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ENHANCING OIL PALM SEEDLING DEVELOPMENT THROUGH OIL PALM SOLID WASTE AND NPKMg APPLICATION

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ABSTRAK

Pembibitan awal (pre-nursery) dalam budidaya kelapa sawit (*Elaeis guineensis* Jacq.) merupakan tahap sangat penting untuk memastikan bibit yang sehat sebelum ditanam di lapangan. Optimalisasi media tanam dan pemupukan pada tahap pre-nursery untuk menghasilkan bibit sehat masih menjadi tantangan. Penelitian dilakukan untuk memanfaatkan limbah padat dari industri kelapa sawit dan pupuk NPKMg (15:15:6:4) untuk meningkatkan kualitas media tanam. Tujuan penelitian (1) menentukan pengaruh kombinasi dosis limbah padat kelapa sawit dan pupuk NPKMg (15:15:6:4) terhadap pertumbuhan bibit kelapa sawit pada tahap pre-nursery, (2) menentukan dosis optimal limbah padat untuk pertumbuhan bibit kelapa sawit pada tahap pre-nursery, dan (3) menentukan dosis terbaik pupuk NPKMg (15:15:6:4) untuk pertumbuhan bibit kelapa sawit pada tahap pre-nursery. Percobaan dilakukan di Stasiun Percobaan Pertanian, Universitas Bengkulu, pada bulan Januari hingga April 2024. Desain percobaan menggunakan Rancangan Acak Lengkap (RAL) dengan dua faktor: faktor pertama adalah aplikasi limbah padat pada tiga level—0 kg/1 kg tanah, 0,5 kg/1 kg tanah, dan 1 kg/1 kg tanah—dan faktor kedua adalah dosis NPKMg pada empat level—1 g/polybag, 2 g/polybag, 3 g/polybag, dan 4 g/polybag. Hasil penelitian menunjukkan terdapat interaksi antara limbah padat dan NPKMg (15:15:6:4) terhadap jumlah daun. Aplikasi limbah padat secara signifikan berpengaruh positif terhadap pertumbuhan bibit yang ditunjukkan oleh tinggi tanaman, diameter batang, kehijauan daun, bobot kering tajuk, dan bobot kering akar yang lebih tinggi dibandingkan kontrol. Namun, aplikasi pupuk NPKMg (15:15:6:4) tidak berpengaruh secara nyata terhadap pertumbuhan bibit sawit. Hasil penelitian ini mengindikasikan bahwa pemanfaatan limbah padat kelapa sawit sebagai bahan amelioran media tanam dapat secara signifikan meningkatkan kualitas pertumbuhan bibit kelapa sawit pada tahap pre-nursery, sehingga dapat menjadi solusi berkelanjutan untuk mengurangi ketergantungan pada input pupuk sintetik.

ABSTRACT

Oil palm (*Elaeis guineensis* Jacq.) is a major commodity in Indonesia's plantation industry, significantly contributing to the national economy. The pre-nursery stage in oil palm seedling

Keywords:

NPKMg fertilizer; Oil palm seedling; Pre-nursery; Solid waste; Ultisol

cultivation is crucial to ensure healthy seedlings before field planting. However, optimizing the growing medium and fertilization at this stage remains challenging. This study focuses on the practical application of solid waste from the palm oil industry and NPKMg (15:15:6:4) fertilizer, to enhance the quality of the growing medium. The objectives of this study are (1) to determine the combination effect of the dosage of palm oil solid waste and NPKMg (15:15:6:4) fertilizer on the growth of oil palm seedlings in the pre-nursery stage, (2) to identify the optimal dosage of solid waste for the growth of oil palm seedlings in the pre-nursery stage, and (3) to determine the best dosage of NPKMg (15:15:6:4) fertilizer for the growth of oil palm seedlings in the pre-nursery stage. This experiment was conducted at the Agricultural Experimental Station, Bengkulu University, Indonesia, from January to April 2024. The experimental design was a Completely Randomized Design (CRD) with two factors: the first factor was the application of solid waste at three levels—0 kg/1 kg soil, 0.5 kg/1 kg soil, and 1 kg/1 kg soil—and the second factor was NPKMg at four levels—1 g/polybag, 2 g/polybag, 3 g/polybag, and 4 g/polybag. The results showed there was a combination effect of solid waste and NPKMg (15:15:6:4) on leaf number. The application of solid waste significantly affected seedling growth indicated by plant height, stem diameter, leaf greenness, shoot dry weight, and root dry weight. However, the application of NPKMg (15:15:6:4) did not significantly affect seedling growth. The findings are significant for the improvemnet of oil palm seedling.

