Optimization rate of empty fruit bunch and NPK compound fertilizer for 4-years-old oil palm

Sudradjat* and A N Diansyah

1 Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University, Bogor 16680, Indonesia.
2 Study Program of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University, Bogor 16680, Indonesia.

*Email: sudradjat@apps.ipb.ac.id

Abstract. Indonesia is the world’s largest producer of Crude Palm Oil (CPO), followed by Malaysia as the second producing country. CPO production of Indonesia and Malaysia reaches 80% of all world production. However, fertilizing empty fruit bunches should be combined with inorganic fertilizers. Empty fruit bunches of oil palm are waste from CPO processing, and the amount is very abundant. The use of empty bunches combined with compound NPK fertilizer is intended to increase the vegetative growth and support productivity. The purpose of this study is to determine the optimum rate of empty fruit bunches and NPK compounds. The research was conducted at the Teaching Farm of IPB-University, Jonggol, Bogor, from March 2016 to March 2017. The treatment consists of two factors, the first factor is the treatment of empty bunches (0, 50, 100, and 150 kg plant\(^{-1}\) year\(^{-1}\)) and the second factor is NPK compound (0, 2, 4, and 6 kg of plant\(^{-1}\) year\(^{-1}\)). The results of this study determined that the optimum rate of empty fruit bunches fertilizer is 128 kg palm\(^{-1}\), and the optimum rate of NPK compound fertilizer is 4.61 kg palm\(^{-1}\) for 4-year-old oil palm.

1. Introduction
The average productivity of Indonesian Crude Palm Oil (CPO) is 3.81 tonnes\(^{-1}\) hectare\(^{-1}\) year\(^{-1}\) [1]. This productivity is still low compared to the productivity of Malaysian CPO, which reaches more than 10 tonnes\(^{-1}\) hectare\(^{-1}\) year\(^{-1}\). The total area of oil palm plantations in Indonesia is 11.7 million hectares, about 20% of that area is cultivated on marginal lands [2]

Oil palm productivity could be increased by rehabilitating land, using superior varieties, innovative cultivation techniques, and optimal fertilization. Availability of suitable land is needed to increase productivity, i.e. by expanding new plantations and applying appropriate fertilizers. Based on the Presidential Instruction year 201, regulations requiring a postponement of issuance of new permits for conversion of natural forests, include production forests and peat areas located in conservation forests. This makes oil palm exploitation use existing land and there is no new land expansion. According to Noor et al. [3], the efforts that need to be made is to increase productivity or rehabilitation of existing plants and application of fertilizers based on plant needs.

Fertilization is to provide nutrients needed by plants, so that plants can grow well and can produce with high productivity. Fertilization using organic and inorganic fertilizers can improve soil properties in marginal lands [4]. According to Andri et al. [5], oil palm empty bunches are good organic material
for compost because they are available in large quantities and can improve soil physical, chemical, and biological properties. Compound NPK is a fertilizer that contains more than one type of macro element needed by plants such as N, P, and K. Hardjowigeno [6] states that the advantage of compound NPK is that fertilization is more efficient when compared to single fertilizers.

Fertilization should be applied in a balanced condition, effective and efficient manner, and suitable with the availability of soil nutrients. Application of the right dosage of fertilizer to plants will increase production. Determination of the optimum fertilizer dosage for oil palm is to obtain fertilization efficiency. The fertilizer recommendations based on soil analysis and plant analysis, this is to identify the deficiency or excess of fertilizers application [7]. Use of organic fertilizers combined with inorganic fertilizers intended to increase vegetative growth and increase the productivity of oil palm. This study aims to study the effect of empty bunches and determine the dosage of empty bunches, NPK compound, and their combinations to increase the productivity of fresh fruit bunches.

2. Materials and methods
The research was conducted at the Teaching Farm of Oil Palm of IPB-Cargill, Jonggol District, Bogor Regency. The research was conducted in March 2016-March 2017. Soil, fertilizer, and tissue analysis was carried out at the Chemical and Soil Fertility Laboratory of the Department of Soil and Land Resources, Faculty of Agriculture, IPB University. The materials used are 4-years old oil palm var. Damimas, compound NPK fertilizer (NPK Phonska 15:15:15), organic fertilizer of empty fruit bunches. The tools used are the scale, measuring instrument, soil drill, microscope, and chlorophyll meter SPAD-502Plus.

