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The Roles of Organic and NPK Compound Fertilizers for Four Year Old Mature Oil Palm (*Elaeis guineensis* Jacq)

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Abstract

Oil palm becomes an important commodity as source of foreign exchange. Oil palm need a large of quantity of nutrients, thus fertilization is a key factor that must be considered to increase its growth and productivity. The objectives of this research were to study the role of organic and NPK compound fertilizers and its combination on growth and productivity for 4 year old of oil palm. The research was conducted at IPB-Cargill Teaching Farm of Oil Palm, Jonggol, Bogor West Java from March 2016 to March 2017. The experiment was carried out in a factorial randomized block design with three replications. The first factor was organic fertilizer, consisted of 0 kg (O0), 60 kg (O1), and 120 kg (O2) plant^{-1} year^{-1}. The second factor was NPK compound fertilizer (15:15:15), consisted of 0 kg (MO), 3 kg (M1) and 6 kg (M2) plant^{-1} year^{-1}. The result of this research showed that organic fertilizer application increased on trunk girth, leaf K nutrient content and leaf greenness level. The application NPK compound increased plant height, trunk girth, frond length, leaf area, total bunch production, total fresh fruit bunches, average fresh fruit bunch weight and productivity.

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There was an interaction between manure and NPK compound fertilizer on leaf area, leaf N nutrient content and leaf P nutrient content. The best NPK compound fertilizer was 6 kg of plant^{-1} year^{-1}.

Keywords: organic fertilizer; NPK compound fertilizer; vegetative growth; productivity.

1. Introduction

Oil palm (*Elaeis guineensis* Jacq.) is one of the important plantation commodities because it is the raw material for food, cosmetics, medicines and biodiesel [1]. Oil palm plants require large amounts of nutrients so that fertilization is a factor that must be considered to increase growth and productivity [2]. The productivity of oil palm is influenced by several factors such as soil fertility and fertilizer input with the right rate so that the potential of crop productivity can be achieved [3]. The availability of limited fertile land causes the expansion of oil palm plantations to move to less fertile land [4]. Oil palm plants require large nutrients, but the soil's ability to provide continuous nutrients for growth and palm oil production is limited. Limitations of the carrying capacity of the land to provide nutrients must be offset by replacements through the addition of nutrients, especially the use of a combination of organic and inorganic fertilizers [5]. Fertilization of oil palm crops can improve soil fertility so that the level of crop production becomes relatively stable and increase plant resistance to disease attacks, and unfavorable environmental influences [6]. Application of organic fertilizer can increase the effectiveness of inorganic fertilizers as well as increase plant height, the number of fronds, trunk girth and total P content of oil palm seedlings in the main nursery [7].

Organic fertilizers are able to reduce the amount of inorganic fertilizer due to the presence of organic materials that can improve the physical, chemical and biological properties of the soil [8]. Improvements to the physical properties of the soil due to organic fertilizer because the soil becomes loose, improves aeration, drainage, increases the bonding of particles and increases the soil's capacity to retain water. Organic fertilizers can improve chemical properties through increased cation exchange capacity, increase nutrient availability and accelerate the mineral weathering process [9]. As for the biological nature, organic fertilizers can increase the activity of beneficial microorganisms such as fungi and bacteria [10]. Organic fertilizers can supply macro nutrients such as (N, P, K, Ca Mg and S), providing micro nutrients to prevent micro element deficiencies in marginal soil or intensive cultivated land [11]. Application of high rates of inorganic fertilizers and not applying organic materials, it can cause soil organic matter to be very low and become limiting factor to achieve high yield [12]. The use of inorganic fertilizers in addition to nutrients, has several advantages such as being able to provide nutrients in relatively quicker time, producing available nutrients ready to be absorbed by plants, more nutritional content, odorless, practical and easy to apply. The most dominant element found in inorganic fertilizers are elements of N, P and K, these elements are called primary nutrients [13]. One of the commonly used inorganic fertilizers is compound fertilizer. Compound fertilizer is a fertilizer containing two or more nutrients, easy to apply and more efficient in terms of time and labor. Increasing vegetative plant growth of one year old oil palm (Immature plant 1) in marginal soil of Jonggol can be achieved by giving 30 kg of organic fertilizer and 2.6 kg of compound NPK fertilizer (15:15:15) for each plant and there was no interaction effect between organic fertilizer and NPK compound [14]. Application of organic fertilizer with rate of 90 kg of plant^{-1} year^{-1} improves greennes leaves, photosynthetic rate and nutrient content of oil palm aged 2 years old (immature

