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Change of heterotrophic respiration and biomass in oil palm planted on tropical peat soil by application of nitrogen fertilizer

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Abstract

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Management of nitrogen nutrients through fertilization in oil palm plantations on peatland is essential to minimize the impact of CO_2 emissions and ensure the growth and development of the palms. The objective of this study is to understand the relationship between N fertilizer dosage and heterotrophic respiration, vegetative growth, and physiology in oil palm planted on tropical peatland. The study was conducted by using a randomized complete block design with four replications of nitrogen fertilizer treatment dosages of 0.5 kg N/palm/year, 1 kg N/palm/year, 1.5 kg N/palm/year, and a control with 0 kg N/palm/year. Observation variables include heterotrophic respiration, environmental parameters (soil temperature and ground water level, vegetative growth (height, length of fronds, girth of trunk, leaf area and dry biomass), and physiological responses (leaf greenness level and N nutrient content in palms). The research results show that the application of nitrogen fertilizer has an effect on cumulative CO_2 emissions with a positive linear relationship. Environmental factors such as soil temperature and ground water level have a role in influencing CO_2 emissions, heterotrophic respiration reaches its peak at temperature 31.0°C and ground water depth 59.3 cm. The application of nitrogen fertilizer also has an influence on *palm height, frond length, palm dry biomass*, and leaf greenness, but has no effect on trunk diameter, leaf area and nitrogen nutrient content in leaf tissue, where the fertilizer dose is 1.5 kg N/palm/year had a significant response.

Keywords: CO_2 Flux; Peat soil; Nitrogen Fertilizer; Oil Palm

Introduction

The development of oil palm plantations along with the increase in domestic crude palm oil (CPO) production is forcing palm oil industry players to expand plantation areas on land that has limiting factors for oil palm cultivation. One of the lands used for oil palm plantations is peat land. Peatlands are spread across Sumatra, Kalimantan and Papua, with a total area of around 14.9 mln ha (Wahyunto et al., 2014). Peatlands that have been converted into oil palm plantations, face the problem of low nutrient availability. One nutrient that has low availability in peatlands is nitrogen (N), although total N analysis usually shows relatively high levels. This is because most of the N is in organic form and requires a mineralization process so that it can be used by palms (Hartatik et al., 2011). The nutrient N is very important for palm growth, increasing photosynthesis results, and supporting palm vegetative growth, such as palm height, leaf area index, and palm diameter (Rahhutami et al., 2015; Amiratul et al., 2017). Therefore, in peatlands it is necessary to apply appropriate doses of N fertilizer (Salma et al., 2019).

Recommendations for N fertilizer dosages for oil palm plantations vary according to climatic conditions, soil type, age of the palm, and potential palm yield (Comte et al., 2012). However, increment of nitrogen fertilizer dose will increase CO_2 emission (Comeau et al., 2016). The factor that is thought to influence is increased respiration of soil microorganisms, which require nutrients such as nitrogen, carbon, hydrogen, oxygen, phosphorus, sulfur and iron contained in N fertilizer. The number of microorganism in peat soil increase along with increment of peat soil's nutrient status (Agus, 2013). In addition, the increased activity of these microorganisms is associated with the hydrolysis process of N fertilizer, which also contributes to increased CO_2 emissions, in accordance with the findings of Prayitno & Runtung (2018).

The release of CO_2 in soil comes from the decomposition of soil organic matter by microbes (heterotrophic respiration). This process is a metabolic activity where organic materials as an energy source are broken down into simpler materials which then produce water, energy and CO_2 (Batubara et al., 2019). Heterotrophic respiration can increase greenhouse gas concentrations in the atmosphere, while autotrophic respiration can, to a large extent, be neutralized through the process of photosynthesis which absorbs carbon dioxide (CO_2) from the atmosphere. Fertilization also has the potential to increase plants root respiration, although at the same time, photosynthesis plays a role in absorbing CO_2 by plants (Putri et al., 2016). The respiration process is closely related to physical environmental conditions and the speed of decomposition which is influenced by the characteristics of organic material in peat soil (Rosalina & Kahar, 2018).

