International Journal of Environment, Agriculture and Biotechnology
Vol-7, Issue-4; Jul-Aug, 2022

Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Peer Reviewed

Utilization of Biochar as organic fertilizer for Seedling growth of *Zea mays* (Maize)

Opara Ifeoma Juliet[1], Ukoha Pius Oziri[2], Obasi Nnamdi Lawrence[2], Ekere Nwachukwu[2]

[1]Department of Chemical Sciences, Faculty of Pure and Applied Sciences, Federal University Wukari, Taraba State. P.M.B.1020 Wukari, Nigeria.
[2]Department of Pure and Industrial Chemistry, Faculty of Physical Sciences, University of Nigeria, Nsukka
Corresponding Author: Opara Ifeoma Juliet, j.opara@fuwukari.edu.ng, ifygreat06@gmail.com, +2348035306015

Received: 30 Jul 2022; Received in revised form: 19 Aug 2022; Accepted: 26 Aug 2022; Available online: 31 Aug 2022

***Abstract*— *The seedling growth of maize, their germination rate and seedling length were ascertained using biochar pyrolyzed at temperatures between 400-550^{o}C. All the biochar used were alkaline and contained mineral-rich components such as; C, Ca, O, K, Na, Mg, Si, Al, that could enrich the soil and as well treat acidic soil. Also all the biochar produced are good for planting. However, biochar pyrolyzed at 400^{o}C gave the maximum seedling growth length. The germination rate was between 75%-100%. Biochar produced at 400^o C was significantly (P <1.000) greater than SDB450. There is no significant difference between SDB450 and SDB500 (P < .461), also no significant difference between SDB 550 and control (P < .192 at a 95% level of significance. Biochar utilization could be a promising way of reducing the negative environmental effect of fertilizer.*

Keywords— ***Biochar, pyrolysis, seedling growth, biomass, sawdust.***

I. INTRODUCTION

Food security is one of the recent issues discussed globally. Sustainable strategies and methods are required to sustain the growing population's demand for food. Crop yields can be greatly improved by the application of some useful practices and methods such as increasing organic fertilizer use efficiency (Yang *et al.*, 2017; Lu *et al.*, 2014). The use of fertilizer has proved to be beneficial but it is usually accompanied by some environmental negative effects such as; nitrate leaching, groundwater pollution, river, lake, and coastal water eutrophication. Constant use of fertilizer in order to solve the rising human demands may lead to a consequential effect of accumulating huge environmental costs (Claudia *et al.*, 2015). Thus, an eco-friendly, renewable alternative or complementary approach capable of reducing the negative impact of fertilizer as well as enhance plant growth and promote soil carbon sequestration is of great interest. Biochar has received significant interest in the literature, mostly for its ability to improve soil quality and sequester carbon (Klasson, 2017). Biochar is a solid product obtained from the thermochemical conversion of biomass in an oxygen-limited environment (IBI, 2012). This process of thermochemical decomposition of biomass produces biochar, bio-oil, and syngas.

Biomass can be of plant and animal origin such as sawdust, rice husk, pea nut shell, cow dung, palm kernel. Sawdust is a waste biomass from forest resources (Timber). These wastes are not properly managed and thus constitute to environmental pollution. Sawdust wastes are transformed to useful resources through pyrolysis to improve the economy as well as solve the problem of pollution. During pyrolysis, moisture and volatile materials are lost leaving behind a solid carbon-rich, fine-grained porous structured material with aromatic surface and different functional groups (Lee *et al* ., 2017). Biochar has a high specific surface area, high amounts of oxygen-containing functional groups, and high stability (Huang *et al.*, 2016). This unique nature of this pyrogenic carbon material (biochar) offers its applications in areas such as agriculture, climate change, environmental remediation, energy (Tan *et al.*, 2017; Wang *et al.*, 2018; Zhou *et al.*, 2017), and soil amendment. Biochar has contributed positively to the agricultural sector to improve plant growth owing to its porosity and sorption capacity, liming capacity, the improvement of soil fertility, and water holding capacity. Biochar is very recalcitrant and can contribute to climate change mitigation by carbon sequestration and reduction of agricultural emissions of CO_2, N_2O, and CH_4 (Hagemann *et al.*, 2017).

