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# Effect of Incubation of Coconut Coir Biochar and Liquid Organic Fertilizer on Nutrient Uptake of Mustard Samhong King (*Brassica rapa subsp. chinensis*)

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## ABSTRACT

**Green mustard greens. Samhong King variety (*Brassica rapa* subsp. *chinensis*) is a popular vegetable in Indonesia. Green mustard greens have the advantage of being able to grow in both low and high elevations. The application of biochar in soil can help to improve its chemical qualities. The study employed a factorial randomized block design with two components. The treatment factor was the incubation duration of coconut fiber biochar at four levels: control, two weeks, four weeks, and six weeks. The amount of liquid organic fertilizer applied at four different levels: 1 mL/L water, 2 mL/L water, 3 mL/L water, and 4 mL/L water.The study found that coconut fiber biochar and liquid organic fertilizer had no significant effect on nutritional absorption in plant tissue or Samhong King mustard plants, however they did have the highest absorption of K, P, and N nutrients. The incubation period of coconut fiber biochar and liquid organic fertilizer had no significant effect on Samhong King mustard plant production, but the coconut fiber biochar treatment with a 6-week incubation period produced the highest yield, 2.96 t/ha. The treatment of liquid organic fertilizer yielded the best results.**

**Keywords: *Brassica rapa subsp. Chinensis*, mustard Samhong King, plant nutrients, soil improver**

## INTRODUCTION

Samhong King mustard greens (*Brassica rapa* subsp. *chinensis*) is a favorite vegetable among the Indonesian people. The mustard greens have the advantage of being able to grow in both low and high elevations, economically valuable after cabbage, cauliflower, and broccoli. This vegetable is economically and commercially viable for development or cultivation to suit consumer demand and market potential (Nurkhalifah *et al*. 2022), with the production climbing by 652,727 tons in 2019; 667,473 tons in 2020; and 727,467 tons in 2021 (BPS 2022). This implies that the expanding domestic mustard greens production is insufficient. As a result, efforts are being undertaken to increase intensification, specifically by providing adequate planting media and using high-quality organic fertilizers. Biochar is a high-carbon (C) charcoal solid produced by biomass conversion with incomplete combustion and negligible oxygen (pyrolysis). Biochar is more resistant to oxidation and more stable in soil (Mawardiana *et al*. 2013). Biochar's potential to boost soil fertility is determined by its role as a soil conditioner. The mineral composition of biochar, such as carbon, oxygen, and silicate, is a key aspect of its usage as a soil conditioner (Zaitun *et al*. 2022). The application of biochar in soil is thought to improve its chemical characteristics. Habieb *et al*. (2018) found that using coconut fiber biochar at different amounts improved soil pH and C:N ratio. The optimal dose for increasing Entisols soil pH is 5 t/ha enhanced soil productivity. Biochar can improve soil qualities while also influencing plant growth and production. Yunilasari *et al*. (2020) reported that applying 10 t/ha coconut fiber biochar increased soil pH, organic C, total N, C/N ratio, available P, and CEC, and that both treatments had a significant effect on peanut seed weight and increased the potential yield of peanut plants by 3.96 t/ha. Zaitun *et al*. (2020) found that using rice husk biochar residue and coconut fiber biochar on peanut plants during the second planting season had a significant effect on plant growth indicators such as plant height and number of plant branches.

The addition of organic matter to the soil improves soil structure, allowing mustard plants to absorb more nitrogen and potassium. Organic matter improves soil chemical properties by allowing plant roots to penetrate deeper into the soil and absorb large amounts of nutrients and water. It also improves the rhizosphere, maintains the nutrient cycle, increases root exudation, and accelerates the degradation of soil organic matter

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and nitrogen mineralization. Improves soil biological characteristics since organic matter is a source of energy for most soil organisms, maximizing soil N absorption (Warzukni *et al*. 2022). The use of liquid organic fertilizers makes work easier, and the use of liquid fertilizers means doing three types of processes in one job, namely fertilizing, watering, and treating plants (Sampurno *et al.* 2018).

