Acceleration and improvement of productivity by inorganic and organic fertilizer application for six-year-old mature palm oil

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Abstract. The objectives of this research are to study the effect of single fertilizer package, compound NPK fertilizer package, organic fertilizer package, and micro fertilizer package on growth (morphology and physiology), and productivity for six-year-old oil palm. The research was conducted from April 2018 to March 2019 at IPB-Cargill Oil Palm Teaching Farm, Jonggol, Bogor, West Java. The research was designed in Randomized Complete Group with three repetitions. There are eleven treatments: control (P0), 3 kg urea + 2 kg SP-36 + 3 kg KCl + 50 g Borat + 50 g CuSO\textsubscript{4}.5H\textsubscript{2}O (P1), 6 kg urea + 4 kg SP-36 + 6 kg KCl + 50 g Borat + 50 g CuSO\textsubscript{4}.5H\textsubscript{2}O (P2), 9 kg urea + 6 kg SP-36 + 9 kg KCl + 50 g Borat + 50 g CuSO\textsubscript{4}.5H\textsubscript{2}O (P3), 4 kg Borat + 50 g CuSO\textsubscript{4}.5H\textsubscript{2}O (P4), 6 kg NPK + 50 g Borat + 50 g CuSO\textsubscript{4}.5H\textsubscript{2}O (P5), 12 kg NPK + 50 g Borat + 50 g CuSO\textsubscript{4}.5H\textsubscript{2}O (P6), 6 kg urea + 4 kg SP-36 + 6 kg KCl (P7), 8 kg NPK (P8), 6 kg urea + 4 kg SP-36 + 6 kg KCl + 100 kg organic fertilizer (P9), dan 6 kg urea + 4 kg SP-36 + 6 kg KCl + 200 kg organic fertilizer (P10) per plant per year. Data were analyzed with analysis variance, if there was a significant treatment effect, the further analysis using Duncan’s Multiple Range Test (DMRT). The result showed that inorganic fertilizer and organic fertilizer package significantly increased stem girth but did not significantly affect other morphological variables. The treatments of inorganic fertilizer and organic fertilizer package significantly increased effect of variable productivity (production number of bunches, number and weight of fresh fruit bunches (FFB) and productivity). The increased productivity with organic fertilizer package 6,0 kg urea + 4,0 kg SP-36 + 6,0 kg KCl + 100 kg organic fertilizer per plan per year (P9) is the higher effect (265.59%) compared to control.

1. Introduction
Oil Palm (Elais guineensis Jacq.) is one of the best commodity in the industry of plantation and being one of the export economic of Indonesia, it is used as the biggest devise which is made by the non-bienergy. Indonesia is the largest oil palm producer in the world, in the year of 2015 reached 31.07 million ton of Crude Palm Oil (CPO), and it’s being increased eventually from 2018 which had 40.56 million ton CPO. In the year 2017, the total amount export commodity of oil palm reached in the amount of 1.78 million ton Kernel Palm Oil (KPO). Besides, the utility of export, the oil palm market and the kernels still have very high demand from the people.

The total area for the oil palm commodity keep increasing year per year especially in Indonesia. In 2015, total areas for the oil palm is approximately 11.26 million ha and in the year of 2018 escalates become 14.32 million ha with the production is 40.56 million ton CPO [1]. The sub optimum field has
characteristics of low fertility, indeed could be fertilized by using high rate of fertilizer. One of the innovation which could be used to strenghten the availability of the mineral nutrient inside of the soil is by using the exact fertilizer treatment to the damaged land.

Fertilization affects on the production and quality from the production of the plants of the oil palm. Soil has a low fertility which could be re-soiled by using the add-ons of the mineral nutrients, so it could become what is necessity for the plants. The Oil Palm is the plant basically from the nursery plantation in order to grow bigger needs a lot of macronutrients and micronutrients inside of the plant to make the oil palm reached the highest productivity. The deficieny is one of the macronutrients show to use the significant symptomps and to prevent the growth process also to reduce the production. The fertilization needs an exact amount of weight and necessity in order to make the exact necessity for the oil palm plantation.

Every nutrients inside of the soil has its own function in order to affect the growth and the development of the oil palm trees. The macronutrients are needed with the enormous amount, such as C, H, O, N, P, K, Ca, Mg, and S. The nutrients of N, P, and K have a lot of important role in the process of physiology, growth, and the production rate of oil palm [2].The research still a continue-based research to knowing the important role of using the organic fertilizer and inorganic fertilizer to make an impact to enhance the growth of the oil palms especially 6-year-oil oil palm trees. The objective of the research is to analyze the effect of single fertilizer treatment, multi-fertilizer treatment, such as organic fertilizer, and also micro-fertilizer package to the growth and productivity of the 6-year-old oil palm trees.

