THE EFFECTS OF BIOCHAR-COMPOST (BIOCOM) ON CADMIUM AVAILABILITY AND GREEN MUSTARD (*BRASSICA JUNCEA*) GROWTH

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Abstract

Recently, as the result from resulting from various natural processes and industrial activities, the concentration of heavy metals commonly found in the soil such as cadmium has increased. However, the combination of biochar and compost (BioCom) as one of the potential methods for remediating the contaminated soil is not well defined. Therefore, a study was conducted to evaluate the responses of BioCom on cadmium availability and green mustard growth. Four randomly arranged treatments with four replications ranging from 0 to 40% application of biochar in combination with compost and cadmium (Cd) contaminated mineral soils were done in the glasshouse. Soil chemical properties, plant chlorophyll content, fresh weight, dry weight and root length were assessed after 30 days of planting. The data was analyzed with a one-way ANOVA applied at significant level of 95%. The Cd concentration in plant tissue decreased up to 87% with the application of 20% BioCom. The soil pH was found to be significantly higher soil amended with 40% BioCom as compared to the unamended soil. However, the addition of BioCom has no effects on the plant growth. The study suggests that the BioCom application has great potential in reducing the cadmium availability.

Keywords: biochar, compost, biochar-compost, cadmium, remediation

Introduction

Soil contamination is defined as the presence of harmful elements in soil that adversely affects human health and land biodiversity. Soil contamination or known as soil pollution majorly occurs due to the presence of xenobiotic substances which led to the change in characteristics of the soil. The pollution commonly brought about from industrial activities, such as agrochemicals, or poor waste disposal from agricultural activities such as cadmium (Cd). Toxic elements like Cd had caused significant risks to the quality of soil, food safety, and the human health due to its toxicity. Cadmium was reported introduced into the soil ecosystem via a variety of human sources that including the agricultural practices with the usage of phosphate fertilizer, sewage sludge and manures.

In west coast of Malaysia Peninsular, heavy metal element was reported oil palm area which might be attributed due to excessive usage of chemical fertilizer (Aini *et al*., 2021). As the Cd presence naturally in phosphate rock, the application of fertilizer with the highest

concentration of phosphorus into the soil had led to the introduction of Cd into the soil system (Van, 2001). A previous study discovered that plants growing in Cd-containing soil displayed decreased plant growth, yields and performance. Meanwhile, a similar finding from a prior study also showed that growing plants in soil contaminated with Cd inhibited their leaf and phenological development (Ryse *et al*., 2006). Cadmium toxicity in soil and plant systems also has an adverse effect on human health when introduced into the food chain system.

The vegetable is a major component in human daily diet supplement for nutrients, vitamins and antioxidants. Green mustard or *Brasica juncae*, is one of the preferably consumed leafy vegetables in Malaysia that has been identified as heavy metals accumulator (Raskin *et al*., 1997). Therefore, this greatly shows the significance to assess the potential transfer of the heavy metals from soils to plant and their effects on the plant growth.

Organic amendment application in remediating the contaminated soil is a sustainable method and cost effective. This method uses different types of local organic amendments such as crop residues, biosolids and livestock manures. Therefore, recently, the combination of biochar-compost (BioCom) has gained people's interest due to its potential for remediating contaminated soil and improving plant growth performance. Numerous studies have discovered the possibility of combing these two organic amendments to lessen the amount of cadmium that is present in the soil. Previous findings found that the application of palm kernel shell biochar results in removing up to 80% of Cd concentration in soil (Ayob *et al*., 2021). Meanwhile, the combination of corn, stalk, peanut hulls, and rice hull biochar is shown to reduce the Cd availability in soil (Tianyi *et al*., 2016). Similar findings are found in the application of bamboo biochar which reducing up to 76.9% of Cd concentration in soil (Ma *et al*., 2007). This might be attributed due to adsorption mechanisms in reducing the availability of the metals in the soil system. Besides, the addition of biochar-compost combination also showed positive responses on soil properties by improving the soil pH, organic carbon, and macronutrients (Tang *et al*., 2020).

Therefore, the objectives of the present study are; (i) to determine the effectiveness of BioCom in reducing cadmium (Cd) concentration, and (ii) to evaluate the responses of BioCom on the green mustard growth performance.

