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# Growth Characteristics of Lettuce (*Lacttuca Sativa* L. ) As Affected by Biochars and Inorganic Fertilizer

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***Abstract:*** *The objective of this study was to determine the effect of biochars and inorganic fertilizer application rates on soil nutrients and growth characteristics of lettuce. The experimental design was Randomized Block Design (RBD) in a 2x4 factorial scheme, with 2 types of biochar ( rice husk biochar and wood biochar), 4 rates of inorganic fertilizer (0, 100, 200 and 300 kg ha-1) phonska. Both of these factors were combained and each treatment repeated three times. Data collected were analysed statistically by using analysis of variance at 5% level and significant treatments effect were separated with honestly significant difference at $P \leq 0.05$. Plant height, number of leaves, leaf area, total shoot fresh were test as well as soil nutrient status. The use of biochar types did not influence plant growth and soil nutrients status including soil pH, total-N, available-P and exchangeable-K. However, inorganic fertilizer application directly increased all the soil characteristics were evaluated, and also increased the total fresh weight by increasing the plant height, number of leaves and leaf area of lettuce as commercial characteristics for consumers. Application of 200 kg $ha^{-1}$ inorganic fertilizer should be sufficient to improve growth characteristics of lettuce.*

***Keywords****: rice husk, wood, biochar, lettuce, growth characteristics*

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## I. Introduction

Studies on the use of organic materials become important as the price of fertilizers is increasing. Agriculture waste such as : rice husks, rice straw, maize straw, wood or twigs, cocconut shells, tobacco stems, manure and other crop residues, recently have been transformed into biochar for the purpose of carbon sequestration. Biochar is commonly defined as charred organic matter, which is rich in carbon material and obtained from the agriculture waste under the limited oxygen condition, which refer to a solid product that derived from biomass pyrolysis (Lehmann, 2007). Rice husk contains a high content of silicon and potassium, nutrients, which have great potential for amending soil, while those with a relatively higher carbon content (e.g. wood or nut shells) are currently used for the production of activated carbon.

The use of biochar can be sustained soil organic carbon sequestration that would improve the soil quality because biochar is a stable substances and has the longterm effect (Glaser *et al*., 2002). It possibly due to that biochar contains an aromatic structure, hence it is physically, chemically and biologically more stable in soil and would be resistant to decompose for hundred to thousand years (Woolf, 2008). Moreover, Chan *et al*. (2008) reported that adding biochar into the soil would change the soil physical and chemical properties of soil (Lehman, 2009).

Previous study has shown that incorporation of biochar can be used as soil amendment and significantly improve the soil properties by enchancing soil nutrients availability, soil pH, organic carbon which lead to increase the soil quality (Steiner *et al*., 2008; Mulyati *et al*., 2014a). Research has shown the use of rice husks in the field has been practiced for some time and incorporation of rice husks can significantly improve soil properties by decreasing soil bulk density, enhancing soil pH, adding organic carbon, increasing available nutrients and removing heavy metals from the system, ultimately increasing crop yields (Williams *et al*., 1972). In addition, studies on soybean and maize have also supported the application of biochar as a way to increase crop yields (Yamato *et al*., 2006). Therefore, these residues could be a valuable resource for the production of biochar to improve soil fertility and soil quality.

Carbonized (*incompletely burned*) rice husk consist of a very light material and this carbonization process also can increase the organic carbon, water holding capacity (WHC). In addition the farmers practice of burning rice straw in the field showed that the black carbon from rice burned residues would be an important source of organic material in rice field (Schmidt and Novak, 2000). The effects of biochar application may vary from soil to soil and crop to crop. So that there is a need to find out the change of soil chemical properties and agronomic properties of horticulture crops.

Lettuce (*Lactuca sativa* L.) is one of the most popular green vegetables worldwide. Lettuce contains several dietary minerals important for human health such as Phosphorus,

(P), Magnesium (Mg), Potassium (K), Calsium (Ca), Zinc (Zn), Iron (Fe), and Manganese (Mn), but essentially no protein or fat (Kim et al., 2016). In general, leaves contain Vitamin A, Vitamin C, Minerals, Water and Fibber. In addition, lettuce also contains lactocin and lactucopicrin that can be improved sleep. Also contain antioxidants, the compounds inhibit the formation of carcinogenic substances in the body. (Rubatzky and Yamaguchi, 1997).

