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Frond Base Fracture and Oil Palm Production: Quantitative Evidence from Indonesia

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Abstract
The frond base supports the oil palm tree trunk and distributes photosynthesis results. Frond base fracture (*sengkleh*) is thought to reduce plant growth performance and production. This study aims to quantitatively analyze the effect of frond base facture on vegetative and reproductive growth of oil palm. The study was conducted for three months at the KUD Sumber Sawit Makmur oil palm plantation, Central Kalimantan, Indonesia. The method used was an agronomic survey with observations on six plant blocks: three blocks with healthy trees and three with unhealthy trees (there were more than three sengkleh fronds). Three plant samples were observed in each block. The parameters observed included the number of frond bases facture, new frond growth, number of female flowers, number of bunches harvested, and average bunch weight. Data were analyzed using two-factor ANOVA and continued with a 5% DMRT test if there was a significant difference. The results showed that frond base conditions had a very significant effect on all observation parameters. Plants with normal frond bases showed faster new leaf sheath growth, more female flowers, and higher yields than plants with fractured frond bases. These findings confirm that frond bases can be used as important visual indicators in technical decision making in the field.

Keywords—Average Weight Bunch; Female Flowers; Frond Base; Harvest Bunches; Palm Oil.

Introduction

The frond base is an important part of the morphological structure of the oil palm (Elaeis guineensis Jacq.), which supports the crown and becomes a distribution route for photosynthesis results to other plant organs. The health of oil palm leaves significantly affects oil production (Herman et al., 2024). Damage to the base of the leaf is characterised by hanging petioles (*Sengkleh*). In the oil palm production system, the stability and health of the frond base directly affect vegetative growth, flower formation, and bunch production results. Physiological changes can inhibit growth and yield, emphasising the importance of maintaining leaf health for optimal

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oil palm productivity (Neto et al., 2021). Therefore, understanding the role of the frond base in supporting plant performance is important as a basis for technical decision making in the field.

Research by Xu et al. (2021) shows that oil palms at the productive plant stage will allocate more resources to fruits than leaves, increasing fruit yield. According to Konstantis et al (2022), structurally damaged leaf parts can reduce photosynthetic efficiency and inhibit the formation of female flowers. Frond bases facture correlates with increased leaf sheaths and decreased plant canopy stability. On the other hand, Levionnois et al. (2021) state that weak leaves are more susceptible to damage. Plants with strong leaf structures support the overall strength of oil palms, increasing reproductive success and fruit formation (Gintoron et al., 2023).

Although the frond base has a vital physiological role, few studies quantitatively examine the impact of frond base damage on the growth performance and yield of oil palm. Based on previous studies. The main question in this study is: Does frond base fracture significantly impact the vegetative and reproductive growth of oil palm plants? This problem is important because early identification of frond base fracture symptoms can potentially increase the efficiency of plantation management and plant productivity. This study hypothesises that frond bases that experience fractures will reduce the growth of new fronds, the number of female flowers, and bunch yields. Thus, this study aims to quantitatively analyze the effect of frond base conditions on the growth of new fronds, the emergence of female flowers, bunches harvested and the average weight of oil palm bunches

This study provides an important contribution in filling the knowledge gap regarding the relationship between frond base health and oil palm productivity performance. This study offers a quantitative evidence-based solution to assess frond base conditions as a visual indicator of plant health. By comparing growth and yield parameters between plants with normal and fractured frond bases, this study encourages using an easy-to-conduct observational approach to accelerate early detection and corrective actions. The results are expected to be the basis for developing routine monitoring protocols for frond structures to increase plant productivity sustainably.

Literature Review

According to Dassou et al (2022), leaf health significantly impacts oil palm productivity during the fruit-forming phase. Stress or structural damage to oil palm plants can affect the quality and quantity of reproductive organs (Abubakar et al., 2021). Physiological damage to plants can inhibit vegetative and generative growth (Neto et al., 2021). A study by Konstantis et al (2022) found that physical damage to the frond can reduce photosynthetic efficiency and flower formation. The physical integrity of the frond is crucial for supporting the efficient distribution of photosynthates. Plants in the productive stage will divert their resources toward fruit rather than leaf formation (Xu et al., 2021). Weak or damaged leaves are more susceptible to additional damage, which can reduce the strength of the plant canopy (Levionnois et al., 2021). Meanwhile, Gintoron et al (2023) emphasized that strong and intact leaf structures support reproductive success by increasing the number of flowers and fruit. Overall, previous studies have established a theoretical and empirical basis for the importance of frond structure in oil palm production systems, but have not directly and quantitatively evaluated the impact of frond base fracture on plant performance.