2. Method
This research was conducted from April 2018 to March 2019 at IPB-Cargill Oil Palm Teaching Farm, Jonggol, Bogor, West Java, Indonesia at an altitude of 113 masl. Analysis of fertiliser and soil was carried out at the Laboratory Chemistry and Soil Fertility, Department of Soil Science and Land Resources, stomata density was observed in the Laboratory Microtechnical, Department of Agronomy and Horticulture, IPB University.

The oil palm were planted with 9.2 m x 9.2 m x 9.2 m triangular pattern. The materials used were mature oil palm Tenera Damimas variety aged 6 years, the single fertilizer of Urea, SP-36, KCl, terusil, borate, compound fertilizer NPK (15-15-15), and organic fertilizer. The tools used were gauge, scale, SPAD-502 plus chlorophyll meter, and microscope.

The experimental design used a single factor arraged with complete randomized block design with three replication and each experimental unit consisted of five plants, the total was 165 plants. Fertilizer treatment consisted of eleven packages, there were: control (P0), 3 kg urea + 2 kg SP-36 + 3 kg KCl + 50 g Borate + 50 g CuSO₄.5H₂O (P1), 6 kg urea + 4 kg SP-36 + 6 kg KCl + 50 g Borate + 50 g CuSO₄.5H₂O (P2), 9 kg urea + 6 kg SP-36 + 9 kg KCl + 50 g Borate + 50 g CuSO₄.5H₂O (P3), 4 kg + 50 g Borate + 50 g CuSO₄.5H₂O (P4), 8 kg NPK + 50 g Borate + 50 g CuSO₄.5H₂O (P5), 12 kg NPK + 50 g Borate + 50 g CuSO₄.5H₂O (P6), 6 kg urea + 4 kg SP-36 + 6 kg KCl (P7), 8 kg NPK (P8), 6 kg urea + 4 kg SP-36 + 6 kg KCl + 100 kg organic fertilizer (P9), dan 6 kg urea + 4 kg SP-36 + 6 kg KCl + 200 kg organic fertilizer (P10) each plant each year. These treatment levels were obtained form previous research. Fertilizer application was given two times every six month in May 2018 and November 2018. Rate of fertilizer for each application was a half of the total rate. The fertilizer were manually applied by spreading around the circle (1.5-2 m) of oil palm plants.

Plant morphological responses were evaluated based in the variable plant height, stem girth, and accretion of frond. Plant morphological responses observed every three months for 12 months. Plant height was measured with gauge from the soil surface to the end of petiole in the first fully opened frond. Stem girth was measured at ± 30 cm above soil surface using gauge.

Evaluation of physiological plant response were based on the variables stomata density by counting the number of stomata in a certain area and leaf greenness using SPAD 502 plus (chlorophyll meter). Physiological plant responses observed every six month in September 2018 and March 2019.
Observation of yield response was done on the number of fresh fruit bunch (FFB) harvested, the weight of FFB, and productivity by converting weighing the FFB it to units of hectares.

Relative agronomic effectiveness (RAE) were declared the agronomical effective if they have a RAE value more than 100%. RAE is calculated by comparing the increase for certain treatment of fertilizer with increase of comparable fertilizer multiplied by 100%. The comparative treatment used in this research was package fertilizer 6 kg urea + 4 kg SP-36 + 6 kg KCl + 50 g Borate + 50 g CuSO₄·5H₂O each plant each year (P2).

Data were statistically analysed at significant level P<0.05 using analysis of variance (ANNOVA). If the ANOVA showed significant effect, data analysis was continued by Duncan’s Multiple Range Test analysis.