Biochar can be used more effectively when paired with organic fertilizers. Some of these benefits include ease of use, practicality, and efficiency in conveying nutritional composition; the effect is quick, allowing for visible effects on plants (Harahap *et al*. 2020). The application of organic fertilizers to less fertile soil, such as Entisols, is critical since this soil has a low organic matter content and is less fertile, thus organic materials must be added.

## METHODS

### Place and Time

The research was conducted at the Biochar Research Station, Center for Biochar and Sustainable Tropical Forest Research, Syiah Kuala University, from March to August 2023.

### Tools and Materials

The following tools were utilized: Kon-Tiki, Thermo Scientific Prisma E SEM (scanning electron microscope), EDS (energy dispersive X-ray spectroscopy), Wintact WT323D infrared thermometer, alcohol thermometer, hygrometer, analytical scales, hand sprayer, meter, hoe, polybags, camera, and data format. The materials utilized were coconut fiber collected from coconut merchants in Aceh Besar, liquid organic fertilizer, and Samhong King variety mustard seeds purchased online.

### Research Design

The investigation was conducted utilizing a randomized block design factorial pattern with two components. The treatment element was the incubation duration of coconut fiber biochar (B), which had four levels: B1 (control), B2 (2 weeks), B3 (4 weeks), and B4 (6 weeks). The treatment factor of liquid organic fertilizer (P) was divided into four levels: P1 (1 mL/L water), P2 (2 mL/L water), P3 (3 mL/L water), and P4 (4 mL/L water).

### Procedures

The implementation of the research began with the preparing biochar using the Kon Tiki method. The Kon-Tiki used was cone-shaped, with a maximum depth of 90 cm, a diameter of 1.65 m, a width of 792 mm, a volume of 1100 L, and an angle of 64.5°.

The planting media was Entisols soil from the Biochar Research Station research location, the Center for Biochar Research and Sustainable Tropical Forests at Syiah Kuala University. The Entisols soil was a topsoil layer that has been cleaned of plant residues, weeds, and other dirt; the soil was then sieved through a 2 cm sieve to generate fine and clean soil grains. The prepared soil was then dried for one week. The polybag weighs the same, 5 kg soil per polybag, and measures 30 cm × 35 cm.

Before planting, coconut fiber biochar was applied in accordance with the treatment and at the appropriate dose per plant. During the incubation period, the planting media was irrigated to maintain its humidity. The amount of coconut fiber biochar utilized was 5 t/ha, or 6.25 g/polybag. Furthermore, liquid organic fertilizer was sprayed on the leaves of Samhong King mustard greens. The dosage was 1, 2, 3, or 4 mL/L of water. A hand sprayer was used to spray the leaves three times, applied every week in accordance with the planting dose.

Samhong King mustard greens that were 14 days old (4−5 leaves) were put into polybags with planting material that was irrigated daily to keep the soil moist. The greens were planted after the biochar has been incubated in the treatment polybags for 0, 2, 4, and 6 weeks. Harvesting occured when the greens meet the harvest standards. Samhong King mustard greens can be harvested at the age of 35 days after planting (DAP). Harvesting can be accomplished by removing the stems and roots. The observation parameters noticed include SEM analysis. To surface of each biochar was scanned using thermo scientific Prisma E; the nutrient content of each biochar was analyzed using EDS. Other observerd parameters were initial analysis of soil chemical properties, tissue analysis, nutrient absorption N, P, and K, and plant production.

