Inorganic and organic fertilizer packages for growth acceleration and productivity enhancement on a four-year-old mature oil palm

Sudradjat¹, S Yahya¹, Y Hidayat², O D Purwanto¹ and S Apriliani¹

¹Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University, Bogor, Indonesia
²Department of Soil Science and Land Resources, Bogor Agricultural University, Bogor, Indonesia

E-mail: sudradjat_ipb@yahoo.com

Abstract. Fertilization is one of the efforts to increase the productivity of oil palm. This study aimed to determine the best combination of fertilizer packages and to find out the rate of organic fertilizers to reduce the use of inorganic fertilizers on 1st mature oil palm. This study used one factor of randomized complete block design that consisted of 11 treatment levels with three replications. The treatment levels were: control (P0), 1500 g urea + 1000 g SP-36 + 1500 g KCl + 50 g borate + 50 g CuSO₄·5H₂O per palm (P1), 3000 gurea + 2000 g SP-36 + 3000 g KCl + 50 g borate + 50 g CuSO₄·5H₂O per palm (P2), 4500 g urea + 3000 g SP-36 + 4500 g KCl + 50 g borate + 50 g CuSO₄·5H₂O per palm (P3), 2000 g NPK + 50 g borate + 50 g CuSO₄·5H₂O per palm (P4), 4000 g NPK + 50 g borate + 50 g CuSO₄·5H₂O per palm (P5), 6000 gNPK + 50 g borate + 50 g CuSO₄·5H₂O per palm (P6), 3000 g urea + 2000 g SP-36 + 3000 g KCl per palm (P7), 4000 g NPK per palm (P8), 3000 g urea + 2000 g SP-36 + 3000 g KCl per palm + 50 kg organic fertilizer per palm (P9), 3000 g urea + 2000 g SP-36 + 3000 g KCl per palm + 100 kg organic fertilizer per palm (P10). Fertilizer package (P3) is the best combination of fertilizer packages to increase the growth and yield such as trunk girth, bunch number, and productivity. Fertilizer package (P3) could increase the bunch number by 37.31% and productivity by 72.97% compared to control (P0). Application of 50 kg organic fertilizer year⁻¹ (P9) could reduce by 30% of the use of a single package of inorganic fertilizers (P3).

1. Introduction

Oil palm (Elaeis guineensis Jacq.) is one of the plantation commodities that play an important role in the Indonesian economy, especially as enhancement of foreign exchange. The area of oil palm in 2015 reaches of 11.30 million ha, consisting of smallholders by 4.58 million ha (40.49%), government estates by 0.75 million ha (6.64%), and private estates by 5.98 million ha (52.88%) in Indonesia. The average productivity of crude palm oil (CPO) in Indonesia is 2.77 ton ha⁻¹ that consisted of smallholders by 2.33 ton ha⁻¹, government estates by 3.05 ton ha⁻¹, and private estates by 3.07 ton ha⁻¹ [1]. The low productivity in smallholder plantation due to the low national productivity of palm oil because the area of smallholder plantations occupy by 40.49% of the total area of oil palm plantations in Indonesia. The effort that needs to be done to improve productivity is the rehabilitation of existing plantations [2] and the fertilization with the appropriate rate according to the characteristics of the region [3].
The productivity of fresh fruit bunches (FFB) is influenced by climate, soil, plant genetic potential and plant maintenance [4,5,6]. Plant maintenance especially fertilization is one of the factors that determine the success of the oil palm plantation business. Fertilization costs range from 40-60% of the cost of plant maintenance or about 30% of total production costs [7]. Fertilization aims to provide sufficient nutrients for the plant [8,9].

Nutrients that are absorbed by plants can be obtained from inorganic and organic fertilizers. Inorganic fertilizers contain macro and micronutrients which are commonly found in single mineral fertilizers such as urea, KCl, SP-36 and borate and compound fertilizers such as NPK fertilizers. Inorganic fertilizers contain high nutrients and are readily available to plants, while organic fertilizers play a greater role in improving the physical, chemical and biological properties of the soil. Organic fertilizers also contain both macro and micronutrients, but at low levels.

Single fertilizer is a type of fertilizer that is often used in the phase of immature and mature oil palm. The advantages of using a single fertilizer are the high nutrient content and the number of nutrients can be determined according to the needs of plants, but the use of single fertilizer requires a high cost for labor costs in the application fertilizers [10]. NPK compound fertilizer is commonly used in oil palm plantations. Compound fertilizer is more efficient, easy in application and slow release [11].