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1. INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq.) is a vital plantation commodity in Indonesia, contributing significantly to foreign exchange earnings. The production of oil palm in Indonesia is relatively high due to several factors. One of the critical factors influencing plant productivity in oil palm plantations is the use of high-quality seedlings. Quality planting materials are essential for success in achieving sustainable plantations. The plants' genetic potential and competitive traits are reflected in the description of the plant varieties (Ginting et al., 2019).

Nursery activities usually begin 12-14 months prior to field planting. This stage is crucial to producing high-quality seedlings, ensuring that the oil palm seedlings can eventually grow well in the field (Sianturi, 1993). One way to obtain quality seedlings is by improving nursery techniques through optimal growing media (Rosa & Zaman. 2017). Oil palm nurseries can be conducted using various growing media, such as Ultisols.

The use of Ultisols as a growing medium presents several challenges. Hardjowigeno (1993) explains that Ultisols has acidic soil reactions (low pH), high aluminum content, and low nutrient levels. Addressing these problems requires soil management, focusing on increasing and maintaining organic matter content, particularly in Ultisols, as a critical solution to improving soil fertility and plant productivity. The abundant availability of palm oil solid waste can be utilized as a source of organic fertilizer to enhance the fertility of Ultisol.

One ton of oil palm is known to produce waste such as empty fruit bunches (EFB) amounting to 23% or 230 kg, shell waste of 6.5% or 65 kg, wet decanter solid (palm sludge) of 4% or 40 kg, fiber of 13% or 130 kg, and liquid waste of 50% (Haryanti et al., 2014). Decanter solid is one of the solid wastes produced from processing fresh fruit bunches (FFB) in plantations using a decanter system (Mulana et al., 2018). Decanter solids contain nutrients, organic matter, protein, fat, and cellulose, making them a suitable medium for microorganism growth (Imran & Mustaka, 2020). Research by Manurung & Djs (2021) shows that solid waste contains relatively high organic matter, which positively influences vegetative growth, including seedling height, leaf count, and stem diameter of oil palm seedlings. Solid waste from oil palm contains relatively high nutrients, including N (3.52%), P (1.97%), K (0.33%), and Mg (0.49%) (Ardiana et al., 2016).

The application of solid waste at a dose of 450 g solid/kg of soil can improve plant height, leaf number, leaf area, stem diameter, shoot fresh weight, shoot dry weight, root fresh weight, and root dry weight in oil palm seedlings (Syahputra et al., 2022). Solid application in oil palm medium significantly increases height, number of leaves, hump diameter, and dry weight of oil palm seedlings. 200 g/polybag solid application is the best dose for seedling oil palm growth in the main nursery (Ardiana et al., 2016). Apart from organic fertilizer, the growth of oil palm seedlings also requires synthetic fertilizer as a source of nutrients.

NPKMg fertilizer in nurseries is highly recommended for perennial crops such as oil palm because it significantly affects seedling growth and quality. Furthermore, Damanik et al. (2011) noted that the main advantage of NPKMg fertilizer is low cost in application, transportation, and storage of fertilizers. Untung & Islan (2015) reported that the application of NPKMg fertilizer (15:15:6:4) to oil palm seedlings in the pre-nursery stage significantly affects plant height, stump diameter, and dry weight of oil palm seedlings but does not significantly influence leaf number and root-to-shoot ratio.

Solid waste application needs to be suplemented with synthetic fertilizers, including NPKMg. The nutrients from organic solid waste are relatively slow release for plant absorption, and their nutrient content is low. Therefore, it is necessary to combine them with NPK fertilizer, which has a relatively high nutrient content and is quickly available to plants. The advantage of NPKMg fertilizer is to provide multiple nutrients, making it more efficient than single fertilizers. The use of solid waste combined with NPKMg can reduce the application of NPKMg by up to 25% of the recommended synthetic fertilizer dosage for oil palm nurseries. According to Ginting et al. (2019), applying NPKMg fertilizer can influence plant height and leaf area in early oil palm nurseries. Therefore, it is essential to determine the optimal dosage for the combination of solid waste and NPKMg and the appropriate growing medium composition to optimize the growth of oil palm seedlings in the pre-nursery stage.

The objectives of the study were to determine the best combination of doses of palm oil solid waste with NPKMg fertilizer (15:15:6:4) for the growth of oil palm seedlings in the pre-nursery stage, to identify the optimal dosage of solid waste for the growth of oil palm seedlings in the pre-nursery stage; and to determine the appropriate dosage of NPKMg (15:15:6:4) fertilizer for the growth of oil palm seedlings in the pre-nursery stage.

2. METHODOLOGY

Experimental Site

This study was carried out at the Agricultural Experimental Station of the Faculty of Agriculture, Bengkulu University, in Kandang Limun, Muara Bangkahulu District, Bengkulu City. The study was carried out from January 2024 to April 2024.