plant 2). The application of NPK compound fertilizer of 6.9 kg of plant^{-1} year^{-1} can increase plant height, stem girth, frond number, length of frond, leaf area, number of leaflets, photosynthesis rate, leaf greenness and nutrient content of oil palm leaves immature plant. Interaction occured between organic fertilizer and NPK compound fertilizer on the rate of photosynthetic photos of plant oil palm trees of two years old [15]. The treatment of organic fertilizer and the combination of organic fertilizer and NPK compound fertilizer did not give any significant effect on morphology and physiology response. The treatment of NPK compound fertilizer at a rate of 2.5 kg of plant^{-1} year^{-1} increases plant height, stem girth, frond length and leaf area on three years of oil palm [16]. This research was a follow up research conducted by Sukmawan and his colleagues [14], Kanny and his colleagues [15], Pebrianto [16] on the immature plant. The purpose of this research was to study the role of organic fertilizer and NPK compound fertilizer and its combination of growth and productivity of mature plant (age four years) and to determine the best combination rate of organic fertilizer and NPK compound fertilizer on growth and production of oil palm aged four years.

2. Materials and Methods

The present research was carried at IPB-Cargill Teaching Farm of of Palm Oil, Jonggol district, Bogor, West Java, from March 2016 to March 2017. The materials used in the study were as follows: oil palm (Dami Mas variety) at the age of 4 years old, hybrid of *Dura* and *Pisifera* (D x P), cow manure as organic fertilizer, NPK compound fertilizer 15:15:15 and herbicides. Tools was used consisted of weighing machine, measuring tape, auger, oven and SPAD-502 plus chlorophyll meter. The experimental design was factorial arranged in a Completely Randomized Block Design. The first factor was the organic fertilizer, consisted of 3 rates i.e. (O0) 0 kg, (O1) 60 kg and (O2) 120 kg plant^{-1} year^{-1}. NPK compound fertilizer was used as the second factor and consisted of 3 rates i.e. (M0) 0 kg, (M1) 3 kg and (M2) 6 kg plant^{-1} year^{-1}. Nine combinations were used in this study and each combination was replicated 3 times. Thus, a total of 27 experimental units. Each experimental trial unit consisted of 5 plants, leading to the use of 135 plants for the research. The rates were determined based on a previous research conducted according [17]. NPK compound fertilizer was applied twice, in April and November 2016, after the application of organic fertilizer. . Fertilizer application was performed by evenly spread fertilizer all around the circle of the oil palm. Plant morphological variables that were observed in this study were plant height, trunk girth, frond length number 17, frond leaf area number 17. Physiological variables of the plant that were observed were leaf nutrient content on frond number 17 and leaf greenness level. Plant production variables that were observed included total bunch production, total fresh fruit bunch, average fresh fruit bunch weight and productivity. All data were analyzed using ANOVA test (on SAS ver. 9.4) at an interval of $P < 0.05$. An ANOVA test was followed by Duncan's test if significant differences [18].

