JUATIKA
JURNAL AGRONOMI TANAMAN TROPIKA
VOL. 8 No. 2 May 2026

DOI :https://doi.org/10.36378/juatika.v8i2.5504
eissn 2656-1727
pissn 2684-785X
pages : 736 – 744

REVIEW ARTICLE **Open Access**

Growth Morphology Seeds Oil palm (*Elaeis guineensis* Jacq.) DXP PPKS Simalungun Variety under pressure Salinity During Phase *Pre-Nursery*

Alvi Ismu Azhar Panjaitan[1,*], Eka Bobby Febrianto[1], Sri Murti Tarigan[1], Wagino[1]

Abstract

This study aims to understand the morphological and physiological responses of coconut oil palm (*Elaeis guineensis* Jacq.) variety DxP PPKS Simalungun seeds to salinity stress during the pre-nursery phase. High-quality seeds are crucial for the successful growth and productivity of coconut oil palm plants in the field. The experiment employed a randomized group design with three salinity levels: no salinity, moderate salinity, and high salinity. Each treatment was repeated three times, with 10 seeds per repetition. Observed variables included plant height, stem diameter, number of leaves, chlorophyll content, root length, shoot length, fresh weight, volume, and dry weight of the plants. Data were analyzed using various methods of analysis of variance (ANOVA) followed by Duncan's multiple range test (DMRT) at a 5% significance level when significant effects were detected. The results showed that moderate salinity induced the best growth response, particularly in stem diameter from week 2 to week 8, as well as in the fresh weight of roots and shoots. Plant height was superior under non-saline conditions only during the third week, while the number of leaves and chlorophyll content showed no significant differences. This study indicates that DxP PPKS Simalungun coconut oil palm seeds possess good tolerance to salinity stress during the pre-nursery phase.

Keywords: Chlorophyll Content, Nurseries Beginning, Plant Physiology, Salt Tolerance, Vegetative Growth

1. Introduction

Coconut palm oil (*Elaeis guineensis* Jacq.) is one of the plantation commodities that plays an important role in the Indonesian economy. The Directorate General of Plantations (2010) designated coconut palm oil as a strategic national commodity, while the Coordinating Ministry for Economic Affairs of the Republic of Indonesia (2021) affirmed that coconut palm oil significantly contributes to economic, social, and environmental aspects through job creation, improvement of foreign exchange earnings, and the development of plantation areas. However, the development of coconut palm oil still faces various environmental constraints, one of which is soil salinity, commonly found in coastal areas, tidal lands, and marginal lands (Silalahi et al., 2024).

Salinity is a fundamental problem in plant cultivation because high salt content in the soil can cause osmotic stress, inhibiting the absorption of water and nutrients by plant roots. Additionally, the accumulation of Na^+ and Cl^- ions within the plant disrupts cellular ion balance, reduces photosynthetic activity, inhibits chlorophyll formation, and suppresses cell division and elongation. These effects impair root and crown growth, thereby reducing seed quality. In coconut and oil palm plants, this issue becomes more severe during the pre-nursery phase because the seeds are at in early stage of root development and are therefore more vulnerable to environmental stress. If salinity stress (Zebua, 2024) persists continuously from the nursery phase, subsequent plant growth can be adversely affected, potentially reducing productivity in the field.

The DxP PPKS Simalungun variety, known as a superior variety, has the potential for high yield and sufficient adaptability across a wide range of environmental

*Correspondence: aiapanjaitan@gmail.com
1) Institut Teknologi Sawit Indonesia - Jl. Willem Iskandar (Jl. Pancing), Komplek LPP Agro Nusantara, Kota Medan, Sumatera Utara 20226, Indonesia

conditions. However, scientific information regarding the response of this variety to salinity stress during the early nursery phase remains very limited. Research by Madusari et al. (2024) in the early nursery phase showed that stress conditions cause a decline in the growth of coconut palm oil seedlings, particularly in plant height, stem diameter, and leaf number, compared to normal conditions. Another study by Sianipar (2024) during the main nursery phase also reported that environmental stress results in reduced root and crown growth, as well as lower biomass accumulation in plants. These findings indicate that coconut palm oil seedlings exhibit growth responses from the early phase when exposed to stress conditions. However, previous research has largely focused on the general effects of water stress. It has not specifically examined the morphological and physiological responses of DxP PPKS Simalungun coconut palm oil seedlings to salinity stress during the pre-nursery phase.

