Recycling rubberwood bark wastes into biochar to enhance chemical properties of peat soils

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Abstract. Peat soils in Malaysia is renowned for its poor chemical properties and often lead to restriction in agricultural uses. The abundance of waste in particle board and furniture industry offers a potential for producing biochar products with ability to enhance peat soil chemical properties. This study intends to evaluate the effects of different rate of rubberwood bark biochar on selected chemical properties of peat soils and growth performance of paddy variety MRIA 1, as a test crop. Results showed that application of rubberwood bark biochar at the rate of 226.80 grams (Treatment 3) significantly improve the soil pH, soil exchangeable potassium (K), calcium (Ca) and magnesium (Mg) combined with positive increment of tillers number, root length and height of paddy plant compare to other treatments. This study suggested a positive potential of rubberwood bark biochar to enhance the chemical properties of peat soils which led to good plant growth performance.

Keywords: rubberwood bark, biochar, peat, chemical, soil

1. Introduction

Peat soil in Malaysia which belongs to oligotrophic type had restricted the potential of the soils for extensive agricultural usage. The soils originate from the accumulation of organic matter due to slow decomposition rate which often impeded by high water table coupled with high amount of precipitation [1]. Physically, peat soils exhibit high water holding capacity which approximately more than 80% (weight/volume). The build-up of organic matter allows peat to have high porosity with low bulk density, often ranging between 0.12g/cm\(^3\) to 0.20g/cm\(^3\) [2]. Chemically, the nutrient availability in peat soils is often inhibited due to low soil pH, ranged between pH 3 to pH 4.5 [1] and the dynamics of the nutrients is influenced by the fluctuating of water table in the soils [3]. The soil cation exchange capacity (CEC) is depending on the rate of decomposition where advance decomposition led to higher soil CEC as the lignin-derivates from the process enable higher site for cation exchange [1], [4], [5]. However, the proportion of basic cation to acidic cation is often low, with the percentage of base saturation is less than 10% [1]. There are many initiatives of improving the peat soil properties such as through lime formulation and application, soil amendments and biochar application. However, much of the amendment sources are raw, and often led to higher cost of production. Due to the emergence of efforts in recycling the wastes globally as related to climate change issues, this study focused on recycling the wastes produced from the rubberwood particle board and furniture industry. In the industry, rubberwood logs are processed into products such as
plywood, fibreboard and wood-cemented board with good durability and good dense grain character [6]. During the process, much of the wastes from the rubberwood bark were produced [7]. Due to the abundance of wastes, one of the options is to turn them into biochar. Biochar is the product of pyrolysis process called anthropogenic product [8]. Pyrolysis is the carbonization process of raw materials under absence or least of oxygen. The biochar may made up from various raw materials such as empty fruit bunch, rubber sawdust, rice husk and pitch pine [9][10][11] and has potential to be use as carbon sequestration agent and soil amendment for agricultural productivity improvement. Hence, this study intends to evaluate the effects of different rate of rubberwood bark biochar on selected chemical properties of peat soils and growth performance of paddy variety MRIA 1, as a test crop.

2. Materials and Methods

2.1. Sample collection
Samples of rubberwood bark wastes was collected from particle board and furniture factory in Negeri Sembilan. The rubberwood bark was dried at 60°C overnight before passed through the 2.0mm sieve.

2.2. Production of biochar
The dried rubber bark wood was weighted into 30 grams per 100mL of crucible. The crucibles were placed into muffle furnace and dry rubber bark wood undergone pyrolysis by heated 5°C/min at increasing rate and was hold for 1 hour at temperatures of 700°C. The final weight of rubber bark wood biochar was weighted [12].

2.3. Field experiment
The peat soil samples were collected from Jasin, Melaka. The mean soil pH of collected samples were pH 3.8 and having a bulk density of 0.33g/cm3. Each of the experimental pot was filled with approximately 10kg of the soils. The pots were arranged into completely randomized design (CRD) with three replications. The treatments applied in the experiment were shown in Table 1.

| Treatment | Biochar application rate (grams) |
|-----------|----------------------------------|
| T0        | No biochar (Control)             |
| T1        | 60.48                            |
| T2        | 151.19                           |
| T3        | 226.80                           |

Upon application, the rubberwood bark biochar was mixed thoroughly with the soil and left for 14 days to allow the chemical reaction takes place. Then, the paddy seedlings of variety MRIA 1 were transferred into the pot. Standard fertilizer application rate for paddy planting was applied, specifically the Urea, Triple Super Phosphate and Muriate of Potash.