3. Result and Discussion

3.1 Morphological Response

3.1.1 Plant Height and Frond Lenght

The treatment of NPK compound fertilizer significantly increased plant height at 41 to 48 months after planting

(MAP) (Table 1). The growth of plant height on the treatment of NPK compound fertilizer with a rate of 6 kg plant^{-1} year^{-1} is not significantly different with that of 3 kg plant^{-1} year^{-1} treatment. Increased plant height with treatment rate of 6 kg plant^{-1} year^{-1} was higher by 20.14% compared to control. This result is consistent with the research conducted by [19] which indicated that NPK compound fertilization increased plant height, stem diameter, the number of frond leaves, dry weight of oil palm crops than those without NPK compound fertilizer (control). Moreover, the research [20] showed that the application of NPK compound fertilizer significantly increased the growth of oil palm such as plant height, the number of frond, leaf area, chlorophyll content and nutrient content of tissues on frond leaves number 9 at one year after planting (Immature 1 year of oil palm).

The treatment of NPK compound fertilizer significantly increased the length of frond at 36 to 48 MAP (Table 1). The length of frond on the treatment of NPK compound fertilizer with a rate of 6 kg of plant^{-1}year^{-1} was not significantly different with the rate of 3 kg of plant^{-1} year^{-1}. The frond length increase of the rate of 6 kg plant^{-1} year^{-1} was higher by 8.20% than control. The effect of NPK compound fertilizer treatment at the phase of immature 1 year, immature 2 year and immature 3 year still has residual, so that at 36 MAP, it suggested a significant effect on frond length. However, the application of NPK compound fertilizer treatment at the phase of mature 1 year (Mature 1 year) revealed a significant effect at 37 MAP. This result was in line with the previous research [3], showed that NPK compound fertilizer (15:15:15) has a significant effect on the growth of oil palm plants, it was because of the high content of nitrogen and phosphorus in NPK compound fertilizer, moreover, it plays an important role in the process of cell division to speed up the plant growth.

Table 1: Influence of various organic and NPK compound fertilizers on plant height and frond length variables

Treatment	Observation time (MAP)					
	41	45	48	36	42	48
	Plant height (cm)			Frond length (cm)		
Organic fertilizer (kg plant^{-1} year^{-1})						
0	175.62	187.16	201.43	329.97	403.13	461.66
60	185.05	200.76	217.67	344.33	409.77	482.91
120	181.11	200.65	214.85	330.28	402.38	476.76
NPK compound fertilizer (kg plant^{-1} year^{-1})						
M0	159.84c	175.15b	190.28b	314.90c	381.71c	453.67b
M1	184.01b	199.92a	215.05a	333.73b	406.30b	476.76a
M2	197.93a	213.50a	228.62a	355.95a	427.27a	490.91a

Description: [a] The following characters on number in the same column means not significantly different at DMRT test with level of α 5%. MAP: month after planting.

3.1.2 Trunk Girth and Leaf Area

Organic fertilizer treatment significantly increased the growth of the trunk girth on 48 BST. NPK compound fertilizer significantly increased the trunk girth from 36 to 48 BST (Table 2). The growth of the trunk girth with application of NPK compound fertilizer treatment at a rate of 6 kg plant^{-1} year^{-1} was not significantly different to that of 3 kg plant^{-1} year^{-1}. The increment in trunk girth with a rate of 6 kg plant^{-1} year^{-1} was about 12.55% higher than that of the control. According [21] indicated that release of organic fertilizer nutrients occurs slowly in the soil so as to give effect to the plant in a long time. According [22] showed that the biggest trunk girth of oil palm was observed in plant supplemented with both inorganic fertilizer (NPK Mg) and organic fertilizer from livestock. Nutrient elements contained in inorganic fertilizers are more readily available to plants. This result was in line with the previous research [23] that demonstrated that NPK compound fertilizer could result in the biggest trunk girth on oil palm.

NPK compound fertilizer treatment significantly increased the leaf area from 36 to 46 MAP (Table 2). The increment in leaf area with a rate of 6 kg plant^{-1} year^{-1} significantly differed to that of the 3 kg plant^{-1} year^{-1}. The highest increment in leaf area was noticed in the 6 kg plant^{-1} year^{-1} treatment, being 23.15%.

