The role of humic substances to improve degraded soils for increasing crops production

Suwardi1*

1 Department of Soil Science and Land Resources, Faculty of Agriculture, IPB University, Jalan Meranti, IPB Dramaga Campus, Bogor, Indonesia

*Email: suwardi-soil@apps.ipb.ac.id

Abstract. One of the main problems of lowering crops production on degraded soils is the low soil organic matter. Application of humic substances may improve the quality of degraded soils. The objectives of this research were to study the effect of humic substances application on the production of rice, water spinach, sweet potato, and oil palm, and to describe the mechanism of increasing crops production due to the application of humic substances. In this study, the humic substances were extracted from soft brown coal using a strong base KOH. Humic substances in difference doses are applied to various soil types for several crops. The results showed that application of humic substances increased the production of rice, water spinach, sweet potato, and oil palm. The highest production increase is obtained with a dose of 10-15 liters of the humic substance/ha with a carrier zeolite of 10-20 kg/liter of humic substances. The application of humic substances to soils increases the nutrients available in the soils as well as the the growth of plant roots so that plants can absorb more nutrients from the soils.

1. Introduction

The utilization of agricultural land in Indonesia is more intensive in pursuing food production due to the faster population growth than the expansion of agricultural land. Intensive use of agricultural land causes a decrease in physically, chemically, and biologically quality of the land. The decline in the quality of agricultural land is also triggered by a humid tropical climate, which causes a very intensive process of nutrient leaching resulting in degraded soils. It is necessary to apply a soil amendment to improve the quality of degraded soil so that the soil quality remains high for producing various crops. Farmers generally only apply chemical fertilizers to maintain soil fertility without being accompanied by organic matter, resulting in a decrease in soil quality, which is marked by a decrease in the content of organic matter, pH, macro- and micronutrients. The application of a suitable soil amendment is needed to return the soil to its normal condition. One of the soil amendments that can improve soil physical and chemical properties is humic substances.

The humic substance is the humified fraction of humus, which is characterized by its complex structure, high molecular weight, resistance to decomposition, colloidal, and blackish-brown. Humic substances make up most of the soil organic matter and have an essential role in soil properties and plant growth [1][2]. Humic substances can be extracted from lignite, peat, plant residue compost, and kitchen waste [3]. An essential result of the overhaul of soil organic matter is humus, which is mostly water-insoluble material called humic substances or humic compounds. Organic matter can be applied to the soil in the form of humic compounds. Humic compounds consist of fulvic acid, humic acid, and humin. According to [4], humic substances can improve plant growth through its accelerating respiration,
increasing cell permeability, and increasing water and nutrient absorption. The humic substances can increase protein synthesis, growth hormone activity, increase the rate of photosynthesis and enzyme activity.

One of the problems that need to be solved is how to add humic substances into the soil to make it useful and efficient. Zeolites may be one of the materials that can function as carriers of humic substances. Zeolite is an aluminosilicate mineral that has unique properties, including having a hollow structure, high cation exchange capacity (CEC) value, as an adsorbent and molecular filter, catalyst, and ion exchanger. Zeolite with has a high CEC (120-180 meq/100g), can be used as a humic substances carrier. In addition, the application of humic substances with zeolite will indirectly improve the properties of the soil with the impact of zeolite as a soil amendment [5].

Humic substances can be applied to plants through soil or spraying on the leaves. Various studies, both at the greenhouse and field-scale, have attempted to combine humic substances with other soil amendments, including zeolite carriers [5]. Zeolites, which have a cavity structure that is selective to specific ions and molecules, can absorb the added humic substances and release it slowly into the soil solution.

The objectives of this research were to (1) study the effect of humic substances application with zeolite as a carrier on the production of rice, water spinach, sweet potato, and oil palm; (2) describe the mechanism of increasing agricultural production due to the application of humic substances with zeolite as a carrier.