This study is novel in that it tests the morphological and physiological responses of coconut palm oil seed varieties DxP PPKS Simalungun to various salinity levels from the pre-nursery phase onward, with comprehensive observations throughout. It not only examines vegetative growth parameters such as plant height, stem diameter, and leaf number but also evaluates chlorophyll content, root characteristics, shoot traits, and plant biomass as indicators of seed tolerance to salinity stress. Therefore, the results of this study are expected to provide scientific information on the adaptive capacity of the DxP PPKS Simalungun varieties under saline conditions, which can serve as a basis for managing coconut oil palm nurseries on land with specific salinity levels.

2. Material and Methods

This study was conducted at the Laboratory and Home Glass Institute of Technology Sawit Indonesia in Medan, North Sumatra, located at approximately 3°35' N and 98°40' E, with an elevation of about 25 meters above sea level (masl). The experiment was arranged in a completely randomized design with one factor treatment: salinity level. The salinity levels used were S0 = 0 mmhos NaCl, S1 = 5–6 mmhos NaCl, and S2 = 6–7 mmhos NaCl. Each treatment was repeated three times, with 10 seeds per repetition, resulting in a total of 90 seeds. Before treatment, the seeds were maintained until they were 4 weeks old.

The observed parameters in this study included plant height, stem diameter, and the number of leaves, which were recorded every Sunday for eight weeks. Leaf chlorophyll content was measured from the fourth to the eighth week. At the end of the study, additional measurements were taken, including root length, shoot length, fresh root weight, fresh crown weight, root volume, crown volume, dry root weight, and dry shoot weight after seed removal. Plant height was measured using a meter stick, stem diameter was measured with a Vernier caliper, and the number of leaves was counted from fully expanded leaves. Root volume was determined using the water displacement method. Chlorophyll content was measured using a chlorophyll meter (SPAD). Dry weight was determined by oven-drying the samples to constant weight.

The research used various supporting tools, including a meter, a caliper slide, a digital scale, a drying oven, glassware, and a chlorophyll meter (SPAD). Data processing was performed using Microsoft Excel 2019 software. The obtained data were analyzed using analysis of variance (ANOVA). If the analysis results indicate a significant effect, further testing is conducted using Duncan's Multiple Range Test (DMRT) at the 5% significance level.

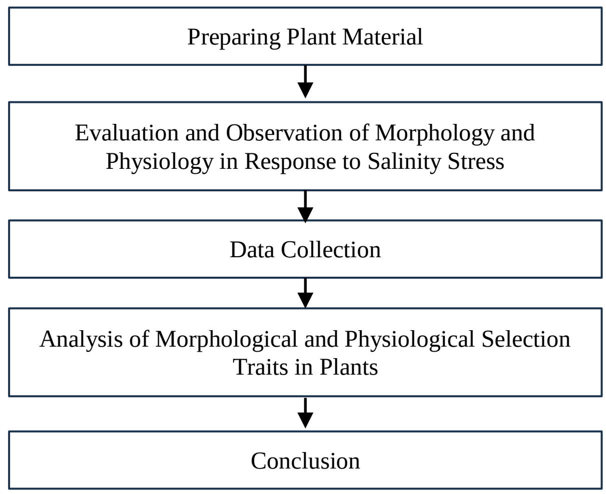

Figure 1. Research Flow

3. Results and Discussion

3.1. Growth morphology of seeds for 8 weeks

Salinity treatment elicits varying responses in several morphological parameters of seeds during the pre-nursery phase. At higher parameter levels, plants under the S0 treatment showed significant superiority only in the third week, with an average height of 12.02 cm. In the other weeks, no significant differences were observed between treatments. Interestingly, by the end of the observation period, the tallest seedlings were found in the S1 treatment, reaching 20.52 cm—an increase of approximately 1.68% compared to S0, which measured 20.18 cm. The S2 treatment resulted in the shortest seedlings, averaging 19.55 cm. These results indicate that DxP PPKS Simalungun seedlings can still tolerate the current level of salinity during the initial growth phase. According to Munns and Tester (2008), during the early growth phase, plants under salt stress can still maintain turgor pressure, so cell expansion is not yet significantly affected.