The study used a factorial design in a completely randomized block design (CRBD). The treatment consisted of two factors, namely: organic fertilizer and compound NPK fertilizer with four levels. The organic fertilizer (O) treatment consisted of 0 (O0), 50 (O1), 100 (O2), 150 (O3) kg per plant per year. Compound NPK fertilizer consists of 0 (N0), 2 (N1), 4 (N2), 6 (N3) kg per plant per year. Fertilizer application was applied by spreading around the canopy. The treatment obtained were 16 combinations, each combination was repeated three times so that there were 48 experimental units. Each experimental unit consisted of five plants so that the total number of all sample plants was 240 plants.

The variables observed consisted of plant morphology, physiology, and production. Morphological variables were trunk circumference (cm), midrib length (cm) of 17th leaf. Physiological variables observed were leaf greenness (SPAD unit). Meanwhile, the production components observed were the production of fresh fruit bunches, the average weight of the fruit bunch (kg), and the productivity of the fresh fruit bunches (tonnes/ha/year). Data were analyzed using SAS 9.1 (Statistical Analysis System) with variance at the level of α = 5% and followed by a polynomial contrast test if there was a significant effect.

3. Results and discussion

3.1. Morphological response

3.1.1. Trunk girth. Fertilization treatment of empty bunches, compound NPK, and the interaction between the two did not have an effect on palm oil trunk girth aged 36-48 months (Table 1). According to Mite et al. [8], stems are the sink when plants are in the vegetative phase, but after entering the generative phase, the main photosynthate products are used for fruit development. Legros et al. [9] stated that oil palm stems do not have secondary stems, so the increase of trunk stem girth tends to be constant. The growth of oil palm stems can be observed from the increased biomass weight. According to Amira et al. [10] decomposition of empty bunches naturally, without using a decomposer, it takes about four to six months to be decomposed, so that the released nutrients for plants take a long time to become available. Ermadani et al. [11] stated that the nutrients in organic fertilizers are released slowly, so that they are beneficial for plants in the long term.

3.1.2. Length of frond. The application of empty fruit bunches had a significant quadratic effect at the 45th month. The same effect occurred due to NPK compound applications having a significant linear
effect at the 45th month, and quadratically significant at the 48th month (Table 2). The interaction between empty fruit bunches and NPK compounds showed a response at 45 months. This can be presumed due to the application of empty bunches at the 43rd month and a half rate of NPK compound at the 44th month which can increase the frond length of oil palm. NPK compound application for oil palm was carried out twice, that is, half the treatment dose. The second fertilization application is able to provide additional nutrients. Sukmawan et al. [12] stated that the application of NPK compound significantly increased the number and length of frond, trunk girth, and leaf area.

**Table 1.** Trunk girth response on application of empty fruit bunches and NPK compound

| Fertilizer rate | Oil palm age (months) | Empty fruit bunches (kg palm\(^{-1}\)) | NPK compound (kg palm\(^{-1}\)) |
|----------------|-----------------------|----------------------------------------|----------------------------------|
|                | 36                    | 39                                     | 42                               |
| 0              | 169.6                 | 186.3                                  | 204.3                            |
| 50             | 172.1                 | 191.3                                  | 203.7                            |
| 100            | 169.8                 | 188.7                                  | 202.2                            |
| 150            | 170.9                 | 189.9                                  | 203.9                            |
|                | 0.9080                | 0.6616                                  | 0.9176                           |
| Pr\(^a\)       | ns\(^b\)              | ns\(^b\)                               | ns\(^b\)                         |
| Response       |                       |                                       |                                   |
| Pr\(^a\)       | 0.1112                | 0.1887                                  | 0.5241                           |
| Response       | ns                    | ns                                     | ns                               |

\(^a\) Probability  
\(^b\) Not significance
### Table 2. Frond length response on application of empty fruit bunches and NPK compound

