Effect of biochar from young coconut waste to improve chemical properties of ultisols and growth coffee \([Coffea arabica \text{ L.}]\) plant seeds

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**Abstract.** This study aims to determine the effect of biochar from young coconut \([Cocus nucifera \text{ L.}]\) waste to improve the chemical properties of Ultisols and the growth of coffee \([Coffea arabica \text{ L.}]\) plant seeds. The research has been carried out at the Laboratory of Chemistry and Soil Fertility and Experimental wirehouse of the Faculty of Agriculture, Andalas University, Padang. This research used a Completely Randomized Design [CRD] with 3 replications. The formulation is biochar of young coconut waste/8 kg of soil ie: A = 0.0%; B = 0.5% [173 g]; C = 1.0% [348 g]; D = 1.5% [520 g]; and E = 2.0% [693 g]. The results of the utilization of young coconut waste as a source of biochar could improve the chemical properties of Ultisols. Addition 2% [693 g.8 kg/l of soil] of biochar young coconut waste can increase pH and decrease Al and H-exch, so that increase available P, organic C and CEC by 1.70 ppm; 0.99% and 9.12 cmol[+]kg\(^{-1}\), compared to 0% of biochar. Application 1.5% [520g.8kg/l of soil] almost the same 2% of biochar young coconut waste to increase total N and exchangeable of the cation [K, Ca, and Mg]. Whereas addition up to 2% of biochar young coconut waste has not shown a significant increase in growth coffee \([Coffea arabica \text{ L.}]\) plant seed at the age of 3 months [12 after week planting].

**Keywords:** Biochar, Coffee, Ultisols, Young coconut waste

1. Introduction

Utilization of waste in the globalization as nowadays received less special attention from the surrounding community. Lack of public awareness in utilizing waste due to lack of community knowledge of the content in waste. Most people only think that waste only has a negative impact. Actually, types of waste, especially natural or organic waste that can be utilized, especially in agricultural activities one of which is young coconut waste. Young coconut waste is from various processed products utilized by the community from the production of coconut plants \([Cocus nucifera \text{ L.}]\). Based on the Directorate General of Plantation in 2017 that Indonesia as a country rich in natural products produced coconut production up to 2,871,280 tons, whereas for West Sumatra coconut production was 84,121 tons, while the Central Statistics Agency in Padang in 2015 declared Padang City has a coconut production of 1,146 tons [1].

The results of production, there will be waste generated in this case, including young coconut waste. Based on data from the Environmental Office of the City of Padang, West Sumatra in 2018, states that young coconut waste reaches 7 tons/day but cannot be utilized optimally. Therefore, to encourage commitment and to support community welfare, especially farmers in a program and
sustainable manner. It is hoped that the utilization of young coconut waste which is used as biochar can be an effort to reduce environmental pollution and the creation of ameliorant, in improving soil fertility and increase the growth and production of plants.

Biomass charcoal [Biochar] is one of the most popular sources of soil ameliorant and produced from the pyrolysis or combustion process of organic material under limited oxygen conditions. Different from organic matter, biochar is composed of aromatic carbon rings that are more stable and durable in the soil [2]. Biochar application can increase pH in acid soils [3], increase soil CEC [4], provide nutrients N, P and K [5]. Biochar maintains soil moisture so that its water holding capacity is high [6] and remediates soils contaminated with heavy metals such as [Pb, Cu, Cd, and Ni] [7]. Also, the provision of biochar in the soil and increase growth and nutrient uptake in plants [8]. The quality of biochar is determined by the manufacturing process and the raw materials [feedstock] used later. Biochar can be produced from materials lignocellulose, such as wood, crop residues [rice straw, rice husks, oil palm empty fruit bunches, and sago waste] and manure [2] as well as from young coconut waste. To improve the quality of biochar application from young coconuts the need for a suitable method is needed in the pyrolysis process for making biochar such as Kon-Tiki cone kiln. Thus this method is expected to be able to improve the quality of biochar produced and be able to improve the chemical properties of marginal lands [e.g Ultisols] and increase plant growth [e.g Coffee sp.] and production.