Material and Method

Study site

The research was carried out at PT Tunggal Mitra Plantation, Perkebunan Manggala 3, Rokan Hilir Regency, Riau Province. The research area has flat topography with typical haplohemist soil types. The peat soil of the research location at a depth of 0–20 cm has an average water content of 74.98%, a bulk density of 0.24 g/cm^3, the pH (H_2O) of the soil is classified as very acid with a value of 3.07, the C-organic content is classified as very high, namely 24.39%, the total N content is classified as very high (1.26%), the available P content is classified as very high (18.67 ppm), the base saturation is classified as very low, and the cation exchange capacity (CEC) is classified as very high (91 .21 mol/kg).

Experimental design

Experimental Design used a randomized block design with 4 treatments and 3 replications, with 4 levels of nitrogen fertilizer dosage, namely 0 kg/palm/year, 0.5 kg/palm/year, 1 kg/palm/year, 1.5 kg/palm/year. Each plot consists of 16 oil palm trees with 4 trees as recorded palms and 12 trees as guard palms between treatments.

Measurement of heterotrophic respiration

Heterotrophic respiration measurements were carried out using the closed hood method. In each plot, one piece of PVC is installed with a diameter of 8 inches and a length of 80 cm. 60 cm of PVC is embedded in the peat and 20 cm is left to capture CO_2 released into the air. The hood is placed in the field between the oil palm plants in the middle between the palm. The time span between installing the hood and observing CO_2 emissions is six months after installing the hood. This is intended to restore the condition of the soil that was disturbed after installing the hood, and the residue of palm roots that were cut off and inside the hood no longer has any influence on respiration results. CO_2 emissions were measured using a portable Infrared CO_2 Analyzer (CO_2 A-3010E). Measurements were carried out at 08.00–11.00 with a measurement duration of 2 minutes and an interval of 10 s.

Measurement of environmental parameters, vegetative growth and palm physiology

Soil temperature was measured using a digital thermometer and water level was measured using a piezometer every time heterotrophic respiration was measured. Palm vegetative growth was carried out in a period of 1 year after treatment application. Parameters measured include palm height, trunk diameter, frond length, leaf area and measurement of palm dry biomass. Observations of palm physiology include leaf greenness and leaf nutrient levels.

Leaf greenness level

Observation of leaf greenness level was carried out once, namely one year after the application of nitrogen fertilizer. Measuring the greenness of the leaves was carried out using a SPAD-502 plus chlorophyll meter, which works digitally by displaying results based on the light passed by the leaves on the instrument indicator. Leaf samples were measured at the 17th frond, the leaf samples were measured at a point 0.6 x the length of the frond, and measurements were taken at three different points on each leaflet, i.e: one third from the base, the middle, and one third from the tip of the leaflet.

Analysis of leaf nutrient content (Nitrogen)

Sampling for analysis of leaf nutrient levels was carried out in the first year after fertilizer application. Leaf samples were taken at the 17th frond with the sampling point located at a point 0.6 × the length of the frond.

Result and Discussion

Heterotrophic respiration in peat soil due to nitrogen fertilization

Data from measuring CO_2 emissions in each nitrogen fertilizer application treatment for three days before fertilization to 10 days after fertilization is illustrated in Figure 1. This figure shows that the pattern of CO_2 emissions increased after the application of N fertilizer and then decreased until the 8th (eighth) day after N fertilization. The graph also shows the same pattern as without N fertilizer application treatment on day 9 (nine).

