Increasing oil palm (Elaeis guineensis Jacq.) production by the application of humic substance and zeolite as carrier

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Abstract. Oil palm is considered as the flagship plantation crop in Indonesia in terms of developed area and its contribution to national GDP. It can grow well enough even on marginal lands such as in acid sulfate soils, acid soils, and peat soils given high annual rainfall and good site management, particularly in terms of controlled soil water regimes. However, many oil palm plantations in the country, especially those developed and managed by rural farmers, still suffer from relatively low production yields. This can be attributed to poor soil quality, which are characterized mainly by low pH, CEC, and organic C values. Thus, in order to increase oil palm production, soil amendment practices, such as fertilization, are required. Humic substances are complex organic compounds that can improve the physical, chemical, and biological properties of soils and stimulate plant growth. However, they are generally applied in the field in small quantities, in liquid form. As such, humic substances in the soil can be leached quickly, hence, a carrying and binding medium is needed to hold them longer and release them back slowly. Zeolite, which is a highly porous and adsorbent material and has a high cation exchange capacity (CEC), can serve this function. Thus, this study aimed to increase oil palm production by using humic substance with zeolite as carrier. Twelve treatment combinations, consisting of 4 doses of humic substance (HS): 0 L/ha (H0), 5 L/ha (H1), 10 L/ha (H2), and 15 L/ha (H3); and 3 doses of carrier zeolite: 0 kg of zeolite/L HS (Z0), 10 kg of zeolite/L HS (Z1), and 20 kg of zeolite/L HS (Z2). Each treatment was applied to oil palm trees aged 6 years in Block 26, Compartment 1 of PT Perkebunan Nusantara (PTPN) VIII in Cimulang, Bogor. The results showed that the application of humic substance could increase gross fresh fruit bunch (FFB) weight. The application of 10 L/ha of humic substance with 20 kg zeolite/L HS (H2Z2) produced FFB that can yield 32 tons/ha/year, or a 30% increment, compared to Control. In summary, the best treatment combination in this study was 10 L/ha HS with 20 kg zeolite carrier for every liter HS.

Keywords: Humic substances, oil palm production, fresh fruit bunches, soil amendment, zeolite

1. Introduction
Oil palm (Elaeis guineensis Jacq.) is a rising flagship plantation crop of Indonesia being the country’s key source of natural oil. Every year sees a sharp increase in the hectarage of new oil palm plantations being developed inside the country. One reason for this fast expansion is its capacity to grow robustly even on marginal lands, for as long as there is ample rainfall throughout the year. To illustrate, this year (2019), the total land area planted to oil palm has reached over 15 million hectares yielding more than 50 million tons of crude palm oil (CPO) of which around 70% is exported. Oil palm is the main source
of such products as cooking oil, industrial oil, fuel oil (biodiesel), among many other oil-based commodities. Aside from these, the production residues of oil palm can be used as livestock feed, fertilizer, and alternative fuel material.

Most of the oil palm plantations in Indonesia are located outside Java, especially in Sumatra and Kalimantan. Nevertheless, the productivity level of oil palm plantations in Indonesia is still generally low, averaging only 20 tons of fresh fruit bunches (FFB) per hectare per year. In comparison, oil palm productivity in Malaysia averages 28 tons/ha/year. Lower productivity levels are observed in oil palm plantations of farmers, which can be attributed mainly to lower intensity of plantation management, particularly soil improvement and site maintenance. The soils in oil palm plantations are characteristically poor due to low levels of pH (highly acidic), cation exchange capacity (CEC), and organic matter content. Thus, it follows that raising the soil quality can boost materially the growth and yield of oil palm. One such promising soil amendment method is the use of humic substances, which can be extracted from organic materials like compost and weathered coal. Humic substances are complex organic compounds that can improve the physical, chemical, and biological properties of soils and stimulate plant growth. However, they are generally applied in the field in small quantities, in liquid form, so that they can be leached in the soil rather quickly. Therefore, a carrying and binding agent is needed to hold them longer and release them back slowly. Zeolite, which is a highly porous and adsorbent material, with a high CEC (120-180 meq/100g) [1], adsorption and molecular filtering capacity, and can function both as a catalyst and an ion exchanger, can serve this crucial purpose. The overall effect of this humic substance-zeolite combination is effective and cost-efficient fertilization of oil palm, which will improve soil quality and nutrient uptake, which, in turn, will promote root development, plant growth, and, ultimately, crop yield.

