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# NITROGEN NUTRIENT UPTAKE OF OIL PALM PLANTED IN TROPICAL PEAT SOIL WITH APPLICATION OF AMELIORANT AND NITROGEN FERTILIZER

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**Abstract**

Fertilizer is the largest component of production costs in the palm oil industry. High use of fertilizer will increase production costs, but on the other hand, the use of fertilizer is necessary, especially in oil palm plantations operating on marginal soils with low soil fertility. Peat soil is one of the marginal lands that is widely cultivated for oil palm plantations. An accurate fertilization recommendation will be very important to obtain high crop production and optimum costs. Information about nutrient uptake by palms is essential during making fertilization recommendations to prevent excessive use of fertilizers and get the optimum and most profitable yield. This study aims to determine the absorption of nitrogen nutrients by oil palm plants on peatlands. The results showed that nitrogen fertilizer application significantly improve FFB yield by increase the bunch number, whilst boiler ash that rich with potassium improve FFB yield by increase the bunch weight. That nitrogen recovery by the palm varied from 53.16% to 79.45%. The results of the study also showed that the lower dose of nitrogen fertilizer given a better percentage of nutrient uptake compared to the plots that received higher nitrogen fertilizer.

**Keywords:** Nitrogen, Peat Soil, Oil Palm

## INTRODUCTION

The development of oil palm plantations on peatlands is developing very quickly (Miettinen et al., 2016). About 20% of the oil palm plantation area on the islands of Sumatra, Kalimantan and Papua is located on peatlands. Cultivating oil palm plants on peat soil areas increases soil temperature and microbial activity in peat soils during drainage activities which results in a lowering of the water table and the use of drainage ditches/canals for transportation purposes in oil palm plantations (Minkinen et al., 2007). Based on the degree of decomposition, peat soils are classified into fibric, hemic and sapric peat. Fibric materials contain lots of fibers that are maintained in their original form and can still be identified or slightly decomposed. Hemic material if the decomposition level is moderate, and sapric if the decomposition level is advanced (Soil Survey Staff, 2010).

Nitrogen is an element that is mostly sourced from the decomposition process of organic matter, where the amount of N supply from the decomposition process is highly dependent on the quality and quantity of organic matter (Vahdat et al., 2012). Peatland as an organic matter has a relatively high N content, so that the presence of peat and organic matter on it is a source of N for the soil. However, the N content in peat soils is low due to the high C/N ratio, slow decomposition, low nitrification process, so that free N is also low (Hayden, et al., 2005)

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Nitrogen in the soil mainly comes from the process of decomposing organic matter (Fahmi and Radjagukguk, 2013). Nitrogen is one of the main macronutrients needed for the growth of oil palm plants. Nitrogen in plants functions in protein formation, chlorophyll synthesis and metabolic processes. Nitrogen composes important organic compounds such as amino acids, proteins and nucleic acids (Goh and Hardter, 2010).

The low level of peat fertility causes high use of fertilizers in the oil palm plantation industry that operates on peatlands. In immature oil palm inputs of fertilizer on peatlands it can reach 0.70 tons/ha/year in the first year, 1.05 tons/ha/year in the second year and 1.35 tons/ha/year in the third year, while in mature oil palm inputs fertilizer received can reach 1.77 tons/hectare/year (PPKS, 2020). Nutrient loss is a very detrimental thing for oil palm plantations operating on peatlands, because of the huge cost of fertilization and also the environmental impact it causes (Najiyati et al., 2005). This study aims to determine the value of nitrogen nutrient uptake in peat soils. Knowledge of the percentage of nutrient uptake is important in making fertilization recommendations to prevent excessive doses of recommended fertilizer.

## METHODOLOGY

The study was conducted in oil palm plantation PT Tunggal Mitra Plantation, Manggala-3 estate, Rokan Hilir regency, Riau province. The design used in this study was Completely Randomized Block Factorial Design with 2 factor treatment: the 1$^{st}$ factor is soil ameliorant with dose 0-ton/ha/yr, 1.5 ton/ha/yr and 3-ton/ha/yr, the 2$^{nd}$ factor is Nitrogen Fertilizer with dose 0 kg N/palm/yr, 0.45 kg N/palm/yr and 0.9 kg N/palm/yr. This trial has 3 replications.