3. Result

3.1. Plant morphological responses

3.1.1. Plant height. The treatment of inorganic and organic fertilizer packages did not significantly affect the height of plant oil palm at 63-72 MAP (Table 1). The average plant height was range from 453.67 cm to 521.00 cm at 72 MAP. This study was a similar result with the study of [3] that the application of fertilizer packages did not absorb completely by the roots. The increase of plant height for the highest rate (P5: 8 kg NPK + 50gr Borate + 50 g CuSO₄·5H₂O per plant) was 14.8% compared to control at 72 MAP. The research [3][4] showed that the organic fertilizer did not significantly affect the height of plant oil palm at immature 2 years of oil palm, mature 1 and 2 year of oil palm.

| Treatment | Plant height (cm) | 63 MAP | 66 MAP | 69 MAP | 72 MAP |
|-----------|-------------------|--------|--------|--------|--------|
| P0        |                   | 415.47 | 430.47 | 441.00 | 453.67 |
| P1        |                   | 440.20 | 460.93 | 471.80 | 488.07 |
| P2        |                   | 441.60 | 456.27 | 472.40 | 507.80 |
| P3        |                   | 461.07 | 476.00 | 491.20 | 509.00 |
| P4        |                   | 438.53 | 450.73 | 461.27 | 481.80 |
| P5        |                   | 472.20 | 484.53 | 498.87 | 521.00 |
| P6        |                   | 460.20 | 476.93 | 488.27 | 510.53 |
| P7        |                   | 442.67 | 462.87 | 472.33 | 496.80 |
| P8        |                   | 440.07 | 455.80 | 467.87 | 487.33 |
| P9        |                   | 441.28 | 458.90 | 469.85 | 497.18 |
| P10       |                   | 448.04 | 465.09 | 477.80 | 494.09 |
| CV (%)    |                   | 4.64   | 4.62   | 4.49   | 4.16   |
| F-value   | ns                | ns     | ns     | Ns     |

Notes: The following characters on number in the same column means not significantly different at DMRT test with level of α = 5%, ns: not significant, MAP: months after planting

3.1.2. Stem girth. Inorganic and organic fertilizer packages treatment significantly increased the growth of the stem girth on 72 MAP (Table 2). The average of the stem girth was range form 318.42-349.98 cm. The increase of palm stem girth for the highest rate (P3) was 9.91% compared to control at 72 MAP. The significant affect showed that the treatment of single fertilizer packages with the highest rate (P3) was 9 kg urea + 6 kg SP-36 + 9 kg KCl + 50 g Borate + 50 g CuSO₄·5H₂O per plant, it was still increase oil palm stem girth. This result was in line with the previous research that treatment of single fertilizer could increase linearly stem girth for mature two-year oil palm.

Palm oil plant stems function as a water transport system, plant nutrients, and the results of photosynthesis and the largest food storage in plants. Application of the highest rate of compound
fertilizer NPK (P6) did not significantly different to the highest rate of single fertilizer (P8). The research [5] showed that the application of N fertilizer with the optimum level will have a significant effect on the growth of the stem circumference of oil palm plants so that the element N is still needed for stem growth in mature plants. Moreover, the research [6] state that the application of K fertilizer is consistently able to increase the growth of oil palm stem circumference at the age of one to three years.

Application organic fertilizer (P9 and P10) did not significantly affect compared to fertilizer without organic (P7). This result was in line with the previous research the influence of organic fertilizer is not yet optimal. Plants will use organic fertilizer for a long time and be absorbed slowly.

Table 2. Effect of inorganic and organic fertilizer application on stem girth at 63, 66, 69, and 72 MAP

| Treatment | 63 MAP | 66 MAP | 69 MAP | 72 MAP |
|-----------|--------|--------|--------|--------|
| P0        | 299.00 c | 312.34 b | 313.31 b | 318.42 b |
| P1        | 322.93 ab | 336.20 a | 339.07 a | 343.27 a |
| P2        | 333.20 ab | 335.67 a | 338.27 a | 342.00 a |
| P3        | 340.02 ab | 344.82 a | 347.03 a | 349.98 a |
| P4        | 325.40 b | 331.07 a | 333.20 a | 336.47 a |
| P5        | 328.07 ab | 331.67 a | 336.40 a | 341.07 a |
| P6        | 343.47 a | 345.27 a | 347.27 a | 349.73 a |
| P7        | 333.00 ab | 338.40 a | 340.67 a | 344.60 a |
| P8        | 328.13 ab | 332.27 a | 335.27 a | 340.40 a |
| P9        | 332.13 ab | 335.25 a | 339.12 a | 343.68 a |
| P10       | 337.22 ab | 340.00 a | 343.89 a | 347.98 a |
| CV (%)    | 2.64    | 2.86    | 2.44    | 2.42    |

F-value **  *  **  *

Notes: The following characters on number in the same column means not significantly different at DMRT test with level of α = 5%.*, significant effect at level P<0.05, **: significant effect at level P<0.01 ns: not significant, MAP: months after planting