Materials and methods

BioCom Production

The composting raw material were a mixture of; 2.5 kg of oil palm empty fruit bunch (EFB), 5 kg of chicken manure, 3.5 kg of peat moss and 0.36 kg of vegetables with a ratio of 30:1 of carbon and nitrogen. Then, the mixed materials were incubated in a compost bin and applied with rice water regularly. The temperature of the compost was measured at three-day intervals ranging from 32 to 43^{o}C. Meanwhile, biochar was produced from an oil palm empty kernel shells which was collected from Sime Darby Plantation Kempas Palm Oil Mill, Melaka, Malaysia. The palm kernel shell was pyrolyzed in the biochar burner with the temperature ranging between 250 to 350 °C. Biochar was added into the compost bin on day 15 and mixed thoroughly with 1 :1 ratio for biochar and compost, respectively. The biochar-compost mixture (BioCom) was incubated in the bin for 30 days.

Greenhouse experimental set-up

The soil sample was collected from a field area at UiTM Cawangan Melaka Kampus Jasin, Merlimau, Melaka, Malaysia. The 4 kg of air-dried and sieved soil was then placed into a 12-

inch × 15-inch size of the polybag. The soil was spiked with 1000 ppm of Cd prior to the application of BioCom. Treatments that were applied one week prior to the transplanting process of green mustard subjected to; T0-0% application of BioCom (control), T1-10% of application BioCom, T2-20% of application BioCom, and T3-40% of BioCom with four replications. Each polybag was planted with a seedling of green mustard. All treatments (16 experimental units) were applied with 150 kg/ha of NPK green (15:15:15) on the first, second and third week of planting. The plants were harvested on 30 days after transplanting.

Green Mustard Growth Analysis

The plant growth was analyzed based on fresh weight biomass, dried weight biomass, chlorophyll content and plant roots length. The weight of fresh biomass was measured by using laboratory weight scale after harvesting and cleaning prior dried in the oven at 60^{o}C for 48 hours (dried weight biomass). The chlorophyll content and root length was measured by using chlorophyll meter and tape measure, respectively.

Soil Chemical Properties Analysis

The soil's pH was determined using a potentiometric pH meter with 1 to 2.5 ratio of soil and distilled water in weight. The determination of phosphorus (P) content in soil was measured using Bray II method. Meanwhile, for the exchangeable of potassium (K), calcium (Ca) and magnesium (Mg) in soil were measured by using a modified shaking method. The extractable Cd was prepared using 1N HCl. All the samples were filtered and elements concentration were detected by using the Optima 8000 Inductively Coupled Plasma–Optical Emission Spectrometry (ICP-OES) (PerkinElmer, Inc., MA, USA).

Green Mustard and BioCom Plant Tissues Analysis

The identification of Cd contents in green mustard plant and BioCom was determined by using the dry ashing method. The sample of green mustard leaves were collected and dried in oven at temperature 60°C for 48 hours. Then, samples were grinded and weighed at 0.5g a crucible. The samples were then ashed in a muffle furnace for 5 to 6 hours at temperature ranging from 300°C to 600°C. Next, the samples were added with distilled water and concentrated hydrochloric acid prior dried on the hot plate. The samples were then placed into the water bath with a temperature of 100°C for 30 minutes after the addition of 10 ml of 20% of HNO□. Finally, the samples were diluted and filtered prior elemental analysis by using the Optima 8000 ICP-OES.

Statistical Analysis

The data were analysed with a one-way analysis of variance (ANOVA) by using the SPSS 17.0 software package (SPSS inc., Chicago, IL, USA). The differences between treatments are reported as significant at $p \leq 0.05$ with Tukey's post hoc test.

Results and Discussion

Basic Chemical Properties of BioCom

Biochar and compost showed differences in nutrients composition (**Table 1**). Compost had high percentage of P, K, Ca and Mg due to the release of nutrients during the degradation process of composting (Zulfiqar *et al*., 2019). Palm kernel shell biochar showed a low amount of nutrients especially in P. The biochar nutrients contents were determined by biochar feedstock and pyrolysis condition. Biochar produced at low pyrolysis temperature (<350^{o}C) were found to have low nutrients contents as compared to the high pyrolysis temperature (Zheng *et al*., 2013). The high and low nutrients range of these organic amendments resulted a medium range of nutrients composition of these mixture (BioCom). The pH of all amendments was alkaline. This might be attributed to the ash content produced by biochar during the pyrolysis process.

Table 1 Nutrient composition and pH in Compost, Biochar and BioCom

Type	P%	K%	Ca%	Mg%	pH
Compost	32.21	65.09	58.5	12.64	8.36
Biochar	1.29	5.68	22.12	1.67	9.11
BioCom	16.99	27.48	39.4	6.56	8.95.

