Optimization Rate of Organic and NPK Compound Fertilizers on Second Year Immature Oil Palm

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ABSTRACT---- ***Oil palm is a potential vegetable oil producer and its productivity needs to increase. This experiment aimed to determine the optimum rate of organic and NPK compound fertilizer on second year immature oil palm. Morphological and physiological observation yearly found the optimization rate. Organic fertilizer did not affect plant height, trunk girth, leaf area, NAR, chlorophyll, and N, P, K leaf content significantly. NPK fertilizer affected plant height, trunk girth, leaf area, NAR, chlorophyll, and N, P, K leaf content significantly. The optimization rate for second year immature palm oil is 3.52 kg NPK compound fertilizer plant^{-1} year^{-1} and optimization rate for organic fertilizer could not be determined in this experiment.***

Keywords--- cow manure, nutrient level, vegetative growth

1. INTRODUCTION

Palm oil is a potential plant and has high economic value. In 2014, world consumption of vegetable oils increased 8.4 times compared to 1980. World consumption of vegetable oil in 2014 was 151.6 billion tons. Palm oil occupies the largest edible oil consumption 41% and outperformed dominance soybean oil (GAPKI, 2014).

Indonesian palm oil productivity is only 3-4 tons ha^{-1}, while the productivity potential can reach up to 6 tons of Crude Palm Oil (CPO) (Goenadi, 2008). Oil palm national productivity is low caused by low productivity of smallholder plantations. According to World Growth (2011), 41% of Indonesia's oil palm plantations owned by smallholder. The lack of knowledge in oil palm cultivation techniques is the reason of low productivity. Compound fertilizer usage is more practical in application and labor-saving appropriate to be applied in smallholder agriculture. Application of compound fertilizers generally showed better results than the standard single fertilizer application (PTPN III, 2007).

Fertilization is an important aspect when palm oil being cultivated on soils with low physical and chemical fertility. Proper fertilization will support the productivity of oil palm hybrids which are generally very responsive to fertilization (Hakim, 2007). However, fertilization is required the greatest cost in the cultivation of oil palm. Fertilization requires 40% - 60% of maintenance cost, or about 20% of the total cost of production (Waluyo *et al*. 2012). The aim of fertilization optimization is to decrease production costs. The principle of optimization is fertilizer application in accordance with the target result to be achieved and still maintaining soil fertility status. Fertilization aspects need to be considered since the immature period. During this period, palm requires more intensive maintenance. In addition, Better growth during the immature period will accelerate and increase production in the mature period (Santoso and Widiastuti, 2011).

This experiment is a sequel research which based on previous research conducted by Siallagan *et al.* (2014). Siallagan *et al.* (2014), found that the interaction of cow manure and NPK compound in the first year oil palm has a significant effect on the trunk girth, plant height and leaf nitrogen and phosphorus levels. The optimum rate for first year immature oil palm was 1.9 kg NPK compound and 40.7 kg organic fertilizer plant^{-1} year^{-1}. This experiment aimed to determine the optimum rate of organic fertilizer and compound NPK fertilizer on second year immature oil palm.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted at IPB-Cargill Oil palm Teaching Farm, Jonggol, Bogor, West Java - Indonesia, with

located 115 m above sea level. The experiment was conducted from March 2014 to March 2015. Analysis of soil, fertilizer and plant tissue was performed at the Laboratory of Soil Fertility, Department of Soil Sciences and Land Resources IPB Bogor.

2.2 Experimental Design and treatment

The Experiment used factorial design in complete randomized block design with three replications. The treatment consists of two factors: the organic fertilizer with 4 levels, and the NPK compound with 5 levels. Treatment with organic fertilizers consists of 0, 25, 50 and 75 kg organic fertilizer plant^{-1} year^{-1}. NPK compound fertilizer consists of 0, 1.2, 2.4, 3.6 and 4.8 kg NPK compound fertilizer plant^{-1} year^{-1}. Each experimental unit consisted of 5 plants, so there were 300 plant samples.