Experimental Design

The study employed a Completely Randomized Design (CRD) consisting of 2 factors and 3 replications. The first factor was the application of Solid (S) with 3 levels of solid waste dosage S1 = 0 kg/1 kg soil, S2 = 0.5 kg/1 kg soil, S3 = 1 kg/1 kg soil. he second factor was the dosage of NPKMg (15:15:6:4) consisting of 4 levels N1 = 1 g/polybag, N2 = 2 g/polybag, N3 = 3 g/polybag, N4 = 4 g/polybag. Each treatment was replicated three times. Each experimental unit contained 5 seedlings, yielding 180 oil palm seedlings.

Planting medium, fertilizer, and seedling

The planting medium was Ultisols, collected from Bengkulu City at a depth of up to 30 cm from the soil surface. The soil was then air-dried for two days. After air-drying, the soil was sieved using a 10-mesh sieve to remove debris and obtained uniform soil particle size as a planting medium. Solid waste, used as organic fertilizer, was obtained from the palm oil mill solid waste at PT. Agra Sawitindo, Ujung Karang, Central Bengkulu, Indonesia. The synthetic fertilizer was NPKMg (15:15:6:4), indicating the content of 15% nitrogen (N), 15% phosphorus (P), 6% potassium (K), and 4% magnesium (Mg). The oil palm seedlings were DxP variety from the Oil Palm Research Center (PPKS)-Medan. The experimental site was shaded to protect the planting medium's seedlings and surface from excessive sunlight and rainwater. The planting media were the mixture of Ultisols and solid wastes according to each treatment. A 2 kg Ultisols and solid waste were incorpotrated ad placed into a polybag. The seedlings were planted at a 2-3 cm depth, with the plumule facing upward and the radicle facing downward.

Fertilization and Pest Control

The application of synthetic NPKMg (15:15:6:4) fertilizer was carried out as follows. The NPKMg fertilizer was ground into a fine powder and then dissolved in water according to the treatment: S1 = 1g/100ml water, S2 = 2g/200ml water, S3 = 3g/300ml water, S4 = 4g/400ml water. The fertilizer solution was then applied by pouring it around the base of the oil palm seedlings. The seedling was watered every morning and evening to maintain soil moisture. Weed was controlled manually, while pest and disease was controlled once a week using an insecticide with 85% Carbaryl as the active ingredient, which is effective against armyworms (Spodoptera litura) and leafhoppers.

Variables measures

The observed parameters were plant height, number of leaves, leaf greenness, leaf area, and stem diameter, which were measured at 6, 8, 10, and 12 weeks after planting (WAP). Additionally, root volume, dry weight of roots and shoots, and shoot-to-root ratio were observed. Supporting variables include soil pH, organic carbon (C-organic), nitrogen (N), phosphorus (P), and potassium (K) content of Ultisols, as well as agroclimatic data such as rainfall, relative humidity, and sunlight exposure during the study.

Data Analysis

Data were analyzed using analysis of variance (ANOVA) at a 5% F-test. Treatment means were separated using Orthogonal Polynomial (OP) to determine the relationship model between the treatments and the observed variables.

3. RESULTS AND DISCUSSION

Research overview

During the seedling stage, oil palm seedlings often experience abnormal growth., due to several factors. Palm oil seedling abnormalities can be indicated in some ways such as affecting growth, development, and eventual productivity. The most common abnormalities in palm oil seedlings include issues with germination, seedling morphology, or physiological functioning. The seedlings experienced Malformed Seedlings (Twisted or Deformed) during the research. Seedlings develop abnormally, with leaves curling, twisting, or showing irregular growth. This abnormality can be linked to genetic mutations, poor-quality seed stock, or damage during early seed development. Another abnormality observed is Stunted Growth, where the seedlings remain small and grow very slowly compared to normal seedlings. This phenomena might be associated with nutrient deficiencies, especially nitrogen or phosphorus, soil compaction, or poor aeration, which restrict root development, as well as pests or diseases affecting root systems or other parts like the leaves. Abnormal seedlings are smaller compared to normal ones, with smaller leaf areas. The results of this study show that the leaf area produced by seedlings at 12 weeks after sowing (WAS) was smaller than the normal leaf growth.

Ginting et al. (2019) reported the highest total leaf area, reaching 30.13 cm² at seven weeks after sowing (WAS) and 55.85 cm² at 9 WAS, while in the study by Rohmiyati & Suryanti (2023), a leaf area of 32.53 cm² was recorded at 12 WAS. Due to seedling abnormalities, the leaf area at 12 weeks observed in this study only ranged between 24.85 cm² and 29.39 cm², which is smaller than normal growth.

Figure 1. Malformed Seedlings Figure 2. Seedling attacked by grasshopper.

