Potential of Compost Tea and Biochar from Rice Husks and Lotus Plants as Soil Amendments

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Abstract- Wild-growing lotus plants in swampy marshes and rice production waste in the form of husks are potential resources for use as soil amendments through biochar and compost tea. Therefore, this research aimed to evaluate the potential of compost tea and biochar from rice husks and lotus plants based on physical and chemical characteristics as soil amendments. The treatments experimented for compost tea included the composition ratios of 1:20 (w/v), 1:10 (w/v), and 1:5 (w/v) of rice husks or lotus compost with water. For the analysis, compost tea was made from mature compost extracted aerobically with the tested composition ratios. Biochar from lotus plants (L) and rice husks (S) was produced using a furnace method with a burning duration of 2 hours at a temperature of 200°C, followed by determination of functional group through FTIR and SEM-EDS approaches. The laboratory-scale testing results showed that pH values of lotus and husks compost tea were considered neutral, while lotus biochar tended to be higher compared to husks biochar. Furthermore, it was discovered that concentration of humic substances and nutrients produced increased with a high compost tea solution. Functional group testing using FTIR on biochar detected carbonyl, various aromatic, as well as Si-O-Si and Si-O in rice husks biochar. In lotus biochar, carbonyl, phenolic, lignin, holocellulose, as well as C-O and C-C functional groups were found at different wavelengths. Based on SEM-EDS results, the pores in rice husks biochar were smoother and more abundant compared to lotus biochar, which appeared larger. However, higher concentrations of essential micro-nutrients were found in lotus biochar.

Index Terms- Biochar, compost tea, soil conditioner, organic material characterization

I. INTRODUCTION

Agricultural sector is significantly essential in the Indonesian economy, serving as a crucial source of financial income for the country. In this sector, the improvement of production outcomes is achieved by enhancing soil fertility and increasing nutrient availability through the application of soil amendments (Coordinating Ministry for Economic Affairs, 2022). As an essential source for sustaining the food needs of the country, agricultural sector faces inherent developmental challenges. This is because several agricultural lands remain underutilized due to low productivity, such as acidic sulfate soils, wetlands, or continuous degradation. To overcome these challenges, the productivity of soil must be considered by adding amendments to enhance fertility. Several natural resources that have been proven effective as soil amendments include organic materials often found in waste rice husks and lotus. Although the use of rice husk is not optimal, the amount of waste generated from milling is 20-23% of the grain [2]. According to previous research, lotus is a wild plant with significant potential due to its widespread availability in several swamplands in Indonesia [3]. Rice husks and lotus plants are materials that are readily available and possess the potential to be developed as well as processed into soil amendments including biochar and organic fertilizer.

Soil amendments are materials added to soil to improve increase productivity [4]. One of these materials is biochar, a porous charcoal substance obtained from incomplete combustion. Biochar plays a role in improving soil chemical, physical, and biological fertility, increasing pH, nutrient availability for plants, and providing habitat for soil microorganisms [5]. Based on previous research, the combination of rice husk biochar and compost significantly increased c-organic and total N, as well as corn growth, compared to the control treatment, which was not given rice husk biochar and compost [6]. Additionally, the application of microbial and biochar-based organic fertilizers in subsoil soil influenced the growth and production of mustard greens. This combination increased soil microbial activity, physical and chemical characteristics, but caused a significant reduction in the use of inorganic fertilizers [7].

Another material that can be added to increase soil and plant productivity is compost tea, which is produced from solid compost extracted using water [8]. This material offers several advantages, which include high plant resistance to diseases, nutrient supply, reduction in the use of inorganic fertilizers, and improved microbial activity [9]. Previous research has proven that compost tea contains NO_2, K_2O, humic acid, and microorganisms such as aerobic bacteria, N_2-fixing bacteria, and actinobacteria, which play a role in plant growth and resistance [10]. Based on the description, lotus and rice husks can be used as soil amendments in the form of biochar and compost tea. Therefore, this research aimed to investigate the physical and chemical characteristics of compost tea as well as biochar from lotus and rice husks as soil amendments.

II. MATERIALS AND METHODS

2.1. Materials

The organic materials source used in this research were lotus plants and rice husks. The plants were taken from the Lebak swamp area, Pemulutan Sub-district, Ogan Ilir Regency, South Sumatra. Meanwhile, the rice husks were obtained from milled rice produced in the Lebak swamp area in the Pemulutan Sub-district..

2.2. Methods

2.2.1. Making Compost Tea

The initial process of making compost tea started with the preparation of solid compost using the primary raw material (lotus or rice husks) mixed with cow dung in a ratio of 5:1 (w/w) into a composting container for 4 weeks by stirring every day until mature. Moreover, mature compost was characterized by raw materials that had been completely decomposed, resulting in a texture similar to soil, absence of bad odor, and smell resembling soil, with a temperature of around 28°C. Subsequently, mature compost was extracted aerobically using cloth in a bucket with an aerator, resulting in the production of compost tea. The production process included wrapping mature compost in cloth and soaking in water at ratios of 1:20 (w/v), 1:10 (w/v), and 1:5 (w/v) for approximately 3 days. After completion, compost tea is fully prepared for chemical analysis.

2.2.2. Making Biochar

The production of biochar is carried out using the drum or furnace method [11]. In this process, after stabilizing the flame, the material designated for biochar production, dried lotus stems or rice husks, is gradually added to the combustion furnace. Subsequently, the temperature is carefully maintained at 200°C for 2 hours, ensuring complete the material turns black. After the 2-hour combustion period, the flame is extinguished with water, and the post-pyrolysis biochar is left to cool. Once cooled, biochar is sieved using a 3 mm mesh to ensure uniformity in biochar particles.

2.2.3. Measurement of pH, EC, and TDS

The analysis of pH values and EC in compost tea was measured during the soaking process using a pH, EC, and TDS meter. Specifically, pH values of biochar were measured in the laboratory using pH meter calibrated with buffer solutions of pH 4 and 7.

2.2.4. N, P, and K Nutrient Analysis

Analysis of the total N, P, and K nutrient content in compost tea was analyzed at PT Bina Sawit Makmur Laboratory, Palembang, after a complete soaking period of 72 hours. Total N analysis was carried out using Kjedahl-Titrimetry method, consisting of 3 stages, namely destruction, distillation, and titration. Compost tea's total P and K content was analyzed using the 25% HCl extraction method. The total P concentration was measured using a UV-VIS spectrophotometer, while the total K concentration was measured with a flamephotometer.