2. Materials and Methods

2.1. Effect of humic substances on the production of rice, water spinach, sweet potato, and oil palm

Research on the application of humic substances on rice production was carried out in a rice field at Bogor. The rice field was divided into 12 plots measuring 4 x 3 m², and the land of each plot was prepared for planting rice. This study used a factorial randomized block design with two factors. The first factor is the dose of humic substances consisting of 4 levels, namely H0 (0 liters/ha), H1 (5 liters/ha), H3 (10 liters/ha), and H4 (15 liters/ha). The second factor is zeolite as a carrier with three levels, namely Z0 (0 kg zeolite/liter humic substances), Z1 (10 kg zeolite/liter humic substances), and Z2 (20 kg zeolite/liter humic substances). The rice seeds used are the Ciherang variety. Rice is planted when the seeds are 21 days old with a spacing of 25 X 25 cm² with three seeds per planting hole. Each treatment plot was given a necessary fertilizer of urea 150 kg/ha, SP-18 300 kg/ha, and KCl 200 kg/ha. Furadan is used for plant protection. Weeding and eradicating plant diseases were done if necessary. Measurement of rice production parameters was carried out to evaluate the effect of humic substances and zeolites as carriers. Rice is ready to be harvested after 14 weeks of planting and then measured by the rice straw biomass, root weight of samples, and unhulled rice.

Research on the application of humic substances to increase water spinach production was carried out using a completely randomized block design with a single factor. The treatments are (1) control (without application of humic substances and zeolite), (2) humic substances were applied into the soil at the dose of 15 liters/ha, (3) spray humic substances to the leaves at a dose of 15 liters/ha once every four days after diluting 100 times, (4) zeolite was applied into the soil at a dose of 150 kg/ha, and (5) humic substances at a dose of 15 liters/ha applied to soil with zeolite 10 kg/liter of humic substances as a carrier. Each treatment consisted of three replications, so that there were 15 experimental units. The water spinach was planted on a 2 x 3 m² plot with a distance of 40 cm between lanes. Each plot was applied necessary fertilizers in compost and urea at a dose of 3 tons/ha and 150 kg/ha, respectively. Compost was applied simultaneously as planting, while urea was applied half the dose at one week after planting (WAP), and the rest was applied at 2 WAP. Growth parameters, including plant height, number of leaves, and leaf length, were measured. Five plants were sampled in each plot. Harvesting is done when the plants reach 28 days. Data from observations and laboratory analyses were processed using a One-way Analysis of Variance (ANOVA). If the treatment had a significant effect on the observed parameters, a further test was carried out using Duncan's multiple range test (DMRT) at the 5% significant level.
The application of humic substances on sweet potato production was carried out in the agricultural area of Bantarjaya Village, Rancabungur District, Bogor Regency. The field experiment was carried out with a randomized block design consisting of 5 treatments in 3 groups as replications in order to obtain 15 experimental units. The treatments are (1) control (without application of humic substances and zeolite), (2) humic substances were applied into the soil at a dose of 15 liters/ha, (3) spray humic substances to the leaves at a dose of 15 liters/ha once every four days after diluting 100 times, (4) zeolite was applied into the soil at a dose of 150 kg/ha, and (5) humic substances at a dose of 15 liters/ha applied to soil with zeolite 10 kg/liter of humic substances as a carrier. The necessary fertilizers used are urea fertilizer 100 kg/ha, SP-18 98 kg/ha, and KCl 245 kg/ha. Data analysis used the Analysis of Variances (ANOVA) with the Duncan Multiple Range Test (DMRT) advanced tests at the 5% level. Parameters observed at harvest including (1) tuber weight per plant: calculated by weighing the tuber yield after harvesting in the sample plants; (2) number of tubers: counted by adding up the tubers in the sample plant; (3) tuber weight per plot: calculated by weighing the total tuber yield of each treatment; (4) biomass weight per plant: calculated by weighing crop after harvesting for each sample plant.