The research results show a relatively small decline in plant height compared to the study by Gunady et al. (2023), which reported that applying 200–300 mM NaCl to coconut palm seedlings reduced plant height by 10–15% reduction in plant height compared to the control. In this study, the difference in plant height between the best treatment (S1) and the highest salinity treatment (S2) at the eighth week was only about 4.73%. This indicates that the salinity levels used are still within the tolerance range for oil palm seeds during the pre-nursery phase. These results are also more stable than those of Firmansyah (2018), which showed that salinity conditions caused a more significant decline in vegetative growth in four-month-old seeds.

Table 1. Table Average Plant Height Value

Observation Time	Treatment		
	S0	**S1**	**S2**
M1	8.25 ± 0.31 a	8.44 ± 0.24 a	7.87 ± 0.25 a
M2	10.09 ± 0.32 a	10.53 ± 0.35 a	9.63 ± 0.28 a
M3	12.02 ± 0.46 a	10.57 ± 0.35 b	9.87 ± 0.28 b
M4	13.92 ± 0.64 a	14.19 ± 0.47 a	13.09 ± 0.42 a
M5	16.20 ± 0.70 a	16.86 ± 0.59 a	15.27 ± 0.51 a
M6	18.08 ± 0.71 a	18.29 ± 0.48 a	16.82 ± 0.58 a
M7	19.01 ± 0.67 a	19.45 ± 0.48 a	18.41 ± 0.53 a
M8	20.18 ± 0.66 a	20.52 ± 0.55 a	19.55 ± 0.54 a

*Numbers followed the same letter in the same column /row show different No real according to the DMRT test at 5% level

Figure 2. Average Plant Height

The increase in stem diameter observed in this research is better compared to the study by Madusari et al. (2024), who reported that salinity conditions cause a decrease in stem diameter of coconut palm oil seeds by approximately 8–12% under normal conditions. Furthermore, research by Tambunan and Madusari (2021) indicates that salinity stress in certain hybrid oil palms results in reduced stem enlargement due to disturbance in osmotic cell balance. However, in this study, the S1 treatment was still capable of maintaining, or even increasing, the stem diameter. Therefore, this parameter appears to be the most sensitive morphological indicator for detecting the seed response to salinity.

The number of leaves did not differ significantly across treatments. In the 8th week, the number of leaves ranged between 3.03 and 3.07 strands. The difference between treatments was only around 1.3%, indicating that this parameter is not sufficiently sensitive to describe the influence of salinity. The research results are relatively consistent with the study by Yeza (2025), which showed that the number of leaves in oil palm seeds during the initial stress phase declined only slightly, of about 1–2 strands, compared to the control. Similarly, research by Manurung (2022) explains that during the early growth phase, oil palm plants tend to maintain leaf formation to ensure that photosynthesis continues normally.

Table 2. Table Average Stem Diameter Value

Observation time	Treatment		
	S0	**S1**	**S2**
M1	3.09 ± 0.10 a	3.42 ± 018 a	3.16 ± 0.10 a
M2	3.70 ± 0.09 ab	3.88 ± 0.07 a	3.50 ± 0.08 b
M3	4.15 ± 0.09 ab	4.27 ± 0.07 a	3.70 ± 0.08 b
M4	4.59 ± 0.18	4.69 ± 0.15 a	4.07 ± 0.16 b
M5	5.25 ± 0.21 ab	5.29 ± 0.13 a	4.44 ± 0.14 b
M6	5.40 ± 0.20 ab	5.76 ± 0.15 a	4.91 ± 0.18 b
M7	5.68 ± 0.21 ab	6.32 ± 0.11 a	5.27 ± 0.18 b
M8	5.78 ± 0.21 ab	6.65 ± 0.14 a	5.71 ± 0.20 b

*Numbers followed by the same letter in the same column /row show different No real according to the DMRT test at 5% level