3.2. Plant physiological response

Application of organic and inorganic fertilizer packages increased stomatal density of plant at 66 MAP and leaf greenness at 72 MAP. The average stomatal density ranged from 174.27 mm$^{-2}$ to 225.90 mm$^{-2}$. Stomatal density was influenced by [7] environmental factors such as temperature, water availability, light intensity, and CO$_2$ concentration, suggesting that rising of CO$_2$ concentration led to reduction of the number of stomata, vice versa. The leaf greenness measurements of oil palm using SPAD-502 can be used as an indicator to estimate chlorophyll content (Table 3). Higher leaf greenness indicates that the chlorophyll contained in the leaves is also higher [8]. Nitrogen is one of the nutrients that the nutrients can increase the leaf greenness and chlorophyll content on oil palm.

3.3. Plant yield responses

The result showed that application of organic and inorganic fertilizer increased the number of fresh fruit bunch (FFB), mean FFB weight, and the productivity (ton ha$^{-1}$) (Table 4). This result was in line with the previous study indicated that organic and inorganic fertilizer packaged application can be applied to balance the nutrients in the soil and significantly increased fruit production in oil palm plant mature at six years old. The highest productivity is being gathered by the application of P9 (6 kg urea + 4 kg SP-36 + 6 kg KCl + 100 kg organic fertilizer per plant) with the amount of 27.31 ton ha$^{-1}$ dan gives increasing productivity about 265.59% more than control plants (P0) which has productivity as big as 7.47 ton ha$^{-1}$.

The average of FFB which was being harvested per year is around 8-21 FFB, with the detail of the highest of the harvested FFB made from the P9 compound fertilizer (6 kg urea + 4 kg SP-36 + 6 kg KCl + 100 kg organic fertilizer per plant) 158.26% more higher than plant control (P0). The highest of the
FFB process made also from the compound fertilizer (P3: 9 kg urea + 6 kg SP-36 + 9 kg KCl + 50 g Borate + 50 g CuSO₄·5H₂O per plant) which gives no significant effect than the impact made by the P9 compound fertilizer.

Table 3. Effect of inorganic and organic fertilizer packages on stomatal density and leaf greenness

| Treatment | Stomatal density (mm⁻²) | Leaf greenness (SPAD/unit) |
|-----------|--------------------------|-----------------------------|
|           | 66 MAP | 72 MAP | 66 MAP | 72 MAP |
| P0        | 216.40 ab | 207.22 | 67.88 | 70.55 b |
| P1        | 210.30 abc | 225.90 | 70.23 | 75.87 a |
| P2        | 200.08 abcd | 193.46 | 69.79 | 73.79 a |
| P3        | 211.63 abc | 190.74 | 71.54 | 75.14 a |
| P4        | 205.52 abcd | 193.46 | 70.74 | 73.45 a |
| P5        | 214.27 ab | 200.47 | 71.54 | 74.39 a |
| P6        | 174.27 d | 195.16 | 72.15 | 75.39 a |
| P7        | 225.22 a | 204.84 | 70.71 | 74.14 a |
| P8        | 201.78 abdc | 211.63 | 71.54 | 73.43 a |
| P9        | 188.70 bcd | 199.53 | 73.70 | 75.26 a |
| P10       | 210.28 abc | 190.18 | 72.91 | 74.59 a |
| CV (%)    | 8.54 | 9.12 | 0.09 | 1.83 |

Notes: The following characters on number in the same column means not significantly different at DMRT test with level of α = 5%.*: significant effect at level P<0.05, **: significant effect at level P<0.01 ns: not significant, MAP: months after planting

Table 4. Effect of inorganic and organic fertilizer packages on number of fresh fruit bunch (FFB) harvested, mean fresh fruit bunch (FFB) weight, and productivity

| Treatment | Production (year⁻¹) |
|-----------|---------------------|
|           | Number of FFB | Mean FFB weight (kg) | Productivity (ton ha⁻¹) |
| P0        | 8.17 c | 6.80 b | 7.47 c |
| P1        | 20.60 ab | 8.58 a | 22.28 ab |
| P2        | 16.20 b | 9.38 a | 20.37 b |
| P3        | 20.93 a | 9.51 a | 26.94 a |
| P4        | 20.40 ab | 8.02 ab | 21.78 ab |
| P5        | 18.60 ab | 9.08 a | 22.80 ab |
| P6        | 20.33 ab | 9.04 a | 25.18 ab |
| P7        | 19.07 ab | 8.71 a | 22.64 ab |
| P8        | 19.67 ab | 9.16 a | 24.44 ab |
| P9        | 21.10 a | 9.62 a | 27.31 a |
| P10       | 19.40 ab | 9.04 a | 24.09 ab |
| CV (%)    | 12.90 | 9.58 | 13.24 |

