

Optimization of Oil Palm (*Elaeis guineensis* Jacq.) Seedling Growth in the Main Nursery Through the Integrated Application of Urea Fertilizer and Cow Urine-Based Liquid Organic Fertilizer

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ABSTRACT

The study entitled Optimization of Oil Palm Seedling Growth in the Main Nursery Through the Integrated Application of Urea Fertilizer and Cow Urine-Based Liquid Organic Fertilizer was conducted in Koto Panjang Village, Koto Tangah District, Padang City, West Sumatra Province, Indonesia. The aim of this study was to obtain the best dose of urea and cow urine LOF for the growth of oil palm seedlings. The experiment employed a Completely Randomized Design consisting of five treatments and five replications. The treatments were: A = 0 g urea + 0 mL L⁻¹ cow urine LOF; B = 10 g urea + 200 mL L⁻¹ cow urine LOF; C = 20 g urea + 150 mL L⁻¹ cow urine LOF; D = 30 g urea + 100 mL L⁻¹ cow urine LOF; and E = 40 g urea + 50 mL L⁻¹ cow urine LOF. The collected data were subjected to analysis using the F-test. Significant differences among treatments were further evaluated using Duncan's New Multiple Range Test at the 5% significance level. The results showed highly significant effects on plant height increment and shoot fresh weight, significant effects on shoot dry weight, root length, root fresh weight, and root dry weight, while no significant effects were observed on leaf number increment and stem diameter. Economically, the most efficient treatment was the application of 10 g urea + 200 mL L⁻¹ cow urine LOF, which produced the best overall growth performance of oil palm seedlings in the main nursery stage.

KEYWORDS: cow urine-based liquid organic fertilizer, main nursery, seedlings, oil palm, urea

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INTRODUCTION

The development of the oil palm plantation sector in Indonesia has experienced remarkable growth over the past several years. Oil palm plantation area in Indonesia reached 14,621,700 ha in 2021 with a total fresh fruit bunch (FFB) production of 203.56 million tons. In 2022, the plantation area increased to 14,985,700 ha with an FFB production of 204.30 million tons, while in 2023 it expanded further to 16,833,985 ha, producing 210.26 million tons of FFB (Directorate General of Estate Crops, 2024).

Oil palm is one of Indonesia's strategic plantation commodities and plays a crucial role in the national economy. Its derivative products are widely utilized not only as raw materials for the food industry, such as cooking oil and margarine, but also in non-food industries including cosmetics, soap, pharmaceuticals, and oleochemicals. Furthermore, palm oil has significant potential as a feedstock for biodiesel production, supporting the development of renewable energy sources. The utilization of palm oil-based biodiesel represents an alternative approach to reducing dependence on fossil fuels, whose availability is increasingly limited and non-renewable. As a biological resource that can be cultivated sustainably, oil palm has the potential to contribute to energy security while generating substantial economic value for both the plantation and industrial sectors in Indonesia (Paminto, *et al.*, 2022).

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According to Abdul (2023), oil palm propagation is generally carried out through generative methods using seeds. Oil palm seedling production is commonly conducted using a two-stage nursery system, consisting of a pre-nursery stage and a main nursery stage. The pre-nursery stage aims to produce seedlings with uniform growth before they are transferred to the main nursery. Seedlings from the pre-nursery cannot be planted directly in the field because they are still too small and susceptible to growth disturbances. Therefore, the main nursery stage is essential to ensure further seedling development before field transplantation.

One of the major challenges in oil palm cultivation is the availability of high-quality seedlings. Inappropriate seedling selection can pose substantial risks, resulting in significant losses of financial resources, time, and labor if the planted seedlings fail to achieve the expected performance. Improving the quality of oil palm seedlings requires suitable growing media as well as adequate nutrient supplementation through fertilization practices. Proper nutrient management during the nursery stage is essential for promoting vigorous growth and ensuring the production of healthy and productive planting materials (Pratiwi, *et al.*, 2025).