Biochar obtained and its application depends on the feedstock and pyrolysis condition (Enders *et al.*, 2012). The biochar obtained from relatively low-temperature pyrolysis possess a high content of volatile matter which contains labile compounds that decompose easily within a short period which affects plant growth positively (Jindo *et al.*, 2014; Liu *et al.*, 2014), while the structure of biochar produced at high -temperature pyrolysis has a large surface area and contains aromatic-carbon which may increase the adsorption capacity and recalcitrant character (Jindo *et al.*, 2014; Ahmad, 2012). Such biochar is usually employed for environmental bioremediation and carbon sequestration; which directly removes carbon dioxide from the atmosphere. (Jindo *et al.*, 2014; Lehmann, 2007). The stability of biochar in the soil is higher with increased pyrolysis temperature (Purakayastha *et al.*, 2015).

Several investigations have been reported on the effect of biochar on plant growth. Berihun *et al.*, (2017) reported that biochar application on soil significantly affected the soil bulk density, porosity, pH, and exchangeable acidity which resulted in (95.23%) maximum germination percentage observed in the garden pea seeds at 18 t ha^{-1} of Lantana biochar. Hagemann *et al.*, (2017) reported in their study that biochar promotes plant growth, especially when combined with nutrient-rich organic matter, e.g., co-composted biochar. Adding char to soil has been found to increase crop yield, increase water retention, and to increase soil stability. Moreover, it releases carbon much more slowly than biomass left on the field and thus contributes to carbon sequestration (Dupont and van Hullebusch, 2018). Claudia *et al.*, (2015) reported the greatest positive plant responses observed with mineral-rich biochars made from manure and straw on the application of large doses (> 10 t ha−1 biochar) at once.

The aim of this research involves the utilization of biochar from sawdust biomass to enhance maize seedling growth.

II. MATERIALS AND METHODS

Biochar was produced through slow pyrolysis at different temperatures between 400-550 ºC at Forest Reserve Institute Malaysia (FRIM). The pH, EDX and Zeta potential of the biochar produced were determined.

2.1 pH value

The pH of biochar was determined in a mixture of 1 g biochar and 20 mL deionized water. The mixture was stirred using a magnetic stirrer for 1 h and allowed to stand for 10 mins. The pH level was measured with a pH meter (JENCO Vision Plus 6175-3C).

2.2 EDX

The elemental analysis of biochar were observed with a scanning electron microscope (HITACHI FESEM SU8220) equipped with an energy dispersive X-ray (EDX) spectrometer and X-max detector (oxford – instruments). The sample was mounted on the SEM stub using carbon tape and inserted into the chamber, at accelerating voltages between 10-20 kV and 2,500-10000 times magnification.

2.3 Zeta potential

Biochar powder (20 mg) was dispersed in 200 ml of distilled water to make a suspension in a conical flask. The conical flask was shaken at 150 r/min for 12 h, and the zeta potential of biochar in the suspension was measured using a Zeta Potential Analyzer (Malvern zeta sizer) (Hong *et al.*, 2019).

2.3 Germination test.

Biochar was used to monitor the germination rate and seedling growth of maize following the method reported by Marmiroli *et al.*, (2018) with modification. Biochar samples were sieved to pass through a 250 µm mesh. A dilute solution of methanol was dabbed in cotton wool and was used to clean Petri dishes to kill any bacteria present in them and to remove impurities as well as sanitize the Petri dishes. A ball of fresh small cotton wool was placed on the Petri dishes which were used as soil. 0.5 g of dried sieved biochar at different pyrolytic temperature were placed on the cotton wool in triplicate biological analysis. 3-4 seeds of maize were sown on each petri dish in a triplicate biological analysis followed by the addition of 10 mL of distilled water to each of the Petri dishes and were kept in the dark to germinate. After three days the germinated seeds were counted and their root length was measured daily until the tenth day and the germination rate percent was calculated.