Unsuitable planting medium conditions can also cause leaf abnormalities. Too high or too low pH of planting media can inhibit nutrient absorption by the plant. In this study, the pH of the planting medium was acidic (4.17), which is lower than optimal pH for plant growth. The nutrient content of Ultisol can be seen in Table 2.

Table 2. The characteristic of Ultisols from Agricultural Experimental Station, Medan Baru, Bengkulu

Soil	N (%)	P (ppm)	K (me/100g)	C-organic (%)	pH
Ultisol	0.32	4.12	0.29	2.99	4.17

Growth Pattern of Oil Palm Seedlings

Figures 6, 7, 8, and 9 show the growth partern of oil palm oil seedling 6 to 12 WAP. The growth pattern of the oil palm seedlings increases during the study and tends to be comparable across all treatments, with an increase from 6 WAP to 12 WAP

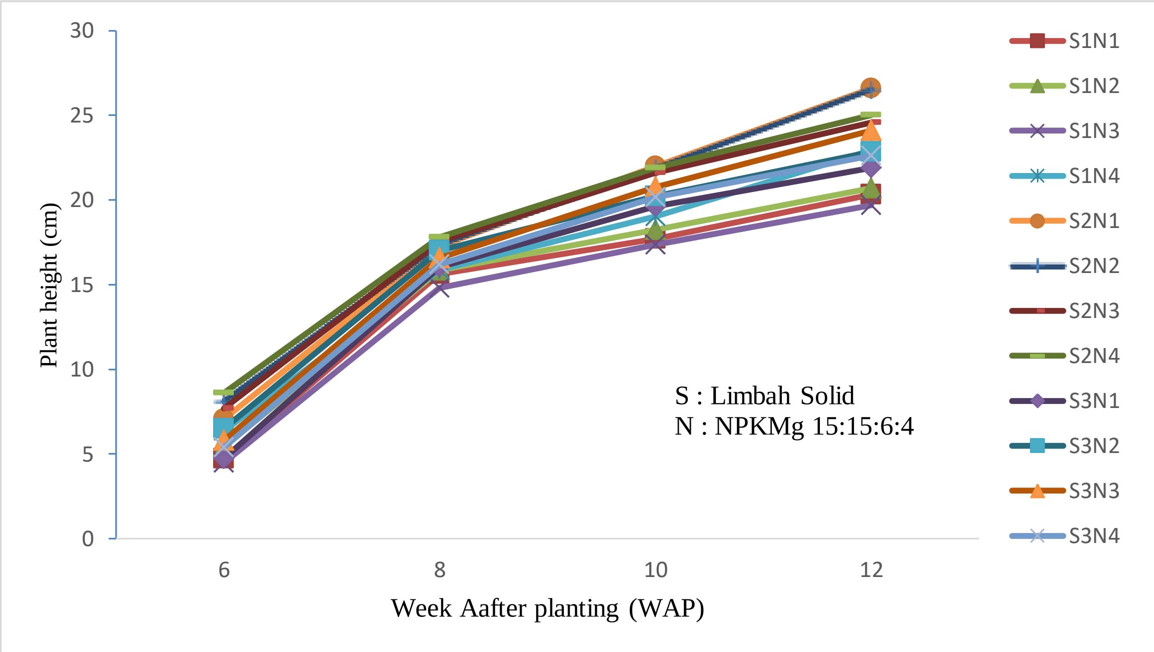

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Figure 3. The height of oil palm seedlings in various treatment combinations at 6 -12 WAP.

