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Influence of Manure, Nitrogen, Phosphorus and Potassium Fertilizer Application on Growth of One-year-old Oil Palms on Marginal Soil in Jonggol, Bogor, Indonesia.

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Abstract

The oil palms (*Elaeis guineensis* Jacq.) are highly efficient oil producers. It produces five to seven times more vegetable oil per hectare than soybean, sunflower, and rapeseed. The objectives of this research were to study the role of organic and N, P, and K fertilizers on growth of one-year-old immature oil palm on marginal soil in Jonggol. The research was conducted at IPB Cargill Teaching Farm (ICTF) of Oil Palm, Jonggol, Bogor, West Java from March 2013 to March 2014. The experiment was arranged in a factorial experiment following a randomized block design with three replications. The first factor was organic fertilizer (manure) consisting of 0 (O), 15 (O1) and 30 (O2) kg per tree per year. The second factor was inorganic fertilizer consisting of 0 (S0); 0.25 kg N + 0.25 kg P_2O_5 + 0.39 kg K_2O (S1) and 0.50 kg N + 0.50 kg P_2O_5 + 0.78 kg K_2O (S2) per tree. The results demonstrated that application of manure up to 30 kg per tree per year did not affect the growth of one-year-old oil palm. Application of 0.50 kg N + 0.50 kg P_2O_5 + 0.78 kg K_2O per tree gave the highest result in increasing frond production, stem girth, and leaf nutrient concentration. The results of leaf analysis and plant growth responses suggested that the rates of manure and inorganic fertilizers applied in this study are not sufficient to improve young oil palm growth in marginal soil in Jonggol.

Keywords: cow manure, critical nutrient level, inorganic fertilizer, soil fertility, vegetative growth

Introduction

The oil palm (*Elaeis guineensis* Jacq.) which belongs to the Family Arecaceae is a highly efficient oil producer. The oil palm produces five to seven times more vegetable oil per hectare than soybean, sunflower, and rapeseed (Basiron and Weng, 2004; Obi and Udoh, 2012). Indonesia is the major oil palm producer in the world. The oil palm plantation in Indonesia has rapidly increased from four decades ago. The area of oil palm plantation in Indonesia has expanded exponentially from about 80,000 ha in 1965 to 9.8 million ha in 2012 and produce 23.5 million tonnes of crude palm oil (Directorate General of Estate Crops, 2013).

The demand for edible vegetable and palm oil has increased due to the increase of per capita consumption and population growth. The demand of palm oil is expected to double from present consumption of around 120 to 240 million tonnes by 2050 (Corley, 2009). If oil palm production does not expand to contribute to the increase of demand, it will result in a shortage of supply of palm oil. Production can be increased by area expansion and yield intensification in existing plantations. Yield improvement can be achieved by improvement of crop management. Increase in yield can reduce the amount of land expansion for palm oil production. The main issue that will occur in the future in expansion area is shifting the use of agricultural lands of fertile lands to marginal lands. Most of oil palms were planted in soil with poor fertility status (Ng et al., 2011; Obi and Udoh, 2012). Therefore application of organic and inorganic (synthetic) fertilizers are important to supply nutrients for the crops grown on this marginal soil.

Maximizing oil productivity of the oil palm through sound agricultural practices and providing balanced nutrition raised oil palm yields (Ng, 2001). Application of inorganic fertilizer provide plant nutrients that can not be supplied by the soil. Nitrogen fertilizer is one of the most expensive nutrient inputs in oil palm production (Amir et al. 2001). Therefore, it is very important to manage fertilizer application and use the nitrogen efficiently.

Organic fertilizer can improve the soil physical, chemical and biological properties such as improving water capacity, aeration, porosity, soil agregation, cation exchange capacity and microorganism activity in the soil (Yang et al., 2004; Leszczynska and Malina, 2011). Studies investigating the role of organic residues on young oil palm growth were conducted by Khalid (1999; 2000) in Malaysia. Organic fertilizer application was effective to increase growth of oil palm seedlings (Uwumarongie-Ilori et al., 2012, Ovie et al. 2014).

