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The Growth Performance of Oil Palm Seedlings in Pre-Nursery and Main Nursery Stages as a Response to the Substitution of NPK Compound Fertilizer and Organic Fertilizer

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Abstract

The need of nitrogen (N), phosphate (P) and potassium (K) nutrient in oil palm nursery are usually fulfilled with synthetic chemical fertilizers such as NPK fertilizer. The application of NPK fertilizer can cause the soil to become hard due to the accumulation of the residue left on the ground. Cow manure is able to substitute NPK fertilizer based on the chemical status of the soil. This study aimed at analyzing the effect of NPK fertilizer substitution with cow manure on the growth of oil palm seedlings in the pre-nurseries and main nurseries. The experiment was conducted from February to September 2018 in the Banguntapan research and experimental field, Faculty of Agriculture, Universitas Gadjah Mada. The experiment applied the Randomized Complete Block Design (RCBD) with one factor and six blocks as replications. The factors were subtitution using the replacement series method with five levels of doses, 100% NPK, 75% NPK + 25% cow manure, 50% NPK + 50% cow manure, 25% NPK + 75% cow manure and 100% cow manure. The observed parameter variables were root lenght, root area, hump diameter, leaf area, the number of leaves, plant height and plant dry matter. The use of 25% NPK substitute with 75% organic material was the best result in increasing the growth performance of oil palm seddlings in pre-nursery and main nursery.

Keywords: cow manure; NPK; oil palm; substitution

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INTRODUCTION

Oil palm is one of the plantation commodities that develop rapidly. In 2017, the total land area reached 12.30 million ha (Nasir, 2015). The productivity of oil palm plantations has not been currently maximum, and therefore, various efforts are required to improve the productivity of oil palm, one of which is by using NPK fertilizer. The use of NPK fertilizer can cause the soil to become hard due to the residue left on the ground. The need of nitrogen (N), phosphate (P) and potassium (K) can be substituted by utilizing waste around oil palm. Utilization of waste is environmentally friendly.

One of the determinants of the growth of oil palm plant seeds is planting medium. One of the materials for composing planting media for oil palm plant seeds is topsoil. The availability of topsoil is limited, and thus, many have used the second layer to replace topsoil (Rosenani et al., 2016). The second layer of soil has low organic matter contents such as regosol soil, causing

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slower decomposition process. According to Afandi et al. (2015), the decomposition process can be enhanced by the addition of organic matter in the regosol soil. Because the organic matter content in the second layer soil is low, alternative efforts are needed to meet the requirements for the composition of the planting media for oil palm seeds (Steve et al., 2014).

Regosol is a type of soil that is still developing, formed from the deposition of ground holding material transported from other places (Putinella, 2014). Regosol that has a high sand content will have good porosity because it is dominated by macro pores, but has a low soil fertility rate because its ability to bind nutrients and water is low (Azmi et al., 2015). Omotayo and Chukwuka (2009) have reported that the addition of organic material in the treatment will improve soil texture.

The main source of nutrients in oil palm nurseries is NPK fertilizer. Simanjuntak et al. (2013) have stated that the use of synthetic chemical fertilizers in the long term can cause a decrease in soil organic matter, damaging soil structure and leaving chemical residues to the soil that are difficult to degrade. Due to the use of synthetic fertilizer, an eco-friendly-alternative is necessary (Kamarulzaman et al., 2012). Manure as a source of organic material added to the soil will experience several phases for soil micro-organisms to become humus (Elnasikh and Satti, 2017). Manure is defined as all animal waste products that can be used to increase nutrients and improve the physical and biological properties of soil. Nutrient content in manure is relatively low, but its role in the chemical properties of the soil far surpasses chemical fertilizers (Hartatilk et al., 2015).

Regosol has a low organic matter (<1%) so that the binding capacity of nutrients and cation exchange capacity are low (Gohi et al., 2018). Besides, the carrying capacity of the quantity and activity of organisms is also low. Therefore, to support the success of cultivation in regosol soil, it is necessary to improve its physical, chemical and biological properties. Organic fertilizers can significantly improve the development and growth of plants, compared to inorganic fertilizers (Ji et al., 2017). Yang et al. (2016) have noted that manure is an important source of nutrients because it has higher N and P content than other manure. Khandaker et al. (2017) have confirmed that the addition of manure can increase plant growth. The addition of manure increases the availability of N, P and K nutrients essential for plants during their growth.