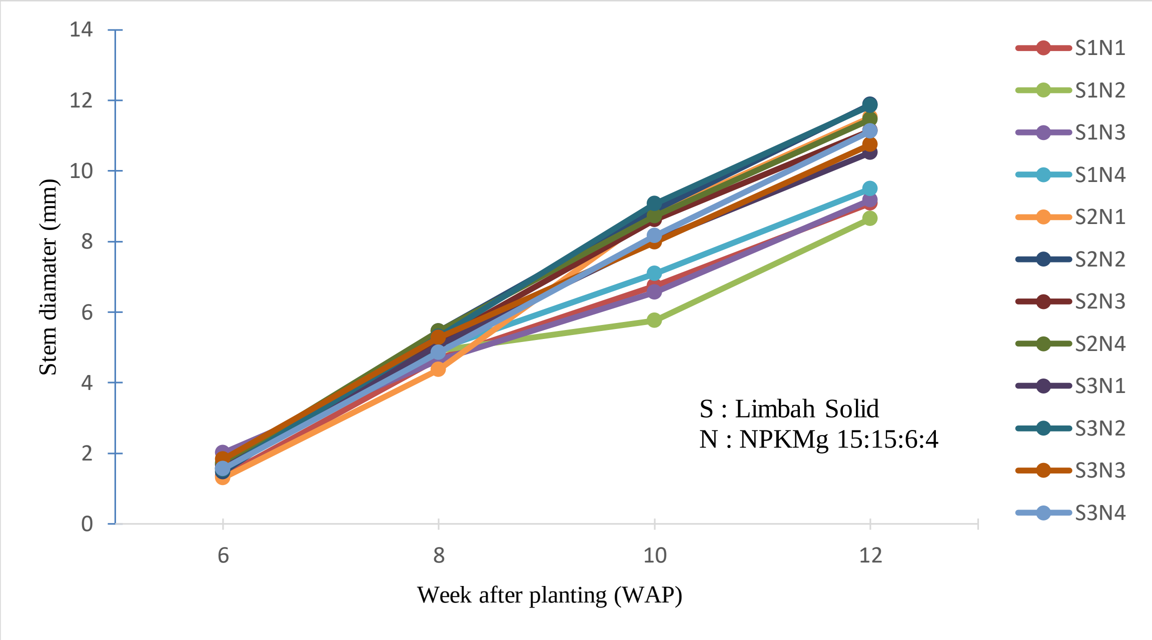

Figure 4. Plant diameter of oil palm seedlings in various treatment combinations at 6 -12 WAP.

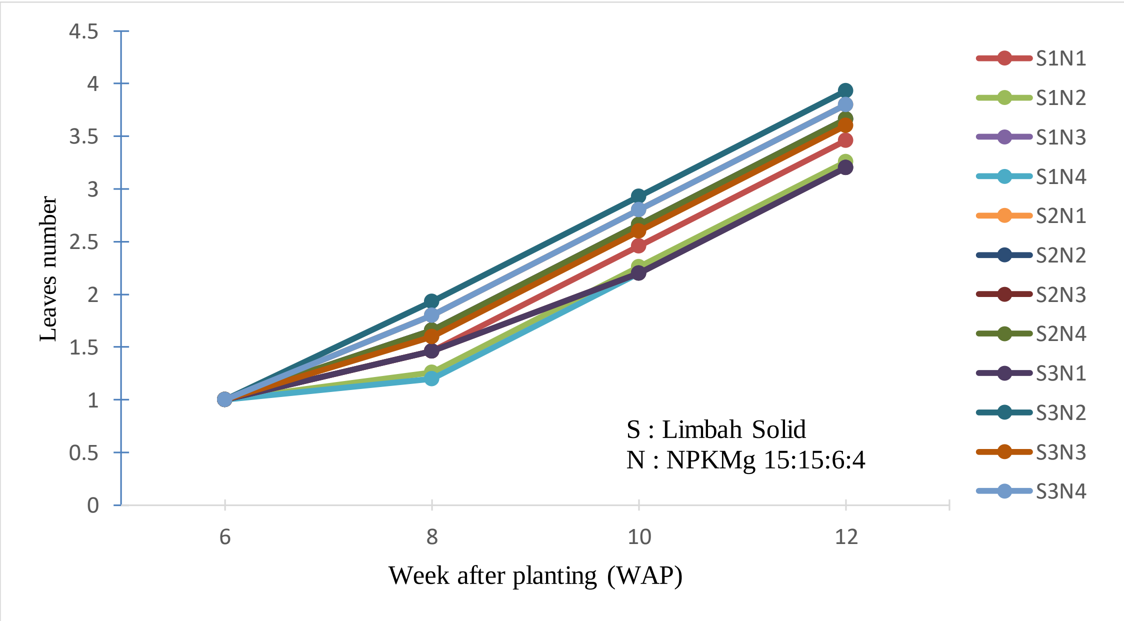

Figure 5. Leaves number of oil palm seedling in various treatment combinations at 6 -12 WAP.

