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The Effect of LOF Concentration in AB MIX on the Growth of Oil Palm Seedlings (*Elaeis guineensis* Jacq) Wick System

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Abstract

Conventional oil palm nursery systems face significant challenges, including limited nutrient availability, land dependency, and pest infestations, which drive the adoption of hydroponic systems as a sustainable alternative. This study evaluated the effect of liquid organic fertilizer (LOF) derived from goat manure and straw waste on the growth of pre-nursery oil palm seedlings (*Elaeis guineensis*) using a wick hydroponic system. While standard hydroponic systems typically use water-soluble inorganic fertilizers like AB Mix, which provide complete macro- and micronutrients readily available to plants, this study investigated LOF as a sustainable alternative that aligns with organic agriculture principles. The experiment was conducted in a greenhouse over three months using a non-factorial completely randomized design (CRD) with seven treatments and three replications. Treatments included AB Mix (control) and mixtures of AB Mix with goat manure LOF or straw waste LOF at concentrations of 400, 800, and 1,200 ppm. Observed variables included plant height, leaf count, stem diameter, and leaf width. Results indicated that the AB Mix treatment alone yielded superior vegetative growth compared to treatments supplemented with goat manure or straw waste LOF. These findings suggest that while AB Mix remains more effective for supporting oil palm seedling growth in the pre-nursery phase, LOF holds potential as a supplementary nutrient in hydroponic systems with optimized formulations and concentrations. This research provides a foundational basis for developing more efficient and sustainable oil palm nursery technologies.

Keywords: Liquid Organic Fertilizer, Plant Nutrition, Seedling Production, Sustainable Agriculture, Vegetative Growth

1. Introduction

Oil palm nurseries are generally carried out using a conventional soil-based system that consists of two stages: Pre Nursery and Main Nursery. In the *pre-nursery stage*, superior cross-bred seedlings such as DxP 540 PPKS are planted in a media box for ± 3 months in a limited area to facilitate easier monitoring and care. DxP 540 PPKS seedlings have the advantages of strong initial vigor, straight stem growth, shiny green leaves, and a sturdy root system, so that they are more adaptive when transferred to the field. These advantages make DxP 540 PPKS seedlings widely used as a standard in oil palm plantations because they can produce plants with high productivity potential (Saputra et al., 2017).

Although soil-based systems are considered practical and widely used, they still have several limitations, such as the often unbalanced nutrient availability in the growing medium, the high risk of pest and disease attacks, and the

need for large areas of land. These limitations are the main weaknesses of conventional methods, resulting in suboptimal land-use efficiency and plant productivity (Panggabean and Wardati, 2015; Muhibuddin and Andik, 2014). Therefore, alternative approaches, such as hydroponic cultivation with a wick system, have begun to be implemented at the Pre-Nursery stage to increase nursery efficiency and effectiveness. The *wick system* allows for more controlled nutrient absorption through a more sterile growing medium, reduces dependence on soil, and saves space and water, making it considered more adaptive to the challenges of modern nurseries.

The wick system allows for a stable distribution of water and nutrients according to plant needs and reduces the risk of overwatering, as absorption occurs via capillary action through the wick. Implementing this system in the pre-nursery stage of oil palm nurseries provides an innovative solution to the limitations of conventional soil

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media, particularly in terms of nutrient absorption efficiency, moisture control, and minimizing pest and soil disease problems. Thus, the *wick system* not only enhances oil palm seedling growth in the early stages but also supports more environmentally friendly, resource-efficient nurseries (Resh, 2004).

Wick systems are more suitable for small-scale use or for beginners due to their simple design and low operational costs (Mardhiah *et al.* , 2011). The trend towards wick systems is growing because they offer cost savings, are easy to set up, do not require pumps or electricity, and are suitable for small-scale research or nurseries. Nutrient distribution is also even, thus increasing overall plant growth efficiency (Resh, 2004).

In this study, organic fertilizer (LOF) was produced from goat manure, an easily obtained, nutrient-rich organic material. Goat manure was fermented using *Effective Microorganism 4* (EM4) to accelerate the decomposition process and increase nutrient content. The LOF from goat manure contained 1.15% N, 60.68 ppm P, and 519.07 ppm K, while the raw material contained approximately 31% organic matter, with a C/N ratio of 25–30% (Lingga, 1991; Suparhun, 2015). Furthermore, goat manure is readily available, inexpensive, and efficient in increasing plant growth and productivity (Rahmah *et al.*, 2014; Liu *et al.*, 2011).

Meanwhile, rice straw waste is one of the largest agricultural wastes that has the potential to be used as raw material for liquid organic fertilizer (LOF) because it contains important nutrients such as N around 0.5–0.8%, P around 0.07–0.12%, and K around 1.2–1.7% (Sari *et al.* , 2023). Using rice straw as LOF not only benefits plants but also prevents nutrient loss from combustion (Rhofita and Chana, 2019). LOF from straw is used because it has a high nutrient content, can improve the quality of hydroponic nutrient solutions, increase plant resistance to stress, and support sustainable waste processing (Bachtiar and Ahmad, 2019; Siswanti, 2009).

The use of liquid organic fertilizer (LOF) in hydroponic systems has been widely studied to improve nutrient utilization efficiency and support sustainable agriculture. Several studies have reported that LOF made from organic waste, such as livestock manure and rice straw, can enhance plant growth by improving nutrient availability and microbial activity. However, its effectiveness is greatly influenced by the raw material, concentration, and cultivation system used. Previous research has generally focused on horticultural crops or on hydroponic systems other than wick systems, so information on the effectiveness of LOF in oil palm nurseries remains limited.

