Further Potential of Sago Palm and Sago Starch in Shaping the Future of the Asia-Pacific Region

Hiroshi Ehara

Director, International Center for Research and Education in Agriculture,
Nagoya University, Japan
Professor, Graduate School of Bioagricultural Sciences, Nagoya University, Japan

Dr. Hiroshi Ehara is the Director of the International Center for Research and Education in Agriculture at Nagoya University. He studied as a visiting scientist in the Palm Room, Herbarium, at the Royal Botanic Gardens, Kew, under the Royal Society – Japan Society for the Promotion of Science (JSPS) fellowship from 1999 to 2000. From 2011 to 2015, he contributed to Mie University as the Vice President for International Affairs. In 2008, he received the Academic Award from the Japanese Society for Tropical Agriculture (JSTA) for his ecophysiological and phylogenetic studies on the sago palm. He was elected President of the Society of Sago Palm Studies in 2016 and Vice President of the JSTA in 2020.

Abstracts

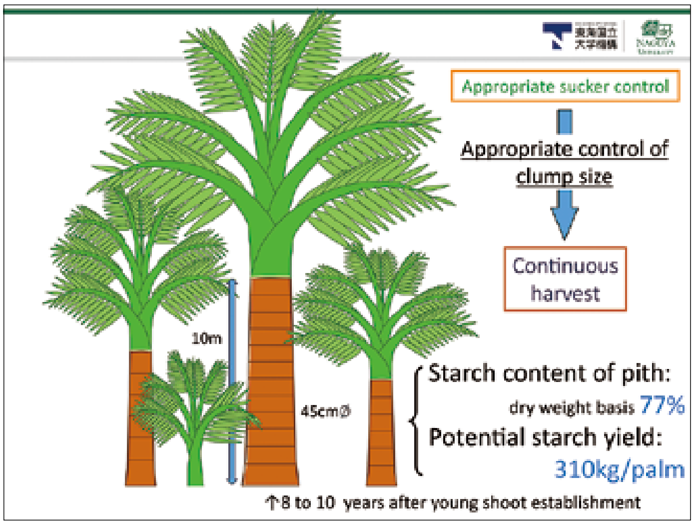
The sago palm (*Metroxylon sagu*), a starch-producing plant found across Southeast Asia and Melanesia that thrives in challenging environments, is not only a food source but is also gaining attention as a raw material for allergen-free foods, biofuels, and other industrial applications. Recently, the demand for sago palm has been increasing, driven by the new societal norms emerging after the COVID-19 pandemic and by Sustainable Development Goals (SDGs). This growing demand for sago palm and sago starch is set against a backdrop of environmental degradation due to climate change, unexpected social issues, and an urgent need to bolster food security and the resilience of food systems. Another contributing factor is the increasing global desire to promote a healthy life.

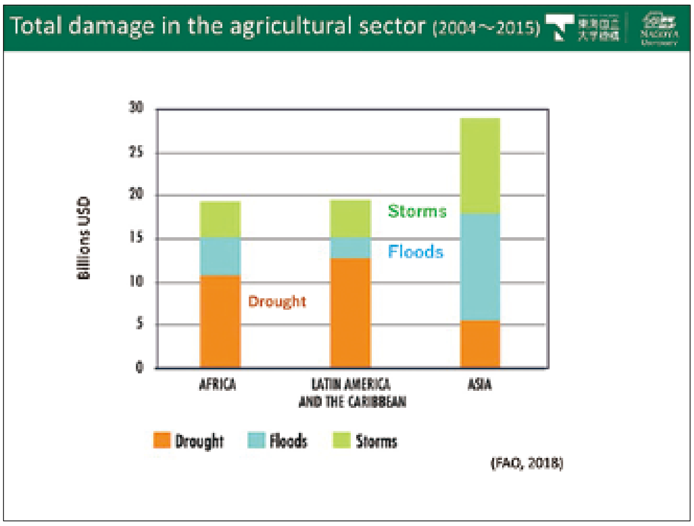
Metroxylon palms, including the sago palm and related species, grow in swamps, as well as on alluvial and peat soils, where few other major crops can thrive without drainage and soil improvement. These palms are essential biological resources for promoting sustainable agriculture and rural development in tropical wetlands. The potential habitat range for *Metroxylon* palms is likely to expand over the next 45 years as a result of climate change[1]. *Metroxylon* palms, such as the sago palm, are considered underutilized, as they are mainly harvested from natural forests and semi-cultivated with minimal care. Given the social context of the past two decades, characterized by rising competition between biofuel and food production as well as diversifying food demands, there is increasing interest in the efficient utilization of carbohydrates from sago palm and related species, which could drive further land development and greater use of wetland areas. Against this background, the FAO Technical Cooperation Program, "Enhancing Food Security and Combating Climate Change through Scaling Up Sago Palm Production," was conducted in Papua New Guinea from 2022 to 2024[2].

