

## THE DISTRIBUTION OF OIL PALM (*ELAEIS GUINEENSIS* JACQ.) FEEDING ROOTS UNDER VARIOUS TYPES OF GROUND COVER, PEAT DEPTHS, AND DISTANCES FROM THE TRUNK IN PEATLANDS

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### ABSTRACT

Oil palm cultivation on peatlands is growing rapidly, but information regarding the distribution patterns of suction roots beneath different types of vegetation cover and at varying peat depths remains limited. This study aims to analyze the distribution of oil palm suction roots under various types of land cover, at different peat depths, and at varying distances from the trunk in peatland plantations. This study used a factorial randomized block design (RBD) with three factors: land cover (V0 = discs and carrying poles; land cover percentage 0%, V1 = leaf litter piles; land cover percentage 50%, V2 = weed vegetation on dead stakes; land cover percentage 100%), peat depth (D1 = peat depth 0.5–1.5 m; mean 1.0 m, D2 = peat depth 1.5–3.0 m; mean 2.0 m, D3 = peat depth >3.0 m; average 4.0 m) and distance of the sampling point (J) from the oil palm trunk (J1 = distance 1.0 m, J2 = distance 2.0 m, J3 = distance 3.0 m, J4 = distance 4.0 m, J5 = distance 4.5 m). The data were analyzed using analysis of variance and multiple regression. The results showed that land cover type and sampling distance significantly influenced the development of suction roots, whereas peat depth did not show any statistically significant differences. The highest surface area and volume of suction roots were observed in the open circle and harvest path areas (V0), reaching 1,012.20 cm<sup>2</sup> and 25.56 ml, respectively. The highest distribution of nutrient-absorbing roots occurred at a distance of 1.0 m from the stem, with surface area and volume values of 1,234.71 cm<sup>2</sup> and 32.52 ml, respectively. Peat depths of 1.5–3.0 m tended to support better root development due to higher levels of organic matter and available phosphorus.

**KEYWORDS:** Feeding Roots, Oil Palm, Peatlands, Phosphorus Availability.

### INTRODUCTION

Palm oil is one of Indonesia's most important plantation commodities and makes a significant contribution to national export revenue (USDA, 2022). In 2022/2023, global palm oil production is estimated to reach 77.22 million tons, with Indonesia accounting for approximately 45.5 million tons, or nearly 59% of total global production (USDA, 2022). The value of Indonesia's crude palm oil (CPO) exports in 2022 reached US\$29.62 billion, marking the highest figure in the past decade.

The expansion of oil palm plantations has led to a growing scarcity of suitable mineral soil, resulting in an increasing use of peatlands for plantations (Winarna *et al.*, 2014). Indonesia has one of the world's largest tropical peatland areas, spanning approximately 13.43 million hectares across Sumatra, Kalimantan, and Papua (Masganti *et al.*, 2017). Peatlands hold great potential for agricultural and plantation development, but they also present various challenges such as low pH, poor aeration, low nutrient availability, and very high organic matter content (Utama, 2021).

The root system plays a crucial role in the uptake of water and nutrients by plants (Rianta, 2010). The effectiveness of nutrient uptake is greatly influenced by the development and distribution of *Feeding Roots*, particularly tertiary and quaternary roots (Lim *et al.*, 2002). Environmental factors such as soil moisture, porosity, aeration, the water table, and nutrient availability significantly influence plant root development (Osman, 2013).

In oil palm plantations, fertilization is generally applied to the ring area, thereby promoting a concentration of active roots around that area (Fuady Z. *et al.*, 2019). *Feeding Roots* tend to develop in locations with high availability of water and nutrients. Therefore, understanding the distribution patterns of *Feeding Roots* under various environmental conditions is crucial for improving nutrient management efficiency in oil palm plantations on peatlands.

Although many studies have evaluated oil palm productivity on peatlands, information regarding the spatial distribution of *Feeding Roots* under various vegetation cover types and peat depths remains very limited. This study aims to evaluate the distribution and development of *Feeding Roots* under various land cover conditions, peat depths, and distances from oil palm trunks in peatland ecosystems. It also seeks to provide new insights into the interactions between peat characteristics, vegetation cover, and the development of *Feeding Roots* in mature oil palm plantations.

