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# Research Article
# Effects of Durian Wood Waste Biochar on Acid Sulphate Soil Properties and Rice Yield in Indonesia

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## Abstract

**Background and Objective:** Millions of hectares of acid sulphate soils in Indonesia have been cultivated with low yield. The study was carried out to analyze the rate of durian wood waste biochar to improve soil properties and rice yield on acid sulphate soil. **Materials and Methods:** The research was performed from September, 2017-July, 2018. Biochar was made by pyrolysis of feedstock at 550°C for 2 h and quenched with water. The treatments were biochar rates of 4, 8, 12, 16 and 20 t ha$^{-1}$ which added on the acid sulphate soil. Analyses of soil characteristics were made at the end of vegetative, generative and harvest phases. This study was used completely randomized design (CRD) with three replications. **Results:** Along with increasing biochar rate and planting periods, the properties of acid sulphate soils were significantly increased, except for exchangeable Mg. There was no significant difference in plant growth with different rate of biochars, meanwhile, increasing biochar rate significantly increased the filled grain weight of rice. **Conclusion:** At the end of vegetative, generative and harvest phases, biochar rate had positive effects on pH-$H_2O$, SOC, available P, total N, total K, exchangeable bases of Ca, K, Na and CEC. Durian wood biochar provided the optimum weight of filled grain at a rate of 15.29 t ha$^{-1}$ and maximum plant height of 16.47 t ha$^{-1}$ in the acid sulphate soil.

Key words: Biochar rate, acid sulphate soil, planting period, rice yield, plant height

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

## INTRODUCTION

There is over 17 million ha of acid sulphate lands in the world[1,2], which 6.7 million ha are located in Indonesia[3]. Acid sulphate soils exhibit considerable limitations to the agricultural purpose which have pH<4. The extreme acidity is generated by sulphuric acid established by the pyrite oxidation, because of sharp acidity, millions of hectares of acid sulphate soils have been cultivated with low results[4]. The acid sulphate soils yield rice below 2 t $ha^{-1}$ $season^{-1}$. Nationally, this condition is under the rice yield on average (3.8 t $ha^{-1}$ $season^{-1}$)[5]. Therefore, there are significant challenges to increase the productivity of rice on acidic soils. Development of the acid sulphate soil for agricultural lands faces a problem due to several constraints[6]. One of the primary constraints in managing acid sulphate lands is soil acidity due to the pyrite existence under aerobic condition, which become very acid when the soils are utilized for cultivation. In consequence, the high Al and Fe are detached to environment[7,8]. Al and Fe toxicity played a vital role as a factor that limits rice growth in acidic soils[4]. The pH of acid sulphate soil is still under 5.0 even though its grounds are flooded for rice farming. It means that land is still at a toxic level, because of the $Al^{3+}$ presence[9]. Besides, flooding of the paddy field on acidic soil is still under the requirements for proper paddy growth (±pH 6)[9,10].

One method to improve acidic soils performances is biochar application[11,12]. It is widely suggested as a soil amendment on acid sulphate soil to enhance characteristics of soil and increase the productivity of rice in Indonesia[13]. It means that biochar is potential to give benefit in acidic soil fertility[14-16], which contains many elements to alkalize soil such as; calcium, magnesium, potassium and phosporous[17]. Biochar's alkalizing effect is recommended to increase soil pH in acidic soils and provided a solid organic matter in long-term[18]. Raw materials and production conditions are two factors that profoundly affect the physicochemical biochar's characteristic[16,19,20].

Lignocellulosic materials, including wood-derived biomass[21,22] have significantly been used as feedstock. Indonesia has abundant woody biomass as the feedstock of biochar[23,24]. Woody biochars have more aromatic compounds than biochar derived from other materials[25]. The high proportion of aromatic structure in biochar showed further resistance against decomposition for many years[26]. Durian plants are widely distributed and cultivated in south east Asia, especially in Indonesia, Thailand, Malaysia, and Philippines[27]. Previously, there is no study related to the application of durian wood waste biochar on acid sulphate soil. Therefore, this study was aimed to analyze the biochar rate to improve soil properties and rice yield on acid sulphate soil in Indonesia.

