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Influence of Various Types of Biochar Supplemented with Compost (BioKom) on the Status of Soil Nutrients in Inceptisols

Darusman[1,3], Syakur[1,3], Zaitun[2,3]*, Manfarizah[1]

[1]Soil Science Department, Faculty of Agriculture, Universitas Syiah Kuala, Indonesia
[2]Agrotechnology Department, Faculty of Agriculture, Universitas Syiah Kuala, Indonesia
[3]Research Center for Biochar and Sustainable Tropical Forests, Universitas Syiah Kuala, Indonesia

***Corresponding Author:** zaitundara@usk.ac.id
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Abstract
Application of biochar to soil requires an incubation period to become effective. Applying biochar without supplementary amendments such as compost may not yield the desired outcomes. The synergy between these two amendments; biochar and compost, is crucial for investigation; however, the appropriate incubation time for effective use must be determined. This study aims to status of soil nutrients after a 10-day incubation affected by several combination between biochar and compost in Inceptisol. The research employs a non-factorial randomized block design with three replications. Biochar was produced from young coconut husks, rice husks, cassava peels, sugarcane bagasse, and pulai wood. Compost was applied at 20 t ha^{-1} for each type of biochar. The biochar production used a Kon-tiki chamber, and all treatments were incubated for 10 days. The observed nutrient status parameters included pH, C-organic, N-total, P-total, P-available, number of microbial populations and their respiration. The results indicated that a 10-day incubation period did not significantly influence the pH and N-total. But other parameters were altered significantly. The combination of biochar and compost enhances soil quality by adding organic matter that stabilizes carbon and phosphorus levels while promoting microbial respiration involved in nutrient cycling. These findings support the role of biochar and compost as sustainable approaches to improving the fertility of Inceptisol, making it more productive in the long term.
Keywords: biochar compost, incubation, soil amendment, soil nutrient

Introduction
Indonesia has a variety of soil types, including Inceptisol, which is commonly found in many areas. Inceptisol is a type of young soil that comes from new parent material and has an underdeveloped horizon, resulting in low fertility. A main feature of Inceptisol is its low organic matter content, which affects water retention, cation exchange capacity (CEC), and the availability of essential nutrients for plants (Hardjowigeno, 2012). Low soil fertility often limits crop productivity, especially

without proper soil amendment interventions.

Inceptisol, covering around 70 million hectares in Indonesia, is frequently used in marginal agriculture. However, with good soil amendment, it can yield better results. Adding organic materials like biochar and compost is one effective way to improve Inceptisol's fertility. Biochar, a product of biomass pyrolysis, is rich in carbon, stable, and lasts a long time in soil. These qualities make biochar suitable for improving soil structure and nutrient availability (Lehmann & Joseph, 2015).

Using biochar in soil amendment has gained attention due to its ability to improve soil's physical and chemical properties. It also supports soil microorganisms that are important for nutrient cycling and organic matter breakdown (Zhang et al., 2021). With these properties, biochar is expected to enhance the fertility of Inceptisol, which often lacks favorable chemical and biological conditions for plant growth.

In this study, biochar was produced from young coconut waste, rice husks, cassava peels, sugarcane bagasse, and pulai wood. For instance, biochar from young coconut waste has high carbon content, which can improve cation exchange capacity and water retention in soil (Jyoti et al., 2024). Rice husk biochar, on the other hand, has a higher pH and can help reduce soil acidity (Widyantika & Prijono, 2019). Each biochar type is expected to have a different effect on soil nutrients based on its chemical and physical properties.

Compost is another beneficial soil amendment, as it contains decomposed organic material and essential nutrients like nitrogen, phosphorus, and potassium (Aytenew & Bore, 2020). Adding compost to soil can increase microbial activity, improve soil structure, and boost nutrient availability for plants. Mixing biochar with compost creates a synergy where biochar helps improve soil structure, while compost supplies nutrients and supports soil microbes (Agegnehu et al., 2017).

Previous studies have shown that applying biochar and compost can impact plant growth, such as in maize. A study by (Lebrun et al., 2024) found that maize treated with biochar and compost had increased root length and mass compared to maize treated with only compost or no treatment at all. Improved root growth is linked to better soil structure, which allows roots to grow deeper and spread wider (Lebrun et al., 2024). This study examines the effects of different biochars enriched with compost (BioKom) on soil nutrient status and biology in Inceptisol. Combining biochar and compost is expected to optimize plant growth, especially in low-fertility soils like Inceptisol. This study also explores the potential of different types of biochar, as each type has unique properties that may affect soil quality differently.

