The Roles of Bio Organic and NPK Compound Fertilizer to Growth and Production of Four Year Old Oil Palm

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ABSTRACT— ***Organic fertilizers should be combined with inorganic fertilizers to improve the productivity of soil and crops considering their sustainability. The purpose of this research was to study the roles of bio-organic fertilizer and NPK compound fertilizer, and to determine the best combination between the rate of bio-organic fertilizer and NPK compound fertilizer on the growth and production of oil palm of 4 years old. This research was conducted from March 2016 to March 2017. The experimental design used randomized block design, one factor with three replications. The combination of fertilizer were nine treatments, consisted of different combinations were used including bio-organic fertilizer1 to 4 kg. NPK compound fertilizer 3 to 6 kg and 60 kg organic manure fertilizer. The results showed that combination application of bio-organic and NPK compound fertilizers increased plant height, production number of bunches, number of fresh fruit bunches (FFB) and productivity. Combination fertilizer resulted the highest productivity was the treatment of 1 kg of bio-organic fertilizer + 6 kg of NPK compound fertilizer. Application of 4 kg bio-organic fertilizer can reduce 50% NPK compound fertilizer with productivity 20.39 ton of fresh fruit bunches ha^{-1} year^{-1}.***

Keywords— bio organic, inorganic, organic, fertilizer, vegetative growth, productivity

1. INTRODUCTION

Fertilization is one of maintenance activities to increase growth and production. Fertilizer as one of the production inputs in the oil palm cultivation system, this plant requires a large amount of fertilizer during the production period [1]. The purpose of fertilization is to ensure the availability and balance of plant nutrients [2]. Fertilization can increase the productivity of oil palms, because oil palm is a plant that requires large amounts of nutrients [3]. Generally, palm oil productivity is influenced by many factors such as environment, genetic, and cultivation techniques [4]. Specific factors affecting palm oil productivity is fertilization [3]. Nutrient elements contained in the fertilizer is needed for plant growth and production. Fertilizer is needed to meet the availability of plant nutrients. The availability of nutrients can be provided by the application of fertilizer, either inorganic or organic fertilizer [5].

Application of organic fertilizer can increase the effectiveness of Nitrogen, Phosphorus, Potassium (NPK) compound fertilizer through the improvement of physical and biological properties of the soil. NPK compound fertilizers will be more effective when applied with organic fertilizer for oil palm seedlings in the main nursery [6]. NPK compound fertilizers are aimed to increase growth and production, and also to accelerate flowering and ripening of fruit [7].

Vegetative growth increased with the application of organic fertilizer and NPK compound. The recommended rate of organic fertilizer and NPK compound for immature oil palm at the age of one year is 40.7 kg of organic fertilizer year^{-1} plant^{-1}, and 1.9 kg of NPK compound fertilizer [8]. The optimum rate of NPK compound on oil palm plants not yet yielding the age of two years was 3.52 kg of NPK compound plant^{-1} year^{-1} [9].

Organic bio fertilizer can improve the efficiency of inorganic fertilizer, organic bio fertilizer is also an environmentally friendly fertilizer, one of which is Bio-organic Soil Treatment (BIOST). BIOST fertilizer is a biological fertilizer that can improve the structure and soil fertility. This fertilizer contains humus, fossil flour, natural protein, and

multi-strain microbes. The microbes contained in this fertilizer are *Azotobacter*, *Azospirillum*, *Mycorrhiza*, *Bacillus*, and *Tricoderma* [10].

Azotobacter is a nitrogen-fixing bacteria for plants, whereas *Azospirillum* is a nitrogen-fixing bacteria associated with rooting plants [11]. *Mycorrhiza* can increase the uptake of micro nutrients such as Zn and Cu and increase the ability of plants to absorb water. *Bacillus* can increase available P in the soil. *Trichoderma* sp is used to accelerate the decomposition process of composting organic material [12]. Soil microbial activities can improve soil physical properties, soil chemistry that ultimately enhances plant growth [13]. Biological fertilizers can activate microorganisms that are in the soil, and are environmentally friendly [14].