Previous studies has shown that structural damage to the frond can disrupt photosynthesis and nutrient allocation. Damage to the frond base is correlated with a decrease in the number of female flowers and the weight of fresh fruit bunches (Konstantis et al., 2022). Visual monitoring of frond base condition can be used as an early indicator of plant health. Physiological studies also show that structurally healthy plants have better reproductive performance (Gintoron et al., 2023). However, no quantitative approach has directly compared plants with normal and damaged frond

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bases in terms of growth and yield indicators. Previous research has focused more on physiological and visual aspects of frond base fracture, but few have quantitatively tested its impact on oil palm growth and yield. Empirical data statistically comparing normal and damaged frond bases on production performance is available.

This study aims to address this gap by providing quantitative evidence on the impact of frond base fracture on oil palm growth and reproductive parameters. Thus, this study aims to quantitatively analyze the effect of frond base conditions on the growth of new fronds, the emergence of female flowers, bunches harvested, and the average weight of oil palm bunches. The problem addressed is the limited quantitative understanding of how frond base damage affects oil palm productivity. This hampers plantation management's ability to take early corrective action. This study provides a novel contribution using a quantitative approach to evaluating frond base as a visual indicator of oil palm health and productivity.

Research Method

This study used an agronomic survey method. The study was conducted for four months. This study used an agronomic survey method. The study was conducted for three months in one of the oil palm plantations, KUD Sumber Sawit Makmur, Central Kalimantan, Indonesia. Oil palm plantation blocks were selected based on attacks of sengkleh fronds and not. The observation blocks consisted of 3 blocks for healthy trees and three for unhealthy trees. Determination of plant samples based on the number of sengkleh fronds, between 1-3 for healthy and large plants, and above 3 for unhealthy plants. Each observation block took three plant samples, both healthy and unhealthy. Field observations were carried out every 1 week after harvesting in the observation block for 3 months. The first is to count the sengkleh fronds on unhealthy plants. The second is to observe the emergence of new fronds, female flowers, the Number of harvested bunches and Average Bunch Weight. Data were analyzed using two-factor ANOVA analysis with interaction, if significantly different, a 5% DMRT test was carried out.

Results and Discussion

New Frond Base Growth

Analysis of variance (ANOVA) was conducted to determine the effect of leaf stalk condition, leaf stalk growth, and the interaction between the two on the observed variables. The ANOVA results are shown in Table 1.

Table 1. Analysis of New Frond Base Growth

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Frond Base	5.555556	1	5.555556	25	0.000309*	4.747225
Frond Base Growth	0.111111	2	0.055556	0.25	0.782758ns	3.885294
Interaction	0.111111	2	0.055556	0.25	0.782758ns	3.885294
Within	2.666667	12	0.222222			
Total	8.444444	17				

Note: *Significan; ns: Note significan

Table 1 shows the analysis results show that the frond base condition factor significantly affects the growth of new fronds with an F value = 25 and P-value = 0.000309 (<0.05). On the other hand, the frond base growth factor did not show a significant effect (F = 0.25; P = 0.782758), as well as the interaction between the two factors, which was also not significant. This shows that the growth of new fronds is mainly influenced by the condition of the frond base directly, without being influenced by the growth category or a combination of the two. Thus, attention to the condition of the frond base is an important key in managing the vegetative growth of oil palm plants. The frond base condition significantly influences the growth of new fronds in oil palm plants. The structural integrity of the frond base is an important factor in supporting the physiological function of the plant's vegetative. This finding indicates that the impact of frond base damage on crop yields is indirect or long-term. Therefore, maintaining an intact frond base can be part of a plantation management strategy to increase vegetative growth and overall plant productivity potential.

Frond base fracture is the main variable affecting oil palm growth and production, which has not been studied quantitatively, unlike previous studies that focused more on general nutritional and physiological aspects (Dassou et al., 2022; Kamireddy et al., 2023). This study systematically raises structural mechanical aspects, showing that the frond base is not only a structural part, but also an important indicator for the sustainability of new leaf growth. This approach provides a unique methodological contribution and fills a gap in the oil palm agronomy literature. This study opens opportunities for developing field observation strategies based on physical damage as a practical approach to evaluating plant performance.

Addition of Oil Palm Female Flowers

Variance (ANOVA) was analysed to determine the effect of frond base conditions, addition of female flowers, and the interaction between the two on the observed variables. The results of the ANOVA are shown in Table 2.