Fatimah & Asfianti (2023) reported that cow urine contains 0.05–0.08% nitrogen (N), 0.02–0.05% phosphorus pentoxide (P_2O_5), and 0.10–0.20% potassium oxide (K_2O). These nutrient concentrations can increase after the fermentation process, indicating that cow urine has considerable potential as a liquid organic fertilizer for enhancing plant growth and productivity. According to Manurung, *et al.*, (2022), the application of cow urine-based liquid organic fertilizer should be complemented with inorganic fertilizers to optimize nutrient availability in the growing medium of oil palm nurseries. Such an integrated fertilization approach is expected to provide a more balanced nutrient supply and support the vigorous growth of seedlings. Among the inorganic fertilizers commonly applied in oil palm nurseries, urea is one of the most widely used nitrogen sources. The combined use of urea fertilizer and cow urine-based liquid organic fertilizer has the potential to improve the growth performance of oil palm seedlings while simultaneously reducing dependence on inorganic fertilizers. The macro- and micronutrients contained in cow urine can supplement plant nutrient requirements, thereby allowing a reduction in inorganic fertilizer use without compromising seedling growth.

Khairani, *et al.*, (2024) reported that the application of 12 g of urea per polybag significantly enhanced the growth of oil palm seedlings in the main nursery stage. Similarly, the study conducted by Manurung, *et al.*, (2022) demonstrated that the application of cow urine-based liquid organic fertilizer at a concentration of 20 mL L⁻¹ of water improved stem height, stem diameter, leaf number, fresh weight, and dry weight of oil palm seedlings.

Therefore, this study was conducted to evaluate the optimization of oil palm (*Elaeis guineensis* Jacq.) seedling growth in the main nursery through the integrated application of urea fertilizer and cow urine-based liquid organic fertilizer. The findings are expected to provide information on the most effective fertilization combination for improving seedling growth while promoting more efficient and sustainable nutrient management practices in oil palm nurseries.

MATERIALS AND METHODS

This study was conducted in Koto Panjang Ikur Koto Village, Koto Tengah District, Padang City (0°57' S, 100°21' E), West Sumatra Province, Indonesia, at an altitude of approximately 20 m above sea level. The materials used in this experiment included oil palm (*Elaeis guineensis* Jacq.) seedlings of the DXP Simalungun variety, topsoil, urea fertilizer, cow urine-based liquid organic fertilizer (LOF), and polybags measuring 30 cm × 35 cm.

The experiment was arranged in a Completely Randomized Design (CRD) consisting of five treatments and five replications, resulting in a total of 25 experimental units. Each experimental unit consisted of four seedlings, giving a total of 100 seedlings. All seedlings were used as observation samples. The treatments consisted of different combinations of urea fertilizer and cow urine-based liquid organic fertilizer concentrations as follows: A = 0 g urea + 0 mL L⁻¹ cow urine LOF, B = 10 g urea + 200 mL L⁻¹ cow urine LOF, C = 20 g urea + 150 mL L⁻¹ cow urine LO, D = 30 g urea + 100 mL L⁻¹ cow urine LOF, E = 40 g urea + 50 mL L⁻¹ cow urine LOF. The experimental data obtained from the observed variables were subjected to analysis of variance (ANOVA) using the F-test. When the calculated F-value exceeded the critical F-value at the corresponding significance level, treatment means were further compared using Duncan's New Multiple Range Test (DNMRT) at the 5% level of significance.

RESULTS AND DISCUSSION

Plant Height Increment (cm)

The application of urea fertilizer and cow urine liquid organic fertilizer (LOF) significantly affected the increase in plant height of oil palm seedlings in the main nursery.

Table 1. Average Increase in the Height of Oil Palm Seedlings in the Main Nursery Following the Application of Urea and Cow Urine Liquid Organic Fertilizer (LOF).

Treatment (Urea + Cow Urine LOF Dose)	Increase in Seedling Height (cm)
A (0 g + 0 ml/l water)	5,54 a
B (10 g + 200 ml/l water)	7,32 b

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C (20 g + 150 ml/l water)	8,08 b
D (30 g + 100 ml/l water)	8,30 b
E (40 g + 50 ml/l water)	9,36 b

KK : 17,65%

Values in the same column followed by the same lowercase letter are not significantly different according to Duncan's New Multiple Range Test (DNMRT) at the 5% significance level.

The application of urea and cow urine liquid organic fertilizer (LOF) significantly affected the increase in seedling height. This effect was attributed to the nitrogen supplied by both urea and cow urine LOF, which was sufficient to meet the nutritional requirements of the seedlings, thereby promoting optimal cell division and elongation. According to Putrianingsih, *et al.*, (2025), nitrogen is an essential macronutrient involved in the formation of chlorophyll, proteins, and vegetative plant tissues, and its adequate availability can enhance plant height growth. Furthermore, Anwar *et al.* (2025) reported that cow urine LOF can serve as an organic nitrogen source with an effectiveness comparable to that of urea fertilizer in supporting plant growth. Nitrogen plays a crucial role in the synthesis of chlorophyll, proteins, and meristematic tissues, all of which contribute to vegetative development.