The availability of cow dung is abundant around oil palm plantations. Cow dung has the potential to be used as organic fertilizer after composting. This is in line with the opinion of Budiyanto (2011) that cow dung is one of animal dungs highly prospective to be utilized as organic fertilizer. Unutilized cow dung will possibly pollute the environment. Therefore, the use of cow dung as organic fertilizer is highly recommended to maintain healthy environmental conditions. Cow dung contains organic material so that the weathering process runs optimally. Based on the data obtained from Irfan et al. (2017), cow dung contains N 0.4%, P 0.2% and K 0.1%. This proves that cow manure is potential to substitute nutrient sources such as N, P and K, which are utilized in the nursery of oil palm.

The potential of cow manure as a substitute for NPK fertilizer can be applied for topsoil in the composition of the planting media of oil palm nursery. Aside from abundant availability, cow manure also provides a variety of nutrients for the metabolic needs of oil palm seedlings. Prasetyo (2014) has stated that the use of manure as a source of nutrition can increase crop production and quality. Additionally, the use of manure in the long term can increase the humus content in the soil. Humus acts as a binder of water and nutrients in the soil, and thus reducing the possibility of soil erosion and nutrient loss (Lal, 2006). The ability of manure to increase production can also be observed from its ability to hold water. Oil palm seedlings demand enough water for metabolic needs during their growth. According to Fauzi and Puspita (2017), the average water need of oil palm seeds is 2.25 l day^{-1}. Organic fertilizer can hold water content in the soil as confirmed by Purwono et al. (2011) that the provision of organic fertilizer as much as 5 tons ha^{-1} can lessen the frequency of watering.

The purpose of this study was to examine the effect of cow manure in substituting NPK to increase the growth of oil palm seedlings. This research is fundamental because the use of synthetic chemical fertilizers to meet the nutritional needs of plants, in the long run, can pollute the environment and there is a potential that utilizing cow dung as manure found around oil palm plantations can be optimized.

MATERIALS AND METHOD

The research was conducted in February-November 2018 in the Tri Darma experimental field, the Plant Management and Production Laboratory, Faculty of Agriculture, Universitas Gadjah Mada, Yogyakarta, and in the Soil Chemistry Laboratory, Faculty of Agriculture, Universitas Sebelas Maret, Surakarta. The materials used were oil palm seeds PPKS-239 from Indonesian Oil Palm Research Institute, NPK 15-15-15 fertilizer, cow manure and polybags (50 cm x 35 cm). The type of soil used in this study was regosol.

This study was completed in two stages, namely the pre-nursery stage and the main nursery stage. The experimental design in pre-nursery and main nursery were arranged in the Randomized Complete Block Design (RCBD) with one factor consisting of five levels and six replications as blocks. In the pre-nursery stage, the factor used was a dose combination of NPK fertilizer substitute with cow manure; 18 g NPK + 0 g cow manure (100% NPK + 0% cow manure), 13.5 g NPK + 120 g cow manure (75% NPK + 25% cow manure), 9 g NPK + 240 g cow manure (50% NPK + 50% cow manure), 4.5 g NPK + 360 g cow manure (25% NPK + 75% cow manure) and 0 g NPK + 486 g cow manure (0% NPK + 100% cow manure). At the main nursery stage, the factor used was a dose combination of NPK fertilizer substitute with cow manure; 30 g NPK + 0 g cow manure (100% NPK + 0% cow manure), 22.5 g NPK + 198 g cow manure (75% NPK + 25% cow manure), 15 g NPK + 402 g cow manure (50% NPK + 50% cow manure), 7.5 g NPK + 600 g cow manure (25% NPK + 75% cow manure) and 0 g NPK + 810 g cow manure (0% NPK + 100% cow manure) (Hevrizen and Basri, 2017).

Observations of plant growth were carried out to seedlings and were started when the seedlings were two weeks old. The observations focused on plant height, the number of leaves, hump diameter, leaf area, root length, root area and plant dry matter, at 12 and 24 weeks after planting (WAP). The analysis of cow manure and soil were carried out on organic C content, pH, C/N ratio, total N, P available and K available. All the observation data were examined using analysis of variance with α=5% and followed by Duncan Multiple Range Test (DMRT) analysis, if there were significant differences between treatments.