| Fertilizer rate (kg palm⁻¹) | Oil palm age (months) | 37   | 39   | 42   | 45   | 48   |
|-----------------------------|-----------------------|------|------|------|------|------|
| Empty fruit bunches         |                       |      |      |      |      |      |
| 0                           |                       | 409.5| 450.2| 458.9| 488.8| 542.8|
| 50                          |                       | 422.9| 467.1| 477.3| 505.5| 544.1|
| 100                         |                       | 407.6| 448.5| 467.7| 491.7| 532.6|
| 150                         |                       | 410.8| 457.5| 479.2| 499.7| 541.0|
| Pr                          | 0.2858                | 0.0492| 0.0701| 0.0360| 0.44  |
| Response                    | ns                     | ns    | ns    | *c   | ns    |
| Response pattern            | -                      | -     | -     | Q    | -     |
| NPK compound                |                       |      |      |      |      |      |
| 0                           |                       | 413.8| 454.7| 461.5| 488.2| 517.3|
| 2                           |                       | 417.4| 457.6| 474.5| 496.1| 551.4|
| 4                           |                       | 410.7| 458.8| 476.7| 505.9| 543.9|
| 6                           |                       | 408.9| 452.2| 470.2| 500.8| 547.8|
| Pr                          | 0.7661                | 0.7768| 0.2820| 0.0453| 0.0004|
| Response                    | ns                     | ns    | ns    | *c   | **d  |
| Response pattern            | -                      | -     | -     | L    | Q°    |
| Interaction                 |                       |      |      |      |      |      |
| Pr                          | 0.6040                | 0.1773| 0.3887| 0.0443| 0.0502|
| Response                    | ns                     | ns    | ns    | *c   | ns    |

*Probability
b Not significance
c Significance at 5%
d Highly significance at 1%
e Linear
f Quadratic

#### 3.2. Physiological response: leaf greenness

The treatment of NPK compound increased significantly leaf greenness at the 37th month and highly significantly at the 39th month. The application of empty fruit bunches had no significant effect on the greenness of the leaves. Likewise, there was no interaction between empty fruit bunches and NPK compounds on the greenness of the leaves (Table 3).

Nitrogen contained in NPK compounds can increase the leaf greenness. This is consistent with the statement of Gastal and Lemaire [13], that nitrogen deficiency will reduce the green color of the leaves and reduce the intensity of photosynthesis. According to Rafael et al. [14] nitrogen is a structural element of chlorophyll and protein, thereby increasing the formation of chloroplasts and proteins.
Table 3. Greenness response application of empty fruit bunches and NPK compound

| Fertilizer rate | Oil palm age (months) |
|-----------------|-----------------------|
|                 | 37                    |
|                 | 39                    |
| Empty fruit bunches (kg palm⁻¹) | SPAD unit          |
| 0               | 74,0                  |
| 50              | 75,1                  |
| 100             | 74,4                  |
| 150             | 74,7                  |
| Pr a            | 0,4021                |
| Response        | ns b                  |
| NPK compound (kg palm⁻¹) |                     |
| 0               | 73,4                  |
| 2               | 74,2                  |
| 4               | 75,3                  |
| 6               | 75,3                  |
| Pr a            | 0,0140                |
| Response        | ns b                  |
| Interaction     |                       |
| Pr a            | 0.9371                |
| Response        | ns                    |

---

3.3. Production components

3.3.1. **Number of fresh fruit bunches (FFB)**. The application of empty fruit bunches had no effect on the number of fresh fruit bunches (FFB). However, NPK compound applications significantly increased the number of FFB. Likewise, there was no interaction between the treatment of empty fruit bunches and NPK compounds on the number of FFB (Table 4). Fresh Fruit Bunches (FFB) are harvested when the loose fruit number 4-5 in the area of circle weeding. Fruit maturity from anthesis is around 140-180 days depending on genetic, environmental factors and nutrient supply [15]. The loss of fruit before ripening usually occurs between 2-4 months after anthesis [16], it is caused by incomplete pollination process or lack of nutrients.
Table 4. Fresh fruit bunches number (FFB), average bunches weight (ABW) and productivity responses on empty fruit bunches and NPK compound

| Fertilizer rate       | FFB number (bunches) | ABW (kg) | Productivity (ton ha\(^{-1}\) year\(^{-1}\)) |
|-----------------------|----------------------|----------|---------------------------------------------|
|                       |                      |          |                                             |
| Empty fruit bunches   |                      |          |                                             |
| (kg palm\(^{-1}\))   |                      |          |                                             |
| 0                     | 5.06                 | 9.14     | 6.50                                        |
| 50                    | 5.55                 | 9.61     | 6.74                                        |
| 100                   | 5.23                 | 9.01     | 6.23                                        |
| 150                   | 5.50                 | 8.97     | 6.68                                        |
| Pr                     | 0.2586               | 0.3161   | 0.4943                                      |
| Response              | ns\(^{b}\)           | ns\(^{b}\) | ns\(^{b}\)                                  |
| NPK compound (kg tan\(^{-1}\)) |                      |          |                                             |
| 0                     | 4.46                 | 9.41     | 5.93                                        |
| 2                     | 5.40                 | 8.98     | 6.63                                        |
| 4                     | 5.61                 | 9.47     | 7.08                                        |
| 6                     | 5.86                 | 8.87     | 6.30                                        |
| Pr                     | <.0001               | 0.297    | 0.0272                                      |
| Response              | **d\(^{c}\)          | ns\(^{b}\) | *c                                          |
| Response pattern      | L**e                 | ns\(^{b}\) | Q\(^{f}\)                                   |
| Interaction           | -                    | -        | -                                           |
| Pr                     | 0.1624               | 0.2147   | 0.282                                       |
| Responds              | ns\(^{b}\)           | ns\(^{b}\) | ns\(^{b}\)                                  |