Table 2. Addition of Oil Palm Female Flowers

Source of Variation	SS	df	MS	F	P-value	F crit
Frond Base	6.722222	1	6.722222	7.5625	0.017602*	4.747225
Female Flower	2.111111	2	1.055556	1.1875	0.338408ns	3.885294
Interaction FB v FF	0.111111	2	0.055556	0.0625	0.939717ns	3.885294
Within	10.66667	12	0.888889			
Total	19.61111	17				

Note: *Significan; ns: Note significan

Table 2 shows that the frond base condition factor significantly affects the number of female flowers that appear, with an F value of 7.5625 and a P-value of 0.017602 (<0.05). On the other hand, the number of female flowers did not have a significant effect (P = 0.338408), as did the interaction between the frond base condition and female flowers, which was also insignificant (P = 0.939717). The increase in the number of female flowers is more influenced by the physical condition of the base of the frond than the number of existing flowers or their interactions. Therefore, observation and management of frond base conditions can be an important indicator in supporting oil palm generative productivity.

Plants with normal frond bases tend to form more female flowers than plants with fractures, indicating that the integrity of plant structure is important for vegetative growth and affects

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generative aspects. This phenomenon can be explained through physiological mechanisms, where physiological damage interferes with water and nutrient transport (Khor et al., 2021). In addition, stress or structural damage to oil palm plants can affect the quality and quantity of reproductive organs (Abubakar et al., 2021; Neto et al., 2021; Saipol Anuar & Syd Ali, 2022). Therefore, an intact frond base is an indicator of structural health and a predictor of long-term productivity in oil palm cultivation systems. Fracture of the stem base as a physiological variable affecting the emergence of female flowers has not been widely explored in the scientific literature on oil palm. Different from most major studies that highlight the influence of climate factors that affect oil palm flowering (Tani et al., 2020). The research of Gintoron et al (2023), the role of *Elaeidobius kamerunicus* in pollination and fruit development in oil palm. Therefore, this study introduces a new framework that uses simple morphological indicators, such as the condition of the frond base, which can be used as a field diagnostic tool to assess the potential for generative production. The results of this study also contribute to developing more adaptive and evidence-based cultivation strategies.

Number of bunches harvested

Variance (ANOVA) was analysed to determine the effect of frond base condition, number of bunches harvested and the interaction between the two on the observed variables. The results of ANOVA are shown in Table 3.

Table 3. Number of bunches harvested

Source of Variation	SS	df	MS	F	P-value	F crit
Frond Base	18	1	18	46.28571	1.89E-05*	4.747225
Bunches Harvested	1.444444	2	0.722222	1.857143	0.198299^{ns}	3.885294
Interaction FB v BH	0.333333	2	0.166667	0.428571	0.661029^{ns}	3.885294
Within	4.666667	12	0.388889			
Total	24.44444	17				

Note: *Significan; ns: Note significan

Table 3 shows that the condition of the fronds has a very significant effect on the number of bunches that are successfully harvested, with an F value of 46.29 and a P-value of 1.89E-05 (<0.05). On the other hand, the factor of the number of bunches harvested did not show a significant effect (P = 0.198299), as did the interaction between the condition of the fronds and the number of bunches harvested (P = 0.661029). Differences in the condition of the plant fronds are more dominant in influencing the harvest compared to variations in the number of previously formed bunches. Thus, maintaining optimal frond conditions can be an important strategy in increasing oil palm harvest yields.

Damage to the base of the frond directly impacts productivity, especially the number of bunches formed and harvested. This finding supports studies by Luo et al (2020); Melkikh and Sutormina (2022); and Yadav et al (2021), the structural health of vegetative organs increases the ability to efficiently transport nutrients to generative organs, which ultimately affects yields. Tissue damage to the frond reduces the effectiveness of nutrient and water transport, resulting in a failure of bunch formation. Thus, frond base integrity is important for supporting plant structure and plays a role in the success of physiological processes that determine yields. Frond base fractures as physiological and functional indicators can directly affect the number of oil palm bunches harvested. Previous studies, Behera et al (2022); Prabowo et al (2023); and Adu et al (2022) emphasised the influence of fertilization factors affecting oil palm production. This study fills this gap with a quantitative approach based on field data. It proposes a visual evaluation of frond base conditions as a potential indicator in oil palm production monitoring systems. This is in line with the approach of certain morphological, physiological, and phenological traits, allowing accurate modelling of photosynthesis, carbon allocation, and biomass density (Xu et al., 2021). Therefore, this study contributes to the scientific literature of tropical agronomy and presents a new approach in managing oil palm plantations more adaptively and efficiently.