Figure 3. Stem Diameter

Table 3. Average Value of Total Leaf

Observation Time	Treatment		
	S0	S1	S2
M1	1.87 ± 0.06 a	1.90 ± 0.05 a	1.90 ± 0.07 a
M2	2.00 ± 0 a	2.03 ± 0.03 a	2.10 ± 0.07 a
M3	2.10 ± 0.07 a	2.17 ± 0.06 a	2.17 ± 0.08 a
M4	2.13 ± 0.07 a	2.23 ± 0.07 a	2.23 ± 0.09 a
M5	2.77 ± 0.09 a	2.70 ± 0.08 a	2.70 ± 0.08 a
M6	2.83 ± 0.08 a	2.90 ± 0.05 a	2.83 ± 0.06 a
M7	3.03 ± 0.07 a	3.07 ± 0.06 a	3.03 ± 0.08 a
M8	3.03 ± 0.07 a	3.07 ± 0.06 a	3.03 ± 0.08 a

*Numbers followed the same letter in the same column /row show no real differences according to the DMRT test at 5% level

Figure 4. Number of Leaf Blades

In general, weekly observations indicate that the effects of salinity on seedling morphology have not yet appeared evenly across all parameters, but are beginning to become apparent in stem diameter. In other words, the morphological response of seedlings is specific depending on the observed characteristics. Plant height and leaf number remain relatively stable, while stem diameter more quickly captures differences in response across treatment levels. This pattern reinforces the notion (Firmansyah, 2018) that salinity stress in oil palms elicits different levels of sensitivity in each organ. Similarly, Madusari et al. (2024) demonstrated that not all seedling growth parameters change in the same pattern under drought stress.

3.2. Response physiology of seeds based on chlorophyll content

The chlorophyll content showed no significant differences throughout the treatments. The chlorophyll value increased from a range of 39.69–42.53 SPAD in the 4th week to about 51 SPAD at 8 weeks. Quantitatively, the chlorophyll content increased by approximately 22–29% during the observation period. This result indicates that the photosynthetic system in the seeds remains functional even under salinity conditions.

These results are better compared to those reported by Chan et al. (2017), who stated that severe salinity stress can reduce chlorophyll content by more than 20%, leading to damage to photosynthetic pigments. In this study, no significant decrease in SPAD values was observed overall, suggesting that the applied salinity level remains within the physiological tolerance limit of oil palm seeds. Similar findings were reported by Muhammad et al. (2021), who found that young coconut palm seeds are still capable of maintaining chlorophyll content under light stress conditions.

Table 4. Table Average Chlorophyll Value

Observation Time	Treatment					
	S0		S1		S2	
M4	39.69 ± 0.96	a	40.35 ± 1.04	a	42.53 ± 1.23	a
M5	43.24 ± 1.51	a	43.67 ± 0.69	a	44.13 ±0.73	a
M6	47.56 ± 1.10	a	47.17 ± 0.59	a	47.72 ± 0.56	a
M7	51.85 ± 1.03	a	50.74 ± 0.88	a	50.75 ± 0.70	a
M8	51.30 ± 1.22	a	51.06 ± 0.89	a	51.09 ± 0.72	a

*Numbers followed by the same letter in the same column /row show no real differences according to the DMRT test at the 5% level

These results indicate that the seedlings maintained their basic physiological functions during the pre-nursery phase. Thus, despite differences in several morphological parameters, the plants remained physiologically relatively stable. (Wahyuningsih, 2025) explains that the initial physiological response in young oil palms is often not immediately followed by sharp visual changes in all parameters. Therefore, the stability of chlorophyll content in this study can be interpreted as an indication that the level of stress applied was still within the range that the seedlings can tolerate.

3.3. Growth morphology after demolition seeds

At the end of the observation, the morphological response of the seedlings was assessed by measuring the roots and shoots. The results showed that the S1 treatment produced the highest values for root and shoot fresh weight, at 0.52 g and 1.77 g, respectively, higher than those of S0 and S2. This superior wet weight indicates that the plants in this treatment still maintained high fresh biomass and tissue water content. (Bu et al., 2024) explained that in the early phase of stress, osmotic adjustment is often first reflected in the tissue's ability to retain water. The results of this study are better than those of Sianipar (2024), which showed that stressful environments can reduce the fresh biomass of oil palm seedlings by more than 20%. Additionally, Rajesra (2025) explains that young roots are the first organ to be affected by salinity because they are directly in contact with the salt solution. However, in this study, the roots of S1 reached a length of 21.13 cm, which is 7.75% longer than the control. This indicates the ability of the roots to adapt by maintaining water and nutrient absorption under current salinity conditions.