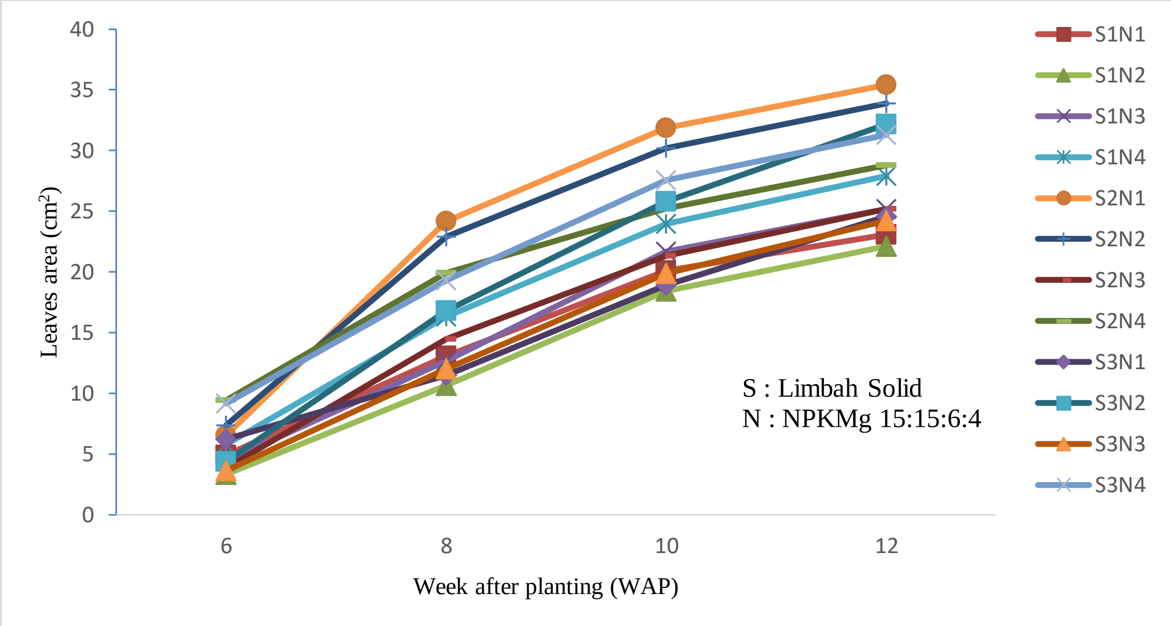

Figure 6. Leaf area of oil palm seedlings in various treatment combinations at 6 -12 WAP.

The uniform growth pattern in plant height, stem diameter, and the number and area of leaves are attributed to genetic factors. During the early germination stage, up to 8 weeks after sowing (WAS), the seedlings still rely on food reserves from the endosperm. Endosperm provides nutrients such as proteins, carbohydrates, and fats to oil palm seedlings. After that, the plants utilize the nutrients available in the planting medium as a source of nutrition for the growth of the oil palm seedlings (Hastuti & Titiaryanti, 2013).

In addition to genetic factors, environmental factors that are relatively consistent also contribute to the uniform growth of oil palm seedlings. The availability of nutrients is crucial to meet the nutritional needs of the plants. Solid waste was applied during the preparation of the planting medium one week before planting. In addition to slowly providing nutrients to the plants, organic matter also significantly improves the soil's physical, chemical, and biological properties (Saygın et al., 2023), in turn, promoting good growth in oil palm seedlings. Furthermore, NPKMg fertilization was applied when the plants reached 4 WAS.

Nitrogen and P are essential for formation of new cells and are key components for the synthesis of organic compounds that affect the vegetative growth of the seedlings (Taiz et al., 2018). L:ikewise, K plays a role in accelerating the growth of meristematic tissues, particularly in the seedling stems (Amira et al., 2018).

Variance Analysis

The summary of the variance analysis on the effect of solid waste and N, P, K, Mg (15:15:6:4) on the growth of oil palm seedlings in the pre-nursery stage is presented in Table 1. There is a significant interaction between solid waste and NPKMg (15:15:6:4) on the number of leaves in the oil palm seedlings. The solid waste treatment had a highly significant effect on the variables of plant height and stem diameter, leaf greenness, shoot dry weight, and root dry weight. Meanwhile, the NPKMg 15:15:6:4 fertilizer treatment had no significant effect on the observed variables.

Table 1. Effect of solid waste and NPKMg fertilizer on oil palm seedling development

Variables	F-calculated			Coeff. Var. (%)
	Solid waste	NPKMg	Solid waste x NPKMg	
Plant height	22.77***	0.35 ns	1.75 ns	7.52
Stem diameter	15.03***	0.33 ns	0.46 ns	10.82
Leaves number	1.65 ns	0.33 ns	2.78*	9.37
Leaves area	1.57 ns	0.54 ns	0.73 ns	15.55
Leaf greenness	8.92**	1.42 ns	2.13 ns	8.40
Root volume	1.12 ns	0.51 ns	0.26 ns	17.06
Shoot dry weight	9.07**	0.59 ns	0.89 ns	27.64
Root dry weight	4.00*	1.00 ns	0.15 ns	28.44
Shoot: Root ratio	2.74 ns	2.58 ns	1.64 ns	27.53
F-table	3.4	3.01	2.51	

Note: * = significantly different, ns = not significantly different. Data transformation of Total Leaf Area, Root Volume, Shoot Dry Weight, and Root Dry Weight using Microsoft Excel with the formula =SQRT.

The Effect of Solid Waste on the Growth of Oil Palm Seedlings

Solid waste is a byproduct of the palm oil industry that has the potential as an organic material for plant cultivation. Released nutrients from solid waste can support the initial growth of plants. However, the impact of solid waste on oil palm seedlings' growth still needs to be evaluated. The use of appropriate growing media will stimulate optimal plant growth and development.