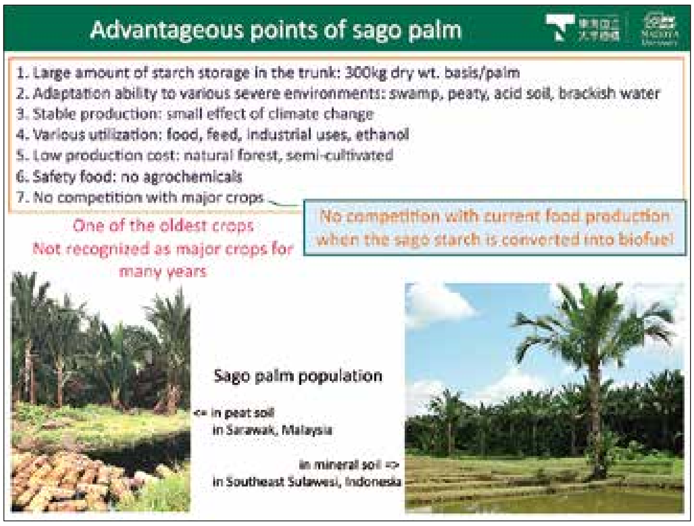
This presentation will showcase recent activities and initiatives based on interdisciplinary thinking and multidisciplinary approaches aimed at advancing the SDGs through collaboration between sago palm-producing countries and Japan, one of the world's largest consumers of sago starch. Highlights include developments in tolerance to various environmental stresses, such as submergence, salt stress, and acidic soils; innovative approaches to using beneficial microorganisms for sustainable plant nutrition management; and emerging trends in utilizing sago starch to promote health and well-being. The goal is to inspire consideration of the further potential of sago palm and sago starch in shaping the future of the Asia-Pacific region.

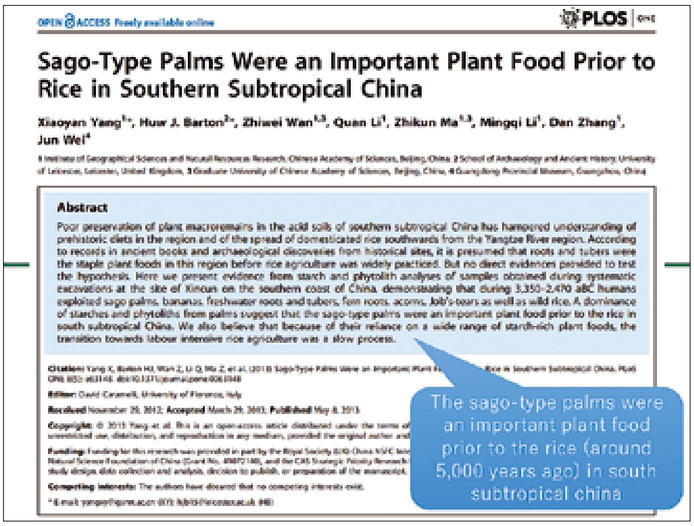
[1] Itaya, A., M. Masamitsu, H. Ehara, H. Naito, I. Rounds, A. Naikatini and M. Tuiwawa. *Tropical Ecology* 63, 596-603 (2022).

[2] Toyoda, Y., H. Ehara, H. Naito, T. Mishima and K. Galgal. *Proceedings of the 14th International Sago Symposium*, The Society of Sago Palm Studies (Tokyo), 33-36 (2023).







