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Differences in Soil Nutrient Levels in Oil Palm Plantations (*Elaeis guineensis* Jacq.) Planting Age 6 and 8 Years

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Abstract

Oil palm plantations in Riau Province were commonly found on suboptimal lands, such as Inceptisol soils, which exhibited inherently poor soil chemical fertility. This research aimed to determine the chemical properties of Inceptisol soil in 6- and 8-year-old oil palm plantations. This research was conducted from July to December 2024 at the Oil Palm Plantation, Sub-District Perhentian Raja, Kampar District, Riau. The analysis of soil chemical properties was carried out at the Instrumental Chemistry Laboratory, Faculty of Mathematics and Natural Sciences, Padang State University. This research employed a quantitative descriptive method, where data collection was conducted through direct observation and subsequently analyzed in the laboratory. A purposive sampling technique was employed to collect soil samples, where each sites was divided into four sampling plots. Within each plot, soil samples were collected and composited from five sub-samples, yielding a total of eight Inceptisol soil samples for subsequent analysis. The following soil parameters were analyzed: pH (H_2O), OC, total N, P, K, Ca, Mg, SO_4, and CEC. The chemical properties of the Inceptisol at the research sites were characterized by: a pH range of very acidic to acidic, sufficient levels of OC, and total-N, very low levels of total (P and K), excessive of total-Ca, deficient of total-Mg, very low levels of SO_4, and moderate to high levels of CEC; there were significant mean differences in soil N, SO_4, and CEC, whereas soil pH, OC, P, K, Ca, and Mg levels were not influenced by oil palm age.

Keywords: Inceptisol, Nutrient Losses, Palm Oil, Plantation, Soil Chemical

1. Introduction

Elaeis guineensis Jacq. plantations continue in Riau Province due to the increasing demand for palm oil. The area of oil palm plantations in Riau is 3.49 million hectares (20.5% of the total area of oil palm plantations in Indonesia), making it the largest in Indonesia (Directorate General of Plantations, 2023). The large area of oil palm plantations in Riau does not always indicate better productivity when compared to several other provinces with smaller areas. Based on data from the Directorate General of Plantations (2023), oil palm productivity in Riau is 3.86 tons. This figure is still below that of Papua (5.06 tons), Central Kalimantan (4.57 tons), North Sumatra (4.50 tons), Bangka Belitung, and South Sumatra (4.22 tons). This finding is thought to be related to land conditions in Riau, which are dominated by sub-optimal land.

Oil palm plantations in Riau are often found on acidic soils, including Inceptisol soils. Inceptisol soil is the second most widely distributed soil type in Riau, after peat soil, covering an area of 2.6 million hectares (Harahap et al., 2022). Inceptisol soil is classified as a young soil that has undergone moderate weathering, with active leaching and erosion processes, resulting in a low nutrient absorption capacity (Suryani et al., 2022), relatively high soil acidity, basic cation content such as Ca2+, Mg2+, K+, and low base saturation (Lubis and Sebayang, 2024). Based on the results of research by Suhemi et al. (2022), the chemical status of Inceptisol soil in smallholder oil palm plantations has a pH value of 4.06, organic C 1.42%, total N 0.20%, available P 15.09 ppm, K-dd 32.5 cmol(+)/kg, CEC 9.06 cmol(+)/kg, KB 19.30% and Al saturation reaching 39.55% at a depth of 0-30 cm. In addition, the parent material and soil particles that determine texture also affect the mobility and bioavailability of nutrients in Inceptisol soils (Taalab et al., 2019).

Efforts to increase oil palm productivity must be

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carried out with proper fertilization management, primarily on Inceptisol soils, where soil that has not undergone complete weathering may still actively release H+ ions, thereby accelerating the rate of weathering of soil minerals (Zhao et al., 2022). These ongoing mineral changes will undoubtedly affect nutrient dynamics, particularly in terms of their availability in the soil. Differences in oil palm plants aged 6 and 8 years will affect the mineralization process, which in turn will result in different nutrient availability at these ages. Fertilization of oil palms aged 4 years or more must be carried out according to soil and leaf analysis, as nutrient requirements also increase with plant age, allowing the provided nutrients to be utilized optimally by the plant (Sanputawong et al., 2017). According to the research results by Viégas et al. (2024), there is an increase in Ca accumulation in the leaf veins of oil palm plants, which continues to rise until the age of 8 years. In addition, the addition of soil organic C value is known to increase with plant age, from 0.82% at 5 years to 2.21% after more than 15 years (Farrasati et al., 2019).