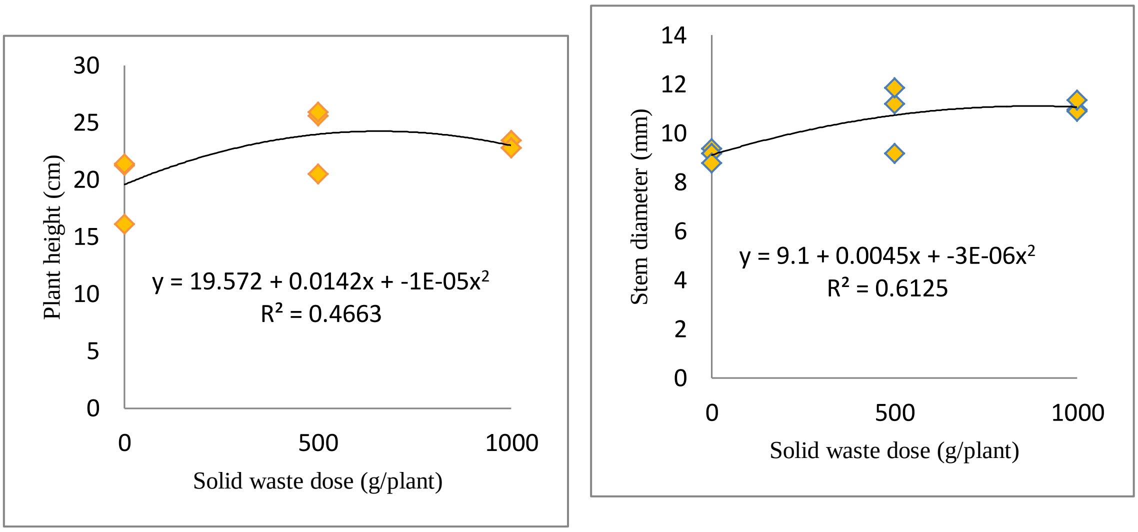

Figure 7. Effect of solid waste dosage on seedling height and oil palm stem diameter at 12 WAP.

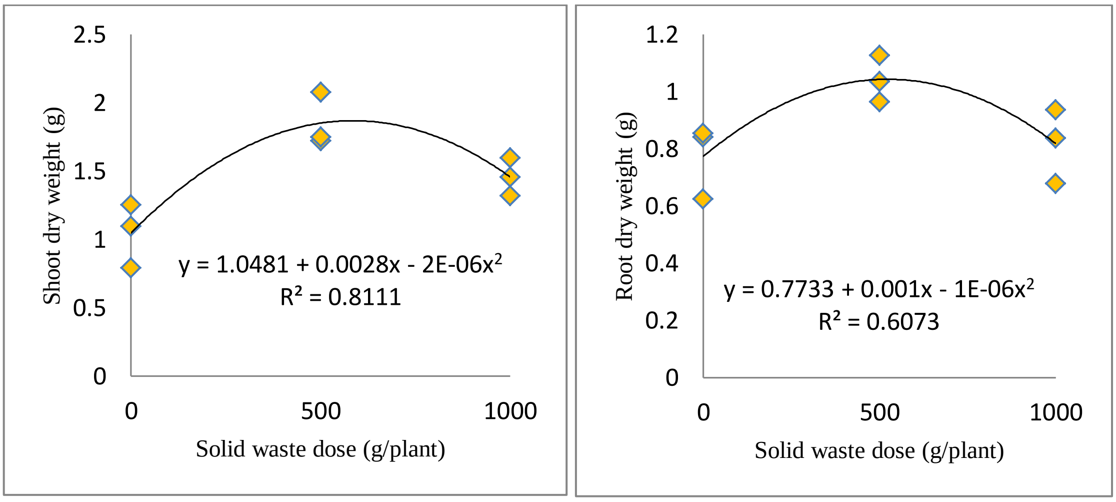

Figure 8. Effect of solid waste dosage on seedling shoot and rootdry weight at 12 WAP.