The objective of this research was to study the effect of manure and single element of N, P, and K fertilizer application on growth of one-year-old young oil palms on marginal soil in Jonggol.

Material and Methods

Experimental Site

The research was conducted at IPB-Cargill Teaching Farm located in Jonggol District, West Java, Indonesia (6.453144°S, 107.039198°E) from March 2013 to March 2014. Soil type in the research area is Ultisols with an altitude of ± 113 m above the sea level. The rainy season usually occurs between November and February and the dry season between June to September each year. Average rainfall in the research area was 302.6 mm per month with a total rainfall from March 2013 to March 2014 of 3,631 mm. Average air temperature was 28.8 °C and average relative humidity was 77.3%.

Materials

The study used oil palm Tenera var. Damimas. One-year-old plants were planted in December 2012 in 9.2 m x 9.2 m x 9.2 m triangular pattern with a population of 136 trees per hectare. Sixty kg of organic fertilizer in the form of decomposed cow manures, 500 g rock phosphate and 500 g dolomite were applied to each planting hole.

Experimental Design and Treatments

The experiment was arranged in a factorial experiment following a randomized block design with three replications. The first factor was organic fertilizer (cow manure) consisting of 0, 15, and 30 kg per tree per year, applied once in March 2013. The second factor was single element fertilizers consisting of 0 (S0), 0.25 kg N + 0.25 kg P_2O_5 + 0.39 kg K_2O (S1) and 0.50 kg N + 0.50 kg P_2O_5 + 0.78 kg K_2O (S2) per tree. The N, P, and K fertilizer treatment were applied three times, i.e. in March, June and December 2013. The soil analysis was conducted on the levels of total nitrogen, available P, exchangable K, bulk density and organic matter content.

Scoring was conducted monthly from March 2013 to March 2014 on frond production, stem girth and leaf area. Leaf chlorophyll and leaf nutrient concentration were measured at 6 and 12 month after treatment (MAT). The youngest fully expanded leaf on the top of the leaf crown was assigned as number 1, the next down as number 2, and so on (Legros et al., 2009). Leaf area was measured based on a measurement method developed by Hardon et al. (1969).

The effect of treatments were analyzed by ANOVA and further analysed using Duncan Multiple Range Test (DMRT) and considered significant at $P<0.05$.

Results and Discussion

The soil chemical and physical properties are presented in Table 1. Based on the soil criteria for oil palms, the soil

Table 1. Physical and chemical properties of Jonggol soil

Parameter	Value	Criteria*
pH: H_2O	5.00	low
KCl	4.30	low
Organic C (%)	1.83	low
Total N (%)	0.17	low
C/N	10.76	intermediate
Avaible P (ppm)	7.60	very low
Ca (me.100 g^{-1})	5.70	intermediate
Mg (me.100 g^{-1})	4.74	intermediate
K (me.100 g^{-1})	0.20	very low
Na (me.100 g^{-1})	0.23	low
Cation Exchange Capacity (me. 100 g^{-1})	21.59	intermediate
Base Saturation (%)	50.35	intermediate
Exchangeable Al (me.100 g^{-1})	3.45	-
Exchangeable H (me.100 g^{-1})	1.14	-
Texture: Sand (%)	24.65	
Silt (%)	49.43	loam
Clay (%)	25.92	

*Criteria by Indonesian Oil Palm Research Institute.

in Jonggol was acidic and low in organic matter. The soil total N, available P, and exchangable-K are low or very low, soil bulk density is 1.20 g cm^{-3} thus indicating poor soil fertility. Manure application had no significant effect on the vegetative growth of oil palm from the beginning to the end of the experiment.

Application of N, P, and K fertilizer significantly increased the growth of oil palm at five MAT onwards. Response of oil palm to fertilization was low for several months after transplanting, likely due to transplanting shock. It took time for the seedlings to build an effective root system (Goh and Hardter, 2003). Application of N, P, and K fertilizer at S2 level gave the highest results to improve the growth of one year-old young oil palm on marginal soil in Jonggol.

