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Morphological Responses and Seedling Quality of Areca Nut (Areca catechu L.) Varieties Batara and Saluang to Areca Husk-Based Liquid Organic Fertilizer in Peat Soil

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ABSTRACT
This study evaluated the effects of areca husk liquid organic fertilizer (LOF) concentrations and areca nut varieties (Batara and Saluang) on seedling morphological responses in peat soil media. The experiment was conducted using a factorial completely randomized design with five LOF concentration levels (150, 300, 450, 600, and 750 mL L^{-1}) and two areca nut varieties, replicated four times. The results showed that there was no significant interaction between LOF concentration and variety on plant height and stem diameter; however, both factors independently affected these parameters. The optimum plant height and stem diameter were observed at LOF concentrations of 150–300 mL L^{-1}, while higher concentrations reduced growth performance, indicating that excessive application may reduce nutrient uptake efficiency.Significant interaction effects were observed for shoot–root ratio and seedling quality index (SQI). The highest SQI was obtained in Batara seedlings at 150 mL L^{-1}, while Saluang showed the highest shoot–root ratio at 300 mL L^{-1}. All treatments produced SQI values above 0.09 (3.33–4.49), indicating that all seedlings were suitable for field transplantation.Plant dry weight was highest at 150–300 mL L^{-1}, with Batara showing slightly higher biomass than Saluang. The improvement in growth performance was attributed to better nutrient availability and uptake efficiency at moderate LOF concentrations. The integration of LOF with half-dose NPK fertilizer reduced inorganic fertilizer use by 50% while maintaining seedling quality.The beneficial effects of LOF were associated with its nutrient content as well as plant growth regulators such as auxin (52.20 ppm), cytokinin (18.31 ppm), and vitamin B1 derived from rice washing water. These components enhanced root development, shoot growth, and stress tolerance. Additionally, microbial activity in LOF contributed to organic matter decomposition and improved nutrient availability in peat soil.
Overall, LOF derived from areca husk combined with reduced NPK fertilizer application can improve seedling growth and quality while reducing dependence on chemical fertilizers.

KEYWORDS: areca nut, liquid organic fertilizer, peat soil, seedling quality index, plant growth

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INTRODUCTION

Indonesia is the world's leading supplier of areca nut, contributing approximately 30.05% of global areca nut demand. In 2024, Indonesia successfully exported 182.115 million kg of areca nuts to the global market, generating foreign exchange earnings of USD 116,662,578. Indragiri Hilir Regency (Inhil) is one of the regions with extensive areca nut plantations. The regency is predominantly characterized by peat soils, covering an area of approximately 998,610.4 ha (Mubekti, 2011), which have considerable potential for areca nut cultivation. In 2024, the total area of areca nut plantations in Indragiri Hilir Regency reached 19,149 ha, of which 4,158 ha were classified as damaged plantations. In 2025, the plantation area decreased to 19,049 ha (Indragiri Hilir Plantation Office, 2026). This reduction was mainly caused by plant mortality and the failure to replant areca nut on approximately 100 ha of abandoned land. Therefore, replanting efforts are necessary to increase both the plantation area and areca nut production in the region.

Successful replanting requires high-quality seedlings to ensure optimal growth and establishment. Farmers in Indragiri Hilir generally use peat soil as a growing medium. However, peat soils present several constraints, including low soil pH, limited availability of macro- and micronutrients, and low base saturation. One approach to overcoming these limitations is the cultivation of Batara areca seedlings, a nationally recognized superior variety, and Saluang areca seedlings, a superior local variety of Indragiri Hilir Regency, supplemented with liquid organic fertilizer (LOF) derived from areca husk waste, an agricultural by-product generated from areca nut production.

Areca husk is the most abundant waste component of the areca fruit compared with its other parts. According to Lutony (1992), approximately 60–80% of the fresh weight of areca fruit consists of husk. Naveenkumar and Tippeswamy (2013) reported that areca husk contains hemicellulose (35–64.8%), lignin (13–26%), pectin, protopectin, and twenty-four species of fungi capable of degrading cellulose in organic materials. In addition to its microbial content, areca husk contains 65.41% moisture, 34.59% dry matter, 2.22% crude protein, 0.10–0.05% crude fat, 47.02% crude fiber, 0.28% calcium (Ca), and 0.36% phosphorus (P) (Nisa, 2018). Furthermore, Rosalina and Febriadi (2019) reported that areca husk waste has considerable potential as a raw material for liquid organic fertilizer production. Rosalina and Sukmawati (2022) found that the application of areca husk LOF improved soil chemical properties, increasing soil pH from 4.34 to 5.26, organic carbon content from 0.80% to 1.35%, and total nitrogen content from 0.09% to 0.14%.