Effects of BioCom on Soil Cadmium Availability

The application of all rates of BioCom to the artificially contaminated soil did not significantly (P>0.05) effect the Cd availability in soil (**Figure 1**). However, there was a decreased trend of Cd concentration from 15.27 mg/kg (control) to 11.41 mg/kg at 40% BioCom application rate, followed by 20% and 10% BioCom application. This trend showed a potential of BioCom application in reducing the Cd availability with the increased of BioCom rates. The reduction of Cd concentration might be attributed the adsorbent characteristics of biochar like high surface area and rich in functional groups (Bashir *et al*., 2018).

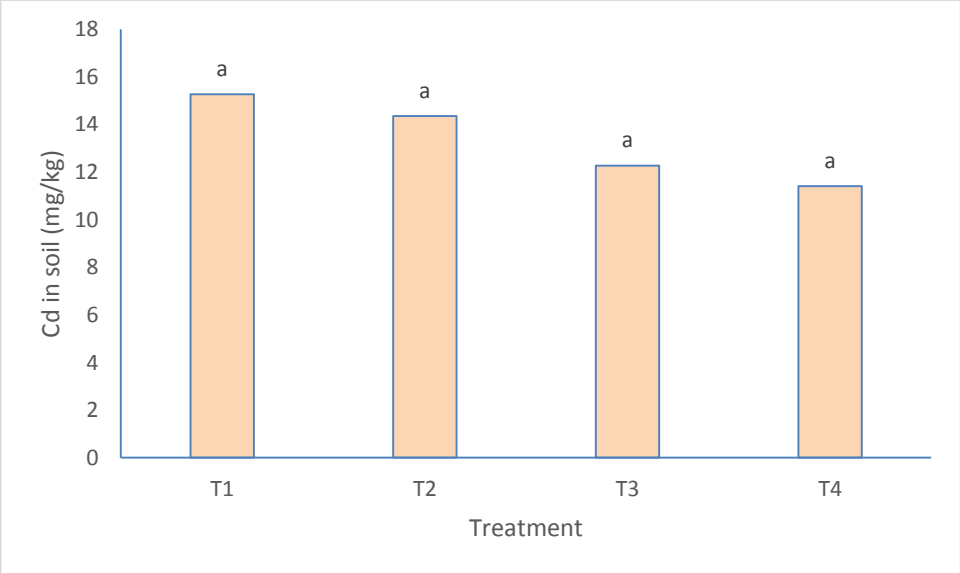

Figure 1 Cadmium concentration in soil; T0 – 0% application of BioCom, T1- 10% of

application BioCom, T2- 20% application of BioCom, and T3- 40% application of BioCom. Means with the same alphabet were not significantly different at p-value >0.05.

Effects of BioCom on Cadmium Content in Green Mustard

The statistical results indicated that BioCom application at 20% significantly reduced the Cd concentration in green mustard (**Figure 2**). There was an 87% of reduction of Cd with 20% BioCom application in the contaminated soil as compared to the control, which is similar to the findings reported by Al-Wabel *et al*., (2015). The addition of BioCom strongly increased the Cd immobilization by reducing the Cd from availability and uptake by plants. These results are in line with Zubaidi *et al*., (2021) who found that biochar application in soil increased the fixed fraction of heavy metals and reduced the plant uptake.