2.3 Experimental Procedure

The organic and NPK compound fertilizer treatment were given twice, at 14 and 20 months. Method of application is scattered around the disk. Every application used a half of the total dose of treatment.

2.4 Data collection

Morphological parameters observed every 2 months from March 2014 to March 2015. Morphological parameters observed were plant height, trunk girth, and the ninth leaf area. Physiological parameters observed on October 2014 and March 2015. Chlorophyll was measured by SPAD-502 and converted by Farhana *et al*. (2007). Net photosynthetic rate observed using Li 6400, USA.

2.5 Data analysis

The data was analyzed by analysis of variance. If the analysis variance test results was significant at 5%, then it continued to be analyzed by orthogonal polynomial contrasts test.

3. RESULT AND DISSCUSSION

3.1 Plant height

Plant height response of oil palm in treatment of organic fertilizer and NPK compound is presented in Table 1. The treatment of organic fertilizer and its interaction with NPK compound did not significant during the observation. Treatment of compound NPK fertilizer was highly significant quadratic on 12-24 months.

Table 1 : Height plant response of oil palm on organic fertilizer and NPK compound.

Dose of fertilizer (kg plant^{-1})	Age of the plant (months)						
	12	**14**	**16**	**18**	**20**	**22**	**24**
	……. (cm) …….						
Organic							
0	275.0	305.0	339.4	371.2	385.9	414.1	441.5
25	268.7	299.9	337.3	371.1	386.3	413.1	439.8
50	271.1	288.4	333.9	373.9	391.1	414.4	441.9
75	279.1	302.2	337.6	368.6	382.0	410.7	446.9
Pr	0.5172	0.7718	0.9833	0.9854	0.9330	0.9938	0.9664
Response	ns	ns	ns	ns	ns	ns	ns
Response Pattern	-	-	-	-	-	-	-
NPK Compound							
0	252.8	244.5	290.7	333.1	352.5	372.1	391.3
1.2	275.6	310.4	342.7	373.1	387.3	405.3	437.2
2.4	278.2	313.2	350.4	384.9	400.8	433.0	464.1
3.6	277.4	310.8	349.1	382.9	397.6	426.0	459.4
4.8	283.5	315.4	352.2	382.0	393.4	429.0	460.6
Pr	0.0051	0.0019	0.0012	0.0080	0.0260	0.0025	0.0002
Response	**	**	**	**	*	**	**
Response Pattern	Q*	Q*	Q*	Q*	Q*	Q*	Q*

Remarks : *: Significantly different at 5%; **: Significantly different at 1%; Pr: Probability; L: linier; Q: Quadratic; ns: not significant

Application of organic did not affect plant height of second year immature oil palm. In the first year, Sudradjat *et al.* (2014) had same report that application of up to 30 kg plant^{-1} year^{-1} did not affect the growth. Application of organic fertilizer is beneficial for long-term production the due to slow release nature of the nutrients (Ermadani and Muzar, 2011).

NPK compound fertilizer increased the growth of palm oil to the optimum limit. Growth increases due to higher nutrient of NPK fertilizer treatment. One of them is caused by the availability of potassium fertilizer better than the control. Magen (2008) mentioned that the state of potassium limitation in the long term will cause damage to soil fertility, which leads to stagnation, and decline in production.

3.2 Trunk girth

The palm trunk girth response on organic fertilizer and NPK compound fertilizer treatment can be seen in Table 2. The treatment of organic fertilizer and its interaction with NPK compound did not significant during observation. Treatment of compound NPK fertilizer was highly significant linearly on 12, 18, 20, 22 and quadratic on 14, 16 and 24 months.