Figure 1. Schematic diagram showing the roles of biochar functional groups [AFG ¼ acidic functional groups, SOM ¼ soil organic matter].

In Figure 1 that biochar functional groups 1. The AFG are responsible for the liming effect of biochar; 2. the electrostatic attraction between the carboxyl groups of biochar with the nutrient cations...
effectively retains nutrients to ensure a nutrient supply to soil; 3. to immobilize heavy metals, thus reducing heavy metal toxicity; 4. electrostatic attraction, as well as polar and non-polar organic attraction, of humic acid molecules, can result in the adsorption of soil organic matter that is beneficial for carbon sequestration [further discussed in a later chapter]; 5. hydrogen bonding between OH groups on biochar with oxygenated anions can adsorb inorganic anions to supply nutrients or reduce anion contaminant toxicity; and 6. electron transfer to form free radicals on the biochar surface can facilitate organic contaminant degradation and heavy metal transformation [to be detailed discussed in a later chapter] and can reduce contaminant toxicity [9].

Ultisols are the most extensive land in Indonesia around 45.794.000 ha or 25% of the total land area of Indonesia and in Sumatra, the area is almost 21 million ha [10]. Meanwhile, Mulyani et al., [2004] that the area of Ultisols in West Sumatra is around 1.224.880 ha. Ultisols are an acidic soil with an Argilic horizon with a low base saturation which is 29% and has a high aluminum [Al] saturation of 42% [11]. Prasetyo and Suriadikarta [12] explain that the high Al saturation value in Ultisols comes from sediment and granite [> 60%]. As a result of all that causes the washing of the results of mineralization, especially base cations [Ca, Mg, K and Na] which results in the soil sorption complex being filled with H+ and Al3+ ions which makes the pH in the soil decrease that it can be toxic to plants and cause phosphorus [P] fixation and low nutrient supply [14]. To overcome these problems, it can be applied biochar of young coconut waste to improve the chemical properties of Ultisols and the growth of coffee plant seeds [Coffea arabica L.] as an indicator plant.

Coffee is a very important commodity in world trade which involves several producing countries and many consumer countries. According to the Central Statistics Agency in 2017 that coffee plantations in Indonesia currently cover a total area of approximately by 1.24 million ha [933 ha of Robusta coffee plantations, 307 ha of arabica coffee plantations and 90% of the total plantations are cultivated by small-scale farmers] with coffee production [Robusta and Arabica] in Indonesia by 666.992 tons. While coffee production in West Sumatra by 22.771 tons. Thus, to encourage and support the welfare of farmers in a programable and sustainable way to increase the growth and production of coffee in Indonesia, especially in West Sumatra, it is hoped that young coconut waste as source feedstock of biochar can be the latest alternative ameliorant that is environmentally friendly and the creation of Smart Fertilizer in the agricultural. The purpose of this study was [1] Effect of biochar from a young coconut [Cocos nucifera L.] waste to improve chemical properties of Ultisols and [2] Application of young coconut [Cocos nucifera L.] waste as biochar to growth coffee [Coffea arabica L.] plant seeds.

2. Materials and Methods

2.1. Experimental Design
This research used a Completely Randomized Design [CRD] with 3 replications [Table 1]. Thus there were 5 treatments and each consisted of 3 replications so that there were 15 experimental units. Each experimental unit consisted of one coffee seedlings arranged with a distance between 30 cm x 30 cm polybags.

Table 1. Formulation of biochar young coconut waste

| Code of Treatment | Description of Formula |
|-------------------|------------------------|
| A                 | 0.0% [0 g] of biochar young coconut waste |
| B                 | 0.5% [173 g] of biochar young coconut waste |
| C                 | 1.0% [348 g] of biochar young coconut waste |
| D                 | 1.5% [520 g] of biochar young coconut waste |
| E                 | 2.0% [693 g] of biochar young coconut waste |
2.2. Feedstock, Biochar and Soil Sampling
Young coconut waste has been obtained from the Aie Dingin landfill final disposal site, Lubuk Minturun Padang. Biochar was made through the pyrolysis process using the Kon-Tiki method. Ultisols samples were taken in a composite at a depth of 0 - 20 cm from the soil surface from the experimental garden of the Faculty of Agriculture, Andalas University. It was dried, ground, sieved with a 2 mm sieve, then homogenized and put into the experiment pot. Biochar that has been weighed as much as treatment then incubated into the soil for 10 days and after incubation soil samples are taken for analysis of changes in soil chemical properties after biochar administration.