Nitrogen nutrient uptake was reviewed by taking samples of oil palm tissue which included: samples of leaves, petioles, rachis, trunk, bunches and male flowers. Nitrogen nutrient uptake data by oil palm and other observations were statistically analyzed using analysis of variance (F test), with Statistix 8.0 software. The difference in Nitrogen efficiency and other parameters is analyzed with the least significant difference (LSD) test at the 95% confidence level ($\alpha$ = 0.05).

Sampling of leaves, rachis, petioles to obtain nutrient uptake by oil palm plants was carried out on the 17th frond with the sampling point located at a point 0.6 x frond length. In perennial crop, the destructive sampling method can be used to measure nutrient uptake in fertilized and unfertilized plots in each harvest round and calculation of fertilization efficiency can then be calculated by the difference between the two. It is easy to explain why in annual crops, measuring nutrient use efficiency is standard practice when analyzing data from field trials. Destructive sampling cannot be used in oil palm trials, as it is expensive and precludes the possibility of further measurement in trials (Fairhurst, 2003).

Measurement of the vegetative growth of oil palm plants is important to determine the impact of treatment on the growth and production of oil palm plants. Nutrient uptake in oil palm can be calculated using the minimally destructive sampling method, where plant tissue is only taken on representative tissue so as to minimize injury to the plant. Nutrient uptake is calculated

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based on the concentration of nutrients in each plant tissue and the amount of biomass produced by each tissue, i.e: leaves, rakis, stems and fruit bunches.

The measurement of the total dry weight of biomass in the fronds of the Tenera oil palm plant has been reported by Prabowo et al., (2006) by using the equation obtained by calculating the cross-section of the fronds. The dry weight of fronds is measured by the formula: Dry weight of fronds (Kg) = 0.0781 x cross-sectional area of fronds + 0.3948, with $R^2$ = 0.9098. This equation has updated the equation previously used by Corley et al., (1971) who based his research on Dura plants with the formula: Dry weight of fronds (Kg) = 0.1023 x cross-sectional area of fronds + 0.2062. In addition, predictions can also be developed for each component of the frond by using the cross-sectional area of the frond such as: dry weight of leaflet, dry weight of rachis and petiole.

## RESULT AND DISCUSSION

Oil palm production data was taken after 1 year from the first application of each treatment. The production data shown in Table 5 is data from the period June 2022- May 2023. The application of boiler ash at rate of 1.5 and 3 tons/ha/year significantly increased the production of fresh fruit bunches (FFB) by 4.61 tons /ha/year and 6.66 tons/ha/year respectively compared to plots without boiler ash application. The increase in FFB production due to the application of boiler ash was mainly due to an increase in bunch weight, where the application of 1.5 tons of boiler ash/ha/year and 3 tons of boiler ash/ha/year respectively increased the bunch weight to 14.22 kg and 15.07 kg, this increase was statistically significantly different from the control treatment which only gave a bunch weight value of 11.59 kg.

**Table 1: Effect of Boiler Ash and Nitrogen fertilizer to FFB Yield and Its Components**

| Treatment | level | FFB Yield and Its Components | | |
|---|---|---|---|---|
| | | FFB Yield (t/ha/yr) | Bunch Weight (kg) | Number of Bunches / Ha |
| Boiler Ash (t/ha/year) | 0 | 16.41 b | 11.59 b | 1,417.30 a |
| | 1,5 | 21.02 a | 14.22 a | 1,484.00 a |
| | 3 | 23.07 a | 15.07 a | 1,556.00 a |
| Nitrogen Fertilizer (kg N) | 0 | 15.45 b | 13.51 a | 1,157.30 b |
| | 0,45 | 23.39 a | 14.32 a | 1,629.30 a |
| | 0,9 | 21.65 a | 13.04 a | 1,670.70 a |
| CV | | 16,08 | 13.48 | 10.96 |

Note: numbers followed by the same letter are not significantly different at $\alpha = 0.05$ according to the Least Significant Difference Test.