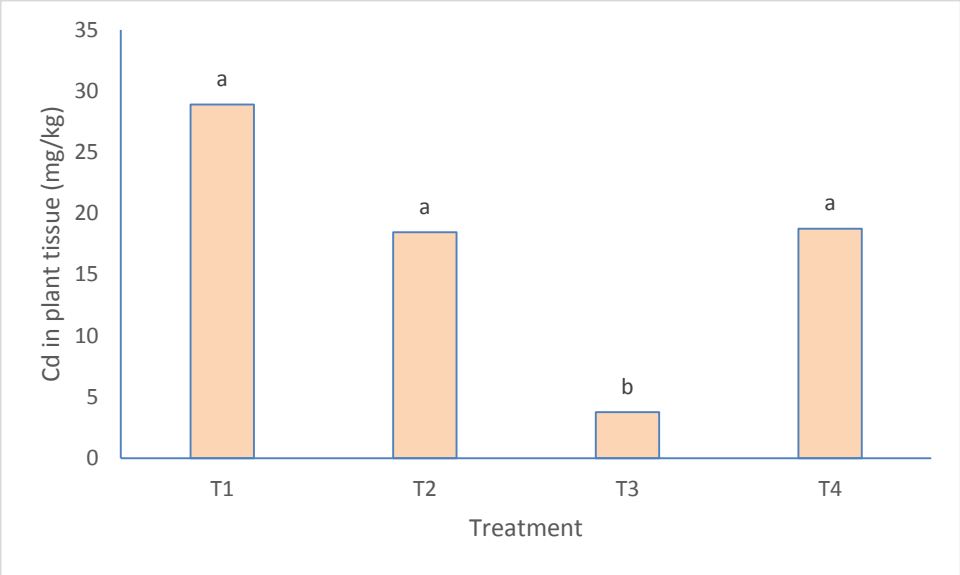

Figure 2 Cadmium concentration in green mustard: T0 (0% of BioCom), T1(10% of BioCom), T2(20% of BioCom) and T3(40% of BioCom). Means with the same alphabet were not significant different at p-value >0.05.

Effects of BioCom on Soil Chemical Properties

BioCom had effects on the soil pH. Relative to the control, BioCom at highest rate of application (40%) significantly (P<0.05) increased pH by 16.74% (**Table 2**). It was apparent that the BioCom used in this study had a high pH (8.95), which was alkaline, leading to an increase in soil pH when incorporated with BioCom. The high of BioCom value might be attributed to the liming potential of biochar towards basic reaction in acidic soils (Irfan *et al*., 2016). In addition, many studies have reported the application of biochar resulted in reduction of acidity element availability, which is aluminium (Al) (Lin *et al*., 2018). In the present investigation, thou statistically there was a non-significant impact of BioCom application towards Al availability, it showed a decrease of Al concentration as compared to the control. The soil's pH improvement was also found to have effects on the Cd availability as supported by past studies (Lin *et al*., 2018; Tian *et al*., 2017). However, the addition of BioCom in soils had no significant effects (P>0.05) on the soil nutrients (P, K, Ca and Mg).

Table 2 Chemical Properties in Soil Applied with Different Rates of BioCom

Parameter	T0 (0%)	T1(10%)	T2(20%)	T3(40%)
pH	4.54 b	4.73 b	4.75 b	5.30 a
Al (mg/kg)	49.19a	23.61a	32.7a	20.12a
P (mg/kg)	96.82 a	140.76 a	103.91 a	133.83 a
K (mg/kg)	361.38 a	366.08 a	492.23 a	497.35 a
Ca (mg/kg)	155.95 a	163.45 a	199 a	212.88 a
Mg (mg/kg)	56.06 a	72.82 a	54.63 a	72.82 a

*Notes: Means with the same alphabet in a row were not significantly different at p-value >0.05.

Effects of BioCom on Chlorophyll Content and Green Mustard Growth

There was no significant difference in green mustard chlorophyll content, dry and fresh biomass, and root length with the addition of BioCom in soil (**Table 3**). However, the result above showed that T3 performed highest in green mustard chlorophyll content percentage, dry and fresh biomass, and root length. In other words, T3 performed well compared to the green mustard was been applied with 0%, 10% and 20% of BioCom. From a previous study's findings, it was also discovered that by adding biochar in compost as a soil amendment was resulting an increase in chlorophyll percentages and photosynthesis activity (Tian *et al*., 2017).

Table 3 Chlorophyll Content and Green Mustard Growth analysis

Treatment/ Yield	Chlorophyll Content (%)	Dry Biomass (g)	Fresh Biomass (g)	Root Length (cm)
T0 (0%)	21.3 a	0.51 a	7.79 a	11.13 a
T1(10%)	23.92 a	0.57 a	7.03 a	11 a
T2(20%)	19.69 a	0.33 a	4.83 a	11.17 a
T3(40%)	31.32 a	0.59 a	8.25 a	14.47 a

*Notes: Means with the same alphabet in column were not significant different at p-value >0.05.

Conclusion

This study showed that BioCom at 20% application rate had significant effects in reducing Cd availability in green mustard tissues, whereas the addition of 40% BioCom in this acidic soil showed an increase of soil's pH. This finding suggested that BioCom has a potential as an amendment in remediating contaminated soil. However, due to the organic amendments used in the present study, a lengthy reaction time may be necessary. As a result, a longer incubation period is advised for future research.

Ethics Statement

The research does not require research ethics approval.

Authors Contribution

Data collection and Writing - Original draft preparation, Jerry, G.J; Literature Review, Writing - Review and editing, Norazlina, A.S; Review - Nur Maizatul, I.O; Statistical review – Nur Aziera, R; Data collection - Mohd Aizuddin, M.