Table 2: Influence of various organic and NPK compound fertilizers on trunk girth and leaf area variables

Treatments	Observation time (MAP)				
	36	42	48	36	42
	Trunk girth (cm)			Leaf area (m^2)	
Organic fertilizer (kg plant^{-1} year^{-1})					
0	211.24	235.34	258.70b	2.17	4.23
60	219.19	247.56	270.91a	2.31	4.87
120	215.20	247.97	272.48a	2.18	4.33
NPK compound fertilizer (kg plant^{-1} year^{-1})					
M0	193.90c	225.10b	250.02b	2.06b	4.04b
M1	217.77b	246.44a	270.66a	2.24ab	4.37b
M2	233.96a	259.33a	281.41a	2.36a	5.02a

Description: [a] The following characters on number in the same column means not significantly different at DMRT test with level of α 5%. MAP: month after planting.

The treatment of organic fertilizer and NPK compound fertilizer interacted on leaf area at 48 MAP. The combined treatment between organic and NPK compound fertilizers with a rate of 60 kg plant^{-1} year^{-1} and 6 kg of plant^{-1} year^{-1} showed the largest leaf area (Table 3). According to [24] stated that the combination of organic and inorganic fertilizer can increase the metabolism of plants which led to the optimal absorption of nutrients derived from the fertilizer. In addition, it will be more effective because of increasing soil bearing capacity due to the addition of organic matter affected the better plant growth and yield. According to [14] stated that

fertilizer is the main input in increasing plant growth in infertile land. NPK Compound fertilizer significantly increased the number of frond, stem diameter, leaf area and lenght of frond. Leaf factor has a strong correlation with cell differentiation and acts as assimilate source.

Table 3: Interaction of organic and NPK compound fertilizers on leaf area at 48 MAP

Rate of organic fertilizer	Rate of NPK compound fertilizer (kg plant^{-1} year^{-1})		
	0	3	6
	Leaf Area (m^2)		
0 kg	3.53b	4.20b	4.13b
60 kg	4.13b	4.16b	5.86a
120 kg	4.13b	4.26b	4.50b

Description: The numbers followed by different letters show significantly different according to the DMRT test at 5% level.

3.2 Physiological Response

NPK compound fertilizer treatment had a significant effect on leaf nutrient contents that were N and P. However, it had no significant effect on leaf K content (Table 4). The organic fertilizer treatment had a significant effect on the leaf greenness level at 42 and 48 MAP. The NPK compound fertilizer treatment had a significant effect on the the leaf greenness level at 42 and 48 MAP.

Table 4: Influence of various organic and NPK compound fertilizer treatments on leaf nutrient contents and leaf greenness level

Treatments	Observation time (MAP)				
	48			42	48
	N (%)	P (%)	K (%)	leaf greenness level	
Organic fertilizer (kg plant^{-1} year^{-1})					
0	2.27	0.21	0.67b	70.05b	67.41b
60	2.35	0.22	0.76b	73.67a	70.62a
120	2.27	0.22	1.06a	72.60ab	71.86a
NPK compound fertilizer (kg plant^{-1} year^{-1})					
0	2.20b	0.21b	0.87	68.50b	67.62b
3	2.25b	0.21b	0.75	74.14a	70.60a
6	2.43a	0.23a	0.87	73.64a	71.67a

Description: [a] The following characters on number in the same column means not significantly different at DMRT test with level of α 5%. MAP: month after planting. Table 4 shows that the P nutrient content in the leaf appeared to be enough, while the nutrient content of N and K were observed to be insufficient. According to [25], the critical nutrient level in oil palm leaves number 17 are 2.60 % for N, 0.16 % for P, and 1.10% for K. According to [26], organic fertilizer application could increase both the synthesis and the number of chlorophyll pigments. Thus, the supplementation of potassium increased the N uptake, leading to a rise in growth characters. The treatment of organic fertilizer and NPK compound fertilizer interacted on leaf N nutrient content at 48 MAP. The combined treatments between organic and NPK compound fertilizers is 60 kg and 6 kg plant^{-1} year^{-1} rates showed the highest N nutrient content (Table 5). Nitrogen plays an important role in stimulating the vegetative growth of the plant and influencing chlorophyll content. According [27], phosphor has an important role in N absorption that is influenced by P fertilization.