Application of humic substances on oil palm production was conducted in Block 26, Afdeling 1 PTPN VIII oil palm plantation in Cimulang, Bogor. The study used a randomized block design with 12 treatments from a combination of 4 doses of humic substances H0 (0 liters/ha), H1 (5 liters/ha), H3 (10 liters/ha), and H4 (15 liters/ha) and three doses of zeolite as a carrier: Z1 (0 kg zeolite/liter humic substances), Z2 (10 kg zeolite/liter humic substances), Z3 (20 kg zeolite/liter humic substances). Humic substances in the form of liquid according to treatment ratio mixed with zeolite in the form of grain 2-5 mm. The area of the oil palm plantations for this study was selected in an area with homogeneous growth on a flat plot. One line was used as one treatment so that the total number of oil palms was 12 x 9 trees. Observations were made on the number of bunches and fruit weight of each bunch measured every week for six months. The number of bunches and each bunch’s weight in one year was calculated based on data for six months.

2.2. Effect of humic substances on soil properties and plant nutrients
In the experiment applying of humic substances on sweet potato production, besides measuring the production parameters as described above, soil and plant analyzes were also carried out. Soil analysis was conducted at the Department of Soil and Land Resources, Faculty of Agriculture, IPB University. Parameters of soil chemical properties analyzed to evaluate effect of the application of humic substances and zeolite as a carrier to the soil properties are cation exchange capacity (CEC) and exchangeable bases, soil organic C, total soil N, available P, and micronutrients (Fe, Cu, Zn, and Mn). CEC and exchangeable bases were extracted using ammonium acetate pH 7.0. Ca and Mg were measured by the atomic absorption spectrophotometer (AAS), while K and Na were measured by flame photometer. Soil organic C was analyzed by the Walkley-Black titration method, and total N was analyzed by the Kjeldahl method. The soil P was analyzed by the Bray-1 method, while micronutrients was extracted by the DTPA solution. The parameters of elemental content in sweet potato plants were N, P, K, Ca, Mg, Na, Fe, Mn, Cu, and Zn. N was analyzed by wet ashes using H2SO4 and H2O2, then distilled and titrated with HCl. P was analyzed using dry ashes using HNO3 and HCl, then measured by a spectrophotometer. K was analyzed by dry ashes using HNO3 and HCl, then measured with a flame photometer. Other elements were analyzed by dry ashes and measured by AAS.

3. Results and Discussion
3.1. Effect of humic substances on the production of rice, water spinach, sweet potato, and oil palm
The application of humic substances did not significantly increase the biomass, root weight, total unhulled rice but tended to increase the root weight and percentage of increased production. The more humic substance dose, the higher the rice production. For the amount of humic substances and zeolite as a carrier, the amount of 15 liters/ha of humic substances and zeolite 10 kg/liter humic substances were the optimal amount. With these doses, the increase in rice production, reaching 33% compared to the control. There is a very close relationship between root weight and rice production. The greater the root weight, the greater the rice production. The application of humic substances seems to stimulate root
development, which can then absorb more nutrients from the soil. With the higher number of nutrients absorbed by plants in soil treated with humic substances, rice production will increase (Table 1).

Table 1. Effect of humic substances on rice production

| Treatment  | Biomass (g) | Root weight (g) | Total Unhulled Rice (kg/plot) | Equivalent Production (ton/ha) | Increased Production (%) |
|------------|-------------|-----------------|-----------------------------|-------------------------------|-------------------------|
| H0Z0       | 249.5       | 54.0            | 4.49                        | 3.74                          | 100                     |
| H0Z1       | 231.3       | 76.8            | 4.93                        | 4.11                          | 110                     |
| H0Z2       | 273.3       | 72.8            | 5.23                        | 4.36                          | 116                     |
| H1Z0       | 281.5       | 60.5            | 5.19                        | 4.33                          | 116                     |
| H1Z1       | 264.0       | 80.5            | 5.18                        | 4.32                          | 115                     |
| H1Z2       | 213.0       | 94.0            | 5.23                        | 4.36                          | 116                     |
| H2Z0       | 238.3       | 68.8            | 5.67                        | 4.73                          | 126                     |
| H2Z1       | 361.0       | 96.0            | 5.21                        | 4.34                          | 116                     |
| H2Z2       | 175.5       | 83.5            | 5.48                        | 4.57                          | 122                     |
| H3Z0       | 232.5       | 75.3            | 5.90                        | 4.92                          | 131                     |
| H3Z1       | 310.0       | 97.5            | 5.97                        | 4.98                          | 133                     |
| H3Z2       | 233.0       | 71.0            | 4.67                        | 3.89                          | 104                     |

Notes: H0=humic substances 0 liter/ha; H1=humic substances 5 liter/ha; H2=humic substances 10 liter/ha; H3=humic substances 15 liter/ha; Z0=0 kg zeolite/liter humic substances; Z1=10 kg zeolite/liter humic substances; Z2=20 kg zeolite/liter humic substances; * Compared to H0Z0 as control treatment.