\(^{a}\) Not significance
\(^{c}\) Significance at 5%
\(^{d}\) Highly significance at 1%
\(^{e}\) Linear
\(^{f}\) Quadratic

The condition of the clay texture is able to hold water higher than the other type of textures, in this study it has not shown a significant effect on the application of empty fruit bunches. Theoretically, empty fruit bunches have the ability to improve soil structure and provide nutrients needed by plants. Chan \textit{et al.} [17] stated that the application of empty fruit bunches of 275 kg per ha per year significantly increased the number of FFB in oil palm plantations which had low rainfall and sandy soil conditions.

3.3.2. \textit{Average bunches weight (ABW)}. The application of empty fruit bunches and NPK compounds had no effect on ABW. Likewise, there was no interaction between empty fruit bunches and NPK compounds (Table 4). According to Soon and Hoong [18], the average weight bunches can be significantly increased with the application of nitrogen and potassium fertilizers. Reddi \textit{et al.} [19] also stated that applying the right NPK fertilizer dosage will increase the weight of oil palm bunches. However, in this study, the NPK compound application has not had an effect.

3.3.3. \textit{Fresh fruit bunches productivity}. The application of empty fruit bunches has no effect on FFB productivity. However, the NPK compound application showed a quadratic response to FFB productivity. There was no interaction between empty fruit bunches and NPK compounds on FFB productivity (Table 4). There is an increase to the FFB productivity by 26.25\% at the highest NPK compound rate (6 kg per ha per year), compared to the control. This is consistent with the research
results of Soon and Hong's [18], that nitrogen and potassium are important nutrients that affect FFB production, and can increase production by 15-20%, while the application of phosphorus can increase FFB production by 13-14%.

3.4. Optimization rate
Determination of the optimum rate is based on morphological and production variables which give a quadratic response significantly. This is because the quadratic curve has a peak point that makes a variable have a maximum value at each treatment level. Siallagan et al.[19] stated that the calculation of the optimum rate is done by deriving the quadratic response curve regression equation. Based on the quadratic response curve regression equation for morphological and production variables, it was found that the optimum rate for empty fruit bunches was 92.27 kg per plant per year (table 5) and for NPK compound fertilizer was 4.61 kg per plant per year (table 6).

Table 5. Regression equation and optimum rate of empty fruit bunches fertilizer on a four-year-old oil palm based on morphological variable

| Variable          | Equation                          | R²    | Optimum rate of empty fruit bunches (kg palm⁻¹ year⁻¹) |
|-------------------|-----------------------------------|-------|--------------------------------------------------------|
| Frond length      | $y = -0.001x^2 + 0.256x + 490.7$  | 0.533 | 128                                                    |
| Average           |                                   |       | 128                                                    |

Table 6. Regression equation and optimum rate of NPK compound fertilizer on a four-year-old oil palm based on production variables

| Variable          | Equation                          | R²    | Optimum rate of NPK Compound (kg palm⁻¹ year⁻¹)       |
|-------------------|-----------------------------------|-------|-------------------------------------------------------|
| Production of fruit bunch number | $y = -0.116x^2 + 0.849x + 7.036$ | 0.989 | 3.56                                                  |
| Productivity      | $y = -0.042x^2 + 0.477x + 4.499$  | 0.975 | 5.67                                                  |
| Average           |                                   |       | 4.61                                                  |

4. Conclusions
The application of empty fruit bunch fertilizer has not affected trunk girt, but it can increase the frond length. NPK compound increases the frond length, leaf greenness, number of fresh fruit bunches, and fresh fruit bunch productivity. The results of this study can determine the optimum rate of empty fruit bunch fertilizer, it is 128 kg palm⁻¹. Meanwhile the optimum rate of NPK compound fertilizer is 4.61 kg palm⁻¹ for 4-year-old oil palm.