Materials and Methods

This study was conducted at the Experimental Farm of the Faculty of Agriculture, Universitas Syiah Kuala, Darussalam, Banda Aceh, Aceh Province, Indonesia, from April to June 2024. Inceptisol soil samples were collected from the Barbate Date Palm Farm, Krueng Raya, Aceh Besar Regency, located at N 5°33'16" and

E 95°30'46", alt 600 m asl. Soil and compost analyses were performed at the Soil and Plant Research Laboratory, Universitas Syiah Kuala.

Biochar was produced using a Kon-Tiki kiln following the method by (Schmidt et al., 2014). The biomass used included young coconut, rice husks, cassava peels, sugarcane bagasse, and pulai wood. Compost materials included rain tree (*Samanea saman*) leaves, manure, EM4, and brown sugar. The study used a non-factorial randomized block design with six treatments (including control) and three replications, totaling 18 experimental units. For each biochar type, 20 tons of compost per hectare were added. All samples were incubated for 10 days.

Soil nutrient parameters observed included soil pH, C-organic, N-total, P-total, and P-available. Observations were also made on soil microbial populations and respiration. Data from the observations were analyzed using analysis of variance (ANOVA) to determine the effects of treatments on the measured parameters. If significant effects were found, further testing was done using the honest significant difference (HSD) test.

Results and Discussion

Biochar Characteristics

To understand the characteristics of the biochar used, proximate testing was conducted. Proximate analysis is essential to identify attributes such as mineral content (Cantrell et al., 2012), organic matter content that may contain phytotoxic compounds (Deenik et al., 2010), and overall impact on plant growth (Rajkovich et al., 2012) due to potential phyto toxicity or nitrogen immobilization (Singh et al., 2017). Table 1 provides proximate analysis results for the five types of biochar.

Table 1. Biochar characteristic

No Treatment	pH	Moisture (%)	Fixed carbon (%)
Young Coconut Biochar	9,22	5,91	66,43
Rice Husk Biochar	7,29	5,00	70,53
3. Cassava Peel Biochar	9,22	12,40	68,20
Sugarcane Bagasse Biochar	8,74	12,00	76,01
5. Pulai Wood Biochar	7,6	10,24	90,62

Proximate analysis results (Table 1) show differences in biochar characteristics regarding pH, moisture content, and fixed carbon content. Biochar from young coconut and cassava peel had the highest pH (9.22), making it suitable for acid-neutralizing soil amendments (Darusman et al., 2019). Rice husk and pulai wood biochar had a near-neutral pH, suitable for soils closer to neutral conditions. Sugarcane bagasse biochar, with a pH of 8.74, offers moderate pH adjustment.

Moisture content indicates the biochar's ability to retain water, influenced by surface area and porosity. Cassava peel and sugarcane bagasse biochar had the highest moisture contents (12.4% and 12.0%), making them ideal for improving water retention in dry soils. Conversely, young coconut and rice husk biochar, with low moisture content (5.91% and 5.00%), are suitable for pH adjustment without significantly increasing soil moisture (Fahreza et al., 2019).

Fixed carbon, which mainly comprises fused aromatic carbon structures, serves as an indicator of biochar's ability to sequester carbon (Singh et al., 2017). Pulai wood biochar had the highest fixed carbon content (90.62%), making it highly suitable for enhancing soil structure over time. Sugarcane bagasse biochar, with high fixed carbon (76.01%), balances soil structure improvement and water storage capacity. Rice husk, cassava peel, and young coconut biochar have fixed carbon levels around 66-70%, which, while durable, may not persist as long in the soil as pulai wood biochar (Darusman et al., 2024). Each biochar type's unique qualities can be matched to soil needs to achieve optimal improvement.

Effect on Soil pH, C-organic, and N-total

Table 2 presents the average soil pH, C- organic, and N- total after applying several biochar types enriched with compost in Inceptisol.