The purpose of this research was to study the roles of bio-organic fertilizer and NPK compound fertilizer, and to determine the best combination between the rate of bio-organic fertilizer and NPK compound fertilizer on the growth and production of oil palm of 4 years old.

2. MATERIALS AND METHOD

The research was conducted from March 2016 to March 2017 at IPB-Cargill Teaching Farm of Oil Palm, Jonggol, Bogor Indonesia. Analysis of plant tissue was done in Laboratory of Agronomy and Horticulture Department, Bogor Agricultural University. The materials used in this research were four years old oil palm of Dami Mas variety. The fertilizers used were bio-organic fertilizer, organic fertilizer from cow dung, and NPK compound fertilizer (15:15:15). The tools used in this research were balance scale, SPAD-502 plus chlorophyll meter, and microscope.

The research design used was randomized complete block design, with nine treatments consisted of: B1 (1 kg bio-organic + 3 kg NPK compound fertilizer), B2 (1 kg bio-organic + 6 kg NPK compound fertilizer), B3 (2 kg bio-organic + 3 kg NPK compound fertilizer), B4 (2 kg bio-organic + 6 kg NPK compound fertilizer), B5 (4 kg bio-organic + 3 kg NPK compound fertilizer), B6 (4 kg bio-organic + 6 kg NPK compound fertilizer), B7 (60 kg organic manure + 3 kg NPK compound fertilizer), B8 (60 kg organic manure + 6 kg NPK compound fertilizer), B9 (plantation standard fertilizer : 6 kg NPK compound fertilizer). The rate of NPK compound fertilizer was tested based on the results of the research conducted by [9], to determine the optimum rate of NPK compound fertilizer. The treatments tested in this study consisted of nine treatments, with three replications for each treatment, thus there were 27 experimental units. Each experimental unit consists of five plants, thus the number of oil palm samples observed was 135 plants.

Organic fertilizers derived from cow dung were applied once in the early application of fertilization (April 2016). Manure fertilizer is made from 100 kg of cow dung and then added with 5 mL decomposer dissolved in 10 L water. The cow dung material is mixed and closed for 7 days. Provision of microbes conducted every week for 3 weeks consecutively. Further dried by sun drying to 20% moisture content. Bio-organic fertilizers and NPK compound fertilizers were applied twice in April and November 2016. The rate of bio-organic fertilizer and NPK compound fertilizer in each application is half of the rate per year. The application of fertilizer was spread on circle of the oil palm. Maintenance of oil palm, such as weed and pest control and disease was done according to standard. Harvesting of fresh fruit bunches was done by cutting the bunches as close to the base, it is a maximum of 2 cm from the base.

The variables observed in this study were plant morphology, plant height and stem girth. Plant height was measured from the base of the stem, 10 cm above ground level. The stem girth circle was measured ± 10 cm from the surface using a meter scale. The plant physiological variables observed were the greenness of leaves and stomata density. The level of leaves greenness measured at the three points (base, middle and end) of the leaflet of frond 17. Measurement of greenness level was done by placing leaf samples on SPAD-502 plus chlorophyll meter reader. Stomata density measurements were performed by applying clear nail polish on the underside of the leaves and allowed to dry for several minutes. Leaf surface that has been smeared nail polish, then pasted clear insulation and pressed for nail polish can be attached. The insulation was removed and then affixed to the preparatory glass. Further stomata have been taken, and then was brought to the laboratory to be observed using a microscope.

The production component observed was the number and weight of fresh fruit bunches per plant of each treatment. Other variables observed were leaf nutrient content (N, P and K), and relative agronomic effectiveness. The data were analyzed using F-test analysis. If F test was significantly different, then it was followed by Duncan Multiple Range Test (DMRT), at test level α 0.05 [15].