Oil palm plants absorb nutrients from the soil to form plant parts and produce Fresh Fruit Bunches (FFB), which allows nutrients also to be transported at harvest time. According to Sinaga et al (2024), nutrients transported by harvest in 1 ton of oil palm FFB are equivalent to 3.7 kg K, 2.9 kg N, 0.8 kg Ca, 0.8 kg Mg, and 0.4 kg P. Meanwhile, Purwanto, E., et al. (2019) stated that differences in the age of oil palm plants significantly affect the results. The study showed that surface runoff in oil palms aged 3 years (1.9 mm) was greater than in those aged 5 years (1.5 mm) in each rainfall event. The average erosion in 3-year oil palms was 0.07 tons ha-1, while for 5-year oil palms it was 0.05 tons ha-1. Based on this fact, understanding the characteristics of soil spatially and over time periods is important as a material for evaluating nutrient balance to increase soil fertility and productivity.

2. Material and Methods

2.1. Place and Time

This research was conducted at Sei Pagar Plantation - East District Regional III - PTPN IV Kampar Regency, Riau Province, located at 0° 25' 26.308" N and 101° 24' 30.104" E. and continued with analysis of soil chemical properties at the Instrumental Chemistry Laboratory, Faculty of Mathematics and Natural Sciences, Padang State University in July - December 2024.

2.2. Materials and tools

The materials used were Inceptisol soil taken from the PTPN IV Sei Pagar Oil Palm Plantation at 6 and 8 years old, along with chemicals for laboratory analysis. The tools used were a mineral soil drill, a hoe, a mobile phone camera, a measuring tape, a tray, a 10-mesh sieve, a mortar and pestle, and laboratory equipment.

2.3. Research methods

This research employed a quantitative descriptive method, implemented through direct observation followed by laboratory analysis. Soil samples were collected from 6- and 8-year-old oil palm plantations using purposive sampling and then composited.

This study used two data sources: primary and secondary data. Primary data consisted of soil chemical analysis results, including N, P, K, S, Ca, Mg, organic carbon, pH, and CEC. Secondary data consisted of a general description of the research location and soil characteristics, as described in previous references obtained from the PTPN IV Sei Pagar Oil Palm Plantation.

2.4. Research Stages

The research location was determined based on the uniformity of the land cover. The soil sampling location for 8-year-old oil palms was in section 1, block 25R1 (0º18'34" N, 101º21'4" E), and the soil sampling for 6-year-old oil palms was in section 2, block 21N1 (0º17'60" N, 101º18'54" E). Soil samples were collected using a purposive sampling technique, where one oil palm plantation block was divided into four sample plots. In each sample plot, soil was collected and composited from five sub-samples, resulting in a total of eight samples for the two blocks. The soil sampling point at each location was carried out in a diagonal pattern with a distance of approximately 50 m between sub-samples. Soil samples were collected around the oil palm plants using a mineral soil drill or hoe at a depth of 0-40 cm. At each sub-sample point, ±500 g of soil was collected with a sampling distance of 100 m from the main road and then sample preparation for soil chemical analysis was conducted.