2.3. Experimental Area Preparation and Making Shade Buildings
The area used for research was cleared of weeds and other crop residues that could be a source of plant-disturbing organisms. Weed cleaning is done chemically and manually using a hoe. Then do the land measurements and set the layout of the construction of the shade building. Shade material used comes from the para net with a shade intensity of 50%. Shade intensity building is made of ropes that are arranged between wire poles such as the roof of a house measuring 1000 cm x 300 cm with a height of 175 cm. Then spread the para net with the specified shade intensity.

2.4. Coffee Seed Nursery and Planting Media
The seeds used are arabica coffee varieties Sigarar Utang [No: 205/Kpts/SR.120/4/2005 with the date of the decree of the Ministry of Agriculture 12 April 2015]. The seeds obtained are from nurseries from CV. Muda Tani, Batusangkar which is already 3 months old, usually done during the phase of the Kepelan stadium characterized by the formation of a pair of Kepelan leaves. The leaf is the development phase of the cotyledon before the actual leaf is formed [14]. Coffee seeds are planted in the nursery for 3 months, then transferred to a black polybag measuring 40 cm x 30 cm with a thickness of 0.10 mm which already contains a mixture of Ultisols and biochar treatments. Biochar treatment is based on the percentage of carbon and soil organic matter and volume polybag [Table 1], with a volume of around 10882.28 cm$^3$ per polybag or weight around 8 kg per polybag equivalent to the absolute dry weight. Filling polybags with planting media adjusted to the biochar treatment.

2.5. Planting Seeds, Fertilization and Maintenance
The planting of coffee seeds at the kepelan stage is done by first selecting the seeds. Seedlings are selected based on normal and uniform growth. Planting begins with watering the nursery first to facilitate the process of taking coffee seeds. Taking seeds are carried out one by one carefully so that the roots of the coffee seedlings are not cut off. Furthermore, the Kepelan stage coffee seedlings are planted in a polybag that has been made a planting hole first. Growing media around the base of the stem is compacted so that no air cavities occur between the roots of the coffee seedlings and the growing media. If there are cavities can cause dry seedlings and eventually experience death. Fertilization will be done to spur plant growth by providing fertilizer as needed. Fertilization is done at the beginning of the transfer of seedlings with a dose of 20 grams of Urea, 10 grams of SP-36 and 10 grams of KCl. The next fertilization is carried out in the third month with a dose of 30 grams of Urea, 15 grams of SP-36 and 15 grams of KCl [15]. Seedling maintenance includes watering, weeding, controlling pests and diseases. Watering is done every day when it rains, no watering is done. Weed control is done manually by pulling out weeds in and around the polybags, while simultaneously loosening the soil if there is the hardening of the soil. Pest and disease control is done by spraying insecticides with active ingredients Endosulfan concentration of 0.2% and Mankozeb of 2 gl/l water.

2.6. Analysis of Soil and Plant
Soil analysis includes: pH H$_2$O [1:1] by the Electrometric method, Exch-Al by the Volumetric method, CEC, and Exch-K; Ca; and Mg by the leaching of NH$_4$OAc pH 7 method and measured using AAS, Available of P by the Bray II Method, Organic C by the Walkley and Black method, total N by the Kjeldahl method [16]. Whereas plant analysis includes: Plant height [cm], number of leaves, leaf
length [cm], leaf width [cm] and number of branches. Observation starts when the seedlings are 1 week after treatment for 3 months of observation in each treatment.

2.7. Statistical Analysis
The statistical analysis has carried the software Statistix 8 and Excel 2016 to analyzed soil and plant. It submitted to an analysis of variance [ANOVA] and when significant [F test p <0.05], the mean were compared using the DNMRT test {p<0.05 or F test > F table 5% [*] and 1% [**]}.