2.2.5. C-Organic Analysis and C/N Ratio

The c-organic content and C/N ratio of compost tea were measured after 72 hours of soaking. The laboratory measurement of c-organic content was carried out using the Walkey and Black method. Meanwhile, the C/N ratio was obtained by dividing the analysis results of c-organic and total N in compost tea.

3.2.6. UV-Vis Humic Concentration Analysis

The concentration of humic acid contained in compost tea was measured using a UV-VIS spectrophotometer at 324nm wavelength.

3.2.7. Functional Group Analysis with FTIR

The characteristics of biochar functional groups were analyzed using a Fourier Transform Infra-Red (FTIR) instrument to identify organic and inorganic materials as well as polymeric materials. Initially, the sample was dissolved in distilled water until there were no air bubbles. This was followed by placement on the sample plate and the readings that appeared on the FTIR instrument monitor were obtained.

3.2.8. Biochar Characterization Using SEM-EDS

Samples in biochar, standard plaster, and plaster + biochar were characterized with various instruments to obtain a complete picture of the effects of adding biochar to plaster. Furthermore, morphological testing was conducted using Scanning Electron Microscope - Energy Dispersive X-ray spectroscopy (SEM-EDS).

2.3. Data Analysis

The research data at each stage were analyzed using Analysis of Variance (ANOVA) to observe the influence of treatments on the observed variables. Treatments that showed a significant effect were further subjected to the Least Significant Difference (LSD) test with $P \leq 0.05$ to identify differences between various levels.

1) Read already published work in the same field.
2) Goggling on the topic of your research work.
3) Attend conferences, workshops and symposiums on the same fields or on related counterparts.
4) Understand the scientific terms and jargon related to your research work.

III. RESULTS AND DISCUSSIONS

3.1. Characterization of Compost Tea Made from Lotus and Rice Husks

Tables 1, 2, and 3 show the observed characteristics of lotus and rice husks compost tea, namely pH, EC, and TDS values measured on days 1, 2, and 3. After 3 days of soaking, samples were taken to analyze the content of N, P, and K presented in Table 4, as well as C-organic, C/N ratio, and humic acid, as shown in Table 5.

3.1.1. Compost Tea pH Value

The results showed that pH value of lotus compost tea and rice husks increased on the first to the second day of soaking, However, only pH of lotus compost tea 1:5 (w/v) increased on the second to the third day, as shown in Table 1. Both lotus compost tea and rice husks with a ratio of 1:10 (w/v) on the second and third day had the same pH value, while lotus compost tea with a ratio of 1:20 (w/v) on the third day decreased from 7.00 to 6.87. In rice husks compost tea, pH on the third day, insignificant decrease was observed in treatment ratios of 1:5 (w/v) and 1:20 (w/v). Generally, compost contains organic acids, with varying pH depending on the type of compost and water source. As composting progresses, organic acids are neutralized [11], suggesting that the increase in pH during the soaking process is attributed to the neutralization. Jika dilihat, nilai pH pada teh kompos sekam lebih tinggi dibandingkan pada teh kompos lotus. Namun, pH akhir teh kompos lotus maupun sekam merupakan pH umum yang terdapat pada teh kompos. teh kompos memiliki pH dengan kisaran 6,00 hingga 7,70 [12].

3.1.2. EC Compost Tea Value

Table 2 shows that the EC value of lotus compost tea and rice husk increased from the first to the third day after soaking. The EC value of lotus compost tea was greater, showing a significant difference compared to rice husk compost tea. High and low EC values were influenced by variations in the ratio of compost and water, causing differences in dissolved salts [13]. Moreover, the compost tea EC value increased due to the storage time of compost tea, which showed the potential to affect microbial activity and nutrient content [14].

3.1.3 Total Dissolved Solids Value

The compost tea TDS value for both lotus and rice husks increased from the first to the third day of soaking. For rice husk in the ratio of 1:20 (w/v) on the third day, the value decreased from 98.00 to 97.00, as shown in Table 3. Based on the comparison, TDS value in rice husks compost tea treatments is smaller than lotus treatments. Moreover, TDS value serves as indicator of concentration, where a high value shows a more concentrated solution [15], indicating the nutrient elements. When a high value is observed in compost tea, dilution is required before being absorbed by plants. According to [16], nutrient solutions with excessively high TDS value cannot be optimally absorbed by plants.

3.1.4. Nutrient Content of N, P, K Compost Tea

The test results presented in Table 4 showed that N, P, and K content in lotus compost tea was higher than in rice husks. In lotus compost tea, a greater ratio of water and compost resulted in smaller N, P, and K nutrient content. In rice husks compost tea, the ratio of 1:5 (w/v) and 1:10 (w/v) showed satisfactory nutrient levels. Although N and P content had the same levels, compost tea ratio of 1:20 (w/v) decreased significantly. Based on Agricultural Standards Number 261 Permentan SR.310/M/4/2019 concerning liquid organic fertilizer with a minimum N, P, and K content of 2%, it was evident that lotus and rice husks compost tea did not meet the standards. This was because the N, P, and K content was still <2%, lower than the recommended standards.

3.1.5 C-Organic Content, C/N Ratio, and Humic Acid Compost Tea

Lotus compost tea showed higher C-organic content and C/N ratio compared to rice husks, as presented in Table 5. Treatment of lotus compost tea with a ratio of 1:5 (w/v) produced the highest C-organic content but did not significantly differ from 1:20 (w/v). The highest C-organic content in rice husks compost tea was obtained in soaking treatment with a ratio of 1:10 (w/v). C-organic content showed the level of organic matter in the fertilizer solution [17], where higher values indicated greater organic matter content.

The 1:20 (w/v) lotus compost tea treatment showed the highest C/N ratio but was not significantly different from the 1:5 (w/v) treatment. It also produced the highest C/P ratio and significantly differed from the other treatments. The highest C/N ratio in rice husk compost tea was obtained in the 1:20 (w/v) soaking treatment, while the highest C/P ratio was found in the 1:10 (w/v) rice husk compost tea treatment. These results suggested that greater composition of the compost tea soaking water corresponded with larger C/N and C/P ratio values. However, the greater the soaking composition (the more dilutes the solution), the lower the dissolved nutrients, as shown in Table 4. The levels of C, N, and P influenced the C/N and C/P ratios. The C/N and C/P ratios showed the speed of weathering or decomposition processes by microbes. The greater the ratio value, the slower the decomposition process occurs [18].