3. RESULT AND DISCUSSION

3.1 Plant Morphology

The measurement result of plant height of oil palm at 41 Month After Planting (MAP) showed that the plant height of oil palm was not significantly different. The application of combination of bio-organic fertilizer and NPK compound

fertilizer rate significantly increased plant height at 45 and 48 MAP. The effect of combination of bio-organic and NPK compound fertilizer on plant height at 41, 45 and 48 MAP is presented in Table 1.

Table 1: The effect of rate combination of bio-organic and NPK compound fertilizer on plant height at 41, 45 and 48 MAP

Rate combination of fertilizers	Plant height (cm)		
	41 MAP	45 MAP	48 MAP
B1 (1 kg bio-organic fertilizer + 3 kg NPK compound fertilizer)	183.87	215.13 ab	238.07 ab
B2 (1 kg bio-organic fertilizer + 6 kg NPK compound fertilizer)	178.93	213.33 ab	248.00 a
B3 (2 kg bio-organic fertilizer + 3 kg NPK compound fertilizer)	167.13	197.27 b	224.73 b
B4 (2 kg bio-organic fertilizer + 6 kg NPK compound fertilizer)	173.73	203.67 ab	232.27 ab
B5 (4 kg bio-organic fertilizer + 3 kg NPK compound fertilizer)	168.87	199.07 b	230.33 ab
B6 (4 kg bio-organic fertilizer + 6 kg NPK compound fertilizer)	185.87	221.08 a	250.45 a
B7 (60 kg organic manure + 3 kg NPK compound fertilizer)	174.80	209.80 ab	232.27 ab
B8 (60 kg organic manure + 6 kg NPK compound fertilizer)	167.27	196.93 b	224.47 b
B9 (plantation standard fertilizer: 6 kg NPK compound fertilizer)	183.47	214.20 ab	247.93 a
Probability	0.11	0.04	0.04

Notes : the number in the same column followed by the same letter are not significantly different at the 5% level (Duncan's multiple range test). MAP: Month After Planting.

Table 1 showed that plant height parameter, at 48 MAP, the highest obtained by treatment B6, B2 and B9, respectively. The standard fertilizer treatment (B9) was not significantly different compared to the combination of bio-organic and NPK compound fertilizers (B6 and B2). Research result of [10] showed that plant height with combination of bio-organic and single fertilizer N, P, K was not significantly different compared to single fertilizer treatment N, P, K. However, 4 kg bio-organic fertilizer and NPK compound fertilizer 6 kg (B6) had the highest plant height.

According to [16] that marginal land of Jonggol required a high rate of fertilizer to produce good immature of one year oil palm performance. High rate application of fertilizers was recommended on marginal soils to maintain nutrient balance in the soil and increase soil fertility, so that soil can provide nutrient needs [17]. Plant height with treatment of B1, B5, and B7 was not different with standard fertilizer treatment (B9) at 48 BST. It showed that bio-organic fertilizer or organic manure can reduce a half of the rate of inorganic NPK compound fertilizer, which was 3 kg. The application of organic fertilizers can improve the effectiveness and substitution of inorganic fertilizers (NPK) for oil palm seedlings in main nursery [6]. Application of bio-organic fertilizers in the soil improved soil microbes and minimized the use of chemical single fertilizers [11].

Data of the effect of the rate combination of bio-organic and NPK compound fertilizers on stem girth at 36, 42 and 48 MAP is presented in Table 2.

Table 2: The effect of the rate combination of bio-organic and NPK compound fertilizer on stem girth at 36, 42, and 48 MAP

Rate combination of fertilizers	Stem girth (cm)		
	36 MAP	42 MAP	48 MAP
B1 (1 kg bio-organic fertilizer + 3 kg NPK compound fertilizer)	220.47	261.13	291.13
B2 (1 kg bio-organic fertilizer + 6 kg NPK compound fertilizer)	221.60	258.93	283.53
B3 (2 kg bio-organic fertilizer + 3 kg NPK compound fertilizer)	216.27	250.60	278.87
B4 (2 kg bio-organic fertilizer + 6 kg NPK compound fertilizer)	212.40	259.20	281.87
B5 (4 kg bio-organic fertilizer + 3 kg NPK compound fertilizer)	218.47	257.53	284.52
B6 (4 kg bio-organic fertilizer + 6 kg NPK compound fertilizer)	219.20	266.87	293.33
B7 (60 kg organic manure + 3 kg NPK compound fertilizer)	221.73	258.40	278.60
B8 (60 kg organic manure + 6 kg NPK compound fertilizer)	215.87	262.87	283.87
B9 (plantation standard fertilizer: 6 kg NPK compound fertilizer)	219.87	262.87	297.00
Probability	0.84	0.25	0.24

Notes : MAP: Month After Planting.

