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Optimization of N, P, and K Single Fertilizer Package for Oil Palm Aged Four Years

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Abstract

Fertilizer is one of the main sources of nutrients given for oil palm. High plant productivity in oil palm plantations can not be separated from the role of good fertilization. The goal of this research was to study the effect of N, P, K and to determine the optimum rate of N, P, K single fertilizer package on growth and production of four years of oil palm. This research was conducted from April 2016 to march 2017 at IPB-Cargill Teaching Farm of Oil Palm, Jonggol, Bogor, West Java. The experiment was arranged in a randomized block design with one factor and three replications. The fertilizer treatments were four packages, they were: control (P0), fertilizer package of 1500 g urea + 1000 g SP-36 + 1500 g KCl + 50 g borat + 50 g $CuSO_4.5H_2O$ each plant (P1), fertilizer fackage of 3000 g urea + 2000 g SP-36 + 3000 g KCl + 50 g borat + 50 g $CuSO_4.5H_2O$ each plant (P2), fertilizer package of 4500 g urea + 3000 g SP-36 + 4500 g KCl + 50 g borat + 50 g $CuSO_4.5H_2O$ each plant (P3).

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The result showed that the increasing of application rate of N, P, and K single fertilizer package linearly and significantly increased plant height, stem girth, yield of bunches, number and weight of fresh fruit bunches (FFB), stomatal density, and leaf nutrient content B but did not significantly affect to leaf area of frond 17, length of midrib, leaf greeness, and average weight at FFB. So that optimum rate of N, P, and K single fertilizer package has not yet been determined.

Keywords: inorganic fertilizer; recommendation; vegetative growth.

1. Introduction

Fertilization is one of the largest maintenance cost components in oil palm crops. One of the major problems in oil palm plantation management is determining the optimum dosage of fertilizer and the type of fertilizer [1]. Oil palm plants need nutrients in large quantities to achieve high productivity [2]. The main nutrients needed by oil palm are N, P, K, and micro nutrients such as Cu and B. Nitrogen is an essential element for cell formation, protein, chlorophyll, cytoplasm and other cell components [3]. Phosphorus is a DNA and RNA compound that functions as a genetic information system, and as a structural component of a number of molecular compounds that play a role to transfer the energy of ADP, ATP, NAD, NADH [4]. Potassium plays an important role to improve fruit quality and strengthen plant stem tissue [5]. Copper is a cell wall compound that provides the strength for plants to grow upright, and Boron has a function for fruit formation, flowering, cell division, and movement of plant hormones [6].

Results of research conducted by [7], indicated that single fertilizer packaged application can linearly increase the growth of oil palm crops for plant height, stem girth, leaf area, chlorophyll content and leaf P content, and increased quadratically on the number of frond. Further research conducted by [8] showed that single ertilizer package application can increase linearly growth of plant height, stem girth, number of frond, and frond length at two year old oil palm trees. Based on the results of research of Rahhutami and his colleagues [8] that the provision of single fertilizer package N, P, K did not increase quadratically, then the optimum rate can not be determined. The dose of fertilizer used is higher than the dose used by previous researchers. Proper rate of fertilizer is essential to achieve the efficiency and effectiveness of fertilization in oil palm. The purpose of this study was to study the effect of single fertilizer package N, P, K on growth, productivity and to determine the optimum rate of oil palm plant at age four years.

2. Materials and Methods

The research was conducted from April 2016 to March 2017 at IPB-Cargill Teaching Farm of Oil Palm, Jonggol, Bogor, West Java, with an altitude of 113 m above the sea level. Plant material used was Tenera Oil palm of four year old. The oil palms were planted with 9.2 m × 9.2 m × 9.2 m triangular pattern. The fertilizers used consted of urea (45% N), SP-36 (36% P_2O_5), KCl (60% K_2O), copper ($CuSO_4.5H_2O$), boron (B). Experimental tools used was gauge, analytical scale, SPAD-502 plus chlorophyll meter, and microscope.