The objective of this study was to determine the effects of the application of humic substance with zeolite as carrier on the growth and yield of oil palm in plantation.

2. Material and methods
Field research was conducted from December 2010 to June 2011 in a 6-year old oil palm plantation in Block 26, Compartment 1 PTPN VIII in Cimulang, Cindali village, District of Rancabungur, Bogor Regency in Java. The initial phase of this study involved finding a suitable experimental location. A randomized block experimental design was used with 12 treatment combinations consisting of 4 dosages of humic substance: 0 L/ha (H0), 5 L/ha (H1), 10 L/ha (H2), and 15 L/ha (H3); and 3 levels of carrier zeolite: 0 kg zeolite/L humic substance (Z0), 10 kg zeolite/L humic substance (Z1), and 20 kg zeolite/L humic substance (Z2). Humic substance used was in liquid form while zeolite was in 2-5 mm solid particles. The individual treatments were applied evenly around each test oil palm tree.

The oil palm plantation that was chosen for this study was of uniform visible growth attributes, and was located on generally flat terrain. For this study, 9 oil palm trees were selected in each planting row to serve as a sample test unit, making up a total of 12 x 9, or 108 oil palm trees. Observation parameters included the number and weight of fresh fruit bunches (FFB) per oil palm tree, that were measured weekly over 6 months, and the estimated total yield (production) was extrapolated for one whole year. The 6-month weekly data were tabulated. In actual plantation situation, the fresh fruit bunches of oil palm are harvested at weekly intervals, but the harvesting scheme depends mainly on the ground topography and availability of workers [2].

3. Results and discussion

3.1. Effects of application of humic substance-zeolite on number of fresh fruit bunches
The 6-month weekly data on the effects of the application of humic substance with zeolite as carrier on the total number of fresh fruit bunches (FFB) of oil palm are summarized in Table 1. It can be observed that the treatments generally did not significantly increase FFB production. Nevertheless, while Treatment H2Z1 produced the lowest number of fresh fruit bunches (61), Treatment H0Z2 produced the highest quantity (100).
Fruit production in oil palm is a direct function of the number of fruit stalks, but not all stalks bear harvestable fruits. Fruit bearing is influenced by several factors such as available soil nutrients, climatic condition, and plantation management regime. According to [3], oil palm in plantation can produce up to 2 fruit stalks per month, or as many as 24 fruit stalks in one year, and each tree continues to grow new stalks until the next harvest time, and the growing-harvesting cycle continues. To determine maturity (ready for harvest), the visual indicators used are changes in fruit color and other ripening signs. Oil palm fruits usually change color from green to blackish and, later, to reddish or orange [2].

3.2. Effects of application of humic substance-zeolite on weight of fresh fruit bunches (FFB)

Based on the data on the observed weights of fresh fruit bunches (FFB) of the treated oil palm trees (Table 2), there was a general tendency of increased FFB weights, particularly with Treatment H2. For instance, Treatment H2Z2 exhibited the highest gross weight (977.5 kg/9 trees), which corresponded to an FFB production of 32.0 ton/ha/year. This yield represented a 30% rise compared to Control (Table 3). Although the humic substance-zeolite application did not significantly affect the average bunch weight (ABW), which was obtained by dividing the total FFB weight by the number of fruit bunches, based on Table 3, there was a marked tendency for a higher ABW. However, the range of ABW values differed from the range in FFB yield (Figure 1).