Table 2 : Trunk girth response of oil palm on organic and NPK compound fertilizer treatments

Dose of fertilizer (kg plant^{-1})	Age of the plant (months)						
	12	**14**	**16**	**18**	**20**	**22**	**24**
	..... (cm)						
Organic							
0	78.3	109.3	131.3	151.6	160.4	167.1	203.9
25	77.3	109.3	130.0	150.6	161.3	170.2	200.9
50	79.2	113.1	133.9	153.6	163.0	173.7	210.0
75	78.5	115.1	138.6	161.2	172.0	184.4	219.4
Pr	0.9681	0.3317	0.2786	0.3518	0.3939	0.1415	0.0979
Response	ns	ns	ns	ns	ns	ns	ns
Response Pattern	-	-	-	-	-	-	-
NPK Compound							
0	66.0	96.0	114.8	134.3	144.4	154.5	183.3
1.2	78.9	111.8	134.0	152.7	160.2	168.7	203.4
2.4	80.6	116.8	140.3	161.1	170.9	178.8	216.5
3.6	81.4	115.9	138.6	159.4	169.0	179.6	219.5
4.8	84.8	117.9	138.6	163.7	176.6	187.8	220.1
Pr	0.0011	<0.0001	<0.0001	0.0014	0.0044	0.0051	0.0004
Response	**	**	**	**	**	**	**
Response Pattern	L*	Q*	Q*	L*	L*	L*	Q*

Remarks : *: Significantly different at 5%; **: Significantly different at 1%; Pr: Probability; L: linier; Q: Quadratic; ns: not significant

Based on data, it is known that organic fertilizer increases the growth of oil palm trunk girth. Organic fertilizer in a certain amount of plant growth can even compete with inorganic fertilizer. Based on Uwumarongie et al. (2012) research, the organic fertilizer on oil palm seedlings showed strong vegetative growth, high chlorophyll and nitrogen content. This is demonstrated by the high seed, the girth and leaf area were higher compared with inorganic fertilizer treatment (NPKMg).

3.3 Leaf Area

Organic fertilizer significantly linearly on 16 and 18 Months against leaf area (Table 5). NPK compound significantly linearly on 16 and 18 Months and quadratic at 24 Months against leaf area. The interaction between organic and NPK compound fertilizer was highly significant on 16 and 18 months.

NPK compound treatment increasing ninth leaf area. This is due to better availability of nitrogen to the optimum point. The decline in leaf area occurred at the highest dose as a symptom of excessive fertilization. Nitrogen affects leaf area, leaf color, leaf production and net assimilation number of plants. According to Uexküll and Fairhurst (1991), the nitrogen response is more noticeable in young oil palm plants with LAI under 5. The response to nitrogen is hard to observed on old oil palm plants (LAI> 6), due to the competition of light, so the response to this nitrogen would be difficult to see.

Table 3 : Leaf area response of oil palm on organic fertilizer and NPK compound treatments.

Dose of fertilizer (kg plant^{-1})	Age of the plant (months)						
	12	**14**	**16**	**18**	**20**	**22**	**24**
	…… (m^2) ……						
Organic							
0	1.18	1.54	1.63	1.74	1.58	1.62	2.18
25	1.07	1.45	1.65	1.75	1.62	1.72	2.09
50	1.07	1.57	1.63	1.83	1.72	1.81	2.25
75	1.16	1.64	1.97	2.08	1.64	1.88	2.48
Pr	0.3696	0.3603	0.0317	0.0317	0.6905	0.1154	0.0018
Response	ns	ns	*	*	ns	ns	**
Response Pattern	-	-	L*	L*	-	-	L*
NPK Compound							
0	0.96	1.39	1.47	1.61	1.51	1.68	1.93
1.2	0.12	1.55	1.69	1.82	1.66	1.71	2.15
2.4	0.18	1.66	1.73	1.86	1.70	1.89	2.40
3.6	0.15	1.54	1.97	2.10	1.63	1.71	2.43
4.8	1.19	1.60	1.74	1.85	1.71	1.81	2.34
Pr	0.0923	0.2344	0.0336	0.0250	0.5378	0.4091	0.0018
Response	ns	ns	*	*	ns	ns	**
Response Pattern	-	-	L*	L*	-	-	Q*

Remarks : *: Significantly different at 5%; **: Significantly different at 1%; Pr: Probability; L: linier; Q: Quadratic; ns: not significant

3.4 Leaf Chlorophyll and Nutrient Content

Organic fertilizers and interaction with NPK compound did not significantly affect leaf chlorophyll content but compound NPK fertilizer treatment significantly linearly with palm leaf chlorophyll content on 24 months (Table 4).