To date, studies directly comparing the performance of AB Mix nutrients with a combination of AB Mix and goat manure LOF and straw waste LOF in *the pre-nursery phase* of oil palm using a wick hydroponic system are still rarely

reported. Therefore, this study has the novelty of evaluating the effects of various concentrations of goat manure LOF and straw waste LOF combined with AB Mix on the growth of oil palm seedlings in the pre-nursery phase. The results of this study are expected to provide scientific information on the potential of LOF as a supporting nutrient in a wick hydroponic system and become the basis for the development of oil palm nursery technology that is more efficient, environmentally friendly, sustainable and suitable for application on a wider scale in the oil palm industry. The objectives of this study are: 1. To determine the difference in the growth of oil palm seedlings in *the pre-nursery* given AB mix goat manure LOF and AB mix straw waste LOF compared to AB Mix. 2. To determine the difference in the growth of oil palm seedlings in *the pre-nursery* treated with goat manure LOF and straw waste LOF. 3. To determine the difference in the growth of oil palm seedlings in *the pre-nursery* against the concentration of straw waste LOF given. 4. To determine the difference in the growth of oil palm seedlings in *the pre-nursery* with respect to the concentration of goat manure LOF given.

2. Material and Methods

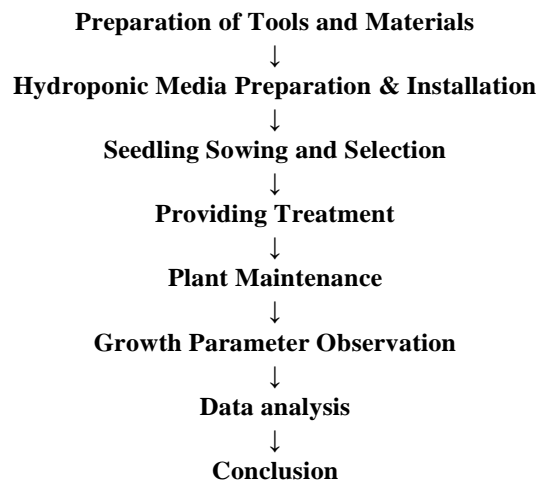
This research was conducted in the greenhouse of the Horticultural Seed Development Unit (UPT) in Deli Serdang Regency, North Sumatra Province, Indonesia. Geographically, the research site is located at 3°34' N, 98°40' E, at an altitude of approximately 25 meters above sea level (masl). The research period was three months, starting from November 2024 to January 2025.

The materials needed are DxP PPKS 540 cross-pollinated oil palm seedlings, goat manure fertilizer, straw waste, distilled water (5 liters), AB Mix nutrients (1 liter), EM4, 96% ethanol, flannel cloth and rockwool measuring 15 × 15 × 7.5 cm.

The tools used are a square tub measuring 30 × 39.5 cm, Netpot, Impraboard, TDS Meter, 25 kg capacity bucket, 30 cm diameter funnel, 25 liter jerry can, cloth meter, glass beaker and measuring cup, filter paper, analytical balance, knife, UV-Vis spectrometer with a wavelength range of 190–1100 nm, used to measure the intensity of light absorption of the solution in determining plant chlorophyll parameters, Camera.

This research uses the Completely Randomized Design (CRD) method. Non-factorial with amount treatment 7, namely: $K_0 = 0$ control + (AB Mix with pH 6.2) (1000ppm). $LJ_1 = 400$ ppm straw waste + (AB Mix with pH 6.2). $LJ_2 = 800$ ppm straw waste + (AB Mix with pH 6.2). $LJ_3 = 1,200$ ppm straw waste + (AB Mix with pH 6.2). $KK_1 = 400$ ppm goat manure + (AB Mix with pH 6.2). $KK_2 = 800$ ppm goat manure + (AB Mix with pH 6.2). $KK_3 = 1,200$ ppm goat manure + (AB Mix with pH 6.2). The data analysis method was a Non-Factorial Completely Randomized Design (CRD-Non-Factorial) with one treatment factor, namely the combination of AB Mix

nutrient solution and liquid organic fertilizer (LOF), using the mathematical model $Y_i = \mu + \tau_i + \varepsilon_i$. Data analysis was carried out using analysis of variance (ANOVA) at a 95% confidence level ($\alpha = 5\%$). If the treatment effect was significant, a contrast test was used to determine differences between treatments. Statistical analysis was conducted using IBM SPSS Statistics version 26, while initial data processing and graphical presentation were conducted in Microsoft Excel 2019. The analytical tools used included the ATC PH-009 digital pH meter (pH range 0–14), the Xiaomi Mi TDS Pen TDS meter (range 0–9990 ppm), the Shimadzu UV-Vis spectrophotometer (wavelength range 190–1100 nm) for chlorophyll content analysis, the Ohaus Pioneer PA214 analytical balance (accuracy 0.0001 g), and a camera for research documentation. The following is a flowchart of research implementation:



The research implementation flow is presented as a diagram to clarify the stages of the research, from the preparation of tools and materials to data analysis.

3. Results and Discussion

3.1. Plant Height

Data on plant height for the liquid straw waste LOF and goat pen LOF treatments aged 2, 4, 6, 8, 10 and 12 MST, along with the analysis of variance, are presented in Appendix 3-14. Based on the results of the analysis of variance with a non-factorial Completely Randomized Design (CRD), as shown in Table 2.