The laboratory analysis showed that rice husk compost tea's humic acid concentration tended to be higher than lotus compost tea, as presented in Table 5. One factor that influenced the humic acid concentration in compost tea was found to be the type and quality of the compost raw material [9], [19]. As shown in Table 6, the concentration of humic acid in lotus and rice husks compost tea indicated that the denser treatment, with a soaking ratio of 1:5 (w/v), produced the highest concentration of humic acid and significantly differed from other treatments. This showed that a more concentrated compost tea solution resulted in a higher concentration of humic acid, similar to nutrient content, as presented in Table 4. According to [20], the 1:5 (w/v) ratio of compost to water in compost tea has a higher concentration of nutrients and humic acid compared to treatments with ratios of 1:10 (w/v) and 1:20 (w/v).

Table 1. pH value of lotus and husks compost tea for 3 days of soaking

Treatment	**Day-to-day pH value**		
	1	**2**	**3**
Lotus compost tea 1:5 (w/v)	6,02 ± 0,030 a	6,23 ± 0,047 a	6,30 ± 0,034 a
Lotus compost tea 1:10 (w/v)	6,10 ± 0,080 a	6,50 ± 0,021 b	6,50 ± 0,022 b
Lotus compost tea 1:20 (w/v)	6,27 ± 0,050 b	7,00 ± 0,022 c	6,87 ± 0,047 c
BNT 5%	0,14	0,08	0,09
Husks compost tea 1:5 (w/v)	6,53 ± 0,047 b	7,67 ± 0,094 b	7,63 ± 0,047 b
Husks compost tea 1:10 (w/v)	6,47 ± 0,047 a	7,50 ± 0,014 a	7,50 ± 0,024 a
Husks compost tea 1:20 (w/v)	6,40 ± 0,082ab	7,57 ± 0,047 b	7,60 ± 0,024 b
BNT 5%	0,15	0,15	0,08

Note: Numbers followed by the same letter in the same column mean they are not significantly different in the 5% BNT test.

Table 2. EC value of lotus compost tea for 3 days of soaking

Treatment	**Day-to-day EC value**		
	1	**2**	**3**
Lotus compost tea 1:5 (w/v)	2029,00 ± 7,87 c	3660,33 ± 7,41 c	4142,67 ± 6,80 c
Lotus compost tea 1:10 (w/v)	1944,00 ± 8,60 b	2144,00 ± 4,32 b	2152,00 ± 5,89 b
Lotus compost tea 1:20 (w/v)	1142,00 ± 5,66 a	1278,00 ± 7,48 a	1260,67 ± 4,11 a
BNT 5%	18,31	16,08	13,97
Husks compost tea 1:5 (w/v)	191,33 ± 6,13 b	271,33 ± 6,80 c	294,00 ± 1,63 c
Husks compost tea 1:10 (w/v)	141,00 ± 2,45 a	186,00 ± 3,27 a	192,00 ± 1,63 a
Husks compost tea 1:20 (w/v)	140,67 ± 1,70 a	196,00 ± 2,83 b	196,67 ± 1,89 b
BNT 5%	9,63	11,38	4,21

Note: Numbers followed by the same letter in the same column mean they are not significantly different in the 5% BNT test.

Table 3. TDS value of lotus and husks compost tea for 3 days of soaking

Treatment	**TDS value (ppm) day-to-day**		
	1	**2**	**3**
Lotus compost tea 1:5 (w/v)	1553,33 ± 4,71 c	1825,67 ± 4,19 c	2061,67 ± 3,09 c
Lotus compost tea 1:10 (w/v)	1206,67 ± 4,71 b	1053,16 ± 4,64 b	1075,00 ± 3,56 b
Lotus compost tea 1:20 (w/v)	578,67 ± 2,62 a	629,33 ± 2,62 a	634,67 ± 3,30 a
BNT 5%	10,12	9,58	8,13
Husks compost tea 1:5 (w/v)	134,00 ± 2,16 c	133,00 ± 2,83 b	147,00 ± 2,45 c
Husks compost tea 1:10 (w/v)	115,33 ± 2,05 a	94,00 ± 2,45 a	96,00 ± 1,63 a
Husks compost tea 1:20 (w/v)	128,33 ± 2,49 b	98,00 ± 2,16 a	97,00 ± 1,25 b
BNT 5%	5,49	6,10	4,52

Note: Numbers followed by the same letter in the same column mean they are not significantly different in the 5% BNT test.

Table 4. Nutrient content of N, P, and K in compost tea after 3 days of soaking

Treatment	**Value (%)**		
	N	**P**	**K**
Lotus compost tea 1:5 (w/v)	0,010 ± 0,0024	0,008 ± 0,0004 c	0,117 ± 0,0045 c
Lotus compost tea 1:10 (w/v)	0,008 ± 0,0004	0,006 ± 0,0004 b	0,059 ± 0,0004 b
Lotus compost tea 1:20 (w/v)	0,006 ± 0,0004	0,004 ± 0,0004 a	0,033 ± 0,0008 a
BNT 5%		0,001	0,006
Husks compost tea 1:5 (w/v)	0,005 ± 0,0020	0,002 ± 0,0005	0,009 ± 0,0005 c
Husks compost tea 1:10 (w/v)	0,005 ± 0,0004	0,002 ± 0,0005	0,006 ± 0,0005 b
Husks compost tea 1:20 (w/v)	0,003 ± 0,0005	0,001 ± 0,0005	0,004 ± 0,0004 a
BNT 5%			0,001

Note: Numbers followed by the same letter in the same column mean they are not significantly different in the 5% BNT test.

Table 5. Organic C content, C/N ratio, and Humic Acid of compost tea after 3 days of soaking

Treatment	**Value (%)**		
	C organic	**C/N**	**Humic Acid (mg/L)**
Lotus compost tea 1:5 (w/v)	0,075 ± 0,0122 b	7,665 ± 0,6830 b	337,901 ± 30,967c
Lotus compost tea 1:10 (w/v)	0,015 ± 0,0041 a	1,976 ± 0,4377 a	214,045 ± 3,511 b
Lotus compost tea 1:20 (w/v)	0,055 ± 0,0122 ab	12,127 ± 3,9239 b	153,698 ± 1,415 a
BNT 5%	0,0251	5,66	44,1
Husks compost tea 1:5 (w/v)	0,015 ± 0,0041	3,730 ± 0,9187	903,787 ± 39,021 c
Husks compost tea 1:10 (w/v)	0,025 ± 0,0122	5,352 ± 2,2500	635,096 ± 3,385 b
Husks compost tea 1:20 (w/v)	0,020 ± 0,0082	7,778 ± 3,1427	315,442 ± 5,082 a
			55,8

Note: Numbers followed by the same letter in the same column mean they are not significantly different in the 5% BNT test.