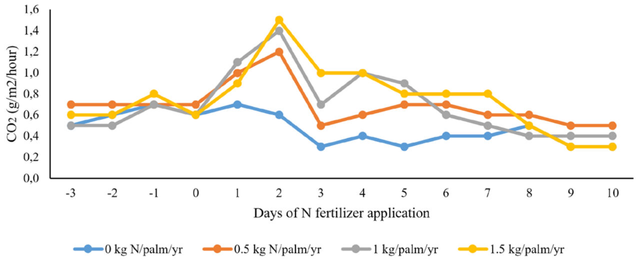

Fig. 1. CO_2 gas emissions in each nitrogen dose treatment on the day before and after nitrogen fertilizer application

The results of the research show that N fertilizer treatment has a significant effect on CO_2 emissions when compared with no N fertilizer treatment. Although there is no significant increase in CO_2 emissions with each additional dose of N fertilizer, additional doses of N fertilizer can generally increase CO_2 emissions. The results of this research are supported by previous research conducted by Comeau et al. (2016) which also confirmed an increase in CO_2 emissions along with increasing doses of N fertilizer. Ghorbani et al. (2018) also reported that nitrogen fertilizer increase green house gasses (N_2O and CO_2). The factor that is thought to influence is the increase in respiration of soil microorganisms, which require nutrients such as nitrogen, carbon, hydrogen, oxygen, phosphorus, sulfur and iron contained in N fertilizer. The more nutrients in peat soil can result in an increase in the number, variety and activity of microorganisms in it (Agus, 2013). In addition, the presence of alternative nitrogen can activate urease production because urease is an enzyme that plays a role in breaking down urea and several other nitrogen compounds (Mobley et al., 1995). The main activity of urease is to convert urea into ammonia (NH_3) and carbon dioxide (CO_2) through hydrolysis reactions (Das & Varma, 2010). This process produces ammonia which can be used by soil microorganisms and plants as a nitrogen source. Thus, when a nitrogen source is available, microorganisms respond by increasing urease production so that they can use nitrogen fertilizer as a nitrogen source (Table 1).

Table 1. Effect of nitrogen dose treatment on average cumulative CO_2 emissions for 8 days after nitrogen fertilization

N Fertilizer	CO_2 ,g/m²/h
0 Kg N/palm/yr	0.507 ± 0.075 b
0.5 Kg N/palm/yr	0.787 ± 0.161 ab
1 Kg N/palm/yr	0.867 ± 0.192 a
1.5 Kg N/palm/yr	0.972 ± 0.284 a
F test	*

Note: The numbers accompanied by the same letters are in the same column. which indicates that there is no significant difference based on the DMRT test results at the confidence level α = 5%. The sign (*) indicates a significant difference

The results of the regression analysis show that nitrogen fertilization on CO_2 emissions has a positive linear relationship with the coefficient of determination value, namely 0.4958, this shows that the effect of N fertilization on CO_2 emissions is 49.58% while the rest is influenced by other factors.

Fig. 2. Measurement of CO_2 emissions in the Experimental Plot using a Portable Infrared CO_2 analyzer

Kii et al. (2020) reported that net primary production (NPP) of oil palm at the age of one year is able to absorb around 9.8 t of CO_2 per hectare per year, and this figure continues to increase until it reaches 117 t of CO_2 per hectare per year at the age of 19 years old. Age 19 is the peak point for significant CO_2 absorption, while after that, there is a slow decline. A striking increase in CO_2 absorption occurred in the 4–13 year age period. Ages 15–19 years show absorption that tends to be stable without a significant increase, while at ages 20–25 years there is a decrease in absorption. On average, over a period of 1–25 years, oil palm is able to absorb around 86.5 t of CO_2 per hectare per year. This figure shows a lower CO_2 absorption value compared to previous findings in Jambi, which recorded a total Net Primary Production (NPP) of around 121 t of CO_2 per hectare per year (Kotowska et al., 2015). This NPP value is calculated by subtracting autotrophic respiration from Gross Primary Production (GPP), where autotrophic respiration includes both growth respiration and ecosystem maintenance respiration.