## MATERIALS AND METHODS

**Experiment site:** The biochar production was performed at bioenergy Laboratory, Tribhuwana Tunggadewi University, Malang, East Java, while biochar application was conducted in a glasshouse at Indonesian Swampland Agricultural Research Institute (BALITTRA) Banjarbaru, south Kalimantan. The research was performed from September, 2017-July, 2018.

**Biochar production and characterization:** Durian wood wastes as raw material were resulted from the sawmill industry in south Kalimantan, Indonesia. The wood wastes were air dried for the removal of moisture. The dry wood waste particles were then pyrolyzed at 550°C with 2 h holding time. The biochar produced was then quickly quenched by soaking the hot biochar in the water. The quenched biochar was then dried in the sun. The biochar produced was kept at approximately 1.00-2.83 mm by crushing and sieving. The characteristics of biochar resulted in this research were ash content 14.75%, pH 8.66, volatile matter (VM) 23.30%, fixed carbon (FC) 53.02%, carbon (C) 59.57%, hydrogen (H) 3.09%, nitrogen (N) 0.49%, oxygen (O) 21.93%, total P 115 mg 100 $g^{-1}$, available P 2.32 mg 100 $g^{-1}$, cation exchange capacity (CEC) 22 me 100 $g^{-1}$, exchangeable cations of Ca, Mg, K, Na: 8.48, 1.93, 2.18 and 1.45 me 100 $g^{-1}$, respectively.

**Experimental design and soil characteristics:** This study was held in a glasshouse under temperatures ranging between 25.5 and 37.5°C and 50-80% of relative humidity. Acid sulphate soils were collected from Belandean Experiment Station, Barito Kuala district, south Kalimantan. The acid sulphate soils were collected from 0-20 cm in depths and dried in the air. In each treatment, the air-dried soil was weighed of 12 kg and put in pots then kept under flooded conditions. The water height was kept about 2 cm along the growth period of paddy. The 0-20 cm depth layer soil had the following characteristics: pH ($H_2O$) 3.68, soil texture (10.47% sand, 77.54% silt, 11.99% clay), soil organic carbon (SOC) 6.00%, total N 0.46%, total P 64.23 mg 100 $g^{-1}$, total K 85.06 mg 100 $g^{-1}$, available P 0.54 mg 100 $g^{-1}$, exchangeable cations of Ca, Mg, K, Na: 0.18, 0.78, 0.12, and 0.61 me 100 $g^{-1}$, respectively and CEC 27.88 me 100 $g^{-1}$. The soils were incorporated with 1 t $ha^{-1}$ dolomite and 20 t $ha^{-1}$ cow manure in all treatments 1 week before transplanting. Biochar was added to these soil based on each treatment rate. The research treatments were (1) Control soil (No biochar/B0), (2) 4 t $ha^{-1}$ biochar+soil (B1), (3) 8 t $ha^{-1}$ biochar+soil (B2), (4) 12 t $ha^{-1}$ biochar+soil (B3), (5) 16 t $ha^{-1}$ biochar+soil (B4), (6) 20 t $ha^{-1}$ biochar+soil (B5). Rice seedlings transplanted to these soils were 22 days old. The rice variety used was Inpara 2. This rice variety was chosen because it was suitable for cultivation in acidic soil with a shorter plant age[28]. The rice plants in all treatment were fertilized with 100 kg $ha^{-1}$ urea and 250 kg $ha^{-1}$ NPK (Mutiara) on two weeks after transplanting. After 90 days after planting (DAP), the rice plants were harvested. The rice plant measurements were analyzed for the maximum plant height and the filled grain weight.

