

Comparative Analysis of Oil Palm Production in Areas with and without Land Application of POME

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ABSTRACT

The oil palm industry plays an important role in Indonesia's economy. One of the key issues in plantation management is the utilization of Palm Oil Mill Effluent (POME). This study aims to analyze the differences in Fresh Fruit Bunch (FFB) production between land application and non-land application areas at PT Perkebunan Nusantara IV Regional III Sei Garo Estate. This study used a quantitative comparative method with a time series approach based on secondary data from 2022–2025. Variables observed included average bunch weight (kg/bunch), number of bunches (bunch/ha), and FFB production (ton/ha/semester). Data analysis included descriptive statistics, Shapiro–Wilk normality test, and Independent Sample t-test. The results showed that average FFB production in land application areas (10.29 ton/ha/semester) was slightly higher than non-application areas (10.06 ton/ha/semester). However, statistical tests indicated no significant differences in average bunch weight ($p=0.945$), number of bunches ($p=0.068$), and FFB production ($p=0.881$). It is concluded that POME application tends to increase production, although the effect is not statistically significant.

Keywords: oil palm, POME, land application, production, FFB

INTRODUCTION

The palm oil industry is one of the strategic sectors in Indonesia's agricultural and economic development. This commodity not only serves as a significant contributor to the country's foreign exchange earnings but also helps create jobs and drives rural development. The area of palm oil plantations in Indonesia continues to expand in line with the high demand for vegetable oil in the global market. While this expansion in area and production has positive impacts on the national economy, it also presents challenges in resource

management and environmental sustainability. Palm oil production, which tends to be volatile, is influenced by various factors, such as agroclimatic conditions, the age of the plants, varieties, and the cultivation techniques and land management practices employed [1].

In an effort to maintain optimal productivity while supporting the principles of sustainability, innovation is needed in the management of cultivation systems, including the utilization of waste from the palm oil processing industry. One

type of waste produced in large quantities is palm oil mill effluent (POME). POME is a byproduct of the fresh fruit bunch (FFB) processing that has the potential to pollute the environment if not managed properly [2]. However, this waste also has a fairly high content of organic matter as well as macro- and micronutrients, making it a potential source of nutrients for plants [3].

POME is utilized as an organic fertilizer through land application, which involves applying treated liquid waste to oil palm plantation land. This concept aligns with the principles of the circular economy, where waste is no longer viewed as a residue to be discarded, but rather as a resource that can be reused to improve soil fertility and crop productivity [4]. The application of POME is known to improve soil physical properties, such as enhancing soil structure and porosity, as well as improving soil chemical and biological properties through increased organic matter content and microbial activity [5].

Yuni's research [6] shows that the application of POME can have a positive impact on oil palm growth and production. The increase in FFB production in treated areas compared to untreated areas is often attributed to the increased availability of nutrients such as nitrogen (N), phosphorus (P), and potassium (K), which play a crucial role in plant physiological processes, including flower and fruit formation. In addition, the organic matter in POME also plays a role in increasing the soil's cation exchange capacity, thereby improving fertilization efficiency. However, research findings regarding the effectiveness of POME still show variation, where under certain conditions, production increases are not always significant and tend to be influenced by other factors such as soil conditions, rainfall, and the fertilization management practices applied [7].

The factors influencing oil palm production are highly complex and interrelated. In addition to environmental and technical cultivation factors, internal plant factors such as fruit set also have a significant impact on productivity. Fruit set is an indicator of the success of fruit formation from

pollinated flowers. The higher the fruit set value, the higher the potential for the number and weight of the bunches produced [8]. Therefore, the availability of sufficient and balanced nutrients is crucial in supporting optimal fruit formation. In this context, the use of POME is expected to serve as an alternative to enhance fertilization efficiency while improving soil conditions [6].

The use of POME as a nutrient source cannot fully replace inorganic fertilizers. The nutrient content in POME tends to be unstable and is highly dependent on the processing methods at the factory. Therefore, POME is generally used as a supplement in integrated fertilization systems. This underscores that the success of increasing oil palm production is not determined by a single factor, but rather is the result of the interaction of various interrelated factors [9].