Lettuce can be grown well in fertile soil that contain organic matter. However, in West Nusa Tenggara, lettuce or vegetable crops in general are mainly grown in sandy soil with very low in production due to the low soil fertility such as low in macro and micro nutrients, low in carbon organic content with less than 1%, low in cation exchange capacity (CEC), poor soil aggregate, decreasing soil bulk density and also low in water and nutrients retention (Mulyati *et al*., 2014b). Therefore, to overcome this constraints, there are several ways can be done to improve the soil quality and increase growth and yield of lettuce i.e. by inorganic fertilizers and biochars application. Marchi *et al*. (2015) found that the use of fertilizers and limimg would affect the lettuce growth, and Milla *et al*. (2015) reported that growth of Water Spinach influenced by the use of biochars.

Although a number of studies have reporting growth and yiled of lettuce, but there are only a few studies working on the influence of using biochar especially rice husk and wood biochars on soil quality improvement, growth and yield of lettuce. Therefore, this study addresses to examined the effects of rice husk (RHB) and wood (WB) biochar applications on the growth and yield of lettuce ; and also to evaluate the effects of biochars on the soil nutrients status.

## II. Materials and methods

### 2.1. Experimental Design

A field experiment trial was conducted in Mataram, Lombok Indonesia. The design was a Randomized Block Design (RBD), consisting two factors, and arranged in a factorial pattern. The first factor was two different biochars types namely : B1 = Rice Husk Biochar and B2 = Wood Biochar. Each plot was treated by the same level of biochar (10 ton ha$^{-1}$) and the second factors was inorganic as phonska (NPK) fertilizers (F) rates, which consisted of four rates namely : F0 = without NPK fertilizer, F1 = 100 kg NPK ha$^{-1}$, F2 = 200 kg NPK ha$^{-1}$ and F3 = 300 kg NPK ha$^{-1}$. Both of these factors were combined, and obtained 8 treatments. Each treatment combination comprised of three replications, so that 24 plots were obtained.

### 2.2. Biochar Preparation

Organic materials from agriculturial waste were produced from Rice Husk (RHB) and Wood (WB) biochars. Woods were chopped into small size, and pyrolysized using a small scale of modified drum at 300-350 °C for 3 hours. Afterward, the carbonized of RHB and WB are extinguished by pouring water to cooling down the biochar. Then, air dry for 3 days and sieve them with 2 mm in diameter. Several analysis for biochar, including pH, CEC, Organic Carbon, total-N, total-P and also total-K.

### 2.3. Soil Analysis

Soil samples were collected from 0 -20 cm horizon on Usti-psamment Lombok (USDA, 1998), which typically used for growing vegetable. Sampling were taken after the soil tillage or before applying fertilizers and biochar, then air dried for 3 days and sieved by 0.5 mm in diameter for soil analysis need. Soil analysis including Texture, soil pH, organic-C, CEC, total-N, available-P, and exchangeable-K.

### 2.4. Variable Test

Variable tested were carried out for agronomics and soil characteristics. Agronomic variables measured were plant height from day 7 until 35 days after transplanting, number of leaf, leaf area, shoot fresh and dry weight and also root fresh and dry weight. The method for soil analysis were pH measured by pH meter, organic-C by Walkley and Black, total-N by Kjeldahl method, available-P was extracted by using Bray I and exchangeable-K by Morgan Wolf method. The data collected were analyzed statistically using the analysis of variance (ANOVA), and the significant difference among the treatments was tested by Honestly significant difference at ($P \leq 0.05$) using MINITAB program.

## III. Results and discussion

### 3.1. Characteristics of Biochar

Biochars used in this study were produced from rice husk and wood. The characteristics and the amount of mineral nutrients produced would be different depend on the plant species or plant part that was combusted, that can essentially have different physical and chemical soil characteristics, plant growth and nutrient uptake by plant (Demeyer *et al.,* 2001), and also yield of lettuce. The result of biochars analysis as shown in Table 1.