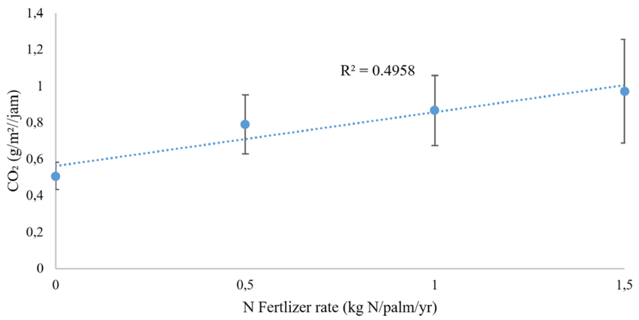

Fig. 3. Correlation between CO_2 and Nitrogen fertilizer

Cumulatively for one year, the increase in CO_2 emissions due to N fertilization in oil palm plantations on peatlands has no effect because CO_2 emissions only last a few days after the application of N fertilizer and are still below the NPP (Figure 4), this is in line with the results of Handayani and Meine's research (2015) and research by Comeau et al. (2016) which states that the application of N fertilizer increases CO_2 emissions a few days after application and then decreases relatively to the same as CO_2 emissions before fertilization. The research results also showed that CO_2 emissions only lasted shortly after N fertilizer application, namely several days after application and then decreased relatively to the same as CO_2 emissions without N fertilizer treatment.

Relationship between CO_2 emissions and environmental parameters

CO_2 emission measurements were carried out for three months, namely April – June 2023. The results of CO_2 emission measurements showed emission values between 0.547 g/m²/h or equivalent to 47.92 t of CO_2/ha/year and 0.750 g/m²/h or equivalent with 65.70 t CO_2/ha/year (Figure 4). The emission values found in the research location were still lower than the results of research conducted by Razak (2019), where the emission values from peatlands covered with oil palm plants reached the range of 126.14 – 169.07 t of CO_2 per hectare per year. Meanwhile, Uning et al. (2020) presented different findings and also confirmed that emissions from peatlands on oil palm plantations in Indonesia during the 2007–2017 period ranged from 10 to 95 t of CO_2 per hectare per year.

During the measurement period at the research location, it was recorded that the average daily soil temperature was in the range of 25.7°C to 28.4°C (Figure 5), and the average depth of the groundwater level at the time of measurement at the research location was between 40.83 cm and 66.33 cm (Figure 5). Soil temperature fluctuations are influenced by various factors, such as air temperature above the ground surface and the process of heat and energy exchange between air and soil through the convection mechanism. The deeper the soil layer, the temperature will tend to be more stable than at the surface of the soil. According to Chadirin et al. (2016) the depth of the groundwater table affects humidity, when the depth of the groundwater table decreases, this is followed by a decrease in soil moisture. Another study by Susilawati et al. (2016) also reported that groundwater levels have a significant influence on soil reduction and oxidation conditions. Several studies have reported on the influence of temperature and soil moisture on CO_2 emissions.

A number of researchers, including Chadirin et al. (2016), Martins et al. (2016), Fenn et al. (2010), and Astiani et al. (2016), report that CO_2 emissions are significantly influenced by temperature and soil moisture levels. According to Saptomo et al. (2019), CO_2 emissions tend to increase at higher temperatures and when soil moisture levels are adequate to support soil respiration processes and microorganism activity.

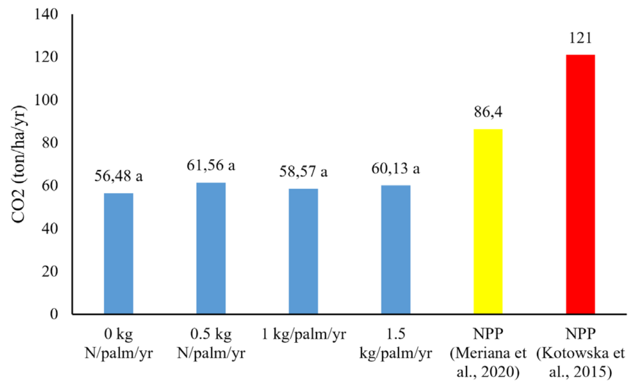

Fig. 4. Effect of nitrogen dose treatment on one year cumulative CO_2 emissions and average Net Primary Production (NPP) of oil palm plants

Soil temperature

Soil temperature has a quadratic relationship with CO_2 emissions with a coefficient of determination value obtained