Table 2 showed that standard rate of NPK compound fertilizer (6 kg) indicated no significant difference of stem girth compared to combination of bio-organic fertilizer, or organic manure and and NPK compound fertilizer. Study reported by [10] showed that reduction of NPK single fertilizer rate resulted the same similar stem girth compared to the treatment of 100% N, P, K single fertilizer.

3.2 Plant Physiology

3.2.1 Greenness of leaves and Stomata Density

The effect of the rate combination of bio-organic and NPK compound fertilizers on the greenness of leaves and stomata density at 42 and 48 MAP is presented in Table 3.

Table 3: The effect of the rate combination of bio-organic and NPK compound fertilizers on the greenness of leaves and stomata density

Rate combination of fertilizers	Greenness of leaves		Stomata density (mm^{-2})	
	42 MAP	48 MAP	42 MAP	48 MAP
B1 (1 kg bio-organic fertilizer + 3 kg NPK compound fertilizer)	75.17	73.01	187.40	203.26
B2 (1 kg bio-organic fertilizer + 6 kg NPK compound fertilizer)	73.68	73.23	215.15	221.12
B3 (2 kg bio-organic fertilizer + 3 kg NPK compound fertilizer)	73.97	72.70	211.18	223.69
B4 (2 kg bio-organic fertilizer + 6 kg NPK compound fertilizer)	75.32	72.51	192.50	226.24
B5 (4 kg bio-organic fertilizer + 3 kg NPK compound fertilizer)	72.95	71.98	209.48	221.74
B6 (4 kg bio-organic fertilizer + 6 kg NPK compound fertilizer)	75.85	73.88	197.59	228.03
B7 (60 kg organic manure + 3 kg NPK compound fertilizer)	74.61	71.49	196.46	212.99
B8 (60 kg organic manure + 6 kg NPK compound fertilizer)	74.35	73.45	203.26	210.45
B9 (plantation standard fertilizer: 6 kg NPK compound fertilizer)	75.21	72.95	199.29	211.80
Probability	0.48	0.80	0.73	0.61

Notes : MAP: month after planting.

The combined treatment of bio-organic and NPK compound fertilizers on the greenness of leaves and stomata density did not significantly affect at 42 and 48 MAP (Table 3). Treatment B6 showed that the highest average of leaf greenness at 42 and 48 MAP. The result of [18] indicated that the high of leaf grenness degrees had a correlation with the high chlorophyll content in plants. Nitrogen is an essential elemen for chloroplast formation [19] The chlorophyll concentration is influeced by the absorption of the nitrogen and magnesium that play an important role in chlorophyll synthesis [20].

The effect of the rate combination of bio-organic and NPK compound fertilizers on stomata density showed no significant effect on 42 and 48 MAP. The treatment of organic and NPK compound fertilizers had no significant effect on stomata density, it is because that stomata density is more influenced by temperature factors, light intensity and crop adaptation to the environment [8]. Stomata of oil palm leaves were classified as semi-xeromorphic structures that are able to adapt to long dry periods [21]. Factors of light intensity, temperature, and air pressure play a role important to control the opening of stomata as well as the amount of exchange of CO_2 and H_2O in leaves [22].