3.2. Biochar Characteristics

The characteristics of lotus biochar and rice husks consist of pH value, water content, functional groups, and SEM-EDS.

3.2.1 pH Value and Water Content of Biochar

The measurement results of pH and moisture content of lotus and rice husks biochar are presented in Table 6. The results showed that H_2O pH value of lotus biochar was higher at 9.93 compared to rice husks at 7.97. Both types of biochar showed pH values categorized as high (>7) due to the production of high-pH active carbon by biochar [21]. Due to the high pH value, biochar can effectively contribute to increasing pH of acidic soils [22].

As presented in Table 7, lotus biochar had a moisture content of 3.71%, which was higher than rice husks biochar at 0.51%. According to SNI 06-3730-1995 regarding biochar requirements, both types of biochar met the standard of <10% moisture content. The low moisture content in biochar has a positive effect on soil, thereby increasing water and nutrient absorption [23].

3.2.2. Characterization of Biochar Functional Groups

FTIR spectrum of rice husks biochar in Figure 1 showed that absorption peaks occurred at wave numbers 1703.50 cm^{-1}, 1604.51 cm^{-1}, 1039.44 cm^{-1}, and 790.76 cm^{-1}. The spectrum with weak intensity at 1703.50 cm^{-1} represented the absorption of C=O functional group from the carbonyl [24].

The C=C functional group spectrum of rice husk biochar was observed in the range 1549-1607 cm^{-1}. The spectrum was the observed characteristic peak representing the aromatic structure [24]. The aromatic C=C functional group in rice husk appeared at a wave number of 1604.51 cm^{-1} [24], [25]. The peaks appearing at wave numbers 1039.44 cm^{-1} and 790.76 cm^{-1} represent Si-O-Si and Si-O, respectively, which are usually observed for rice husk biochar due to the abundant Si [24], [26].

In the FTIR spectrum of Lotus biochar shown in Figure 1, absorption appeared at wave numbers 3317.89cm^{-1}, 1627.19 cm^{-1},1363.21 cm^{-1},1097.17cm^{-1},1035.30 cm^{-1}. The spectrum with a strong intensity appearing at 3317.89 cm^{-1} was the absorption of the OH group from the carbonyl and phenol groups [27]. Meanwhile, the spectrum of the C=C functional group from biochar could be observed at the wave number 1627.19 cm^{-1}, serving as the characteristic peak representing its aromatic structure [28]. The C-H functional group at wave number 1363.21 cm^{-1} originated from lignin and holocellulose, which consisted of cellulose and hemicellulose [28]. The C-O functional group was the peak that appeared at 1097.17 cm^{-1} [28]. At wave number 1035.30 cm^{-1}, C-C functional groups from cellulose and hemicellulose were usually found in the biochar [28]. Based on the FTIR in Figure 1, there were differences in functional groups in rice husk and lotus biochar. Rice husk biochar was dominated by the C=O (carbonyl), C=C (aromatic), and Si-O-Si and Si-O functional groups. Meanwhile, the C=C (aromatic) group, C-OH (phenol), and C-H (lignin, cellulose, and hemicellulose) were observed in lotus biochar.

3.2.3. Structural Characterization and Elemental Analysis of Biochar

In this research, SEM testing on rice and lotus husk biochar was carried out to determine the pore structure of the two biochars. Meanwhile, EDS testing was used to detect the presence of dominant elements in the rice husk and lotus biochar specimens. The results of SEM for rice husks and EDS testing are presented in Figure 2, while lotus biochar is shown in Figure 3. Based on SEM results with a magnification of 500x, EDS analysis was performed on four spectrum images of rice husks biochar. EDS testing results showed the dominance of C and O elements for all four spectra of rice husks biochar. In spectrum 1, only C (46.93% atom), O (42.38% atom), and Si (10.69% atom) were found at the peaks. Meanwhile, in spectrum 2, C (61.17% atom), O (28.54% atom), Si (4.05% atom), and some other elements such as Al (0.29% atom), K (0.19% atom), Ca (0.39% atom), Pd (1.44% atom), Ba (0.27% atom), and Au (3.67% atom) were detected. In spectrum 3, rice husks biochar contained C (66.05% atom), O (26.5% atom), Si (7.11% atom), K and Ca at 0.21 and 0.13% atom, respectively. In spectrum 4, C (59.49% atom), O (31.77% atom), Si (8.25% atom), Al (0.17% atom), K (0.19% atom), and Ca (0.14% atom) were found.

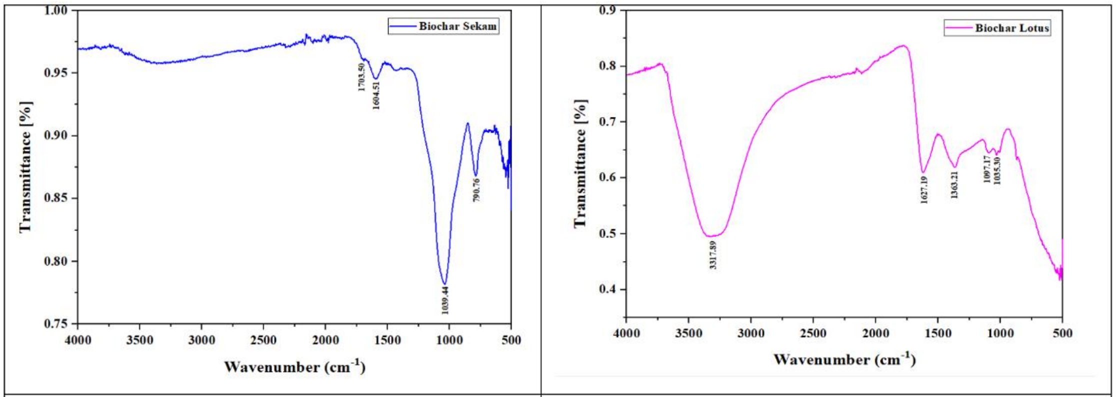
Based on SEM results with a magnification of 500x, EDS analysis was conducted on three spectrum images of lotus biochar. In spectrum 1, EDS testing showed the presence of C (88.66% atom), O (8.92% atom), Mg (0.40% atom), Al (0.63% atom), Si (0.22% atom), P (0.12% atom), Cl (0.15% atom), K (0.55% atom), and Ca (0.35% atom). In spectrum 2, C (62.22% atom), O (27.00% atom), Na (0.37% atom), Mg (0.15% atom), Al (3.95% atom), Si (3.51% atom), Cl (0.12% atom), K (0.67% atom), Ca (0.26% atom), Cl (0.21% atom), K (2.3% atom), and Fe (0.29% atom) were detected. In spectrum 3, lotus biochar showed the presence of C (86.29% atom), O (11.04% atom), Na (0.23% atom), Mg (0.35% atom), Al (0.62% atom), Si (0.21% atom), P (0.22% atom), and S (0.12% atom).