Plant tissue nutrient levels describe nutrient contained in the plant tissue, to indicate the level of adequacy, deficiency and excess nutrients. Analysis was performed on leaf tissue (leaflets) of palm oil on the entire treatment. Application of organic manure and NPK compound on levels of N and P leaf can be seen in Table 4. Interaction of organic manure and NPK compound significant effect on 18 and 24 months but there is interaction on P level of 24 months leaf.

The results of the analysis indicated that leaf tissue nutrient concentrations on the growth of the network is in a quite zone when compared to the nutrient status of the critical nutrient levels in immature amounted to 2.50% N (Ollagnier and Ochs 1981). Based on the analysis in Table 4, only the highest dose of NPK passing the critical limit N. This shows that there is deficiency in the palm with a lower fertilization rate.

The optimum value of P concentration in leaves of palm oil is 0.165% (Foster et al. 1988). Leaf P content analysis results in Table 4 is almost entirely under the optimum concentration. This shows that the rate of fertilization with lower doses causes a deficiency of phosphorus that has not been seen directly. According to Rankine and Fairhurst (1999), it is not easy to recognizable leaf P deficiency symptoms in oil palm. However, P deficient plants may be stunted with short fronds, and the palm trunk may have a pronounced pyramid shape.

Table 4: Levels of chlorophyll and nutrient content of N, P, K oil palm leaves on organic fertilizer treatment and NPK compound

Dose of Fertilizer (kg plant^{-1})	Age of the plant (months)							
	18				24			
	chl	N	P	K	chl	N	P	K
	..... (%)							
Organic (kg plant^{-1})								
0	0.045	2.147	0.154	0.572	0.042	2.467	0.175	1.032
25	0.043	2.473	0.157	0.789	0.043	2.738	0.191	1.051
50	0.045	2.343	0.161	0.797	0.042	2.746	0.188	1.089
75	0.043	2.378	0.162	0.764	0.043	2.817	0.198	1.056
Pr	0.6404	0.0380	0.0872	0.0113	0.4805	0.027	<0.0001	0.9137
Response	ns	*	ns	*	ns	*	**	tn
Response Pattern	-	Q*	-	Q*	-	L*	L*	-
NPK Compound (kg plant^{-1})								
0	0.046	2.087	0.146	0.743	0.040	2.428	0.174	1.114
1.2	0.041	2.301	0.155	0.741	0.041	2.716	0.184	1.005
2.4	0.043	2.388	0.162	0.713	0.043	2.759	0.191	1.010
3.6	0.438	2.404	0.163	0.703	0.043	2.736	0.194	1.039
4.8	0.454	2.495	0.168	0.753	0.045	2.821	0.198	1.118
Pr	0.2703	0.0241	<0,0001	0.9689	0.0003	0.0046	<0.0001	0.5737
Response	ns	*	**	ns	**	**	**	ns
Response Pattern	-	L*	L*	-	L*	L*	Q*	-
Interaction								
Pr	0.635	0.3175	0.116	0.7819	0.798	0.7509	0.032	0.3658
Response	ns	ns	ns	ns	ns	ns	*	ns

Remarks : *: Significantly different at 5%; **: Significantly different at 1%; Pr: Probability; L: linier; Q: Quadratic; ns: not significant

The content of potassium in the palm leaves with various treatments has a fairly high diversity. This is because K is a mobile element and was not present in the complex structure of the plant body. The content of potassium in the plant also depends on the total cation concentration of leaves, plant age, soil moisture, and plant spacing. According to Teoh and Chew (1988), the measurement of potassium content should be performed on the midrib tissue because it is more sensitive and shows the status of K in the leaves.