Effectiveness and efficiency of applied fertilizers are influenced by the type and rate, method, time, place of application and supervision in the implementation of fertilization [12]. Excessive and inappropriate fertilization (types and rate) can result in toxicity for plants so that the information on the types and rates of inorganic fertilizers both single and compound fertilizers as well as appropriate of organic fertilizers for mature oil palm is needed. The oil palm requires large amounts of nutrients to achieve the productivity by 30 tons ha⁻¹ year⁻¹[13,14]. The elements of nitrogen (N), phosphorus (P) and potassium (K) are the three major macronutrients that are needed for the growth and production of oil palm. The aims of this study were: 1) to determine the best combination of fertilizer packages to achieve maximum productivity on 1st mature oil palm; 2) to achieve the rate of organic fertilizer that could substitute and reduce the use of inorganic fertilizer so that the sustainability of palm oil plantation could be achieved.

2. Materials and methods
2.1. Study site
The research was conducted at IPB-Cargill Oil Palm Teaching Farm, Jonggol, Bogor, Indonesia at an altitude 113 m above sea level. Analysis of fertilizer, soil, leaf tissue, and tissue fronds was carried out in the Laboratory of Chemistry and Soil Fertility, Department of Soil Science and Land Resources, Bogor Agricultural University. The study was conducted from March 2016 to March 2017.

2.2. Materials and experimental design
The planting system was an equilateral triangle with a spacing of 9.2 m × 9.2 m × 9.2 m so that the plant density was 136 palms ha⁻¹. The plant material used in this study was a four-year-old mature oil palm, Tenera oil palm, Dami Mas variety. The fertilizers used in this study were manure, urea (45% N), SP-36 (36% P₂O₅), KCl (60% K₂O), NPK compound fertilizer (15% N, 15% P₂O₅, 15% K₂O), terusi (24% CuSO₄·5H₂O), and boric (12% B). This study used one factor of randomized complete block design that consisted of 11 treatment levels with three replications. The treatment levels were control (P0), 1500 g urea + 1000 g SP-36 + 1500 g KCl + 50 g borate + 50 g CuSO₄·5H₂O per palm (P1), 3000 g urea + 2000 g SP-36 + 3000 g KCl + 50 g borate + 50 g CuSO₄·5H₂O per palm (P2), 4500 g urea + 3000 g SP-36 + 4500 g KCl + 50 g borate + 50 g CuSO₄·5H₂O per palm (P3), 2000 g NPK + 50 g borate + 50 g CuSO₄·5H₂O per palm (P4), 4000 g NPK + 50 g borate + 50 g CuSO₄·5H₂O per palm (P5), 6000 g NPK + 50 g borate + 50 g CuSO₄·5H₂O per palm (P6), 3000 g urea + 2000 g SP-36 + 3000 g KCl per palm (P7), 4000 g NPK per palm (P8), 3000 g urea + 2000 g SP-36 + 3000 g KCl per palm + 50 kg organic fertilizer per palm (P9), 3000 g urea + 2000 g SP-36 + 3000 g KCl per
palm + 100 kg organic fertilizer per palm (P10). Each experimental unit consisted of five oil palms so that the total of observation unit was 165 palms.

2.3. Data collection and measurement
Fertilizer application was made twice a year at 37 months after planting (MAP) in April 2016 and 43 MAP in October 2016 that each application was one half of the whole rate of fertilizer in one year. Fertilizer application was made using the broadcasting method on the circle of oil palm. Soil analysis was done before the first application of fertilizer that was done by taking a composite of soil samples with a depth of 30 cm using a auger soil drill. Measurements were made on morphological responses (trunk girth, length of frond 17, and leaf area of frond 17), physiology (leaf greenness, stomata density, and leaf nutrient content), and yield response (bunch number, average bunch weight, and FFB productivity). The trunk girth was measured about 25 cm above the ground by using a roll meter. The length of frond 17 was measured from the base of the frond to the end of the frond. Leaf area measurement was done on the leaflets of frond 17. The leaf greenness measurement was done on the leaflets of frond 17 by using SPAD 502 plus chlorophyll meter. The measurement of stomata density was done by taking stomata samples on the leaflets of frond 17 and was measured by using an electron microscope at a magnification of 40 x 10. Analysis of leaf nutrient content was done on the leaflets of frond 17. The measurements of yield response were conducted on variables such bunch number, average bunch weight, and FFB productivity on bunches. Criteria of matured FFB that could be harvested was two fruits released per kg FFB.