In contrast, treatment S0 showed the highest values in root volume and shoot volume, namely 1.32 mL and 4.45 mL, respectively. These values are higher than those of S1, which reached only 0.62 mL for root volume and 2.90 mL for shoot volume, and S2, which recorded 0.43 mL and 3.25 mL. Quantitatively, the root volume in S0 increased by about 51.52% compared to S1 and 67.42% compared to S2. For crown volume, S0 was also higher, approximately 53.44% more than S1 and 26.97% more than S2. These findings suggest that the condition without salinity provides the most supportive environment for the growth and development of plant organs. In other words, the control treatment offers more optimal conditions for the expansion of plant tissues.

This result aligns with the study by Anggraini (2024), which reported that salinity stress causes a decrease in the volume and development of plant organs due to disturbances in cell division and enlargement. According to this study, biomass growth and network expansion decrease by around 20–35% under salinity treatment compared to the control. The decrease observed in this research is relatively small, especially in the crown volume parameter, which decreased by only about 26.97% in S2 compared to S0. This indicates that DxP PPKS Simalungun seeds still possess sufficient adaptive ability under the given salinity level.

Table 5. Average morphological parameters after germination of seeds

Observation Parameters	Treatment					
	S0		S1		S2	
Root length	19.61 ±	a	21.13 ±	a	18.33 ±	a
Length of the title	19.16 ± 0.83	a	19.66 ± 0.56	a	19.06 ± 0.59	a
Wet weight of roots	0.41 ± 0.03	a	0.52 ± 0.05	a	0.36 ± 0.04	a
Wet weight of the cover	1.69 ± 0.10	a	1.77 ± 0.10	a	1.35 ± 0.11	b
Root volume	1.32 ± 0.36	a	0.62 ± 0.13	a	0.43 ± 0.09	a
Volume title	4.45 ± 0.71	a	2.90 ± 0.29	a	3.25 ± 0.25	a
Dry weight of roots	0.13 ± 0.02	a	0.12 ± 0.009	a	0.11 ± 0.02	a
Dry weight of the cover	0.38 ± 0.01	a	0.41 ± 0.02	a	0.33 ± 0.03	a

*Numbers followed by the same letter in the same column /row show no real differences according to the DMRT test at 5% level

Figure 5. Root Length

Figure 6. Header Length

Figure 7. Weight Wet and Dry Root

Figure 8. Weight Wet and Dry Title

Figure 9. Root Volume

Figure 10. Header Volume

Sitinjak (2026) explains that osmotic pressure can limit cell enlargement and reduce organ expansion when ion accumulation increases. In drought conditions, Setiowati et al. (2021) also showed that decreased water availability can limit seed development morphology, although not all parameters are necessarily affected simultaneously.

Temporarily, the length of the roots, dry root weight, and dry shoot weight showed results that are not significantly different. However, the longer roots in S1 reached 21.13 cm, approximately 7.75% longer than S0 (19.61 cm) and 15.28% longer than S2 (18.33 cm). This trend remains noteworthy because roots are the first organs to come into direct contact with the salt solution (Elfina et al., 2025).

Overall, the results of this study are better than those of Aminullah et al. (2025), which reported that stressful environments could reduce root length in oil palm seedlings by more than 10% compared to the control. In this study, treatment S1 was still capable of increasing root length compared to the control, indicating an adaptive response of the roots to maintain water and nutrient absorption under current salinity conditions.

The dry shoot weight in S1 reached 0.41 g, slightly higher than S0 with 0.38 g and S2 with 0.33 g. The difference shows an improvement of about 7.89% compared to the control and 24.24% compared to S2. These results indicate that the accumulation of dry biomass in the plant can still be maintained under moderate salinity levels. Research by Mangin et al. (2017) explains that salt-tolerant plants generally remain capable of maintaining dry biomass through mechanisms such as osmotic adjustment and efficient water use.