Table 2. The Effect of humic substances on the growth and production of water spinach aged 4 WAP

| Treatment                        | Plant Height (cm) | Length of Leaf (cm) | Number of Leaves | Production kg/plot | Increased Production (%) |
|----------------------------------|-------------------|--------------------|------------------|-------------------|-------------------------|
| Control                          | 19.3 b            | 11.5               | 23               | 4.81              | 100                     |
| Humic substances through soil*   | 20.0 ab           | **11.8**           | 28               | 6.18              | 128                     |
| Humic substances through leaf**  | 20.6 ab           | 11.9               | 27               | 6.47              | 135                     |
| Zeolite                          | 20.3 ab           | 10.9               | 27               | 5.95              | 124                     |
| Humic substances with zeolite****| 22.0 a            | 12.1               | 30               | 7.63              | 159                     |

Notes: *15 liters/ha of humic substances applied through the soil; **15 liters/ha of humic substances applied through leaf; ***150 kg/ha applied to soil; ****15 liters/ha humic substances applied through the soil with zeolite as carrier 10 kg zeolite/liter humic substances; The numbers followed by the same letter are not significantly different at the 5% level, according to the DMRT test.

The height of water spinach plants at 4 WAP treated with humic substances 15 liters/ha with zeolite as a carrier increased significantly compared to control (Table 2). An increase in plant height is also followed by an increase in leaf length and leaf number. The production of water spinach was up to 7.63 kg/plot or an increase of 59% compared to the control. It can also be seen that applying humic substances with zeolite as a carrier is better than without carrier. If the application of humic substances without a carrier, it is better applied through leaves than soil. However, application through leaves requires more time or labors. It appears that the carrier of humic substances such as zeolite provides better results. Zeolites will act as ingredients that hold humic substances longer, keeping them in the soil.

Application of humic substances 15 liters/ha with zeolite carrier at a dose of 10 kg zeolite/liter of humic substances significantly increased tuber weight per plant of sweet potato, which was also
followed by tendency an increase in the number of tubers/5 plants, biomass weight per plant and tuber weight per plot (Table 3). The increase in the percentage of tuber weight per plot in this treatment reached 20% compared to the control. The increase in potato production by application of humic substances through leaves was higher than that of application through the soil. From these data, it can be seen that the best application of humic substances with zeolite as a carrier if it is applied through the soil. If humic substances are applied without a carrier, it is better to apply humic substances through leaves.

| Treatment                        | Number of tubers/5 plants | Tuber weight per plant (g) | Biomass weight per plant (g) | Tuber Weight (kg/plot) | Increased Tuber Weight (%) |
|----------------------------------|---------------------------|----------------------------|------------------------------|------------------------|---------------------------|
| Control                          | 9                         | 416 b                      | 320                          | 26.36                  | 100                       |
| Humic substances through soil*   | 11                        | 542 ab                     | 410                          | 26.81                  | 102                       |
| Humic substances through leaf**  | 11                        | 575 ab                     | 446                          | 28.70                  | 109                       |
| Zeolite***                       | 10                        | 496 ab                     | 413                          | 27.41                  | 104                       |
| Humic substances with zeolite****| 12                        | 629 a                      | 461                          | 31.95                  | 120                       |

Notes: *15 liter/ha of humic substances applied through the soil; **15 liter/ha of humic substances applied through leaf; ***150 kg/ha applied to soil; ****15 liters/ha humic substances applied through the soil with zeolite as carrier 10 kg zeolite/liter humic substances; The numbers followed by the same letter are not significantly different at the 5% level, according to the DMRT test.