3. Results and Discussion
3.1. The Chemical Properties of Ultisols
3.1.1. pH, Available P, and Exchangeable Al and H
Based on the results of variance shows that the effect biochar of young coconut waste was significantly different on the pH, exch H and available P content of Ultisols [Figure 2]. While exchangeable Al has decreased the effect biochar young coconut waste with Kon-Tiki method no measurable [tu] of Ultisols.

Figure 2. Effect of biochar young coconut waste on pH, available P, exchangeable Al and exch H of Ultisols.

In Figure 2 it can be seen that soil pH has increased from 4.17 to 5.26 units by administering biochar of young coconut waste for active pH [pH H₂O] with an increase of 1.09 units compared to 0% biochar. Where active pH expresses H⁺ concentration in soil solution and potential pH expresses H⁺ concentration in colloidal soil. An increase in pH is due to the contribution of OH⁻ from biochar [Figure 1]. The alkali nature of biochar is formed from H⁺ ions which can be exchanged with the surrounding soil, thereby causing an increase in soil pH with the application of biochar [17]. Whereas biochar is alkaline with a pH of 9.73 [in water] probably due to the ash produced during the pyrolysis process, and this is consistent from another study who studied the same type of biochar [18]. The application of biochar to the soil can reduce the concentration of exch Al due to the reduction of Al which can be exchanged through adsorption on the surface of the negatively charged of biochar from OH⁻ [18].

The best increase in available P was seen from the additions 2% of biochar young coconut waste an increase of 1.70 ppm compared to 0% of biochar. The provision of biochar can reduce the solubility
of Al and increase the pH [Figure 2] so that the binding of P can be overcome and P available in the soil can increase. This is following the opinion of Mindari et al., [19] reducing the solubility of metal ions such as Al and Fe can reduce adsorption of P and P-available in the form of \(\text{PO}_4^{3-}\), \(\text{HPO}_4^{2-}\), and \(\text{H}_2\text{PO}_4^{-}\).

### 3.1.2. Organic C, Total N, and C/N ratio

The results of variance showed that the effect of biochar young coconut waste with the Kon-Tiki method was significantly different from the content of organic C, total N, and C/N ratio of Ultisols. In Figure 3 show that the highest organic C content was found in the addition of 2% an increase of 0.99% compared to 0% of biochar young coconut waste. This is thought to be the contribution of C from biochar [56.10 %] and increased activity of microorganisms. According to Syuhada et al., [18] suggested that the greater availability of C stimulates microbial activity, results in greater N demand, encourages immobilization, and recycles NO\(_3\), thereby reducing the availability of N.

![Figure 3](image-url)  
Figure 3. Effect of biochar young coconut waste on organic C, total N, and C/N ratio of Ultisols.

The highest total N content has shown in the addition 2% of biochar young coconut waste with Kon-Tiki method and higher 0.05% compared to 0% of biochar and not significant with addition 1.5 %. Total N in the soil is organic N and minerals N in the form of ammonium [\(\text{NH}_4^{+}\)] and nitrate [\(\text{NO}_3^{-}\)] which are easily lost in the soil due to the process of ammonification, nitrification, washing, and evaporation. However, N leaching can be significantly reduced by applying biochar to the planting medium [19]. It can be seen that the C/N ratio shows the process of mineralization and N immobilization by microbial decomposers in organic matter. In Figure 3 it also could be shown that the C/N ratio is all minor treatments out of 20 which indicate that there is a process of mineralization and release of N and other nutrients in the soil. This is in accordance with Syuhada et al., [18] that low N in the soil results from the utilization and immobilization of N by microorganisms during the decomposition of mineral fractions from biochar which has low N content.