3.5 Net assimilation rate

The response variables photosynthetic rate of oil palm on the treatment of organic fertilizer and NPK compound fertilizer can be seen in Table 5. Treatment of organic fertilizer and its interaction with NPK compound had no significant effect on the rate of photosynthesis. However, the NPK compound significant effect on the rate of photosynthesis is quadratic. This was due to differences in leaf area and nitrogen fertilization. At the highest dose, there was a decrease in the rate of photosynthesis due to reduced leaf area. Nitrogen fertilization that is too high causes growth restriction leaf area.

Table 5 : Net assimilation rate of oil palm on organic fertilizers and NPK compound

Dose of fertilizer (kg plant^{-1})	Net assimilation rate (μmol CO_2 m^{-2} s^{-1})
Organic	
0	15.412
25	15.172
50	15.424
75	15.470
Pr	0.7743
Response	ns
Response Pattern	-
NPK Compound	
0	13.461
1.2	15.841
2.4	15.900
3.6	15.773
4.8	15.873
Pr	<0.0001
Response	**
Response Pattern	Q*

Remarks : *: Significantly different at 5%; **: Significantly different at 1%; Pr: Probability; L: linier; Q: Quadratic; ns: not significant

NPK fertilization treatment is better than the control. This is due to the presence of nitrogen content more on treatment with NPK compound. According to Corley and Mok (1972), the application of nitrogen will increase the number of leaves and net assimilation palm. The increase in net assimilation is due to the increase in leaf area index which occurs in young oil palm. Increased leaf area index will directly increase the net assimilation and biomass production.

3.6 Optimization Rate

Optimization rate of NPK compound treatment presented in Table 6. Optimization results can be used as a tool to determine basic fertilization rate. Optimum rate determined by response curve regression equation with quadratic pattern (Ramadhaini *et al.* 2014). Optimization obtained from average of all quadratic parameters, i.e. plant height, trunk girth, leaf area, and net assimilation rate. The organic fertilizer could not be optimized, because the response is linier. The optimize rate of NPK compound is 3.52 kg plant^{-1} year^{-1}.

Table 6 : Optimization rate in the treatment of NPK compound fertilizer

Parameters	Age (months)	Function	Optimize rate (kg plant^{-1} year^{-1})
Plant height	12	$y = -1.818N^2 + 14.00N + 255.5$	3.85
	14	$y = -6.342N^2 + 42.30N + 252.1$	3.33
	16	$y = -5.297N^2 + 36.21N + 295.8$	3.42
	18	$y = -4.736N^2 + 31.70N + 336.0$	3.62
	20	$y = -4.698N^2 + 30.23N + 354.3$	3.22
	22	$y = -4.705N^2 + 33.80N + 372.6$	3.59
	24	$y = -5.999N^2 + 42.19N + 393.1$	3.52
Trunk girth	14	$y = -1.666N^2 + 11.97N + 97.34$	3.59
	16	$y = -2.295N^2 + 15.35N + 116.2$	3.34
	24	$y = -2.433N^2 + 19.16N + 183.5$	3.94
Leaf Area	24	$y = -0.041N^2 + 0.292N + 1.91$	3.56
NAR	18	$y = -0.235N^2 + 1.527N + 13.74$	3.25
Average			**3.52 ± 0.29**

4. CONCLUTION

Organic fertilizer did not affect plant height, trunk girth, leaf area, NAR, chlorophyll, and N, P, K leaf content significantly. NPK fertilizer affected plant height, trunk girth, leaf area, NAR, chlorophyll, and N, P, K leaf content significantly. The optimization rate for second year immature palm oil is 3.52 kg NPK compound fertilizer plant^{-1} year^{-1} and optimization rate for organic fertilizer could not be determined in this experiment.

5. ACKNOWLEDGEMENT

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