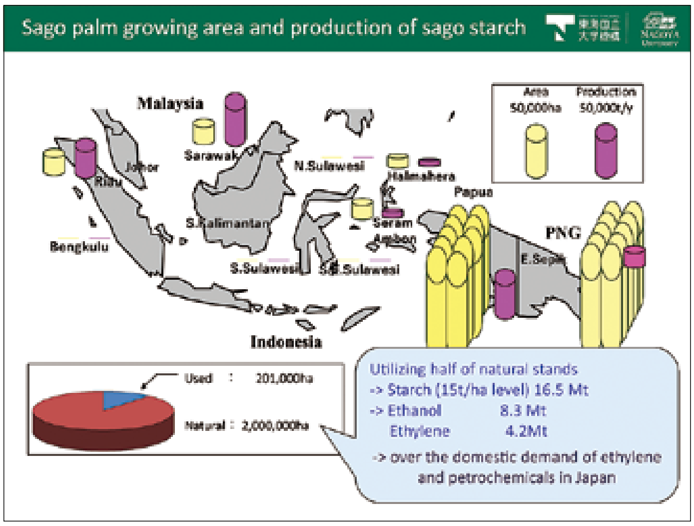

OPEN ACCESS Freely available online
PLOS ONE

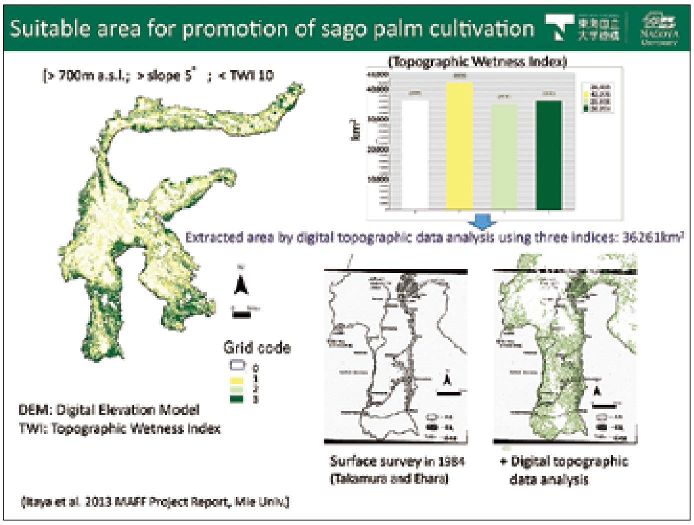
Sago-Type Palms Were an Important Plant Food Prior to Rice in Southern Subtropical China

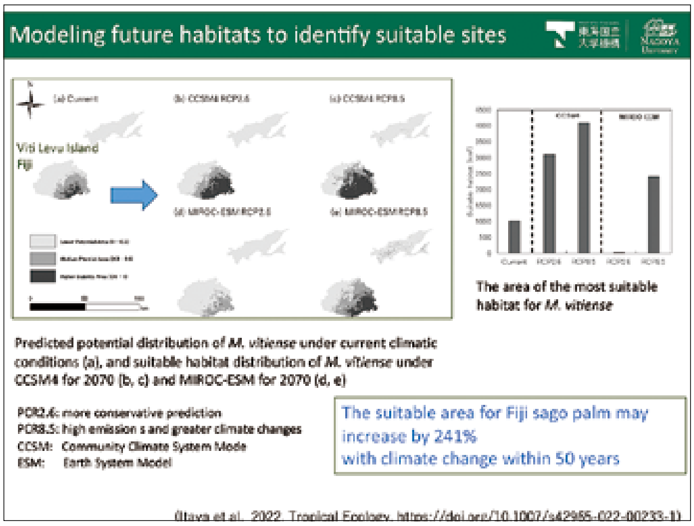
Xiaoyan Yang[1*], Huw J. Barton[2*], Zhiwei Wan[1,3], Quan Li[1], Zhikun Ma[1,3], Mingqi Li[1], Dan Zhang[1], Jun Wei[4]