3.4. Implications of seed tolerance to salinity stress

Based on all observed parameters, the DxP PPKS Simalungun variety shows a sufficient ability to adapt well to salinity during the pre-nursery phase. This is evidenced by the dominant results that are not significantly different in key parameters such as plant height, morphology, and physiology. Quantitatively, only a few parameters showed significant differences, particularly stem diameter and wet shoot weight. In contrast, other parameters such as the number of leaves, chlorophyll content, root length, and dry weight of the plant remained relatively stable.

At the end of the observation, plant height in the medium salinity treatment (S1) reached 20.52 cm, which is slightly taller—about 1.68%—compared to the control (S0), which was 20.18 cm. The stem diameter in S1 reached 6.65 mm, an increase of approximately 15.05% compared to S0, which was only 5.78 mm. These results indicate that the level of salinity applied has not yet caused a drastic decline in coconut palm seedling growth.

Quantitatively, these results show a better response than those reported by Irawan et al. (2025), who found that salinity stress reduced vegetative growth in coconut palm oil by 20–40% compared to the control, particularly in biomass and growth parameters. In this study, the reductions in the main parameters were relatively small. For example, the wet shoot weight in the highest salinity treatment (S2) was only 1.35 g, a decrease of about 20.11%

compared to the control, which had a weight of 1.69 g. This value is still lower than the reported decline levels (Arifin, 2026). This indicates that the DxP PPKS Simalungun variety has a sufficient tolerance capacity to withstand light salinity stress during the early growth phase.

Although the apparent tolerance observed in this study is more accurately understood as the ability of seeds to survive and adapt to the tested salinity levels, it does not imply that salinity always has beneficial effects. Treatment S1 still shows the best response in several important parameters, especially stem diameter, wet root weight, and wet shoot weight. The stem diameter in S1 reaches 6.65 mm, which is approximately 16.46% larger than in S2 (5.71 mm). Meanwhile, wet root weight in S1 reached 0.52 g, an increase of about 44.44% compared to S2, which is only 0.36 g. The wet shoot weight in S1 also increased by around 31.11% compared to S2. These findings indicate that the current salinity level is still tolerated and may even trigger adaptive responses in several seed growth parameters of the seeds.

On the other hand, the control treatment (S0) remains superior in plant height at the third week, as well as in root volume and shoot volume at the end of the observation. The root volume in S0 reached 1.32 mL, which is approximately 51.52% higher than in S1 and 67.42% higher than in S2. Similarly, the crown volume in S0 was 4.45 mL, an increase of about 53.44% compared to S1. Overall, these results suggest that the condition without salinity provides the most optimal environment for plant organ expansion and growth.

This aligns with the findings of Aminullah et al. (2025), who reported that increased salinity causes a decrease in tissue volume in plants due to disturbances in cell enlargement and osmotic balance. Their study indicated that biomass and organ expansion decline by approximately 25–35% at high salinity levels, whereas in this study, many parameters remained relatively stable, with only a low decline.

In the context of stress in different environments, Rodríguez et al. (2021) also reported that oil palm seeds are still capable of maintaining several growth components under stress conditions that have not yet reached severe levels. Their research showed that stress can reduce biomass growth by more than 20%, but some parameters in this study still showed improvement in the S1 treatment.

Therefore, this study demonstrates that the DxP PPKS Simalungun variety has sufficient capacity for adaptation to salinity during the pre-nursery phase, especially at the current salinity level.

4. Conclusion

Salinity treatment during the pre-nursery phase indicates that the DxP PPKS Simalungun variety of coconut palm oil has a sufficient ability to adapt well to salinity stress. Most morphological and physiological parameters did not show significant differences, suggesting that the seeds remain capable of maintaining normal growth at the tested salinity levels.

Treatment S1 provided the best growth response, especially in stem diameter, wet root weight, and wet shoot weight. The stem diameter in S1 reached 6.65 mm, which is approximately 15.05% larger than in the control (S0). Additionally, wet root weight increased by about 26.82% compared to S0. Furthermore, chlorophyll content remained relatively stable, indicating that salinity at this level has not yet significantly disrupted the physiological processes of the seeds.