Based on Table 2, the application of LOF from goat manure and straw waste significantly affected the height of oil palm seedlings at 4 weeks after planting, but had no effect at 2, 6, 8, 10, and 12 weeks after planting. The results of the orthogonal analysis are presented in Table 3.

Based on Table 3, the results of the orthogonal test show that the administration of straw waste LOF (LJ) and goat manure LOF (KK) in the *pre-nursery phase* of oil palm seedlings did not significantly affect plant height at the age of 12 WAP. The control treatment (K0), which

applied AB Mix fertilizer showed the highest plant height growth, averaging 30.33 cm, higher than the LOF treatment (LJ + KK), which produced an average of 28.02 cm, with a difference of 2.31 cm. Quantitatively, these results are in line with previous studies, which reported that the use of inorganic nutrients in the *pre-nursery phase* resulted in oil palm seedling heights ranging from 29–32 cm at the age of 12 WAP, while the application of liquid organic fertilizer resulted in plant heights of around 26–29 cm at the same age.

The comparison between the LJ and KK treatments also showed no significant difference, where LJ produced an average plant height of 27.99 cm, while KK produced 28.06 cm, with a difference of only 0.07 cm. These results support previous research, which reported that different types of liquid organic fertilizers provide a relatively small increase in plant height, namely less than 1 cm, and are not statistically significant. Furthermore, the absence of significant differences between treatment levels in both LJ₁ – LJ₃ and KK₁ – KK₃ indicates that increasing the LOF dose does not always significantly increase plant height. Previous research also reported that increasing the LOF dose increases plant height by only 0.5–1.2 cm, so the growth response is often statistically insignificant.

3.2. Number of Leaves

The number of leaves with the treatment of liquid waste, LOF straw and goat pen LOF aged 2, 4, 6, 8, 10 and 12 MST, along with the analysis of variance, can be seen in Appendix 15-26. Based on the results of the analysis of variance with a non-factorial Completely Randomized Design (CRD), as shown in Table 4.

Based on the results of observations of plant height at the age of 2 to 12 WAP, the application of liquid straw waste LOF and goat manure LOF showed a relatively uniform growth response at each observation time. At the age of 12 WAP, the plant height produced by the LOF treatment ranged from 26.59–29.02 cm, while the control treatment with AB Mix nutrients produced a plant height of 30.33 cm. Quantitatively, the difference in plant height between the LOF and inorganic nutrient treatments reached 1.31–3.74 cm. These results are in line with previous research which reported that the application of liquid organic fertilizer in the *pre-nursery phase* of oil palm resulted in a plant height of around 25–29 cm at the age of 12 WAP, while the use of inorganic nutrients was able to produce a higher plant height, which ranged from 29–32 cm. This difference indicates that inorganic nutrients are more quickly available and absorbed by plants than liquid organic fertilizers, which require a decomposition process before the nutrients can be optimally utilized. In addition, increasing the LOF dose from 2 to 12 WAP at age 2 did not result in a significant increase in plant height. Quantitatively, the difference in plant height between dose levels only ranged from 0.5–1.2 cm, so statistically there

was no significant difference.

Table 1. Height of Oil Palm Seedlings (Pre-Nursery) with Treatment of Straw Liquid Waste LOF and Goat Pen LOF in the Wick System Hydroponic Method

Treatment	Plant Height Age					
	2 MST	4 MST	6 MST	8 MST	10 MST	12 MST
(cm).....					
K ₀	8.64	14.26	18.29	22.28	25.76	30.33
LJ ₁	8.21	12.72	16.76	20.3	24.33	28.04
LJ ₂	8.07	12.88	16.58	21.2	25.43	29.02
LJ ₃	8	11.73	15.46	19.53	22.43	26.92
KK ₁	8.73	13.67	17.66	22.25	24.7	28.65
KK ₂	9.18	13.66	18.07	21.1	24	26.59
KK ₃	8.48	12.99	17.33	22.14	25.94	28.93
Information	tn.	*	tn.	tn.	tn.	tn.

Note: * sign indicates significant difference, tn: not significant

Table 3. Orthogonal Test Results for Oil Palm Seedling Height (Pre-Nursery) with Straw Liquid Waste LOF and Goat Pen LOF Treatment in the Wick System Hydroponic Method

Contrast	Average Value (cm)	Information
	12 MST	
K ₀ vs LJ+KK	30.33 vs 28.02	tn.
LJ vs KK	27.99 vs 28.06	tn.
LJ ₁ vs LJ ₂ LJ ₃	28.04 vs 27.97	tn.
LJ ₂ vs LJ ₃	29.02 vs 26.92	tn.
KK ₁ vs KK ₂ KK ₃	28.65 vs 27.76	tn.
KK ₂ vs KK ₃	26.59 vs 28.93	tn.

Description: tn sign: not real

Table 4. Number of Leaves of Oil Palm Seedlings (Pre-Nursery) with Treatment of Straw Liquid Waste LOF and Goat Pen LOF in the Wick System Hydroponic Method

Treatment	Age Number of Leaves					
	2 MST	4 MST	6 MST	8 MST	10 MST	12 MST
(strands).....					
K ₀	1.17	1.92	2.42	3.08	3.75	4.58
LJ ₁	1	1.92	2.33	2.67	3.33	4.5
LJ ₂	0.75	1.17	2.33	2.67	3.5	4.42
LJ ₃	0.75	1.5	2.08	2.92	3.42	4.5
KK ₁	1.25	1.83	2.17	3.25	3.75	4.83
KK ₂	0.83	1.58	2.25	2.75	3.42	4.08
KK ₃	0.58	1.58	2.42	2.92	3.17	4.33
Information	tn.	*	tn.	tn.	tn.	tn.