## RESULTS AND DISCUSSION

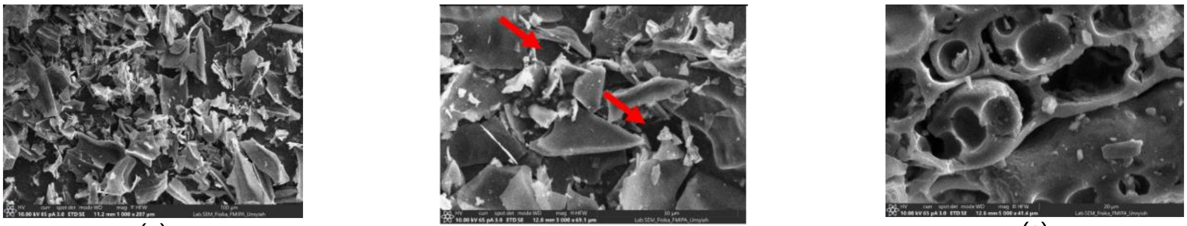
### Initial Analysis of Soil Chemical Properties

The preliminary analysis of soil chemical parameters in the Biochar Research Station land (Table 1) shows Entisols had a sandy loam soil texture of a relatively coarse class. The issues with Entisols soil on the land include C-organic, N-total, and CEC K values ranging from very low to low, as well as a dusty clay soil texture with a moderate level of fertility. This is consistent with the findings of Costa *et al*. (2019), who discovered that the chemical composition of Entisols soil has high amounts of K, Ca, Mg, and CEC and low levels of Al, (H+Al), and Na. The presence of organic matter, which improves soil management while not inhibiting root growth, necessitates an improvement effort that can increase the quality and productivity of

Table 1 Initial analysis of soil chemical properties

| Parameter | Method | Criteria* | Value |
|---|---|---|---|
| Soil texture | | | |
| Sand (%) | Filtering | | 26 |
| Silf (%) | Pipette | | 72 |
| Clay (%) | Pipette | | 2 |
| Texture class | | | H |
| Soil reaction | | | |
| pH | $H_2O$ (1:2.5) – Electrometric | Slightly acidic | 5.93 |
| pH | KCl (1:2.5) – Electrometric | Neutral | 5.38 |
| C–organic (%) | Walkley and Black | Very low | 1.08 |
| N–total | Kjeldahl | Very low | 0.06 |
| Phosphorus and potassium reserves (P and K total): | | | |
| $P_2O_5$: HCl 25% extract | | Very low | 0.06 |
| $K_2O$: HCl 25% extract | | High | 0.17 |
| Available P: | | | |
| P Bray II (mg kg$^{-1}$) | Bray II extracted P | Very high | 51.75 |
| P Olsen (mg kg$^{-1}$) | Olsen extractabel P | | |
| Exchangeable base cation | | | |
| Ca–exchangeable (cmol kg$^{-1}$) | 1 N $NH_4COOCH_3$ pH 7 | High | 7.48 |
| Mg–exchangeable (cmol kg$^{-1}$) | 1 N $NH_4COOCH_3$ pH 7 | Low | 0.76 |
| K–exchangeable (cmol kg$^{-1}$) | 1 N $NH_4COOCH_3$ pH 7 | Medium | 0.43 |
| Na–exchangeable (cmol kg$^{-1}$) | 1 N $NH_4COOCH_3$ pH 7 | Very low | 0.08 |
| Cation Exchange Capacity (CEC) (cmol kg$^{-1}$) | | Low | 12 |
| Base Saturation (%) | | Very High | 72.92 |
| Potential Acidity: | | | |
| Al– exchangeable (cmol kg$^{-1}$) | 1 M KCl | Very Low | 0.16 |
| H– exchangeable (cmol kg$^{-1}$) | 1 M KCl | Very Low | 0.16 |
| Electrical Conductivity (mS cm$^{-1}$) | | Very Low | 0.07 |

Remarks: H (Silk Clay) *Source: Soil Research Center, Balitbangtan, Ministry of Agriculture, Bogor (2009).



(a) (b) (c)

Figure 1 Distribution of coconut fiber biochar pores (a) 1000× magnification, (b) 3000× magnification, and (c) 5000× magnification: (→) biochar pores.