2.4. Data analysis
Data were analyzed by analysis of variance (ANOVA) at the level $P < 0.05$. If there was a significant effect, then analysis was proceeded by Duncan Multiple Range Test (DMRT) at level $P < 0.05$.

3. Results and discussion
3.1. Soil characteristics and climatic conditions
Initial soil analysis of the study site was conducted in April 2016 on the dead pathway (the area of two rows between palm). Based on [15], soil texture in the study location was clay that consisted of sand (19.71%), dust (29.81%), and clay (50.48%). The soil acidity was classified as very acid (pH 4.19), C-organic content was considered moderate (2.08%), N-total was considered moderate (0.22%), P-available was considered low (9.74 ppm), Ca was considered low (4.35 cmol (+) kg$^{-1}$), Mg was considered high (1.82 cmol (+) kg$^{-1}$), K was considered low (0.19 cmol (+) kg$^{-1}$), and Na was considered low (0.12 cmol (+) kg$^{-1}$). Cation exchange capacity (CEC) was considered high (27.34 cmol (+) kg$^{-1}$) and base saturation (BS) was considered low (23.70%). The content of Al-dd and H-dd were 7.17 cmol (+) kg$^{-1}$ and 1.24 cmol (+) kg$^{-1}$, respectively. Micronutrients content were Fe (72.30 ppm), Cu (0.50 ppm), Zn (3.88 ppm), Mn (25.77 ppm), and B (2.51 ppm).

Climatic conditions at the study sites over a 12 month period showed that rainfall was spread evenly throughout for a year without dry months (table 1). Climatic factors such as rainfall play an important role in plant physiology processes, especially in the formation of fruit bunches and the growth of oil palm [16]. The oil palm can experience growth disorder and decrease in yield productivity if the water requirement is not sufficient. Water is part of the plant cell and plays an important role as the raw material of photosynthesis [17] and as a nutrient solvent to be absorbed by plant roots [18].
Table 1. The average of rainfall, rainy days, temperature, and humidity from April 2016 to March 2017a.

| Month-Year    | Age of palm (MAP) | Rainfall (mm) | Rainy day (days) | Minimum temperature (°C) | Maximum temperature (°C) | Humidity (%) |
|---------------|-------------------|---------------|------------------|--------------------------|--------------------------|--------------|
| April 2016    | 37                | 405           | 11               | 27                       | 32                       | 80           |
| May 2016      | 38                | 213           | 9                | 27                       | 31                       | 80           |
| June 2016     | 39                | 196           | 8                | 26                       | 31                       | 78           |
| July 2016     | 40                | 196           | 6                | 26                       | 31                       | 78           |
| August 2016   | 41                | 272           | 12               | 26                       | 31                       | 78           |
| September 2016| 42                | 124           | 5                | 26                       | 32                       | 79           |
| October 2016  | 43                | 362           | 13               | 26                       | 31                       | 80           |
| November 2016 | 44                | 489           | 14               | 26                       | 31                       | 79           |
| December 2016 | 45                | 133           | 6                | 26                       | 31                       | 79           |
| January 2017  | 46                | 240           | 12               | 26                       | 30                       | 78           |
| February 2017 | 47                | 278           | 14               | 26                       | 30                       | 79           |
| March 2017    | 48                | 303           | 13               | 26                       | 30                       | 79           |
| **Total**     | **3211**          | **123**       | -                | -                        | -                        | -            |
| **Average**   | **268**           | **10**        | **26**           | **31**                   | **79**                   |              |

a Source: IPB-Cargill Teaching Farm of Oil Palm, Jonggol, Bogor.

3.2. Morphological responses

The application of inorganic and organic fertilizer packages affected the trunk girth, but did not affect the length of frond 17 and leaf area of frond 17 on 1st mature oil palm. The application of inorganic and organic fertilizer packages affected the trunk girth at 36, 39, 42, 45, and 48 MAP (Table 2). The trunk girth was an organ that was responsive to the application of inorganic and organic fertilizers.