In actual practice, land application has been implemented by various oil palm plantation companies, including PT Perkebunan Nusantara IV Regional III at the Sei Garo Plantation. This company has adopted a sustainable waste management system by utilizing POME as a source of organic matter to support increased fresh fruit bunch (FFB) production. The application of POME is expected to improve soil fertility and provide the nutrients needed by the plants, thereby enhancing productivity in a sustainable manner. However, the effectiveness of POME application in boosting production still requires further study, particularly in comparing production performance between areas where POME is applied and those where it is not.

This study aims to analyze oil palm production in areas where palm oil mill effluent (POME) is applied and in areas where it is not, as well as to test whether there are significant differences in production between these two areas at PT Perkebunan Nusantara IV Regional III Sei Garo Estate. The results of this study are expected to contribute both scientifically and practically to the development of waste management technologies and the sustainable improvement of oil palm productivity.

MATERIALS AND METHODS

This study was conducted over approximately four years of data collection, beginning with data collection, data processing, and culminating in the preparation of the research report. Data collection took place from January 2022 through December 2025. The study was conducted in the oil palm plantation area of Afdeling IV, PT Perkebunan Nusantara IV Regional III, Sei Garo Plantation. The research location specifically covered production blocks with different treatments, namely areas with the application of palm oil mill effluent (POME) and areas without POME application. The blocks used in the application area were blocks 22K and 22L, while the non-application blocks were blocks 26L and 24L.

This study was conducted using a quantitative method with a descriptive-comparative approach aimed at providing an overview and comparing oil palm production under two different treatment conditions. This approach was used to describe the production data obtained without manipulating the research variables. The research locations were selected using purposive sampling, which involves intentionally choosing sites based on specific criteria, including uniformity of plant age, the variety used (DxP Socfindo), environmental conditions, and

relatively similar crop management systems. This was done to minimize the influence of external variables, ensuring the research results are more representative in illustrating the effects of POME application.

This study utilized secondary data in the form of fresh fruit bunch (FFB) production data from oil palm plantations in areas with and without land application. The data included average bunch weight (kg/bunch), number of bunches (bunch/ha), and FFB production (ton/ha). The data were obtained from plantation production management reports and then compiled on a semester basis, resulting in two observation periods per year.

The data obtained were then tabulated and analyzed using SPSS statistical software. The analysis included descriptive statistics to determine the mean, minimum, and maximum values of each variable. Additionally, a normality test was conducted using the Shapiro–Wilk method to assess the data distribution. If the data were normally distributed, the analysis proceeded using an Independent Sample T-Test with a significance level (α) of 5% or 0.05 at a 95% confidence level. This test was used to determine whether there was a significant difference between oil palm production in the POME application and non-application areas.

RESULTS AND DISCUSSION

Comparison of Oil Palm Production in Areas Where POME Land Application Was Applied and Where It Was Not Applied

Palm oil mill effluent (POME) is a byproduct of the fresh fruit bunch (FFB) processing that contains high levels of organic matter and nutrients, making it a potential source of plant nutrients through land application. The use of land application in oil palm plantations aims to improve soil fertility and support increased crop production. POME applied to the land has previously undergone a treatment process to meet application standards, particularly regarding BOD,

COD, and pH levels, ensuring it is safe for both the environment and plants [6].

In this research, the plots with and without land application had relatively similar conditions, in terms of plant age, variety (DxP Socfindo), and maintenance practices such as fertilization and weed control. This was done to ensure that any differences in yield more accurately reflect the effects of the POME application treatment. Both plots also received inorganic fertilization according to recommendations, so that POME served as a supplementary nutrient source rather than a replacement for the primary fertilizer.