As can be seen in Table 1, the characteristics of RHB and WB had very high in organic-C, total-N, P and K also were very high. It seems that, this characteristics of biochars would improve the soil characteristics including soil physical, chemical and biological, and should be maintained the sustainable agriculture production. Therefore, there were important implications to improve the soil quality. In this study, the pH of both biochar tested were slightly alkaline. Numerous studies have reported that biochar

**Tabel 1.** The Characteristics of Rice Husk and Wood Biochars

| Variable | Unit | Biochar Types | |
|---|---|---|---|
| | | Rice Husk | Wood |
| pH-$H_2O$ | Units | 8.18 | 8.07 |
| EC (1:5) | dS/m | 8.87 | 9.2 |
| CEC | cmol $kg^{-1}$ | 21.18 | 16.78 |
| Carbon (C) | (%) | 29.34 | 52.44 |
| Nitrogen (N) | (%) | 0.65 | 0.50 |
| Phosphorus (P) | (%) | 0.9 | 1.9 |
| Potassium (K) | (%) | 1.85 | 2.07 |
| Exch. Calcium (Ca) | cmol $kg^{-1}$ | 3.57 | 4.51 |
| Exch. Magnesium (Mg) | cmol $kg^{-1}$ | 2.35 | 2.83 |

EC: electrical conductivity; Exch: exchangeable; CEC: cation exchange capacity

application are important as a soil amendment, especially for acidic soil (Lehman and Joseph, 2009 ; Mulyati *et al.,* 2014a). Electrical conductivity of RHB and WB was almost the similar, CEC of WB was lower than RHB (21.18) and WB (16.78) cmol $kg^{-1}$, but WB contain high carbon 52.44% almost double compared to RHB 29.34%. The nutrients status of WB slightly higher than RHB for N, P and K, however RHB have a higher amount of Ca and Mg than WB.

### 3.2. Characteristics of Soil Used

Soil that used in this experiment was analysed in the Laboratory of Department of Research and Development Agriculture Technology, West Nusa Tenggara, Indonesia. The initial soil characteristics were as indicated in Table 2.

From Table 2, it can be seen that soil was used in this experiment had low in soil fertility, with sandy loam texture contain 56.7% sand, 32,7% silt and 10.7% clay. Soil pH was 5.82, low in organic-C (1.04%), CEC 18.18 cmol $kg^{-1}$ and also low in soil nutrients content especially total-N and available-P, but high in exchangeable-K. Possibly, it due to the parent materials of soil derived from volcanic materials which contain abundance of potassium. Therefore, by adding biochar into the soil would be improved the soil fertility. Lehmann and Joseph (2009) reported that, when biochar adding to the soil, it may improve the soil characteristics which would increase the

**Table 2**. Initial Soil Characteristics used in the experiment

| Variables | Method | Values | Chriterium |
|---|---|---|---|
| Texture | | | |
| Sand (%) | | 56.67 | |
| Silt (%) | Sedimentation | 32.67 | Sandy Loam** |
| Clay (%) | | 10.66 | |
| pH- $H_2O$ | pH metre | 5.12 | Acid* |
| CEC (cmol $kg^{-1}$) | Ammonium. Acetat at pH 7.0 | 18.18 | Low* |
| Organic-C (%) | Walkley & Black | 1.04 | Low* |
| Total-N (%) | Kjedahl | 0.07 | Low* |
| C/N ratio | - | 10.2 | Mederate* |
| Total-P (%) | Spectrophotometre | 0.21 | Moderate* |
| Available-P (ppm) | Bray I | 10.58 | Low* |
| Total-K (%) | AAS | 0.54 | High* |
| Exch-K (cmol $kg^{-1}$) | AAS | 7.85 | High* |

Note : * Soil Research Centre, Bogor (1983)
**United Stated Department of America (USDA) 1998.

nutrient supply to the plant. From the data above, it seemed that total-P was moderate and total- K and exchangeable K were high.

Organic carbon status was low, hence to improve the organic carbon and biological cycling of nutrients is important to the success of soil management. Moreover, soil organic carbon content has been suggested as a soil quality indicator which related to functional soil processes and can be used to evaluated soil health status, chemical aspects (Allen *et al*., 2011).

### 3.3. Nutrient Status in Soil

The application of biochars and inorganic individually had a positive effects on nutrient status after harvesting (Table 3). No significant different were found on nutrients status on RHB and WB, but there were an increased in nutrient status including N, P and K by adding biochar both WHB and WB compare to initial soil. This phenomenon indicated that biochars had a benefit as soil amendment. In contrast, Table 3 showed that biochar applications (RHB and WB) to sandy loam soil did not significantly affect the nutrients status N, P and K. However, by adding inorganic fertilizer NPK had a significantly effect on the total N and available P but not for exchangeable K. It can be seen that RHB tended to have higher total N compared to WB, and WB had slightly higher in available P and exchangeable K content. The analysis of variance showed that N and P status affected by inorganic fertilizers and not for K.