The Effect of Manure and Fertilizer Application on Palm Oil Vegetative Growth and Frond Production

Manure application did not significantly affect frond production, whereas N, P, and K fertilizer significantly increased frond production on 5 and 10 MAT (Table 2). The highest frond production was achieved by application of N, P, and K fertilizers at S1 and S2 level. N, P, and K fertilizers at S1 and S2 level increasing frond production 26.3-32.1% and 21.0-42.7%, respectively, compared to control. The effect of N, P, and K fertilizers were significant only at 5 and 10 MAT; this may be associated with time of fertilizer application. Application of single component N, P, and K fertilizers were conducted three times, i.e. in March 2013 (0 MAT), June 2013 (3 MAT) and December 2013 (9 MAT), so frond production shows a significant response to N, P, and K fertilizers at one to two months after application.

Frond production is also affected by climatic factors such as rainfall (Figure 1). Water is important for plants

Table 2. The effects of manure and N, P, K fertilizer application (S) on frond production

Treatment	Time (MAT)							
	1	3	5	7	9	10	11	12
	Frond production (frond.$month^{-1}$)							
Rates of Manure (kg.$tree^{-1}$)								
0 kg	0.80	1.60	1.82	0.36	2.18	1.44	2.27	2.69
15 kg	0.87	1.73	1.96	0.56	2.41	1.73	2.51	2.93
30 kg	0.76	1.76	2.02	0.36	2.34	1.73	2.40	2.98
N, P, K fertilizer (S)								
S0	0.78	1.62	1.67b	0.33	2.11	1.31b	2.35	2.89
S1	0.73	1.73	2.11a	0.40	2.32	1.73a	2.24	2.80
S2	0.91	1.73	2.02a	0.53	2.50	1.87a	2.58	2.91

Note:
-MAT = month after treatment;
-S0 = without application of N, P, K fertilizer
-S1 = application of 0.25 kg N + 0.25 kg P_2O_5 + 0.39 kg K_2O
-S2 = application of 0.50 kg N + 0.50 kg P_2O_5 + 0.78 kg K_2O
-Values followed by different letters within a column are significantly different at 95% DMRT

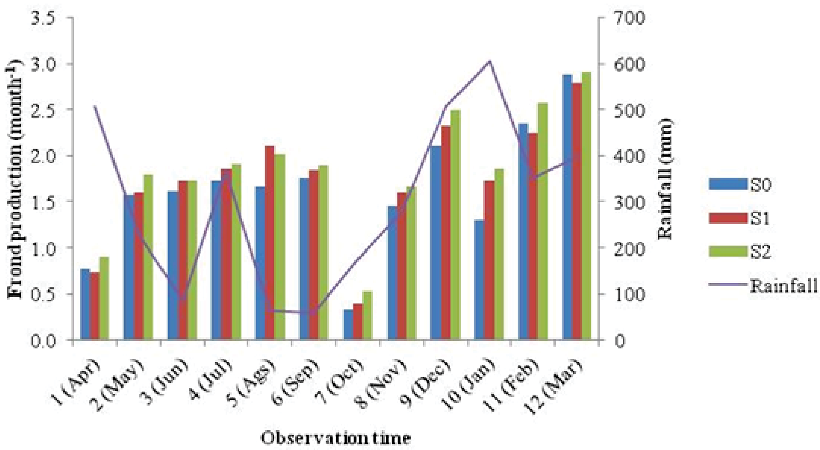

Figure 1. Effect of N, P, K fertilizer application and correlation with rainfall (mm) on frond production.

as raw material for photosynthesis, part of the plant cell, and solvent for the nutrients. Frond production in a month is influenced by rainfall one to two months earlier. Frond production ranged from 1.5 to 3 per months under sufficient rainfall (>100 mm per month) and can dramatically decrease to 0.5 per months or less under lower rainfall (<100 mm per month). However, based on observations in the field the plants still formed a few spears under low rainfall. When rainfall is sufficient the spears open sooner so that frond production increases to 2.5 per month (9 MAT, Table 2). The fewer frond production during dry season is probably related to the poor nutrients absorption by the plants. Water plays an important role in dissolving nutrients that can be absorbed by plant roots in the soil so that water shortages will disrupt nutrient uptake, which will result in a stunted plant growth.