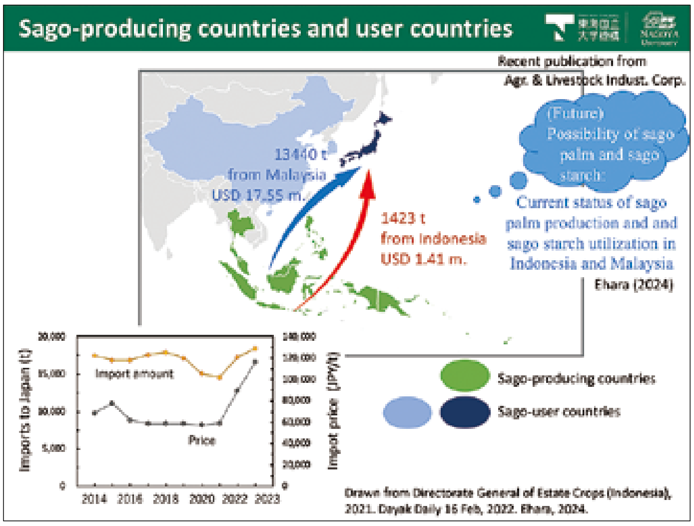
Abstract

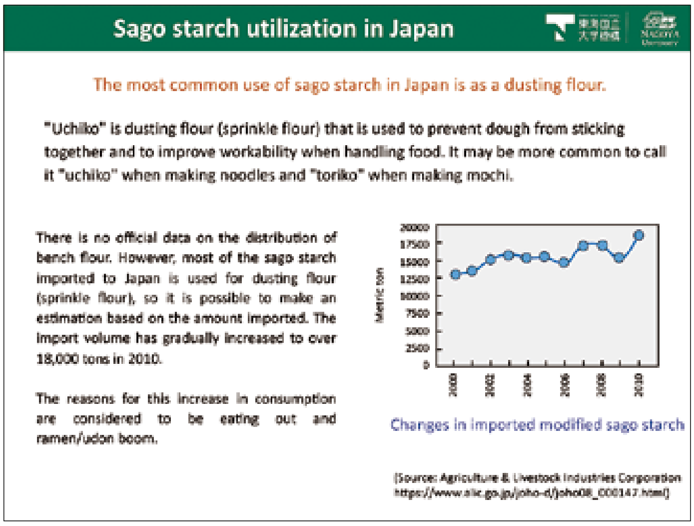
Poor preservation of plant macroremains in the acid soils of southern subtropical China has hampered understanding of prehistoric diets in the region and of the spread of domesticated rice southwards from the Yangtze River region. According to records in ancient books and archaeological discoveries from historical sites, it is presumed that roots and tubers were the staple plant foods in this region before rice agriculture was widely practiced. But no direct evidences provided to test the hypothesis. Here we present evidence from starch and phytolith analyses of samples obtained during systematic excavations at the site of Xincun on the southern coast of China, demonstrating that during 3,350–2,470 aBC humans exploited sago palms, bananas, freshwater roots and tubers, fern roots, acorns, Job's-tears as well as wild rice. A dominance of starches and phytoliths from palms suggest that the sago-type palms were an important plant food prior to the rice in south subtropical China. We also believe that because of their reliance on a wide range of starch-rich plant foods, the transition towards labour intensive rice agriculture was a slow process.

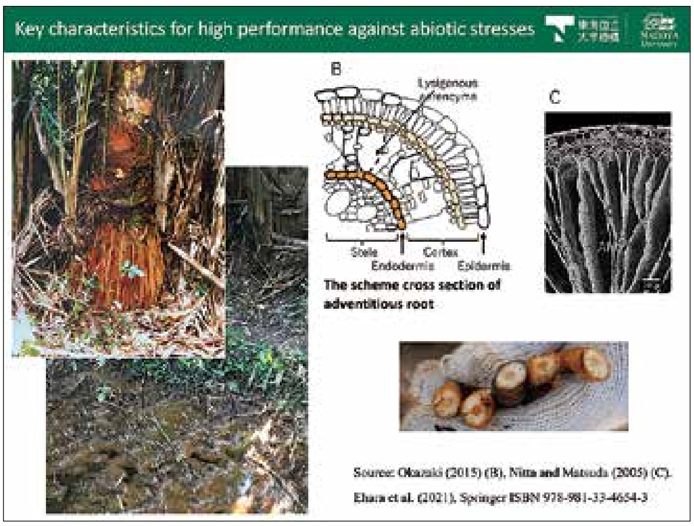


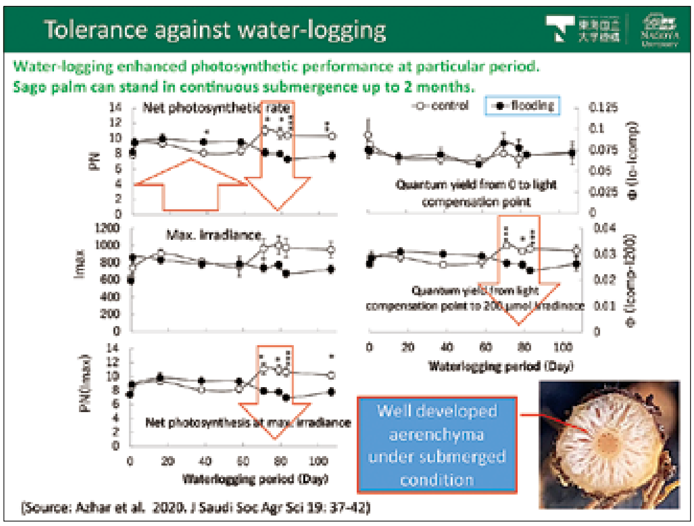

Suitable area for promotion of sago palm cultivation
[> 700m a.s.l.; > slope 5° ; < TWI 10
(Topographic Wetness Index)
km²
Extracted area by digital topographic data analysis using three indices: 36261km²
Grid code
DEM: Digital Elevation Model
TWI: Topographic Wetness Index
Surface survey in 1984 (Takamura and Ehara)
+ Digital topographic data analysis
(Itaya et al. 2013 MAFF Project Report, Mie Univ.)