Average Weight Bunch for Harvested

Analysis of variance (ANOVA) was conducted to determine the effect of the frond Base, average weight bunch for harvested and the interaction between the two on the observed variables. The results of ANOVA are shown in Table 4.

Table 4. Average weight bunch of Harvested

Source of Variation	SS	df	MS	F	P-value	F crit
Frond Base	31.31042	1	31.31042	22.8908	0.000445182*	4.747225
AWB	2.678433	2	1.339217	0.979091	0.403751755ns	3.885294
Interaction FB v AWB	1.947544	2	0.973772	0.711917	0.510302807ns	3.885294
Within	16.4138	12	1.367817			
Total	52.3502	17				

Note: *Significan; ns: Note significan

Table 4 shows that the frond base factor significantly affects AWB, with an F value of 22.89 and a P-value of 0.000445 (<0.05). On the other hand, the AWB category factor did not show a significant effect (P = 0.40375), as did the interaction between frond base and AWB, which was also not significant (P = 0.5103). Variations in the weight of harvested bunches were mainly determined by the condition of the frond base, not by the classification of bunch weight or the interaction of the two factors. Therefore, managing the physical condition of the base of the frond is important in supporting increased harvest weight.

Frond bases Facture can disrupt the distribution of photosynthesis results, water, and nutrients to the bunches, resulting in reduced bunch size and weight. This finding aligns with research by Polivanova and Bedarev (2022), stating that structural disturbances in plant tissue can inhibit the growth and formation of generative parts of the plant. Thus, a healthy frond base supports plant structure and is key to maintaining optimal bunch productivity.

The novelty of this study lies in the quantitative approach that highlights explicitly the effect of frond base fracture on average bunch weight as an indicator of harvest yield. So far, most studies on oil palm productivity have focused on pest and disease control variables on oil palm production (Bharudin et al., 2022; Zakaria, 2023). This study fills the gap in tropical agronomy literature and adds a new perspective in evaluating oil palm productivity based on visual indicators. Therefore, this study's results contribute to science and offer an applicable approach for more efficient and evidence-based oil palm plantation management.

DMRT Results

Untuk mengetahui perbedaan nyata antar perlakuan yang berpengaruh signifikan berdasarkan hasil ANOVA, dilakukan uji lanjut menggunakan Duncan’s Multiple Range Test (DMRT) pada taraf nyata 5%. Hasil uji DMRT disajikan pada Tabel5.

Table 5. DMRT Results

Condition Frond Base	New Frond Base Growth	Female Flower	Bunch	AWB
Frond Base Normal	6.0 a	4.33 a	3.44 a	36.15 a
Frond Base Facture	4.9 b	3.11 a	1.44 a	33.51 a

Note: Numbers followed by different letters in the same column are significantly different according to the 5% DMRT test

Table 5 shows that normal frond bases produce significantly higher new frond growth than fractured frond bases. No significant differences were found between frond base conditions for the number of female flowers, number of bunches, and average bunch weight. The effect of frond bases is more significant on vegetative growth than on reproductive aspects. Normal frond bases significantly increase new frond growth. This finding confirms that the integrity of the frond structure plays an important role in supporting plant physiological activities related to forming vegetative organs. Thus, the condition of the frond base can be used as an important visual indicator in quantitatively assessing plant health and the potential for early oil palm growth.

Conclusion

The study results showed that the frond base condition significantly affects oil palm's vegetative and reproductive growth aspects. An intact frond base has been statistically proven to increase the growth of new fronds, produce more female flowers, and make a higher number and weight of bunches. The structural integrity of the frond not only plays a role in supporting the plant canopy, but is also a key factor in the efficiency of the distribution of photosynthesis results to the generative organs. This study has implications for the importance of periodically monitoring the condition of the frond base as part of plantation management, especially during the active production phase. This strategy supports the precision agriculture approach in a simple way but has a significant impact on oil palm productivity. The results of this study can be the basis for developing more appropriate operational standards for plant maintenance to increase the efficiency and yield of sustainable palm oil production.

However, this study has several limitations. The study focused only on one harvest cycle and plants with a specific age range and environmental conditions, so generalisation of the results to various soil types, varieties, or other agroclimatic conditions still requires further validation. This study also has not explored the long-term impact of frond base damage on physiological performance and seasonal production of plants. Therefore, it is recommended that further studies integrate longitudinal analysis and physiological and anatomical approaches to deepen the understanding of the mechanism of yield reduction due to frond fracture. Developing a technology-based visual detection system can be a future innovation for early detection and rapid decision-making in the field.

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