The effect of humic substances on oil palm production showed that the highest oil palm production was obtained in the treatment of humic substances 10 liters per hectare with a carrier of zeolite 20 kg/liter humic substances. The oil palm production reached 32.0 ton/ha/year or increased 32 percent compared to control (Table 4). The increase in production was due more to the increase in the number of bunches.
than the increase in the average weight of bunches.

3.2. Effect of humic substances and zeolites as carriers on the chemical properties of soil and plant tissues

Effect of humic substances of macronutrients in the soil after planting sweet potato can be seen in Table 5. CEC and exchangeable K values tend to increase in the treatment of humic substances and zeolite. This is because the humic material contains carboxyl and phenolic groups, which are a source of negative charges, so that the higher the humic substances, the more generous the contribution of the functional groups of carboxyl and phenolic, which means that the negative charge of the soil increases. Zeolite has a high CEC value, which can contribute to the increase of zeolite, and even zeolite has been known as an ameliorant to increase soil CEC.

Table 5. Effect of humic substances of macronutrients in the soil after planting sweet potato

| Treatment                           | Total-C % | Total-N % | CEC meq/100g | Ex-Ca ppm | Ex-Mg ppm | Ex-K ppm | Ex-Na ppm | Av-P ppm |
|-------------------------------------|-----------|-----------|--------------|-----------|-----------|----------|-----------|----------|
| Control                             | 2.00      | 0.17      | 15.78        | 9.14      | 2.40      | 0.75     | 1.20      | 24.4     |
| Zeolite*                            | 1.77      | 0.16      | 16.61        | 8.11      | 2.27      | 0.75     | 1.18      | 24.3     |
| Humic substances through soil**     | 1.98      | 0.22      | 15.42        | 8.42      | 2.21      | 0.71     | 1.33      | 24.8     |
| Humic substances through leaf***    | 2.04      | 0.16      | 17.22        | 8.65      | 2.31      | 0.70     | 1.10      | 23.8     |
| Humic substances with zeolite****   | 2.00      | 0.19      | 16.33        | 8.82      | 2.31      | 0.83     | 1.45      | 24.9     |

Notes: * zeolite 150 kg/ha applied to soil; **15 liters/ha of humic substances applied through the soil; ***15 liters/ha of humic substances applied through leaf; ****15 liters/ha humic substances applied through the soil with zeolite as carrier 10 kg zeolite/liter humic substances. The numbers followed by the same letter are not significantly different at the 5% level, according to the DMRT test.

Table 6. Effect of humic substances on micronutrients content in the soil after planting sweet potato

| Treatment                           | Fe (ppm) | Cu (ppm) | Mn (ppm) | Zn (ppm) |
|-------------------------------------|----------|----------|----------|----------|
| Control                             | 4.13     | 0.61     | 129.98 ab| 35.80 b  |
| Zeolite*                            | 3.86     | 0.59     | 118.18 ab| 93.69 a  |
| Humic substances through soil**     | 3.95     | 0.60     | 129.85 ab| 91.21 b  |
| Humic substances through leaf***    | 3.60     | 0.56     | 99.04 b  | 42.15 b  |
| Humic substances with zeolite****   | 3.78     | 0.58     | 151.58 a | 24.20 b  |

Notes: * zeolite 150 kg/ha applied to soil; **15 liters/ha of humic substances applied through the soil; ***15 liters/ha of humic substances applied through leaf; ****15 liters/ha humic substances applied through soil with zeolite as carrier 10 kg zeolite/liter humic substances. The numbers followed by the same letter are not significantly different at the 5% level, according to the DMRT test.