In addition to supplying macronutrients, cow urine LOF contains natural plant growth regulators such as auxin (IAA), which stimulate root development, cell division, and tissue elongation. Consequently, the application of cow urine LOF has the potential to enhance the growth of oil palm seedlings during the nursery stage (Prayoga & Salim, 2025). This effect can be observed in the rate of seedling height increment during the main nursery phase, as illustrated in Figure 1.

Figure 1 shows that the rate of oil palm seedling height growth increased progressively with nursery age. This finding indicates a linear relationship between the application rates of urea and cow urine LOF and the increase in seedling height. Higher application rates generally resulted in greater height increments due to increased nitrogen availability, which promotes vegetative growth through enhanced photosynthetic activity, protein synthesis, and the formation of new plant tissues (Motasim, *et al.*, 2024).

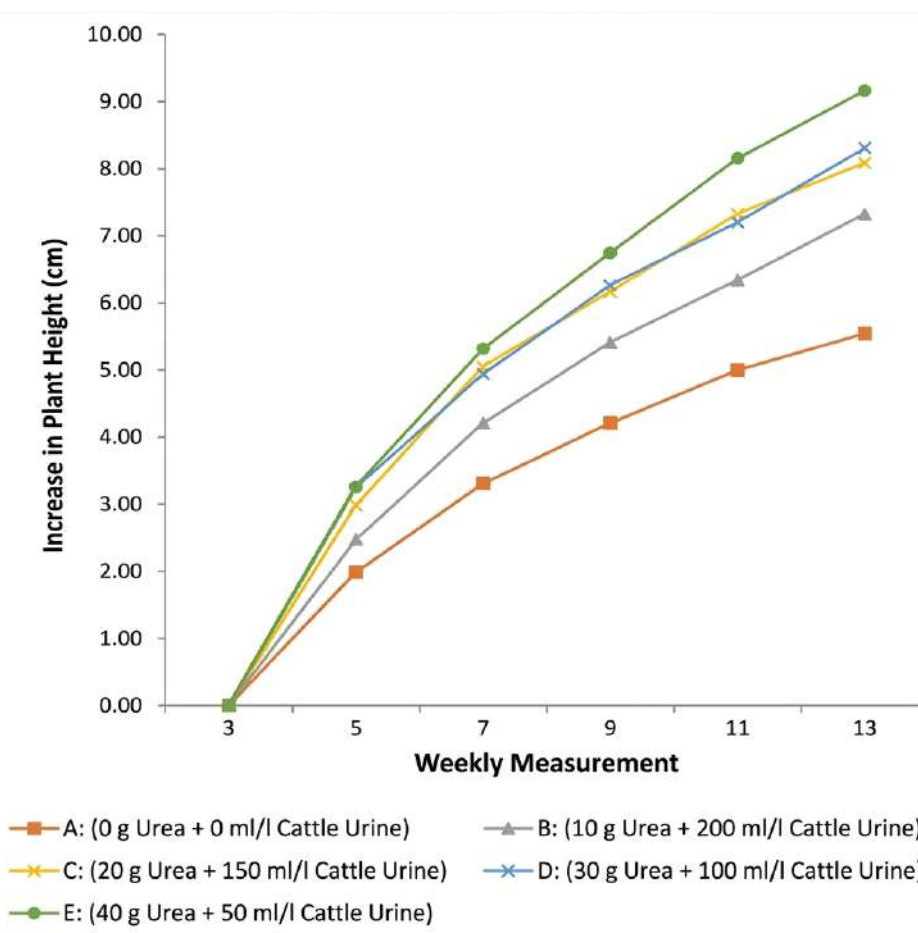


Figure 1. Growth Curve of Oil Palm Seedling Height in the Main Nursery Following the Application of Urea and Cow Urine Liquid Organic Fertilizer (LOF) from 3 to 13 Weeks After Transplanting (WAT).

Increase in Number of Fronds and Basal Stem Diameter (mm)

Table 2. Average Number of Fronds and Increase in Basal Stem Diameter (mm) of Oil Palm Seedlings in the Main Nursery Following the Application of Urea and Cow Urine Liquid Organic Fertilizer (LOF).