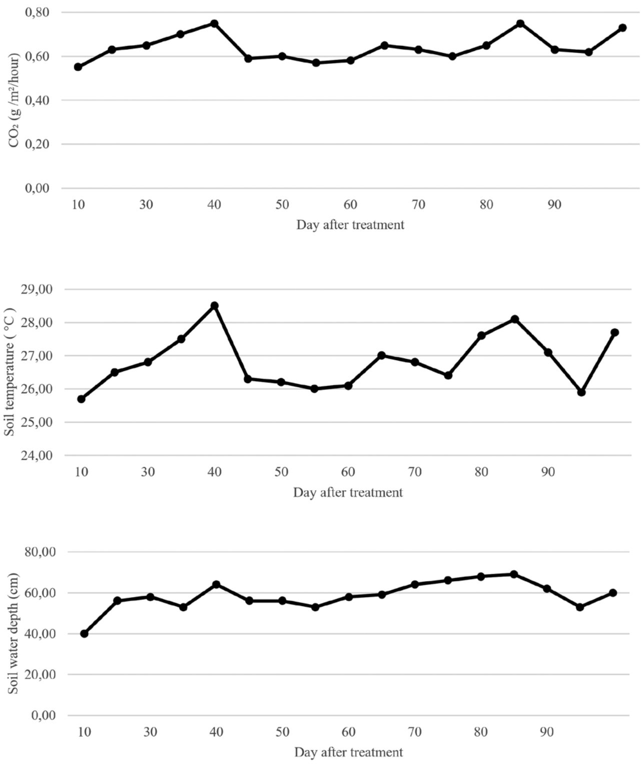

Fig. 5. Average results of CO_2 measurements, soil temperature and groundwater level

of 0.9525. This shows that the influence of soil temperature on CO_2 emissions is 95.25%, while the rest is influenced by other factors. Furnando et al. (2014), reported that there is a relationship between soil temperature and CO_2 emissions in oil palm plantations. An increase will cause changes in CO_2 emissions. However, when the temperature reaches 32°C, the CO_2 flux begins to decrease again. Meanwhile, research conducted by Saptomo et al. (2019) shows that in conditions without rain, CO_2 emissions will increase starting from a temperature of 29°C and peak at a temperature of 32.7°C. After reaching the peak, CO_2 emissions will begin to fall again until they reach the maximum measured temperature, namely 37°C.

Soil temperature affects soil moisture through the processes of evaporation, aeration, the activity of microorganisms in the soil related to enzymatic processes, decomposition of litter or plant remains, and the availability of nutrients for plants. This activity is limited to temperatures below 10°C, and the rate of soil biota activity reaches its peak at temperatures between 18 and 30°C. At optimum temperatures, enzyme systems function with efficiency and remain stable for long periods of time. However, at low temperatures, although the enzyme structure remains stable, its ability as a biocatalyst becomes limited. On the other hand, at high temperatures, enzymes can experience denaturation, which causes the loss of their catalytic activity (Salampak & Amelia, 2014). Karhu et al. (2014) noted that increasing temperature can increase the metabolic rate of microorganisms in the soil which play an important role in the decomposition process of organic matter. This increase in metabolic rate tends to be more significant in soils with a high C/N ratio (Figure 6).