**Table 3.** Effects of biochar and inorganic fertilizers fertilizer rates applications on the soil nutrients status after harvesting

| Treatment | Soil Nutrients Status | | |
|---|---|---|---|
| | Total-N (%) | Available P (ppm) | Exchengeable K (cmol kg$^{-1}$) |
| B1 | 0.11 a | 12.95 a | 8.10 a |
| B2 | 0.08 a | 13.54 a | 8.20 a |
| HSD (5%) | - | - | - |
| F0 | 0.082 a | 6.25 a | 6.64 a |
| F1 | 0.080 a | 7.85 a | 7.09 a |
| F2 | 0.108 b | 17.19 b | 8.69 a |
| F3 | 0.101 b | 21.68 c | 10.18 a |
| HSD (5%) | 0.016 | 0.56 | - |

***Note :*** Means followed by the same letter in the same column are not significantly different by HSD test at 5%.

Biochar as a soil amendment has potential benefits to improve the chemical characteristics of soils. Numerous research findings indicate significants changes in soil quality including change in physical properties, such as soil aggregation and water holding capacity (WHC) and decreased the soil strength; and also would affect the chemical properties, such as increase the soil pH, cation exchange capacity (CEC), organic carbon, total-N and others nutrients status in the soil (Glaser *et al.,* 2002; Chan *et al.,* 2007 ; Mulyati *et al*., 2014b). In addition, Mulyati *et al* (2014b) reported that using biochars have decreased N fertilizer requirement in maize due to that the role of biochars in water and nutrients retention.

Effect of biochars and inorganic fertilizers showed the change the soil chemical characteristics (Table 4). Application of biochar types to soil did not influence the soil reaction (pH), but may increase soil (pH) from 5.12 (initi al soil pH) to 5.91 (RHB) and 6.0 (WB). Soil pH is an important soil characteristics in term of nutrients availability and plant growth. In general, plants have a preferred soil pH range where maximum growth and production can be achieved (Fageria and Baligar, 2008). Previous studies have shown that high pH on biochar is usual practice to amend acidic soil to raise the pH, which allow the plants to grow. The pH of the biochars used in this study were 8.18 for RHB and 8.07 for WB depending on the type of agriculture waste.

**Table 4.** Effect of biochar and inorganic fertilizer rates applications on soil chemical characteristics after harvesting

| Treatment | Soil Characteristics | | |
|---|---|---|---|
| | pH | CEC (cmol kg$^{-1}$) | Organic-C (%) |
| B1 | 5.91 a | 22.72 a | 2.14 a |
| B2 | 6.00 a | 23.00 a | 2.34 a |
| HSD (5%) | - | - | - |
| F0 | 5.6 a | 18.16 a | 1.91 a |
| F1 | 5.9 a | 19.46 b | 2.14 a |
| F2 | 6.2 b | 23.87 c | 2.58 b |
| F3 | 6.2 b | 22.68 c | 2.64 b |
| HSD (5%) | 0.02 | 1.24 | 0.32 |

*Note :* Means followed by the same letter in the same column are not significantly different by HSD test at 5%.

### 3.4. Effect of Biochars in Agronomic Properties

Lettuce growth characteristics were modified according to the biochars and inorganic fertilizer applications. The analysis of variance showed that lettuce height data were affected significantly by application of biochars and inorganic fertilizer (Table 5). other agronomic

**Table 5**. Effect of biochar and inorganic fertilizer rates applications on plant height (cm)

| Treatment | Plant height (cm) at ... Days after transplanting | | | | |
|---|---|---|---|---|---|
| | 7 | 14 | 21 | 28 | 35 |
| B1 | 6.28 a | 8.18 a | 11.23 a | 15.15 a | 21.14 a |
| B2 | 6.20 a | 8.02 a | 10.87 a | 14.79 a | 20.34 a |
| HSD (5%) | - | - | - | - | - |
| F0 | 6.12 | 7.16 a | 9.16 a | 11.83 | 16.41 a |
| F1 | 6.33 | 7.76 a | 10.14 b | 12.59 | 17.57 a |
| F2 | 6.62 | 8.62 b | 11.87 c | 14.63 | 19.73 b |
| F3 | 6.90 | 8.95. b | 12.08 c | 15.75 | 21.64 b |
| HSD (5%) | - | 0.18 | 0.54 | 1.25 | 1.15 |