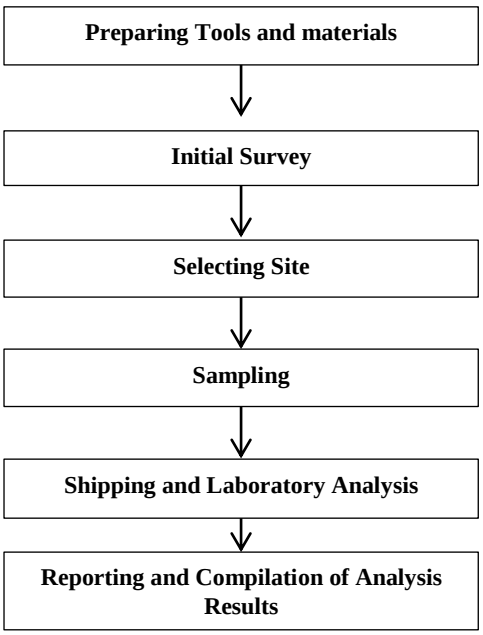

Figure 1. Research flow diagram

2.5. Data analysis

Data in the form of soil chemical characteristics, namely pH H_2O, C-organic, Total-N, P-total, K-total, Ca-total, Mg-total, SO_4, and CEC on oil palm plantations aged 6 and 8 years were analyzed for their diversity using the T test on normally distributed data groups, and using the Mann-Whitney U test on non-normally distributed data groups with the SPSS 25.0 application. If the Sig. (2-tailed) A value of $p<0.05$ indicates a significant difference in soil chemical characteristics between the ages of 6 and 8 years. The categories of soil chemical analysis results for the parameters pH, C-organic, Total-N, SO_4, and CEC are adjusted to the assessment criteria of the Soil Research Institute (2005), for the parameters P-total and K-total according to the FAO criteria (1980), and Ca-total and Mg-total according to the criteria according to Winarso (2005).

3. Results and Discussion

3.1. Soil Reaction (pH H_2O)

Soil pH measurements carried out in the laboratory using the pH meter method on oil palm plantations aged 6 and 8 years were statistically processed using the Mann-Whitney test, as shown in Table 1.

Table 1. Soil pH Values at Two Oil Palm Planting Locations

Oil Palm Planting Age	Soil Reaction (pH)				Criteria
	Mean	Standard Deviation	CV	Sig. 2-tailed	(Soil Research Institute. 2005)
6 years	4.40 [a]	0.61	13.96	0.546	Very Acid
8 years	4.54 [a]	0.46	10.14		AC ID

Description: The average number followed by the same letter indicates no significant difference based on the Mann-Whitney U test at the 5% level.

Table 1 shows that the average pH of Inceptisol soil in 6-year-old plants is 4.40, which is classified as very acidic. In contrast, the average pH of the soil in 8-year-old plants is 4.54, classified as acidic. The results of the statistical test (Mann-Whitney U) show that there is no significant difference between the average pH of soil at ages 6 and 8, as indicated by the value.

The results of research by Suhemi et al. (2022) showed a pH value of 4.06 from the analysis of Inceptisol soil in smallholder oil palm plantations, indicating a very acidic condition. The criteria indicate that the average pH of Inceptisol soil remains suitable for oil palm plant growth. This result is also supported by the opinion of Novansius et al. (2023), who state that oil palm plants are tolerant and can grow in acidic pH conditions ranging from 4 to 5.5, with optimal growth occurring at pH levels between 5 and 6.5.

It is suspected that the condition of Inceptisol soil, which has experienced moderate weathering and leaching, can affect the pH of acidic soils. According to Zhao et al. (2022), soil that has not undergone complete weathering allows the release of H+ ions, which accelerates the rate of chemical weathering. The presence of H+ ions can lower the soil pH. Although low soil pH is not a problem for oil palm plants, the issue that arises at low soil pH is the high solubility of Al and Fe, which can be toxic to plants under extreme conditions (Sumarni et al., 2020).

3.2. Soil Organic Carbon

The data from the laboratory analysis of soil organic matter (OC) conducted using the Walkley and Black method on oil palm plantations aged 6 and 8 years were statistically processed using the Independent-Sample T-Test, as shown in Table 2 below.

Table 2. Soil Organic Carbon Content at Two Oil Palm Planting Locations

Oil Palm Planting Age	Organic Carbon				Criteria
	Mean	Standard Deviation	CV	Sig. 2-tailed	(Soil Research Institute, 2005)
6 years	2.74 [a]	0.40	14.42	0.051	Currently
8 years	2.05 [a]	0.40	19.71		Currently

Description: The average numbers followed by the same superscript do not differ significantly based on the Independent-Sample T Test at 5% level.

Table 2 shows that the average soil organic C for 6-year-old plants is 2.74%, which is classified as moderate, while the average soil organic C for 8-year-old plants is 2.05%, also classified as moderate. Statistical test results (T-test) show that there is no significant difference in the average organic C yield of Inceptisol soil at the age of 8 years.