Notes: The following characters on number in the same column means not significantly different at DMRT test with level of α = 5%,.*: significant effect at level P<0.05, **: significant effect at level P<0.01 ns: not significant, MAP: months after planting

3.4. Relative agronomic effectiveness (RAE)

Relative agronomic effectiveness (RAE) result showed that the combination of organic and inorganic fertilizer was agronomically effective compared with standard fertilizer P2 (6 kg urea + 4 kg SP-36 + 6 kg KCl + 50 g Borate + 50 g CuSO₄·5H₂O per plant per year. According [9] RAE assessment examined
the result of relative fertilized plant compared to standard fertilizers, and if the value is close to 100% or more, it signifies that the combination fertilizer possesses the same abilities (or more) as the standard fertilizer. Table 8 shows that the application of P9 fertilizer packages (6 kg urea + 4 kg SP-36 + 6 kg KCl + 100 kg organic fertilizer per plant per year) has the highest effectiveness value of 153.72% with the productivity of 27.30 tons ha\(^{-1}\). P4 fertilizer package (4 kg compound NPK + 50 g Borate + 50 g CuSO\(_4\).5H\(_2\)O per plant per year) has the lowest effectiveness value of 110.89% with the productivity of 21.78 tons ha\(^{-1}\).

| Treatment | Productivity (ton ha\(^{-1}\)) | RAE (%) |
|-----------|-------------------------------|---------|
| P0        | 7.47                          | -       |
| P1        | 22.28                         | 114.76  |
| P2        | 20.37                         | 100.00  |
| P3        | 26.94                         | 150.87  |
| P4        | 21.78                         | 110.89  |
| P5        | 22.80                         | 118.83  |
| P6        | 25.18                         | 137.24  |
| P7        | 22.64                         | 117.57  |
| P8        | 24.44                         | 131.55  |
| P9        | 27.30                         | 153.72  |
| P10       | 24.09                         | 128.81  |

4. Conclusion
The application of inorganic and organic fertilizer packages has a significant effect on the variables of stem circumference response, the level of greenness of leaves, the number of FFBs, average FFB weights, and the productivity of six-year-old (TM 3) oil palm plants. Increased productivity with the highest dose treatment of a single fertilizer package of 9 kg urea + 6 kg SP-36 + 9 kg KCl + 50 g Borate + 50 g CuSO\(_4\).5H\(_2\)O per plant per year increased productivity by 260.64% (26.94 ton ha\(^{-1}\)) compared to controls (7.47 ton ha\(^{-1}\)). Increased productivity with the highest dose treatment of compound fertilizer packages 12 kg NPK compound + 50 g Borate + 50 g CuSO\(_4\).5H\(_2\)O per plant per year can increase productivity by 237.08% (25.18 ton ha\(^{-1}\)) compared to controls. The treatment of 6 kg urea + 4 kg SP-36 + 6 kg KCl + 100 kg organic fertilizer per plant per year gives the highest productivity increase of 265.59% compared to the control.

References
[1] Direktorat Jenderal Perkebunan 2018 Statistik Perkebunan Indonesia Komoditi Kelapa Sawit 2017-2019 (Jakarta:Dirjenbun) p 5
[2] Corley R H V and Tinker P B 2003 The Oil Palm Fourth Edition (UK: Blackwell Science Ltd)
[3] Silvana A, Sudradjat and Sudirman Y 2017 IJSBAR 36 202-12
[4] Rahhutami R, Sudradjat and Sudirman Y 2015 Asian Journal of Applied Sciences 3 382-7
[5] Oky D P, Sudradjat and Supijatno 2017 Asian Journal of Applied Sciences 5 1108-15
[6] Sudradjat, Oky D P, Rga F, Feni S and Supijatno 2018 Journal of Agriculture and Rural Development in the Tropics and Subtropics 119 13-22
[7] Kimbal J W 2011 Gas exchange in plants (http://www.biology-pages.info/G/GasExchange.html)
[8] Law C C, Zaharah A R, Husni M A H and Akmar A S N 2014 Journal of Oil Palm, Environment, and Health 5 8-17
[9] Winarna, Sutarta E S and Darmosarkoro W 2003 Jurnal Penelitian Kelapa Sawit 11 107-15