Studies investigating the fertilization of Batara areca seedlings using liquid organic fertilizers are still very limited. To the best of the author's knowledge, no previous studies have evaluated the use of areca husk-based liquid organic fertilizer on Batara areca seedlings. Moreover, studies examining the application of areca husk LOF to other crops are also scarce. Likewise, research on Saluang areca has not been found in the available literature. Therefore, the author was interested in evaluating the use of areca husk liquid organic fertilizer on Batara and Saluang areca varieties.

The main raw materials used for producing the liquid organic fertilizer in this study were areca husk waste and rice washing water, both of which are inexpensive and readily available to farmers in their surrounding environment.

MATERIALS AND METHODS

2.1. Study Site and Duration

The experiment was conducted from March to September 2024 at the nursery site of the Faculty of Agriculture, Indragiri Islamic University, Indragiri Hilir Regency, Riau Province, Indonesia. Initial soil analysis was carried out at the Testing Laboratory of the Riau Agricultural Instrument Standardization Implementation Center (BSIP Riau). Analyses of nutrient content in the areca husk liquid organic fertilizer (LOF) and plant tissue nitrogen (N) content were performed at the Central Plantation Services Laboratory, PT Central Alam Resources Lestari, Riau Province.

The analysis of hormone content in the areca husk LOF was conducted at the International Research Institute, Advanced Biotechnology Center Laboratory, IPB University, Bogor, Indonesia. This laboratory is accredited by the National Accreditation Committee of Indonesia (KAN).

PREPARATION OF ARECA HUSK LIQUID ORGANIC FERTILIZER (LOF) AND TREATMENT APPLICATION

The preparation of areca husk liquid organic fertilizer (LOF) was carried out as follows: chopped areca husk and rice washing water were mixed and placed into a decomposer container at a ratio of 1:1. Subsequently, 1% brown sugar and 0.8% EM4 (Effective Microorganisms 4) based on the weight of solid organic materials were added. The container was then tightly closed and the mixture was fermented for 28 days. The fertilizer was considered mature when a white layer appeared on the surface of the solution and a characteristic fermentation odor was produced.

The application of areca husk LOF was carried out according to the treatment levels at a dose of 100 mL per plant. The LOF solution was diluted with water at a ratio of 1:1, resulting in 200 mL of diluted solution per plant. The solution was then applied by spraying it onto all parts of the plant, while the remaining volume was applied to the soil. Applications were carried out every two weeks, starting at 4 weeks after planting (WAP) until 16 WAP. Thereafter, the application frequency was increased to once per week until the plants reached 19 WAP.

Basal fertilization was conducted using NPK fertilizer (16-16-16) at a rate of 2 g per plant, which represents half of the recommended dose for Batara areca seedlings during a five-month pre-nursery period (4 g per plant). NPK fertilizer was applied once at 2 weeks after planting (WAP).

OBSERVATION PARAMETERS

The observed parameters included plant height growth (cm), stem diameter (mm), shoot-root ratio, seedling quality index (SQI), and plant dry weight.

EXPERIMENTAL DESIGN AND STATISTICAL ANALYSIS

The experiment was arranged in a factorial Completely Randomized Design (CRD) consisting of two factors. The first factor was the concentration of areca husk liquid organic fertilizer (LOF), consisting of five treatment levels: p1 = 150 mL L^{-1}, p2 = 300 mL L^{-1}, p3 = 450 mL L^{-1}, p4 = 600 mL L^{-1}, and p5 = 750 mL L^{-1}. The second factor was areca nut variety, consisting of two levels: v1 = Batara (national superior variety) and v2 = Saluang (local superior variety of Indragiri Hilir Regency). Each treatment combination was replicated four times, resulting in a total of 40 experimental units.

The collected data were statistically analyzed using the F-test (analysis of variance/ANOVA). When significant differences were detected, the means were further compared using Tukey's Honestly Significant Difference (HSD) test at the 5% significance level.