The fertilizer package affected variables such the trunk girth, the leaf greenness, the bunch number, and the productivity of 1st mature oil palm. The application of inorganic fertilizer + micro fertilizer package (P1, P2, and P3), compound inorganic fertilizer + micro fertilizer package (P5, P6), and single inorganic fertilizer + organic fertilizer package (P10) was able to increase the trunk girth compared to control (P0) at 48 MAP. Reference [16] explained that the trunk has a function as structures to support the growth of plant organs such as leaves, flowers, and fruit. The trunk also transports nutrients, water and the result of photosynthesis. The study [19] mentioned that the single fertilizer treatment of N, P, K with the rate of 0.50 kg N + 0.50 kg P2O5 + 0.78 kg K2O could increase the trunk girth on one-year-old immature oil palm. The study [20] stated that NPK compound fertilizer could improve root development and biomass production. The increase in biomass indicated the better growth. NPK compound fertilizer can increase the trunk girth on 2nd immature oil palm [21]. The application of NPK compound fertilizer package can increase leaf area, chlorophyll content, as well as N and P content in leaves on one-year-old immature oil palm [22]. The study [23] stated that the application of organic fertilizer could increase the trunk girth because it can improve the physical and chemical soil properties. The trunk girth was the most responsive of morphological variable compared to the fronds and leaves.
Table 2. The response of trunk girth to the application of inorganic and organic fertilizer packages on 1st mature oil palm.

| Treatments | Trunk girth (cm)* | 36 MAP | 39 MAP | 42 MAP | 45 MAP | 48 MAP |
|------------|-------------------|--------|--------|--------|--------|--------|
| P0         |                   | 249.0 c| 274.8 b| 285.7 b| 293.3 b| 296.1 c|
| P1         |                   | 267.8 b| 290.0 ab| 309.7 a| 316.0 a| 321.7 ab|
| P2         |                   | 279.3 ab| 289.7 ab| 304.3 a| 312.8 a| 320.7 ab|
| P3         |                   | 284.1 ab| 302.5 a| 319.3 a| 323.7 a| 335.4 ab|
| P4         |                   | 267.5 b| 274.1 b| 302.2 a| 307.2 ab| 309.7 bc|
| P5         |                   | 273.7 ab| 292.9 ab| 307.3 a| 315.3 a| 320.7 ab|
| P6         |                   | 291.2 a| 306.0 a| 320.2 a| 326.6 a| 330.5 ab|
| P7         |                   | 276.1 ab| 288.8 ab| 309.7 a| 318.5 a| 316.5 abc|
| P8         |                   | 273.1 ab| 285.5 ab| 305.3 a| 310.4 a| 309.9 bc|
| P9         |                   | 277.6 ab| 283.5 ab| 306.3 a| 307.1 ab| 315.2 abc|
| P10        |                   | 279.6 ab| 299.7 a| 317.0 a| 320.1 a| 332.3 ab|
| CV(%)      |                   | 3.79   | 3.98   | 3.03   | 3.38   | 3.98   |

* The numbers followed by the same letters in the same column did not significantly different based on the DMRT test at P < 0.05.
*: significantly different at P < 0.05.

MAP: months after planting.
CV: coefficient of variation.

The trunk girth was an important variable as an indicator that indicates good vigor on the plant. It was seen that the response of inorganic and organic fertilizer packages showed significant differences in the trunk girth variable, while the length of frond 17 and the leaf area of frond 17 did not show any significant difference. The application of inorganic and organic fertilizer packages did not affect the length of frond 17 at 36, 39, 42, 45 and 48 MAP (table 3). The application of single fertilizer packages (N, P, and K) does not affect the length of frond 17 [24]. The length of frond 17 on 1st mature oil palm have averaged of 348 cm and 375 cm [25]. The length of frond 17 is very diverse and is also influenced by genetic factors, plant density, and plant material. The development of fronds and leaves consists of three stages: the slow initiation period followed by the rapid elongation phase and the starting phase of the assimilate production characterized by the opening of the leaflets [26].

The application of inorganic and organic fertilizer packages did not affect the leaf area of frond 17 at 36, 39, 42, 45, and 48 MAP (table 4). The leaf area is affected by fertilization, but did not very sensitive to other factors [27,16] The leaves were needed by oil palm to absorb and to convert light energy into carbohydrates that will be translocated for growth and yield production. Nitrogen deficiency also caused a reduction in leaf area due to the aging of the lower leaves. The study [28] stated that P deficiency would reduce the leaf expansion, leaf surface, and leaf number, as well as affect the decrease in biomass production at harvest. It was caused by insufficient P that can slow down the process of carbohydrate metabolism including photosynthesis and respiration which result in accumulation of carbohydrate and development of dark leaf color. The wide of the canopy associated with the leaf area, the length of frond and the number of leaflets that has an arbitrary growth pattern. The change of the wide canopy is an adaptation mechanism for regulating transpiration rates as the response of water balance changes on plant [29].
Table 3. The response of length of frond 17 to the application of inorganic and organic fertilizer packages on 1st mature oil palm.