![Figure 1](image-url)

**Figure 1.** Graph showing the relationship between Treatment and average bunch weight (ABW) and fresh fruit bunches (FFB)
**Table 1.** Number of fresh fruit bunches (FFB) of oil palm yielded over 6 months

| Treatmen | Harvest No. | Total FFB (/9 trees) |
|----------|-------------|---------------------|
| t        | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| H0Z0     | 0 | 2 | 5 | 4 | 1 | 4 | 2 | 4 | 1 | 3 | 4 | 4 | 3 | 4 | 5 | 4 | 4 | 9 | 6 | 4 | 1 | 1 | 75 |
| H0Z1     | 1 | 3 | 3 | 2 | 2 | 3 | 4 | 4 | 2 | 7 | 5 | 7 | 3 | 2 | 6 | 8 | 3 | 2 | 5 | 5 | 3 | 2 | 82 |
| H0Z2     | 0 | 2 | 6 | 6 | 3 | 7 | 6 | 8 | 5 | 8 | 7 | 5 | 6 | 5 | 3 | 5 | 2 | 1 | 5 | 4 | 3 | 3 | 100 |
| H1Z0     | 0 | 2 | 1 | 1 | 1 | 5 | 3 | 4 | 5 | 5 | 6 | 3 | 3 | 4 | 4 | 4 | 4 | 3 | 4 | 5 | 3 | 4 | 74 |
| H1Z1     | 0 | 1 | 2 | 1 | 1 | 4 | 3 | 3 | 1 | 4 | 3 | 4 | 4 | 5 | 4 | 2 | 4 | 3 | 4 | 7 | 6 | 5 | 71 |
| H1Z2     | 2 | 3 | 5 | 0 | 3 | 5 | 4 | 1 | 1 | 5 | 6 | 2 | 3 | 4 | 3 | 4 | 4 | 4 | 5 | 4 | 76 |
| H2Z0     | 1 | 1 | 0 | 1 | 0 | 0 | 5 | 5 | 6 | 7 | 6 | 6 | 3 | 5 | 4 | 3 | 5 | 3 | 2 | 3 | 3 | 5 | 74 |
| H2Z1     | 0 | 4 | 1 | 1 | 1 | 0 | 2 | 2 | 2 | 3 | 5 | 3 | 3 | 6 | 2 | 1 | 5 | 4 | 2 | 4 | 3 | 7 | 61 |
| H2Z2     | 0 | 5 | 3 | 6 | 5 | 4 | 4 | 5 | 3 | 2 | 5 | 1 | 2 | 6 | 2 | 4 | 7 | 6 | 3 | 7 | 5 | 4 | 89 |
| H3Z0     | 1 | 1 | 3 | 3 | 4 | 3 | 6 | 2 | 5 | 4 | 5 | 4 | 1 | 4 | 0 | 0 | 6 | 2 | 0 | 2 | 8 | 4 | 68 |
| H3Z1     | 0 | 0 | 2 | 1 | 1 | 1 | 5 | 4 | 6 | 4 | 6 | 4 | 2 | 4 | 6 | 2 | 2 | 2 | 4 | 4 | 4 | 3 | 67 |
| H3Z2     | 0 | 2 | 2 | 3 | 5 | 1 | 4 | 5 | 2 | 3 | 2 | 4 | 3 | 6 | 1 | 2 | 1 | 4 | 3 | 6 | 3 | 4 | 66 |

Notes: H0: 0 L humic substance/ha; H1: 5 L/ha; H2: 10 L/ha; H3: 15 L/ha
Z0: 0 kg zeolite/L humic substance; Z1: 10 kg zeolite/L humic substance; Z2: 20 kg zeolite/L humic substance
### Table 2. Weights of fresh fruit bunch (FFB) yielded during each harvest over 6 months

