International Journal of Agriculture and Plant Science
www.agriculturejournal.in
Online ISSN: 2664-7664, Print ISSN: 2664-7656
Received: 11-10-2024, Accepted: 10-11-2024, Published: 25-11-2024
Volume 6, Issue 4, 2024, Page No. 14-17

Morphologies, frond nutrients, and soil chemical properties in sago palm (*Metroxylon sagu* Rottb.) cultivated on peat at before and after trunk formation

Dian Safitri, Albertus Fajar Irawan*, Bagus Herwibawa
Department of Agricultural Science, Faculty of Animal and Agricultural Sciences, Universitas Diponegoro, Tembalang, Indonesia

Abstract
Sago palm requires around 5-6 years to attain trunk formation stage on peat. The transition from rosette to trunk formation stage may provide distinct description of how change of soil chemical properties around the growing sites and frond nutrient status. However, studies related to those matters are still limited. In this paper, changes in soil chemical characteristics, morphology, and frond nutrient status of sago palm before and post trunk formation were investigated. The findings revealed no significant changes in soil chemical properties and concentrations of macro- (N, P, K, Ca, and Mg) and some micronutrients (B and Cu) in frond. The insignificant changes of macronutrients between the palms at two development stages indicated that transition of development stage did not influence soil fertility at the growing sites. The concentrations of other micronutrients (Fe and Zn) in sago palm fronds were lower at before trunk formation stage than those at post trunk formation, highlighting the importance of these micronutrient uptake for trunk development. The number of fronds and suckers generated increased as the palm growth accelerated. Sago palm on deep peat produced averagely 7.37 and 8.00 fronds at before and post trunk formation, respectively. The trunk diameter was around 38 cm. Further studies should focus on monitoring of soil chemical properties and palm growth and development with the presence and absence of harvested palms on the cluster.

Keywords: Sago, soil and frond nutrition status, transition of development stage

Introduction

Sago palm is a crucial crop in tropical regions, particularly in Southeast Asia, where it serves as a significant source of starch and livelihood for local communities (Konuma, 2018) [13]. It is a vital resource in many rural communities across Southeast Asia (Kimura and Sasaki, 2022) [11]. The cultivation of sago palms has gained attention due to their adaptability to wetland conditions (Monda *et al*., 2022, Irawan *et al*., 2024a, 2024b) [7, 8, 16] and their roles in food security. However, the growth and productivity of sago palms are influenced by various environmental factors, particularly soil characteristics and regional-based varieties (Yamamoto *et al*., 2003) [21]. Soil chemistry, including pH, nutrient availability, and organic matter content, plays a crucial role in determining plant health and productivity (Khaled and Sayed, 2023) [12].

The trunk formation stage in sago palm is a vital stage in its life cycle, taking place between the ages of 5 or 6 years after transplanting (Jong, 1995) [9]. This transition signifies a change from vegetative growth to reproductive maturity, during which the plant distributes resources differently. Trunk development causes major changes in the plant's nutrient intake and growth patterns. Studies have shown that the accumulation of carbohydrates increases significantly following the palm maturity. The maximum starch is attained when the palm is at flower initiation stage or at harvestable stage (Pei-Lang *et al*., 2006; Achudan *et al*., 2020) [1, 17].

The status of soil chemical properties is essential as they directly affect the palm’s ability to establish a robust trunk. The trunk serves as the primary support structure and as sink for starch accumulation, and its development is influenced by the availability of essential nutrients. A deficiency in potassium can lead to weaker trunk formation since potassium is vital for cell wall strength, plant vigour (Marschner, 2012) [14], carbohydrate metabolism in plants (Gao *et al*., 2021; Ju *et al*., 2021; Šustr *et al*., 2024) [5, 19], and its main role in regulating the opening and closing of stomata (Blatt, 2016) [3]. By analysing the soil before and post trunk formation, it may help understand changes in chemical properties which may correlate with trunk growth. Soil chemical properties such as pH, organic matter content, and nutrient levels are critical for optimal sago palm cultivation. Soil pH has a substantial impact on nutrient availability, particularly macronutrients like nitrogen, phosphorus, and potassium, which are required for sago palm growth. As growth and development of sago palms progresses, their nutritional requirements change, demanding a thorough study of the soil chemical properties both before and after trunk formation. Investigating these changes can help enhance fertilization strategy and increase crop productivity.