These results demonstrate that the current salinity level can still be tolerated by the coconut oil palm seedlings of the DxP PPKS Simalungun variety during the early growth phase. Therefore, this variety is recommended for nursery development on land with light to moderate salinity levels, especially during the pre-nursery phase.

References

Aminullah, E., Rauf, A., & Hanum, C. (2025). Evaluasi pertumbuhan dan produksi kelapa sawit (*Elaeis guineensis* Jacq.) aksesi liar asal Kamerun di lingkungan kebun percobaan PPKS Adolina. *Agrium, 28*(2).

Anggraini, E. (2024). *Respons pertumbuhan bibit kelapa sawit (Elaeis guineensis* Jacq.) terhadap pemberian trichokompos limbah kelapa sawit pada berbagai dosis di pembibitan awal*. Universitas Jambi.

Arifin, S. (2026). Evaluasi kesesuaian lahan kelapa sawit pada lahan gambut di Pesisir Selatan, Sumatera Barat. *Jurnal Tanah dan Sumberdaya Lahan, 13*(1), 42–51. https://doi.org/10.21776/ub.jtsl.2026.013.1.4

Bu, J., Gan, G., Chen, J., Su, Y., & Yuan, M. (2024). *Dryland evapotranspiration from remote sensing solar-induced chlorophyll fluorescence: Constraining an optimal stomatal model within a two-source energy balance model*.

Chan, K., Tatarinova, T. V., Rosli, R., Amiruddin, N., Azizi, N., Amin, M., Halim, A., Shazana, N., Mohd, N., Jayanthi, N., Ponomarenko, P., Triska, M., Solovyev, V., Firdaus-Raih, M., Sambanthamurthi, R., Murphy, D., & Low, E. L. (2017). Evidence-based gene models for structural and functional annotations of the oil palm genome. *Biology Direct, 6*, 1–23. https://doi.org/10.1186/s13062-017-0191-4

Elfina, Y., Sabirunah, A., & Ningsih, W. (2025). Identification of the causes of base rot disease of palm oil in two villages in Kampar and Siak districts of Riau Province. *Jurnal Agronomi Tanaman Tropika (JUATIKA), 7*(1). https://doi.org/10.36378/juatika.v7i1.3819

Firmansyah, E. (2018). Perubahan morfologis dan anatomi kelapa sawit pada rezim air dan salinitas berbeda. *Jurnal Agro, 5*(1), 13–29. https://doi.org/10.15575/1963

Gunady, P. S., Wirianata, H., & Andayani, N. (2023). Respon stress air dan pupuk K terhadap pertumbuhan morfologi kelapa sawit di pembibitan. *AGROFORETECH, 1*, 1596–1600.

Irawan, H., Setyorini, T., & Suryanti, S. (2025). Respon pertumbuhan beberapa varietas bibit kelapa sawit di pre-nursery pada kondisi cekaman kekeringan. *Agroista: Jurnal Agroteknologi, 9*(2), 117–129. https://doi.org/10.55180/agi.v9i2.1203

Kementerian Koordinator Bidang Perekonomian Republik Indonesia. (2021a). *Industri kelapa sawit Indonesia: Menjaga keseimbangan aspek sosial, ekonomi, dan lingkungan*. Kementerian Koordinator Bidang Perekonomian RI.

Kementerian Koordinator Bidang Perekonomian Republik Indonesia. (2021b). *Industri kelapa sawit nasional perkuat kemitraan petani sawit untuk masa depan sawit Indonesia yang berkelanjutan*. Kementerian Koordinator Bidang Perekonomian

RI.

Kementerian Koordinator Bidang Perekonomian Republik Indonesia. (2024). *Industri kelapa sawit berperan strategis bagi perekonomian Indonesia*. Kementerian Koordinator Bidang Perekonomian RI.

Kementerian Pertanian Direktorat Jenderal Perkebunan. (2010). *Peran strategis kelapa sawit*. Kementerian Pertanian RI.