The criteria show that the average organic C for 8-year-old soil is close to deficiency, this is supported by the opinion of Musinguzi et al. (2016) in general 2-3% organic C can support microbial performance in the soil, but in some cases estimates 1.9-2.2% organic C as the critical concentration range for high crop yields.

Based on the research results of Suhemi et al. (2022), the organic C content in Inceptisol soil in smallholder oil palm plantations is 1.42%, which falls below the low criteria. The organic C content at the research site is primarily derived from decomposed organic matter generated during land clearing. In contrast, organic matter in the form of litter from fronds, empty bunches, and other remaining cover crops that are still present has not contributed organic C to the Inceptisol soil. It is suspected that this is also what causes the low soil pH at the research site due to the ongoing decomposition of organic litter. In

line with the opinion of Andriany et al. (2018), during the decomposition process assisted by bacterial activity, CO2 and H+ ions are released, causing a decrease in soil pH.

3.3. Total- N

The data from the total N analysis of the soil, conducted in the laboratory using the Kjeldahl method on oil palm plantations aged 6 and 8 years, were statistically processed using the Independent-Sample T-Test, as shown in Table 3.

Table 3. Soil Total-N Content at Two Oil Palm Planting Locations

Age of Oil Palm	Soil Total N Content (%)				Criteria (Soil Research Institute, 2005)
	Mean	Standard Deviation	CV	Sig. (2-tailed)	
6 years old	0.28 [a]	0.048	17,096	0.03	Currently
8 years old	0.21 [b]	0.026	12,599		Currently

Description: The average number followed by a superscript indicates no significant difference based on the Independent-Sample T Test at 5% level.

Based on Table 3, the average Total-N soil value for 6-year-old plants is 0.28%, which is classified as moderate, while the average Total-N soil value for 8-year-old plants is 0.21%, which is also classified as moderate. Statistical test results (T-test) show that there is a significant difference in the average Total-N yield of Inceptisol soil at age 6 (M = 0.28, SD = 0.05) with age 8 years (M = 0.21, SD = 0.03), t (6) = 2.83, p = 0.030 < 0.05.

This finding aligns with the research results of Suhemi et al. (2022), which showed that the total N value of Inceptisol soil was 0.20%, meeting the moderate criteria. Judging from the fertilization history carried out at the research location, urea fertilizer was applied to 6- and 8-year-old plants at a dose of 3.75 kg/tree. However, the source of N in Inceptisol soil does not only come from urea but also from organic matter. According to Punuindoong et al. (2021), the primary source of N and its availability in the soil generally comes from the decay of plant remains, which represent approximately 3% of the organic matter.

Another factor influencing the total N content in Inceptisol soils is the presence of LCC plants, which help fix N in the soil. According to Nurlaila (2017), legumes are more suitable as cover crops and green manure because they can fix N in the soil and their roots do not compete heavily with the main crop.

3.4. Soil Total P

The data from the total soil P analysis carried out in the laboratory using the XRF method on 6- and 8-year-old oil palm plantations were statistically processed using the Independent-Sample T-Test, as shown in Table 4.

Table 4. Soil Total P Content at Two Oil Palm Planting Locations

Age of Oil Palm	Soil Total P Content (%)				Criteria (FAO, 1980)
	Mean	Standard Deviation	CV	Sig. (2-tailed)	
6 years old	3.42 [a]	0.139	4,061	0.887	Very Low
8 years old	3.38 [a]	0.630	18,653		Very Low

Description: The average numbers followed by the same superscript do not differ significantly based on the Independent-Sample T Test at 5% level.

Based on Table 4, the average total soil P value for 6-year-old plants is 3.42%, which is classified as very low. Similarly, the average total soil P value for 8-year-old plants is 3.38%, also classified as very low. Based on the history of fertilization, the primary source of P comes from the provision of TSP at a dose of 1.25 kg/plant for 6-year-old plants and 1.5 kg for 8-year-old plants. Statistical test results (T-test) showed that there was no significant difference in the average total P yield of Inceptisol soil at the ages of 6 and 8 years.