The experimental design used a single factor arranged with complete randomized block design (CRBD) with three replications and each experimental unit consisted of five oil palms, so the total was 60 plants. Single fertilizer treatments consisted of 4 levels: control (P0), 1500 g urea + 1000 g SP-36 + 1500 g KCl + 50 g borate + 50 g $CuSO_4.5H_2O$ (P1), 3000 g urea + 2000 g SP-36 + 3000 g KCl + 50 g borate + 50 g $CuSO_4.5H_2O$ (P2), 4500 g urea + 3000 g SP-36 + 4500 g KCl + 50 g borate + 50 g $CuSO_4.5H_2O$ (P3) tree^{-1} year^{-1}. These treatment levels were obtained from previous research by [8]. Fertilizer treatment was applied twice, i.e. in April and November 2016. Rate of fertilizer for each application was a half of the total rate. The fertilizers were manually applied by spreading around the circle of oil palm plants.

Stem girth was measured at ± 5 cm above soil surface using gauge. The gauge was also used to measure frond length (number 17). The leaf area of the 17th frond was calculated by measuring of length and width of leaflets and then multiplied by constant factor. Plant height was measured from the soil surface to the end of petiole in the first fully opened frond. The production component observed consisted of the number of bunches, the number of fresh fruit bunches (FFB) harvested, the weight of FFB.

The greenness of the leaf was measured using SPAD-502 plus chlorophyll meter, stomatal density was observed by counting the number of stomata in a certain area. The leaf nutrient content of the 17th frond was analyzed by standard method at 48 MAP. Data were analyzed using SAS (Statistical Analysis System) program. Significance of treatments at $\alpha = 0.05$ was verified using orthogonal polynomial test.

3. Result and Discussion

3.1 Morphological Response

3.1.1 Plant Height

The results showed that application of single fertilizer linearly increased oil palm height at 48 MAP (Table 1). This study was similar result with the study of [9] that single fertilizer of N, P, and K can increase the plant height of oil palm aged one year. The increase of plant height for the highest rate (P3) was 17.22% compared to control at 48 MAP. Single fertilizer with the highest rate P3 was 4500 g urea + 3000 g SP-36 + 4500 KCl + 50 g borate + 50 g $CuSO_4.5H_2O$ g tree^{-1} year^{-1}. Application of P3 rate showed that plant height was still increase, it mean that we can not determine the optimal rate based on this parameter (Figure 1).

Table 1: Effect of single fertilizer application on plant height at 41, 45, and 48 MAP

Single fertilizer packages	Plant Age (MAP)		
	41 MAP	45 MAP	48 MAP
P0	238.47	262.33	269.80
P1	247.07	279.40	286.33
P2	249.47	283.33	292.00
P3	264.80	300.87	316.27
Response pattern ¢	ns	ns	*L

Notes: ¢: orthogonal polynomial test; L: linier, ns: not significant, *: significant at P<0.05; MAP: month after planting; P0: control (without fertilizers), P1: 1500 g urea + 1000 g SP-36 + 1500 g KCl + 50 g borate + 50 g $CuSO_4.5H_2O$, P2: 3000 g urea + 2000 g SP-36 + 3000 g KCl + 50 g borate + 50 g $CuSO_4.5H_2O$, P3: 4500 g urea + 3000 g SP-36 + 4500 g KCl + 50 g borate + 50 g $CuSO_4.5H_2O$ $tree^{-1}$ $year^{-1}$.

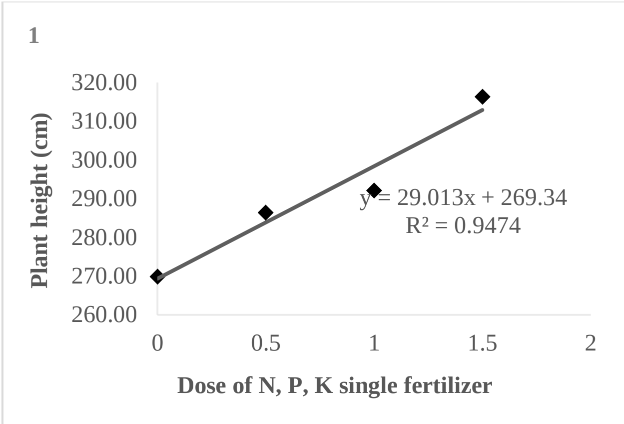

Figure 1: Curve and regression of plant height affected by different doses of N, P, K single fertilizer at 48 MAP

3.1.2 Stem Girth

The data in Table 2 show that single fertilizer increased linearly to the oil palm stem girth variables at 42 and 48 MAP. The increase of oil palm stem girth for the highest rate (P3) was 12.13% compared to control (without fertilizer) at 48 MAP. The linear effect showed that the treatment of single fertilizer with the highest rate (P3) was 4500 gurea + 3000 g SP-36 + 4500 g KCl + 50 g borat + 50 g $CuSO_4.5H_2O$ $plant^{-1}$, it was still increase oil palm stem girth (Figure 2). According [10], stated that treatment of single fertilizer (N, P, K) at a rate of 0.50 kg N + 0.50 kg P_2O_5 + 0.78 kg K_2O could increase stem girth for one-year oil palm.