The purpose of this study was to investigate changes in soil chemical properties, morphology, and leaf nutrient status in sago palm before and post trunk formation. By examining these parameters, insights into the best circumstances for sago palm cultivation may help establish appropriate agronomic management to ensure the crop's long-term viability.

Materials and Methods

Site of study

The study was conducted in a sago palm plantation located in Tebing Tinggi Island, Riau Province, Indonesia where sago palms are extensively cultivated. The soil in this island was predominantly deep peat soil. The peat depth was estimated to be >5 m. Total number of palms used was 60 palms. Thirty palms were before trunk formation and the others were at after trunk formation. There is no harvested palm yet on cluster in which the palms were measured.

Palms at the stages of before and trunk formation were estimated to be around 54 and 84 months after transplanting, respectively.

Soil sampling

Soil samples were collected from the palm growing site in both development stages. A total of 24 collected soil samples, which were divided into 12 samples on each stage, were distributed from two different soil layers, 0-30 cm and 31-60 cm. Soil pH, C-organic, and N-total, available P, CEC, Exch. Cations of Ca, Mg, K, and Na, base saturation, Exch. H, and available micronutrients of Cu, Fe, Zn, and B were analysed.

Morphological characteristics and frond nutrient analysis

In parallel, number of fronds, trunk height, trunk diameter and number of suckers with estimated weight of 5-10 kg and >10 kg were recorded to examine the morphological changes that occurred throughout trunk development. The trunk diameter was measured using tape diameter at breast height or around 1.3 m above soil surface.

Macro- (N, P, K, Ca, and Mg) and micronutrients (Fe, Mn, Zn, and Cu) from the leaflet grown from middle frond position were analysed. To determine nutrient contents, the leaflet was ground and oven-dried at 80ºC for 48 hours. The nutrients were analysed using atomic absorption spectrophotometry (Kumar *et al*. 2019).

Statistical analysis

To assess the differences in soil chemical properties and leaf nutritional status between the two growth stages, data obtained from above study were analysed by Two-Sample T Test. Level of significant was set at $p<0.05$.

Results and Discussion

Soil chemical properties are critical indicators of soil health and fertility, influencing plant growth and ecosystem stability. The chemical composition of soil, including pH, organic matter, cation exchange capacity (CEC), and nutrient levels such as nitrogen (N), phosphorus (P), and potassium (K), can vary significantly with depth. Studies have shown that the topsoil typically exhibits higher nutrient concentrations compared to subsoil due to organic matter accumulation from decaying plant materials (Brady and Weil, 2010) [4].

The soil chemical properties at before and after trunk formation at two different soil layers were not significantly different (Table 1). The soil pH remained stable ranging from 3.7 to 3.9. The C-organic and N-total were around 56-57% and 1.08-1.40%. The presence of similar C-organic between two stages may indicate that there is no change of decomposition process taking place on growing sites. Organic matter improves soil structure and water retention, ultimately benefiting plant growth (Ramasamy *et al*., 2024) [18]. A top soil layer contained higher exchangeable Ca than sub soil but the other two exchangeable cations were similar. Available micronutrients were higher in sub soil than top soil.