Entisols soil by supplying organic matter such as coconut fiber biochar and liquid organic fertilizer.

**SEM Analysis**

The SEM examination results (Figure 1) reveal that, at 5000× magnification, coconut fiber biochar has wide pores and a less uniform size. The growth of pores in biochar increases dramatically as the temperature rises and the pore characteristics of biochar improve. The pyrolysis temperature influences the size of the biochar pores, increasing the crystallinity of the mineral components and forming a very uniform aromatic structure in biochar (Warzukni 2022). The combustion temperature employed in this work to produce biochar was 266−783 °C, with a combustion time of 67 minutes.

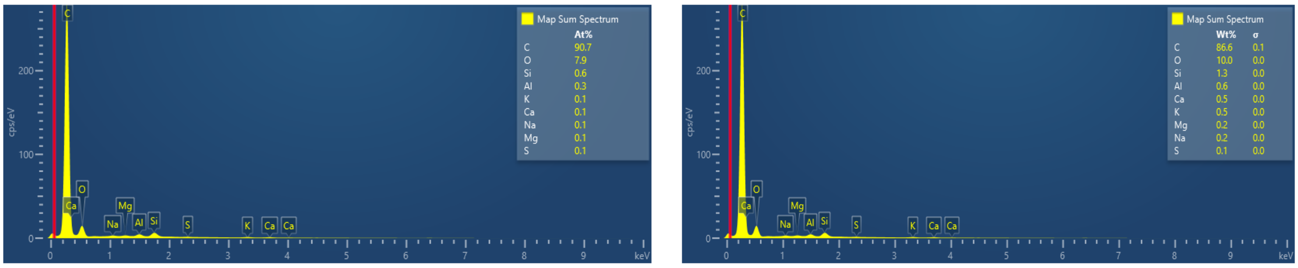
The carbon and oxygen content are proportional to the gasification temperature. The higher the temperature, the higher the carbon concentration and the lower the oxygen content in biochar, affecting the morphological features of the biochar surface (Zaitun *et al*. 2022). Biochar is an excellent absorbent due to its high pore surface area, thicker polyaromatic structure, and much higher pH; however, if the soil to be improved is low nutrient, a good biochar combustion temperature is low (below 500 °C) due to the higher concentration of volatile organic matter and macronutrients (Luo *et al*. 2018).

**Mineral Content**

The mineral composition of biochar, including carbon, oxygen, potassium, chlorine, silica, sodium, magnesium, phosphorus, and sulfur, is thought to be crucial for the properties of biochar applications as soil conditioners (Figure 2). Carbon (86.6%) and oxygen (10.0%) were the most abundant mineral elements in coconut fiber biochar, followed by silicon (1.3%), aluminum (0.6%), potassium (0.5%), magnesium (0.2%), sodium (0.2%), and sulfur (0.1%). The high carbon concentration is assumed to be caused by the biochar combustion process, which uses high temperatures ranging from 266−783°C. High temperatures are thought to increase carbon content. According to Quratulain *et al*. (2021), biochar is a carbon-rich stable product generated by pyrolyzing biomass in a pyrolysis reactor with little or no oxygen. In his research using a high combustion temperature of 600°C it was found that high temperatures cause a greater difference between the amount of carbon and oxygen.

The composition of biochar elements consists of macro- and micronutrients (Figure 2 and Table 2) serve as the primary nutrients in plant growth. Because of its high carbon content, adding biochar to planting land or planting medium is an effective way to boost the availability of organic matter, improving the soil's physical, chemical, and biological qualities. Biochar can also improve the growth of soil bacteria on agricultural land (Kavitha 2018).