| Treatments | 36 MAP  | 39 MAP  | 42 MAP  | 45 MAP  | 48 MAP  |
|------------|---------|---------|---------|---------|---------|
| P0         | 445.5   | 489.9   | 516.4   | 521.4   | 572.9   |
| P1         | 465.2   | 497.0   | 531.5   | 545.3   | 590.9   |
| P2         | 462.7   | 499.3   | 521.7   | 539.8   | 576.9   |
| P3         | 480.1   | 527.8   | 540.9   | 560.9   | 593.4   |
| P4         | 459.1   | 491.9   | 529.5   | 534.3   | 580.2   |
| P5         | 466.2   | 508.7   | 526.1   | 549.3   | 577.1   |
| P6         | 474.1   | 490.5   | 540.0   | 525.7   | 580.2   |
| P7         | 456.4   | 506.4   | 523.9   | 526.6   | 556.9   |
| P8         | 455.6   | 493.7   | 511.0   | 535.7   | 570.5   |
| P9         | 464.5   | 506.5   | 518.7   | 526.1   | 567.2   |
| P10        | 460.7   | 514.3   | 532.3   | 546.6   | 587.3   |
| CV (%)     | 2.68    | 3.10    | 4.96    | 4.38    | 3.25    |
| Response   | ns      | ns      | ns      | ns      | ns      |

ns: not significantly different at \( P < 0.05 \).

MAP: months after planting.

CV: coefficient of variation.

Table 4. The response of leaf area of frond 17 to the application of inorganic and organic fertilizer packages on 1st mature oil palm.

| Treatments | 36 MAP  | 39 MAP  | 42 MAP  | 45 MAP  | 48 MAP  |
|------------|---------|---------|---------|---------|---------|
| P0         | 5.16    | 4.50    | 5.72    | 5.92    | 5.76    |
| P1         | 5.46    | 4.40    | 6.02    | 6.04    | 6.15    |
| P2         | 5.08    | 4.36    | 6.02    | 5.98    | 6.31    |
| P3         | 5.36    | 4.70    | 5.90    | 6.31    | 6.50    |
| P4         | 5.83    | 4.33    | 5.67    | 5.87    | 6.46    |
| P5         | 5.42    | 4.23    | 5.77    | 5.76    | 6.08    |
| P6         | 5.35    | 4.43    | 5.93    | 6.01    | 6.73    |
| P7         | 4.45    | 4.43    | 5.70    | 5.68    | 5.80    |
| P8         | 5.42    | 4.46    | 5.67    | 5.65    | 6.11    |
| P9         | 5.30    | 4.33    | 5.57    | 5.69    | 5.89    |
| P10        | 5.51    | 4.56    | 6.05    | 6.16    | 6.34    |
| CV (%)     | 14.8    | 8.17    | 8.33    | 6.25    | 9.84    |
| Response   | ns      | ns      | ns      | ns      | ns      |

ns: not significantly different at \( P < 0.05 \).

MAP: months after planting.

CV: coefficient of variation.
3.3. Physiological response

The application of inorganic and organic fertilizer packages affected the leaf greenness level, but did not affect the stomata density and leaf nutrient content on 1st mature oil palm. The application of inorganic and organic fertilizer packages did not affect the leaf greenness at 42 MAP, but the affected 48 BST. The application of inorganic and organic fertilizer packages did not affect stomata density at 42 and 48 MAP. The application of inorganic and organic fertilizer packages (P1, P4, P5, P7, and P9) could increase the leaf greenness at 48 MAP. The higher leaf greenness level indicates, the higher chlorophyll content [30]. Optimum chlorophyll content would increase the growth and yield of oil palm because chlorophyll played an important role in the photosynthesis process.

The application of inorganic and organic fertilizer packages did not have a significant effect on stomata density on 1st mature oil palm. The average value of stomata density in this study was 159–191 mm$^{-2}$. Reference [16] stated that the study of stomata density in Nigeria is an average of 146 mm$^{-2}$, while in Malaysia is 175 mm$^{-2}$. Stomata density is influenced by several environmental factors such as temperature, water availability, light intensity, and CO$_2$ concentration. The stomata density will decrease if CO$_2$ concentration increases.