### 3.1.3. CEC and Exchangeable of the cation [K, Ca, and Mg]

In Figure 4 can see that the effect of biochar young coconut waste was significantly different on CEC and exch K; Ca and Mg of Ultisols. The highest Ultisols of CEC was seen besides 2% of biochar young coconut waste by 9.12 cmol\(_{\text{+}}\) kg\(^{-1}\) compared to 0% of biochar young coconut waste [Figure 4]. It is suspected that biochar donates negative ions such as carboxyl groups. According to Syuhada et
al., [18] suggested that the oxidation of aromatic C and the formation of carboxyl groups was believed to be the main reason for the observed increase in CEC. According to Syuhada et al., [18] reported that many negative charges were not expressed in the soil because it was pH-dependent and most negative charge sites were blocked by interactions with Al.

Figure 4. Effect of biochar young coconut waste on CEC and exchangeable of the cation [K, Ca, and Mg] of Ultisols.

The base content [Ca, Mg, and K] shown in Figure 4, have increased along with the increase in CEC, where the increase in exch-K, Ca and Mg also 2% of biochar young coconut waste with Kon-Tiki method respectively by 0.43; 1.83 and 2.12 cmol[+].kg⁻¹ compared to 0% of biochar young coconut waste. According to Madhavi et al., [17] that biochar has a high cation exchange because it has a high surface area capacity, which leads to an increase in soil pH and water holding capacity, and affinity for micro and macronutrient plants. However, over time, the soil buffering capacity will again lower the pH which causes the soil CEC to return to a state of equilibrium [17]. Furthermore, the addition of biochar into the soil shows an increase in the availability of basic cations and concentrations of P and N [20].

3.2. Growth Coffee [Coffea arabica L.] Plant Seed
The results of variance showed that the effect of biochar of young coconut waste with Kon-Tiki method was not significantly different from height, several leaf and branches, leaf length and width of 3 months [12 weeks after treatment] growth coffee plant seed, but in the numerically it has increase [Figure 5]. This is assumed from the availability of nutrients needed by plants in the soil as shown in Figure 2, 3 and 4. Biochar has the potential to produce farm-based renewable energy in an eco-friendly way. Specifically, the quality of biochar depends on several factors, such as the type of soil, metal, and the raw material used for carbonization, the pyrolysis conditions, and the amount of biochar applied to the soil [20]. Besides, the biochar amendment to the soil proved to be beneficial to improve soil quality and retain nutrients, thereby enhancing plant growth [20]. Since biochar contains organic matter and nutrients, its addition increased soil pH, electric conductivity [EC], organic carbon [C], total nitrogen [TN], available phosphorus [P], and the cation exchange capacity [CEC]. Earlier, Rawat et al., [20] reported that the biochar application affected the toxicity, transport, and fate of various heavy metals in the soil due to improved soil absorption capacity.
Figure 5. Effect of biochar young coconut waste on growth coffee [Coffea arabica L.] plant seed

The presence of plant nutrients and ash in the biochar and its large surface area, porous nature, and the ability to act as a medium for microorganisms have been identified as the main reasons for the improvement in soil properties and increase in the absorption of nutrients by plants in soils treated with biochar [20]. Chan et al., [21] and Rawat et al., [20] reported that biochar application decreased the tensile strength of soil cores, indicating that the use of biochar can reduce the risk of soil compaction. A lot has already been discussed on the benefits of inoculation of rhizobacteria in soil, but the addition of biochar can also provide more nutrients to the soil, thus benefiting the crops. The mixing of the plant growth-promoting microorganisms with biochar was referred to as the best combination for growth and yield of French beans [20].

4. Conclusion
The utilization of young coconut waste as a source of biochar could improve the chemical properties of Ultisols. Addition 2% [693 g.8kg/lof soil] of biochar young coconut waste can increase pH and decrease exch Al and H, so that increase available P, organic C and CEC by 1.70 ppm P; 0.99% C and 9.12 cmol(+)kg(-1); compared to 0% of biochar. Application 1.5% [520g.8kg/lof soil] almost the same 2% of biochar young coconut waste increase total N and exchangeable of the cation [K, Ca, and Mg]. Whereas addition up to 2% of biochar young coconut waste has not shown a significant increase in growth coffee [Coffea arabica L.] plant seed at the age of 3 months [12 weeks after treatment].

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