The analysis of variance results for the analysis of plant tissue N, P, and K of Samhong King mustard greens revealed that the treatment of incubation duration and administration of liquid organic fertilizer doses had no significant effect on the analysis of plant tissue N, P, and K. Table 3 displays the analysis of plant tissue N, P, and K in the greens as a function of incubation period and liquid organic fertilizer dosage. The incubation period of coconut fiber had no significant effect on the analysis of plant tissue N, P, and K, but it was highest in the analysis of plant tissue K, followed by that of plant tissue P and N. Plant tissue K levels increased after treatment with coconut fiber biochar, ranging from 3.24% to 3.00%. The application of liquid organic fertilizer had no significant effect on the analysis of plant tissue N, P, and K in plants, but was




(a) (b)

Figure 2 Disperse electron X–ray (EDX) of coconut fiber biochar (a) At% spectrum and (b) Wt% spectrum

Table 2 Percentage of mineral content in biochar by EDX (Energy Dispersive X-ray Spectroscopy) analysis

| Mineral content of coconut fiber biochar | | |
|---|---|---|
| Element | Heavy (%) | Atom (%) |
| Carbon (C) | 86.6 | 90.7 |
| Oxygen (O) | 10.0 | 7.9 |
| Silicon (Si) | 1.3 | 0.6 |
| Aluminum (Al) | 0.6 | 0.3 |
| Calcium (Ca) | 0.5 | 0.1 |
| Potassium (K) | 0.5 | 0.1 |
| Magnesium (Mg) | 0.2 | 0.1 |
| Sodium (Na) | 0.2 | 0.1 |
| Sulfur (S) | 0.1 | 0.1 |

Table 3 N, P, and K contents in Samhong King mustard plants due to incubation period and liquid organic fertilizer dosage

| Coconut fiber biochar incubation period (B) | Contents (%) | | | | | |
|---|---|---|---|---|---|---|
| | N (%) | Criteria | P (%) | Criteria | K (%) | Criteria |
| B1 (0 Week) | 0.14 | VL | 0.18 | VL | 3.16 | M |
| B2 (2 Week) | 0.16 | VL | 0.17 | VL | 3.00 | M |
| B3 (4 Week) | 0.18 | VL | 0.17 | VL | 3.24 | M |
| B4 (6 Week) | 0.15 | VL | 0.19 | VL | 3.23 | M |
| Liquid organic fertilizer (P) | | | | | | |
| P1 (1 mL/L water) | 0.15 | VL | 0.17 | SR | 3.35 | M |
| P2 (2 mL/L water) | 0.16 | VL | 0.18 | SR | 3.06 | M |
| P3 (3 mL/L water) | 0.16 | VL | 0.17 | SR | 3.11 | M |
| P4 (4 mL/L water) | 0.16 | VL | 0.18 | SR | 3.12 | M |

Remarks: SR (Very Low), S (Medium) *Source: Barker and Pilbeam (2007). Information: B (Biochar), P (Liquid organic fertilizer) most effective in the analysis of K tissue, ranging from 3.35% to 3.06%. The analysis of plant tissue P in coconut fiber biochar treatment ranged from 0.19% to 0.17%, while the analysis of plant tissue N in liquid organic fertilizer treatment ranged from 0.18% to 0.14%. Potassium is the second most abundant element after nitrogen and one of those that respond to plant output. Plants absorb potassium in the form of K ions, which are either in solution or negatively bound in the tissue (Sufardi 2019). Potassium is a vital macronutrient for plants, especially mustard greens, therefore a shortage of it disrupts plant metabolism (Fahmi *et al*. 2022).