Table 5. The response of leaf greenness and stomata density to the application of inorganic and organic fertilizer packages on 1st mature oil palm.

| Treatments | Leaf greenness (SPAD unit)$^a$ | Stomata density (stomata mm$^{-2}$)$^a$ |
|------------|-------------------------------|----------------------------------|
|            | 42 MAP | 48 MAP | 42 MAP | 48 MAP |
| P0         | 72.35  | 74.09 bc | 159.7 | 165.8 |
| P1         | 73.28  | 76.32 a  | 169.9 | 175.7 |
| P2         | 72.26  | 73.53 c  | 172.1 | 173.9 |
| P3         | 72.90  | 74.78 abc | 181.7 | 191.3 |
| P4         | 72.91  | 76.01 a  | 178.9 | 177.7 |
| P5         | 72.45  | 76.36 a  | 185.1 | 186.8 |
| P6         | 73.67  | 75.14 abc | 173.8 | 174.3 |
| P7         | 72.31  | 76.59 a  | 172.7 | 180.0 |
| P8         | 73.46  | 75.12 a bc | 154.6 | 163.2 |
| P9         | 68.90  | 76.12 a  | 172.1 | 182.0 |
| P10        | 73.51  | 75.79 ab | 150.0 | 160.2 |

Coefficient of variation(%) | 4.45 | 1.25 | 13.69 | 9.15 |

Response | ns | * | ns | ns |

$^a$ The numbers followed by the same letters in the same column did not significantly different based on DMRT test at $P < 0.05$.

*: significantly different at $P < 0.05$.

ns: not significantly different at $P < 0.05$.

MAP: months after planting.

Leaf nutrient content such as N, P, and K in leaves also did not show asignificant difference to the application of inorganic and organic fertilizer packages. The highest nutrient content was on the application of fertilizer package P2 (3000 g urea + 2000 g SP-36 + 3000 g KCl + 50 g borate + 50 g CuSO$_4$·5H$_2$O per palm). The application of inorganic and organic fertilizer packages did not affect the leaf nutrient content such as N, P, and K on 1st mature oil palm. The leaf nutrient content (N, P, and K)
in this study were N (2.43-2.61%), P (0.16-0.20%), and K (0.82-0.98%), respectively. Critical nutrient level in the leaf of frond17 are N (2.75%), P (0.16%), and K (1.25%)[31].

**Table 6.** The response of leaf nutrient content to the application of inorganic and organic fertilizer packages on 1st mature oil palm.

| Treatments | Leaf nutrient content |
|------------|-----------------------|
|            | N (%)  | P (%)  | K (%)  |
| P0         | 2.50   | 0.18   | 0.82   |
| P1         | 2.56   | 0.17   | 0.87   |
| P2         | 2.43   | 0.16   | 0.92   |
| P3         | 2.45   | 0.18   | 0.98   |
| P4         | 2.54   | 0.17   | 0.92   |
| P5         | 2.58   | 0.18   | 0.85   |
| P6         | 2.56   | 0.17   | 0.85   |
| P7         | 2.50   | 0.16   | 0.83   |
| P8         | 2.52   | 0.19   | 0.82   |
| P9         | 2.61   | 0.20   | 0.90   |
| P10        | 2.43   | 0.19   | 0.95   |

Coefficient of variation(%) 5.13  7.84  11.02

Response ns  ns  ns

ns: not significantly different at $P < 0.05$.

### 3.4. Yield response

The application of inorganic and organic fertilizer packages affected bunch number and FFB productivity, but did not affect average bunch weight (table 7). The application of single inorganic fertilizer + micro fertilizer on fertilizer package P3 (4500 g urea + 3000 g SP-36 + 4500 g KCl + 50 g borate + 50 g CuSO$_4$·5H$_2$O per palm) showed the highest yield on the variable of bunch number. The application of fertilizer package P3 could increase the bunch number by 37.31% compared to control (P0). The application of single inorganic fertilizer + micro fertilizer package (P2, P3), NPK compound fertilizer + macro fertilizer (P5), single inorganic fertilizer (P7), NPK compound fertilizer (P8), and single inorganic fertilizer + organic fertilizer (P9, P10) could increase the productivity of 1st mature oil palm. The application of fertilizer package P3 (4500 g urea + 3000 g SP-36 + 4500 g KCl + 50 g borate + 50 g CuSO$_4$·5H$_2$O per palm) could increase the productivity by 72.97% compared to control (P0) on 1st mature oil palm.