Several differences were found in nutrient content between rice husks and lotus biochar. Specifically, rice husks biochar contained lower carbon but higher oxygen and silica compared to lotus. Essential macro-nutrients found in rice husks biochar included potassium and calcium, while lotus biochar contained potassium, phosphorus, calcium, magnesium, and sulfur. Biochar has the ability to provide nutrients directly to plants, including macro and micro-nutrients [29]. Therefore, lotus biochar has more potential as soil amendment considering the nutrient content.

Apart from the differences in elemental composition, as shown in Figure 4, there was a difference in the micro-porosity structure between rice husks and lotus biochar. The pores in rice husks biochar were smoother and more abundant compared to the larger pores observed in lotus. These pores enhance the surface area and active sites of material, playing a significant role in water and nutrient retention, reducing soil density, and promoting microorganisms development [30]. Transforming rice husks and wild lotus plant waste into biochar has the potential to increase the commercial value of biodegradable waste in the production chain.

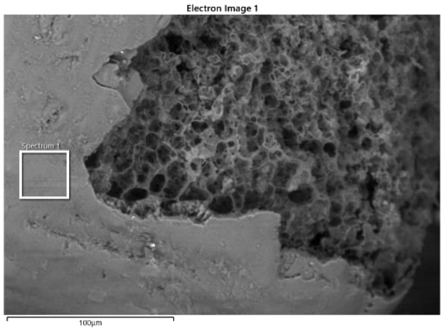
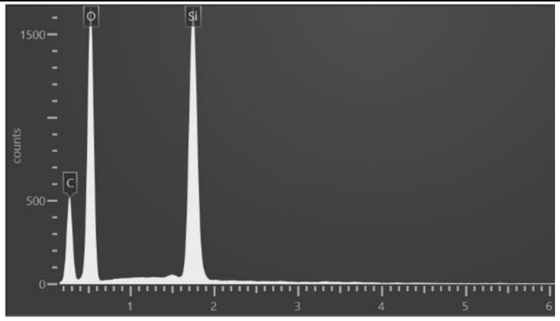
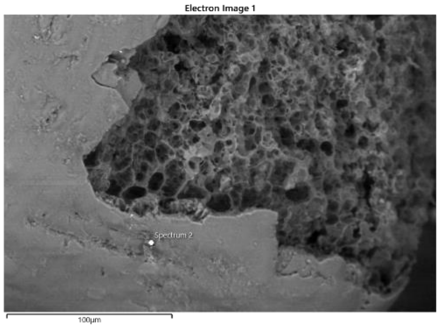
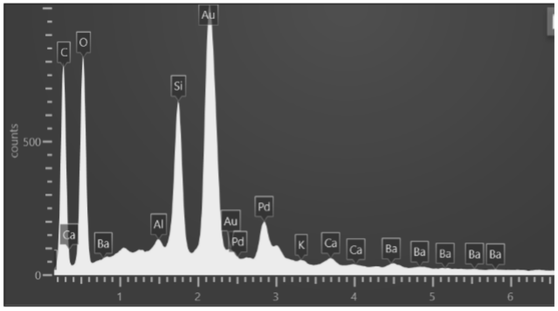
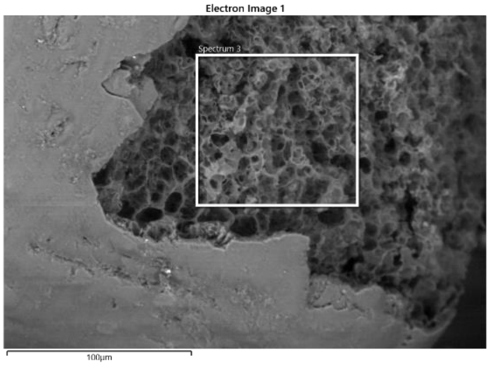
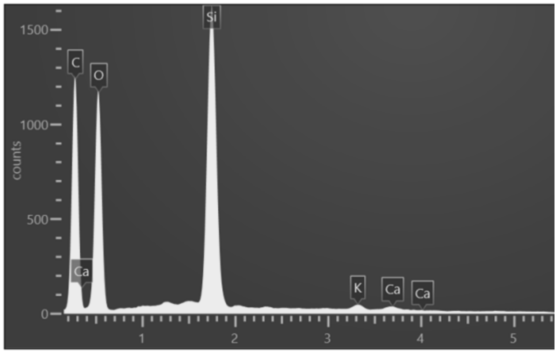
Table 6. pH value of H_2O lotus biochar and husk

Types of biochar	H_2O pH value	Moisture content (%)
Lotus Plant	9,93	3,71
Husk	7,97	0,51



FTIR Spectrum of Biochar Husk	Lotus Biochar FTIR Spectrum

Figure 1. FTIR spectrum of husks and lotus biochar

	
Spectrum 1	C (46,93% atom), O (42,38% atom), Si (10,69% atom)
	
Spectrum 2	C (61,17% atom), O (28,54%) atom, Si (4,05% atom), Al (0,29% atom), K (0,19% atom), Ca (0,39% atom), Pd (1,44% atom), Ba (0,27% atom), Au (3,67% atom).
	

