Reduction of synthetic fertilizer application and heavy metal absorption on oil palm nursery related to the application of humic substances

H Agusta\textsuperscript{1,2}, D Asmono\textsuperscript{3}, M Fajri\textsuperscript{1}

\textsuperscript{1}Department of Agronomy and Horticulture, IPB-University, Bogor 16680, Indonesia.
\textsuperscript{2}Surfactant and Bioenergy Research Center, IPB University, Bogor 16144, Indonesia
\textsuperscript{3}PT Sampoerna Agro Tbk, Sampoerna Strategic Square, North Tower, Jakarta 12930, Indonesia

agusta@apps.ipb.ac.id

Abstract. Humic acid with amorphous and colloidal characteristics can improve soil chemical properties, especially tropical soil with lower fertility. To contribute to an environmentally friendly farming system, the capacity of humic acid to reduce the consumption of synthetic fertilizer on nursery oil palm was tested in this experiment. The experiment's purpose was to confirm the minimizing fertilizer application and reduce the heavy metal absorption in oil palm nurseries without any deterioration effects on the growth performance. Varied composition types of humic substance products were applied, i.e., in combination with fish meal, seaweed, and chicken manure. The concentration of heavy metals Ba, Cd, Ba and the absorption of macronutrients N, P, K, Ca, and Mg in the growing plants was also observed. It showed that humic acid in the dosage of 40 g/plant in the main nursery was capable of reducing the application of mineral fertilizer by 25% based on recommended standard application and at the same time reducing heavy metal Ba and Cd absorption by the plant.

1. Introduction

Oil palm seedlings require additional fertilizer for their growth, where fertilizers and their application cost can reach about majorly at the processing cost in the plantation [1]. Excessive use of fertilizers can waste the expenditure and increase greenhouse gas emissions [2], sourced from applied inputs and emissions occurring in the field. Oil palm nurseries with germinated seeds can be grown through pre-nursery and then the main nursery before being planted at the field.

Humic acid application is proposed to reduce fertilizer consumption. The humic fraction is soluble in bases, colloidal dispersed, amorphous, yellow to blackish brown, and relatively high molecular weight. Humic acid is relatively resistant to degradation and contains a negative charge affected by pH. Humic acid can bind to toxic metal ions so that it becomes insoluble. Humic acid also plays a direct role in plant growth, which can stimulate the growth of roots and the upper part of plants. Related to this, humic acid can be used as a stimulant for plant growth and support plant growth and productivity. Fertilizer is a source of nutrients for plants and microflora. Humic acid helps move the micronutrients from soil to plant.
Cd, Hg, and Pb are not essential elements of plants. However, other heavy metals Fe, Cu, Zn, and Mn, are required in small quantities, where a shortage of essential heavy metals can be defective for living plants. Humic compounds as metal chelators in the soil react with metal ions, acting as a metal rectification in the plants.

Due to routine operations and maintenance of production lines in oil palm companies, the attention on environmental problems, weighty metal absorption issues by the plants related to intensive synthetic fertilizers application was not explored sufficiently. There is a challenging method to overcome this sustainable concern on oil plantations, whereas abundant humic substances resources in nature can be explored. The humic substances have advantages potency to be combined with the synthetic fertilizer, which will be expected to reduce mineral fertilizer application and as a consequence, it will support the greenhouse gas emission by reducing the use of synthetic fertilizer.

The experiment’s purpose was to confirm the minimizing fertilizer application and reduce the heavy metal absorption in oil palm nurseries without any deterioration effects on the growth performance. The novelty of this research was to reveal the affectivity rate of various humic acid applications and its application rates on the reduction of consumption rate of standard fertilizer dosage at the main nursery stage of oil palm plantation, especially on its interaction with heavy metal Pb, Cd and Ba absorption by the plant without reducing the plant growth performance.

2. Methodology
This research was conducted in the Nursery Plantation of Hikmah Dua - PT. Sampoerna Agro Tbk, Ogan Komering Ilir Regency, South Sumatra. Soil analysis and humic acid content determination were conducted in Soil Science Laboratory, University of Sriwijaya Palembang, and Laboratory of Nusa Pusaka Kencana- PT. Asian Agri Inc. Plant tissue analysis was conducted in Soil Science and Land Resources Laboratory, IPB, and IPB Integrated Laboratory, Bogor. This research was carried out in April 2008 – January 2009. The humic acid used in this study was the product of PT Green Planet Indonesia, whose main characteristics are presented in Table 1. PT Sampoerna Agro Tbk provided the oil palm cultivar SJ2 with female number 930/42 and male number 321/204 from a pre-nursery plantation at the exact location. Pesticides Deltamethrin 25 g/l and Mancozeb 75% were applied for plant protection purposes. The planting media used was the subsoil of the plantation site. A relatively large polyybag size 40 cm x 50 cm was prepared for the leading nursery transplanting until the plants were ready to be transplanted to the plantation.