Boiler ash contains nutrients needed by plants, especially $K_2O$ of 13.80% (Yahya et al., 2013). The positive effect of boiler ash application on bunch weight is explained by the mechanism of adding $K_2O$ nutrients at the study site. Application of 1.5-tonne boiler ash and 3-tonne boiler ash respectively equivalent to 345 kg MOP and 690 kg MOP per hectare, on peat soils, Potassium nutrient is one of the limiting factors in plant growth, where Potassium nutrient status is usually in deficiency status (Purnamayani et al. 2004). The results of this study are in

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line with the research of Tohiruddin et al, (2007) which explained that the application of KCl fertilizer with a $K_2O$ content of 60% increased oil palm FFB production by increasing bunch weight in North Sumatra and South Sumatra. Potassium is a macro nutrient element needed by plants. The increase in the weight of oil palm bunches with the application of boiler ash which is rich in potassium content is due to the role of Potassium in enzymatic reactions including the metabolism of carbohydrates and proteins as well as improving the quality of seeds and fruit (Subandi, 2013).

Application of Nitrogen fertilizer (Ammonium Sulphate) at a dose of 0.45 kg Nitrogen and 0.9 kg Nitrogen increased production by 7.94 tons/ha/year and 6.2 tons/ha/year respectively compared to the control plot. In contrast to the application of boiler ash, the increase in fresh fruit bunches (FFB) production by the application of nitrogen fertilizer was caused by a significant increase in the production yield component, the number of bunches/ha/year, where the increase in the number of bunches in plots that received 0.45 kg of nitrogen fertilizer /ha/year increased significantly from the control plot by 40%, while the plot with a dose of 0.9 kg of nitrogen fertilizer/ha/year increased by 44% compared to the control plot. Meanwhile Nitrogen fertilizer did not give a significant effect on the increase in bunch weight. The increase in the number of bunches per hectare due to the application of nitrogen fertilizers is also consistent with the results of research by Tohiruddin et al., (2006) that the application of nitrogen fertilizers in long-term oil palm fertilization experiments in locations with volcanic soil parent material and high average rainfall in Sumatra Utara significantly increased the production of oil palm plants by increasing the number of bunches per hectare component.

Nitrogen fertilizer treatment with a dose of 0.45 kg/palm/ha gave the highest average production of 23.39 tons/ha/year. The increase in production was not only contributed by an increase in the number of bunches/ha/year but also due to an increase in bunch weight. This shows that the application of Nitrogen fertilizer is very important in increasing the production of oil palm plants and providing sustainable production.

**Table 2: Effect of Boiler Ash and Nitrogen fertilizer to Palm Vegetative Growth**

| Treatment | level | Oil palm Vegetative Growth | | | | |
|---|---|---|---|---|---|---|
| | | Trunk Diameter (cm) | Frond Weight (kg) | Palm Height (cm) | Frond Production | Petiole Cross Section ($cm^2$) |
| Boiler Ash (t/ha/year) | 0 | 48.33 a | 2.69 a | 267.08 a | 22.95 a | 29.44 a |
| | 1.5 | 50.44 a | 2.55 a | 269.58 a | 23.26 a | 27.63 a |
| | 3 | 49.67 a | 2.82 a | 275.55 a | 25.13 a | 31.08 a |
| Nitrogen Fertilizer (kg N) | 0 | 48.89 a | 2.47 b | 263.91 a | 22.64 a | 26.64 b |
| | 0.45 | 49.22 a | 2.72 ab | 271.56 a | 23.12 a | 29.74 ab |
| | 0.9 | 50.33 a | 2.88 a | 277.75 a | 25.58 a | 31.78 a |
| CV | | 6.5 | 11.86 | 10.48 | 16.92 | 13.9 |

Note: numbers followed by the same letter are not significantly different at $\alpha = 0.05$ according to the Least Significant Difference Test.