## MATERIALS AND METHODS

### a) Research Location

This study was conducted from February 2024 to May 2024 at the Umbul Mas Wisesa South Plantation, PT Umbul Mas Wisesa, South Labuhanbatu Regency, North Sumatra. The Umbul Mas Wisesa South Plantation is located at latitudes 2°11'48" to 2°16'46" and longitudes 100°15'01" East to 100°21'54" East. The distance from the city of Medan to the southeast via the Medan–Pekanbaru Highway to the Perlabian Plantation is 319.9 km, and from there, the route continues eastward toward the Umbul Mas Wisesa South Plantation via a district road for 35.9 km.

### b) Materials and Tools

The equipment required for this study includes a sample box measuring 30 x 30 x 30 cm made of 2 mm thick steel plate with a volume of 27,000 cm<sup>3</sup>, a sample ring with a diameter of 4 cm and a length of 5 cm with a volume of 62.8 cm<sup>3</sup>, a hoe, a grinder, a welder, rope, a water pump, a water hose, a bucket, used fertilizer sacks, a scale, an oven, a machete, a knife, scissors, a measuring tape, a vernier caliper, plastic bags, paper, and writing utensils. The materials required for this study are oil palm roots, soil, and water.

### c) Research Methodology

The study was designed using a 3-factor randomized

block design (RBD) and repeated three times. This is a descriptive study with three factors: land cover (V), consisting of three levels (V0 = clearings and open spaces; land cover percentage 0%, V1 = clumps of palm fronds; land cover percentage 50%, V2 = weed vegetation on dead stumps; land cover percentage 100%), peat depth (D) consisting of 3 levels (D1 = peat depth 0.5–1.5 m; average 1.0 m, D2 = peat depth 1.5–3.0 m; average 2.0 m, D3 = peat depth >3.0 m; average 4.0 m) and distance of the sample point (J) from the oil palm trunk, consisting of 5 factors (J1 = distance 1.0 m, J2 = distance 2.0 m, J3 = distance 3.0 m, J4 = distance 4.0 m, J5 = distance 4.5 m).

### d) Observed Variable

The study examined four aspects: the surface area of *Feeding Roots* (cm<sup>2</sup>), the volume of *Feeding Roots* (ml), organic matter (%), and available phosphorus (ppm).

- 1) Surface area of *Feeding Roots* (cm<sup>2</sup>), which serves as the service area. Formula for calculating the service area :

$$\text{Area of the circle of roots } (A) = 2\pi r$$

Service area = Area of the *Feeding Roots* circle × Length of the *Feeding Roots*

- 2) Volume of *Feeding Roots* (ml): The volume of all *Feeding Roots* that have been weighed (wet weight) is then measured. The feeding root sample is placed in a measuring cylinder and water is added until the volume reaches 1,000 ml. The *Feeding Roots* are removed from the measuring cylinder using tweezers and briefly drained over the rim of the measuring cylinder to collect any remaining dripping water, which is then collected in a container. The volume of water remaining in the measuring cylinder is read and recorded on the provided form. The volume of the *Feeding Roots* is calculated by subtracting the volume of the water from the combined volume of the roots and water.

$$\text{Final volume (ml)} = \text{volume of water} + \text{volume of roots}$$

- 3) Organic Matter Analysis (%), the method used for this analysis is the Walkley & Black Method (Titrimetry). This method is most commonly used to determine organic matter content based on the oxidation of organic carbon using potassium dichromate. The formula used is :

$$\%BO = \%C \times 1.724$$

- 4) Analysis of Available Phosphorus (ppm); the method used is the Bray I Method. Phosphorus is extracted using a mixture of NH<sub>4</sub>F and HCl, then reacted to form a blue molybdate complex, which is measured using a spectrophotometer. The formula used is:

$$P \text{ available (ppm)} = \frac{C \times V_{\text{extract}}}{\text{Sample Weight}}$$

Description :

C = concentration of the standard curve (mg/L)

V<sub>Extract</sub> = volume extract

Sample weight in grams

### e) Data Analysis

*Feeding Roots* were collected using soil sample boxes for each treatment combination. The parameters observed included the volume and surface area of the *Feeding Roots*. The data were analyzed using analysis of variance (ANOVA), followed by a Bonferroni test. Multiple regression analysis was performed using SPSS software.

## RESULTS

### The Effect of Land Cover on the Distribution of *Feeding Roots*

Observations of the distribution of oil palm *Feeding Roots* were conducted to determine the response of

active root development under various conditions of land cover, peat depth, and distance from the plant stem. The parameters observed included the surface area and volume of *Feeding Roots* as indicators of the roots' ability to explore nutrients and water in the soil. The analysis results showed variations in feeding root development across the treatments. The mean surface area and volume of *Feeding Roots* for each treatment are presented in Table 1.