The increase in the production of FFB is not unseparated from the nutrients available in the soil, especially N, P, and K. Reference [32] stated that N is a major component of amino acids and proteins and is part of the chlorophyll molecules that play a role in photosynthesis. Phosphorus plays an important role in the new tissue development and cell division. Phosphorus is needed for photosynthesis as well as storage and transport of nutrients throughout the plant. Potassium regulates the opening and closing of stomata and regulates CO$_2$ absorption, triggers the activation of biochemical enzymes, and facilitates protein synthesis so that increase the photosynthesis rate and starch synthesis. The study [33] stated that application of K fertilizer increase the bunch number, the bunch weight, and the productivity compared without application of K fertilizer. Potassium fertilizer is an essential element that required for oil palm to obtain optimal yield. Potassium plays an important role in the growth and fruit formation of oil palm.
Table 7. The response of bunch number, average bunch weight, and productivity to the application of inorganic and organic fertilizer packages on 1st mature oil palm.

| Treatments | Bunch number (FFB palm\(^{-1}\)) | Average bunch weight (kg FFB\(^{-1}\)) | Productivity (ton FFB ha\(^{-1}\)) |
|------------|----------------------------------|----------------------------------------|----------------------------------|
| P0         | 6.7 bc                           | 8.8                                    | 7.4 c                            |
| P1         | 6.7 bc                           | 10.7                                   | 9.9 abc                          |
| P2         | 8.5 ab                           | 10.6                                   | 11.9 a                           |
| P3         | 9.2 a                            | 10.3                                   | 12.8 a                           |
| P4         | 6.9 bc                           | 9.5                                    | 8.8 bc                           |
| P5         | 8.1 abc                          | 9.4                                    | 10.3 ab                          |
| P6         | 6.3 c                            | 10.8                                   | 8.8 bc                           |
| P7         | 8.4 ab                           | 10.3                                   | 11.5 ab                          |
| P8         | 8.3 abc                          | 10.1                                   | 11.1 ab                          |
| P9         | 7.9 abc                          | 9.4                                    | 10.3 ab                          |
| P10        | 8.2 abc                          | 10.4                                   | 11.0 ab                          |
| Coefficient of variation(%) | 13.51 | 9.76 | 14.94 |

Response * ns ns

The numbers followed by the same letters in the same column did not significantly different based on the DMRT test at \( P < 0.05 \).

*: significantly different at \( P < 0.05 \).

ns: not significantly different at \( P < 0.05 \).

The response of the trunk girth, the leaf greenness level, the bunch number, and the productivity did not significantly different on the treatment of P9 fertilizer package (3000 g urea + 2000 g SP-36 + 3000 g KCl + 50 kg organic fertilizer), P3 fertilizer package (4500 g urea + 3000 g SP-36 + 4500 g KCl + 50 g borate + 50 g CuSO\(_4\).5H\(_2\)O) and P6 fertilizer package (6000 g NPK + 50 g borate + 50 g CuSO\(_4\).5H\(_2\)O). The application of organic fertilizer with a rate of 50 kg palm\(^{-1}\) could substitute the use of single inorganic fertilizers and compound inorganic fertilizers. The application of organic fertilizer affects the vegetative growth, chlorophyll content and leaf N content on oil palm seedlings [23]. The application of organic fertilizer is used for the long term because the nutrient elements are released slowly. The application of organic fertilizer did not result in immobilization of available nutrients for the plant, but would increase nutrient turnover through the increase in biomass and microbial activity [34].

The application of organic fertilizer was expected to improve the effectiveness of fertilization. The study [35] stated that the application of organic fertilizer could increase the effectiveness of NPK compound fertilizer up to 179.38% on the main nursery of oil palm. The organic fertilizer can improve the physical, biological and chemical of soil properties. The combination of organic and inorganic fertilizers can provide the nutrients availability so that it will increase the growth [36]. The increase in CEC was able to bind nutrients and improve the effectiveness of inorganic fertilizer [37]. Organic fertilizer can increase the nutrients availability that leads to increased groundwater capacity [38] and increases organism activity in the soil. The soil organisms release phytohormones that can stimulate plant growth and assist in the nutrients absorption [39].
4. Conclusion
The treatment of P3 was the best combination of fertilizer package to increase growth and yield such as trunk girth, bunch number, and FFB productivity on 1st mature oil palm. The application of P3 fertilizer package could increase the bunch number by 37.31% and FFB productivity by 72.97% compared to control (P0) on 1st mature oil palm. The application of organic fertilizer with the rate of 50 kg palm\(^{-1}\) year\(^{-1}\) (P9) was able to reduce by 30% the use of single inorganic fertilizers (urea + SP-36 + KCl) on P3 treatment and could substitute the use of NPK compound fertilizer and micro fertilizer such as borate and CuSO\(_4\).5H\(_2\)O on P5 treatment.