Germination rate % = (number of germinated seeds/number of starting seeds) ∗ 100 (1)

III. RESULTS

3.1 pH value

The pH results of biochars displayed in Table 3.1, indicate the level of alkalinity of biochar at different pyrolytic temperature. The result shows that the biochars produced in this study are alkaline.

3.2 EDX

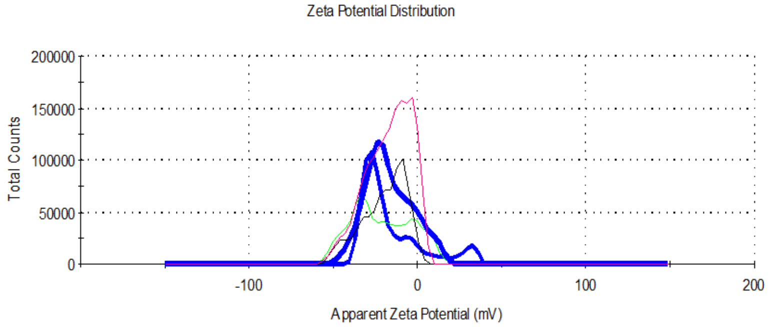
EDX of sawdust biochar is shown in Fig.3.1. The presence of mineral-rich components such as C, Ca, O, K, Mg, Si, P, and Al, enriched the biochar.

Table 3.1: EDX analysis (Elemental analysis (wt %)) and pH sawdust biochar

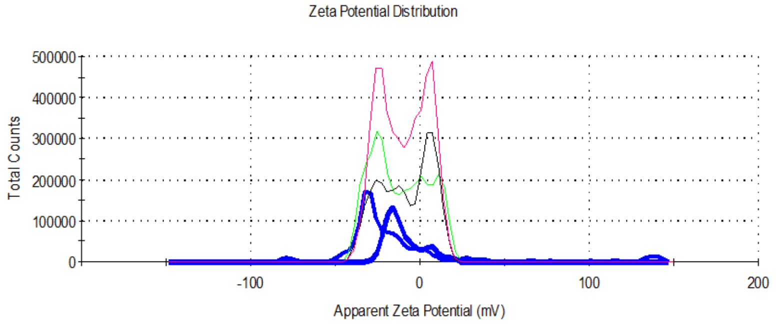
sample	C	O	Mg	K	Ca	Si	P	Al	pH
SDB 400	74.02	14.71	0.49	2.94	0.98	3.92		2.94	7.94
SDB 450	92.16	16.24	0.58	1.14	0.39		0.17		8.6
SDB 500	92.42	11.32	0.22	0.7	0.29	0.06	0.06		9.1
SDB 550	94.09	4.88	0.15	0.33	0.33	0.18			9.22

3.3 Zeta potential of SDB biochar

The zeta potential obtained was negative for all the biochar samples as shown in Fig.3.1. The zeta potential of SDB450 at pH 8.6 was -16.9 mV and became slightly less negative at SDB500 with increasing pH (8.9) -14.8 mV.



SDB450



SDB500

Fig. 3.1 Zeta potential of SDB450 and SDB500

3.4 Effect of biochar on seedling growth and germination rate

Effect of biochar on seedling growth test was performed by placing seeds of maize on cotton wool in the presence of sawdust biochar of different temperatures in water. The effect is measured by taking into account the number of seeds that germinated and the seedling growth length after 3 days of planting compared to the control and also their seedling length after 10 days of planting as shown in Fig.3.2