RESULTS AND DISCUSSION

Based on the analysis results, cow manure contains high levels of organic C, high total N and moderate C/N ratio. This indicates that the use of cow manure in cultivation can provide good results because it provides essential nutrients for plant growth (Raj et al., 2014). Cow manure comprises high total N so that it can substitute NPK fertilizer used in the cultivation of oil palm seedlings. Organic C soil can alter soil properties physically, chemically and biologically. Carbon is a food source of soil microorganisms so that it will encourage microorganism activities in enhancing the soil decomposition process (Afandi et al., 2015). Evidence of organic matter in the soil is based on Organic C and total N content, so a C/N ratio can be used to estimate nutrient availability from mineralization of organic matter (Sukmawati, 2015).

Table 1. The results of cow manure analysis

Parameter	Unit	Result	Degree
C organic	%	40.94	High
N total	%	2.33	High
C/N Ratio	-	17.60	Moderate

Fertilization of oil palm seedlings aged 12 weeks gave a different response to the variable of root length. The increase in root length was followed by an increase in the percentage of cow manure on NPK fertilizer substitution. Table 2 provides information about the effect of NPK fertilizer substitution with cow manure on root length. The treatment of 25% NPK + 75% cow manure had a significantly higher result, compared to the results of other treatments at 12 WAP. At 24 WAP, the treatment of 100% NPK fertilizer did not have a significant effect on the substitution of cow manure 25-75%, but it was significantly different from the treatment of 100% NPK fertilizer. Fertilizing 100% cow manure increased the root length of oil palm plants up to 53.61%.

The effect of cow manure treatment on root length is due to the ability of cow manure to improve soil structure. The addition of cow manure can increase the negative charge of the soil, which later rises the cation exchange capacity in the soil (Hartati et al., 2013). The cation exchange capacity has an important role in the absorption of cations, which are then exchanged in soil solutions. In general, the value of cation exchange capacity reflects the level of soil fertility. If the soil has a high cation exchange capacity, it can be said that the land has a high fertility rate. Moreover, the addition of cow manure can also stimulate the release of nutrients in the soil. Cow manure also has a high content of organic matter thereby increasing the levels of organic matter in the soil. Organic matter plays a role in holding water and nutrients. Table 1 shows that the organic matter content in cow manure is high. Sriharti and Salim (2010) stated that manure can increase the content of organic matter in the soil. Organic matter can enhance soil aggregation, increase the ability to retain groundwater, and facilitate root penetration (Mccauley et al., 2017).

Table 2. The effect of NPK fertilizer substitution with cow manure on the root length and root surface area of oil palm seedlings

Treatment	Root length (cm)		Root surface area (cm^2)	
	12 WAP	24 WAP	12 WAP	24 WAP
100% NPK	23.61c	140.87b	1.66	11.27b
75% NPK + 25% cow manure	43.18b	232.58ab	2.33	14.97ab
50% NPK + 50% cow manure	44.41b	222.82ab	2.36	12.68b
25% NPK + 75% cow manure	71.72a	231.01ab	3.37	15.19ab
100% cow manure	47.91b	303.62a	2.35	18.91a
Pr > F	0.001	0.02	0.09	0.04
CV (%)	29.05	15.41	18.89	28.29

Note: Different letters in each column show a significant effect at $p \leq 0.05$ by DMRT

Cow manure contains organic material that can enhance the aeration in the rhizosphere so that the root can grow better (Sabrina et al., 2009). The surface area of the root represents the number of roots that are in the zone throughout the roots. The wider surface area of the root is, the sturdier oil palm seedlings will be. Table 2 summarizes the effect of NPK fertilizer substitution with cow manure on the root surface area of oil palm seedlings. Treatments with 100% NPK fertilizer, the substitution of NPK with cow manure 25-75% and 100% cow manure presented the same effect on root surface area at 12 WAP. At 24 WAP, the substitution of NPK fertilizer began to give a different result to the root surface area. The treatment of 100% cow manure gave a significantly higher effect than the treatment of 100% NPK and 50% NPK + 50% cow manure. It is believed that secondary, tertiary and quaternary roots just start to emerge when the seedlings are 24 WAP.