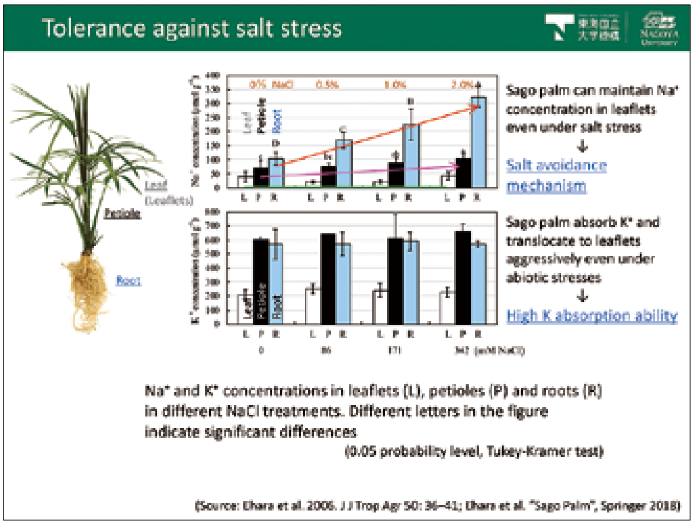

Modeling future habitats to identify suitable sites
Viti Levu Island
Fiji
The area of the most suitable habitat for M. vitiense
Predicted potential distribution of M. vitiense under current climatic conditions (a), and suitable habitat distribution of M. vitiense under CCSM4 for 2070 (b, c) and MIROC-ESM for 2070 (d, e)
PCR2.6: more conservative prediction
PCR8.5: high emission s and greater climate changes
CCSM: Community Climate System Mode
ESM: Earth System Model
The suitable area for Fiji sago palm may increase by 241% with climate change within 50 years
(Itaya et al., 2022, Tropical Ecology, https://doi.org/10.1007/s42965-022-00233-1)

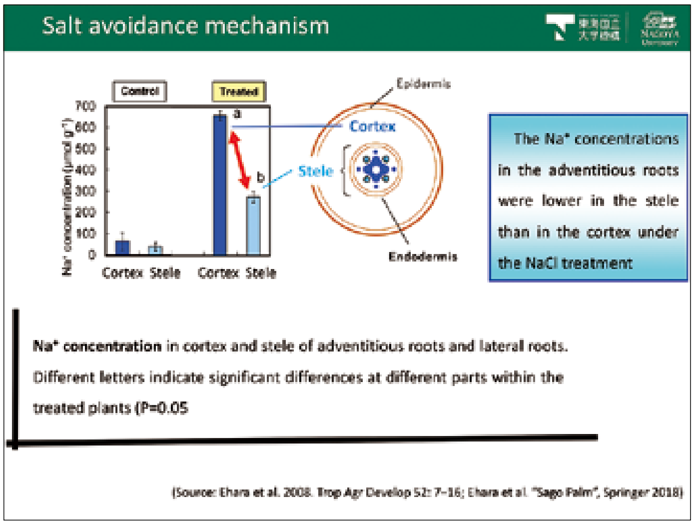

Sago-producing countries and user countries
Recent publication from Agr. & Livestock Indust. Corp.
(Future) Possibility of sago palm and sago starch
13440 t from Malaysia USD 17.55 m.
1423 t from Indonesia USD 1.41 m.
Current status of sago palm production and and sago starch utilization in Indonesia and Malaysia
Ehara (2024)
Import amount
Price
Imports to Japan (t)
Impot price (JPY/t)
2014 2016 2018 2020 2022 2023
Sago-producing countries
Sago-user countries
Drawn from Directorate General of Estate Crops (Indonesia), 2021. Dayak Daily 16 Feb, 2022. Ehara, 2024.