Treatment (Urea + Cow Urine LOF Dose)	Increase in Number of Fronds (fronds)	Increase in Basal Stem Diameter (mm)
A (0 g + 0 ml/l water)	6,65	14,73
B (10 g + 200 ml/l water)	7,50	14,72
C (20 g + 150 ml/l water)	7,70	14,70
D (30 g + 100 ml/l water)	7,74	14,72
E (40 g + 50 ml/l water)	7,76	14,73
KK:	9,01%	6,27%

Values within the same column were not significantly different according to the F-test at the 5% significance level.

The application of different rates of urea and cow urine liquid organic fertilizer (LOF) in the main nursery stage of oil palm cultivation did not significantly affect either the increase in the number of fronds or the increase in basal stem diameter. This finding indicates that the nutrients and plant growth regulators contained in cow urine LOF were able to support vegetative growth, although the resulting increases were not sufficiently large to produce statistically significant differences among treatments. Furthermore, the genetic characteristics of the seedlings and the relatively adequate nutrient availability across all treatments may have contributed to the uniform responses observed in frond production and basal stem diameter growth (Indonesian Oil Palm Research Institute, 2023; Rahman, *et al.*, 2021).

The increase in leaf number and basal stem diameter of oil palm seedlings is influenced by both genetic and environmental factors. Genetic factors determine the inherent growth pattern of the plant, whereas environmental conditions, including water availability, light intensity, and nutrient supply, affect the rate of organ development. Consequently, leaf formation and stem diameter enlargement often exhibit relatively slow responses to fertilization treatments because these growth parameters are strongly regulated by the plant's internal physiological processes and the developmental stage of the seedlings. Therefore, variations in fertilizer application may not immediately result in significant differences in leaf production and basal stem diameter, particularly during the early stages of seedling growth (Manurung *et al.*, 2024).

Fresh Shoot Weight (g)

Table 3. Average Fresh Shoot Weight of Oil Palm Seedlings in the Main Nursery Following the Application of Urea and Cow Urine Liquid Organic Fertilizer (LOF)

Treatment (Urea (g) + Cow Urine LOF Dose)	Fresh Shoot Weight (g)
A (0 g + 0 ml/l air)	21,40 a
B (10 g + 200 ml/l air)	24,83 b
C (20 g + 150 ml/l air)	25,80 b
D (30 g + 100 ml/l air)	26,80 b
E (40 g + 50 ml/l air)	26,82 b
KK : 8,9%	

Values within the same column followed by the same lowercase letter are not significantly different according to Duncan's New Multiple Range Test (DNMRT) at the 5% significance level.

The results showed that the application of different rates of urea and cow urine liquid organic fertilizer (LOF) significantly affected the fresh shoot weight of oil palm seedlings during the main nursery stage. The increase in fresh shoot weight indicates that the seedlings were able to utilize the available nutrients more efficiently to support vegetative growth. Fresh plant weight is an important growth indicator that reflects the accumulation of photosynthetic products, water content within plant tissues, and the development of plant organs such as leaves and stems. Improved availability of essential nutrients, particularly nitrogen, phosphorus, and potassium, enhances physiological processes within the plant, thereby promoting biomass accumulation and overall plant growth (Motasim *et al.*, 2024).

Nitrogen plays a vital role in chlorophyll and protein synthesis, which support photosynthetic activity. Phosphorus is involved in energy transfer and cell division, whereas potassium functions in enzyme regulation and the maintenance of plant water balance. Adequate availability of these macronutrients enhances the formation of new tissues and the accumulation of photosynthates, resulting in improved vegetative growth. Consequently, the aboveground growth of oil palm seedlings increases, as evidenced by the higher fresh shoot weight observed under appropriate fertilization treatments (Manurung *et al.*, 2024; Sujana, *et al.*, 2023).

Dry Shoot Weight (g)

Table 4. Average Dry Shoot Weight of Oil Palm Seedlings in the Main Nursery Following the Application of Urea and Cow Urine Liquid Organic Fertilizer (LOF)

Treatment (Urea (g) + Cow Urine LOF Dose)	Dry Shoot Weight (g)
A (0 g + 0 ml/l air)	6,50 a
B (10 g + 200 ml/l air)	10,85 b
C (20 g + 150 ml/l air)	10,85 b
D (30 g + 100 ml/l air)	10,87 b
E (40 g + 50 ml/l air)	10,88 b
KK : 8,93%	

Values within the same column followed by the same lowercase letter are not significantly different according to Duncan's New Multiple Range Test (DNMRT) at the 5% significance level.