K nutrients play a role in tuber formation [6], where the weight and quality of tubers will increase if the K element available in the soil is sufficient. Elemental K has a powerful effect on tuber root growth, and in general, an increase in K concentration will be followed by an increase in tuber dry matter production and an increase in the strength capacity of the container to accommodate photosynthate [7]. The potassium content in treating of humic substances with zeolite as a carrier had a higher value than the control. The higher K content is caused by the release of elemental K due to humic substances application. According to [4], humic and fulvic acids increase the release of K embedded in the intercellular space of the clay. The element potassium is most needed because it plays an essential role in increasing photosynthetic activity, especially potassium is needed to increase cambium activity in the roots that store starch in them and also to increase the activity of starch synthesis in tubers in the tuber formation period rather than stem and leaf growth [8].
Humic compounds are also useful in the binding micronutrients. All treatments tended to reduce Fe and Cu levels in the range of 4-13% and 2-8% compared to the control (Table 6). By applying humic substances, some of the excess micronutrients are taken from the solution by forming complexes with humic compounds. At one point, these nutrients can be released to the plants in smaller amounts as needed. This means that the binding of metal ions by humic compounds can reduce the danger of poisoning to plants.

Table 7. The effect of humic substances on macronutrients content in sweet potato leaves

| Treatment                      | N (%) | P (%) | Mg (%) | K (%) | Na (%) |
|--------------------------------|-------|-------|--------|-------|--------|
| Control                        | 2.73  | 0.17  | 0.26   | 3.16  | 0.99   |
| Zeolite*                       | 3.53  | 0.19  | 0.27   | 3.09  | 1.05   |
| Humic substances through soil**| 3.58  | 0.17  | 0.26   | 3.29  | 1.00   |
| Humic substances through leaf***| 3.66  | 0.19  | 0.29   | 3.06  | 1.00   |
| Humic substances with zeolite****| 3.16  | 0.21  | 0.27   | 3.02  | 0.97   |

Notes: *zeolite 150 kg/ha applied to soil; **15 liters/ha of humic substances applied through the soil; ***15 liters/ha of humic substances applied through leaf; ****15 liters/ha humic substances applied through the soil with zeolite as carrier 10 kg zeolite/liter humic substances. The numbers followed by the same letter are not significantly different at the 5% level, according to the DMRT test.

Effect of humic substances on macro-and micro nutrients content in sweet potato leaves can be seen in Tables 7 and 8. The concentrations of N and P in plants are in line with soil analysis results where after application of humic substances, the concentrations of N and P tended to increase compared to controls. The increase in N in leaf tissue in all treatments ranged from 15-34%, and the increase in P was 12-24% higher than the control. This illustrate shows that plants absorb N and P more quickly because in the soil, these elements become more available after the application of humic substances and zeolite. Adequacy of nitrogen content is the key to plant growth because the N nutrient stimulates the use of photosynthesis products for canopy growth at the beginning of plant growth to be more optimal. Besides, nitrogen can increase the absorption of potassium and phosphorus nutrients. Micronutrient concentrations of Fe, Cu, and Zn in plants decreased in all treatments, while Mn concentrations increased compared to controls.

Table 8. Effect of humic substances on micro nutrients content in sweet potato leaves

| Treatment                      | Fe (ppm) | Cu (ppm) | Mn (ppm) | Zn (ppm) |
|--------------------------------|----------|----------|----------|----------|
| Control                        | 94.61 a  | 43.12    | 96.32    | 52.11    |
| Zeolite*                       | 9.09 b   | 20.55    | 120.65   | 29.94    |
| Humic substances through soil**| 52.64 ab | 23.60    | 149.46   | 35.42    |
| Humic substances through leaf***| 15.00 b  | 20.56    | 174.25   | 24.48    |
| Humic substances with zeolite****| 21.54 b  | 21.34    | 135.97   | 26.66    |

Notes: *zeolite 150 kg/ha applied to soil; **15 liters/ha of humic substances applied through the soil; ***15 liters/ha of humic substances applied through leaf; ****15 liters/ha humic substances applied through the soil with zeolite as carrier 10 kg zeolite/liter humic substances. The numbers followed by the same letter are not significantly different at the 5% level, according to the DMRT test.