Table 1. Average Oil Palm Yield in Areas Where POME Is Applied and Where It Is Not Applied

Year	Semester	Average Production					
		AWB		JJG/HA		TON/HA	
		LA	NLA	LA	NLA	LA	NLA
2022 (TM 1)	SM1	4,88	4,76	999	869	4,84	4,16
	SM2	5,09	4,94	1162	819	8,86	7,50
2023 (TM 2)	SM1	7,18	7,05	1267	935	9,05	8,83
	SM2	8,50	8,44	1183	773	13,29	13,51
2024 (TM 3)	SM1	8,56	8,73	1246	1189	10,63	10,39
	SM2	9,23	9,51	1224	1297	12,04	13,31
2025 (TM 4)	SM1	10,00	9,83	1116	1120	11,15	11,05
	SM2	10,38	9,97	1158	1161	12,45	11,77

Notes:

LA : POME Application

NLA : Non-POME Application

JJG : Bunches

AWB : Average Bunch Weight

Source : Data Analysis, 2026

Based on Table 1, the following production graph was obtained:

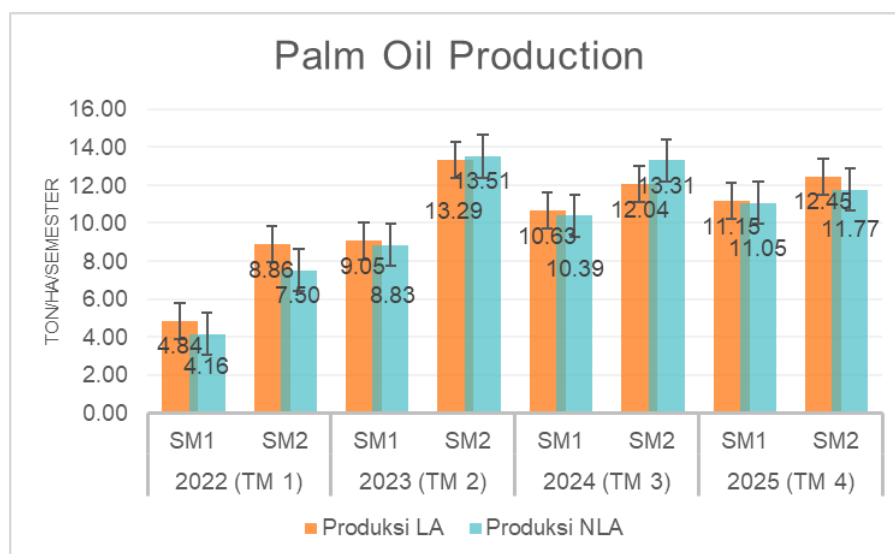


Figure 1. Comparison Chart of Production (Tons/Ha/Semester) in Areas Where POME Was Applied and Where It Was Not Applied

Based on the figure above, it can be seen that oil palm production from 2022 to 2025 fluctuated each semester, both in areas where POME was applied and in those where it was not. Nevertheless, overall production on land where POME was applied tended to be higher than on land where it was not applied. This can be seen from the tons/ha parameter, which showed higher values in the application areas in nearly every

period.

In 2022, the production difference between application and non-application areas was 0.68 tons/ha in the first semester and increased to 1.36 tons/ha in the second semester. Furthermore, in 2023, the production difference was relatively small in the first semester at 0.22 tons/ha; in fact, in the second semester, the non-application areas were slightly higher by 0.22 tons/ha. Entering

2024, production once again showed an advantage in the application area with a difference of 0.24 tons/ha in the first semester; however, in the second semester, the non-application area was higher with a difference of 1.27 tons/ha. Meanwhile, in 2025, production between the two areas tended to be more stable, with a difference of 0.10 tons/ha in the first semester and increasing to 0.68 tons/ha in the second semester, where the treated area again showed higher production.

The average grain weight per ear in the area where POME was applied was 7.97 kg/ear, while in the non-application area it was 7.90 kg/ear. These values indicate that the grain weight per ear in the POME-treated area was slightly higher than in the non-application area. The average number of bunches in the POME-treated area was 1,169 bunches/ha, while in the area without POME application it was 1,120 bunches/ha. These values indicate that the number of bunches in the POME-treated area is higher than in the area without POME application. Meanwhile, the average fresh fruit bunch (FFB) production in the POME application area was 10.29 tons/ha/semester, while in the non-application area it was 10.06 tons/ha/semester. These values indicate that production in the POME application area is slightly higher than in the non-application area.