It is suspected that the total P content in Inceptisol soil has been partially absorbed by both ages of oil palm plants, so that its stock in the soil is very low. This finding aligns with the results of research by Suhemi et al. (2022), which showed the results of the available P analysis in Inceptisol soil, namely 15.09, meeting the moderate criterion. Therefore, the P stock in the soil may be very low due to absorption by oil palm plants. Although P easily binds with dominant elements at acidic pH, when viewed from the organic C content, it is possible that P absorption can still occur, albeit in limited quantities. In line with the results of research by Liang et al. (2020), the role of organic matter can increase the presence of phosphate-solubilizing bacteria (PSO), which can change the form of insoluble phosphate in the soil through the secretion of phytase and phosphatase enzymes to produce soluble phosphate and can be directly absorbed by plants. However, unsuitable soil pH remains a major influence on P elements in the soil, as stated by Johan et al. (2021). P elements can be maximized at a pH of 6.5 for mineral soil and 5.5 for organic soil.

3.5. Soil Total K

The data from the results of the soil total potassium analysis carried out in the laboratory using the XRF method on oil palm plantations aged 6 and 8 years were statistically processed using the Independent-Sample T-Test, as shown in Table 5.

Table 5 shows that the average K-total soil value for 6-

year-old plants is 3.81%, which is classified as very low; the average K-total soil value for 8-year-old plants is 3.97%, also classified as very low.

Table 5. Soil Total Potassium Content at Two Oil Palm Planting Locations

Age of Oil Palm	Soil Total K Content (%)				Criteria (FAO, 1980)
	Mean	Standard Deviation	CV	Sig. (2-tailed)	
6 years old	3.81 [a]	0.403	10,580	0.600	Very Low
8 years old	3.97 [a]	0.442	11,130		Very Low

Description: The average numbers followed by the same superscript do not differ significantly based on the Independent-Sample T Test at 5% level.

Judging from the fertilization history, the primary source of K comes from the application of MOP at a rate of 3.5 kg/tree for 6-year-old plants and 4 kg/tree for 8-year-old plants. The results of the statistical test (T-test) showed no significant difference in the average total K yield of Inceptisol soil at the ages of 6 and 8 years.

It is suspected that both ages of oil palm plants have absorbed some K, this is in line with the results of research by Suhemi et al . (2022) which showed that the available K content in Inceptisol soil was 32.5 cmol/kg with moderate criteria, so that the total K in Inceptisol soil was reduced due to absorption by oil palm plants. If viewed from a sufficient N content, it can also aid in the absorption of cations, including potassium. This finding aligns with the results of research by Noto et al. (2023), which indicate a positive interaction that enhances K absorption due to the addition of N fertilizer, potentially leading to a significant increase in K absorption in oil palm roots, leaves, and bunches. The low total K content of the soil is thought to be due to the acidic soil pH, which causes competition between K and Al or Fe. In line with the opinion of Paramisparam et al. (2021), at low pH, ions are adsorbed into exchange complexes, where Al3+ and Fe2+ replace basic cations, one of which is K, by moving it into the soil solution, which then undergoes leaching to deeper layers. Because K has a single valence, K is easily released from the adsorption complex and is consequently replaced by high valence ions such as Al 3+ and Fe 2+ (Hadi et al, 2015).

3.6. Total Ca

The data from the Ca-total soil analysis results, carried out in the laboratory using the XRF method on oil palm plantations aged 6 and 8 years, were statistically processed using the Independent-Sample T Test, as shown in Table 6.

Based on Table 6, the average Ca-total soil value for 6-year-old plants is 9.28%, which is classified as very high, while the average Ca-total soil value for 8-year-old plants is 9.44%, which is also classified as very high.

Table 6. Total Ca Content of Soil at Two Oil Palm Planting Locations

Age of Oil Palm	Total Ca Content of Soil (%)				Criteria (Winarso, 2005)
	Mean	Standard Deviation	CV	Sig. (2-tailed)	
6 years old	9.28 [a]	1,156	12,455	0.795	Very high
8 years old	9.44 [a]	0.164	1,733		Very high

Description: The average numbers followed by the same superscript do not differ significantly based on the Independent-Sample T Test at 5% level.