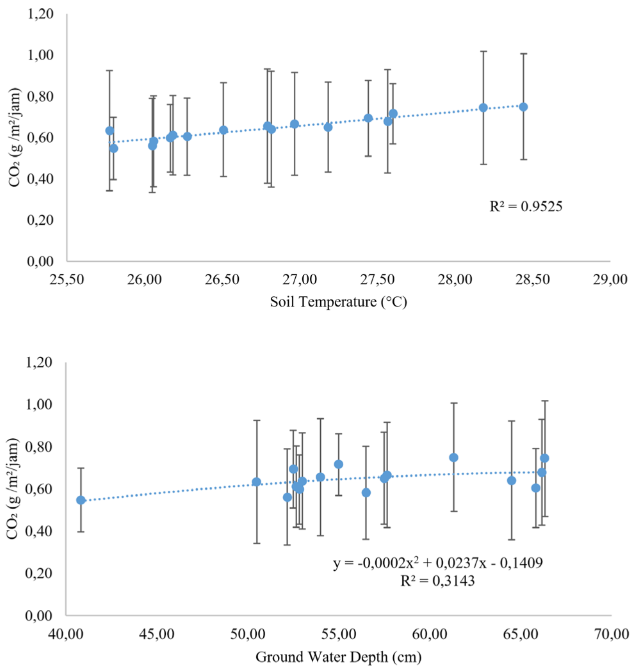

Fig. 6. Correlation between soil temperature, soil water depth and CO_2 flux

Depth of ground water level

The relationship between ground water depth and CO_2 emissions is shown in Figure 6. Ground water depth has a quadratic relationship with CO_2. The regression equation shows that CO_2 reaches its peak at a groundwater depth of 59.3 cm and then decreases with increasing depth of the groundwater table. Astiani et al. (2016) reported that CO_2 emissions increased by 20%, 56%, 100%, and 162% respectively when the depth of the groundwater table increased from 10 cm, 20 cm, 30 cm, and 40 cm. Dariah et al. (2013) concluded that the lowest average CO_2 emissions were achieved at a groundwater table depth of 40 cm, while the highest average CO_2 emissions were achieved at a groundwater table depth of 60 cm, while at a groundwater table depth of 80 cm, the amount of CO_2 emissions decreased again, becomes not significantly different at a groundwater level depth of 40 cm. In addition, Saptomo et al. (2019) concluded that the closer the depth of the groundwater table is to the ground surface, the less space for soil respiration and activity of soil microorganisms. This is because the depth of the groundwater table which is deeper than the ground surface will increase the decomposition process (Astiani et al., 2016).

Winarna & Heri Santoso (2020) reported that the level of CO_2 emissions from peat soil reaches its peak when soil moisture is near field capacity. However, CO_2 emissions tend to decrease when soil moisture increases beyond the field capacity water content. These findings indicate that soil moisture has an effect on reducing CO_2 emissions from peat soil. Another study by Kechavarzi et al. (2010) also stated that excessive soil moisture will inhibit soil microbial activity and result in a reduction in CO_2 emissions.

Peat soil moisture is related to peat soil capillary water. Increased soil moisture is a characteristic of the increase in capillary water in peat soil which reaches 50 cm. In peatlands themselves, capillary water plays an important role in providing water to the root zone (Nugrahaa et al., 2016). Schindler et al. (2003) and Schwärzel et al. (2006) capillary water can reach the root zone even with a drainage depth of up to 70 cm. The speed of capillary water rise does not move optimally if the outflow of lost water (evaporation) is greater than the inflow (inflow) into the soil or the micropores are too large, thereby inhibiting the penetration rate of capillary water rise (Schwärzel et al., 2006; Chesworth, 2008).

Soil moisture content is one of the environmental factors that has a significant influence on microbial activity, as has been explained by several studies such as Casals et al. (2000) and Liu et al. (2009). Changes in soil moisture content have a major impact on microbial respiration processes. In general, aerobic microbial respiration reaches its optimal peak when the soil moisture content is around 60% of its water holding capacity (WHC), while its responsiveness decreases at lower moisture content, namely below 30% WHC.

The movement of glucose solutions in the soil is also strongly influenced by the soil moisture content, as has been observed by Casals et al. (2000) and Liu et al. (2009). Microbial activity and enzymes responsible for the degradation of macromolecules can also be influenced by soil moisture levels (Šnajdr et al., 2008; Geisseler et al., 2011). Low soil moisture content can inhibit the utilization of easily degradable organic carbon (Labile Organic Carbon, LOC) by microbes because the lack of water limits the supply of substrate to microbes in the soil (Schjønning et al., 2003).