2.4. Sample collection
The soil samples were collected biweekly for 6 weeks. The samples were dried, undergo the sieves and analysed for soil pH, available P, K, Ca and Mg using standard lab procedure [13] followed by concentration determination using ICP-OES. On the other hand, the paddy growth performance was monitor through the number of tillers, plant height and length of roots. The plant nutrient analysis was conducted using dry-ashing method and analysed for P, K, Ca and Mg. statistically, the data obtained was analysed using SPSS.
3. Results and Discussions

3.1. Soil chemical properties

Results on soil chemical properties analysis were presented in Figure 1-Figure 5, representing the soil pH, soil available P, soil exchangeable K, Ca and Mg, respectively. Results showed that the addition of rubberwood bark biochar enable the increasing of soil pH (refer Figure 1). A significant increment of soil pH obtained when the existing soil was applied with more than 60.48 grams of rubberwood bark biochar (Treatment 2 and Treatment 3).

![Soil pH Chart](image1)

Notes: T0: No biochar (Control); T1= 60.48 grams of rubberwood bark biochar; T2= 151.19 grams of rubberwood bark biochar; T3= 226.80 grams of rubberwood bark biochar

In contrast with soil pH, the concentration of available P shows a decreasing pattern with increasing amount of rubberwood bark biochar. The significant decrement in soil available P was observed when the soil was applied with rubberwood bark biochar of more than 151.19 grams.

![Available P Chart](image2)

Notes: T0: No biochar (Control); T1= 60.48 grams of rubberwood bark biochar; T2= 151.19 grams of rubberwood bark biochar; T3= 226.80 grams of rubberwood bark biochar
The concentration of exchangeable K, Ca and Mg shows an increasing pattern with the increasing amount of rubberwood bark biochar application. It is expected since the application of rubberwood bark biochar enable the improvement of soil pH which led to exchange of much concentration of exchangeable bases in the soil [14].

For soil exchangeable K (Figure 3), a significant difference clearly observed when more than 151.19 grams of rubberwood bark biochar being applied. This shows that the exchange site is dominated by other cations with higher charges [14], suggested to be Ca$^{2+}$ as reflected by data in Figure 4, where a significant difference of Ca in the soil was experienced when more than 60.48 grams of rubberwood bark biochar was applied into the soil.

The Ca$^{2+}$ in cation form is strongly held on soil surface compare K$^+$ and thus able to replace the H$^+$ adsorb on the soil surface [15]. In addition, the application of fertilizers may influence the availability
of K to compete with Mg in attraction to soil surface. Soil K which is positively charged attracted to the negatively charged of soil surface due to additional exchange site provided by the rubberwood bark biochar [10]. Previous studies had showed that the application of different types of biochar able to increase the soil cation exchange capacity (CEC) by providing additional exchange sites into the soil [8] [10] [11].

![Figure 5: Mean concentration of soil exchangeable Mg](image)

Overall data shows there is a significant difference observed for exchangeable K and Ca whereas no significant difference was observed for exchangeable Mg for all treatments. The application of more than 151.19 grams of rubberwood bark biochar enable the significant increase in the concentration of exchangeable K and Ca.

### 3.2. Soil-plant relationship

The relationship between soil chemical properties and plant growth performance was presented in Table 2.

|                         | Number of tillers | Length of roots | Plant height |
|-------------------------|-------------------|-----------------|--------------|
| Phosphorus (P)          |                   |                 |              |
| Pearson Correlation     | -0.95**           | -0.96**         | -0.96**      |
| Sig. (2-tailed)         | .000              | .000            | .000         |
| Potassium (K)           |                   |                 |              |
| Pearson Correlation     | 0.96**            | 0.99**          | 0.98**       |
| Sig. (2-tailed)         | .000              | .000            | .000         |
| Calcium (Ca)            |                   |                 |              |
| Pearson Correlation     | 0.97**            | 0.98**          | 0.99**       |
| Sig. (2-tailed)         | .000              | .000            | .000         |
| Magnesium (Mg)          |                   |                 |              |
| Pearson Correlation     | 0.96**            | 0.96**          | 0.97*        |
| Sig. (2-tailed)         | .000              | .000            | .000*        |

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
Results in Table 2 showed that there are significant differences between soil chemical properties and plant growth performance specifically the number of tillers, length of roots and plant height. These shows that all nutrients involved (available P, exchangeable K, Ca and Mg) enable the good plant growth. The negative relationship between available P and plant growth indicates that the paddy plant of variety MRIA 1 uptake low amount of P and the increment of P-availability tend to reduce number of tillers with shorter plant roots and lower plant height. This finding is contradicted with the norm of plant growth where much of the plants able to have higher growth performance with higher P-availability [16]. The results are contrasting, suggested to be due to the variety of the paddy use in the study.