The soil characteristics were analyzed at 30 DAP (end of vegetative phase), 60 DAP (end of generative phase) and 90 DAP (harvest phase) including: pH ($H_2O$) by pH meter (HI9124) with 1:5 ratio of soil:deionized water, organic-C by wet oxidation method (Walkley-Black), total N by Kjeldahl method, total P by the technique of wet ashing using HCl 25% measured by UV-Vis spectrometer (Shimadzu 1800), total K by atomic absorption spectrometer (Shimadzu AA-7000) after digestion with $HNO_3$:$HClO_4$ acid mixture; available P by Bray and Kurtz 1 extractor and measured by UV-Vis spectrometer (Shimadzu 1800), CEC by 1 M $NH_4OAc$ extraction at pH 7.0, content of exchangeable bases (Ca, Mg, K, Na) by spectrometer of atomic absorption (Shimadzu AA-7000).

**Analysis of plant growth and rice yield:** Growth parameter was recorded at maximum plant height. The weight of filled grain was recorded as the rice yield parameter.

**Statistical analysis:** This study was used completely randomized design (CRD) with three replicates. This study subjected to one-way analysis of variance (ANOVA) at 5% level of confidence to analyze the biochar effects on soil properties, plant growth and rice yield. Duncan's Multiple Range Test (DMRT) was used to analyze the difference in treatments by SAS version 9.1. The relationship between maximum plant height and weight of filled grain with the rate of biochar was determined by two models (linear and quadratic). The model adequacy was evaluated by adjusted R-squared value. The predicted optimum yields were obtained by equating the first derivative of the response equation to zero in the quadratic model[29]. Analysis biplots of principal component (PCA) were computed on the correlation score of the dataset resulted from soil characterization, plant growth and rice yield by GENSTAT 18.2 software.

## RESULTS

**Biochar effects on acid sulphate soil properties:** The result showed that biochar addition could improve acid sulphate soil properties at all planting periods (Table 1). There was a significantly increased in soil pH compared to control soil. However, the increase in soil pH was not significant after biochar incorporation. The difference of soil pH with the application of biochar rate was not significant at 30 DAP and 60 DAP. Meanwhile, the significant difference was in biochar rate of 12, 16 and 20 t $ha^{-1}$, respectively, 5.68, 5.86, 6.10 at 90 DAP. Soil pH was almost constant as increasing planting periods which could be consequently of biochar ability to buffer the soil. Soil pH reflected the availability of soil organic carbon (SOC). The SOC was significantly increased in general because of the biochar application. The SOC of soil treated with biochar was markedly increased and decreased in control soil after planting days. The high SOC in this study was obtained in 16 t $ha^{-1}$ of biochar application at all planting periods and the highest SOC was 10.48% at 90 DAP.

Biochar derived from durian wood had a high CEC. Therefore, it was rational that the soil amended with a high rate of durian wood biochar also had a high of CEC. The high increasing CEC in this study resulted from 12 t $ha^{-1}$ biochar rate in all planting periods. The soil CEC did not show significant increase on 16 and 20 t $ha^{-1}$ biochar rates. Biochar application could increase N, P, K-total and P-available content.

**Plant growth and rice yield:** Increasing biochar rate significantly increased the weight of filled grain, while plant growth was not significantly increased (Table 2). The maximum plant height after biochar addition was 98.00-99.83 cm on average, while the weight of filled grain was 31.25-34.74 g on average. The increment of filled grain weight had occurred, because biochar was able to increase the presence of nutrient's needed by plants in the soil.

The adjusted R-squared of polynomial regression in the maximum plant height and the filled grain weight was higher than the linear (Table 3). It showed that the response of biochar rate to maximum plant height and the filled grain weight were tended to follow a quadratic pattern. The study showed increasing biochar rate which resulted in increasing maximum plant height and filled grain weight with quadratic pattern based on the first derivative of the polynomial equation, the optimum biochar rate of the plant height and the filled grain weight was 16.47 and 15.29 t $ha^{-1}$, respectively (Table 3).