References
[1] BPS-Statistics Indonesia 2016 *Indonesian Oil Palm Statistics 2015* (Jakarta: BPS-Statistics Indonesia)
[2] Noor J, Fatah A and Marhamnudin 2012 *Media Sains* **4** 48–53
[3] Webb M J, Nelson P N, Rogers L G and Curry G N 2011 *J. Plant Nutr. Soil Sci.* **174** 311–320
[4] Adam H, Jouannic S, Escoute J, Duval Y, Verdeil J L and Tregear J W 2005 *American Journal of Botany* **92** 1836–1852
[5] Wigena I G P, Purnomo J, Tuherkhi E and Saleh A 2006 *Jurnal Tanah dan Iklim* **24** 10–19
[6] Zuraidah Y, Tarmizi M A, Haniff HM and Rahim S A 2012 *Journal of Oil Palm Research* **24** 1533–1541
[7] Goh K J and Hardter R 2003 General oil palm nutrition *Oil Palm-Management for Large and Sustainable Yield* ed T H Fairhurst and R Hardter (Noricross: Potash and Phosphate Institute of Canada) pp 191–230
[8] Tarmizi A M and Tayeb M 2006 *Journal of Oil Palm Research* **18** 204–209
[9] Prasetyo B H and Suriadikarta D A 2006 *Jurnal Litbang Pertanian* **25** 39–47
[10] Winarna, Darmosarkoro W and Sutarta E S 2007 Teknologi pemupukan kelapa sawit *Lahan dan Pemupukan Kelapa Sawit* ed W Darmosarkoro, E S Sutarta and Winarna (Medan: Indonesian Oil Palm Research Institute) pp 153–166
[11] Primanti I S and Haridjaja O 2005 *Jurnal Tanah Lingkungan* **7** 22–26
[12] Poeloengan Z, Fadli M I, Winarna, S Rohuttomo and Sutarta E S 2007 *Permasalahan Pemupukan pada Perkebunan Kelapa Sawit* (Medan: Indonesian Oil Palm Research Institute) pp 65–77
[13] Ng P H C, Gan H H and Goh K J 2011 *Journal of Oil Palm & the Environment* **2** 93–104
[14] Ng S K 1979 *Nutrition and Nutrient Management of the Oil Palm-New Thrust for the Future Perspective* (Malaysia: Agromac Sdn Bhd)
[15] Indonesian Soil Research Institute 2009 *Analisis Kimia Tanah, Tanaman, Air, dan Pupuk* (Bogor: Indonesian Soil Research Institute)
[16] Corley R H and Tinker P B 2003 *The Oil Palm, 4th ed* (Oxford: Blackwell Science)
[17] Hardjowigeno S 2010 *Ilmu Tanah* (Jakarta: CV Akademika Pressindo)
[18] Sudradjat, Darwis A and Wachjar A 2014 *Indonesian Journal of Agronomy* **42** 222–227
[19] Sudradjat, Sukmawan Y and Sugiyanta 2014 *Journal of Tropical Crop Science* **1** 18–24
[20] Barros I D, Gaiser T, Lange F M and Römheld V 2007 *Field Crops Research* **101** 26–36
[21] Rahhutami R 2015 *Optimasi Berbagai Taraf Pemupukan terhadap Pertumbuhan Tanaman Kelapa Sawit Belum Menghasilkan Umur Dua Tahun* MSc Thesis (Bogor: Bogor Agricultural University)
[22] Sudradjat, Saputra H and Yahya S 2015 *International Journal of Sciences: Basic and Applied Research* **20** 365–372
[23] Uwumrongie-Ilori E G, Sulaiman-Ilobu B B, Ederion O, Imogie A, Imoisi B O, Garuba N and Ugbah M 2012 *Greener Journal of Agricultural Sciences* **2** 26–30
[24] Rahhutami R, Sudradjat and Yahya S 2015 *Asian Journal of Applied Sciences* 3382–387
Acknowledgments
This research was funded by Ministry of Research, Technology and Higher Education of the Republic of Indonesia and was supported Department of Agronomy and Horticulture, Bogor Agricultural University.