**Table 1. Description of applied humic acid product at oil palm main nursery.**

| Type | Description                                      | Color  | Odor level | Formulation | Hardness level |
|------|--------------------------------------------------|--------|------------|-------------|----------------|
| B    | Fish meal (20 %) + Humic acid + Chicken manure  | Brownish black | ***       | Pellet/ grannular | ###  |
| C    | Seaweed + Fish meal (20 %) + Humic acid + Chicken manure | Brownish black | ***       | Pellet/ grannular | ###  |
| E    | Fish meal (28 %) + Humic acid + Chicken manure  | Black   | ****       | Pellet/ grannular | #    |
| F    | Seaweed + Fish meal (28 %) + Humic acid + Chicken manure | Black   | ****       | Pellet/ grannular | ###  |
| G    | Humic acid + Chicken manure + Seaweed            | Light brown+ | **        | Pellet/ grannular | ###  |

The design used in the main nursery was a split-split plot design with three doses of fertilizer as the main plot, three doses of humic acid as a subplot, and five types of humic acid as a sub-sub plot. A unit experiment consisted of 16 plants to be observed during the experiment time; there were 2160 plants to be observed. Like the main plot, the Fertilizer dose consisted of 3 levels of fertilizer dosage, i.e., 50%, 75%, and 100% of the company recommendation dosage. This recommendation dosage was set per
plant during the main nursery growing time in 14 g N, 80 g P₂O₅, 60 g K₂O, and 88 g CaO. The dose of humic acid as a subplot consisted of 3 levels, i.e., 0, 20, and 40 g plant⁻¹. The sub-sub plot consisted of the humic acid types B, C, E, F, and G.

3. Result and Discussion

The application of synthetic fertilizer as industrial inorganic fertilizer on the main nursery installment in the dosage of 50%, 75%, and 100% was an effort to reduce fertilizer consumption for the plant. This effort was also combined with the idea to activate the ecological activities with bioactive substances, which was expected to increase soil microorganic activity. The bioactive substances comprised humic acid mixed with other varieties of organic materials such as fish meal, seaweed, chicken manure. The application of these biomaterials should support environmental-friendly agriculture[3,4].

The reduction of fertilizer dosage for the plant at 50% and 75% level of a typical application and the application of the humic acid product in the quantity of 20 and 40 g plant⁻¹ had no significant impact on the possible improvement of soil fertility parameters. Hence, soil quality was still in a range of environmental variability, and no significant improvement was found. The average value from all treatments of experimental soil parameters was as the following, pH H₂O 4.0±1.19, N-total 0.20±0.06%, Soil C-organic content 2.27±0.69%, Phosphate Bray-1 192.0±148.2 ppm, CEC pH7 11.31±3.32 me 100 g⁻¹ soil, K 1.43±0.66 me 100 g⁻¹, Ca 1.28±0.66 me 100 g⁻¹, Mg 3.17±1.71 me 100 g⁻¹, and Al 1.06±0.47 me 100 g⁻¹. The soil quality was categorized as low, with acidic pH value, low in mineral contents, and Al status should be considered for planting management.

The growth of the oil palm in the main nursery generally was not influenced by the increase of the application of humic acid dosage at 0, 20, 40 g plant⁻¹ nor rate of recommended fertilizer dosage at 50%, 75%, and 100%. Only minor differentiation at the experimental growth parameters affected by the type of humic acid applications products was noticed. There was no significant difference in plant height (63.14±0.88 cm), fresh stem weight (268.82±16.81 g plant⁻¹), leaf number per plant (13.21±0.28), stem diameter (37.29±0.59 cm), number of secondary roots in 0-10 cm soil depth (751.32±67.54 plant⁻¹) and number of tertiary root in 20-30 cm (10327±1355) plant⁻¹. After the destruction of the samples, the total dry weight of biomass was an average of 214.70±63.66 g plant⁻¹.