The increase in dry shoot weight is closely associated with enhanced photosynthetic activity and the accumulation of photosynthates within plant tissues. Dry weight is an important indicator of plant growth because it represents the amount of organic matter produced after the water content has been removed from the tissues. Therefore, it provides a more accurate measure of actual plant growth than fresh weight. A greater dry weight reflects a higher capacity of the plant to convert light energy into organic compounds that are subsequently utilized for the formation of new tissues and biomass accumulation (Wu *et al.*, 2025).

The availability of nitrogen supplied by urea fertilizer and cow urine liquid organic fertilizer (LOF) plays a crucial role in the synthesis of chlorophyll, proteins, and enzymes involved in photosynthesis. Nitrogen is a major constituent of the photosynthetic apparatus, and a substantial proportion of leaf nitrogen is allocated to chlorophyll formation and proteins responsible for light capture and energy conversion. Adequate nitrogen availability enhances photosynthetic efficiency and promotes plant growth. In addition, cow urine LOF contains not only macro- and micronutrients but also organic compounds, growth-promoting hormones, and beneficial microorganisms that can improve the fertility of the growing medium and increase nutrient uptake efficiency. The combined application of urea and cow urine LOF therefore provides a synergistic effect in supporting vegetative growth and biomass accumulation in oil palm seedlings (Manurung *et al.*, 2024; Sari *et al.*, 2022).

According to Adnan, *et al.*, (2023), plant dry weight is strongly influenced by the amount of nutrients absorbed throughout the growth period. Nitrogen, phosphorus, and potassium are essential elements for photosynthesis because they contribute to the development of plant organs such as leaves, stems, and roots. Adequate nutrient availability increases chlorophyll content, accelerates photosynthetic processes, and promotes the production of assimilates, which ultimately enhance plant dry matter accumulation. Consequently, higher nutrient uptake is generally associated with increased dry shoot weight and improved overall plant growth (Adnan, *et al.*, 2023; Sukmawan & Riniarti, 2020; Keteku *et al.*, 2024).

Root Length (cm)

Table 5. Average Root Length of Oil Palm Seedlings in the Main Nursery Following the Application of Urea and Cow Urine Liquid Organic Fertilizer (LOF)

Treatment (Urea (g) + Cow Urine LOF Dose)	Root Length (cm)
A (0 g + 0 ml/l air)	47,50 a
B (10 g + 200 ml/l air)	51,35 b
C (20 g + 150 ml/l air)	53,80 b
D (30 g + 100 ml/l air)	54,00 b
E (40 g + 50 ml/l air)	55,10 b
KK : 6,75%	

Values within the same column followed by the same lowercase letter are not significantly different according to Duncan's New Multiple Range Test (DNMRT) at the 5% significance level.

The increase in root length observed in oil palm seedlings receiving applications of urea and cow urine liquid organic fertilizer (LOF) indicates that nutrient availability, particularly nitrogen, plays a crucial role in root system development. Nitrogen is a major component of amino acids, proteins, and enzymes that are essential for cell division and elongation processes. Adequate nitrogen availability stimulates root meristem activity, thereby promoting optimal root growth. A well-developed root system enhances the plant's capacity to absorb water and nutrients from the growing medium, ultimately supporting overall plant growth and development (Yu *et al.*, 2024; Montiel & Dubrovsky, 2024).

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The combined application of cow urine LOF and urea fertilizer is presumed to create a more favorable growing environment for root development. In addition to supplying nitrogen, cow urine LOF contains various macro- and micronutrients, organic compounds, plant growth regulators, and beneficial microorganisms that can enhance biological activity in the growing medium. These components contribute to improved nutrient availability in the rhizosphere, thereby promoting more vigorous root growth. Enhanced root development increases the root absorption area, allowing seedlings to absorb water and nutrients more effectively (Riyanto *et al.*, 2024). Furthermore, liquid organic fertilizers can improve the physical, chemical, and biological properties of the growing medium, thereby supporting more efficient nutrient uptake by plant roots (Hiremath & Hosamath, 2024).

The combination of inorganic and organic fertilizers provides a more balanced nutrient supply than unfertilized conditions. Nitrogen from urea is readily available for plant uptake, while the nutrients and organic compounds contained in cow urine LOF contribute to improving the root-zone environment. The synergistic interaction between these two nutrient sources promotes optimal root growth, leading to enhanced water and nutrient absorption capacity and ultimately supporting better seedling performance (Yu *et al.*, 2024; Riyanto *et al.*, 2024).