| Treat | Harvest No. | FFB Weight (kg/9 trees) |
|-------|-------------|-------------------------|
|       | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| H0Z   | 17 | 32 | 46 | 10.5 | 44 | 21 | 30 | 25 | 51 | 41 | 33 | 47 | 59 | 33 | 38 | 86 | 55 | 41 | 13 | 15 | 751.0 |
| 0     | 0.0 | 5 | 5 | 0 | 0 | 0 | 0 | 5 | 9.5 | 0 | 5 | 5 | 0 | 5 | 0 | 5 | 0 | 0 | 0 | 5 | 0 | 0 | 781.5 |
| H0Z   | 12 | 32 | 30 | 17 | 25.5 | 34 | 39 | 40 | 20 | 57 | 51 | 71 | 25 | 21 | 62 | 76 | 32 | 24 | 43 | 56 | 21 | 19 | 812.5 |
| 1     | 5 | 0 | 5 | 0 | 0 | 0 | 5 | 0 | 5 | 0 | 5 | 0 | 0 | 5 | 0 | 0 | 5 | 0 | 0 | 5 | 5 | 0 | 897.5 |
| H0Z   | 16 | 52 | 58 | 33 | 0 | 63 | 51 | 70 | 49 | 70 | 73 | 55 | 55 | 37 | 31 | 40 | 17 | 13 | 35 | 32 | 22 | 22 | 881.0 |
| 2     | 0.0 | 0 | 5 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 | 0 | 0 | 0 | 5 | 5 | 0 | 0 | 0 | 5 | 5 | 0 | 926.5 |
| H1Z   | 29 | 13 | 16 | 16.0 | 49 | 51 | 58 | 43 | 52 | 63 | 29 | 35 | 49 | 49 | 41 | 48 | 27 | 58 | 78 | 29 | 44 | 909.2 |
| 0     | 0.0 | 5 | 0 | 0 | 0 | 5 | 5 | 0 | 5 | 0 | 0 | 5 | 5 | 0 | 0 | 5 | 5 | 0 | 0 | 5 | 5 | 0 | 914.0 |
| H1Z   | 12 | 10 | 11 | 54 | 20 | 27 | 10 | 33 | 23 | 43 | 67 | 65 | 54 | 23 | 52 | 33 | 47 | 97 | 77 | 54 | 48 | 812.5 |
| 1     | 0.0 | 5 | 5 | 9.0 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 | 0 | 5 | 0 | 5 | 0 | 0 | 0 | 5 | 0 | 0 | 948.5 |
| H1Z   | 26 | 29 | 53 | 41 | 0 | 55 | 53 | 11 | 11 | 48 | 72 | 27 | 43 | 51 | 52 | 48 | 46 | 44 | 34 | 46 | 47 | 51 | 46 |
| 2     | 2.0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 5 | 5 | 0 | 0 | 5 | 5 | 0 | 0 | 5 | 5 | 0 | 948.5 |
| H2Z   | 12 | 15 | 14 | 56 | 50 | 70 | 91 | 79 | 78 | 35 | 67 | 58 | 41 | 66 | 34 | 21 | 36 | 37 | 48 | 69 | 55 | 68 |
| 0     | 0.0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 | 5 | 5 | 0 | 5 | 5 | 5 | 0 | 0 | 5 | 5 | 0 | 977.5 |
| H2Z   | 56 | 12 | 18 | 10.0 | 24 | 26 | 23 | 33 | 64 | 23 | 39 | 78 | 31 | 15 | 68 | 45 | 14 | 55 | 36 | 58 | 48 | 812.5 |
| 1     | 0.0 | 0 | 5 | 5 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 | 5 | 0 | 5 | 5 | 5 | 5 | 0 | 0 | 5 | 5 | 0 | 730.0 |
| H2Z   | 41 | 33 | 53 | 52 | 0 | 44 | 47 | 54 | 30 | 26 | 58 | 18 | 76 | 22 | 57 | 83 | 54 | 27 | 71 | 54 | 48 | 730.0 |
| 2     | 0.0 | 5 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 0 | 0 | 5 | 9.5 | 5 | 0 | 0 | 5 | 0 | 0 | 5 | 5 | 0 | 977.5 |
| H3Z   | 14 | 12 | 31 | 31 | 40.5 | 23 | 55 | 21 | 46 | 44 | 52 | 42 | 10 | 37 | 56 | 24 | 19 | 71 | 47 | 48 | 57 | 54 |
| 0     | 0 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 5 | 0 | 0 | 5 | 0 | 0 | 680.0 |
| H3Z   | 18 | 13 | 17 | 56 | 37 | 77 | 49 | 67 | 52 | 25 | 41 | 64 | 17 | 20 | 22 | 53 | 43 | 44 | 44 | 36 | 57 | 54 |
| 1     | 0.0 | 0 | 5 | 5 | 7.5 | 0 | 5 | 5 | 5 | 5 | 5 | 0 | 0 | 0 | 5 | 5 | 5 | 0 | 0 | 5 | 5 | 0 | 764.0 |
| H3Z   | 32 | 20 | 30 | 57.0 | 13 | 42 | 53 | 20 | 33 | 28 | 43 | 41 | 74 | 12 | 23 | 12 | 43 | 24 | 69 | 41 | 55 | 57 |
| 2     | 0.0 | 5 | 0 | 5 | 0 | 0 | 5 | 5 | 0 | 0 | 5 | 5 | 0 | 0 | 5 | 5 | 0 | 0 | 5 | 0 | 5 | 769.5 |