**Table 1: Surface Area and Volume of *Feeding Roots* Under Various Land Cover Treatments, Peat Depths, and Distances from the Trunk.**

Land Cover Types (V)	Surface Area (cm <sup>2</sup> ) <i>Feeding Roots</i>	Volume (ml) <i>Feeding Roots</i>
V0	1012.20 a	25.56 a
V1	608.09 b	16.00 b
V2	592.03 b	15.10 b
<b>Peat Depth (D)</b>		
D1	682.93 a	18.14 a
D2	812.10 a	20.22 a
D3	717.29 a	18.24 a
<b>Distance from the Trunk (m) of the Oil Palm (J)</b>		
J1	1234.71 a	32.52 a
J2	1078.80 ab	26.93 ab
J3	667.51 bc	16.51 bc
J4	366.48 c	9.54 c
J5	339.69 c	8.85 c

Note: Numbers followed by the same letter in the same column are not significantly different based on the BNJ test. V0 = Discs and carrying poles; land cover percentage 0%; V1 = Piles of palm fronds; land cover percentage 50%; V2 = Weed vegetation on dead stumps; land cover percentage 100%; D1 = Peat depth 0.5–1.5 m; average 1.0 m; D2 = Peat depth 1.5–3.0 m; average 2.0 m; D3 = Peat depth >3.0 m; average 4.0 m; J1 = Distance 1.0 m; J2 = Distance 2.0 m; J3 = Distance 3.0 m; J4 = Distance 4.0 m; J5 = Distance 5.0 m.

The highest surface area and volume of *Feeding Roots* were found in the disc and carrying basket areas (V0). This is believed to be due to minimal competition from weeds, allowing oil palm roots to optimally fill the soil pore space and absorb nutrients more efficiently. In contrast, the development of *Feeding Roots* in the frond clumps (V1) and dead branches (V2) tended to be lower. The area is dominated by weeds, particularly *Nephrolepis sp.*, which are believed to compete with oil palm roots for nutrients, water, and soil pore space. Competition among plants for ecological resources is known to reduce plant growth efficiency. The results of this study indicate that open areas that receive regular fertilizer applications can stimulate the development of active roots. Placing fertilizer in the ring area creates a nutrient-rich zone that encourages *Feeding Roots* to concentrate in that area.

Total pore space has a positive correlation with a very strong relationship to the root spread of oil palm. Martinez *et al.*, 2008, as cited in Ulama and Bakri, 2022,

state that total pore space can influence the root spread of oil palm. Osman (2013) argues that soil depth also affects the root distribution of plants because soil in the lower layers tends to have a low total pore space value. The feeding root groups in the clearings and open areas tend to have higher values compared to the clumps of fronds and vegetation in the dead frond beds. This is likely due to minimal competition with weed vegetation in the ring and the market area, which have no vegetation cover (weeds are nearly 0%), while in the frond clumps there is 50% weed cover covering the soil surface and in the dead frond area it is 100% covered by weeds. Competition between the *Feeding Roots* of oil palms and *Nephrolepis* roots for space in the soil pores is also suspected to result in competition for nutrient uptake.

The planting circles and raised beds lack vegetation because they are continuously managed; as a result, there is no competition between the plant roots and weed roots for space within the soil pores, allowing the plant roots to dominate in absorbing available nutrients. Consequently,

the plant roots grow more vigorously in the planting circles and raised beds. Meanwhile, on the piles of dead fronds and branches, vegetation consisting of *Neprolephis* was found to be growing, covering 50–100% of the soil surface, resulting in competition between the plant roots and the *Neprolephis* roots for soil pores and nutrients. Under optimal conditions, weed vegetation in oil palm plantations will grow rapidly, giving it a competitive advantage over oil palm trees in the competition for growth factors (Sembodo, 2010).

Living organisms within an ecosystem may interact with one another. These interactions can be positive and mutually beneficial, or they can be negative, such as competition (Jumin, 1992). When utilizing natural resources, competing organisms vie for the resources necessary for their survival and growth. According to Werner P.A. (1979), organisms compete for space, food, nutrients, water, light, air, pollinators, dispersal agents, or other ecological factors—all of which are resources necessary for each organism's survival and growth.