Table 2. Soil pH, C-organic, and N-total, content due to the application of various types of biochar supplemented with compost on Inceptisol

No	Treatment	pH	% C-organic	% N-total
1.	Control	4.26	0.94	0.160
2.	Young Coconut Biochar	5.05	1.09	0.133
3.	Rice Husk Biochar	4.75	1.16	0.127
4.	Cassava Peel Biochar	4.82	1.08	0.130
5.	Sugarcane Bagasse Biochar	5.09	1.14	0.127
6	Pulai Wood Biochar	4.69	1.04	0.137

The study results (Table 2) showed that biochar and compost combinations generally raised soil pH compared to the control (4.26). Sugarcane bagasse biochar resulted in the highest pH (5.09), likely due to biochar's alkalinity, which helps neutralize soil acidity (Lehmann et al., 2021). Biochar generally increased the carbon percentage, with rice husk biochar providing the highest carbon content (1.16%).

Total nitrogen tended to decrease in soils with biochar, possibly due to the enhanced decomposition of added organic matter. Biochar decomposes slower than compost; however, compost can counterbalance this effect by supplying essential organic matter and supporting microbial growth that enhances nitrogen availability for plants (Ahmad et al., 2013).

Effect on Total Phosphorus and Available Phosphorus

Table 3 presents average total and available phosphorus in Inceptisol soil following treatments with various biochar types enriched with compost.

Table 3. Soil pH, carbon percentage, and total N, content due to the application of various types of biochar supplemented with compost on Inceptisol

No	Treatment	P-total mg kg^{-1}	P -available mg kg^{-1}
1.	Control	0.010a	1.10a
2.	Young Coconut Biochar	56.120ab	1.80ab
3.	Rice Husk Biochar	26.373ab	3.47b
4.	Cassava Peel Biochar	49.373ab	1.40a
5.	Sugarcane Bagasse Biochar	10.733ab	4.42c
6	Pulai Wood Biochar	92.920b	2.52bc
	HSD*0.05*	87.474	2.06

The results demonstrate that all biochar treatments increased both total and available phosphorus significantly compared to the control. Pulai wood biochar had the highest total phosphorus (92.92 mg kg^{-1}), likely due to biochar's porous structure, which can bind and stabilize phosphorus, reducing losses from leaching. Sugarcane bagasse biochar led to the highest increase in available phosphorus (4.42 mg kg^{-1}), followed by rice husk biochar (3.47 mg kg^{-1}). The combination of biochar and compost enhanced available phosphorus, as compost provides microorganisms that break down phosphorus bonds in soil, making phosphorus more accessible for plant uptake (Mandal et al., 2021).

Effect on Microbial Population and Respiration

Table 4 showed the average microbial population and respiration in Inceptisol soil following biochar and compost treatments.

Table 4. Average microbial population and respiration in Inceptisol soil following biochar and compost treatments

No	Treatment	Microorganism Population	Microorganism Respiration
		(x spk/g bkm soil)	mg $C\text{-}CO_2$ kg^{-1} bkm soil day^{-1}
1.	Control	3.890ab	0.460a
2.	Young Coconut Biochar	3.917ab	0.520a

3.	Rice Husk Biochar	2.430ab	1.290ab
4.	Cassava Peel Biochar	4.440b	1.043ab
5.	Sugarcane Bagasse Biochar	2.387a	2.870b
6	Pulai Wood Biochar	4.040ab	0.815ab
	$HSD_{0.05}$	2.02	2.19

Cassava peel biochar showed the highest microbial population (4.440), surpassing the control and other biochar types. Biochar's porous structure creates a stable environment for soil microbes, protecting them from environmental shifts (Lehmann et al., 2021). Sugarcane bagasse biochar led to the highest microbial respiration rate (2.870 mg C-CO2/kg soil/day), indicating increased microbial activity. Biochar, supported by compost, enhances microbial activity by providing a stable structure for air and moisture, while compost adds nutrients, aiding microbes in breaking down organic matter efficiently (Wu et al., 2021).

Conclusion

Biochar and compost work synergistically to enhance nutrient and biological conditions in Inceptisol soil. Soil pH, organic carbon, and total nitrogen were not significantly impacted by biochar combined with compost. However, other nutrient indicators like total phosphorus, available phosphorus, microbial population, and soil respiration were significantly affected. Sugarcane bagasse biochar showed the most notable effect on available phosphorus and microbial respiration, distinguishing it from other biochar treatments.

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