Palm dry biomass and vegetative growth

Nitrogen is considered the main nutrient which is very important for palm growth. Nitrogen is the main component of amino acids and nucleotides (Chua, 2021). Plants use nitrogen to form protoplasm and synthesize amino acids which are essential in building plant tissues and proteins. The effect of treatment on palm vegetative growth is shown in Table 2. The results of the research show that the application of N fertilizer has an effect on increasing the dry biomass of oil palm plants, the treatment of 1.5 kg N/palm/year N has a significant effect on the dry biomass of oil palm plants when compared with other dose treatments. Biomass content is the result of accumulated biomass from each plant organ which reflects the total organic material produced through the photosynthesis process (Tuah et al., 2017). Providing nitrogen fertilizer can increase the availability of nutrients in plants so that plant development becomes better. The nitrogen nutrient content in fertilizer can stimulate plant growth and development, allowing plants to explore nutrient absorption to a greater extent, which ultimately increases the dry biomass weight of plants. Nitrogen nutrients play a key role in stimulating overall plant growth by overseeing the synthesis of amino acids and proteins in plants, and accelerating plant growth, especially in terms of plant height and diameter (Manahan et al., 2016).

The diameter of a vegetation is correlated with its biomass. Plant diameter is influenced by the results of photosynthesis. The process of photosynthesis is the process of

Table 2. The effect of nitrogen fertilizer on the vegetative growth of oil palm

N Fertilizer rate	Dry biomass, kg/palm	Palm height, cm	Frond length, cm	Trunk circumference, cm	Leaf area Frond 17, m^2
0 Kg N/palm/yr	141.80 ± 7.98 c	339.17 ± 12.06 b	559.42 ± 26.17 b	250.50 ± 13.07a	9.91 ± 0.78 a
0.5 Kg N/palm/yr	152.58 ± 16.79 bc	354.92 ± 39.20 b	574.08 ± 34.66 b	262.58 ± 7.80 a	9.42 ± 1.22 a
1 Kg N/palm/yr	156.19 ± 19.39 b	363.00 ± 35.89 b	583.25 ± 26.75 ab	258.50 ± 28.15 a	10.06 ± 1.43 a
1.5 Kg N/palm/yr	181.71 ± 12.38 a	418.08 ± 29.87 a	602.92 ± 37.56 a	250.67 ± 12.79 a	10.31 ± 1.55 a
F Test	*	*	*	ns	ns

Note: The numbers accompanied by the same letters are in the same column. which indicates that there is no significant difference based on the DMRT test results at the confidence level α = 5%. The sign (*) indicates a significant difference absorbing CO_2 in the air by plants and converting it into carbohydrates which are then distributed throughout the plant body and stored in the plant's organs in the form of leaves, trunk, twigs, flowers and fruit. The results of photosynthesis influence the growth of plant organs including the diameter of the trunk (Tuah et al., 2017).

The results of several previous studies stated that applying N fertilizer can increase the height of oil palm plants that have not yet produced the first year (Shintarika, 2014), not yet produced the second year (Faustina et al., 2015), not yet produced the third year (Albari, 2016), and also increase the production of oil palm crops (Purwanto, 2017). Oil palm height is a growth parameter that is very responsive to fertilizer application. Jacquemard (1979) showed that height growth was not significant in the first 3 years after planting. The growth rate of oil palm increased and stabilized over a period of 6 years to at least 25 years, without experiencing a decline.

The growth response in frond length showed a significant increase in the N fertilizer application treatment of 1.5 kg/palm/year, with a percentage increase in frond length of 7.78% compared to the control without N fertilizer treatment. The results of the study are in line with the research results of Hasputri et al. (2017) stated that the N fertilizer application treatment could increase the length of the fronds by up to 10.28% compared to the control without N fertilizer. The length of the fronds increased as the age of the palm increased until the maximum length was reached. The condition of the frond length is greatly influenced by two factors, namely palm density and the planting material used (Gerritsma & Subagyo, 1999).

The application of N fertilizer had no effect on the trunk circumference of oil palm plants and leaf area on the 17th frond at 8 years of age. The research results are in line with research conducted by Pahan (2008) which states that oil palm plants tend to experience base growth at the age of 1-2 years, and then further growth tends to focus on faster height increases, while research conducted by Sudradjat et al. (2014) showed that the nutrient N can influence palm trunk girth, but the nutrients phosphorus (P) and potassium (K) have a more dominant role in increasing palm trunk girth. Plant root development, cell division are largely determined by the phosphorus. Nitrogen contained in leaves plays an important role in the photosynthesis process. Increasing leaf surface area will positively influence the amount of light that can be captured by plants, which in turn will increase the rate of photosynthesis (Sudradjat et al., 2014). Based on research results (Corley & Gray, 1976; Henson et al., 2003), that leaf area increases continuously with the age of the tree, leaf area reaches a saturation point at 8–10 years after planting, but petiolus cross-section and it is likely that the dry weight of the leaves continues to increase slowly. Leaf area may show a significant response to fertilizer, but is not very sensitive to other external factors.