The interaction between *Feeding Roots* and land cover vegetation can have both positive and negative effects on oil palm at the same time. Land cover plays a crucial role in the process of aggregate breakdown by rainfall and in reducing surface runoff (Saputra and Wawan, 2017), due to competition for soil pore space, water and nutrient uptake, alongside the return of nutrients from the decomposition of weeds, which also occurs, helping to maintain soil moisture and water levels as well as adding organic matter.

Land cover in this study refers to the amount of vegetation around the planting circles and carrying platforms, in the leaf pile areas, and in the fallow fields. It was found that vegetation coverage was 0% in the planting circles and carrying platforms, 50% in the leaf pile areas, and approximately 100% in the fallow fields. The distribution of oil palm *Feeding Roots*, as measured by fresh weight, dry weight, volume, and surface area, shows that the highest values were found in the root plates and root mats compared to the frond clumps and dead root mats.

#### **The Effect of Peat Depth on the Distribution of *Feeding Roots***

Peat depth did not have a statistically significant effect on the development of *Feeding Roots*; however, a peat depth of 1.5–3.0 m (D2) consistently resulted in higher values for the surface area and volume of *Feeding Roots*. The better root development observed in the D2 treatment is likely due to the high content of organic matter (93.38%) and available phosphorus (14.90 ppm). Phosphorus plays a crucial role in root elongation, energy transfer, and plant cell metabolism. Sufficient phosphorus availability stimulates the formation of tertiary and quaternary roots, thereby enhancing nutrient uptake capacity.

In contrast, shallow peat depths (0.5–1.5 m) were associated with reduced feeding root development, presumably due to low available phosphorus and high Al+H concentrations. High aluminum solubility under acidic soil conditions can inhibit root elongation and reduce root system development. Groundwater table conditions also influence feeding root development. Treatment D2 has a relatively stable water table at a depth of less than 40 cm below the soil surface, creating better aeration conditions for root growth. Excessive waterlogging in deep peat can reduce oxygen availability, thereby inhibiting root development.

Different peat depths affect soil fertility levels. Peat fertility decreases as the peat becomes deeper, making it difficult for plants to reach the mineral layer beneath, which disrupts plant growth and can cause plants—particularly annuals—to collapse (Suswati *et al.*, 2011).

#### **The Effect of Distance from the Stem on the Distribution of *Feeding Roots***

The distance from the oil palm trunk has a significant effect on the distribution of *Feeding Roots*. The highest surface area and volume of *Feeding Roots* were found at a distance of 1.0 m from the trunk and decreased gradually with increasing distance. *Feeding Roots* are concentrated near the trunk because fertilization is generally applied to the ring area around the plant. High nutrient concentrations in this area stimulate the proliferation of active roots through the root interception mechanism.

At distances greater than 3.0 m from the stem, the development of *Feeding Roots* declines quite sharply. This decline is thought to be related to low soil porosity and increased competition with *Neprolepis* roots. Soil bulk density increases with distance from the stem, while soil porosity decreases, thereby limiting root penetration and development. Previous studies have also shown that oil palm root density decreases with increasing distance from the trunk. Tertiary roots are generally concentrated in the topsoil layer (0–30 cm), where aeration and nutrient availability are more optimal.

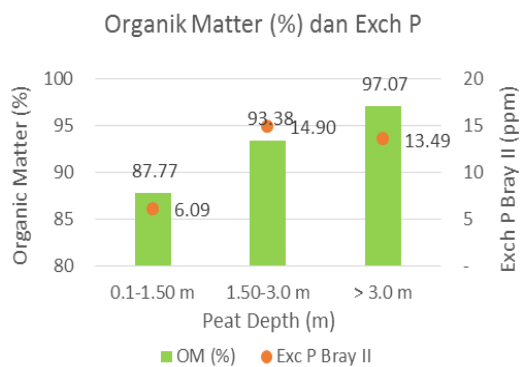
The average root system, which has developed a substantial number of roots, serves to absorb nutrients for the oil palm; however, the secondary and tertiary roots function to absorb water and nutrients from the soil. Most active roots are found at a depth of 5–30 cm, and tertiary roots are located 10 cm below the soil surface, where organic matter is abundant (Lim *et al.*, 2002). At depths of  $\leq 50$  cm, there is still sufficient oxygen available for the physiological processes involved in nutrient uptake, which influences root activity in the absorption of nutrients and water.