RESULTS AND DISCUSSION

Table 2. Effect of Areca Husk Liquid Organic Fertilizer on Seedling Height of Batara and Saluang Areca Seedlings in Peat Media

Variety	Seedling Height (cm)					
	Areca Husk Liquid Organic Fertilizer Concentration (mL.L^{-1})					Average
	150	300	450	600	750	
Batara	50,42	50,91	49,99	48,58	43,99	48,32 b
Saluang	51,76	51,59	48,98	48,61	45,68	49,78 a
Average	51,09 a	51,25 a	49,48 b	48,60 c	44,83 d	

Note: Means followed by the same letter within rows or columns are not significantly different at the 5% level according to Tukey's HSD test.

Table 2. Effect of Areca Husk Liquid Organic Fertilizer on Stem Diameter of Batara and Saluang Areca Seedlings in Peat Media

Variety	Stem Diameter (mm)					
	Areca Husk Liquid Organic Fertilizer Concentration (mL.L^{-1})					
	150	300	450	600	750	Average
Batara	18,93	18,13	17,40	17,36	16,44	17,65 a
Saluang	17,92	18,88	17,94	17,45	16,99	17,84 a
Average	18,42 a	18,50 a	17,67 b	17,40 b	16,71 c	

Note: Means followed by the same letter within rows or columns are not significantly different at the 5% level according to Tukey's HSD test.

Table 3. Effect of Areca Husk Liquid Organic Fertilizer on shoot-root ratio of Batara and Saluang Areca Seedlings in Peat Media

Variety	Shoot-Root Ratio				
	Areca Husk Liquid Organic Fertilizer Concentration (mL.L^{-1})				
	150	300	450	600	750
Batara	2,04 a B	2,10 a B	2,19 a A	2,23 a A	2,36 a A
Saluang	2,55 ab A	3,01 a A	2,18 b A	1,99 b A	2,08 b A

Note: Values followed by the same lowercase letter within the same row and the same uppercase letter within the same column are not significantly different according to Tukey's test at $p > 0.05$.

Table 4. Effect of Areca Husk Liquid Organic Fertilizer on Seedling Quality Index (SQI) of Batara and Saluang Areca Seedlings in Peat Media

Variety	Seedling Quality Index (SQI)				
	Areca Husk Liquid Organic Fertilizer Concentration ($mL.L^{-1}$)				
	150	300	450	600	750
Batara	4,49 a A	4,17 ab A	3,64 bc A	3,43 c A	3,33 c A
Saluang	3,41 a B	3,78 a A	3,66 a A	3,48 a A	3,36 a A

Note: Values followed by the same lowercase letter within the same row and the same uppercase letter within the same column are not significantly different according to Tukey's test at $p > 0.05$.

Table 5. Effect of Areca Husk Liquid Organic Fertilizer on Seedling Quality Index (SQI) of Batara and Saluang Areca Seedlings in Peat Media

Variety	Plant Dry Weight (g/plant)					Average
	Areca Husk Liquid Organic Fertilizer Concentration ($mL.L^{-1}$)					
	150	300	450	600	750	
Batara	21,19	20,44	18,21	17,67	16,69	18,84 a
Saluang	20,44	19,20	17,49	16,67	15,99	17,57 b
Average	19,84 a	19,82 a	17,85 b	17,17 c	16,34 d	

Note: Means followed by the same letter within rows or columns are not significantly different at the 5% level according to Tukey's HSD test.

Tabel 6. Soil Chemistry Ccaracteristic

Analisize	Analisize methode	Value	Criteria
pH H_2O	Potensiometri	3,73	highly acidic
pH KCl	Potensiometri	2,86	highly acidic
C-organik (%)	Gravimetri/ Furnace	43,32	Very high
N-total (%)	K-Jedal	0,46	high
Rasio C/N		48,87	Very high
P- tersedia (ppm)	Bray 1	89,46	Very high
K-dd (me/100 g)	Spektrofotometer	0,031	very low
Na-dd (me/100 g)	Spektrofotometer	0,01	Very low
Ca-dd (me/100 g)	Spektrofotometer	0,02	very low
Mg-dd(me/100 g)	Spektrofotometer	0,02	very low
KTK (cmol/kg)	1N NH4OAc pH 7	59,1	very high
Kadar Abu (%)	Gravimetri	27,21	very high

Source: Testing Laboratory, Center for the Application of Agricultural Instrument Standards (BPSIP) Riau (2024)

