188.3 ± 32.8	208.3 ± 49.7	12.3 ± 1.4	5.5 ± 1.8	0.8 ± 1.3	Apr. 2005
D	121.1 ± 20.1	149.3 ± 27.9	8.8 ± 1.8	1.6 ± 0.8	0.6 ± 0.8	May 2006
E	131.6 ± 8.7	116.0 ± 8.0	11.8 ± 1.0	1.3 ± 1.3	0.5 ± 0.7	Nov. 2006

1) A: Plant introduced as seedling in December 2003 (transplanted in front of the African Seed Health Center; 6°50.891′S, 37°39.487′E)
B: Plants introduced as fruits in December 2003 (transplanted in front and side of the African Seed Health Center)
C: Plants introduced as fruits in December 2003 (transplanted behind the African Seed Health Center)
D: Plants introduced as young seedlings in March 2005 (transplanted in the Crop Museum)
E: Plants introduced as germinated seeds in August 2005 (transplanted in the experimental field of the Department of Crop Science and Production)
2) Number of green leaves including unexpanded and expanding leaves
Data of C, D and E are mean values with S.D. of 6, 19 and 11 plants, respectively.
Data of plant height of E were collected one day before transplantation in the field.

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