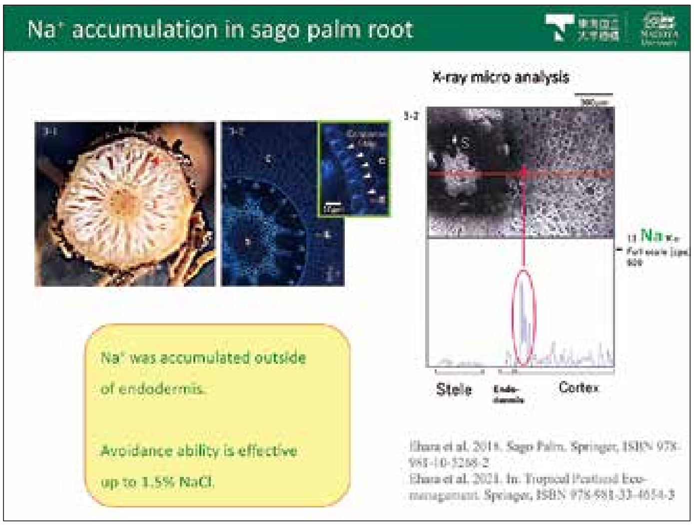

Sago starch utilization in Japan
The most common use of sago starch in Japan is as a dusting flour.
"Uchiko" is dusting flour (sprinkle flour) that is used to prevent dough from sticking together and to improve workability when handling food. It may be more common to call it "uchiko" when making noodles and "toriko" when making mochi.
There is no official data on the distribution of bench flour. However, most of the sago starch imported to Japan is used for dusting flour (sprinkle flour), so it is possible to make an estimation based on the amount imported. The import volume has gradually increased to over 18,000 tons in 2010.
The reasons for this increase in consumption are considered to be eating out and ramen/udon boom.
Metric ton
Changes in imported modified sago starch
(Source: Agriculture & Livestock Industries Corporation https://www.alic.go.jp/joho-d/joho08_000147.html)

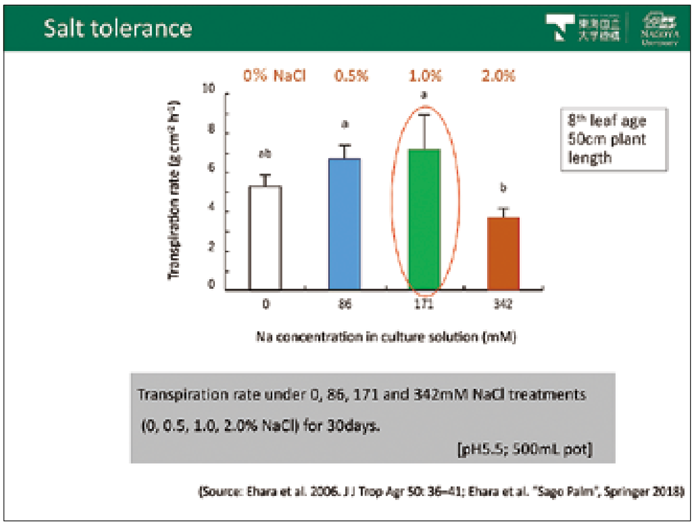

Key characteristics for high performance against abiotic stresses
B
C
Lysigenous aerenchyma
Stele
Endodermis
Cortex
Epidermis
The scheme cross section of adventitious root
Source: Okazaki (2015) (B), Nitta and Matsuda (2005) (C).
Ehara et al. (2021), Springer ISBN 978-981-33-4654-3

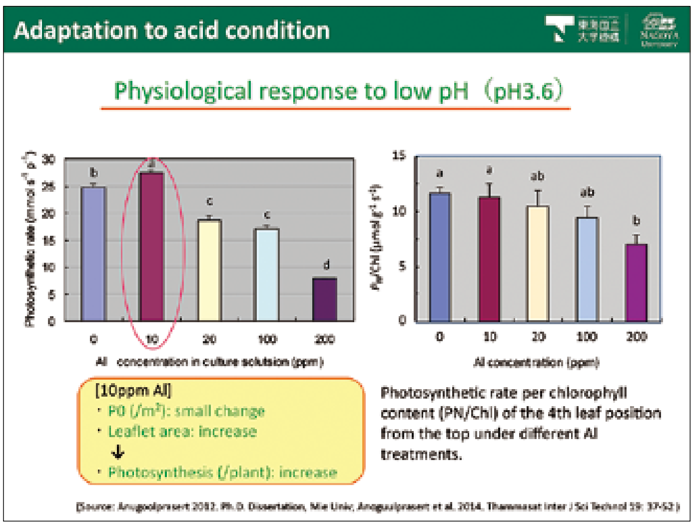

Tolerance against water-logging
Water-logging enhanced photosynthetic performance at particular period.
Sago palm can stand in continuous submergence up to 2 months.
Net photosynthetic rate
control
flooding
Quantum yield from 0 to light compensation point
Max. Irradiance
Quantum yield from light compensation point to 200 μmol irradiance
Net photosynthesis at max. irradiance
Waterlogging period (Day)
Well developed aerenchyma under submerged condition
(Source: Azhar et al. 2020. J Saudi Soc Agr Sci 19: 37-42)