Kementerian Pertanian Direktorat Jenderal Perkebunan. (2021). *Kontribusi minyak kelapa sawit Indonesia mengatasi krisis pangan global*. Kementerian Pertanian RI.

Madusari, S., Sari, V. I., Hardianto, S., & Pirnado, B. (2024). Respons pertumbuhan bibit kelapa sawit pada media tanam kompos limbah organik perkebunan. *Jurnal Galung Tropika, 13*(3), 408–417. https://doi.org/10.31850/jgt.v13i3.1111

Mangin, B., Casadebaig, P., Cadic, E., Blanchet, N., Boniface, M., Carrère, S., & Gouzy, J. (2017). Genetic control of plasticity of oil yield for combined abiotic stresses using a joint approach of crop modelling and genome-wide association. *Plant, Cell & Environment*, 2276–2291. https://doi.org/10.1111/pce.12961

Manurung, A. I. (2022). Performansi morfologi bibit kelapa sawit (*Elaeis quineensis* Jacq.) di pre-nursery pada aplikasi SP-36 dan urea. *Jurnal Darma Agung*, 36–42.

Muhammad, T., Anhar, S., Sitinjak, R. R., Fachrial, E., Pratomo, B. (2021). Respon pertumbuhan bibit kelapa sawit di tahap pre-nursery dengan aplikasi pupuk organik cair kulit pisang kepok. *Agrium, 23*(2). https://doi.org/10.30596/agrium.v21i3.2456

Rajesra, A. R. (2025). *Pengaruh pemberian kompos limbah kelapa sawit terhadap pertumbuhan bibit kelapa sawit (Elaeis guineensis Jacq.) di pembibitan utama*. Universitas Jambi.

Rodríguez, C., Aronco, S. D., Schindler, K., & Wegner, J. D. (2021). Mapping oil palm density at country scale: An active learning approach. *Remote Sensing of Environment, 261*, 112479. https://doi.org/10.1016/j.rse.2021.112479

Setiowati, R. D., Nugroho, K., & Reswari, H. A. (2021). Varietas kelapa sawit toleran genangan: Upaya antisipasi perubahan iklim. *Warta PPKS, 28*(2), 85–94.

Sianipar, A. (2024). *Respons pertumbuhan bibit kelapa sawit (Elaeis guineensis Jacq.) terhadap pemberian kompos limbah kelapa sawit di pembibitan utama*. Universitas Jambi.

Silalahi, C. B., Effendi, A., Lubis, N., & Fadila, H. (2024). Response of nutrient levels of oil palm leaves (*Elaeis guineensis* Jacq.) to polyhalite and KCl fertilizers application in Dystrudepts soil. *Jurnal Agronomi Tanaman Tropika (JUATIKA), 6*(3). https://doi.org/10.36378/juatika.v6i3.3821

Sitinjak, R. R. (2026). *Konsep dan tahapan dasar pemuliaan tanaman (kelapa sawit)*. Universitas Prima Indonesia.

Tambunan, B., & Madusari, S. (2021). Respons pertumbuhan bibit kelapa sawit terhadap bioherbisida saliara di pembibitan awal: The growth responses of oil palm seedling to *Lantana camara* bioherbicide in prenursery. *Jurnal Kultivasi, 20*(2), 91–96. https://doi.org/10.24198/kultivasi.v20i2.32512

Wahyuningsih, A. (2025). Respon pemberian dosis pupuk kieserite terhadap karakteristik fisiologis bibit kelapa sawit (*Elaeis guineensis* Jacq.) varietas Yangambi dan Dumpy pada fase main nursery. *Jurnal Ilmiah Hijau Cendekia, 10*, 52–60. https://doi.org/10.32503/hijau.v10i1.5481

Yeza, T. G. (2025). *Tanggapan delapan hibrida bibit kelapa sawit (Elaeis guineensis Jacq.) terhadap cekaman salinitas*. Universitas Gadjah Mada.

Zebua, A. C. (2024). Application of FMA on soil chemical properties in oil palm (*Elaeis guineensis* Jacq.) plants. *Jurnal Agronomi Tanaman Tropika, 6*(3). https://doi.org/10.36378/juatika.v6i3.3822