**N, P, and K Nutrient Uptake**

Based on observations of N, P, and K nutrient uptake in Samhong King mustard greens, analysis of variance revealed that the treatment of incubation period and administration of liquid organic fertilizer dosage had no significant effect on N, P, and K nutrient uptake, but K nutrients were the most abundant, followed by P and N. Table 4 shows the uptake of N, P, and K nutrients in Samhong King mustard greens based on incubation period and liquid organic fertilizer dosage. The treatment of incubation period and liquid organic fertilizer dose did not have a significant effect on N, P, and K nutrient uptake, although K nutrient uptake was the highest, followed by P and N. In the coconut fiber biochar treatment, K nutrient absorption increased from 4.14 to 3.98 mg/plant, but in the liquid organic fertilizer treatment, K uptake ranged from 4.33 to 3.95 mg/plant. The absorption of P nutrients in the coconut fiber biochar treatment ranged from 1.11 to 1.05 mg/plant, while the absorption of N nutrients in the liquid organic fertilizer treatment ranged from 1.06 to 1.01 mg/plant, and the absorption of P nutrients from 1.06 to 1.00 mg/plant.

Plant nutrient absorption is regulated by a variety of factors, including root morphological structure, improved soil cation exchange capacity due to biochar, and root metabolic rate, which promotes root growth. Furthermore, biochar boosts root development and metabolic rate, which can help plants absorb K nutrients more effectively. This is consistent with the findings of Darusman *et al*. (2021), who discovered that rice husk biochar has a higher nutrient adsorption capacity, allowing maize plants to absorb more K. According to Niazi *et al*. (2023), biochar can improve fertilization effectiveness (e.g., $NO_3^-$, $NH_4^+$, and $PO_4^{3-}$), soil fertility, and stability. However, nutrients absorbed by biochar take time to be released into the soil, known as slow release.

**Crop Production**

According to the study's findings, the analysis of variance revealed that the incubation time treatment and the injection of liquid organic fertilizer doses had no significant effect on Samhong King mustard greens output (Table 5). The incubation length of coconut fiber biochar showed no significant effect on the production of Samhong King mustard greens but tended to be the greatest in the treatment without incubation at 2.93 t/ha, followed by the 2-week incubation treatment with an average production of 2.90 t/ha. The 4–week incubation treatment with an average production of 2.71 t/ha, and the 6–week with an average production of 2.96 t/ha. The treatment of liquid organic fertilizer also showed no significant effect on the production, but the highest was found at a dose of 1 mL/L water, with an average production of 3.07 t/ha, followed by a dose of 2 mL/L water, with an average production of 2.94 t/ha; at a dose of 3 mL/L water, the average production was 2.89 t/ha, and at a dose of 4 mL/L water, the average production was 2.60 t/ha. The production of mustard greens in Aceh in 2020 was around 3,755 t/ha, with a total production across Indonesia of 667,473 t. According to data from the Central Statistics Agency (2022), mustard greens production in Aceh in 2021 was 3,206 t/ha, with total production in Indonesia of 727,467 t. In 2022, mustard greens production in the province decreased to 3,149 t, while total production in Indonesia increased by 760,608 t.

## CONCLUSION

Based on the study's findings, we conclude that the analysis of plant tissue during the incubation period of coconut fiber biochar and liquid organic fertilizer has no significant effect on the absorption of N, P, and K nutrients in plants, but tends to be highest in K nutrients, followed by P and N. The coconut fiber biochar treatment raised K nutrient absorption from 4.14 to 3.98 mg/plant, whereas the liquid organic fertilizer treatment increased K nutrient absorption from 4.33 to 3.95 mg/plant. The incubation duration of coconut fiber biochar and liquid organic fertilizer has no significant impact on Samhong King mustard greens yield. The average output is highest in the coconut fiber biochar treatment after a 6-week incubation period, with a yield of 2.96 t/ha. The highest yields of liquid organic fertilizer are observed when treated with 1 mL/L water, with an output of 3.07 t/ha.

## REFERENCES

[BPS] Badan Pusat Statistik. 2022. Produksi Tanaman Sayuran 2020. Statistik tanaman sayuran dan buah–buahan. Jakarta (ID): Badan Pusat Statistik.