An increasing rate of manure application up to 30 kg per plant per year tends to result in greatest increase of stem girth (Table 3). S2 treatment resulted in the highest growth of stem girth, i.e. 57.09 cm, but not significantly different with S1 treatment, i.e. 53.20 cm. The increase in stem girth due to S1 and S2 treatment were 11.9 % and 20.1%, respectively, compared to control at 12 DAT. Palm trunks serve as support structures of leaves, flowers, and fruit; vascular system that transports nutrients, water and assimilate; and as an organ accumulation of nutrients (Corley and Tinker, 2003). Oil palm trunks represent approximately 50% of the total above-ground biomass when the plants reach the age of 10 years (Corley and Tinker, 2003). The large stem girth will support high fruit production in the future. The increase in stem girth is influenced by the availability of N, P, and K collectively (Corley and Tinker, 2003). Nitrogen is a major constituent of amino acids, amides, proteins, and nucleotides, and plays a significant role in the formation of chlorophyll and increase vegetative growth (Rachman et al., 2008). Phosphorus plays role as molecular component of the energy transferor i.e. ATP, ADP, NAD and NADPH which are energy-rich compound that controls various reactions in plants such as photosynthesis, respiration, protein synthesis and amino acids, and nutrient transport (Booromand and Grough, 2012). Potassium plays role as an enzyme activator, maintaining osmotic potential and water uptake, photosynthesis, and assimilate translocation from leaf to sink (Taiz and Zeiger, 2010).

Application of manure and N, P, K fertilizer did not significantly increase leaf area (Table 3). Leaf area is one of the important variables for the growth of palm oil. Leaf area determines sunlight interception that affect the rate of photosynthesis (Hardon et al., 1969). The wider the leaf area, the higher the rate of photosynthesis is due to an increasing of the portion of leaves that capture sunlight.

Even though the effects were not significant, application of manure increased bulk density and soil C, N, P and K levels (Table 4). Similar results were reported by Uwumarongie-Ilori et al. (2012). Application of organic fertilizer is beneficial for long-term production due to the slow release nature of the nutrients (Ermadani and Muzar, 2011).

The Effect of Manure and Fertilizer Application on Leaf Stomatal Density, and Leaf N, P and K content

Manure and N, P, and K fertilizer application had no effect on leaf stomatal density (Table 5). Leaf stomatal density ranges from 198-211 mm^{-2}. For comparison, the

Table 3. Effects of manure and N, P, K fertilizer application (S) on stem girth and leaf area

Treatment	Time (MAT)							
	0	4	8	12	0	4	8	12
	Stem girth (cm)				Leaf area (m^2)			
Rates of Manure Application ($kg.tree^{-1}$)								
15 kg	23.79	30.02	39.61	53.13	0.32	0.86	0.71	1.29
30 kg	23.43	29.62	41.81	55.98	0.32	0.81	0.67	1.21
N, P, K fertilizer (S)								
S0	23.86	28.67	36.20b	47.53b	0.32	0.74	0.70	1.09
S1	23.71	29.63	40.52ab	53.20ab	0.34	0.83	0.63	1.21
S2	23.21	30.51	41.93a	57.09a	0.33	0.87	0.66	1.29

Note:
-MAT = month after treatment;
-S0 = without aplication of N, P, K fertilizer
-S1 = application of 0.25 kg N + 0.25 kg P_2O_5 + 0.39 kg K_2O
-S2 = application of 0.50 kg N + 0.50 kg P_2O_5 + 0.78 kg K_2O
-Values followed by different letters within a column are significantly different at 95% DMRT

average leaf stomatal density was 146 mm^{-2} in Nigeria and 175 mm^{-2} in Malaysia (Corley and Tinker, 2003). Average leaf stomatal density in this study was 201 mm^{-2} at 6 MAT and 208 mm^{-2} at 12 MAT.