Note: * sign indicates significant difference, tn: not significant

Based on Table 4, the provision of liquid organic fertilizer (LOF) derived from goat manure and straw waste had a significant effect on the number of leaves of oil palm seedlings in the *prenursery phase, especially at 4 Weeks After Planting (WAP) in the wick hydroponic system*. Meanwhile, at the ages of 2, 6, 8, 10, and 12 WAP, the provision of LOF did not significantly affect the number of leaves in oil palm seedlings. Furthermore, the results of the orthogonal analysis of the number of leaves at the age of 4 WAP are presented in Table 5.

Based on Table 5, the results of the orthogonal test on the number of leaves of oil palm seedlings aged 12 weeks after planting show that the number of leaves of oil palm

seedlings aged 12 weeks after planting is in the range of 4.42–4.58 and is not statistically significantly different between fertilizer treatments. This average value is relatively comparable to the results of research by Siregar et al. (2015) which reported that the number of leaves of oil palm seedlings aged 12 weeks after planting is between 4.5–5.0, with an average difference of around 0.4–0.6 ($\pm 8-12\%$).

Similarly, research by Nasution and Lubis (2018) reported that applying liquid organic fertilizer and inorganic fertilizer during the early seedling phase resulted in a leaf count of approximately 4.6 leaves, a quantitative difference of only 0.02–0.18 leaves compared to the highest

yield in this study (4.58 leaves). This relatively small difference indicates that leaf growth responses during the 12-week post-planting phase tend to be stable and less responsive to variations in fertilizer type and dosage.

The lack of significant differences between treatment levels (LJ₁ – LJ₃ and KK₁ – KK₃) is also in line with the findings of Putri et al. (2020), who stated that

increasing fertilizer doses in the early stages of oil palm nursery growth does not always significantly increase leaf number because genetic factors and the physiological phase of the plant more influence leaf growth. Thus, the results of this study, both quantitatively and statistically, confirm that increasing fertilizer doses has not provided significant benefits for leaf formation at 12 weeks after planting.

Table 5. Results of Orthogonal Test on the Number of Leaves of Oil Palm Seedlings (*Pre-Nursery*) with Treatment of Liquid Straw Waste LOF and Goat Pen LOF in the *Wick System Hydroponic Method*

Contrast	Average Value (strand)		Information
	12 MST		
K ₀ vs LJ+KK	4.58 vs 4.44		tn.
LJ vs KK	4.47 vs 4.42		tn.
LJ ₁ vs LJ ₂ LJ ₃	4.50 vs 4.46		tn.
LJ ₂ vs LJ ₃	4.42 vs 4.50		tn.
KK ₁ vs KK ₂ KK ₃	4.83 vs 4.21		tn.
KK ₂ vs KK ₃	4.08 vs 4.33		tn.

Description: tn sign: not real

3.3. Diameter of the Stem Circumference

Data on the circumference diameter of plant stems treated with liquid straw waste LOF and goat manure LOF were observed at 2, 4, 6, 8, 10, and 12 weeks after planting (WAP). These observations were accompanied by analysis of variance to determine the effect of the treatment on the

observed parameters. All observation data and complete analysis are presented in Appendices 27 to 38. Based on the analysis results, a non-factorial Completely Randomized Design (CRD) was used for each treatment. The results of the analysis are briefly shown in Table 6.

Table 6. Diameter of Oil Palm Seedling Stem Circumference (*Pre-Nursery*) with Straw Liquid Waste LOF and Goat Pen LOF Treatment in the *Wick System Hydroponic Method*

Treatment	Age of Stem Circumference Diameter					
	2 MST	4 MST	6 MST	8 MST	10 MST	12 MST
(mm).....					
K ₀	3.83	5.23	6.43	7.2	8.48	10.61
LJ ₁	4.3	4.99	5.8	7.19	7.96	9.95
LJ ₂	4.03	4.61	5.12	6.53	7.15	10.03
LJ ₃	3.75	4.75	5.61	6.74	7.58	9.81
KK ₁	3.88	4.79	5.48	6.81	7.94	10.17
KK ₂	3.98	4.7	5.8	6.37	7.43	9.7
KK ₃	3.99	4.73	5.24	6.37	7.35	9.71
Information	tn.	tn.	*	tn.	tn.	tn.

Based on Table 6, the provision of LOF derived from goat manure and straw waste has a significant effect on the diameter of the stem circumference of oil palm seedlings in the *pre-nursery phase*, especially at the age of 6 Weeks After Planting (MST) in the *wick hydroponic system*, while at the age of 2, 4, 8, 10 and 12 MST the effect given is not significant. Furthermore, the results of the orthogonal analysis of stem circumference diameter at 10 MST are presented in Table 7.

Quantitatively, these results align with research by Siregar et al. (2016), who reported that the stem diameter of pre-nursery-phase oil palm seedlings at 6–8 weeks after planting ranged from 5.5–6.8 mm, with a significant response to initial nutrient availability. The difference in stem diameter values in this study was relatively small, around 0.1–0.7 mm, indicating that stem growth patterns in

the early phase tended to be uniform and were strongly influenced by readily available nutrients.

Research by Nasution et al. (2019) also reported that applying liquid organic fertilizer to oil palm nurseries increased stem diameter by 8–15% compared with unfertilized controls, but this effect was only evident during the early growth phase. This pattern is consistent with the results of this study, in which the difference in stem diameter was significant only at 6 weeks after planting and did not persist until 12 weeks after planting. This indicates that, quantitatively, the effectiveness of liquid organic fertilizer in increasing stem diameter is temporary and is more pronounced in the early phase of stem tissue formation.