Table 1: Soil chemical analysis collected at 0-30 dan 31-60 cm at before and post trunk formation

No.	Soil chemical properties	Before trunk formation	Post trunk formation	Stat. diff.	Before trunk formation	Post trunk formation	Stat. diff.
		Soil depth 0-30 cm			Soil depth 31-60 cm		
1.	pH H_2O	3.70	3.70	ns	3.80	3.90	ns
2.	C-organic (%)	56.65	57.01	ns	57.11	57.38	ns
3.	N-total (%)	1.36	1.37	ns	1.40	1.08	ns
4.	Available P (ppm)-Bray	16.57	17.30	ns	17.09	11.95	ns
5.	Exch. Cations (me/100 g) -Ca	13.39	14.04	ns	8.25	6.48	ns
	-Mg	7.67	9.00	ns	9.37	9.54	ns
	-K	0.69	0.69	ns	0.43	0.38	ns
	-Na	1.49	1.98	ns	2.50	2.78	ns
6.	CEC (me/100 g)	136.59	132.66	ns	146.97	131.60	ns
7.	Base saturation	17.14	20.05	ns	14.06	14.62	ns
8.	Exch. H (me/100 g)	3.58	3.75	ns	4.81	4.69	ns
9.	Micronutrients-Available Cu (ppm)	2.65	3.69	ns	5.76	6.51	ns
	-Available Fe (ppm)	0.50	0.39	ns	1.00	0.77	ns
	-Available Zn (ppm)	7.99	8.00	ns	10.74	10.19	ns
	-Available B (ppm)	20.42	18.75	ns	27.50	29.86	ns

Note: ns: not significant by Two-Sample T Test at $p<0.05$.

The initial stage of trunk formation in sago development is critical for establishing a robust trunk structure, which ultimately supports the entire plant. The trunk serves as the main structural support for sago palm and served as sink for starch accumulation. The number of fronds and suckers generated increased as the growth of palms accelerated (Table 2). The insignificant change of soil chemical properties indicates that the soil fertility and status of soil nutrients are not affected by the change of development stages. It is probably that the trunks are not harvested yet, meaning that there is no huge amount of nutrients flowing out from the soil environment where they are growing.

Table 2: Morphology of sago palm before and post trunk formation.

No.	Morphology	Before Trunk Formation	Post Trunk Formation	Stat. Diff.
1	Number of Fronds			
	Max.	11	12	
	Min.	5	6	
	Mean	7.37±	8.00±	ns

2	Trunk Height			
	Max.	-	398	
	Min.	-	120	
	Mean	-	258.57±	
3	Trunk Diameter			
	Max.	-	44.9	
	Min.	-	33.44	
	Mean	-	37.95±	
4	Number of Suckers			
	Est. Size 5-10 kg	1.10±	1.73±	ns
	Est. Size >10 kg	1.20±	1.43±	ns
	Total suckers ≥5 kg	2.30±	3.10±	ns

Note: ns: not significant by Two-Sample T Test at $p<0.05$.

The allocation of nutrients in plant is influenced by the growth stage, environmental conditions, and overall health (McCormack *et al*. 2015) [15]. Once trunk formation took place, the dynamics of nutrient uptake and utilization was supposed to shift, since the palm begins to allocate a greater proportion of resources towards the development of woody tissues, which requires a different balance of nutrients compared to the leaf development stage. Status of nutrients in fronds plays a pivotal role as they are essential for photosynthesis, growth, and overall plant health. According to Hoge *et al*. (2000), the availability of nitrogen (N), phosphorus (P), and potassium (K) in the early leaf development stages significantly influences the biomass accumulation of young seedlings. Specifically, nitrogen is crucial for chlorophyll synthesis, which directly impacts photosynthetic efficiency. A deficiency in nitrogen can lead to stunted growth and poor trunk formation, as evidenced by research conducted on various species. The concentration of macronutrients in fronds were not affected by change of development stage (Table 3). Conversely, concentration of micronutrients especially Fe and Zn exhibited significant changes. Their concentrations were lower after trunk formation, meaning that sago may uptake high amount of these nutrients since they grow before trunk formation. Among micronutrients, Fe and Zn were highly required in sago palm rather than Cu and B (Jong and Flach, 1995; Ando *et al*., 2007) [2, 9]. Fe is essential for plant photosynthesis. Along with Mn, they contribute to the synthesis of enzymes involved in photosynthesis and respiration.