Table 1: Biochar effects on soil properties at different rate

| | | | | | | Exchangeable bases (me 100 g$^{-1}$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Phase | Biochar rate (t ha$^{-1}$) | | pH (H$_2$O) | C-organic (%) | CEC (me 100g$^{-1}$) | Ca | Mg | K | Na | Total N (%) | Total P (mg 100 g$^{-1}$) | Total K (mg 100 g$^{-1}$) | Available P (mg 100 g$^{-1}$) |
| 30 DAP (end of vegetative phase) | B0 | 0 | 3.85$^{c}$ | 7.39$^{d}$ | 30.08$^{c}$ | 5.14$^{a}$ | 1.27$^{a}$ | 1.41$^{a}$ | 0.49$^{a}$ | 0.21$^{b}$ | 60.60$^{d}$ | 83.46$^{b}$ | 1.32$^{d}$ |
| | B1 | 4 | 5.00$^{b}$ | 7.76$^{b}$ | 32.13$^{c}$ | 5.53$^{a}$ | 1.29$^{a}$ | 1.53$^{a}$ | 0.48$^{a}$ | 0.69$^{a}$ | 79.02$^{c}$ | 89.77$^{b}$ | 2.02$^{c}$ |
| | B2 | 8 | 5.34$^{a}$ | 7.47$^{c}$ | 33.22$^{bc}$ | 5.49$^{a}$ | 1.29$^{a}$ | 1.53$^{a}$ | 0.46$^{a}$ | 0.69$^{a}$ | 81.66$^{bc}$ | 101.41$^{a}$ | 2.98$^{a}$ |
| | B3 | 12 | 5.24$^{a}$ | 7.43$^{cd}$ | 36.99$^{a}$ | 5.70$^{a}$ | 1.29$^{a}$ | 1.39$^{a}$ | 0.47$^{a}$ | 0.64$^{a}$ | 101.95$^{a}$ | 103.56$^{a}$ | 2.10$^{c}$ |
| | B4 | 16 | 5.24$^{a}$ | 8.53$^{a}$ | 36.24$^{ab}$ | 5.46$^{a}$ | 1.29$^{a}$ | 1.53$^{a}$ | 0.50$^{a}$ | 0.59$^{a}$ | 91.18$^{ab}$ | 104.08$^{a}$ | 2.88$^{a}$ |
| | B5 | 20 | 5.39$^{a}$ | 7.21$^{e}$ | 38.38$^{a}$ | 5.81$^{a}$ | 1.23$^{a}$ | 1.42$^{a}$ | 0.46$^{a}$ | 0.72$^{a}$ | 74.11$^{c}$ | 102.79$^{a}$ | 2.44$^{b}$ |
| 60 DAP (end of generative phase) | B0 | 0 | 4.85$^{b}$ | 7.20$^{d}$ | 29.40$^{c}$ | 4.45$^{c}$ | 1.16$^{a}$ | 1.44$^{c}$ | 0.44$^{b}$ | 0.25$^{b}$ | 59.88$^{f}$ | 83.93$^{c}$ | 2.67$^{c}$ |
| | B1 | 4 | 5.76$^{a}$ | 7.64$^{c}$ | 31.75$^{b}$ | 4.51$^{c}$ | 1.17$^{a}$ | 1.55$^{b}$ | 0.51$^{ab}$ | 0.64$^{a}$ | 78.85$^{e}$ | 89.60$^{bc}$ | 3.26$^{b}$ |