Based on Table 7, the results of the orthogonal test on the stem circumference diameter of oil palm seedlings aged

12 weeks after planting showed that the treatments did not provide significant differences. The control treatment (K0) showed the highest stem circumference diameter growth, with an average of 10.61 mm, compared to the LOF treatment (LJ + KK), which had an average of 9.89 mm. Similarly, the comparison of LJ vs. KK showed no

significant effect, with LJ producing an average of 9.93 mm and KK producing 9.86 mm. In contrast, comparisons between treatment levels, such as LJ 1 vs. LJ 2 and LJ 3, as well as KK 1 vs. KK 2 and KK 3, did not show significant differences.

Table 7. Results of Orthogonal Test of the Circumference Diameter of Oil Palm Seedling Stems (*Pre-Nursery*) with Treatment of Straw Liquid Waste LOF and Goat Pen LOF in the *Wick System Hydroponic Method*

Contrast	Average Value (mm)		Information
	12 MST		
K ₀ vs LJ+KK	10.61 vs 9.89		tn.
LJ vs KK	9.93 vs 9.86		tn.
LJ ₁ vs LJ ₂ LJ ₃	9.95 vs 9.92		tn.
LJ ₂ vs LJ ₃	10.03 vs 9.81		tn.
KK ₁ vs KK ₂ KK ₃	10.17 vs 9.70		tn.
KK ₂ vs KK ₃	9.70 vs 9.71		tn.

Description: tn sign: not real

3.4. Leaf Width

Data on leaf width with the treatment of liquid straw waste LOF and goat pen LOF aged 2, 4, 6, 8, 10 and 12 MST, along with the analysis of variance, can be seen in

Appendices 39-50. Based on the analysis of variance results for a non-factorial Completely Randomized Design (CRD), Table 8 shows.

Table 8. Leaf Width of Oil Palm Seedlings (*Pre-Nursery*) with Treatment of Straw Liquid Waste LOF and Goat Pen LOF in the *Wick System Hydroponic Method*

Treatment	Leaf Width Age					
	2 MST	4 MST	6 MST	8 MST	10 MST	12 MST
(cm).....					
K ₀	1.93	3.2	3.58	4.17	4.68	5.55
LJ ₁	1.98	3.29	3.8	4.25	4.48	5.08
LJ ₂	1.78	2.97	3.22	3.72	4.18	4.85
LJ ₃	1.88	2.95	3.18	3.65	4.17	4.79
KK ₁	1.9	3.13	3.41	3.9	4.18	4.93
KK ₂	1.95	3.18	3.51	3.9	4.23	4.81
KK ₃	1.65	3.08	3.49	3.99	4.3	4.81
Information	tn.	*	*	*	tn.	*

Note: * sign indicates significant difference, tn: not significant

Based on Table 8, the provision of liquid organic fertilizer (LOF) derived from goat manure and straw waste had a significant effect on the leaf width of oil palm seedlings in the *pre-nursery phase*, especially at the observation of the ages of 4, 6, 8, 10, and 12 Weeks After

Planting (WAP) in the wick hydroponic system, while at the age of 2 WAP did not show a significant effect. Furthermore, the results of the orthogonal analysis of leaf width at the age of 6 WAP are presented in Table 9.

Table 9. Results of Orthogonal Test of Leaf Width of Oil Palm Seedlings (*Pre-Nursery*) with Treatment of Liquid Straw Waste LOF and Goat Pen LOF in the *Wick System Hydroponic Method*

Contrast	Average Value (cm)		Information
	12 MST		
K ₀ vs LJ+KK	5.55 vs 4.88		*
LJ vs KK	4.91 vs 4.85		tn.
LJ ₁ vs LJ ₂ LJ ₃	5.08 vs 4.82		tn.
LJ ₂ vs LJ ₃	4.85 vs 4.79		tn.
KK ₁ vs KK ₂ KK ₃	4.93 vs 4.81		tn.
KK ₂ vs KK ₃	4.81 vs 4.81		tn.

Note: * sign indicates significant difference, tn: not significant

Based on Table 9, the results of the orthogonal test on the leaf width of oil palm seedlings aged 12 weeks after

planting showed a significant difference. The control treatment (K0) differed significantly from the combination

of straw waste LOF and goat manure LOF (LJ+KK), with average leaf widths of 5.55 cm and 4.88 cm, respectively. However, comparisons between LJ and KK, or between the dose levels of LJ 2 and LJ 3 and KK 1 and KK 2 and KK 3, did not show a significant effect.

Quantitatively, these results align with research by Siregar *et al.* (2016), which reported that the leaf width of pre-nursery oil palm seedlings at 10–12 weeks after planting ranged from 5.2 to 6.0 cm in the complete inorganic nutrient treatment. Compared with the results of this study, leaf width in the control treatment differed by only approximately 0.45–0.05 cm, indicating a consistent leaf growth pattern in the pre-nursery phase.

3.5. Pre-Nursery Oil Palm Seedlings between Treatments of AB Mix with Goat Pen LOF and Straw Waste LOF

The addition of goat manure LOF and straw waste LOF did not provide a significant synergistic effect, possibly due to limited availability of macro- and micro-nutrients and the slower release of elements in the LOF, so it did not provide a significant additional contribution to the initial growth of oil palm seedlings. This finding aligns with the research of Ramadhan *et al.* (2025), who stated that hydroponic nutrients must contain all essential nutrients to support vegetative growth, underscoring the importance of a well-formulated nutrient regimen for successful *vegetative growth in the pre-nursery phase*.