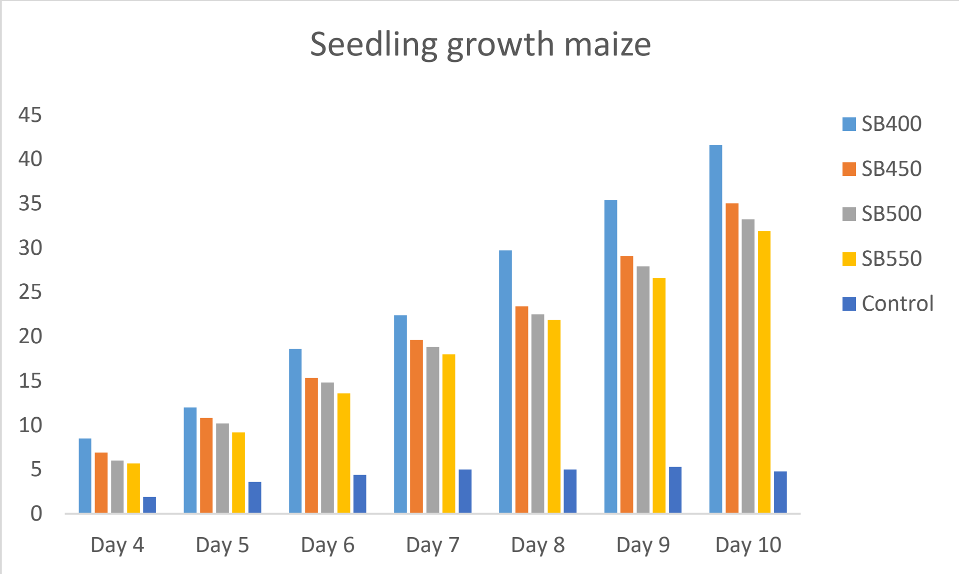


Fig.3.2. Effect of biochar at different temperatures on seedling growth maize

Fig.3.3 Optical images of images of seedling growth of maize plant

3.5 Statistics analysis for seedling growth of Maize

The means and standard deviation of seedling growth of maize results for each day of analysis of different samples are presented in Table 3.2. The results show that SDB400 has greater mean values than other biochar samples.

Table 3.2 Descriptive Statistics for seedling growth of Maize

	Biochar	Mean	Std. Deviation	N		Biochar	Mean	Std. Deviation	N
Fourth day	Control	.708	.6680	12	Eighth day	Control	3.575	1.6466	12
	SB400	5.575	.3888	12		SB400	23.533	1.4067	12
	SB450	2.000	.9909	12		SB450	8.192	2.8234	12
	SB500	1.217	.5859	12		SB500	7.508	1.5246	12
	SB550	.842	.8404	12		SB550	4.267	1.6555	12
	Total	2.068	1.9550	60		Total	9.415	7.5642	60

Fifth day	Control	2.183	1.5608	12	Nineth day	Control	3.408	1.4607	12
	SB400	10.025	.8013	12		SB400	28.233	1.8802	12
	SB450	4.008	1.4126	12		SB450	8.767	2.9724	12
	SB500	3.583	1.0125	12		SB500	8.458	1.4600	12
	SB550	2.375	1.1323	12		SB550	4.733	1.7500	12
	Total	4.435	3.1322	60		Total	10.720	9.2755	60
Sixth day	Control	2.917	1.6694	12	Tenth day	Control	2.708	1.4068	12
	SB400	14.433	1.2565	12		SB400	33.158	2.1441	12
	SB450	6.017	2.2230	12		SB450	9.358	3.0938	12
	SB500	5.567	1.2146	12		SB500	9.017	1.2855	12
	SB550	3.342	1.3846	12		SB550	5.225	1.9429	12
	Total	6.455	4.4757	60		Total	11.893	11.1888	60
Seventh day	Control	3.833	1.9099	12					
	SB400	19.100	1.0863	12					
	SB450	6.983	2.4094	12					
	SB500	6.883	1.4390	12					
	SB550	4.050	1.5413	12					
	Total	8.170	5.9169	60					