Table 5: Interaction between organic and NPK compound fertilizers on N nutrient content of the leaf (%)

Organic fertilizer rates	NPK compound fertilizer rates (kg plant^{-1} year^{-1})		
	0	3	6
0 kg	1.96d	2.37abc	2.48ab
60 kg	2.31abc	2.22c	2.53a
120 kg	2.33abc	2.18c	2.29bc

Description: The numbers followed by different letters show significantly different according to the DMRT test at 5% level.

The treatment of organic fertilizer and NPK compound fertilizer interacted on leaf P nutrient content at 48 MAP. organic and NPK compound fertilizers at 60 kg and 6 kg plant^{-1} year^{-1} rates resulted in the highest P nutrient content which was not significantly different to those of 120 kg and 6 kg plant^{-1} year^{-1} (Table 6). According [28] showed that phosphor contained in oil palm plant plays important roles in every physiological process of the plant i.e. related to both vegetative and generative growths of the plant. In fact, the phosphor can contribute to the production of fruit bunch, but P does not work alone, meaning that it has to be combined with other nutrients.

Table 6: Interaction between organic and NPK compound fertilizers on P nutrient content of the leaf (%)

Organic fertilizer rates	NPK compound fertilizer rates (kg plant^{-1} year^{-1})		
	M0	M1	M2
0 kg	0.19c	0.21ab	0.21ab
60 kg	0.22ab	0.20bc	0.23a
120 kg	0.21ab	0.22ab	0.23a

Description: The numbers followed by different letters show significantly different according to the DMRT test at 5% level.

3.3 Productive Response

The treatment of NPK compound fertilizer significantly increased the number of bunches, the number of fresh fruit bunch (FFB), the average weight of FFB and the productivity (Table 7).

This result was in line with the previous study [29] indicated that NPK compound fertilizer application can be applied to balance the nutrients in the soil thereby affecting the optimal growth of the plant and significantly increased fruit production in oil palm plant mature at eight years old.

Table 7: Influence of various organic and NPK compound fertilizer treatments on bunches of fresh fruit

Treatments	Observation period (36 to 48 MAP)			
	Total bunch production	Total fresh fruit bunches	Average fresh fruit bunch weight	Productivity tons ha^{-1} $year^{-1}$
Organic fertilizer (kg $plant^{-1}$ $year^{-1}$)				
0	21.64	19.44	5.11	14.40
60	24.99	20.78	6.17	17.79
120	22.07	20.95	5.70	16.50
NPK compound fertilizer (kg $plant^{-1}$ $year^{-1}$)				
M0	18.14b	13.71b	4.45b	8.66c
M1	24.54a	22.40a	5.56b	16.51b
M2	26.02a	25.07a	6.97a	23.52a

Description: [a] The following characters on number in the same column means not significantly different at DMRT test with level of α 5%. MAP: month after planting.

3.4 Relative Agronomic Effectiveness

Relative agronomic effectiveness (RAE) results showed that the combination of organic and NPK compound fertilizers was agronomically effective (in general), indicating that NPK compound fertilizer will be more effective if applied with organic fertilizer. According [30], RAE assessment examined the results of relative fertilized plant compared to standard fertilizers, and if the value is close to 100% or more, it signifies that the new fertilizer possesses the same abilities (or more) as the standard fertilizer. Relative agronomic effectiveness results of organic fertilizer supplementation are presented in Table 8 and Table 9.