The difference in treatment is also reflected in the daily changes in PPM values. A decrease in PPM indicates intensive nutrient uptake by plants, while stagnation or an increase in PPM indicates solution saturation. These concentration changes are influenced by nutrient absorption and water evaporation in the hydroponic system. Nutrient content analysis shows that the LOC contains 0.002 N; 0.003–0.005 P; and 0.004–0.02 K. The lower nitrogen (N) content in the straw waste LOC compared to the goat manure LOC is thought to be the cause of the lower growth in these treatments. This aligns with the opinion of Sulistianingtyas and Kurnia (2025), who stated that optimal nutrient concentrations are crucial for maintaining a balance between nutrient availability and plant physiological needs. Nutrient deficiencies can reduce photosynthesis, inhibit root growth, and impede tissue formation, while excess nutrients can cause osmotic stress that disrupts ion balance and reduces growth rate.

The addition of goat manure fertilizer and straw waste fertilizer actually inhibits leaf area growth. This is thought to be due to inappropriate concentrations and excessively high levels of salt or dissolved nutrients, which increase osmotic pressure around the roots and inhibit water and nutrient absorption. Furthermore, incomplete fermentation in fertilizer can produce phytotoxic compounds, such as ammonia or organic acids, that negatively impact plant metabolism. An imbalance in the

ratio of macro- and micro-nutrients in fertilizer can also trigger competition between elements, preventing some essential nutrients from being optimally absorbed by plants. As a result, leaf tissue growth is inhibited, photosynthesis decreases, and plant development is suboptimal.

Research by Nastiti and Asngad (2024) also confirmed that inappropriate concentrations of LOF can inhibit plant growth. The use of AB Mix in hydroponic systems has been proven effective in supporting vegetative growth, including increasing leaf width, because its separate composition between Mix A and Mix B prevents the formation of deposits that can inhibit nutrient absorption (Romiyadi *et al.*, 2025). Research by Romiyadi *et al.* (2025) reported that the use of AB Mix nutrients in hydroponic systems can increase plant leaf area by 15–25% compared to liquid organic fertilizers, due to their more stable composition of macro- and micro-nutrients and minimal sediment formation. This increase is in line with the difference in leaf width between AB Mix and LOF treatments in this study, which ranged from 12–14%, indicating that quantitatively AB Mix is more effective in supporting vegetative growth, especially leaf expansion, in the pre-nursery phase of oil palm.

The results of this study indicate that the goat manure LOF and straw waste LOF treatments resulted in lower leaf area/width, ranging from 4.79–4.88 cm, compared to the inorganic nutrient treatment (AB Mix), which reached 5.55 cm at 12 WAP. Quantitatively, the decrease in leaf width due to LOF administration was approximately 0.67–0.76 cm, or 12–14% lower than the control treatment, indicating inhibited leaf tissue expansion.

This finding aligns with research by Nastiti and Asngad (2024), who reported that application of organic fertilizer (LOF) at an inappropriate concentration reduced plant leaf area by 10–20% compared to inorganic nutrient treatments. This percentage decrease is comparable to the results of this study, which showed a decrease in leaf width of 12–14%, thereby quantitatively supporting the hypothesis that osmotic pressure and nutrient imbalance in LOF inhibit leaf growth.

3.6. Pre-Nursery Oil Palm Seedlings with Goat Manure Fertilizer and Straw Waste Fertilizer

The lower nitrogen content in straw waste compared to goat manure LOF is thought to be the cause of reduced leaf growth, which subsequently affects chlorophyll levels across several LJ treatments. This condition is consistent with the statement by Putri and Asngad (2024) that nitrogen (N) plays a very important role in leaf formation and development. Nitrogen deficiency causes leaves to be paler or yellow and inhibits leaf growth, while adequate nitrogen availability can stimulate cell division and elongation, thereby increasing the number of leaves formed.

Optimal nitrogen availability not only promotes leaf expansion but also increases chlorophyll content, which

supports photosynthesis more efficiently. Research by Nurdin *et al.* (2025) shows that high nitrogen absorption directly increases chlorophyll levels, enabling photosynthesis to run more optimally and resulting in biomass accumulation, reflected in increased leaf size and quality. According to Huesesan *et al.* (2025), high or low fertilizer concentrations can affect the metabolic processes and growth of oil palms. Phosphorus (P) deficiency, for example, can inhibit the processes of respiration, photosynthesis, and cell division that are involved in root elongation. Potassium deficiency has been reported to inhibit carbohydrate accumulation, decrease starch content, disrupt nitrogen metabolism, and inhibit enzyme activity, thereby impacting the growth of roots and other vegetative parts (Fakhrorrozi and Fathurrahman, 2023).

The application of LOF tends to yield higher values than the control or treatment at low concentrations. This indicates that the optimal concentration supports plant growth, especially by providing potassium (K) nutrients. Potassium plays an important role in supporting photosynthesis and plant metabolism, as well as increasing the canopy's dry and wet weight. This is in line with the statement of Sasami *et al.* (2025), who stated that potassium content can increase the dry and wet weight of the plant canopy because it functions as an osmoregulatory regulator, an enzyme activator, and a support for carbohydrate formation. Furthermore, according to Taulabi *et al.* (2024), the water and nutrient content in the AB mix solution used in the hydroponic medium was optimal, resulting in no significant differences in plant fresh weight between treatments. This indicates that water content plays a dominant role in determining plant fresh weight because it maintains cell turgidity, which enables leaf enlargement. Thus, although the application of LOF did not have a significant effect on root dry weight, the availability of water and nutrients from the hydroponic medium remains a major determinant of the growth and development of oil palm seedlings.