Notes: Treat: treatment, H0: 0 L humic substance/ha; H1: 5 L/ha; H2: 10 L/ha; H3: 15 L/ha, Z0: 0 kg zeolite/L humic substance; Z1: 10 kg zeolite/L humic substance; Z2: 20 kg zeolite/L humic substance
Table 3. Effects of application of humic substance-zeolite carrier on the number of fruit bunches, weight of fruit bunches, average bunch weight (ABW), and potential fresh fruit bunches (FFB) yield of oil palm

| Treatment | Total Number of Bunches (Fruits/9 trees) | Weight of Bunches (kg/9 trees) | Average Bunch Weight (kg) | Potential Fresh Fruit Bunch (ton/ha/year) | Increase in FFB (%) |
|-----------|----------------------------------------|-------------------------------|--------------------------|-------------------------------------------|--------------------|
| H0Z0      | 75                                     | 751.0                         | 10.0                     | 24.6                                      | 100                |
| H0Z1      | 82                                     | 812.5                         | 9.9                      | 26.6                                      | 108                |
| H0Z2      | 100                                    | 897.5                         | 9.0                      | 29.4                                      | 120                |
| H1Z1      | 71                                     | 826.5                         | 11.6                     | 27.0                                      | 110                |
| H1Z2      | 76                                     | 909.2                         | 12.0                     | 29.8                                      | 121                |
| H2Z0      | 74                                     | 914.0                         | 12.4                     | 29.9                                      | 122                |
| H2Z1      | 61                                     | 730.0                         | 12.0                     | 23.9                                      | 97                 |
| H2Z2      | 89                                     | 977.5                         | 11.0                     | 32.0                                      | 130                |
| H3Z0      | 68                                     | 680.0                         | 10.0                     | 22.3                                      | 91                 |
| H3Z1      | 67                                     | 764.0                         | 11.4                     | 25.0                                      | 102                |
| H3Z2      | 66                                     | 769.5                         | 11.7                     | 25.2                                      | 102                |

Notes: H0: 0 L humic substance/ha; H1: 5 L/ha; H2: 10 L/ha; H3: 15 L/ha
Z0: 0 kg zeolite/L humic substance; Z1: 10 kg zeolite/L humic substance; Z2: 20 kg zeolite/L humic substance

The prescribed level of fertilizer dosage are usually based on several factors like target FFB yield, plantation age, nutrition status (based on leaf analysis and field observations), fertilization history, soil fertility, rainfall record, and results of prior fertilizer tests. These factors need to be analyzed thoroughly in order to ensure maximum FFB production, as pointed out by [4].

Overall, the application of fertilizer and humic substances produces positive effects on oil palm production, but which are widely variable depending on site conditions and age of plantation. This is consistent with the finding of [5] that there is no single fertilization formula that is generally applicable for oil palm plantations. Among the key factors that must be considered beforehand are soil type and fertility levels as well as climatic factors, which vary from site to site, such that fertilizer regimes should be made site-specific. In addition, genetic potential, age of plantation, and cultural practices also play an important role in determining the appropriate type and dosage of fertilizer for oil palm plantation for a given time period.