Balai Penelitian Tanah. 2009. *Kriteria Kimia Tanah*. Bogor (ID): Pusat Penelitian dan Tanah Agroklimat. Departemen Pertanian.

Barker AV, Pilbeam DJ. 2007. *Handbook of Plant Nutrition*. Cleveland (US): CRC Press.

Table 4 Absorption of N, P, and K nutrients in Samhong King mustard plants due to incubation period and liquid organic fertilizer dosage

| | Nutrient absorption | | |
|---|---|---|---|
| Coconut fiber biochar incubation period (B) | N | P | K |
| | | ……mg/plant…… | |
| B1 (0 Week) | 1.08 (1.03) | 1.29 (1.11) | 23.24 (4.14) |
| B2 (2 Week) | 1.04 (1.02) | 1.13 (1.06) | 20.31 (3.89) |
| B3 (4 Week) | 1.12 (1.06) | 1.12 (1.05) | 20.80 (3.98) |
| B4 (6 Week) | 1.02 (1.01) | 1.25 (1.09) | 21.14 (3.97) |
| Liquid organic fertilizer (P) | | | |
| P1 (1 mL/L water) | 1.18 (1.06) | 1.29 (1.11) | 24.95 (4.33) |
| P2 (2 mL/L water) | 1.05 (1.03) | 1.20 (1.08) | 20.75 (3.95) |
| P3 (3 mL/L water) | 1.05 (1.02) | 1.15 (1.06) | 20.12 (3.89) |
| P4 (4 mL/L water) | 0.98 (1.00) | 1.16 (1.06) | 19.67 (3.82) |

Remarks: The absorption of nutrients N, P, K in the data in brackets is the result of quadratic transformation of data.

Table 5 Average production results of Samhong King mustard greens in terms of incubation period and liquid organic fertilizer dosage

| | Crop production (t/ha) |
|---|---|
| Coconut fiber biochar incubation period (B) | |
| B1 (0 Week) | 2.93 |
| B2 (2 Week) | 2.90 |
| B3 (4 Week) | 2.71 |
| B4 (6 Week) | 2.96 |
| Liquid Organic Fertilizer (P) | |
| P1 (1 mL/L water) | 3.07 |
| P2 (2 mL/L water) | 2.94 |
| P3 (3 mL/L water) | 2.89 |
| P4 (4 mL/L water) | 2.60 |

Costa CRG, da Silva Fraga V Da, Lambais GR, Soares KO, Prazeres Suddarth SR, Medeiros SDS. 2019. Chemical and physical quality of the entisol in a natural regeneration area in the semiarid region of Paraiba. *Journal of Experimental Agriculture International*.35(2): 1–7. https://doi.org/10.9734/JEAI/2017/38489

Darusman D, Syakur S, Zaitun Z, Jufri Y, Manfarizah M. 2021. Morfologi akar tanaman jagung (*Zea mays* L.), serapan hara N, P, dan K akibat pemberian beberapa jenis biochar pada tanah bekas galian tambang. JIPI *(Jurnal IPA and Pembelajaran IPA)*. 5(1): 90–100. https://doi.org/10.24815/jipi.v5i1.19968

Fahmi K, Yusnizar Y, Sufardi S. 2022. Peningkatan serapan hara nitrogen, fosfor, dan kalium tanaman sawi hijau akibat konsentrasi larutan hara AB Mix pada media sabut kelapa. *Rona Teknik Pertanian*. 15(2): 52–66. https://doi.org/10.17969/rtp.v15i2.25892

Habieb M. Zaitun, Sufardi. 2018. The effect of biochar and cowmanure to increase soil fertility in entisol Darussalam. *International Journal of Agronomy and Agricultural Research*. 13(2): 1–7.