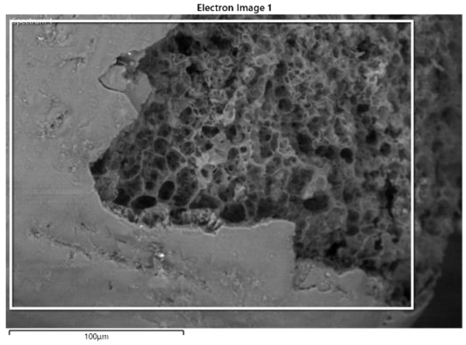
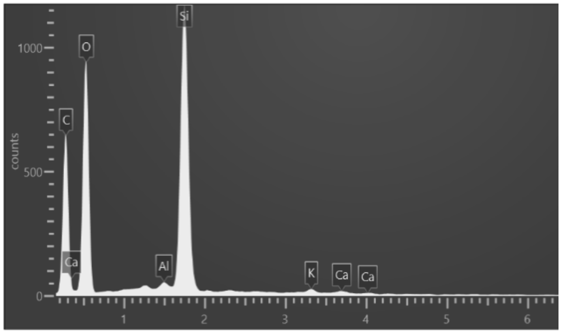
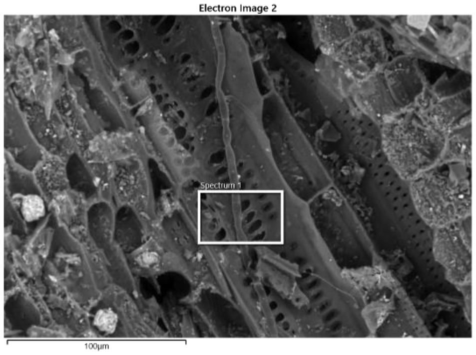
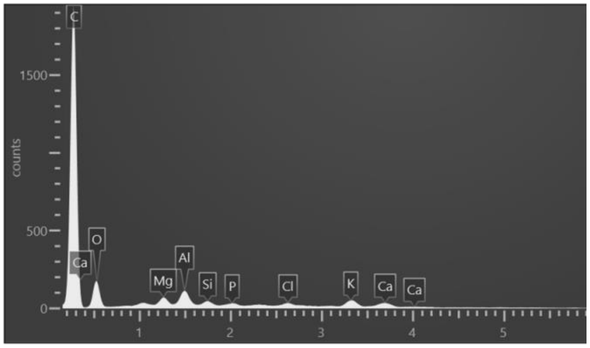
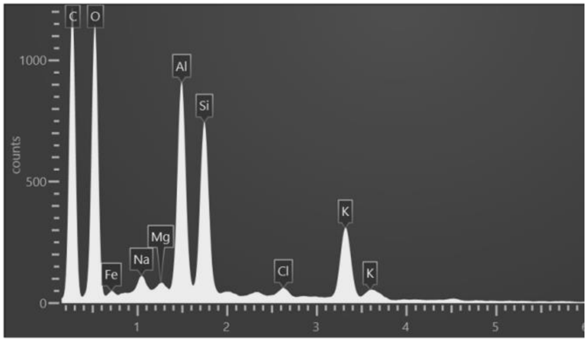
Spectrum 3	C (66,05% atom), O (26,5% atom), Si (7,11% atom), K (0,21% atom), Ca (0,13 % atom)
	
Spectrum 4	C (59,49% atom), O (31,77% atom), Si (8,25% atom), Al (0,17% atom), K (0,19% atom), Ca (0,14% atom)

Figure 2. SEM results (500x magnification) and EDS of rice husks biochar

	
Spectrum 1	C (88,66% atom), O (8,92% atom), Mg (0,40% atom), Al (0,63% atom), Si (0,22% atom), P (0,12% atom), Cl (0,15% atom), K (0,55% atom), Ca (0,35% atom).
	
Spectrum 2	C (62,22% atom), O (27,00% atom), Na (0,37% atom), Mg (0,15% atom), Al (3,95% atom), Si (3,51% atom), Cl (0,12% atom), K (0,67% atom), Ca (0,26% atom), Cl (0,21% atom), K (2,3% atom), Fe (0,29% atom)

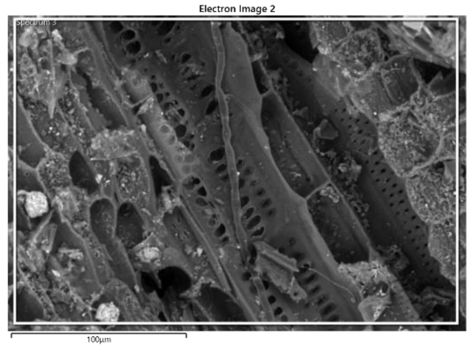
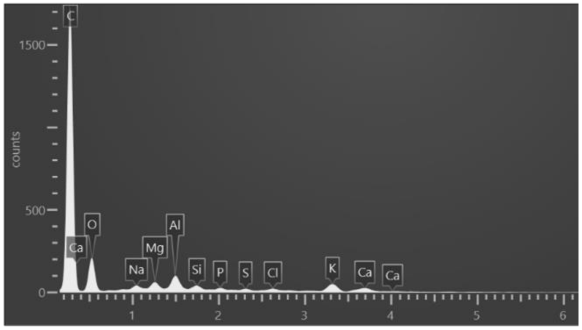
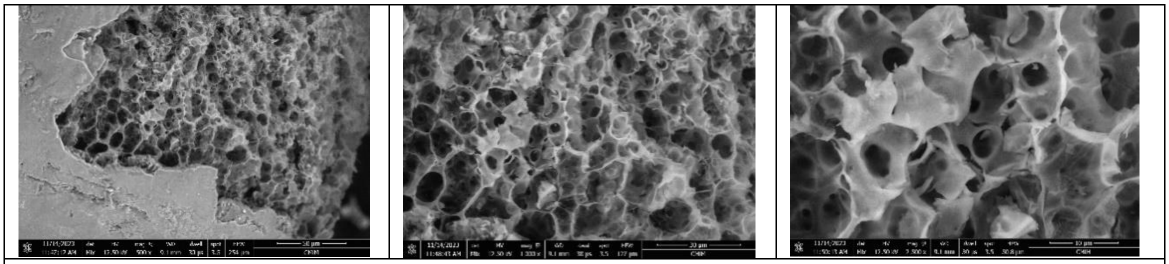
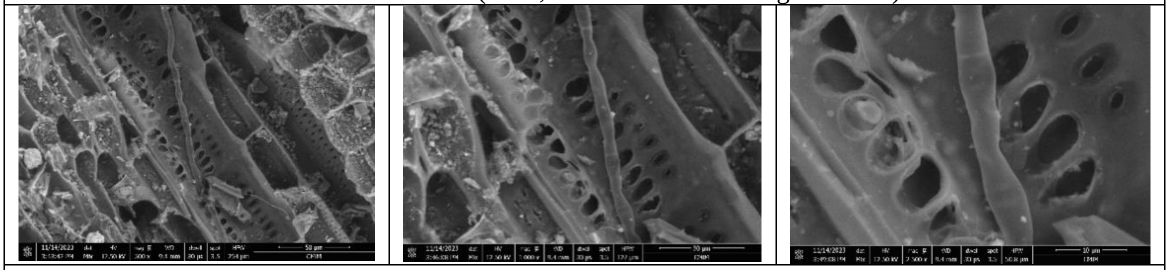
	