IV. DISCUSSION

4.1 pH value

The results displayed in Table 3.1, indicate the level of alkalinity of biochar at different pyrolytic temperature. The result shows that the biochars produced in this study are alkaline. It was observed that as the heat treatment temperature (HTT) increases, the pH value also increases as shown in Table 3.1. Sawdust biochar at 550ºC indicated pH of 9.10. Similar result has been reported by Mary *et al.*, (2018). Biochar pH values between 3.1 and 12.0 have been reported in the literature. During pyrolysis, most of the acidic functional groups are removed and salts of alkali and alkaline earth elements become enriched. These indicate that biochar has the potential to neutralize soil acidity. Biochar can serve as a good liming agent to increase the pH of acidic soil and the availability of nutrients for various types of soil (McElligott et al., 2011). Phosphorus is often tightly bound in soils rich in Fe and Al oxides, but with the addition of biochar, the soil pH is increased, thereby making phosphorous more available to plants and microorganisms (Marmiroli et al., 2018).

4.2 Zeta potential of SDB biochar

The zeta potentials in the pH range of 8-9 were obtained for SDB at 450ºC and 500ºC pyrolytic temperature using Malvern zeta sizer. The zeta potential obtained was negative for all the biochar samples as shown in Fig. 3.1. The zeta potential of SDB450 at pH 8.6 was -16.9 mV and became slightly less negative at SDB500 with increasing pH (8.9) -14.8 mV. The negative values of the zeta potentials of biochar at all pH suggest that the surfaces of biochar are negatively charged. This may be due to the presence of a higher amount of OH-containing functional groups in SDB. However, the negative charge of the biochar surface decreases with an increase in pyrolysis temperature (Hong *et al.*, 2019). This may likely be due to deprotonation of the functional group which makes the surface of the biochar negatively charged which is consistent with the findings of Samsuri *et al.*, (2014) reported. The negative charges across the surface of biochar help in the immobilization of heavy metals such as Cd^{2+} and protect plants especially biochar produced at high temperatures (Hong *et al.*, 2019).

The detection of alkali metals of Na, K, Ca, and Mg by EDX shows that biochar is alkaline in nature and also it is a clear indication that alkali metals cannot volatilize during the pyrolytic process (Chen *et al.*, 2016).

4.3 EDX

The presence of mineral-rich components such as; C, Ca, O, K, Fe, Na, Mg, Si, Al, are found in the biochar structure as displayed in Table 3.1, similar metals have been reported by (Purakayastha *et al.*, 2015). This is an indication that there are some oxides in the biomass which could not be volatilized and in turn, enriched the biochar leading to their application in soil enhancement and plant growth. The results indicated that pyrolysis displayed different impacts on the elemental composition of sawdust biomass.

4.4 Effect of biochar on seedling growth and germination rate

Effect of biochar on seedling growth test was performed by placing seeds of maize on cotton wool in the presence of sawdust biochar of different HTT in water. The effect is measured by taking into account the number of seeds that germinated and the seedling growth length after 3 days of planting compared to the control and also their seedling length after 10 days of planting. Seeds (3-4) of each of the selected plants sown in each petri dish grew on the fourth day of planting and maintained good seedling growth for ten days. It was observed that all the biochar samples improved plant growth as displayed in Fig.3.2. Biochar produced at pyrolysis temperature between 400-550ºC can improve plant growth. The germination rate was between 75%-100% SDB550, and control which had 75% while others had a 100% germination rate. All other seeds germinated and grew very well and their length was measured until the tenth day of planting. However, biochar produced at 400ºC (SDB400) showed maximum seedling growth. This is due to volatile matter and easily labile content present in it which decomposed easily and affects plant growth positively, followed by 450º C, 500ºC, and 550ºC. Therefore, biochar produced at low temperature has more potential to retain fertilizer cations such as NH_4^+ and thereby improve their utilization efficacy. The control which has no treatment only cotton wool and water also grew but not comparable with biochar. Although it was withering after the seventh day.