3.2.2 Nutrient content of plant tissues (N, P, K) on frond 17

Application of bio-organic fertilizer and NPK compound fertilizer did not significantly affect on N, P, K content in the leaf at 48 MAP (Table 4). The results indicated that N and K content was not at optimum level while P content was at optimum level [23]. The optimum level of N, P, K leaf content for immature oil palm plants (less than 6 years old) is situated 2.6-2.9% (N), 0.16-0.19% (P), and 1.1- 1.3% (K). The effect of the rate combination of bio-organic and NPK compound fertilizers on N, P, K leaf content at 48 MAP is presented in Table 4.

Table 4: The effect of the rate combination of bio-organic and NPK compound fertilizer on nutrient content of plant tissues (N, P, K) on frond 17 at 48 MAP

Rate combination of fertilizers	Nutrient content of plant tissues (N, P, K) 48 MAP		
	N (%)	P (%)	K (%)
B1 (1 kg bio-organic fertilizer + 3 kg NPK compound fertilizer)	2.37	0.15	0.76
B2 (1 kg bio-organic fertilizer + 6 kg NPK compound fertilizer)	2.48	0.16	0.87
B3 (2 kg bio-organic fertilizer + 3 kg NPK compound fertilizer)	2.34	0.16	0.75
B4 (2 kg bio-organic fertilizer + 6 kg NPK compound fertilizer)	2.37	0.17	0.73
B5 (4 kg bio-organic fertilizer + 3 kg NPK compound fertilizer)	2.29	0.16	0.75
B6 (4 kg bio-organic fertilizer + 6 kg NPK compound fertilizer)	2.39	0.17	0.77
B7 (60 kg organic manure + 3 kg NPK compound fertilizer)	2.29	0.16	0.74
B8 (60 kg organic manure + 6 kg NPK compound fertilizer)	2.50	0.17	0.75
B9 (plantation standard fertilizer: 6 kg NPK compound fertilizer)	2.50	0.15	0.81
Probability	0.20	0.29	0.93

Notes : MAP: month after planting.

3.3 Plant Production

The effect of the rate combination of bio-organic and NPK compound fertilizer on production component is presented in Table 5.

Table 5: The effect of the rate combination of bio-organic and NPK compound fertilizer on production component

Rate combination of fertilizers	Production component			
	Production number of bunches	Number of FFB	Average weight of the FFB (kg FFB^{-1})	Productivity (ton FFB ha^{-1} $year^{-1}$)
B1	13.04 b	10.12 d	8.43	11.63 d
B2	26.29 a	23.40 a	6.91	21.75 a
B3	15.25 b	13.68 bcd	6.79	12.19 d
B4	14.53 b	13.36 cd	8.11	14.90 bcd
B5	23.43 a	19.60 abc	7.51	20.39 abc
B6	22.60 a	19.60 abc	7.73	20.72 ab
B7	14.99 b	14.16 bcd	8.25	15.96 abcd
B8	21.99 a	20.47 ab	7.13	19.55 abc
B9	15.45 b	13.80 bcd	7.40	13.99 cd
Probability	0.0007	0.004	0.59	0.01

Notes : the number in the same column followed by the same letter are not significantly different at the 5% level (Duncan's multiple range test). B1: 1 kg bio-organic + 3 kg NPK compound fertilizer, B2: 1 kg bio-organic + 6 kg NPK compound fertilizer, B3: 2 kg bio-organic + 3 kg NPK compound fertilizer, B4: 2 kg bio-organic + 6 kg NPK compound fertilizer, B5: 4 kg bio-organic + 3 kg NPK compound fertilizer, B6: 4 kg bio-organic + 6 kg NPK compound fertilizer, B7: 60 kg organic manure + 3 kg NPK compound fertilizer, B8: 60 kg organic manure + 6 kg NPK compound fertilizer, B9: plantation standard fertilizer (6 kg NPK compound fertilizer). FFB: Fresh Fruit Bunches.