Judging from the fertilization history, the primary source of calcium (Ca) is provided through dolomite, with a dose of 2.25 kg/tree for 6-year-old plants and 3 kg/tree for 8-year-old plants. The results of the statistical test (T-Test) showed no significant difference in the average Ca-total results of Inceptisol soil at the ages of 6 and 8 years. This finding is in line with the results of research by Azmi et al . (2022) showing a Ca content with a value of 7.34% with moderate criteria in Inceptisol soil on acidic dry land, where the alluvium parent material mostly carries Ca which will affect the Ca-total content of the soil so that the amount is abundant in the soil. Supported by the opinion of Kowalska et al. (2019), CaCO3 can be formed through river water deposits or mud that carry dissolved Ca, resulting in sedimentation and accumulation in a place to form a layer of soil or rock. CaCO3-rich soils are often found in both dry and humid areas, where large amounts of CaCO3 are repeatedly precipitated from the soil solution (Bing et al., 2017). Furthermore, the sufficient organic carbon content at the study site allows sedimented calcium to be retained on the surface of organic matter, resulting in very high Calcium levels in the soil. In line with Luo et al. 's (2023) opinion, as an important soil nutrient, soil organic matter exhibits strong adsorption and complexation of Ca ions in soils with high Ca content, which can inhibit Ca loss and migration to some extent.

3.7. Mg-Total

The data from the laboratory analysis of total Mg in the soil, conducted using the XRF method on oil palm plantations aged 6 and 8 years, were statistically processed using the Mann-Whitney U test, as shown in Table 7.

Based on Table 7, the average Mg-total soil value for 6-year-old plants is 0.12%, which is classified as low, while

the average Mg-total soil value for 8-year-old plants is 0.58%, also classified as low. However, this average Mg-total has a considerable deviation and variation value. Where the Mg-total test results from all observation points have a significant range of values from 0 (not measurable) to 1.09. Judging from the fertilization history, the primary source of magnesium (Mg) is the provision of dolomite, as well as Calcium fertilization. Showing no significant difference between the average Mg-total soil of Inceptisols aged 6 and 8 years.

Table 7. Total Mg Content of Soil at Two Oil Palm Planting Locations

Age of Oil Palm	Total Mg Content of Soil (%)				Criteria (Winarso, 2005)
	Mean	Standard Deviation	CV	Sig. (2-tailed)	
6 years old	0.12 [a]	0.196	163,441	0.237	Low
8 years old	0.58 [a]	0.491	84,657		Low

Description: The average numbers followed by the same superscript do not differ significantly based on the Independent-Sample T Test at 5% level.

It is suspected that the low Mg in Inceptisol soil at both 6 and 8 years of age is due to the influence of the acidic pH of Inceptisol soil. In line with the results of research by Azmi et al. (2022), which showed that the Mg-dd content had a value of 0.53 cmol/kg, meeting the low criteria, the total Mg in Inceptisol soil was also low due to leaching or washing of Mg. This finding is supported by the opinion of Chaudhry et al. (2021), who note that Mg has a large hydrated radius, allowing it to be weakly absorbed in soil with an acidic reaction (pH < 4.5) and, as a result, can be easily leached. In contrast to Ca, which is more stable at acidic pH, the Mg element is less bound to the surface of soil colloids. In line with the opinion of Purba et al. (2021), the similarity between Mg and Ca elements lies in their divalency and ability to form fairly stable chemical bonds; however, Ca bonds are generally stronger. Ca atoms have a relatively weaker nuclear attraction force, so they release electrons more easily (Farhat et al., 2015).

3.8. Sulfate (SO_4)

Data from the laboratory analysis of SO4 soil, carried out using the Turbidimetry method on oil palm plantations aged 6 and 8 years, were statistically processed using the Independent-Sample T-Test, as shown in Table 8.

Table 8. Sulfate (SO_4^{2-}) Levels in Soil at Two Oil Palm Planting Locations

Age of Oil Palm	Total Sulfate Content of Soil (%)				Criteria (Soil Research Institute, 2005)
	Mean	Standard Deviation	CV	Sig. (2-tailed)	
6 years old	6.02 [a]	2,249	37,360	0.006	Very Low
8 years old	1.67 [b]	0.177	10,570		Very Low

Description: The average numbers followed by the same superscript do not differ significantly based on the Independent-Sample T Test at 5% level.

