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The effect of root cutting on the availability of organic carbon stock in oil palm plants (*elaeis guneensis jacq*)

Cecep Ijang Wahyudin[1*], Hariyadi[2], Sudrajat[2], *Sudirman* Yahya[2], and *Syaiful* Anwar[3]

[1]Graduate Program Agronomy and Horticulture, Department of Agronomy and Horticulture, Faculty of Agriculture, IPB University, Bogor, Indonesia
[2]Department of Agronomy and Horticulture, Faculty of Agriculture, IPB University, Bogor, Indonesia
[3]Department of Soil Science and Land Resources, Faculty of Agriculture, IPB University, Bogor, Indonesia

Abstract. Palm oil (*Elaeis guenesis jacq*) is an important commodity in Indonesia. Assessments of the underlying causes of yield gaps in oil palm production systems worldwide are lacking in exploring existing knowledge about oil palm productivity from a crop physiological perspective. Modifying the roots of oil palm plants through root cutting can affect the availability of carbon stocks in the soil because roots are one of the sources of organic carbon input into the soil. The purpose of the study was to analyses the effect of cutting the roots of oil palm plants on the availability of carbon stocks and soil fertility for these crops. The land where the study took place had a relatively low soil fertility status, there were several parameters observed showing low availability status in the soil. The low content of nutrients in the soil causes limited soil in providing nutrients to support plant growth.

1 Introduction

The growth and shape of the oil palm root system after the juvenile phase undergoes a transition. Morphologically there are eight different types of root morphology based on their developmental patterns and state of differentiation which include primary vertical and horizontal roots, secondary horizontal roots, secondary vertical roots growing upwards and secondary vertical roots growing downward, superficial and deep. Tertiary roots and quaternary roots. These types of oil palm roots determine the morphological and functional units of the root system called the oil palm's 'root system units'. This root polymorphism makes it possible to determine the morphogenetic gradient, reflecting the ontogenesis of the root system of the oil palm [1]. Plants absorb CO_2 and retain carbon while releasing O_2 through photosynthesis and at the same time releasing oxygen through photosynthesis. The carbon retained by plants is passed through the roots during the plant decomposition process. 30-50% of the carbon fixed in photosynthesis is initially transferred to the subsurface of the soil where some part is used for the growth structure of the root system, plant respiration

* Corresponding author: cecepwahyudin@apps.ipb.ac.id

(autotrophic). Some parts are lost into the surrounding soil in organic form (rhizodeposition), either separated in the form of dead tissue from living tissue during root expansion or excreted in various compounds [2]. Therefore, the modification of the root system will certainly affect the availability of soil carbon.

Modification of the roots of oil palm plants through root cutting can affect the availability of carbon stocks in the soil because roots are one of the sources of organic carbon input into the soil. Root cutting causes a decrease in organic carbon normally produced by roots. This can have an impact on the availability of carbon stocks in the soil, especially in the soil layer where roots grow. According to Alonso et al. [3], there is evidence to suggest that increased root growth in oil palm plants can increase carbon sequestration in the soil and strengthen soil carbon stocks, even in conditions where the supply of organic residues is limited. In addition, some articles indicate that changes in the mineralization of organic carbon stocks caused by different agricultural management do not have a significant effect on the capacity of soils to stabilize carbon stocks within them.

Cutting roots is able to increase the available nitrogen content, phosphorus, potassium, total organic carbon and organic carbon activity is also increased in the rhizosphere. Moderate-scale cuts increased the carbon and nitrogen content of microbial biomass and increased basal respiration and decreased metabolic quotient in rhizosphere soils by 8.9%, 5.0%, and 11.4%. Medium cutting increases the growth rate of trunk diameter, tree height, and volume to the highest level. Cutting plant roots can increase exudate production in plants such as an increase in organic acids by 25.82%; amino acids by 1.63% and sugars by 18.25%. Exudate from this plant that is utilized by microorganisms. With the increase in exudate, microorganisms will increase so that the degradation process of organic matter will be higher [4]. Root cutting increases microbial activity, thus affecting the interaction between microbes and plant roots, thus affecting soil carbon content [5].