Acknowledgments
We would like to thank the Ministry of Research and Technology of the Republic of Indonesia for funding this Competition Grant Research, and to the Department of Agronomy and Horticulture, Faculty of Agriculture, IPB University, which gave permission to conduct this research at IPB University Teaching Farm of Oil Palm, Jonggol Bogor.

References
[1] [Ditjenbun] Direktorat Jenderal Perkebunan 2016 Statistik Perkebunan Indonesia 2014-2017 Kelapa Sawit. http://www.ditjenbun.pertanian.go.id [16 Agustus 2017]
[2] Sardi L 2010 Produktivitas minyak kelapa sawit Indonesia hanya 3,7 Juta Ton per hektar per tahun. http://lifestyle.kontan.co.id/news/produktivitas-minyak-kelapa-sawit-indonesia-hanya-
Noor J, A Fatah dan Marhanuddin 2012 Pengaruh macam dan dosis pupuk NPK majemuk terhadap pertumbuhan bibit kelapa sawit (Elaeis guineensis Jacq) Media Sains 4 1 48-53

Yuwono N W 2009 Membangun kesuburan tanah di lahan marginal JITL. 9 2 137-141

Andri S, Nelvia, S I Saputra 2016 Pemberian Kompos TKKS dan Cocopeat pada Tanah Subsoil Ultisol terhadap Pertumbuhan Bibit Kelapa Sawit (Elaeis guineensis Jacq.) di Pre Nursery.

Harjojwigeno S 2010 Ilmu Tanah CV Akademika Pressindo Jakarta

Tarmizi A M dan M Tayeb 2006 Nutrient demands of tenera oil palm planted in inland soils of Malaysia. J Oil Palm Res. 18 204-209

Mite F, M Cirillo M dan J Espinosa 1999 Fertilizer use efficiency in oil palm is increased under irrigation in Ecuador Better Crops International 13 10 30-32

Legros S, Mialet-Sierra, J P Caliman, F A Siregar, A Clement-Vidal, D Fabre dan M Dingkuhn 2009 Phenology, growth, and physiological adjustment of oil palm (Elaeis guineensis) to sink limitation induced by fruit pruning Annals of Botany 104 1183-1194

Amira D R, A R Roshanida dan M I Rosli 2012 Effects of xylanase and cellulase production during composting of EFB and POME using fungi. J Biotechnol 6 8 581

Ermadani, A Muzar, dan I A Mahbub 2011 Pengaruh residu kompos tandan buah kosong kelapa sawit terhadap beberapa sifat Ultisol dan hasil kedelai. JPUJ 13 2 11-18.

Sukmawan Y, Sudrajat, dan Sugiyanta 2015 Peranan pupuk organik dan NPK majemuk terhadap pertumbuhan kelapa sawit TBM 1 di lahan marginal. J. Agron. Indonesia 43 3 242-249

Gastal F dan G Lemaire 2002 N Uptake and distribution in crops: an Agronomical and ecophysiological perspective Journal of Experimental Botany. 53 37 789-799

Rafael F M, G G Ramon, M C Luís, T Irineo, P Juan dan V O A Rosalia 2013 Review of methods for sensing the nitrogen status in plants: Advantages, disadvantages and recent advances Sensors 13 10823-10843

Tahiruddin L, N E Prabowo, H L Foster 2006 Comparison of the response of oil palm to fertilizers at different locations in North and South Sumatra. In: International Oil Palm Conference (IOPC) 19–23 June 2006 Nusa Dua Bali Indonesian Oil Palm Research Institute

Sparrnaaj L.D. 1960. The Analysis of bunch production in the oil palm J. West Afr.Inst. Oil Palm Res. 3 109–180

Chan K W, K C Lim dan A Ahmad 1991 Fertilizer efficiency studies in oil palm. In: Yusof B., B S Jalani, K C Chang, S C Cheah S, I E Henson, K Norman K, K Paranoith, N Rajanaidu, D Mohd Tayed dan D Ariffin D (Eds) Prospects and Challenges towards the 21st Century Kuala Lumpur. PORIM International Palm Oil Conference-Agriculture (module 1) Progress; Kuala Lumpur 1991

Soon B B F dan H W Hoong 2001 Oil palm responses to N, P, K and Mg fertilizers on two major soil types. In: Proceedings PIPOC International Palm Oil Congress (Agriculture) Sabah

Siallagan I, Sudradjat dan Haryadi 2014 Optimizing rate of organic and NPK compound fertilizers for immature oil palm. J. Agron. Indonesia 42 2 166 –172