Based on Table 8, the average SO_4 value of Inceptisol soil for 6-year-old plants is 6.27 ppm, which is classified as very low, while the average SO_4 value of Inceptisol soil for 8-year-old plants is 1.62 ppm, which is classified as very low. The results of the statistical test (T-test) show a significant difference in the average SO_4 results of Inceptisol soil at the ages of 6 and 8 years.

The primary source of S in the soil is highly dependent on organic matter and the parent material of the soil itself. Inceptisol soil conditions at the study site are formed from alluvial parent material, which generally has very little organic matter. In line with the opinion of Malesi et al. (2023), alluvial landscapes naturally have low organic matter content because the soil formation process is not yet complete. When viewed from the organic-C content, oil palms aged 6 years have a higher organic-C value than those aged 8 years. This finding is closely related to the availability of SO_4, resulting in a significant difference between the two plant ages. In line with the results of research by Kaiser and Vetsch (2024), approximately 95% of the total amount of S in the soil is found in organic matter. Therefore, when organic soil material is broken down, S in its organic form is converted into SO4, which plant roots can absorb. Another factor that causes the low availability of SO_4 is that S reacts with other elements, such as Fe, which forms insoluble pyrite (FeS2). This finding aligns with the opinion of Chaudhry et al. (2023), who suggest that when decomposing organic matter in the S cycle, microorganisms can reduce sulfur to sulfide (S2). When reacted with Fe, this sulfide forms the mineral FeS2, which is difficult to dissolve. In addition, SO_4 is susceptible to leaching due to its high mobility in the soil, as its negative charge is not bound to colloids that are also negatively charged (Aspel et al., 2022).

3.9. Cation Exchange Capacity (CEC)

The data from the soil CEC analysis conducted in the laboratory using the NH_4OAc leaching method on 6- and 8-year-old oil palm plantations were statistically processed using the Independent-Sample t-test, as shown in Table 9.

As seen in Table 9, the average soil CEC value for 6-year-old plants is 26.33 cmol/kg, which is classified as high, while the average soil CEC value for 8-year-old plants is 22.72 cmol/kg, which is also classified as medium.

The results of the statistical test (T-test) show a significant difference in the average soil CEC results for Inceptisols at the ages of 6 and 8 years.

Table 9. Soil CEC Values at Two Oil Palm Planting Locations

Age of Oil Palm	Cation Exchange Capacity (cmol.kg $^{-1}$)				Criteria (Soil Research Institute, 2005)
	Mean	Standard Deviation	CV	Sig. (2-tailed)	
6 years old	26,330	1,736	6,594	0.038	Tall
8 years old	22,720	2,097	9,232		Currently

Description: The average number followed by a superscript that is not the same is significantly different based on the Independent-Sample T Test at 5% level.

In contrast to the research results of Suhemi et al . (2022) which showed the CEC content of Inceptisol soil was 9.06 cmol/kg with low criteria, this is suspected to be related to the provision of organic matter at the research location where Inceptisol soil planted with 6-year-old oil palms contains more organic matter which can be seen from the C-organic value in the soil. In line with the research results of Ningsih et al. (2024), C-organic shows a positive correlation with CEC because decomposition produces humus, which plays a role in releasing base cations that can be exchanged in the soil. Supported by the research results of Kong et al. (2021), the removal of organic matter significantly reduces the CEC of the soil by 2.28% to 56.50%, where the CEC value, which is already low, ranges from 8.40 cmol/kg to 4.82 cmol/kg. Apart from the influence of organic matter, other factors, such as soil texture, also affect the CEC. Inceptisol soil has a silty clay texture, characterized by a relatively high clay and silt content. In line with the opinion of Beyene et al. (2022), there is an increase in CEC with increasing soil clay content, as clay particles are smaller, have a high negative charge, and a larger specific surface area, thereby providing more space for cations to bind. Soil with finer particles, such as clay and organic matter, can retain more positively charged ions than soil with larger particles (Reicks, 2021).

4. Conclusion

Significant differences were found in the total N, SO_4^{2-}, and CEC values of Inceptisol soil due to the influence of planting age, ranging from 6 to 8 years.

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