3.3. Mechanism of increasing plant production by application of humic substances

From the data discussed above, there is a similarity of effect applying humic substances on the increased of plant production. Rice production increased 33%, water spinach 59%, sweet potato 20%, and palm oil 32% by applying humic substances 10-15 liters/ha with zeolite as carrier 10-20 kg/liter of humic substances. The increase of plant production is due to an improvement in the availability of nutrients in the soil and followed by an improvement of plant roots so that the roots can absorb more nutrients from the soil. Increasing the number of nutrients in the soil have a positive impact on nutrient uptake and plant growth. Plants uptake nutrients through mass flow, diffusion, and direct absorption by plant roots.
Leaves are the central organ of plants as a place for the results of photosynthesis. A small number of leaves can inhibit the photosynthesis process. Humic substances are excellent foliar activators. Application through leaf spray can stimulate nutrient uptake. Humic substances will increase permeability, so that nutrients can quickly move through the cell membrane, resulting in increased transport of various nutrients to the metabolic system. Humic substances affect hydrophilically (has water affinity) and hydrophobically (lacks water affinity) on the membrane surface. Humic substances can change the phospholipid component of the membrane electrically. As a result of this electrical charge, the membrane surface becomes more active in transporting nutrients from outside the plant cell into the cell’s cytoplasm.

According to [9], humic compounds are known to stimulate plant growth because they increase the absorption of soil nutrients, allow a more excellent distribution of chelating metal ions by plants, and affect metabolic reactions. Organic acids also affect ribonucleic acid (mRNA) in plant cells. Messenger RNA is essential for many biochemical processes in cells. Activation of several biochemical processes leads to an increase in enzyme synthesis and an increase in protein. Besides, the activity of humic compounds in plant tissues is often said to be similar to that of some plant hormones (growth regulators). Plant hormones such as auxins and abscisic acid can regulate proton pump activity that elicits physiological responses. Some organic matter fractions can influence the electrochemical gradient of protons across the cell membrane through modulation of the proton pump. Only part of the nutrients contained in humic substances can be absorbed by plants [10]. The amount of elements absorbed by plants is not sufficient for plant needs. Therefore, the direct effect seen from the application of humic substances is due to the the humic substances’ hormonal properties, not because of the nutrient content that can be absorbed by the plant but stimulation for the increase of nutrients available in the soils.

### 4. Conclusions

The application of humic substances increased the production of rice, water spinach, sweet potato, and oil palm. The highest production increase is obtained with a dose of 10-15 liters of the humic substance/ha with a carrier zeolite of 10-20 kg/liter of humic substances. The application of humic substances to degraded soils increases the nutrients available in the soils and the growth of plant roots so that plants can absorb more nutrients from the soils.

### References

[1] Chen Y, Clapp CE, Magen H. 2004. Mechanisms of plant growth stimulation by humic substances: The role of organo-iron complexes. *Soil Science and Plant Nutrition* **50** (7):1089-1095.

[2] Eyheraguibel, P. Silvestre, J Morard P. 2008. Effects of humic substances from organic waste enhancement on the growth and mineral nutrition of maize. *Bioresource Technology* **99**(10):4206-12.

[3] Dariah Al, Nuruda NL. 2011. Soil improvement formula enriched with humic compounds to increase the productivity of Ultisol in Taman Bungo, Lampung. *Journal of Land and Climate*. (33):33-38.

[4] Tan KH. 1991. *The Principle of Soil Chemistry*. Translated by DH Goenadi. Yogyakarta (ID): Gajah Mada Press.

[5] Suwardi. 2011. Zeolite as a humic substances carrier for increased production of food crops and plantations. Proceedings of the X HITI National Seminar and Congress: Land for a Quality Life, Surakarta 6-8 December 2011.

[6] Lingga P. 1989. *Planting Tubs*. Jakarta (ID): Penebar Swadaya.

[7] Paulus JM. 2011. The growth and yield of sweet potato on potassium fertilization and natural shade in the intercropping system with corn. *J Agrivigor*. **10** (3):260-271.

[8] Nani Z, Supriati Y. 2011. Sweet potato business as alternative food and diversification of carbohydrate sources. *Bul AgroBio*. **4**(1):13-23.

[9] Vallini G, Pera A, Avio L, Valdrighi M, Giovanetti M. 1993. Influence of humic acids on Laurer growth, associated rhizosphere microorganisms, and mycorrhizal fungi. *Biol Fertil Soils*. **16**:1-4

[10] Brady NC. 1990. *The Nature and Properties of Soil*. 10th ed. The Macmillan CO. New York.