Table 2: Effect of single fertilizer application on stem girth at 36, 42, and 48 MAP

Single fertilizer packages	Plant Age (MAP)		
	36 MAP	42 MAP	48 MAP
P0	249.00	285.73	299.07
P1	267.80	309.67	321.73
P2	279.25	304.27	320.67
P3	284.07	319.27	335.37
Response pattern ¢	ns	*L	*L

Notes: ¢: orthogonal polynomial test; L: linier, ns: not significant, *: significant at P<0.05; MAP: month after planting; P0: control (without fertilizers), P1: 1500 g urea + 1000 g SP-36 + 1500 g KCl + 50 g borate + 50 g $CuSO_4.5H_2O$, P2: 3000 g urea + 2000 g SP-36 + 3000 g KCl + 50 g borate + 50 g $CuSO_4.5H_2O$, P3: 4500 g urea + 3000 g SP-36 + 4500 g KCl + 50 g borate + 50 g $CuSO_4.5H_2O$ tree^{-1} year^{-1}.

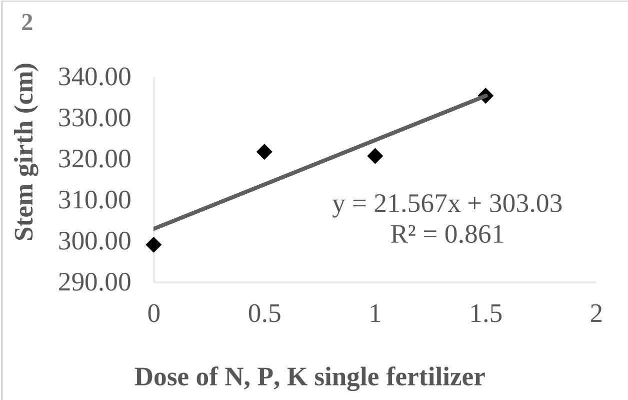

Figure 2: Curve and regression of stem girth affected by different rate of N, P, K single fertilizer at 48 MAP

3.1.3 Frond Length

The response of single fertilizer of N, P, K and micro nutrients (B and Cu) did not significantly affect length of frond 17th of oil palm at 36-48 MAP (Table 3). The average length of frond was range from 445.53 cm to 590.93 cm. According [11] the frond length of oil palm aged 4 years range from 348 cm to 375 cm. The oil palm frond had varying length. It is influenced by genetic factors of oil palm itself. Furthermore, result finding by [8] stated that the single fertilizer of N, P, K had no significant effect to frond length of oil palm aged two years.

Table 3: Effect of single fertilizer application on frond length at 36, 42, and 48 MAP

Single fertilizer packages	Plant age (MAP)		
	36 MAP	42 MAP	48 MAP
P0	445.53	516.40	572.87
P1	465.20	531.53	590.93
P2	462.68	521.73	576.87
P3	480.07	540.87	589.47
Response pattern ¢	ns	ns	ns

Notes: ¢: orthogonal polynomial test; L: linier, ns: not significant, *: significant at $P<0.05$; MAP: month after planting; P0: control (without fertilizers), P1: 1500 g urea + 1000 g SP-36 + 1500 g KCl + 50 g borate + 50 g $CuSO_4.5H_2O$, P2: 3000 g urea + 2000 g SP-36 + 3000 g KCl + 50 g borate + 50 g $CuSO_4.5H_2O$, P3: 4500 g urea + 3000 g SP-36 + 4500 g KCl + 50 g borate + 50 g $CuSO_4.5H_2O$ tree^{-1} year^{-1} .