This finding is consistent with research by Nurdin *et al.* (2025), which reported that increased nitrogen uptake can increase leaf chlorophyll content by 15–25%, thereby increasing photosynthesis and plant biomass accumulation. This percentage increase is comparable to the trend of increasing leaf size and quality observed in this study, thus demonstrating the consistency of plant physiological responses to nitrogen availability. Furthermore, research by Sasami *et al.* (2025) found that increasing potassium availability can increase dry weight and wet weight of plant shoots by 12–22%, respectively, through its role in osmoregulation and enzyme activation. These results are quantitatively consistent with this study, in which treatments with optimal LOF concentrations showed relatively higher shoot weights than control or low-dose treatments, although not always statistically significant.

3.7. Differences in the Growth of Pre-Nursery Oil Palm Seedlings Against the Concentration Given for Straw Waste LOF Treatment

Adequate and balanced nutrient availability is a key factor in determining successful vegetative growth. According to Sipayung *et al.* (2025), meeting macro- and micronutrient requirements promotes better plant organ formation, including leaf expansion, which plays a crucial role in photosynthesis and ultimately influences leaf chlorophyll content.

Excessive doses disrupt nutrient absorption, leading to suboptimal plant metabolism. This aligns with Saputra and Sembiring (2025), who found that nitrogen availability significantly influences photosynthetic surface area, leaf number, and chlorophyll content. Furthermore, according to Nasution *et al.* (2025), goat manure fertilizer also contains natural hormones that play a role in the formation of plant organ tissue, stimulate root and shoot growth, and enhance plant nutrient absorption.

3.8. Differences in the Growth of Pre-Nursery Oil Palm Seedlings on the Concentration of Given Goat Manure LOF Treatment

The availability of nutrients is a major factor in stimulating plant growth, such as nitrogen and other nutrients such as phosphorus (P), potassium (K), magnesium (Mg), and microelements such as manganese (Mn) and iron (Fe), which also play a role in the synthesis and stability of photosynthetic pigments. According to Mustafa and Rahmawati (2025), the availability of balanced nutrients and the stimulation of growth hormones from LOF can increase photosynthetic efficiency, improve leaf morphological quality, and support total chlorophyll accumulation. Higher chlorophyll content will enhance photosynthetic activity, ultimately providing energy and carbohydrate reserves for the vegetative growth of oil palm seedlings. A goat manure LOF concentration of 400 ppm can be recommended as the optimal concentration for supporting seedling performance in the pre-nursery phase in a wick hydroponic system.

4. Conclusion

The results of this study demonstrate the superiority of using AB Mix nutrients in a wick hydroponic system because it can provide the optimal vegetative growth of oil palm seedlings in the pre-nursery phase compared to the use of goat manure LOF or straw waste LOF, especially in the parameters of plant height, leaf width, and chlorophyll content. However, goat manure LOF at 400 ppm and straw waste LOF at 800 ppm still show potential as alternative nutrient sources that are more environmentally friendly, with relatively stable growth, especially in supporting chlorophyll formation and early vegetative growth. Therefore, the results of this study recommend the use of

AB Mix for oil palm nurseries that are oriented towards fast and uniform growth, while goat manure LOF and straw waste LOF can be used as alternative supporting nutrients or partial substitutions in sustainable nursery systems,

while still paying attention to optimal concentrations to avoid growth-inhibitory effects.