4. Conclusions
This study suggested that the application of rubberwood bark biochar able to improve the chemistry of peat soils specifically in improving the soil pH, soil exchangeable K and Ca coupled with good plant growth performance.

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References
[1] J. P. Andriesse, “Nature and management of tropical peats,” in FAO Soils Bulletin, FAO, Rome, 1988, p. 165.
[2] M. K. Shuib et al., “Definitions and engineering classifications of tropical lowland peats.” Bull. Eng. Geol. Environ., vol. 72, no. 3–4, pp. 547–553, 2013, doi: 10.1007/s10064-013-0520-5.
[3] B. K. Nur Qursyna and Y. Adzmi, “Nutrient dynamics in peat soil: Influence of fluctuating water table,” IOP Conf. Ser. Earth Environ. Sci., vol. 327, p. 012024, 2019.
[4] M. R. Aminur, P. K. Kolay, S. N. L. Taib, M. Ibrahim, and A. A. Ahmad Kamal, “Physical, geotechnical and morphological characteristics of peat soils from Sarawak,” Inst. Eng. Malaysia, vol. 72, no. 4, p. 5, 2011.
[5] E. S. Asapo and C. A. Coles, “Characterization and Comparison of Saprist and Fibrist Newfoundland Sphagnum Peat Soils,” J. Miner. Mater. Charact. Eng., vol. 11, no. 07, pp. 709–718, 2015, doi: 10.4236/jmmce.2012.117057.
[6] N. Aini and N. Hazmira, “Assessment of Rubberwood Value-Added in Malaysia ’s Wooden Furniture Industry,” Int. J. Econ. Manag., vol. 8, no. 1, pp. 1–9, 2014.
[7] Z. Yongdong, J. Mingliang, G. Ruizeng, and L. Xiaoling, “Rubberwood Processing Manual Rubberwood Processing Manual,” Res. Inst. Wood Ind. Chinese Acad. For., vol. 4, no. 1, 2007.
[8] A. D. Igalavithana, Y. S. Ok, A. Usman, M. I. Al-Wabel, P. Oleszczuk, and S. S. Lee, “The Effects of Biochar Amendment on Soil Fertility The Effects of Biochar Amendment on Soil Fertility,” Agric. Environ. Appl. Biochar Adv. Barriers., no. November, 2015, doi: 10.2136/sssaspecpub63.2014.0040.
[9] K. Ho, J. Kim, T. Cho, and J. Weon, “Bioresource Technology Influence of pyrolysis temperature on physicochemical properties of biochar obtained from the fast pyrolysis of pitch pine ( Pinus rigida ),” Bioresour. Technol., vol. 118, pp. 158–162, 2012, doi: 10.1016/j.biortech.2012.04.094.
[10] W. Azlina et al., “Biochar production from waste rubber-wood-sawdust and its potential use in C sequestration : Chemical and physical characterization,” Ind. Crop. Prod., vol. 44, pp. 18–24, 2013, doi: 10.1016/j.indcrop.2012.10.017.
[11] R. Radin et al., “Biochar - compost mixture as amendment for improvement of polybag - growing media and oil palm seedlings at main nursery stage,” Int. J. Recycl. Org. Waste Agric., vol. 7, no. 1, pp. 11–23, 2018, doi: 10.1007/s40093-017-0185-3.
[12] N. Farhaneem, S. Se, M. F. Dimin, and A. Shaaban, “Microstructural Analysis on Biochar
Obtained from Rubber Wood Sawdust via Slow Pyrolysis,” *Solid State Phenom.* ISSN 1662-9779, *Vol. 264, pp 13-16* doi:10.4028/www.scientific.net/SSP.264.13 © 2017 Trans Tech Publ. Switz., no. August, 2017, doi: 10.4028/www.scientific.net/SSP.264.13.

[13] Soil Survey Staff, “Soil survey field and laboratory methods manual. Soil Survey Investigations Report No. 51, Version 2.0.R. Burt and Soil Survey Staff (ed.),” 2014.

[14] L. H. John, L. T. Samuel, D. B. James, and L. N. Werner, *Soil Fertility and Fertilizers*, Seventh Ed. Pearson Prentice Hall, 2005.

[15] N. C. and R. R. W. Brady, *The nature and properties of soils 14th edition*. 2008.

[16] S. Siti Zaharah, A. R. Nur Azwani, J. Abdul Shukor, A. Md Amirul, and A. Farzad, “Effects of fermented plant juice and fruit juice on growth and yield of tomato for sustainable practices,” *Bangladesh J. Bot.*, vol. 46, no. 1, pp. 405–412, 2017.