| | B2 | 8 | 5.81$^{a}$ | 7.71$^{c}$ | 30.67$^{bc}$ | 5.92$^{a}$ | 1.17$^{a}$ | 1.65$^{a}$ | 0.51$^{ab}$ | 0.72$^{a}$ | 109.98$^{c}$ | 93.85$^{b}$ | 4.10$^{a}$ |
| | B3 | 12 | 5.88$^{a}$ | 7.75$^{c}$ | 38.99$^{a}$ | 5.92$^{b}$ | 1.16$^{a}$ | 1.72$^{a}$ | 0.52$^{ab}$ | 0.69$^{a}$ | 103.33$^{d}$ | 95.02$^{ab}$ | 4.25$^{a}$ |
| | B4 | 16 | 5.84$^{a}$ | 9.30$^{a}$ | 38.71$^{a}$ | 5.20$^{b}$ | 1.16$^{a}$ | 1.68$^{a}$ | 0.52$^{ab}$ | 0.62$^{a}$ | 150.65$^{a}$ | 101.92$^{a}$ | 4.01$^{a}$ |
| | B5 | 20 | 6.02$^{a}$ | 8.97$^{b}$ | 39.75$^{a}$ | 5.34$^{b}$ | 1.17$^{a}$ | 1.74$^{a}$ | 0.54$^{a}$ | 0.64$^{a}$ | 118.96$^{b}$ | 101.74$^{a}$ | 3.88$^{a}$ |
| 90 DAP (harvest phase) | B0 | 0 | 4.92$^{c}$ | 6.93$^{e}$ | 28.72$^{e}$ | 4.78$^{b}$ | 1.15$^{a}$ | 1.51$^{c}$ | 0.54$^{b}$ | 0.21$^{b}$ | 61.64$^{d}$ | 85.59$^{b}$ | 3.63$^{cd}$ |
| | B1 | 4 | 5.54$^{b}$ | 7.74$^{d}$ | 32.40$^{c}$ | 5.21$^{b}$ | 1.17$^{a}$ | 1.69$^{b}$ | 0.64$^{a}$ | 0.60$^{a}$ | 97.40$^{c}$ | 97.67$^{a}$ | 3.42$^{d}$ |
| | B2 | 8 | 5.61$^{b}$ | 8.51$^{c}$ | 30.86$^{d}$ | 6.57$^{a}$ | 1.16$^{a}$ | 1.87$^{a}$ | 0.68$^{a}$ | 0.66$^{a}$ | 105.66$^{b}$ | 102.73$^{a}$ | 4.01$^{b}$ |
| | B3 | 12 | 5.68$^{ab}$ | 7.62$^{d}$ | 37.63$^{b}$ | 6.85$^{a}$ | 1.15$^{a}$ | 1.77$^{ab}$ | 0.66$^{a}$ | 0.65$^{a}$ | 103.97$^{bc}$ | 100.60$^{a}$ | 4.68$^{a}$ |
| | B4 | 16 | 5.86$^{ab}$ | 10.48$^{a}$ | 38.57$^{ab}$ | 6.87$^{a}$ | 1.13$^{a}$ | 1.80$^{ab}$ | 0.67$^{a}$ | 0.60$^{a}$ | 132.77$^{a}$ | 102.39$^{a}$ | 4.36$^{a}$ |
| | B5 | 20 | 6.10$^{a}$ | 8.78$^{b}$ | 39.80$^{a}$ | 6.76$^{a}$ | 1.15$^{a}$ | 1.81$^{a}$ | 0.69$^{a}$ | 0.65$^{a}$ | 126.71$^{a}$ | 103.46$^{a}$ | 3.80$^{bc}$ |