Fresh Root Weight (g)

Table 6. Average Fresh Root Weight of Oil Palm Seedlings in the Main Nursery Following the Application of Urea and Cow Urine Liquid Organic Fertilizer (LOF)

Treatment (Urea (g) + Cow Urine LOF Dose)	Fresh Root Weight (g)
A (0 g + 0 ml/l air)	10,85 a
B (10 g + 200 ml/l air)	21,80 b
C (20 g + 150 ml/l air)	22,60 b
D (30 g + 100 ml/l air)	24,60 b
E (40 g + 50 ml/l air)	26,65 b
KK : 31,00%	

Values within the same column followed by the same lowercase letter are not significantly different according to Duncan's New Multiple Range Test (DNMRT) at the 5% significance level.

Fresh root weight is one of the important growth indicators influenced by root length, root number, and overall root volume. A well-developed root system enhances the plant's ability to absorb water and nutrients from the growing medium. Phosphorus is an essential nutrient that plays a critical role in root growth because it is involved in energy transfer, cell division, and the formation of new tissues. Adequate phosphorus availability stimulates root development, thereby increasing root volume and root biomass accumulation. Conversely, phosphorus deficiency can restrict root system development and reduce the plant's capacity to absorb nutrients effectively (Liu *et al.*, 2024; Heuer *et al.*, 2024).

Optimal root growth expands the root exploration zone, allowing more efficient uptake of water and nutrients. The phosphorus content present in cow urine liquid organic fertilizer (LOF) contributes to the development of a healthier root system, which ultimately enhances the fresh root weight of oil palm seedlings. Improved root growth not only increases nutrient acquisition but also strengthens the seedling's ability to support overall vegetative development during the main nursery stage (Riyanto *et al.*, 2024; Liu *et al.*, 2024; Polakitan *et al.*, 2024).

Dry Root Weight (g)

Table 7. Average Dry Root Weight of Oil Palm Seedlings in the Main Nursery Following the Application of Urea and Cow Urine Liquid Organic Fertilizer (LOF)

Treatment (Urea (g) + Cow Urine LOF Dose)	Dry Root Weight (g)
A (0 g + 0 ml/l air)	3,00 a
B (10 g + 200 ml/l air)	3,25 b
C (20 g + 150 ml/l air)	3,35 b
D (30 g + 100 ml/l air)	3,36 b
E (40 g + 50 ml/l air)	3,55 b
KK : 6,73%	

Values within the same column followed by the same lowercase letter are not significantly different according to Duncan's New Multiple Range Test (DNMRT) at the 5% significance level.

The increase in dry root weight is closely related to the plant's ability to absorb and utilize nutrients for growth and development. Nitrogen supplied by urea fertilizer plays a vital role in the synthesis of proteins, amino acids, and enzymes that

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support cell division and root tissue development. Meanwhile, phosphorus provided by cow urine liquid organic fertilizer (LOF) is involved in energy transfer, the formation of new tissues, and the stimulation of root growth. The balanced availability of these essential nutrients promotes better root development, resulting in greater root biomass accumulation and increased dry root weight (Yu *et al.*, 2024; Liu *et al.*, 2024).

A well-developed root system enhances the plant's capacity to absorb water and nutrients, thereby contributing to improved overall growth performance. Furthermore, an increase in dry root weight indicates that photosynthates produced in the shoot system are effectively translocated to the roots. These photosynthetic products serve as both energy sources and structural materials for the formation of new root tissues, supporting continuous root growth and development. Therefore, the combined application of urea and cow urine LOF can improve nutrient use efficiency and promote greater biomass accumulation in the root system of oil palm seedlings during the main nursery stage (da Silva *et al.*, 2024; Hiremath & Hosamath, 2024).

CONCLUSIONS

The application of different rates of urea and cow urine liquid organic fertilizer (LOF) to oil palm (*Elaeis guineensis* Jacq.) seedlings during the main nursery stage resulted in highly significant effects on plant height increment and fresh shoot weight. Significant effects were also observed on dry shoot weight, root length, fresh root weight, and dry root weight. However, no significant effects were found on the increase in leaf number and basal stem diameter.

The combination of 10 g urea and 200 ml cow urine liquid organic fertilizer per liter of water was identified as the most efficient treatment for promoting the growth of oil palm (*Elaeis guineensis* Jacq.) seedlings in the main nursery stage. This treatment was able to support optimal seedling growth while utilizing a relatively lower amount of inorganic fertilizer, indicating its potential as an effective and efficient fertilization strategy for oil palm nursery management.

CONFLICTS OF INTEREST

The authors declare no competing financial interests or conflicts of interest relevant to this work.

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