However, there was an unsynchronous effect of the treatment observed, especially on dry root matter and plant leaf dry matter parameters. The application of 75% fertilizer dosage in combination with the application of 75% recommendation dosage of the fertilizer showed the highest plant root dry matter value. The lowest plant leaf dry matter was found under the application of 100% fertilizer dosage recommendation in combination with humic acid products in the amount of 20 g plant⁻¹. In this case, the 100% fertilizer dosage treatment would be safe only if no humic acid was applied (Table 2). On arable land with neutral soil pH value, additional fertilizing of oil palm nurseries is not required[5].

Regarding the plant leaves biomass production, the combination of humic acid products in the amount of 40 g plant⁻¹ in combination with 75% fertilizer recommendation dosage exposed the best performance of the parameters and plant root development. It makes sense to combine both treatments in the recommended dose to reduce fertilizer application in the oil palm main nursery. The effect of the recommended fertilizer dosage level in combination with the varied humic acid products is presented in Table 2. The reduction of fertilizer application would save the environment. On acid soil, the fertilizer application in combination with extra organic carbon to promote microbial activity improved the performance of oil palm nursery plants [6].

The absorbed macro minerals from the soil at the nursery showed no significant difference due to the fertilizer recommendation dosage level nor the rate of humic acid application dosage. The total absorption of nitrogen, phosphor, potassium, calcium, and manganese exposed 1321±395 mg plant⁻¹, 291±86 mg plant⁻¹, 1112±329 mg plant⁻¹, 2726±803 mg plant⁻¹, and 216±66 mg plant⁻¹, respectively.
Table 2. Dry matter of root and Leaf oil palm main nursery related to fertilizer and humic acid and application.

| Treatment          | Dry matter weight | Humic acid dosage         |
|--------------------|-------------------|---------------------------|
|                    |                   | 0 g plant⁻¹ | 20 g plant⁻¹ | 40 g plant⁻¹ |
| Fertilizer dosage  | 50%               | 416.70 abcde | 400.00 bcde  | 333.30 cde   |
|                    | 75%               | 416.70 abcde | 400.00 bcde  | 333.30 cde   |
|                    | 100%              | 666.70 ab   | 300.00 e     | 366.70 cde   |
| Humic acid dosage  | 0 g plant⁻¹       | 120 g plant⁻¹ | 20 g plant⁻¹ | 40 g plant⁻¹ |
|                    | 50%               | 416.70 abcde | 400.00 bcde  | 333.30 cde   |
|                    | 75%               | 400.00 bcde  | 700.00 a     | 700.00 a     |
|                    | 100%              | 300.00 e     | 366.70 cde   | 366.70 cde   |

Note: Unequal indexed letters (a,b) at the same observed parameter show a significant difference level at p=0.05

The heavy metals Cd, Pb, and Ba showed no different values in the plant leaf and stem. The heavy metal concentration value in the leaf was observed at 0.05±0.11 ppm Cd, 0.94±1.04 ppm Pb, and 11.18±9.75 Ba, and in the stem were 0.05±0.09 ppm Cd, 1.13±1.12 ppm Pb, and 3.81±2.00. The affectivity of humic acid products to control Cd, Pb, and Ba in the soil was confirmed, that heavy metal contaminant in the soil was effectively removed achieved using humic acids [7], even more effective than the traditional chelating agent EDTA [8]. The generated metal-humic compound was more stable in the soil [9].

The absorption of Ba in the root was associate with the application of fertilizer. The higher fertilizer application increased the Pb concentration both in root and rachis. On the other side, the application of humic acid products reduces the absorption of heavy metals. Hence, the concentration of Pb and Cd at the application of 40 g humic product plant⁻¹ exposed a lower value than without the application of humic acid (Table 3). The concentration of heavy metal Cd in oil palm plants demonstrated more variability in value ranging 12.7-76.2 ppm, where the Cd concentration in the soil ranged only 0.27-4.26 ppm[10].