Nitrogen contained in leaves plays an important role in the photosynthesis process. Increasing leaf surface area will positively influence the amount of light that can be captured by plants, which in turn will increase the rate of photosynthesis (Sudradjat et al., 2014). An efficient photosynthesis process will produce more assimilate, which has an impact on increasing plant production (Corley & Tinker, 2016). However, more assimilate from photosynthesis is translocated to the fruit so that fruit growth has a faster response to N fertilization compared to the response to leaf area variables. Application of N fertilizer has no effect on leaf area, which could be due to leaf area reaching saturation point 8-10 years after planting (Corley & Gray, 1976; Henson et al., 2003).

Palm physiological responses

The application of N fertilizer has a significant effect on the greenness of oil palm leaves (Table 3). The nitrogen element plays an important role in the formation of chlorophyll, so that applying nitrogen fertilizer at the right dose will increase the green color of the leaves and the chlorophyll content of oil palm plants (Sutarta et al., 2007). Leaf chlorophyll content is closely related to nitrogen availability (Ramadhaini et al., 2014). Chlorophyll is needed by plants because it plays a role in photosynthesis to produce carbohydrates that support plant growth (Suharno et al., 2007).

Table 3. The effect of applying nitrogen fertilizer on the greenness of oil palm leaves and the nitrogen content in leaf tissue

N Fertilizer	Leaf greeness level (SPAD)	Leaf nitrogen, % dry matter
0 Kg N/palm/yr	73.908 ± 2.35 b	2.696 ± 0.06 a
0.5 Kg N/palm/yr	82.080 ± 3.62 a	2.690 ± 0.04 a
1 Kg N/palm/yr	83.123 ± 3.27 a	2.710 ± 0.03 a
1.5 Kg N/palm/yr	84.281 ± 3.72 a	2.740 ± 0.03 a
F test	*	ns

Note: The numbers accompanied by the same letters are in the same column, which indicates that there is no significant difference based on the DMRT test results at the confidence level $\alpha = 5\%$. The sign (*) indicates a significant difference

The nutritional content in the 17th frond leaf tissue can be used as an indicator to evaluate the nutritional status of oil palm plants. Nitrogen plays a role in the formation of chlorophyll that is very important in the photosynthesis proces, as well as playing a role in the formation of proteins, and various other organic compound (Hikosaka, 2005; Cardenas

Fig. 7. Measuring the greenness of leaves

& Campo, 2007). The N content that is considered optimal for oil palm plants ranges from 2.6 to 2.9% (Von Uexkull & Fairhurst, 1991) which means that the nitrogen content values in all experimental plots are within the optimum status.

Conclusions

The application of nitrogen fertilizer has an effect on cumulative CO_2 (Heterotrophic Respiration) emissions for 8 days after fertilizer application with a positive linear relationship, the value of the coefficient of determination is 49.58%. However, the emission value for one year in all research plots is still below the Net Primary Production (NPP) value for palm oil. Environmental factors such as soil temperature and depth of groundwater table have an influence on CO_2 emissions with a quadratic relationship, the coefficient of determination between soil temperature and CO_2 emissions is 95.25%, while the depth of groundwater table and CO_2 emissions has a coefficient of determination, namely amounted to 31.43%. Heterotrophic respiration reached its peak at a temperature of 31.0°C and a groundwater depth of 59.3 cm. The application of nitrogen fertilizer increased vegetative growth, palm dry weight and palm greenness, while the nitrogen content in leaf tissue in all research plots was at the optimum level, so that the application of nitrogen fertilizer did not significantly increase the nitrogen content in the leaves.

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