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Nitrogen fertilizer application with a maximum dose of 0.9 kg N per year can increase the vegetative growth of oil palm plants, especially in the parameters of frond weight and frond cross-sectional area as shown in Table 2. The increase in frond weight in plots with a dose of 0.45 kg of Nitrogen fertilizer/ha/ year increased to 2.72 kg from 2.47 kg in the control plot or increased by 10%, while in the plot that received a dose of 0.9 kg of nitrogen fertilizer/ha/year the increase in frond weight reached 0.41 kg or 17% relative on the control plot, then nitrogen fertilizer increased the petiole cross section by 11% and 19% on the control plot. The results of this study show results that are in line with the research of Shintarika, et al., (2015) that nitrogen fertilization increases vegetative growth in oil palm plants, where nitrogen fertilizer increases palm height, leaf area, trunk diameter and the amount of chlorophyll.

The increase in plant vegetative growth due to the application of nitrogen fertilizers was also seen in the parameter of Petiole cross section (pcs). The application of nitrogen fertilizer at a dose of 0.45 kg/tree/year increased the pcs to 29.74 $cm^2$ compared to the control plot which only gave a cross-sectional area of 26.64 $cm^2$, while the application of nitrogen fertilizer at a dose of 0.9 kg/ palm/year increased the pcs to 31.78 $cm^2$ or 19.3% of the control plot.

Nitrogen fertilizer application did not have a significant effect on the observed variables of trunk diameter, palm height and annual leaf production. Although there was still an increase in the application of higher doses of nitrogen fertilizer compared to the control plot. Nitrogen is a macronutrient for plants that can be a stimulus for vegetative growth of oil palm (Goh and Hardter, 2003) where large amounts of the nutrient are needed to support maximum growth of oil palm plants (Tarmizi and Tayeb, 2006). Oil palm plants require a large amount of N nutrient intake starting from the second year to the fifth year and tends to be stable in the sixth year onwards (Fairhurst and Mutert, 1999; Goh and Hardter, 2003).

**Table 3: Effect of Boiler Ash and Nitrogen fertilizer to Nutrient uptake is Oil palm Tissue**

| Treatment | level | Nitrogen Nutrient Uptake (gram/palm) | | | | |
|---|---|---|---|---|---|---|
| | | Leaf | Rachis | Trunk | Bunch | Total |
| Boiler Ash (t/ha/year) | 0 | 631.56 a | 195.94 ab | 592.29 a | 453.19 b | 1,873.0 b |
| | 1.5 | 607.26 a | 165.66 b | 608.96 a | 540.22 ab | 1,922.1 ab |
| | 3 | 730.99 a | 227.62 a | 693.04 a | 658.18 a | 2,309.8 a |
| Nitrogen Fertilizer (kg N) | 0 | 567.07 b | 166.91 b | 469.86 b | 376.41 b | 1,580.2 b |
| | 0.45 | 641.48 ab | 193.01 ab | 642.54 ab | 666.12 a | 2,143.1 a |
| | 0.9 | 761.26 a | 229.30 a | 781.88 a | 609.07 a | 2,381.5 a |
| CV | | 24.3 | 28.0 | 29.02 | 22.02 | 19.71 |

Note: numbers followed by the same letter are not significantly different at $\alpha = 0.05$ according to the Least Significant Difference Test.

The application of boiler ash at various treatment levels did not give significant results on the vegetative growth parameters of oil palm plants. Boiler ash is the result of burning empty palm oil bunches and fiber at high temperatures, this combustion process causes loss of nitrogen nutrients which are especially needed for plant vegetative growth and leaves only macro nutrients $K_2O$, CaO, $P_2O_5$ and MgO. Nitrogen is a macro nutrient needed for the formation of

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chlorophyll cells which will produce energy in the process of photosynthesis which is then used in cell division, enlargement and elongation (Gardner et al., 1991; Syafaruddin and Syakir, 2015).

Nutrient efficiency studies can be used to answer various questions regarding nutrients, fertilizer applications and the impact of fertilizers on palm productivity. Recovery efficiency answers the question of how many nutrients can be absorbed by plants compared to the nutrients provided through fertilizers. Physiological efficiency answers the question of how much plant productivity is based on nutrients absorbed by plants, while agronomic efficiency answers the question of how much plant productivity is as a result of inputs of fertilizers and nutrients.