Tabel 7. Nutrient Content of Areca Husk and Rice Washing Water

Parameter	C Organik (%)	N Total (%)	P Total (%)	K Total (%)	Ratio C/N
Sabut Pinang	**5,51**	**0,79**	**0,86**	**1,5**	**0,79**
Air Cucian Beras	**0,20**	0,01	**0,03**	**0,03**	**20,00**

Source: Laboratorium Central Plantation Services, Pekanbaru (2024)

Tabel 8. Nutrient Content of Areca Husk Liquid Organic Fertilizer

Parameter uji	pH	N Total (%)	P Total (%)	K Total (%)	C-Organik (%)	C/ N
Nilai	**5,03**	**0,05**	**0,03**	**0,21**	**0,27**	**0,05**
standar*	**4-9**	**2-6**			**0,5**	
Keterangan	**memenuhi**	**belum memenuhi**			**belum memenuhi**	

Source : Laboratorium Central Plantation Services, Pekanbaru (2024)
* Kepmen Pertanian No. 261/KPTS/SR.310/M/4/2019

Tabel 9. Hormones Content of Areca Husk Liquid Organic Fertilizer

Hormon	Auksin/IAA (ppm)	Sitokinin (ppm)
Nilai	50,20	18,31

Source : Pusat Bioteknologi (Biotech Center) Institut Pertanian Bogor (2025)

Tabel 10. N Content of Plant

Kadar N Tanaman (%)	150 $mL.L^{-1}$	300 $mL.L^{-1}$	450 $mL.L^{-1}$	600 $mL.L^{-1}$	750 $mL.L^{-1}$
Batara	1,93	1,91	1.70	1.61	1,53
Saluang	1,69	1,80	1,60	1,51	1,45

Source : Laboratorium Central Plantation Services, Pekanbaru (2024)

Tabel 11. Nitrogen Uptake by Batara and Saluang Varirties

Perlakuan	Serapan hara N Tanaman (g/tanaman)	
	Batara	Saluang
150 POC Sabut Pinang ($mL.L^{-1}$)	0,41	0,31
300 POC Sabut Pinang ($mL.L^{-1}$)	0,39	0,35
350 POC Sabut Pinang ($mL.L^{-1}$)	0,31	0,28
600 POC Sabut Pinang ($mL.L^{-1}$)	0,28	0,25
750 POC Sabut Pinang ($mL.L^{-1}$)	0,26	0,23

DISCUSSION

Growth Parameters: Plant Height and Stem Diameter

The results indicated that there was no interaction between areca nut varieties and areca husk liquid organic fertilizer (LOF) concentration on plant height. However, both factors independently showed significant effects. The highest plant height was observed at LOF concentrations of 150–300 mL L^{-1}, with 300 mL L^{-1} giving the optimum response. Increasing LOF concentration beyond this level significantly reduced plant height, indicating that moderate concentrations were more effective for seedling growth.

Plant height is strongly associated with nitrogen (N) availability and uptake. Adequate N supply promotes vegetative growth, particularly cell division and elongation in meristematic tissues, resulting in increased plant height. As reported by Iswiyanto et al. (2023), during the vegetative stage plants require higher N compared to P and K because nitrogen is a key component in protein synthesis and structural development of roots, stems, branches, and leaves.

Similarly, stem diameter was significantly influenced by LOF concentration but not by variety or interaction effects. The highest stem diameter was recorded at 300 mL L^{-1}, followed by 150 mL L^{-1}, while higher concentrations resulted in a decline. This suggests that excessive LOF may reduce nutrient uptake efficiency, possibly due to nutrient imbalance or osmotic effects in the growing medium. Optimal nutrient availability at moderate concentrations likely enhanced photosynthetic efficiency and structural biomass accumulation.

Shoot–Root Ratio and Biomass Allocation

A significant interaction was observed between LOF concentration and areca nut variety on shoot–root ratio. In Saluang, the highest ratio (3.01) was obtained at 300 mL L^{-1}, indicating a stronger allocation of photosynthates toward shoot development compared to roots. In contrast, Batara showed relatively stable responses across treatments.Overa ll, shoot–root ratios ranged from 1.99 to 3.01, indicating that biomass allocation was predominantly directed toward shoot growth. According to Salisbury and Ross (1995), most plant species allocate a greater proportion of biomass to shoots rather than roots, except in certain xerophytic species with highly developed root systems.