3.1.4 Leaf Area

The treatment of single fertilizer of N, P, K and micro nutrients (B and Cu) did not significantly affect leaf area of the 17th frond. The average leaf area ranged from 4.37 m^2 to 6.47 m^2. In contrast to the results obtained by Sitepu [11], the leaf area on oil palm aged one year ranged from 3.56 m^2 to 4.04 m^2. Leaves are needed by oil palm to absorb and convert light energy into carbohydrates that will be translocated for the plant growth and finally to produce yields. According reference [4] showed that N deficiency also promoted reduction of leaf area due to aging of the lower leaves. Reference [12] reported that P deficiency reduced leaf growth, leaf surface area, and the number of leaves and this led to reduction of biomass production. This is because P insufficiency promotes low rate of carbohydrate metabolism including photosynthesis and respiration, leading to carbohydrate accumulation and development of dark green leaves.

Table 4: Effect of single fertilizer application on leaf area number 17 at 36, 42, and 48 MAP

Single fertilizer packages	Plant age (MAP)		
	36 MAP	42 MAP	48 MAP
P0	4.50	5.72	5.93
P1	4.40	5.95	6.15
P2	4.37	6.02	6.34
P3	4.70	5.90	6.47
Response pattern ¢	ns	ns	Ns

Notes: ¢: orthogonal polynomial test; L: linier, ns: not significant, *: significant at $P<0.05$; MAP: month after planting; P0: control (without fertilizers), P1: 1500 g urea + 1000 g SP-36 + 1500 g KCl + 50 g borate + 50 g $CuSO_4.5H_2O$, P2: 3000 g urea + 2000 g SP-36 + 3000 g KCl + 50 g borate + 50 g $CuSO_4.5H_2O$, P3: 4500 g urea + 3000 g SP-36 + 4500 g KCl + 50 g borate + 50 g $CuSO_4.5H_2O$ $tree^{-1}$ $year^{-1}$.

3.2 Physiological Response

3.2.1 Stomatal Density and Leaf Greenness

Application of single fertilizer packages linearly increased stomatal density of the plants at 48 MAP, but not for leaf greenness (Table 5). This linear correlation indicated that higher level of single fertilizer lead higher stomatal density until the highest dose (P3) as indicated on Figure 3. The average stomatal density ranged from 159 mm^{-2} to 191 mm^{-2}, which was slightly different from average stomatal density of 146 mm^{-2} in Nigeria and 175 mm^{-2} in Malaysia [1]. Stomatal density was influenced by environmental factors such as temperature, water availability, light intensity, and CO_2 concentration [13], suggesting that rising of CO_2 concentration led to reduction of the number of stomata, vice versa. In addition, leaf greenness is closely related to nitrogen sufficiency. Based on leaf tissue analysis, N content ranged from 2.43-2.56%, which was not the optimum level. According to the reference [14] that critical nutrient levels of oil palm of the frond number 17 was 2.75% N. The insufficiency of N may insignificantly affect leaf greenness.

Table 5: Effects of single fertilizer packages on leaf greenness and stomatal density

Single fertilizer packages	Leaf greenness		Stomatal density (mm^{-2})	
	42 BST	48 BST	42 BST	48 BST
P0	74.30	74.09	159.66	165.77
P1	75.40	76.32	169.85	175.71
P2	74.40	73.53	172.12	183.93
P3	73.90	74.78	181.74	191.34
Response pattern ¢	ns	ns	ns	*L

Notes: ¢: orthogonal polynomial test; L: linier, ns: not significant, *: significant at P<0.05; MAP: month after planting; P0: control (without fertilizers), P1: 1500 g urea + 1000 g SP-36 + 1500 g KCl + 50 g borate + 50 g $CuSO_4.5H_2O$,P2: 3000 g urea + 2000 g SP-36 + 3000 g KCl + 50 g borate + 50 g $CuSO_4.5H_2O$, P3: 4500 g urea + 3000 g SP-36 + 4500 g KCl + 50 g borate + 50 g $CuSO_4.5H_2O$ $tree^{-1}$ $year^{-1}$.