Table 3. Plant heavy metal concentration in rachis and root of the main nursery related to fertilizer and humic acid application.

| Treatment | Heavy metal concentration (ppm) | Rachis | Root |
|-----------|---------------------------------|--------|------|
|           | Cd                             | Pb     | Ba   | Cd | Pb | Ba |
| Fertilizer dosage | 50% | 0.28 | 0.42 | 1.64 | 0.07 | 5.16 | 5.51a |
|           | 75% | 0.11 | 0.80 | 1.07 | 0.11 | 3.75 | 7.94ab |
|           | 100% | 0.33 | 0.74 | 2.91 | 0.09 | 2.24 | 12.41b |
| Humic acid | 0 g plant⁻¹ | 0.20 | 1.09a | 1.93 | 0.14a | 4.42a | 8.03 |
|           | 20 g plant⁻¹ | 0.35 | 0.42b | 3.12 | 0.06b | 3.75ab | 9.31 |
|           | 40 g plant⁻¹ | 0.36 | 0.26b | 1.57 | 0.07b | 2.98b | 8.74 |

Note: Unequal indexed letters (a,b) at the same column and the same main plot or subplot show significant difference level at p=0.05
Total heavy metal absorption also showed an inherent pattern with the concentration in the leaf and root of the plant. The fertilizer application in a higher dosage from 50% to 100% recommendation dosage increased the absorbed Ba more than doubled. The increase of humic acid application reduced the Ba and Pb absorption of the plant. Any humification levels in the soil are commonly suitable for increasing the availability of soil fertilizer and play a role in improving contaminated soils by metals and organic pollutants [11]. The interactions that affect nitrogen fertilizing and humic acids application were described, that the increase of nitrate would reduce the humic acid formation, and the microbes were stimulated accordingly, especially those that can promote the humic acid degradation [12].

| Treatment                           | Cd   | Pb   | Ba    |
|-------------------------------------|------|------|-------|
| Fertilizer dosage                   |      |      |       |
| 50%                                 | 0.10 | 1.55 | 3.62a |
| 75%                                 | 0.05 | 1.37 | 4.75ab|
| 100%                                | 0.15 | 1.19 | 8.45b |
| Humic acid dosage                   |      |      |       |
| 0 g plant-1                         | 0.09 | 1.69a| 6.39a |
| 20 g plant-1                        | 0.12 | 1.33ab| 5.97ab|
| 40 g plant-1                        | 0.11 | 1.09b| 4.45b |

Note: Unequal indexed letters (a,b) at the same column and the same main plot or subplot show a significant difference level at p=0.05

4. Conclusion
The application of fertilizer in a higher dosage from 50% to 100% recommendation dosage without the application of humic acid substances increased the absorbed Ba in the plant more than doubled. Humic acid application in the dosage of 40 g/plant in the main nursery was capable of reducing the application of mineral fertilizer by 25% base on recommended standard application and at the same time also reducing heavy metal Cd, Pb, and Ba absorption by the plant.

Acknowledgment
Fund and facilitation is supported by PT Sampoerna Agro Tbk 2008–2009.

References
[1] Foong S Z Y, Goh C K M, Supramaniam C V and Ng D K S 2021 Sustain Prod Consum (in Press)
[2] Kusin F M, Akhir N I M, Muhammat-Y F and Awang M 2015 Atmósfera 28 243-250
[3] Rhebergen R, Fairhurst T, Giller K E and Zingore S 2019 Agric Water Manag 221 377–387
[4] Wu J, Zhao Y, Qi H, Zhao X, Yang T, Du Y, Zhang H and Wei Z Biores Technol 244 1193–1196
[5] Akpo E, Stomph TJ, Kossou DK, Omore AO and Struijk PC 2014 For Ecol Manag 324 28–36
[6] Murugan P, Ong SY, Hashim R, Kosugi A, Arai T and Sudesh K 2020 Biocatal Agric Biotechnol 28 101710
[7] Shi W, Lü C, He J, En H, Gao M, Zhao B, Zhou B, Zhou H, Liu H and Zhang Y 2018 Ecotoxicol Environ 154 59–68
[8] Zingaretti D, Lombardi F and Baciocchi R 2018 Sci Total Environ 619–620 1366–1374
[9] Rashid I, Murtaza G, Dar AA, and Wang Z 2020 Ecotoxicol Environ Saf 205 111347
[10] Olafisoye OB, Fatoki OS, Oguntibejub and Osibote 2020 Toxicol Rep 7 324–334
[11] Zhao Y, Wei Y, Zhang Y, Xin, Wen X, Xi B, Zhao X, Zhang X, Wei Z 2017 Ecol Indic 72 473–480
[12] Shi M, Wei Z, Wang L, Wu J, Zhang D, Wei d, Tang Y and Zhao Y 2018 Biores Technol 258 390–394