Tolerance against salt stress
0% NaCl
0.5%
1.0%
2.0%
Leaf (Leaflets)
Petiole
Root
Sago palm can maintain Na⁺ concentration in leaflets even under salt stress
↓
Salt avoidance mechanism
Sago palm absorb K⁺ and translocate to leaflets aggressively even under abiotic stresses
↓
High K absorption ability
Na⁺ and K⁺ concentrations in leaflets (L), petioles (P) and roots (R) in different NaCl treatments. Different letters in the figure indicate significant differences
(0.05 probability level, Tukey-Kramer test)
(Source: Ehara et al. 2006. J J Trop Agr 50: 36–41; Ehara et al. "Sago Palm", Springer 2018)


Salt avoidance mechanism
Control
Treated
Epidermis
Cortex
Stele
Endodermis
Na⁺ concentration (μmol g⁻¹)
Cortex Stele Cortex Stele
The Na⁺ concentrations in the adventitious roots were lower in the stele than in the cortex under the NaCl treatment
Na⁺ concentration in cortex and stele of adventitious roots and lateral roots. Different letters indicate significant differences at different parts within the treated plants (P=0.05
(Source: Ehara et al. 2008. Trop Agr Develop 52: 7–16; Ehara et al. "Sago Palm", Springer 2018)


Na⁺ accumulation in sago palm root
X-ray micro analysis
Na
Stele
Endodermis
Cortex
Na⁺ was accumulated outside of endodermis.
Avoidance ability is effective up to 1.5% NaCl.
Ehara et al. 2018. Sago Palm. Springer, ISBN 978-981-10-5268-2
Ehara et al. 2021. In: Tropical Peatland Eco-management. Springer, ISBN 978-981-33-4654-3


Salt tolerance
0% NaCl
0.5%
1.0%
2.0%
8th leaf age
50cm plant length
Transpiration rate (g cm⁻² h⁻¹)
Na concentration in culture solution (mM)
Transpiration rate under 0, 86, 171 and 342mM NaCl treatments (0, 0.5, 1.0, 2.0% NaCl) for 30days.
[pH5.5; 500mL pot]
(Source: Ehara et al. 2006. J J Trop Agr 50: 36–41; Ehara et al. "Sago Palm", Springer 2018)


Adaptation to acid condition
Physiological response to low pH (pH3.6)
Photosynthetic rate (mmol s⁻¹ p⁻¹)
Al concentration in culture solution (ppm)
Al concentration (ppm)
[10ppm Al]
・P0 (/m²): small change
・Leaflet area: increase
↓
・Photosynthesis (/plant): increase
Photosynthetic rate per chlorophyll content (PN/Chl) of the 4th leaf position from the top under different Al treatments.
(Source: Anugoolprasert 2012. Ph. D. Dissertation, Mie Univ; Anugoolprasert et al. 2014. Thammasat Inter J Sci Technol 19: 37-52)


Sago palms introduced into Tanzania and growing in the SUA campus

Recent FAO programs and project on sago palm

"Promoting Sago Starch Utilization in Indonesia – Phase I" in Indonesia
TCP/INS/3503 (Phase I)
Nov. 2015 – Dec. 2017

"Promoting Sago Starch Utilization in Indonesia - Phase II" in Indonesia
TCP/INS/3701 (Phase II)
July 2018 – March 2019

The project was expected to contribute to food diversification and food security in Sulawesi island of Indonesia, through capacity building designed to improve the production, utilization and marketing of sago starch and its downstream processed products as alternative carbohydrates sources.

"Enhancing food security and combating climate change through scaling up sago palm production" in Papua New Guinea
TCP/PNG/3901 (Feb. 2022 – Feb. 2024)

"Capacity building of smallholders on improved sago processing and value chains in Jayapura, Papua Province" in Indonesia (Feb. 2024 -)

Function of sago starch

Intestinal retention :

Resistant starch:
Preferable for diet control

"Chrononutrition study of sago pancakes"
Furutani, A. 2022 Sago Palm 29 (2): 75.
The dominant inhibitory effect of sago starch on elevated blood glucose levels was confirmed. This may be due too the size of the starch particles.