Numbers followed by the same letter within each colomn at the same phase were not significantly different based on DMRT $\alpha = 5\%$

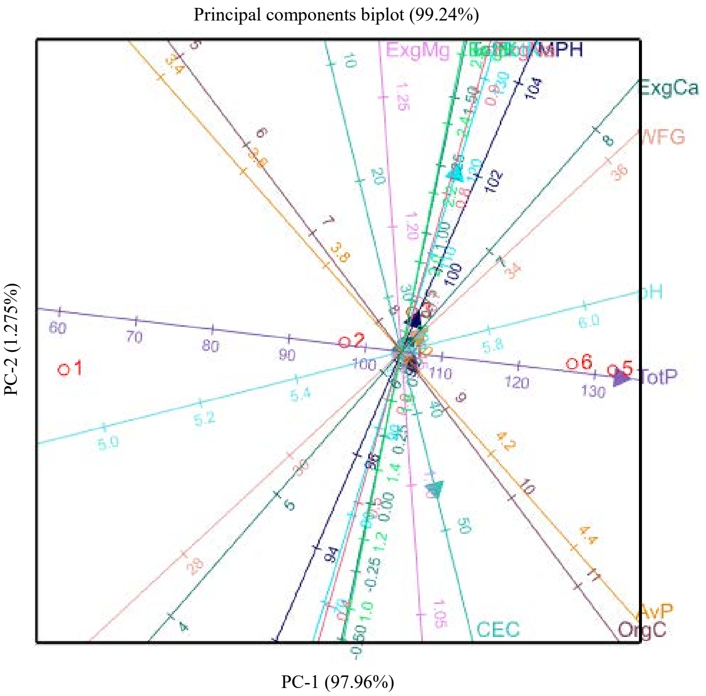

Fig. 1: Biplot of PCA-relationship between pH: pH-H$_2$O, OrgC: Organic-C, AvP: Available P, TotN: Total N, TotK: total K, TotPTotal P, ExgCa: Exchangeable, Ca; ExgMg: Exchangeable Mg, ExgK: Exchangeable K, ExgNa: Exchangeable Na, CEC: Cation exchange capacity, WFG: Weight of filled grain, MPH: Maximum plant height

Table 2: Average of maximum plant height and weight of filled grain

| Biochar rate (t ha$^{-1}$) | Maximum plant height (cm) | Weight of filled grain (g) |
|---|---|---|
| 0 | 95.00±2.00$^{b}$ | 28.61± 1.19$^{c}$ |
| 4 | 98.00±1.00$^{a}$ | 31.25±2.73$^{bc}$ |
| 8 | 98.67±1.53$^{a}$ | 32.79±1.98$^{ab}$ |
| 12 | 99.00± 0.87$^{a}$ | 32.32±1.20$^{ab}$ |
| 16 | 98.83±0.58$^{a}$ | 34.73±0.67$^{a}$ |
| 20 | 99.83±1.44$^{a}$ | 32.95±0.67$^{ab}$ |

Numbers followed by the same letter within each column were not significantly different based on DMRT α = 5%

Table 3: Models for plant height and rice yield in acid sulphate soils

| Parameters | Regression model | Equation | $R^2_{adj}$ | Optimum biochar rate (t ha$^{-1}$)* |
|---|---|---|---|---|
| Maximum plant height | Linear | $y_h = 96.310+0.191x$ | 0.654 | - |
| | Polynomial | $y_h = 95.500+0.494x-0.015x^2$ | 0.799 | x = 16.47 |
| Weight of filled grain | Linear | $y_g = 29.846+0.226x$ | 0.600 | - |
| | Polynomial | $y_g = 28.738+0.642x-0.021x^2$ | 0.793 | x = 15.29 |

*The first derivative of polynomial equation, $y_h$: Maximum plant yield, $y_g$: Weight of filled grain, x: Biochar rate

**Multivariate biplot analysis:** The relationship of soil properties on the plant height and filled grain weight were presented in Fig. 1. The principal components (PC1 and PC2) were captured 99.24% of the variability. This high conformity showed that the results of the biplot were highly representative. There was a high correlation between maximum plant height and soil properties, while the weight of filled grain was strongly correlated with exchangeable Ca, which was explained by 97.96% variance for PC1 and 1.275% for PC2.

## DISCUSSION

Acid sulphate soil had been cultivated with low yield because of its acidity. Biochar could be used as a liming agent to improve acid sulphate soil properties and increase the crop yield. Along with rising biochar rate, pH of acid sulphate soil in this study was increased by 1.15-1.54 units at 30 DAP, 0.91-2.17 units at 60 DAP and 0.62-2.25 units at 90 DAP. Similar to the finding of Van Zwieten *et al*.[30], when biochar was put at high dosage, it could increase the acidic soil pH by 1.5-2 units. The pH increment in acid sulphate soil could be caused by the exchange of the hydrogen ion ($H^+$) between soil and biochar[31].