Table 2. A Test of the Differences in Oil Palm Yield Between Areas Where POME Land Application Was Applied and Those Where It Was Not

Variable		Significant Value
Average Bunch Weight	LA-NLA	0,945
Bunches	LA-NLA	0,068
Fresh Fruit Bunch (FFB) Production	LA-NLA	0,881

Notes:

LA : POME Application

NLA : Non-POME Application

The results of a comparative analysis of oil palm production in areas with and without POME land application, conducted using SPSS Statistics 25, showed that the fresh fruit bunch (FFB) production (tons/ha/semester) yielded a significance value of 0.881. Based on the rules for hypothesis testing, if the significance value is less than 0.05, the null hypothesis (H^0) is rejected. The

These results indicate that although there were some periods when production on non-treated plots was higher, overall, plots treated with POME tended to yield better results. This is due to the additional nutrients from palm oil mill effluent, which can improve soil fertility and support the growth and production of oil palm plants.

The application of palm oil mill effluent can significantly increase the levels of Potassium (K) and Phosphorus (P). The increase in Potassium (K) and Phosphorus (P) resulting from the application of palm oil mill effluent can boost oil palm production. This is because Phosphorus (P) supports flower formation as well as fruit and seed development. Meanwhile, Potassium (K) plays a crucial role in increasing AWB and FFB production [3].

Comparative Analysis of Oil Palm Production in Areas with and without Land Application of POME

Comparative data on oil palm production between areas where POME was applied and those where it was not were analyzed using SPSS 25 at a 95% confidence level. The purpose of this analysis was to test for differences in oil palm production between the two areas using an independent samples t-test.

study results yielded a significance value of 0.881, which is greater than 0.05; therefore, it is concluded that null hypothesis, namely that there is no significant difference in fresh fruit bunch production between areas where palm oil mill effluent (POME) was applied and those where it was not, is accepted. This indicates that there is no significant difference in fresh oil palm fruit bunch

production between the POME application area and the non-application area.

A comparison test of the average bunch weight (AWB) of oil palm in the application and non-application areas of POME land application showed that the average bunch weight (AWB) of oil palm yielded a significance value of 0.945. The research results yielded a significance value greater than 0.05. This indicates that there is no significant difference between the average bunch weight (AWB) of oil palm in POME application areas and non-POME application areas.

A comparative test of the number of oil palm bunches per hectare (Bunch/Ha) in areas where POME was applied and those where it was not showed that the number of oil palm bunches per hectare yielded a significance value of 0.068. The study results yielded a significance value greater than 0.05. This indicates that there is no significant difference in the number of oil palm bunches per hectare between the POME application area and the non-application area.

The absence of a significant difference between the POME application and non-application areas for the three tested variables is likely due to several factors. In both study areas, inorganic fertilization was applied according to recommendations, ensuring that the plants' nutrient requirements were met before POME application. Under these conditions, POME served only as an additional nutrient source and not as the primary determinant of increased production. Fertilization in oil palm cultivation is the result of the interaction of various nutrient sources, where organic materials such as POME generally function as a supplement and do not always result in a noticeable difference in production if the primary nutrient requirements have already been met from other sources [9].

High production variability due to environmental factors, particularly rainfall and agroclimatic conditions during the study period, also contributed to the failure to detect a statistically significant effect of the POME treatment. Oil palm production is highly sensitive to climate change, especially during flowering and fresh fruit bunch formation. Fluctuations in these conditions can cause significant variations in

production, thereby masking the relatively small effect of the POME treatment. Climatic factors have a more dominant influence on oil palm productivity than specific technical cultivation practices [10].

The effect of POME application on production increases is indirect and tends to require a considerable amount of time, primarily through the gradual improvement of soil's physical, chemical, and biological properties. The increase in the uptake of the nutrients Nitrogen (N), Phosphorus (P), and Potassium (K) resulting from the application of oil palm mill effluent occurs gradually alongside the accumulation of organic matter in the soil [5]. Therefore, during the early productive phase (TM 1–TM 4), the impact of POME application is not yet fully optimal in driving statistically detectable increases in production in the short term.

POME is known to significantly increase the levels of potassium (K) and phosphorus (P) in the soil. However, its actual effect on crop yield depends heavily on the overall condition of the plants and the land. Increased phosphorus (P) levels play a role in flower and fruit formation, while potassium (K) contributes to an increase in average bunch weight [3]. However, interactions with various other agronomic factors mean that the effects of POME do not always manifest significantly in statistical analyses, particularly during the early stages of crop production.