Spectrum 3	C (86,29% atom), O (11,04% atom), Na (0,23% atom), Mg (0,35% atom), Al (0,62% atom), Si (0,21% atom), P (0,22% atom), S (0,12% atom)

Figure 3. SEM results (500x magnification) and EDS of lotus biochar



Rice husks biochar (500x, 1000x and 2500x magnification)



Biochar lotus (500x, 1000x, and 2500x magnification)

Figure 4. Microporous structure of rice and lotus husks biochar at various magnifications.

IV. CONCLUSION

Laboratory-scale testing results showed that pH values of lotus compost tea and rice husks were neutral, with lotus biochar having higher values than rice husks biochar. The results showed that a more concentrated compost tea solution produced a higher concentration of humic acid and nutrients. Functional group testing using FTIR detected carbonyl, various aromatic, as well as Si-O-Si and Si-O in rice husks biochar. In lotus biochar, carbonyl, phenolic, lignin, holocellulose, as well as C-O and C-C functional groups were found at different wavelengths. SEM-EDS results showed that the pores in rice husks biochar were smoother and more abundant compared to the larger pores observed in lotus. However, the content of essential micro-nutrients was more abundant in lotus biochar.

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REFERENCES

[1] Kementerian Koordinator Bidang Perekonomian, "Kembangkan Ketangguhan Sektor Pertanian, Indonesia Raih Penghargaan dari International Rice Research Institute." 2022. [Online]. Available: https://www.ekon.go.id/publikasi/detail/4443/kembangkan-ketangguhan-sektor-pertanian-indonesia-raih-penghargaan-dari-international-rice-research-institute

[2] S. D. Widyantika and S. Prijono, "Pengaruh Biochar Sekam Padi Dosis Tinggi Terhadap Sifat Fisik Tanah Dan Pertumbuhan Tanaman Jagung Pada Typic Kanhapludult," *J. Tanah dan Sumberd. Lahan*, vol. 06, no. 01, pp. 1157–1163, 2019, doi: 10.21776/ub.jtsl.2019.006.1.14.

[3] S. Salmiyah, Ainunnisa, E. N. Afifah, E. Handayani, and Firdaus, "Identification of Organic Compounds From Extract Lotus Seeds (Nelumbo nucifera)," *Indones. Chim. Acta*, vol. 10, no. 1, pp. 19–25, 2017, doi: https://doi.org/10.20956/ica.v10i1.6396.

[4] A. Kusuma, M. Riniarti, and Sunaryanti, “Penambahan bahan pembenah tanah untuk mempercepat kolonisasi Ektomikoriza dan pertumbuhan Damar Mata Kucing (Shorea javanica),” *J. Sylva Lestari*, vol. 6, no. 1, pp. 16–23, 2018.

[5] S. Sismiyanti, H. Hermansah, and Y. Yulnafatmawita, “Klasifikasi Beberapa Sumber Bahan Organik Dan Optimalisasi Pemanfaatannya Sebagai Biochar,” *J. Solum*, vol. 15, no. 1, p. 8, 2018, doi: 10.25077/jsolum.15.1.8-16.2018.

[6] G. Abel, R. Suntari, and A. Citraresmini, “Pengaruh Biochar Sekam Padi Dan Kompos Terhadap C-Organik, N-Total, C/N Tanah, Serapan N, Dan Pertumbuhan Tanaman Jagung Di Ultisol,” *J. Tanah dan Sumberd. Lahan*, vol. 8, no. 2, pp. 451–460, 2021, doi: 10.21776/ub.jtsl.2021.008.2.16.

[7] S. Suharyatun, W. Warji, A. Haryanto, and K. Anam, “Pengaruh Kombinasi Biochar Sekam Padi dan Pupuk Organik Berbasis Mikroba Terhadap Pertumbuhan dan Produksi Sayuran,” *J. Teknotan*, vol. 15, no. 1, p. 21, 2021, doi: 10.24198/jt.vol15n1.4.

[8] S. Khoirunisa, B. Irawan, R. Agustrina, E. Nurcahyani, and S. Wahyuningsih, “Penggunaan Compost Tea Diinduksi Inokulum Fungi Lignoselulolitik Pada Media Tanam Cocopeat Terhadap Pertumbuhan Tanaman Kailan (Brassica oleracea L.).,” *J. Penelit. Pertan. Terap.*, vol. 21, no. 1, pp. 78–84, 2021, doi: 10.25181/jppt.v21i1.1731.

[9] A. K. Berek, “Teh Kompos dan Pemanfaatannya sebagai Sumber Hara dan Agen Ketahanan Tanaman,” *Savana Cendana*, vol. 2, no. 04, pp. 68–70, 2017, doi: 10.32938/sc.v2i04.214.

[10] A. I. González-Hernández, M. B. Suárez-Fernández, R. Pérez-Sánchez, M. Á. Gómez-Sánchez, and M. R. Morales-Corts, “Compost tea induces growth and resistance against rhizoctonia solani and phytophthora capsici in pepper,” *Agronomy*, vol. 11, no. 4, pp. 0–11, 2021, doi: 10.3390/AGRONOMY11040781.

[11] M. J. Kim *et al.*, “Effect of aerated compost tea on the growth promotion of lettuce, soybean, and sweet corn in organic cultivation,” *Plant Pathol. J.*, vol. 31, no. 3, pp. 259–268, Sep. 2015, doi: 10.5423/PPJ.OA.02.2015.0024.

[12] T. Luo, L. Ma, C. Wei, and J. Li, “Effects of compost tea on the spatial distribution of soil nutrients and growth of cotton under different fertilization strategies,” *J. Plant Nutr.*, vol. 45, no. 10, pp. 1523–1535, 2022, doi: 10.1080/01904167.2021.2020827.