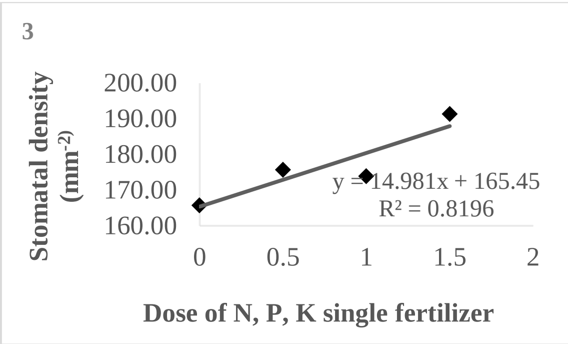

Figure 3: Curve and regression of stomatal density affected by different doses of N, P, K single fertilizer at 48 MAP

3.2.2 Nutrient level of leaf

The result of analysis showed that single fertilizer linearly increased leaf B content at 48 MAP, however, it had not significantly affect N, P, K, and leaf leaf Cu content levels (Table 6). The results of leaf tissue analysis of the 17th frond at 48 MAP were N content was 2.43-2.50%, P content 0.16-0.18%, and K content 0.82-0.98%, Cu content 9-84-39.45 ppm, and B content 23.00-32.36 ppm. Critical nutrient level of oil palm for mature oil palm is N 2.75%, P 0.16%, K 1.25%, while Cu 5-7 ppm and B 15-25 ppm [14].

This indicated that nutrient concentrations of leaf content for P, Cu and B were above on critical nutrient level, while N and K were below on critical nutrient level. These results may correlated with unreachable optimum growth and production of the plants due to destabilized nutrient content in the plant. Therefore, a further experiment using higher rate of fertilizer is required to determine optimum rate.

Table 6: Effects of single fertilizer packages on nutrient level of leaves at 48 MAP

Single fertilizer packages	Nutrient levels				
	N (%)	P (%)	K (%)	Cu (ppm)	B (ppm)
P0	2.50	0.18	0.82	9.84	23.00
P1	2.56	0.17	0.87	18.43	25.12
P2	2.43	0.16	0.92	22.23	32.36
P3	2.45	0.18	0.98	15.45	29.95
Response pattern ¢	ns	ns	ns	ns	*L

Notes: ¢: orthogonal polynomial test; L: linier, ns: not significant, *: significant at $P<0.05$; MAP: month after planting; P0: control (without fertilizers), P1: 1500 g urea + 1000 g SP-36 + 1500 g KCl + 50 g borate + 50 g $CuSO_4.5H_2O$, P2: 3000 g urea + 2000 g SP-36 + 3000 g KCl + 50 g borate + 50 g $CuSO_4.5H_2O$, P3: 4500 g urea + 3000 g SP-36 + 4500 g KCl + 50 g borate + 50 g $CuSO_4.5H_2O$ tree^{-1} year^{-1}.

3.3 Production Response

The results showed that application of single fertilizer of N, P, K and micro nutrients (B and Cu) increased linearly to the number of bunch, the number of FFB, and the productivity (ton ha^{-1} year^{-1}) however, it had no significant affect on the weight of FFB (Table 7). The linear pattern showed that single fertilizer with the highest rate (P3) was still increase on the number of bunch, the number of FFB harvested and its productivity. (Figure 4a, 4b dan 4c). This means that the optimum rate can not be determined yet. This condition is assumed due to K level is still low absorbed by plants.

This is supported by result of leaf analysis at the end of the research, it was indicated that K content was around 0.82-0.98%. The increase of FFB production is associated with nutrient availability in the soil. According to reference [15], that application of K nutrient showed an essential element required for oil palm crop to obtain optimal results. Potassium plays an important role in the flowering production and fruit formation of oil palm crop. Reference [15] also stated that K affected the bunch number, bunch weight and FFB production (ton ha^{-1}).

Nitrogen is an important ingredient in plant growth including cell division and cell enlargement. For plants with sufficient N content, approximately 90% of the photosynthesis results are transferred to shoots, in which the growth of new shoots are stimulated by N which is the site of more robust assimilation utilization than roots [4]. Phosphorus (P) plays a role in the growth of new tissue and cell division as well as to stimulate the development of plant roots needed to obtain the nutrients from soil. Roots are also needed to support the plant. When the roots develop well, the plant is able to penetrate the soil and absorb the nutrients needed by the plant to improve the development of the plant [16]. Potassium (K) works to regulate the opening and closing of stomata and to regulate CO_2 absorption so as to enhance photosynthesis [17].