Table 5 showed that application of bio-organic fertilizer and NPK compound fertilizer increase the production number of bunches, the number of FFB, and plant productivity. The highest production bunches number was to B2, B5, B6 and B8 application, respectively. Although B2 resulted in the highest production, it was not significant different with B5, B6, and B8. The average weight of the FFB ranged from 6.79 to 8.43 kg FFB^{-1}. Application B2 (1 kg bio-organic fertilizer + 6 kg NPK compound fertilizer) showed the highest FFB productivity. However, application of bio-organic fertilizer led to reduction of NPK compound fertilizer rate, the highest productivity was obtained with B5 (4 kg bio-organic fertilizer + 3 kg NPK compound fertilizer) application. This result showed that combination of bio-organic and NPK compound fertilizer can for reduction 50% of NPK compound fertilizer.

Inorganic fertilizer is able to directly provide nutrients that can be absorbed by plants, while presence of microbes in bio-organic fertilizer is able to improve the ability of nutrients especially for macro elements (N, P, K) in the soil. The microbes can fix bind N_2 in the air, and promote availability of P and K. Inorganic fertilizer may release nutrients quickly to improve plant growth [24]. Application of soil organic matter can increase soil macro and micro nutrients [25].

Bio-organic fertilizers contain microbes as *Azotobacter*, *Azospirillum*, *Mycorrhiza*, *Bacillus*, and *Tricoderma*, enabling to enhance the availability of macro and micro nutrients required by plants. *Azotobacter* is recognized as nitrogen-fixing bacteria for plants. Microbes can improve plant nutrient up take, so increase the efficiency of inorganic fertilizers [26]. The application of organic matters affects the development of soil biological populations. Increasing soil biological activity promotes the improvement of soil fertility including physical, chemical and biological characteristics. These soil improvements are beneficial for enhancement plant growth and production [27].

3.4 Relative Agronomic Effectiveness

Relative agronomic effectiveness (RAE) was calculated by comparing the increasing of yields resulted from the combination of fertilizers with the increasing of yields resulted from recommended fertilizer multiplied by 100% [28]. In this research, recommended fertilizer treatment was B9, while B1 was used as control. Bio-organic fertilizer was considered as "effective" agronomically, if had RAE value greater than 100%.

Table 6: Relative agronomic effectiveness

Rate combination of fertilizers	Productivity (ton FFB ha^{-1} $year^{-1}$)	Relative agronomic effectiveness (%)
B1	-	-
B2	21.75	428.81
B3	12.19	23.73
B4	14.90	138.56
B5	20.39	371.19
B6	20.72	385.17
B7	15.96	183.47
B8	19.55	335.59
B9	-	-

Notes : B1: 1 kg bio-organic + 3 kg NPK compound fertilizer, B2: 1 kg bio-organic + 6 kg NPK compound fertilizer, B3: 2 kg bio-organic + 3 kg NPK compound fertilizer, B4: 2 kg bio-organic + 6 kg NPK compound fertilizer, B5: 4 kg bio-organic + 3 kg NPK compound fertilizer, B6: 4 kg bio-organic + 6 kg NPK compound fertilizer, B7: 60 kg organic manure + 3 kg NPK compound fertilizer, B8: 60 kg organic manure + 6 kg NPK compound fertilizer, B9: plantation standard fertilizer (6 kg NPK compound fertilizer). FFB: Fresh Fruit Bunches.

Table 6 showed that application of 1 kg bio-organic fertilizer + 6 kg NPK compound fertilizers $plant^{-1}year^{-1}$indicated the highest RAE value in term of productivity (428.81%). The effectiveness of NPK compound fertilizer can occur because of the application of organic fertilizers that able to absorb nutrients which comes from NPK compound fertilizer, so the nutrients can not lost and can be used by plants [29].

4. CONCLUSION

Combination application of bio-organic fertilizers and NPK compound fertilizers increased plant height, production number of bunches, number of fresh fruit bunches (FFB) and productivity. Combination fertilizer resulted the highest productivity was the treatment of 1 kg of bio-organic fertilizer + 6 kg of NPK compound fertilizer. Application of 4 kg bio-organic fertilizer can reduce 50 % NPK compound fertilizer with productivity 20.39 ton of fresh fruit bunches ha^{-1} $year^{-1}$.

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