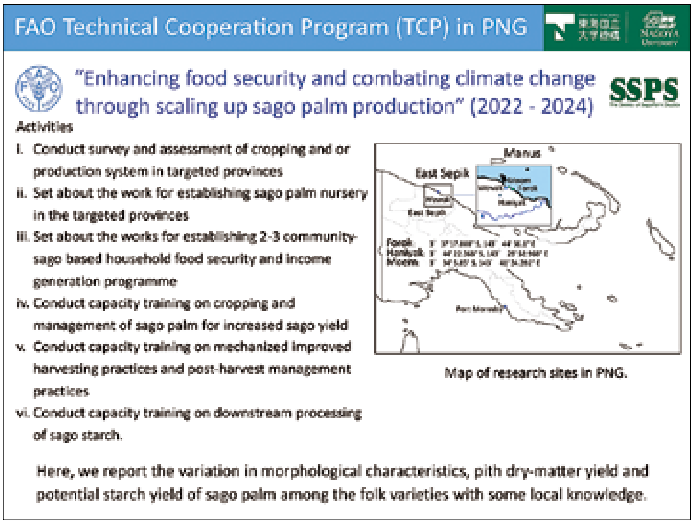
Allergen free :

JAL In-flight Minimal Allergen Meal
(https://www.jal.co.jp/en/inter/service/meal/special/menu/common/pdf/en_pyy_flight_to_japan.pdf)

ANA In-flight Allergen-Free Meal
(https://www.ana.co.jp/www2/pdf/travel-informtion/meals/atml_en_2209.pdf)

Prevention of accidental ingestion :

Adhesion: Does not stick to the inside of the throat
Condensation: Ease of mixing
→ Swallowing support
(http://tender-hearts.jp/kaigoshoku.html)


FAO Technical Cooperation Program (TCP) in PNG
"Enhancing food security and combating climate change through scaling up sago palm production" (2022 - 2024)
SSPS
Activities
i. Conduct survey and assessment of cropping and or production system in targeted provinces
ii. Set about the work for establishing sago palm nursery in the targeted provinces
iii. Set about the works for establishing 2-3 community-sago based household food security and income generation programme
iv. Conduct capacity training on cropping and management of sago palm for increased sago yield
v. Conduct capacity training on mechanized improved harvesting practices and post-harvest management practices
vi. Conduct capacity training on downstream processing of sago starch.
Manus
East Sepik
Map of research sites in PNG.
Here, we report the variation in morphological characteristics, pith dry-matter yield and potential starch yield of sago palm among the folk varieties with some local knowledge.


TCP PNG Interim results report event (May 2023)
SSPS
FAO Agribusiness Advisor
FAO PNG Representative
with Acting Secretary, DAL PNG
Rasping machine introduction
Sago Nursery
EHARA SAGO NURSERY


FAO TCP Workshop in PNG (Oct 2022)
SSPS
Demonstration
Weighing fruits to know the possible ones with germinability
Scarification (Removal part of seed coat tissues)
Seed preparation
Fruits selection
↓
Cleaning
↓
Scarification
Nursery
Germinated and growing Seedlings
Seeding


First transplanting utilizing seedlings germinated from seeds in PNG
SSPS
Transplanted seedling at the new opened field in Moem.
A stick was placed next to the seedling as a marker


Technology Catalog Contributing to Production Potential and Sustainability in the Asia-Monsoon Region
Green Asia
Ver. 3.0 is available.
Technology Catalog Contributing to Production Potential and Sustainability in the Asia-Monsoon Region
Ver. 2.0
Ver. 3.0
Removing seed coat tissues improves the germination rate, enabling seedling propagation to achieve the planned management of sago palms
https://www.jircas.go.jp/en/greenasia/techcatalog


ICREA
Sago Palm Studies
Sago Seed Germination
URL:
https://icrea95.wixsite.com/lab/sago-palm-studies


Published Sago Palm books
Sago Palm
Ehara, H., Toyoda, H. and Johnson, D. V. (eds.) (2018). Sago Palm: Multiple Contributions to Food Security and Sustainable Livelihoods. Springer, pp330. ISBN 978-981-10-5268-2 ISBN 978-981-10-5268-2 (eBook).
Tropical Peatland Eco-management
Sagu
Bintoro, H. M. H., Ehara, H., Azhar, A., Dewi, R. K., Nurulhaq, M. I., Ahyuni, D. (2021). Ekofisiologi Sagu. IPB Press, pp167. ISBN 978-623-256-832-7
Ehara, H. et al. (2021). Sago palm in peatland. In: Osaki, M. et al. eds., Tropical Peatland Eco-management. Springer, p477-507. ISBN 978-981-33-4654-3 (ISBN 978-981-33-4655-0)
The Sago Palm
The Society of Sago Palm Studies; Yamamoto, Y., Ehara, H. et al. eds. (2015). The Sago Palm. The Food and Environmental Challenges of the 21st Century. Kyoto University Press (Kyoto) and Trans Pacific Press (Melbourne), pp450. ISBN 978-4-876983-35-3