Root cutting at a depth of 5 cm increases root fresh weight and root volume in sugarcane crops by 21–59% and 41–127%, respectively, compared to cutting depths of 0 and 10 cm. Root cutting 5 cm below the surface increases sugarcane yields by 43 and 28% respectively compared to cutting depths of 0 and 10 cm below the soil surface as it helps optimize sugarcane ratoon management and improve the ratoon cycle [6].

2 Methods

The research has been carried out from December 2021 to October 2022 in Teluk Merbau Village, Dayun District, Siak Sri Indrapura District, Riau-Indonesia. Analysis of soil chemical properties was conducted at the Department of Soil Science and Land Resources, Faculty of Agriculture, Bogor Agricultural University. Carbon observation research was carried out on oil palm plants with a planting age of 5 years, each treatment was carried out at 0, 3 and 9 months after treatment.. Calculating the carbon content of oil palm plants using the formula:

$$C = Bp \ x \ organic \ matter \quad (1)$$

Description :
C = Oil palm surface carbon content (ton/ha)
Bp = Total potential biomass (ton/plant)
Organic matter = 47% (SNI 2011) while for oil palm plants 0.46% [7]

3 Results and discussion

3.1 N-total soil analysis

The land where the study took place had a relatively low soil fertility status, there were several parameters observed showing low availability status in the soil. The low content of nutrients in the soil causes limited soil in providing nutrients to support plant growth.

Table 1. N-total soil analysis.

Treatment	N-total (%)
Depth 10 cm intensity 25%	0,18 [cd]
Depth 10 cm intensity 50%	0,30 [a]
Depth 10 cm intensity 75%	0,22 [bc]
Depth 20 cm intensity 25%	0,10 [e]
Depth 20 cm intensity 50%	0,15 [de]
Depth 20 cm intensity 75%	0,25 [bc]

Remarks: The numbers of a column followed by the same lowercase letter are not significantly different in the 5% F level test

Table 1 shows differences in soil total N-content at various depths and intensities of root cutting ranging from rendang to medium. Paul [8] stated that a reduced root system can cause low absorption of phosphorus nutrients and for nitrogen, especially the nitrate group (NO_3-) is more susceptible to leaching. Root cutting is able to expand the distribution of root absorption so that there is a greater opportunity to reach water and nutrient absorption. Gardner [9] physical disorders that occur in the root in the form of root injury or cutting will eliminate tip dominance and intensify lateral root growth. The lateral roots formed increase the number of roots so that the distribution of roots both horizontally and vertically will be wider and nutrient absorption will be more optimal.

The availability of nitrogen in the soil is influenced by the presence of plant roots by helping the absorption of nutrients that are important for plant growth and water. Plant roots that are cut at a depth of 10 cm with an intensity of 50% are able to optimize the growth of new roots so that the ability to remove organic compounds such as amino acids, organic acids, and enzymes through the root exudation process. Root exudation can change the form of unavailable nitrogen into a form that can be used by plants in the form of both ammonium (NH_4^+) and nitrate (NO_3-) can be increased. Roots can also improve soil condition by improving air circulation and promoting the growth of microbes that decompose organic matter in the soil, thereby increasing nitrogen availability for plants.

A reduced root system can increase nitrogen nutrient uptake in accordance with the results of research conducted by Paul [8] stating that a reduced root system can cause the lowest absorption of nitrogen nutrients, especially the nitrate group (NO_3-) more susceptible to leaching.

3.2 P-total soil analysis

Analysis of the fingerprints showed a marked difference in the P-total content of the soil. The highest P-total content was found in root cutting treatment at a depth of 10 cm with an intensity of 25% of 51.04 ppm (very high) and the lowest was found in root cutting with a depth of 10 cm with an intensity of 75% of 10.35 ppm (low).

Table 2. P-total soil analysis

Treatment	P-total (ppm)
Depth 10 cm intensity 25%	51,04 [a]
Depth 10 cm intensity 50%	20,76 [b]
Depth 10 cm intensity 75%	10,35 [f]
Depth 20 cm intensity 25%	46,71 [b]
Depth 20 cm intensity 50%	27,68 [d]
Depth 20 cm intensity 75%	38,93 [c]

Remarks: The numbers of a column followed by the same lowercase letter are not significantly different in the 5% F level test

Table 2. shows marked differences in soil P-total levels affected by root cutting at various depths and intensities. Root cutting can increase the nutrient content in the soil because the roots after cutting will try to adapt and regenerate to form new roots so that the growth of new roots that form secondary and tertiary roots is spurred. The formation of new roots will be able to increase water absorption in the soil and indirectly help the absorption of more nutrients such as phosphor. Louk and Raharjo [10] stated that trees whose roots were pruned even twice a season were able to markedly increase nitrogen, phosphorus, calcium, magnesium, iron and boron in leaves compared to plants that were not pruned roots.