A study by Hakim D.L. (2025) notes that as the radius from the trunk increases, the spread of oil palm roots decreases. The greatest value of oil palm root distribution is found within a radius of 0–50 cm from the tree. This

aligns with the findings of this study, where, among all parameters, the highest value was observed at a distance of 1.0 m from the oil palm—the closest radius to the observation point.

### Analysis of Organic Matter and Available Phosphorus at Various Depths in Peat

A well-developed root system enables plants to obtain sufficient water and nutrients for photosynthesis, as root depth significantly influences the amount of water absorbed (Soelaeman Y. & Haryati U., 2006), and the rate of root elongation is influenced by internal factors, such as the supply of photosynthates from the leaves, and environmental factors, including temperature and soil moisture content (Lakitan, 1995). Figure 1 below illustrates the conditions of organic matter and available phosphorus in the soil, and the results can be seen in Figure 1 below.



**Figure 1: Organic Matter and Available Phosphorus at Various Peat Depths.**

The high organic matter content of 93.38% and phosphate availability of 14.90 ppm at peat depths of 1.5–3.0 m was met by the plants with excellent feeding root development, followed by peat depths greater than 3.0 m, which also had a high organic matter content of 97.07% and a phosphate concentration of 13.49 ppm to support feeding root development. Meanwhile, the lowest levels of *Feeding Roots* were found at a peat depth of 0.5–1.5 m, which had an organic matter content of 87.77% and a  $P_2O_5$  concentration of 6.09 ppm—the lowest value compared to the other two peat depths. This is consistent with the low Al+H levels at peat depths of 1.5–3.0 m (2.41 m.e/100 g) and at depths greater than 3.0 m (2.80 m.e/100 g), compared to the 0.5–1.5 m depth, which had a value of 3.26 m.e/100 g. The presence of higher levels of organic matter and  $P_2O_5$ , as well as low levels of Al+H, at peat depths greater than 1.5 m is believed to be a factor contributing to better feeding root development compared to areas with peat depths of 0.5–1.5 m. According to Yahya *et al.* (2010) and Sun *et al.* (2011), high Al solubility resulting from low soil pH inhibits root development.

Different peat depths affect soil fertility levels. Peat fertility decreases as the peat becomes deeper, making it

difficult for plants to reach the mineral layer beneath, which disrupts plant growth and can cause plants—especially annuals—to collapse (Suswati *et al.*, 2011). Meanwhile, the development of *Feeding Roots* at peat depths of 0.5–1.5 m is thought to be influenced by lower  $P_2O_5$  availability compared to peat depths of 1.5–3.0 m. This is explained by Bertham (2011), who states that low phosphorus availability can disrupt plant growth and inhibit root elongation, and according to Sun *et al.* (2011), low phosphorus availability weakens plant roots. This is suspected to be the factor causing lower feeding root development at peat depths of 0.5–1.5 m.

According to Elfiati D. (2013), phosphorus plays a very important role in plant root development. According to Boroomand and Grouth (2012), phosphorus functions as a molecular component in ATP, ADP, NAD, and NADPH, which control various chemical reactions in plants, such as photosynthesis, respiration, protein and amino acid synthesis, and nutrient transport. In line with Bakri *et al.* (2023), a positive correlation was found between phosphate availability and tertiary root distribution, with a value of 1.4103 and a confidence interval of 30.54%.

### CONCLUSION

Based on the research results, it can be concluded that land cover type and distance from oil palm trunks have a significant effect on the distribution of *Feeding Roots* in peatlands, whereas peat depth does not show a statistically significant effect. The disc and market basket (V0) treatments produced the highest surface area and volume of *Feeding Roots* compared to frond clumps and weed vegetation in dead fronds. The absence of vegetation cover in the disc area resulted in low root competition with weeds, allowing *Feeding Roots* to develop more optimally in absorbing water and nutrients.

The highest distribution of *Feeding Roots* was found at a distance of 1.0–2.0 m from the oil palm trunk and decreased with increasing distance from the trunk. This is related to the concentration of fertilizer application around the root zone and the high availability of nutrients in that area. The decline in feeding root development at greater distances is also influenced by increased competition with weed roots and decreased soil porosity.

Peat depths of 1.5–3.0 m tend to provide better conditions for the development of *Feeding Roots* than other depths because they have higher levels of organic matter and available phosphorus, as well as more stable water table conditions. Nutrient availability, soil aeration, porosity, and water table conditions are the primary factors influencing the development of oil palm *Feeding Roots* in peatlands.

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