The amount of nitrogen uptake for each tissue of oil palm plants is shown in table 3. The application of nitrogen fertilizers statistically increased the uptake of nitrogen in all sample tissues, while the application of boiler ash only increased the uptake of nitrogen in the rachis and bunch tissues. Boiler ash itself does not contain nitrogen, the largest content in boiler ash is $SiO_2$ which reaches 40.6% followed by CaO of 19.6% and $Fe_2O_3$ of 15.74% (Yahya et al., 2013).

**Table 4: Physiology Efficiency, Recovery efficiency and Agronomy Efficiency in each Plots**

| Treatment | | Physiology Efficiency | Recovery Efficiency | Agronomy Efficiency |
|---|---|---|---|---|
| Boiler Ash (t/ha/tahun) | Nitrogen Fertilizer (kg N) | | | |
| 0 | 0.45 | 100.28 a | 68.27 a | 77.32 a |
| | 0.9 | 53.63 ab | 79.45 a | 42.36 a |
| 1.5 | 0.45 | 66.88 ab | 79.07 a | 71.06 a |
| | 0.9 | 75.47 ab | 72.35 a | 53.54 a |
| 3 | 0.45 | 72.92 ab | 75.07 a | 116.64 a |
| | 0.9 | 42.44 b | 53.16 a | 51.41 a |
| CV | | 37.65 | 53.76 | 61.57 |

Note: numbers followed by the same letter are not significantly different at $\alpha = 0.05$ according to the Least Significant Difference Test.

The increase in nitrogen uptake in bunches due to the addition of boiler ash was more due to the increase in FFB yields which increased the generative dry weight (Table 1) and nitrogen nutrient uptake.

Recovery efficiency is a factor that can indicate how much inhibiting factor an area has. The absorption of nutrients by palms is influenced by the physical properties of the soil, including: topography, soil drainage level, soil type, climate, etc. Nitrogen recovery efficiency values in each treatment ranged from 53.16% to 79.45%. This means that there is a loss of Nitrogen nutrients provided through the application of Ammonium Sulphate fertilizer of 20.55% to 46.84% either through washing or due to evaporation of Nitrogen nutrients through volatilization.

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The balance between the amount of nutrients needed by plants and the amount of nutrients obtained from fertilizer mineralization greatly affects the efficiency of nutrient uptake (Dobermann, 2007). In addition, root development as a network that absorbs nutrients directly also affects the efficiency of nutrient uptake (Tambunan, et al., 2014). However, root dry weight and root tissue samples were not carried out in this study.

The process of losing nitrogen is affected by the nitrification process in which ammonium turns into nitrates or nitrites which tend to be more easily washed to the soil layer under the plant root system (Arifin, et al., 2019). Results of research by Arifin, et al., (2020); Andert, et al., (2011); Furukawa, et al., (2005) stated that peat soil that has been drained will have a higher nitrification value due to the low water level in oil palm plantations which have many drainage channels, compared to natural peat which has not experienced drainage.

Agronomic efficiency values vary from 42.36% to 116.64%. However, Table 9 also shows that the agronomic efficiency is actually higher in plots with smaller nitrogen fertilizer doses (0.45 kg N/tree/year). This is an indicator that at the research location the dose of nitrogen fertilizer is not needed in large quantities, because the high dose of nitrogen fertilizer is not proportional to the high value of agronomic efficiency. The results of this study are also in line with the research of Ginting, et al., (2018) which states that the lower the dose of fertilizer application, the higher the agronomic efficiency. This is also a basic concept in fertilization that the dose of fertilization is given in small doses but is given with more frequency.

## CONCLUSION

Boiler ash containing potassium and nitrogen fertilizers increased FFB production by increasing the production components of bunch weight and bunch number respectively. Although nitrogen fertilizer treatment had an effect on the vegetative growth of oil palm, conversely the application of boiler ash had no significant effect on vegetative growth. Nutrient uptake was higher in plots treated with high doses, but surprisingly the efficiency of nutrient uptake was higher in plots with lower doses.

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