The oil palm plantations that grow horizontally and are concentrated on the surface of the soil, make the growth of tertiary and quarters roots more extensive. Factors contributing to root expansion are nutrient availability and the volume of water in the soil. The availability of P nutrients in the soil can help root expansion, especially in the formation of cells in the root tissue (Malhotra et al., 2018). Faizin et al. (2015) have suggested that P nutrient is needed to stimulate nutrient uptake by increasing the number of nodes in the roots.

One of the criteria for oil palm seedlings quality is the number of leaves. Table 3 presents that NPK fertilizer substitution with cow manure on leaf area gave a different response to seedlings aged 12 WAP and 24 WAP. At 12 WAP, substitution of 50-100% cow manure could increase the number of leaves. While at 24 WAP, the substitution of manure 75-100% produced a higher number of leaves, caused by the formation of leaf buds in the presence of cow manure. The availability of N in plants affects the formation of leaf buds.

The formation of leaves in oil palm seedlings depends on nutrients, light intensity and water availability. According to Corley and Tinker (2016), the number of leaves of oil palm seedlings grows by one leaf $month^{-1}$, until the seedlings are six months old. Seedling with nutrient deficiencies will be difficult to form a new leaf. Nutrients that play a role in the formation of leaves are N and P. P acts as a stimulus for the formation of primordia in seeds and energy sources in the cell division process, while N plays a role in the formation of cell nuclei (Sommer, 2001). The number of leaves of oil palm seedlings will affect the leaf surface area. Cow manure contains N and P nutrients, which can be used by oil palm seedlings for the growth and development of new leaves. Burhanuddin et al. (2017) have stated that the addition of manure will increase the number of leaves in the nursery of oil palm. This occurs due to the availability of organic matter in the soil that provides a variety of nutrients and can be used by oil palm seedlings for metabolism and growth.

Table 3. The effect of NPK fertilizer substitution with cow manure on the size area of leaf and number of leaves of oil palm seedlings

Treatment	Leaf area (dm^2)		Number of leaves	
	12 WAP	24 WAP	12 WAP	24 WAP
100% NPK	5449.22b	58463.8b	3b	7c
75% NPK + 25% cow manure	9597.67a	75157.0ab	4b	8bc
50% NPK + 50% cow manure	10599.67a	78503.5ab	4a	8abc
25% NPK + 75% cow manure	11902.04a	78440.0ab	4a	9a
100% cow manure	12252.33a	96981.5a	5a	8ab
Pr > F	0.001	0.047	0.004	0.013
CV (%)	24.80	11.75	13.74	10.40

Note: different letters in each column show a significant effect at $p \leq 0.05$ by DMRT

The effect of NPK fertilizer substitution on leaf area gave different responses at the age of 12 WAP and 24 WAP. Table 3 shows that the substitution of NPK with 25-100% cow manure could increase leaf area, compared to treatment 100% NPK. Moreover, 100% treatment of cow manure on 24 WAP had a significantly higher effect on leaf area, compared to leaf area on treatment 100% NPK. This is due to the treatment of 100% cow manure that uptakes and utilizes N optimally to increase leaf area. This result is supported by Prasetyo (2014) that the increase in leaf area is affected by the nutrient N through the formation of new cells.

As Table 4 shows, the substitution of cow manure 25-100% could increase the height of oil palm seedlings at the age of 12 WAP. At 24 WAP, the substitution of 50% NPK with 50% cow manure started to increase plant height. The more cow manure is given, the more macronutrients and micronutrients are available so that it can increase the height of oil palm seedlings. Plant height is the result of cell division and cell elongation. Plant seeds uptake nutrients from the soil into the canopy. Nutrients are used for photosynthesis. The results of photosynthesis in the form of photosynthate are used by plants for the process of cell division so that the seeds of oil palm plants have increased plant height (Burhanuddin et al., 2017).