Seedling Quality Index (SQI)

There was a significant interaction between LOF concentration and variety on seedling quality index (SQI). The highest SQI in Batara was observed at 150 mL L^{-1}, while Saluang showed a relatively stable response across treatments. Increasing LOF concentration tended to reduce SQI in Batara seedlings, suggesting that excessive nutrient supply may not always improve seedling quality.

All treatments produced SQI values above 0.09 (ranging from 3.33 to 4.49), indicating that all seedlings met the criteria for field transplantation. Higher SQI values reflect better seedling vigor and survival potential after transplanting. These findings are consistent with Hendromono and Durahim (2004), who reported that higher seedling quality indices are associated with improved field performance.

Plant Dry Weight and Nutrient Interaction

Plant dry weight was significantly affected by LOF concentration but not by variety interaction. The highest dry weight was observed at 150–300 mL L^{-1}, with Batara producing slightly higher biomass than Saluang. The reduction in dry weight at higher LOF concentrations suggests reduced nutrient use efficiency under excessive application.

The improved biomass production at moderate concentrations can be attributed to more efficient nitrogen uptake via roots and leaves. Additionally, the use of NPK fertilizer (16-16-16) at 2 g per plant as a basal dose contributed approximately 0.32 g N, supporting early seedling growth. As stated by Faizi *et al.* (2020), combining organic and inorganic fertilizers can create synergistic effects in nutrient availability. Organic fertilizers improve soil properties, while inorganic fertilizers provide readily available nutrients, although excessive use of inorganic fertilizers may lead to environmental degradation (Purnomo *et al*., 2013).

Role of LOF Nutrients, Hormones, and Vitamins

The effectiveness of areca husk LOF is also associated with its nutrient, hormonal, and vitamin content. The LOF used in this study contained auxin (52.20 ppm) and cytokinin (18.31 ppm), which play important roles in root initiation and shoot development. Auxin promotes cell elongation and root formation, while cytokinin stimulates cell division and shoot growth (Salisbury and Ross, 1997).

In addition, the LOF contained vitamin B1 (thiamine), derived from rice washing water used in the fermentation process. Thiamine enhances plant stress tolerance, metabolic activity, and root development, thereby improving nutrient uptake efficiency (Fitzpatrick and Chapman, 2020; Aeni, 2022).

Soil Contribution and Nutrient Mineralization

Nitrogen availability was also supported by the growing medium, which contained 0.46% total N. However, most of this nitrogen was in organic form and not directly available to plants. Mineralization by soil microorganisms is required to convert organic N into inorganic forms (NH_4^+, NO_2^-, NO_3^-).

The application of LOF may enhance decomposition processes in peat soil due to its microbial content. As reported by Naveenkumar and Tippeswamy (2013), areca husk contains fungal strains capable of degrading cellulose, thereby accelerating organic matter decomposition and nutrient release.

Integrated Nutrient Supply and Fertilizer Efficiency

The results indicate that LOF combined with half-dose NPK fertilizer was able to reduce inorganic fertilizer use by 50% without compromising seedling quality. All seedlings exhibited SQI values above the minimum threshold, confirming adequate nutrient supply from combined sources including LOF, NPK fertilizer, growing medium, and seed reserves.

This finding is supported by Miftahurridho et al. (2025) and Hawayanti et al. (2021), who reported that integrated organic–inorganic fertilization improves soil productivity while reducing dependency on chemical fertilizers.

Interestingly, residual nutrient supply from seed reserves also contributed to early seedling growth, as the seeds remained attached and functional until the end of the experiment (20 weeks after planting), supporting early establishment (Syukron et al., 2022).

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Based on the results of the study, the following conclusions can be drawn:

1. There was an interaction between the application of areca husk liquid organic fertilizer (LOF) concentration and areca nut varieties (Batara and Saluang) on the shoot–root ratio and seedling quality index (SQI).
2. Batara areca seedlings were more responsive to the application of areca husk LOF compared to Saluang seedlings, as indicated by higher plant dry weight, which represents biological yield, namely 18.84 g compared to 17.57 g in Saluang seedlings.
3. The highest morphological responses of Batara and Saluang seedlings were obtained under the application of areca husk LOF at a concentration of 150 mL L^{-1}. The application of LOF combined with half the recommended dose of NPK fertilizer was able to reduce NPK fertilizer usage by 50%.

RECOMMENDATIONS

Based on the conducted research, it is recommended that further studies be carried out using areca husk LOF at a concentration of 150 mL L^{-1}, but enriched with other organic materials and/or using additional bio-activators to improve its effectiveness.

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