Table 8: Relative agronomic effectiveness value on plant morphology variable

Treatments (kg plant^{-1}year^{-1})	Relative agronomic effectiveness value			
	PH	TG	FL	LA
Organic fertilizer 0 kg + NPK 3	-	-	-	-
Organic fertilizer 0 kg + NPK 6	127.82	144.62	133.69	119.16
Organic fertilizer 60 kg + NPK 0	77.3	74.72	102.3	71.65
Organic fertilizer 60 kg + NPK 3	103.73	117.51	92.16	72.84
Organic fertilizer 60 kg + NPK 6	**156.89**	**158.42**	**145.75**	**280.02**
Organic fertilizer 120 kg + NPK 0	74.96	94.55	91.3	68.46
Organic fertilizer 120 kg + NPK 3	116.42	130.97	117.23	88.4
Organic fertilizer 120 kg + NPK 6	127.37	138.74	100.85	65.05

Description: M0: without NPK *compound* fertilizer, M1: 3 kg, M2: 6 kg plant^{-1} year^{-1}. PH: Plant height, TG: Trunk girth, FL: Frond length, LA: Leaf area

Table 9: Relative agronomic effectiveness value on plant productivity variable

Treatments (kg plant^{-1} year^{-1})	Relative agronomic effectiveness values			
	TBP	TFFB	AFFBW	PRD
Organic fertilizer 0 kg + NPK 3	-	-	-	-
Organic fertilizer 0 kg + NPK 6	**162.59**	**153.50**	139.01	178.78
Organic fertilizer 60 kg + NPK 0	99.46	51.08	84.43	61.47
Organic fertilizer 60 kg + NPK 3	137.41	119.75	100.25	126.86
Organic fertilizer 60 kg + NPK 6	142.45	121.15	**204.60**	**190.89**
Organic fertilizer 120 kg + NPK 0	55.92	38.22	61.84	47.25
Organic fertilizer 120 kg + NPK 3	111.84	118.47	102.51	114.32
Organic fertilizer 120 kg + NPK 6	92.93	140.13	158.96	179.23

Description: M0: without NPK compound fertilizer, M1: 3 kg, M2: 6 kg plant^{-1} year^{-1}. TBP: Total bunch production, TFFB: Total fresh fruit bunches, AFFBW: Average fresh fruit bunch weight, PRD: Productivity.

Table 8 shows that the organic fertilizer at a rate of 60 kg plant^{-1} year^{-1} and NPK compound fertilizer at a rate of 6 kg plant^{-1} year^{-1} had the highest effectiveness values i.e. plant height (156.89%), trunk girth (158.42%), frond lenght (145.75%), leaf area (280.02%). This was supported by the results [31], research demonstrating that organic fertilizer combined with NPK compound fertilizer can increase the relative agronomic effectiveness

compared to treatments without the combination.

Table 9 shows that the organic fertilizer treatment with a rate of 60 kg of plant^{-1} year^{-1} and the compound NPK fertilizer of 6 kg of plant^{-1} year^{-1} suggested the highest effectiveness value of 204.60% for the average FFB weight, 190.89% for productivity. However the number of bunches and FFB in the treatment without organic fertilizer and NPK compound fertilizer with a rate of 6 kg of plant^{-1} year^{-1} revealed the highest effectiveness value, that was 162.59% and 153.50% respectively.

This suggested that the combination of organic fertilizer of 60 kg plant^{-1} year^{-1} and NPK compound fertilizer of 6 kg of plant^{-1} year^{-1} produced the low number of bunches and FFB, but the average weight of FFB produced was higher than that without the combination with organic fertilizer which has a higher number of bunches and FFB but resulting in low average weight of FFB.

4. Conclusions

The application of organic fertilizer can increase trunk girth, leaf K nutrient content and leaf greenness level of oil palm. NPK compound fertilizer application could increase plant height, trunk girth, leaf area, total bunch production, total fresh fruit bunch, average fresh fruit bunch weight, productivity, leaf N nutrient content, leaf P nutrient content and leaf greenness level for mature 1 year old of oil palm. Interactions occurred between organic and NPK compound fertilizers on some variables such as leaf area, leaf N nutrient content and leaf P nutrient content of mature 1 year of oil palm.

The best combination of organic and NPK compound fertilizers on growth and productivity of oil palm can be obtained by supplementing organic fertilizer (60 kg plant^{-1} year^{-1}) and NPK compound fertilizer (6 kg plant^{-1} year^{-1}).

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