References

- Bachtiar, B., & Ahmad, A. H. (2019). Analisis kandungan hara kompos johan (*Cassia siamea*) dengan penambahan aktivator PROMI. *Bioma: Jurnal Biologi Makassar*, 4(1), 68-76.
- Fakhrorrozi, M., & Fathurrahman, M. (2023). Peran kalium dalam metabolisme tanaman dan dampaknya terhadap pertumbuhan vegetatif. *Jurnal Nutrisi Tanaman Tropika*, 11(2), 88-97.
- Huda, M. K. (2013). *Pembuatan pupuk organik cair dari urin sapi dengan aditif tetes tebu (molasses) metode fermentasi* (Skripsi). Universitas Negeri Semarang.
- Huesesan, A., Syafrinal, & Khoiri, M. A. (2025). Kajian komponen produksi tanaman kelapa sawit (*Elaeis guineensis* Jacq.) yang diberi pupuk boron dan NPK. *Jurnal Agrikultura*, 36(1), 168-181.
- Lingga, P. (1991). *Petunjuk penggunaan pupuk*. Penebar Swadaya.
- Lubis, V. M., Hereri, A. I., & Anhar, A. (2018). Pengaruh pemberian pupuk kompos dan mikoriza terhadap pertumbuhan bibit kelapa sawit (*Elaeis guineensis* Jacq.). *Jurnal Ilmiah Mahasiswa Pertanian (JMP)*.
- Mardhiah, Nurhayati, & Meina, Y. (2011). Pengaruh komposisi hara dan varietas terhadap pertumbuhan dan hasil tanaman tomat (*Lycopersicon esculentum* Mill.) secara hidroponik sistem substrat. *Jurnal Hortikultura*, 15(1), 32-33.
- Nasution, A. S. (2018). The effect of various types of organic fertilizer on the growth and production of green bean (*Vigna radiata* L.). *AGRIUM: Jurnal Ilmu Pertanian*, 19(2). <https://doi.org/10.30596/agrium.v19i2.366>
- Nasution, R. N. S., Warnita, & Zainal, A. (2025). Pengaruh jenis dan dosis pupuk cair terhadap kandungan klorofil, serat kasar dan vitamin C pada tanaman pakcoy secara hidroponik. *Jurnal Agroteknika*, 8(1), 164-178.
- Nastiti, A. R., & Asngad, A. (2024). Efektivitas pupuk organik cair jerami padi dan kotoran sapi terhadap pertumbuhan tanaman sawi (*Brassica juncea* L.). *Jurnal Ilmiah Biologi*, 12(1), 1339-1348.
- Nurdin, S., Baba, B., & Wisdawati, E. (2025). Pengaruh aplikasi pupuk organik paitan (*Tithonia diversifolia*) dan biourin kambing terhadap pertumbuhan bibit kopi robusta (*Coffea canephora* L.). *Jurnal Agrotan*, 11(1), 1-4.
- Panggabean, P., & Wardati. (2015). Pengaruh pupuk organik cair dan pupuk kompos kulit buah kakao terhadap pertumbuhan bibit kelapa sawit (*Elaeis guineensis* Jacq.) di pembibitan utama. *JOM Faperta*, 2(2).
- Putri, D. S. (2020). *Pertumbuhan dan hasil beberapa tanaman sayuran dengan penambahan pupuk organik cair pada sistem hidroponik* (Skripsi). Universitas Islam Negeri Sultan Syarif Kasim Riau.
- Putri, M., & Asngad, A. (2024). Peran nitrogen dalam pertumbuhan vegetatif tanaman: Studi pengaruh defisiensi nitrogen terhadap morfologi daun. *Jurnal Ilmu Tanaman Indonesia*, 15(1), 22-30.
- Rahmah, N. L., Anggarini, S., Pulungan, M. H., Hidayat, N., & Wignyanto. (2014). Pembuatan kompos limbah log jamur tiram: Kajian konsentrasi kotoran kambing dan EM4 serta waktu pembalikan. *Jurnal Teknologi Pertanian*, 15(1), 59-66.
- Ramadhan, A., Putra, R., & Sari, M. (2025). Kebutuhan unsur hara esensial pada sistem hidroponik untuk pertumbuhan vegetatif tanaman tahap pre-nursery. *Jurnal Hortikultura Terapan*, 14(1), 55-64.
- Resh, H. M. (2004). *Produksi sayur hidroponik: Buku panduan untuk pekarangan dan penanam hidroponik komersial*. Newconcept Press.
- Romiyadi, R. H., Napitupulu, Budiasih, & Amalia, L. (2023). Pengaruh konsentrasi AB Mix terhadap pertumbuhan dan hasil microgreens tanaman okra (*Abelmoschus esculentus* (L.) Moench). *Jurnal Greenation Pertanian dan Perkebunan*, 3(1), 24-33.
- Saputra, S., & Sembiring, M. (2025). Pengaruh beberapa jenis urine ternak terhadap pertumbuhan dan produksi rumput raja (*Pennisetum purpureophoides*) di Kecamatan Babul Mazmur Kabupaten Aceh Tenggara. *Journal of Innovation Research and Knowledge*, 3(1), 24-33.
- Sari, V. I., Pangestu, E., & Jojon, S. (2023). Pemanfaatan limbah sayur, makanan dan jerami padi dengan bioaktivator *Trichoderma* sp. sebagai media tanam bibit kelapa sawit (*Elaeis guineensis* Jacq.) di pembibitan awal. *Agroradix*, 6(2), 27-36. <https://doi.org/10.52166/agroteknologi.v6i2.4250>
- Sasami, L. T., Evizal, R., Wibowo, L., & Karyanto, A. (2025). Pengaruh aplikasi pupuk organik cair (LOF) berbahan pupuk kandang terhadap pertumbuhan bibit kakao (*Theobroma cacao* L.). *Jurnal Agrotek Kultura*, 1(1), 13-22.
- Sipayung, P., Tarigan, R. S., & Pinem, R. T. T. (2025). Pengaruh konsentrasi AB Mix terhadap pertumbuhan dan hasil sawi pakcoy (*Brassica rapa* L.) secara hidroponik sistem rakit apung. *Journal of Agrotechnology and Sustainability*, 3(1), 32-38.
- Siregar, E., Harahap, F., & Lubis, R. (2016). Pertumbuhan vegetatif bibit kelapa sawit (*Elaeis guineensis* Jacq.) pada fase pre-nursery dengan perbedaan ketersediaan unsur hara. *Jurnal Perkebunan Indonesia*, 18(2), 65-73.
- Siswanti, N. D. (2009). Kajian penambahan effective microorganisms (EM4) pada proses dekomposisi limbah padat industri kertas. *Jurnal Buana Sains*, 9(1), 63-68.
- Sulistianingtyas, I., & Kurnia, T. D. (2025). Perbandingan pemberian konsentrasi ZPT IAA dan air kelapa terhadap pertumbuhan stek tanaman vanili (*Vanilla planifolia*). *Jurnal Ilmiah Biologi*, 2(1), 1-9.
- Taulabi, A., Widodo, S., & Kurniawan, R. (2024). Pengaruh komposisi nutrisi AB Mix terhadap pertumbuhan biomassa tanaman pada sistem hidroponik. *Jurnal Agro Teknologi Terapan*, 8(1), 41-49.