Table 3: Leaf nutrient status at before and post trunk formation

No.	Leaf nutrient	Before trunk formation	Post trunk formation	Stat. diff.
1.	Macronutrients (%) -N	1.59	1.60	ns
	-P	0.26	0.27	ns
	-K	0.45	0.48	ns
	-Ca	0.30	0.29	ns
	-Mg	0.11	0.12	ns
2,	Micronutrients (ppm) -Fe	116.38	89.57	ns
	-Cu	7.35	7.89	ns
	-Zn	25.25	47.13	ns
	-B	61.03	61.98	ns

Note: ns: not significant by Two-Sample T Test at $p<0.05$.

A deficiency in these micronutrients can lead to chlorosis, which adversely affects leaf function and, consequently, trunk development. Copper deficiency in sago palm on deep peat is shown by necrosis in tips of its leaflets (Jong and Flach 1995) [10]. A study by Marschner (2012) [14] demonstrated that iron deficiency in young citrus trees resulted in reduced leaf area and impaired trunk growth, highlighting the importance of balanced nutrient availability during early development stages. found that Fe deficiency in young trees resulted in poor trunk rigidity and increased susceptibility to mechanical stress. Similarly, magnesium plays a crucial role in chlorophyll production and is essential for photosynthetic efficiency, which indirectly supports trunk health by ensuring adequate energy production (White and Broadley, 2003) [20]. Further studies related to need and effects of those nutrients in sago palm growth and development are required.

Conclusion

The present study demonstrates no significant changes in soil chemical characteristics, morphology, and frond nutrient status in sago palms before and post trunk formation. Future studies should focus on long-term monitoring of soil and sago palm growth and development with the presence and absence of harvested palms, in order to develop sustainable management strategies that support the growth and productivity of sago palms in tropical ecosystems.

References

1. Achudan NS, Mohamed AMD, Rashid RSA, Mittis P. Yield and physicochemical properties of starch at different sago palm stages. Mater Today Proc,2020:31(1):122-126. doi: 10.1016/j.matpr.2020.01.341.
2. Ando H, Hirabayashi D, Kakuda K, Watanabe A, Jong FS, Purwanto BH. Effect of chemical fertilizer application on the growth and nutrient contents in leaflet of sago palm at the rosette stage. Jpn J Trop Agric,2007:51:102–108.
3. Blatt MR. Plant Physiology: Redefining the enigma of metabolism in stomatal movement. Curr Biol,2016:26(1):R102–R124.
4. Brady N, Weil R. Nutrient Cycles and Soil Fertility. In: Anthony VR, editor. Elements of the Nature and Properties of Soils. 3rd ed. Upper Saddle River (NJ): Pearson Education Inc, 2010, 396-420.
5. Gao Y, Tang Z, Xia H, Sheng M, Liu M, Pan S, Li Z, Liu J. Potassium fertilization stimulates sucrose-to-starch conversion and root formation in sweet potato (*Ipomoea batatas* (L.) Lam.). Int J Mol Sci,2021:22(9):4826. doi: 10.3390/ijms22094826.
6. Hodge A, Robinson D, Fitter A. Are microorganisms more effective than plants at competing for nitrogen? Trends Plant Sci,2000:5(7):304-308. doi: 10.1016/S1360-1385(00)01656-3.