Harahap R, Gusmeizal G, Pane E. 2020. Efektivitas kombinasi pupuk kompos kubis–kubisan *(Brassicaceae)* dan pupuk organik cair bonggol pisang terhadap produksi kacang panjang *(Vigna Sinensis* L.*)*. *Jurnal Ilmiah Pertanian* (JIPERTA). 2(2): 135–143. https://doi.org/10.31289/jiperta.v2i2.334

Kavitha B, Reddy PVL, Kim B, Lee SS, Pandey SK, Kim KH, 2018. Benefits and limitations of biochar amendment in agricultural soils: A *review. Journal of Eviromental Management*. 227: 146–154. https://doi.org/10.1016/j.jenvman.2018.08.082

Luo Y, Dungait JAJ, Zhao X, Brookes PC, Durenkamp M, Li G, Lin Q. 2018. Pyrolysis temperature during biochar production alters its subsequent utilization by microorganismsin an acid arable soil. *Journal Land Degrad.* 29: 2183–2188. https://doi.org/10.1002/ldr.2846

Mawardiana, Sufardi, Husein E. 2013. Pengaruh residu biochar dan pemupukan NPK terhadap sifat kimia tanah dan pertumbuhan serta hasil tanaman padi musim tanam ketiga. *Konservasi Sumber Daya Lahan*. 1(1): 16–23.

Niazi P, Monib AW, Ozturk H, Mansoor M, Azizi A, and Hassand MH. 2023. Review on surface elements and bacterial biofilms in plant–bacterial associations. *Journal for Research in Applied Sciences and Biotechnology*. 2(1): 204–214. https://doi.org/10.55544/jrasb.2.1.30

Nurkhalifah, Haryanto H, Supeno B. 2022. Populasi dan intensitas serangan hama kumbang perusak daun *(Phyllotreta vittata* F.*)* pada empat jenis tanaman sawi. *Jurnal Ilmiah Mahasiswa Agrokomplek*. 1(1): 38–47. https://doi.org/10.29303/jima.v1i1.1215

Quratulain, Shafiq M, Capareda SC, Bareen F. 2021. Effect of different temperatures on the properties of pyrolysis products of *Parthenium hysterophorus*. *Journal of Saudi Chemical Society*, *25* (3): 101197. https://doi.org/10.1016/j.jscs.2021.101197

Sampurno MH, Hasanah Y, Barus A. 2018. Respons pertumbuhan dan produksi kedelai varietas wilis. *Jurnal Agroekoteknologi*. 4(1): 1721–1725.

Sufardi. 2019. *Pengantar Nutrisi Tanaman*. Banda Aceh (ID): Syiah Kuala University Press.

Warzukni W, Zaitun Z, Jauharlina J. 2022. Changes in soil chemical properties due to the application of young coconut waste biochar and goat manure fertilizer on tomato *(Solanum lycopersicum* L.*)* cultivation land. *Institute of Physics (IOP) Conference Series: Earth and Environmental Science*.1109(1): 1–8 https://doi.org/10.1088/1755-1315/1109/1/012085

Yunilasari M, Sufardi, Zaitun. 2020. Effects of biochar and cow manure on soil chemical properties and peanut *(Arachis hypogaea* L.*)* yields in entisol. Institute of Physics *(IOP) Conference Series: Earth and Environmental Science*. 425(1): 1–9 https://doi.org/10.1088/1755-1315/425/1/012014

Zaitun Z, Halim A, Sa'Dah Y, Cahyadi R. 2022. Surface morphology properties of biochar feedstock for soil amendment. Institute of Physics (*IOP) Conference Series: Earth and Environmental Science*. 951(1): 1–6. https://doi.org/10.1088/1755-1315/951/1/012034

Zaitun Z, Yusnizar Y, Yunilasari M, Persada A. 2020. Effects of biochar residue and cow manure residue on entisol chemical properties, growth, and production of peanut *(Arachis hypogaea* L.*)* in second planting season. Institute of Physics *(IOP) Conference Series: Earth and Environmental Science*. 583(1): 1–7 https://doi.org/10.1088/1755-1315/583/1/012011