Factors Affecting Oil Palm Production at the Sei Garo Estate of PT Perkebunan Nusantara IV Regional III Rainfall

Oil palm production is heavily influenced by rainfall, which is directly linked to flowering and fruit ripening. If rainfall increases evenly throughout the year, it will affect the shedding of ripe fruit and accelerate the formation of the next flowers. The ideal rainfall for oil palms is approximately 2,000–2,500 mm per year with an even distribution. Evenly distributed rainfall can also help slow soil and plant evaporation. Conversely, dry soil makes it difficult for plant roots to absorb minerals from the soil [10].

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Sei Garo Estate has relatively low rainfall, which leads to water deficits. These conditions affect oil palm production, resulting in a lower yield of fresh fruit bunches. Water deficit or water shortage can have negative impacts on the growth and development of oil palm plants. The physiological effects of drought stress on oil palm plants occur when changes in water potential, osmotic pressure, and cell turgor occur, which can affect stomatal behavior or function. During the vegetative phase, drought can inhibit the unfolding of young leaves, damage leaf greenness, cause leaf sheaths to wilt, and even lead to leaf drop and breakage. Meanwhile, during the reproductive phase, drought stress can alter the sex ratio of flowers, cause flowers and fruits to drop, and prevent bunches from developing to maturity. The impact is significant as it can lead to crop failure and reduce fresh fruit cluster production by up to 40% and CPO by 21–65% [11]. Consequently, there is a higher formation of male flowers during the dry season, whereas the rainy season sees a higher formation of female flowers.

Metisa plana Pest Infestation

Metisa plana, commonly known as the bagworm, is a polyphagous leaf-eating pest, meaning it feeds on all types of plant leaves. The bagworm possesses a high adaptive capacity, as it can produce numerous generations through the laying of many eggs to feed on leaves. *Metisa plana* spreads very easily through contact between the canopies of plants and is dispersed by the wind [12]. This bagworm is the most dominant pest on oil palm. Upon hatching, the bagworm begins feeding on oil palm leaves by scraping the upper surface of the leaves. The scratched leaf surface

dries out and forms holes. Severely damaged leaves turn gray and can reduce production yields [13].

Bagworm infestations have occurred in several blocks of PT Perkebunan Nusantara IV Regional III's Sei Garo Estate. These infestations cause damage in the form of spots on the leaf surface that gradually expand over time, resulting in holes in the leaves. This reduces photosynthetic capacity by up to 40% and will lead to a 30–50% decrease in fresh fruit bunch (FFB) production if control measures are not implemented promptly [14].

Behavior of Harvesters

Harvester behavior is one of the factors that influence production. Harvesters who do not follow standard procedures, such as harvesting unripe fruit or failing to harvest ripe fruit, can cause yield losses. Therefore, harvesters play a crucial role in determining the quality and quantity of fresh fruit bunches (FFB) production.

Harvester behavior at PT Perkebunan Nusantara IV Regional III Sei Garo Plantation is a key concern in production activities. Some common mistakes made by harvesters include harvesting unripe fruit. Harvesting unripe fruit results in low average bunch weight and oil content. PT Perkebunan Nusantara IV Regional III Sei Garo Estate has established a harvest supervision policy known as the Inspection Protocol. Under this protocol, harvesters who commit mistakes such as harvesting unripe fruit are subject to a fine of Rp 10,000 per bunch of unripe fruit harvested. This measure is implemented to ensure harvest quality and yield meet company standards.

CONCLUSION

Based on the research results, it can be concluded that the application of palm oil mill effluent (POME) at PT Perkebunan Nusantara IV Regional III Sei Garo Plantation tends to have a positive effect on oil palm production and yields are relatively higher compared to land without application. The average fresh fruit bunch (FFB) yield in the WPL application area was 10.29 tons/ha/semester, while in the non-application area

it was 10.06 tons/ha/semester.

The results of a comparative production study using SPSS Statistics 25 analysis showed that the significance values for average bunch weight, number of bunches, and FFB production were greater than 0.05. This indicates that the results obtained were not significantly different. In other words, there was no statistically significant difference in production (tons/ha) between plots

with and without land application.

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