3.3 Kalium soil analysis

Analysis of the fingerprints showed a marked difference in soil K-dd content. The highest K-dd content was found in the root cutting treatment at a depth of 10 cm with an intensity of 50% in contrast to the intangible depth of 10 cm root cutting with an intensity of 75% and 20 cm with an intensity of 75% with a range of 0.23-0.21 cmol / kg (low).

Table 3. Kalium soil analysis

Treatment	K (cmol/kg)
Depth 10 cm intensity 25%	0,16 [b]
Depth 10 cm intensity 50%	0,23 [a]
Depth 10 cm intensity 75%	0,22 [a]
Depth 20 cm intensity 25%	0,17 [b]
Depth 20 cm intensity 50%	0,17 [b]
Depth 20 cm intensity 75%	0,21 [a]

Remarks: The numbers of a column followed by the same lowercase letter are not significantly different in the 5% F level test

Table 3. shows a marked difference in soil K-dd levels. Potassium in soil exists in four forms in order to form a dynamic equilibrium consisting of: (1) K-dissolved in soil solution, (2) K-interchangeable, (3) K non-interchangeable and (4) K minerals [11]. This availability of K is related to the process of CO_2 assimilation in plants, with an increase in K levels also an increase in CO_2 assimilation.

The movement of K to the root surface is mainly through diffusion, so the diffusion of K is highly dependent on the content and continuity of the soil moisture mass, the difference in K concentration between the K source site and the root surface, and the distance between the two places. The diffusion of K to the root surface accelerates with increasing soil moisture, the difference in K levels is getting bigger, and the distance between the two sites is getting shorter. This phenomenon is important to understand so that K management in soil is optimal. If the K content in the soil solution decreases because it is absorbed by plants or leached, there will be a chain release of K from K-interchangeable, K-embedded, and K- in mineral crystals (through weathering) [7].

3.4 PH soil analysis

Analysis of fingerprints showed a marked difference in soil pH content. The highest pH content was found in the root cutting treatment at a depth of 10 cm with an intensity of 25% but not significantly different from the 20 cm depth treatment with an intensity of 25% with a slightly acidic pH, while the lowest pH was found in the root cutting treatment of 20 cm with an intensity of 75% with a value of 4.98 (sour)

Table 4. PH soil analysis

Treatment	pH
Depth 10 cm intensity 25%	6,28 a
Depth 10 cm intensity 50%	5,29 bc
Depth 10 cm intensity 75%	5,80 ab
Depth 20 cm intensity 25%	6,10 a
Depth 20 cm intensity 50%	5,28 bc
Depth 20 cm intensity 75%	4,98 c

Remarks: The numbers of a column followed by the same lowercase letter are not significantly different in the 5% F level test

Table 4 shows soil pH at root cutting depth of 10 cm with an intensity of 25% and depth of 20 cm with an intensity of 25% close to neutral pH. This also supports the later availability of higher nutrients at the pH.[12], pH that is close to neutral will affect the availability of nutrients and plant growth. Increased pH can be caused by several factors including the decomposition process that releases cations and a certain amount of OH- released in the formation of organic complexes.

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Soil pH can affect the growth and development of plant roots. Optimal pH conditions can affect root development after root cutting so that root regeneration can be optimized and improve plant nutrient absorption conditions. At low soil pH such as root cutting at a depth of 20 cm, the intensity of 75% causes some nutrients to be less available such as phosphorus and calcium so that root growth can be inhibited. High soil pH can also cause problems in root growth and vice versa. Therefore, the ideal soil pH for root growth is between 6 to 7 because it has a tendency for nutrients to be available in optimal and stable amounts.