Recently, palm oil solid waste has less attention by factories and is often discarded, potentially polluting the environment. Disposing of this waste requires significant costs, typically involving the construction of enormous pits. It would be highly beneficial for factories if palm oil solid waste could be widely utilized (Sutrisno et al., 2020). Decanter solids, another type of waste, contain a relatively high amount of nitrogen (N) and phosphorus (P) nutrients. These nutrients are highly beneficial in seedling-growth as they assist in cell division and enlargement, accelerating young leaves' growth. This aligns with Maryani's (2018) statement that nitrogen is a critical nutrient in leaf growth and development. Nitrogen deficiency can inhibit chlorophyll synthesis, protein production, and the formation of new cells, resulting in the plant's inability to properly form organs such as leaves. Based on analysis by Ardiana et al. (2016) in several large plantations in Sumatera, palm oil solid waste contains 3.52% nitrogen (N), 1.97% phosphorus (P), 0.33% potassium (K), and 0.49% magnesium (Mg). Meanwhile, Yuniza (2015) noted that dry decanter solid contains 1.47% nitrogen (N), 0.17% phosphorus (P), 0.99% potassium (K), 1.19% calcium (Ca), 0.24% magnesium (Mg), and 14.4% organic carbon.

Figures 8 and 9 show that the application of solid waste significantly affects the growth of oil palm seedlings. For plant height, the equation is $y = 0.6667 + 0.0018x - 2E\text{-}06x^2$ with a coefficient value of 0.4663, indicating that the effect of solid waste in plant height is 46.63%. Meanwhile, the contribution of solid waste to stem diameter is 61.25%, leaf greenness is 63.96%, shoot dry weight is 81.11%, and for root dry weight, the role of solid waste is 60.73%.

The optimum dosage of solid waste was obtained using the formula:

$$\mathbf{X = -B1/(2.B2)}$$

Where:
B1 = Value of x
B2 = Value of x^2

The results show that the optimum dosage of solid waste for plant height is 710 g/1 kg of soil; for stem diameter, the optimum dosage is 750 g/1 kg of soil; for shoot dry weight, the optimum dosage is 700 g/1 kg of soil, and for root dry weight, the optimum dosage is 500 g/1 kg of soil.

The Effect of NPKMg Fertilizer on the Growth of Oil Palm Seedlings

The results of variance analysisi in Table 1 show that the dose of NPKMg fertilizer did not have a significant effect on the observed variables such as plant height, leaf area, leaf greenness, plant stem diameter, shoot dry weight, root dry weight, and the ratio of shoot and root dry weight in oil palm seedlings.

Table 2. Effect of NPKMg dosage on the growth of oil palm seedlings.

NPKMg dosage (g/polybag)	Plant height (cm)	Stem diameter (mm)	Leaves number (cm)	Leaves area (cm^2)	Leaves greenness
1	22.94	10.37	3.49	27.68	46.75
2	23.36	10.79	3.62	29.39	49.48
3	22.8	10.36	3.49	24.85	45.75
4	23.52	10.69	2.55	29.32	47.73

The height of oil palm seedlings ranges from 22.80 to 23.52 cm; the stem diameter ranges from 10.36 to 10.74 cm; the number of leaves ranges from 2.55 to 3.66; the leaf area ranges from 24.85 to 29.39 cm^2; the greenness level of the leaves ranges from 45.75 to 49.48; the root volume of oil palm seedlings ranges from 2.55 to 3.84 cm^3; the dry weight of the canopy ranges from 2.15 to 2.9 g; the dry weight of the roots ranges from 0.69 to 1.01 g. Meanwhile, the ratio of shoot dry weight to root dry weight ranges from 2.38 to 3.41. Application of NPKMg fertilizer also had no significant effect on the volume and weight of oil palm seedlings (Table 5).

Table 3. Effect of NPKMg dose on root volume and weight of oil palm seedlings.

NPKMg dosage (g/polybag)	Root volume (cm^3)	Shoot dry weight (g)	Root dry weight (g)	Shoot: Root ratio
1	3.44	2.90	0.87	3.41
2	3.00	2.24	0.75	3.07
3	2.55	2.15	0.69	3.21
4	3.89	2.42	1.01	2.38

Applying NPKMg fertilizer at a dose range of 1-4 g per polybag may show no significant difference in root volume and seedling weight due to several factors, including nutrient absorption efficiency. In some conditions, plants may only fully absorb some nutrients from the applied fertilizer, especially if environmental conditions or plant health are not optimal. Additionally, low to moderate doses are often sufficient to meet the needs of young plants, so the difference in fertilizer amounts does not result in significant changes in growth parameters such as root volume and seedling weight.

CONCLUSIONS

Leaves number of pre-nursery oil palm seedling linearly increased in growing media without the addition of solid waste but linearly decreased with the addition of 1 kg of solid waste per polybag, with increasing doses of NPKMg fertilizer up to 4 g/polybag. The best growth of oil palm seedlings was achieved with solid waste treatment at a dose of 500 g for root dry weight, 700 g for shoot dry weight, 710 g for plant height, and 750 g for stem diameter per 1 kg of soil medium. The application of NPKMg fertilizer (15:15:6:4) at doses between 1 and 4 g/polybag did not affect the growth of oil palm seedlings. This research implies that the appropriate amount of solid waste can enhance the growth of oil palm seedlings.

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