Table 4. The effect of NPK fertilizer substitution with cow manure on oil palm plant height and hump diameter

Treatment	Plant heigh (cm)		Hump diameter (mm)	
	12 WAP	24 WAP	12 WAP	24 WAP
100% NPK	18.42b	34.25c	6.83b	18.82b
75% NPK + 25% cow manure	21.98a	36.67bc	9.23ab	23.50ab
50% NPK + 50% cow manure	24.90a	41.67ab	9.52ab	27.27a
25% NPK + 75% cow manure	25.70a	44.08a	11.08a	29.60a
100% cow manure	23.73a	41.87ab	11.82a	27.05a
Pr > F	0.003	0.005	0.01	0.01
CV (%)	12.76	11.12	22.02	19.78

Note: Different letters in each column show a significant effect at $p \leq 0.05$ by DMRT

Cow manure contains organic material that plays a role in holding water and nutrients in regosol soil so that nutrients and water are not easily lost from the soil. This is due to the availability of organic matter in cow manure that forms aggregates in regosol soils as a result of the release of mineral compounds. Soil containing organic matter provides improved nutrients and water for plants. The results of research by Fauzi and Puspita (2017) have suggested that the provision of 750 g of organic material can increase the height of oil palm seedlings. The substitution of NPK fertilizer with cow manure on the diameter of the oil palm seedling hump put a different effect on both 12 WAP and 24 WAP (Table 4). When seedlings were at the age of 12 WAP, treatment with 25% NPK + 75% cow manure and 100% cow manure had a noticeable effect on tuber diameter, compared to treatment with 100% NPK, but it was not significantly different from the treatment substitution with 25-50% cow manure. At 24 WAP, the substitution of NPK fertilizer with 50-100% cow manure could have a significantly higher effect on hump diameter, compared with 100% NPK, but it was not significantly different from the treatment with 75% NPK + 25% cow manure. This is because in 24 WAP, plants need more nutrients N. The uptaken N will soon be transformed into amino acids, which are then used in cell division.

According to Prasetyo (2014), N plays a role in the formation of amino acids in cell division. Oil palm seedlings that have optimal N uptake certainly have a larger hump diameter, due to cell division. Meanwhile, metabolic energy is needed to run the whole set of processes. The energy originates from the process of respiration in the form of ATP. The role of the phosphorus is to form ATP used as energy in carrying out a sequence of processes. This is in line with the opinion of Ichsan et al. (2012) that plant growth and development are due to cell division and an increase in the number of cells that need energy in the form of ATP.

In addition to the phosphorus nutrient, the enlargement of hump diameter is affected by K availability. Astuti et al. (2015) have stated that the increase in hump diameter is inseparable from the availability of K in plants. K plays a role in accelerating meristematic growth, especially on hump plant seeds, strengthening the humps so it does not easily fall. P and K nutrient also play a pivotal role in the assimilation of carbohydrates and translocation of starch to the hump in oil palm plantations, thus forming a well-rounded hump oil palm seedlings.

Table 5 summarizes that the dry matter of oil palm seedlings shows significant differences when seedlings were at the age of 12 WAP and 24 WAP. At the age of 12 WAP, 25-100% cow manure substitution could increase plant dry matter. Substitution of 25% NPK + 75% cow manure gave the highest dry matter of plants. At 24 WAP, substitution of 75-100% cow manure had a significantly higher effect than the treatment with 100% NPK. The treatment of 100% manure cow performed the heaviest plant dry matter. Dry matter accumulation demonstrates the ability of plants to transform energy and sunlight through photosynthesis and its relationship with environmental factors. The plant dry matter is the main indicator of the quality of seedlings, which is determined by root length, root area, hump diameter, leaf area and plant height (Fried and Hademenos, 2000).

Table 5. The effect of NPK fertilizer substitution with cow manure on the dry matter of oil palm seedlings

Treatment	Plant dry matter (g)	
	12 WAP	24 WAP
100% NPK	0.56c	14.82c
75% NPK + 25% Cow manure	0.97b	19.11bc
50% NPK + 50% Cow manure	1.15ab	20.85bc
25% NPK + 75% Cow manure	1.38a	22.85ab
100% Cow manure	1.24ab	25.84a
Pr > F	0.001	0.02
CV (%)	26.37	12.06

Note: Different letters in each column show a significant effect at $p \leq 0.05$ by DMRT

CONCLUSIONS

Based Substitution of NPK fertilizer with cow manure significantly increased root length, root area, hump diameter, leaf area, number of leaves, plant height and plant dry matter of oil palm seedlings in the pre-nurseries and main nurseries. The application of organic material as the substitution of NPK fertilizer with cow manure presented good seedling growth and performance.

These experiments have proven that the use of 25% NPK substituted with 75% organic material contributes to the best results in increasing the growth performance of oil palm seddlings in pre-nursery and main nursery.

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