Manure and N, P, and K fertilizer did not significantly affect leaf chlorophyll content (Table 5). Chlorophyll plays an important role in photosynthesis. Chlorophyll

Tabel 4. Effects of manure application on soil bulk density, soil organic C, soil total N, P and K

Rate of Manure Application ($kg.tree^{-1}$)	Bulk Density ($g\ cm^{-3}$)	Organic C (%)	Total N (%)	Total P (ppm)	Total K (ppm)
0	1.05	1.12	0.10	114.52	54.00
15	1.02	1.15	0.10	125.97	60.60
30	0.98	1.28	0.11	145.98	75.00

Table 5. Effects of manure and N, P, K fertilizer application (S) on leaf stomatal density and chlorophyll content

Treatment	Time (MAT)			
	6	12	6	12
	Stomatal density (mm^{-2})		Chlorophyll content ($mg.cm^{-2}$)	
Manure Manure ($kg.tree^{-1}$)				
0	199.08	208.90	0.032	0.042
15	206.07	207.20	0.036	0.042
30	198.52	208.62	0.035	0.042
N, P, K single fertilizer (S)				
S0	203.61	206.92	0.033	0.042
S1	198.14	206.92	0.034	0.041
S2	201.91	210.88	0.037	0.043

Note:
- -MAT = month after treatment;
- -S0 = without application of N, P, K fertilizer
- -S1 = application of 0.25 kg N + 0.25 kg P_2O_5 + 0.39 kg K_2O
- -S2 = application of 0.50 kg N + 0.50 kg P_2O_5 + 0.78 kg K_2O

Table 6. Effects of manure and N, P, K fertilizer application (S) on leaf nutrient concentration

Treatment	Time (MAT)					
	6			12		
	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
Manure ($kg.tree^{-1}$)						
0	2.64	0.20	1.11	2.14	0.19	0.84
15	2.56	0.20	1.17	2.12	0.19	0.88
30	2.67	0.20	1.31	2.26	0.20	0.89
N, P, K single fertilizer (S)						
S0	2.35	0.19	1.09b	2.03b	0.19	0.80b
S1	2.73	0.20	1.20ab	2.15b	0.20	0.86b
S2	2.79	0.20	1.31a	2.33a	0.20	0.95a

Note:
- -MAT = month after treatment;
- -S0= without application of N, P, K fertilizer
- -S1 = application of 0.25 kg N + 0.25 kg P_2O_5 + 0.39 kg K_2O
- -S2 = application of 0.50 kg N + 0.50 kg P_2O_5 + 0.78 kg K_2O
- -Values followed by different letters within a column are significantly different at 95% DMRT

absorbs light and pass it to the reaction center of photosystem (Karacan, 2006). Chlorophyll content in this study ranged from 0.032 to 0.043 $mg.cm^{-2}$.

Leaf analysis showed that manure application had no significant effect on leaf N, P and K content (Table 6). N, P, and K fertilizer only affected the leaf N at 12 MAT, and leaf K at 6 and 12 MAT, but did not affect leaf P contents (Table 6). Application of N, P, and K fertilizer at S2 level resulted in the highest the increased of leaf N and K contents. Critical nutrient levels in the leaves of young oil palms according to Ochs and Olivin (1977) are 2.75% for N, 0.16% for P and 1.25% for K. S2 treatment resulted in leaf N and K contents above the critical nutrients levels on 6 MAT. Leaf P content in this study was not significantly affected by manure and inorganic fertilizers treatment and the level is classified as sufficient according to Ochs and Olivin (1977). The results of leaf analysis and plant growth responses suggested that rate of organic and inorganic fertilizers applied in this study are not sufficient to improve young oil palm growth in marginal soil. High rate of fertilizer application is usually recommended for marginal soils and soil with low fertility (Vanlauwe et al., 2001; Ng et al., 2011).

Conclusions

Application of manure up to 30 kg per tree per year did not affect the growth of one-year-old oil palm. Application of 0.50 kg N + 0.50 kg P_2O_5 + 0.78 kg K_2O per tree gave the highest increase in frond production, stem girth, and leaf nutrient concentration. Application of manure, N, P, and K fertilizer in this study did not affect leaf stomatal density, leaf chlorophyll and leaf N, P, and K content.

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