Soil pH can significantly change due to root cutting that occurs in the area around the root, the deeper the cutting and the high intensity of root cutting tends to decrease the pH in the soil. In addition, high metal content in the soil has great potential in lowering soil pH. Angeles et al. [13], who stated the bioavailability and toxicity of various metals that are in the soil and around high root areas will be able to lower soil pH.

3.5 Organic matter analysis

Analysis of the fingerprints showed a marked difference in soil C-organic content. The highest C-organic content was found in root cutting treatment at a depth of 20 cm with an intensity of 75% around 2.79% (Medium) and the lowest at a depth of 20 cm with an intensity of 25% with a range of 1.20% (Low).

Table 5. Organic matter analysis

Treatment	Organic matter (%)
Depth 10 cm intensity 25%	1,90 cd
Depth 10 cm intensity 50%	2,07 bc
Depth 10 cm intensity 75%	2,39 ab
Depth 20 cm intensity 25%	1,20 e
Depth 20 cm intensity 50%	1,60 de
Depth 20 cm intensity 75%	2,79 a

Remarks: The numbers of a column followed by the same lowercase letter are not significantly different in the 5% F level test

Table 5 shows the depth of root cutting can affect soil C-organics because plant roots can be a source of soil C-organics derived from dead plant roots and tissues, as well as decomposed organic matter remains. Root cutting at a depth of 20 cm results in higher levels of C-organic compared to cutting at a depth of 10 cm. These results show that cutting roots at a depth of 20 cm with an intensity of 75% shows better results because it will accelerate the growth of new plant roots and increase the absorption of C-organic so that soil C-organic also increases.

Jing et al. [4] stated that root removal performed at moderate levels increases amino acids, organic acids, and total sugars in root exudate and lowers the pH of the rhizosphere soil and increases the content of available nitrogen, phosphorus, potassium, and organic carbon moderate pruning also increases the carbon and nitrogen content of microbial biomass.

3.6 Carbon stock analysis

Analysis of fingerprints showed significant differences in soil carbon stocks across different ages (0, 3 and 9 months). The highest soil carbon stock is found in root cutting with a depth of 20 cm with an intensity of 75% at root cutting aged 0, 3 and 9 months, but at the age of 3 and 9 months it differs insignificantly with a depth of 20 cm with an intensity of 50%.

Table 6. Carbon stock analysis

Treatment	Month		
	0	**3**	9
Depth 10 cm intensity 25%	0.20 a	0.45 a	0.25 a
Depth 10 cm intensity 50%	0.28 a	0.50 a	0.23 a
Depth 10 cm intensity 75%	0.22 b	0.46 a	0.26 a
Depth 20 cm intensity 25%	0.22a	0.48 a	0.26 a
Depth 20 cm intensity 50%	0.20 b	0.45 a	0.21 a
Depth 20 cm intensity 75%	0.25 a	0.84 a	0.27 a

Remarks: The numbers of a column followed by the same lowercase letter are not significantly different in the 5% F level test

Table 6 shows soil carbon stock is an indicator that can be used in soil quality assessment because of the relationship with the role of soil organic matter. Root cutting can lead to the formation of new root growth that allows soil organic carbon to be rapidly altered through stabilization and destabilization mechanisms. Dijkstra et al. [14] stated that roots can affect soil carbon stocks because they can encourage the stabilization of soil organic carbon to become available and the process of destabilization of soil organic carbon which causes carbon loss in the soil. Root performance will help to sequence C soils and affect reservoirs, and new opportunities to understand the sensitivity of SOC ponds to climate change and land use.

Soil carbon stocks are more measurable in topsoil and tend to increase with the cutting age of roots. The longer the cutting life of the roots will certainly give the roots time to form and new roots. This leverages the presence between roots and soil particles to form more complex aggregates so that is where soil carbon stocks are stored. Zeng et al. [15] found in the results of the study that the availability of soil carbon stocks is also related to soil aggregates, especially macro aggregates which have soil carbon stocks of around 36.34-76.09%.

4 Conclusion

The low level of soil fertility and the effect of different treatments for cutting oil palm roots show that the carbon stock content in this reservoir varies. The growth time after root cutting treatment of oil palm plants is best at the age of 3 months with the optimum carbon stock content being cut at a depth of 20 cm with an intensity of 75%.

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