***Note*** : Means followed by the same letter in the same column are not significantly different by HSD test at 5%.

Performance of lettuce such as number of leaves, shoot commercial fresh weight and shoot dry weight were affected significantly by inorganic fertilizer rates (Figure 1a and 1b) , while application of biochar did not affect the shoot fresh and dry weights. From this figure

**Table 6.** Effect of biochar and inorganic fertilizer rates applications on leaf numbers of lettuce

| Treatment | Leaf numbers, at ... Days after transplanting | | | | |
|---|---|---|---|---|---|
| | 7 | 14 | 21 | 28 | 35 |
| B1 | 3.93 a | 5.78 a | 7.28 a | 9.88 a | 15.65 a |
| B2 | 3.86 a | 5.92 a | 8.13 a | 11.79 a | 16.34 a |
| HSD (5%) | - | - | - | - | - |
| F0 | 3.33 | 5.38 a | 6.77 a | 8.83 | 15.41 a |
| F1 | 3.67 | 5.76 a | 6.84 b | 9.59 | 16.57 a |
| F2 | 3.93 | 5.82 b | 7.87 c | 10.63 | 18.73 b |
| F3 | 4.27 | 5.95. b | 8.18 c | 15.75 | 20.64 b |
| HSD (5%) | - | 0.18 | 0.24 | 0.28 | 0.35 |

***Note*** : Means followed by the same letter in the same column are not significantly different by HSD test at 5%.

indicated that inorganic fertilizers increased plant height compared to without inorganicfertilizer (Table 5). The highest plant height was achieved in application of 300 kg $ha^{-1}$ inorganic fertilizer, but did not show a significant different with 200 kg $ha^{-1}$ and the lowest in treatment without inorganic fertilizers. It was indicated that 200 kg $ha^{-1}$ have sufficiently to support plant height, and by increasing the dose of inorganic fertilizer did not significant improve the plant height. Regarding to the number of leaves 300 kg $ha^{-1}$ inorganic fertilizer application resulted in increased the number of leaves (Table 6).

Application of inorganic fertilizers resulted in the highest of number of leaves. The highest number of leaves was obtained in application of 300 kg $ha^{-1}$ NPK and the lowest number of leaves was found at control or treatment without fertilizers added. The similar results obtained for fresh mass and dry mass of lettuce (Figure 1). Without fertilizers adding had the lowest weight compared to the high fertilizers adding. There was no significant different on the increase the fertilizers from 0 to 100 kg $ha^{-1}$. This number of leaves was significantly correlated to the shoot commercial fresh and dry weight of lettuce, which are important characteristics for consumers.

Morover, the increase of leaf number following by the wide of leaf area (Figure 2) would increase the biomass production of lettuce. Data of fresh mass and dry mass were affected significantly only with fertilizers application, while there were no significant different in root fresh mass and dry mass as affected by biochars and inorganic fertilizer

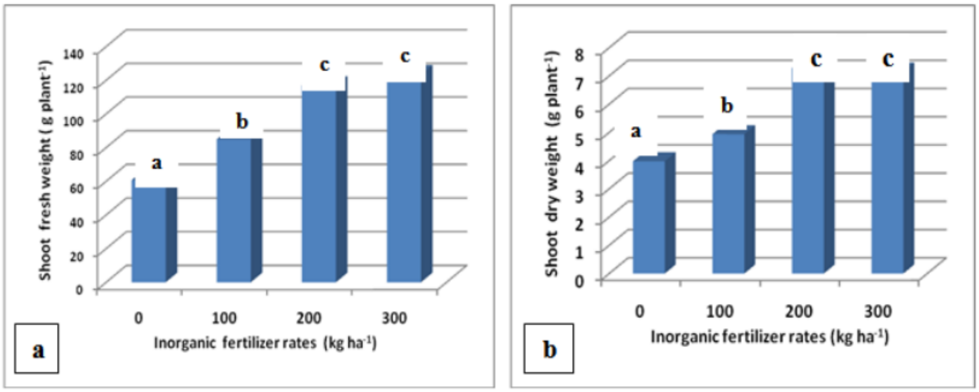


**Figure 1.** The effect of inorganic fertilizer rates on (a) shoot fresh weight (g plant$^{-1}$) and (b) shoot dry weight (g plant$^{-1}$)