Table 7: Effects on single fertilizer packages on number of bunches, FFB number, mean FFB weight, and productivity

Single fertilizer packages	Production ($year^{-1}$)			
	Number of bunches	FFB number	Mean FFB weight (kg)	Productivity (ton ha^{-1})
P0	10.98	13.34	8.77	14.79
P1	12.07	13.46	10.69	19.74
P2	15.87	16.94	10.59	23.89
P3	16.72	18.44	10.29	25.51
Response pattern ¢	*L	*L	ns	*L

Notes: ¢: orthogonal polynomial test; L: linier, ns: not significant, *: significant at $P<0.05$; MAP: month after planting; P0: control (without fertilizers); P1: 1500 g urea + 1000 g SP-36 + 1500 g KCl + 50 g borate + 50 g $CuSO_4.5H_2O$; P2: 3000 g urea + 2000 g SP-36 + 3000 g KCl + 50 g borate + 50 g $CuSO_4.5H_2O$; P3: 4500 g urea + 3000 g SP-36 + 4500 g KCl + 50 g borate + 50 g $CuSO_4.5H_2O$ $tree^{-1}$ $year^{-1}$.

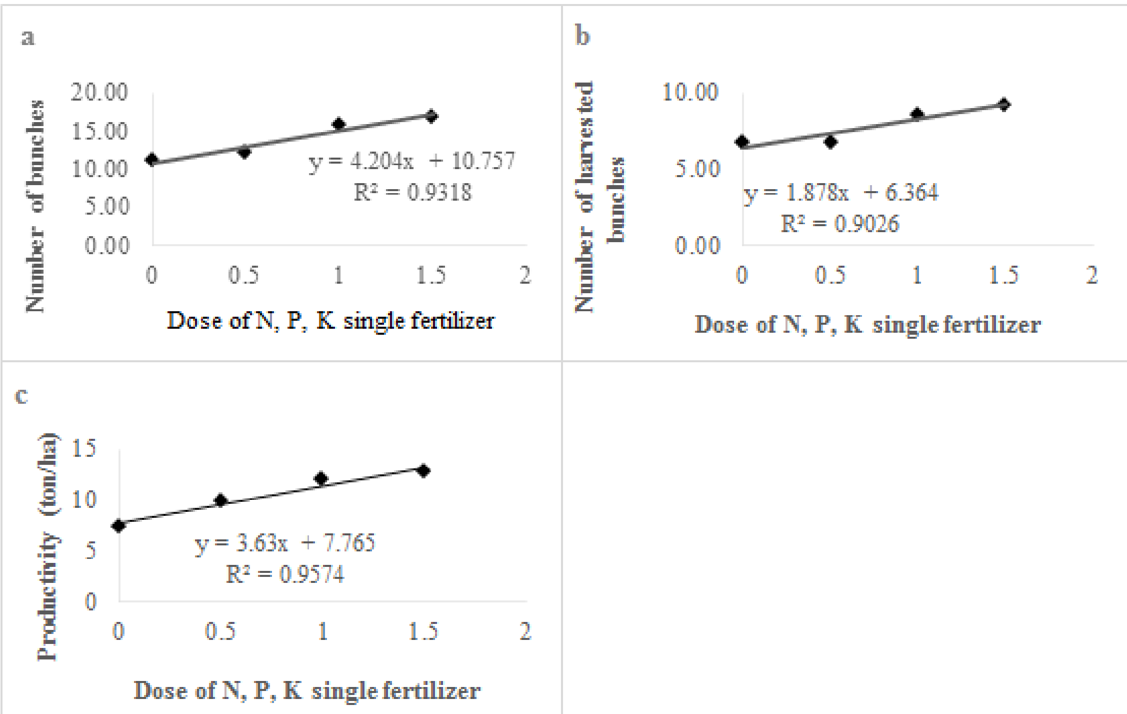

Figure 4: Curve and regression of number of bunches (a) harvested bunches (b) and productivity (c) affected by different doses of N, P, K single fertilizer.

4. Conclusions

In general, application of single fertilizer packages demonstrated linear correlation with plant height, stem girth, stomatal density, B content of leaves, bunch number, number of FFB, and productivity. However, the treatments showed no significant effects on leaf area in frond 17, frond length, FFB weight, leaf greenness, and N, P, K, Cu content in leaves. The optimum dose of N, P, K single fertilizer packages for oil palm aged four years (one year mature plant) could not be determined due to linear effects of the treatments.

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