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Conflict of interests

The authors declare that they have no known competing financial interest or personal relationships that could have appeared to influence the work reported in this paper.

References

Al-Wabel, M.I., Usman, A. R. A., El-Naggar, A. H., Aly, A. A., Ibrahim, H. M., Elmaghraby, S. & Al-Omran, A. (2015). Conocarpus biochar as a soil amendment for reducing heavy metal availability and uptake by maize plants. *Saudi J. Biol. Sci.* 22, 503–511.

Aini, A. A., Fauziah, C. I. & Samsuri, A. W. (2021). Cadmium and Zinc Content in Oil Palm Seedlings and their Phase Associations in Jawa Series Soil Applied with Phosphate Rock and Amended with Palm Oil Mill Effluent Sludge and Lime. *Malaysian Journal of Soil Science*, 25, 29-44, ISSN: 1394-7990.

Ayob, S., Othman, N., Ali, W., Altowayti, H., Khalid, F. S., Bakar, N. A., Tahir, M. & Soedjono, E. S. (2021). A Review on Adsorption of Heavy Metals from Wood-Industrial Wastewater by Oil Palm Waste. *Journal of Ecological Engineering*, 22(3), 49–265, ISSN 2299-8993.

Bashir, S., Zhu, J., Fu, Q. L. & Hu, H. Q. (2018). Cadmium mobility, uptake and anti-oxidative response of water spinach (Ipomoea Aquatic) under rice straw biochar, zeolite and rock phosphate as amendments. *Chemosphere.* 194, 579–587.

Irfan, M., Chen, Q., Yue, Y., Pang, R., Lin, Q., Zhao, X. & Chen, H. (2016). Co-production of biochar ,bio oil and syngas from halo phytegrass (*Achnatherumsplendens*L.) under three different pyrolysis temperatures. *Bioresour. Technol.* 211, 457–463.

Lin, Q., Zhang, L., Muhammad, R., Zhang., M., Xia, H., Lv, B. & Jiang, C. (2018). Assessing the potential of biochar and aged biochar to alleviate aluminum toxicity in an acid soil for achieving cabbage productivity. *Ecotoxicol. Environ. Saf.* 161, 290–295.

Ma, J. W., Wang, H. & Luo, Q. S. (2007). Movement-adsorption and its mechanism of Cd in soil under combining effect of electrokinetics and a new type of bamboo charcoal. *Environ Sci*, 28, 1829-1834.

Raskin, I., Smith, R. D. & Salt, D. E. 1997. Phytoremediation of metals using plants to remove pollutants from the environment. *Curr. Opinion Biotech*, 8, 221–226.

Tang, J., Zhang, L., Zhang, J., Ren, L., Zhou, Y., Zheng, Y., Luo, L., Yang, Y., Huang, H. & Chen, A. (2020) Physicochemical features, metal availability and enzyme activity in heavy metal-polluted soil remediated by biochar and compost *Science of The Total Environment,* 701. DOI 10.1016/j.scitotenv.2019.134751

Tian, D., Liu. A., & Xiang, Y. (2017). Effects of Biochar on Plant Growth and Cadmium Uptake: Case Studies on Asian Lotus (*Nelumbo nucifera*) and Chinese Sage (*Salvia miltiorrhiza). Engineering Applications of Biochar* (*IntechOpen*).

Tianyi, H., Jun, M., Zunqi, L., Wenfu, C., Ting, C., Xiaoyi, C., Yuwe, H. & Xu, Y. (2016). Effects of Biochar on Cadmium Accumulation in Rice and Cadmium Fractions of Soil: A Three Year Pot Experiment. *BioResources,* 12**,** 622-642. DOI 10.15376/biores.12.1.622-642.

Van Kauwenbergh, S. J. (2001). Cadmium in phosphate rock and fertilizers. Paper presented at The Fertilizer Institute 2001 World Fertilizer Conference, Chicago, Illinois. 25.

Zheng, H., Wang, Z., Deng, X., Zhao, J., Luo, Y., Novak, J., Herbert, S. & Xin,g B. (2013) Characteristics and nutrient values of biochars produced from giant reed at different temperatures. *Bioresour Technol*, 130, 463–471. doi:10.1016/j.biortech.2012.12.044

Zulfiqar, F., Younis, A. & Chen, J. (2019). Biochar or Biochar-Compost Amendment to a Peat Based Substrate Improves Growth of *Syngonium podophyllum*. *Agronomy,* 8, 460.