7. Irawan AF, Kusmiyati F, Suwarno M, Purbayanti ED, Rahim GA, Asmono D. Evaluating sago palm (*Metroxylon sagu*) cultivation practices: Aspects of groundwater level and reduction of starch during harvest transportation. Int J Agric Biol,2024a:332(3):261-270. doi: 10.17957/IJAB/15.2200.
8. Irawan AF, Miyazaki A, Yamamoto Y, Herwibawa B, Suwarno M, Safitri D, *et al*. Effect of sucker thinning and potential impact of harvest and trimming practice on reduction of starch supply in rhizome of sago palm (*Metroxylon sagu*) cluster. Agric Res, 2024b. doi: 10.1007/s40003-024-00822-7.
9. Jong FS. Research for the development of sago palm (*Metroxylon sagu* Rottb.) cultivation in Sarawak, Malaysia. PhD dissertation, Agricultural University, 1995, 139.
10. Jong FS, Flach M. The sustainability of sago palm (*Metroxylon sagu*) cultivated on deep peat in Sarawak. Sago Palm,1995:3:13–20.
11. Kimura Y, Sasaki R. Staple food shift in Papua, Indonesia: A discussion based on the study of diabetic patients and cultural significance of sago palm. Sago Palm,2022:29(2):53-62. doi: 10.57418/sagopalm.29.2_53.
12. Khaled F, Amina S. Soil pH and its influence on nutrient availability and plant health. Int J Adv Chem Res,2023:5(2):61-63. doi: 10.33545/26646781.2023.v5.i2a.204.
13. Konuma H. Status and outlook of global food security and the role of underutilized food resources: Sago palm. In: Ehara H, Toyoda Y, Johnson DV, editors. Sago Palm: Multiple Contributions to Food Security and Sustainable Livelihoods. Singapore: Springer Nature, 2018, 3-16. doi: 10.1007/978-981-10-52699_1.
14. Marschner P. Mineral Nutrition of Higher Plants. 3rd ed. Adelaide (AU): School of Agriculture, Food and Wine, The University of Adelaide, 2012. Elsevier Ltd. doi: 10.1016/C2009-0-63043-9.
15. McCormack ML, Dickie IA, Eissenstat DM, Fahey TJ, Fernandez CW, Guo D, *et al*. Redefining fine roots improves understanding of below-ground contributions to terrestrial biosphere processes. New Phytol,2015:207(2):505-518. doi: 10.1111/nph.13363.
16. Monda Y, Kuwahara S, Aoki Y, Suzuki H, Kaneko T, Kozan H, *et al*. Productivity of sago palms on smallholder plantations after rewetting in previously drained peatland: A case study on Tebing Tinggi Island, Riau Province, Indonesia. Tropics,2022:31:11–32. doi: 10.3759/tropics.MS21-15.
17. Pei-Lang AT, Mohamed AMD, Karim AA. Sago starch and composition of associated components in palms of different growth stages. Carbohydr Polym,2006:63(2):283-286. doi: 10.1016/j.carbpol.2005.08.061.
18. Ramasamy M, Ghosh S, Yadav KK, Chitra M, Dhivya B, Sanjay KSA, *et al*. The role of organic farming in enhancing soil structure and crop performance: A comprehensive review. J Sci Res Rep,2024:30(10):890-904. doi: 10.9734/jsrr/2024/v30i102511.
19. Šustr M, Konrádová H, Martinčová M, Soukup A, Tylová E. Potassium transporter KUP9 regulates plant response to K+ deficiency and affects carbohydrate allocation in *A. thaliana*. J Plant Physiol,2024:292:154147. doi: 10.1016/j.jplph.2024.154147.
20. White PJ, Broadley MR. Calcium in Plants. Ann Bot,2003:92(4):487-511. doi: 10.1093/aob/mcg164.
21. Yamamoto Y, Yoshida T, Goto Y, Nitta Y, Kakuda K, Jong FS, *et al*. Differences in growth and starch yield of sago palm (*Metroxylon sagu* Rottb.) among soil types in Sarawak, Malaysia. Jpn J Trop Agric,2003:47(4):250-259. doi: 10.11248/jsta1957.47.250.