[13] S. Suseno and N. Widyawati, “Pengaruh Nilai EC Berbagai Pupuk Cair Majemuk Terhadap Pertumbuhan Vegetatif Kangkung Darat Pada Soilless Culture,” *Agrosains J. Penelit. Agron.*, vol. 22, no. 1, p. 12, Apr. 2020, doi: 10.20961/agsjpa.v22i1.32510.

[14] M. Gondek, D. C. Weindorf, C. Thiel, and G. Kleinheinz, “Soluble Salts in Compost and Their Effects on Soil and Plants: A Review,” *Compost Science and Utilization*, vol. 28, no. 2. Taylor and Francis Inc., pp. 59–75, Apr. 02, 2020. doi: 10.1080/1065657X.2020.1772906.

[15] L. Sulistyowati and N. Nurhasanah, “Analisa Dosis AB Mix Terhadap Nilai TDS Dan Pertumbuhan Pakcoy Secara Hidroponik,” *Jambura Agribus. J.*, vol. 3, no. 1, pp. 28–36, 2021, doi: 10.37046/jaj.v3i1.11172.

[16] D. R. Wati and W. Sholihah, “Pengontrol pH dan Nutrisi Tanaman Selada pada Hidroponik Sistem NFT Berbasis Arduino,” *Multinetics*, vol. 7, no. 1, pp. 12–20, 2021.

[17] A. M. Syahidah and B. Hermiyanto, “Pengaruh Penambahan Pupuk Kandang Sapi dan Pupuk SP-36 terhadap Perbaikan Sifat Kimia Tanah, Pertumbuhan dan Produksi Tanaman Sorghum (Sorghum bicolor L.) pada Tanah tercemar Limbah Padat Pabrik Kertas (Lime Mud),” *Berk. Ilm. Pertan.*, vol. 2, no. 4, pp. 132–140, 2019, doi: 10.19184/bip.v2i4.16306.

[18] Sismiyanti, Hermansah, and Yulnafatmawita, “Klasifikasi Beberapa Sumber Bahan Organik dan Optimalisasi Pemanfaatannya sebagai Biochar,” *J. Solum*, vol. 15, no. 1, p. 8, Jan. 2018, doi: 10.25077/jsolum.15.1.8-16.2018.

[19] A. P. Pant, T. J. K. Radovich, N. V. Hue, and R. E. Paull, “Biochemical Properties of Compost Tea Associated with Compost Quality and Effects on Pak Choi Growth,” *Sci. Hortic. (Amsterdam).*, vol. 148, pp. 138–146, 2012, doi: 10.1016/j.scienta.2012.09.019.

[20] N. E. Kiss, E. Gorliczay, P. T. Nagy, and J. Tamás, “Effect of compost/water ratio on some main parameter of compost solutions,” *Acta Agrar. Debreceniensis*, no. 1, pp. 117–121, Jun. 2021, doi: 10.34101/actaagrar/1/8500.

[21] P. Agviolita, Y. Yushardi, and F. K. A. Anggraeni, “Pengaruh Perbedaan Biochar terhadap Kemampuan Menjaga Retensi pada Tanah,” *J. Fis. Unand*, vol. 10, no. 2, pp. 267–273, Apr. 2021, doi: 10.25077/jfu.10.2.267-273.2021.

[22] Z. M. Solaiman and H. M. Anawar, “Application of Biochars for Soil Constraints: Challenges and Solutions,” *Pedosphere*, vol. 25, no. 5. Institute of Soil Science, pp. 631–638, Oct. 01, 2015. doi: 10.1016/S1002-0160(15)30044-8.

[23] T. Iskandar and U. Rofiatin, “Karakteristik Biochar Berdasarkan Jenis Biomassa Dan Parameter Proses Pyrolisis,” *Tek. Kim.*, vol. 12, no. 1, pp. 28–34, 2017.

[24] J. Shi *et al.*, “Removal of Lead by Rice Husk Biochars Produced at Different Temperatures and Implications for Their Environmental Utilizations,” *Chemosphere*, vol. 235, pp. 825–831, Nov. 2019, doi: 10.1016/j.chemosphere.2019.06.237.

[25] Reza Arrafi Rasyid, E. Erdawati, and D. Darwis, “Pengaruh Penambahan Biokar Sekam Padi Terhadap Penyerapan Gas CO2 (Carbon Dioxide) dan Kuat Tekan pada Plester Dinding,” *JRSKT - J. Ris. Sains dan Kim. Terap.*, vol. 8, no. 1, pp. 10–22, Oct. 2019, doi: 10.21009/jrskt.081.02.

[26] L. Rumiyanti, C. Destiana, R. Oktaviani, S. Sembiring, Syafriadi, and N. L. G. R. Juliasih, “Pengujian Gugus Fungsi Silika Berbasis Sekam Padi Dengan Variasi Suhu & Konsentrasi Cetyltrimethylammonium Bromide Sebagai Bahan Baku Mesoporous Silica,” 2021.

[27] Y. Hou, Y. Liang, H. Hu, Y. Tao, J. Zhou, and J. Cai, “Facile preparation of multi-porous biochar from lotus

biomass for methyl orange removal: Kinetics, isotherms, and regeneration studies," *Bioresour. Technol.*, vol. 329, Jun. 2021, doi: 10.1016/j.biortech.2021.124877.

[28] T. V. Thanh Do *et al.*, "One-pot fabrication of magnetic biochar by FeCl3-activation of lotus seedpod and its catalytic activity towards degradation of Orange G," *Mater. Res. Express*, vol. 9, no. 10, Oct. 2022, doi: 10.1088/2053-1591/ac9819.

[29] Mapegau, Mukhsin, I. Hayati, and H. Setiawan, "Growth and Results of Sorgum (Sorghum bicolor (L.) Moench) Using Chicken Manure and Rice Husk Biochar on Dry Land," *J. Media Pertan.*, vol. 8, no. 1, pp. 50–56, 2023, doi: 10.33087/jagro.v8i1.185.

[30] S. Suswana and D. D. Maulana, "Efek Residu Biochar Sekam Padi terhadap Pertumbuhan dan Hasil Kedelai," *Agrotechnology Res. J.*, vol. 7, no. 1, pp. 41–49, 2023, doi: 10.20961/agrotechresj.v7i1.70894.

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