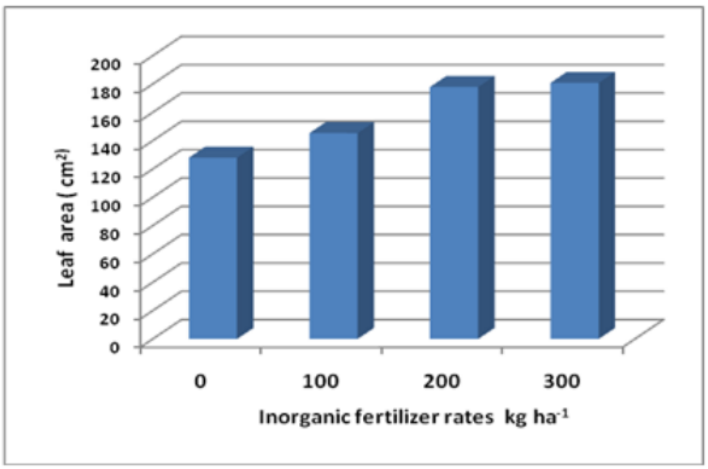


**Figure 2**. The effect of inorganic fertilizer rates on leaf area (cm$^2$)

rates. However, inorganic fertilizer rates showed a significant different on the leaf are of lettuce, but when the rates of inorganic fertilizers added to 200 kg ha$^{-1}$ the leaf area increased significantly. Morover, by added fertlilizers to 300 kg ha$^{-1}$ did not affect the leaf area, shoot fresh and dry weight. The wider the leaf area the higher the weight of shoot mass. The highest shoot commercial fresh masst achieve application of 300 kg ha$^{-1}$ inorganic fertilizer and the lowest obtained in treatment without fertilizer.

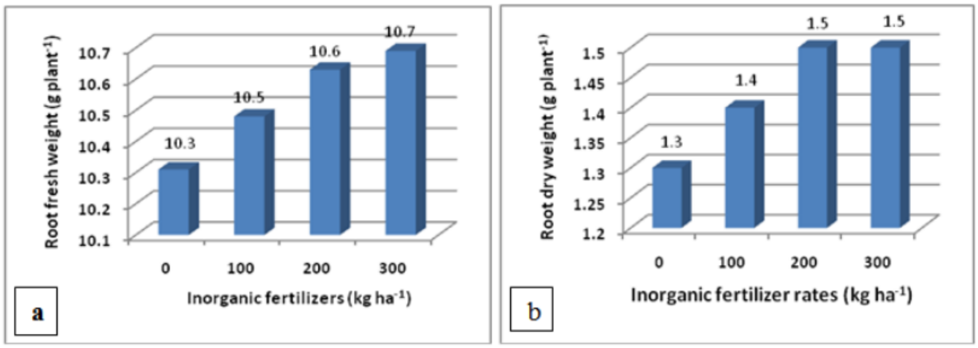


**Figure 1**. The effect of inorganic fertilizer rates on (a) root fresh weight (g plant$^{-1}$) and (b) root dry weight (g plant$^{-1}$)

However, by adding 200 and 300 kg ha$^{-1}$ inorganic fertilizer did not affect the shoot fresh weight, hence 200 kg ha$^{-1}$ would be suffiecient rate for supporting lettuce growth. Eventhough biochar application had no significant effect on the agronomic properties of lettuce but WB tended to have better growth for lettuce growth. In relation to root fresh and dry weight, analysis of variance did not affected statisticaly by the treatments.

## IV. Conclusions

Soil nutrients management is essential for sustainable growth, yield of lettuce, and for maintaining soil quality. From this study, it can be concluded that :

1. The characteristic of rice husk and wood biochars vary substantially according to the type of agricultural wastes. The use of biochars would improve the soil characteristics, but did not influence growth characteristics of lettuce.
2. Inorganic fertilizer had a significant effect on soil nutrient status including soil pH, total N, available P and exchangeable K. Also increased number of leaves, leaf area and shoot fresh weight as important characteristics for consumers.
3. Application of 200 kg ha$^{-1}$ inorganic fertilizer rate should be sufficient to increase growth performance of lettuce.

Based on the conclusion above, it can be confirmed that further research need to be done to investigate the residual effects for the next cropping.


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