The productivity of oil palm varies directly with age of the plantation. Plantations, which are 15 years or older yield much more, than younger oil palms do. Above the age of 10 years, the average bunch weight (ABW) is generally uniform every year. Hence, fertilizer should be applied using a standard or prescribed dose. Each oil palm tree should receive the recommended fertilizer type and dosage to ensure maximum and uniform yield of fresh fruit bunches [4].

While it is true that oil palm is tolerant to less favorable site conditions, in order to produce healthier and more productive plants, cultural treatments that can ameliorate such site conditions should be instituted. As reported [6], plant growth and yield are closely related to available soil nutrients. The capacity of plants to assimilate nutrients is limited by climatic and edaphic factors. Similarly, [7] disclosed that plant production is governed by 3 key factors: genetic traits, climate and soil, and prescribed fertilization. In this connection, plantation crops respond differently to variation in site, even though soil fertility and genetic potential may be comparable. It is widely known that the lack of a nutrient can restrict the development of one or several key plant parts.
From a genetic standpoint, the oil palms that were used as subject of this study were generally uniform, that is, from Avros variety. Avros is known to have a fresh fruit bunch production (FFB) potential of 30 ton/ha and palm oil yield reaching 7.8 ton/ha/year.

The capacity of plants to absorb nutrients is also influenced by climatic condition. The higher water that is available, the faster also will be harvest time and the higher will be production of fresh fruit bunch. The study site was located in Rancabungur Sub-Regency, Bogor Regency, which falls under a climate zone, in which rainfall ranges between 2500 and 4000 mm annually, meaning that there is ample water supply for the oil palm plantation.

Aside from playing an important role in boosting soil fertility, humic substances also positively influence plant growth by facilitating respiration, increasing cell permeability, and promoting the uptake of water and nutrients by roots. In short, humic substances can be used as fertilizer, ameliorating agent, and a hormone stimulating plant growth. Further, humic substances can hasten water absorption, accelerate seed germination, spur root development, and drive root cell lengthening [8].

In this study, zeolite was used as carrier for humic substance. By itself, however, zeolite did not significantly increase the number and weight (total and average) of fresh fruit bunches (FFB). Likewise, the combination humic substance-zeolite did not produce a significant interactive effect on the oil palm growth and yield parameters. These non-significant effects could have been due to the dosage levels of the humic substance and zeolite which might have been too low. Nonetheless, although the zeolite was applied in very small amount, its use as carrier did raise FFB weight of the oil palm. This is clearly demonstrated in Table 4, in which bunch weight for oil palm that was not applied with humic substance (H0) actually exhibited an 8% increase with the addition of 10 kg zeolite/L humic acid, and 20% with the addition of 20 kg zeolite/L humic acid.

Zeolite has a remarkable adsorbent property, brought about by its characteristically porous structure. It can attract a considerable amount of small molecules, or of size allowed by its structural porosity. Exchangeable cations and water molecules in the zeolite are not tightly bound hence, they can be exchanged easily through leaching with a solution containing other cations [9].

The best humic substance-zeolite treatment combination was the application of 10 L/ha mixed with 20 kg zeolite per L humic substance. Oil palm that was given Treatment H2Z2 produced a 30% increase in fresh fruit bunch (FFB), as compared to Control. This could be explained by the fact that humic substance can increase the level of organic matter content of the soil, as well as the adsorbent property of the zeolite that keeps the humic substance for a longer time and release it back at a slower rate.

4. Conclusion

Humic substances can raise oil palm yield by directly increasing the number and weight of harvested fresh fruit bunches (FFB). Zeolite can effectively serve as humic substance carrier, and both interact to bring about marked improvement in oil palm productivity. The best treatment dosage in this study was that of 10 L/ha humic substance mixed with 20 kg zeolite per L humic substance as carrier that can yield up to 32.0 ton/ha/year FFB, or an increase in productivity of 30% compared to Control.

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