Biochar rate also provided a significant increase in soil organic carbon. The increasing of organic carbon could be caused by the existence of very high carbon in durian wood waste biochar. As a net source for carbon, the higher biochar amount, the higher content of soil organic carbon[32-34]. Similar to this study, biochar rate of 20 t $ha^{-1}$ could increase SOC[35,36], which was positively correlated with CEC[37]. The high amount of biochar which had a specific surface area from its carboxylate groups could provide high soil CEC[37]. Biochar could increase soil CEC due to its inherent characteristics such as; highly porous and natural organic matter[38-40], which caused an increase of soil's ability to bind cations[41]. The more organic material and CEC in soil, the higher the soil ability to absorb cations that could be utilized for plant growth. On the contrary, exchangeable Mg was significantly decreased with increasing planting period, implying that biochar firmly retained magnesium[38].

Biochar application was able to increase the total N content of acid sulphate soils. It might be caused by the biochar's ability to retain soil and high CEC[42,43]. Similarly, total K in acid sulphate soil could increase[44,45], but there was no significantly different effect in biochar rate, especially at the harvest phase. In contrary, biochar rate could significantly increase total P content. It was likely that increasing of total P might be attributed by decomposition when the soil was amended with biochar[37]. Biochar application also affected the availability P in acid sulphate soils studied. The interchange of ligand between biochar's functional groups with P anions on aluminol and ferrol in acidic soil could increase the available P[46]. When biochars were mixed to acid sulphate soil, the total concentration of ions in soil solution could increase because of the soluble nutrients were released[31].

The plant would be able to yield optimally because the nutrient availability in acid sulphate soil could provide better conditions as plant-growing medium[47-49]. Based on the first derivative of a polynomial function, the optimum weight of filled grain was at biochar rate: 15.29 t $ha^{-1}$ and maximum plant height was at biochar rate: 16.47 t $ha^{-1}$. Following the finding of another researcher, who stated that biochar applied in the field mainly was conducted[50] using rate <30 t $ha^{-1}$. Based on the biplot analysis, there was a positive correlation between soil properties and rice yield. The maximum plant height and the filled grain weight were strongly correlated with soil pH. It seemed understandable that the soil pH could be an indicator of grain yield. Biochar would generate the precipitation, chemical complexation and hydrolysis process in the soil which was needed for plant roots as a growing medium[51]. Interestingly, besides highly positively correlated with soil pH, the weight of filled grain was also strongly correlated with Ca-exchangeable base, while maximum plant height was strongly associated with soil total N, total K and exchangeable Na. The higher rates of nitrogen might have caused rapid cell division and elongation. Moreover, increasing of N level could promote root growth and increase the mobility of N in solution[52,53].

Durian wood biochar is potentially used as significant amendments to improve nutrient and increase rice productivity in acid soil sulphate. For further research, it is essential to consider the cost-benefit of rice cultivation using durian wood biochar in acid sulphate soil.

## CONCLUSION

This study confirmed the positive impacts of durian wood waste biochar on acid sulphate soil properties. At planting periods, biochar rate provided positive effects on pH-$H_2O$, SOC, available P, total N, total K, exchangeable base (Ca, K, Na) and CEC, except for Mg. There was a positive correlation among soil properties and rice yield. Durian wood biochar provided the optimum weight of filled grain at a rate of 15.29 t $ha^{-1}$ and maximum plant height of 16.47 t $ha^{-1}$.

## SIGNIFICANCE STATEMENT

This study discovered that the acid sulphate soils treated with durian wood waste biochar showed a significant improvement in physicochemical properties that beneficial for increasing rice yield and plant growth. At planting periods, biochar rate had positive effects on acid sulphate soil properties. There was also a positive correlation between soil properties and rice yield. This study will help the researchers to uncover the critical areas of high value-added waste management for the agriculture sector that many researchers might not able to explore. Thus a new theory about the effects of durian wood waste biochar in the acid sulphate soil appeared.

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