4.5 Statistical Analysis

The means and standard errors of the biochar produced at 400ºC was higher and have relatively lesser standard deviation compared to other biochar at 450, 500 and 550ºC. Biochar produced at 400º C was significantly (P <1.000) greater than SDB450. There is no significant difference between SDB450 and SDB500 (P < .461), also no significant difference between SDB 550 and control (P < .192 at a 95% level of significance.

V. CONCLUSION

This study has shown that slow pyrolysis of biochar can improve plant growth positively. Biochar produced at a pyrolytic temperatures between 400 and 550ºC are good for planting. However biochar produced at 400ºC showed maximum plant growth. The Overall seedling growth is as follows; SDB400>SDB450>SDB500 >SDB550. Biochar produced at 400º C was significantly (P <1.000) greater than SDB450. There is no significant difference between SDB450 and SDB500 (P < .461), also no significant difference between SDB 550 and control (P < .192 at a 95% level of significance.

Thus biochar used in this study enhanced maize seedling growth. Therefore, biochar is considered to have great potential for enhancing plant growth and also improves soil quality without negative environmental effects; such as leaching, groundwater pollution, and water eutrophication.

ACKNOWLEDGEMENT

The Researchers appreciate the support by TETFUND and all that contributed to the success of the work.

REFERENCES

[1] Enders, A.; Hanley, K.; Whitman, T.; Joseph, S.; Lehmann, J. Characterization of biochars to evaluate recalcitrance and agronomic performance, Bioresour. Technol 2012, 114 644–653.

[2] Claudia, I.; Kammann, H. S.; Nicole, M.; Sebastian, Li.; Diedrich, S.; Christopher, M.; Hans-Werner, K. ; Pellegrino, C.; Stephen, J. Plant growth improvement mediated by nitrate capture in cocomposted biochar. Scientific Reports 2015, | 5:11080 | DOI: 10.1038/srep11080

[3] Dupont, C.; Van Hullebusch, E. D. The potential of biomass agricultural waste recovery as char in Western Africa in in Proceedings of the Workshop on Water-Energy-Food-Ecosystems (WEFE) and Sustainable Development Goals (SDGs), 25-26 January 2018. Editors: S. Barchiesi, C. Carmona-Moreno, C. Dondeynaz, M. Biedler. Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-99562-0, doi 10.2760/867467, JRC109346.

[4] Mary, G.S.; Sugumaran, P.; Niveditha, S.; Ramalakshmi, B.; Ravichandran P.; Seshadri, S. Production, characterization and evaluation of biochar from pod (Pisum sativum), leaf (Brassica oleracea) and peel (Citrus sinensis) wastes. Int J Recycl Org Waste Agricult 2016, 5:43–53. DOI 10.1007/s40093-016-0116-8

[5] Hagemann, N.; Joseph, S.; Schmidt, H. P.; Kammann, C. I.; Harter, J.; Borch, T. Organic coating on biochar explains its nutrient retention and stimulation of soil fertility. Nat. Commun 2017, 8, 1–11. doi: 10.1038/s41467-017- 01123-1120

[6] Wang, H.; Xing, Y.; Lizhi, H.; Lu, K.; Karin, M; Kim, M,; Song, Xu.; Xiaokai, Z.; Jianwu, L.; Huagang, H; Guodong, Y; Guotao, H; Xingyuan, L. Using Biochar for Remediation

of Contaminated Soils. In book: Twenty Years of Research and Development on Soil Pollution and Remediation in China Project: Environmental functions of biochar 2018, https://doi.org/10.1007/978-981-10-6029-8_47

[7] Huang, X; Cao, J. P.; Zhao, X.Y.; Wang, J. X.; Fan, X,; Zhao, Y. P,; Wei, X. Y. Pyrolysis kinetics of soybean straw using thermogravimetric analysis. Fuel 2016, 169, 93–98.

[8] International Biochar Initiative [IBI]. Standardized Product Definition and Product Testing Guidelines for Biochar that is used in Soil. (IBI Biochar Standards) Version 2.1 2012. Available at: http://www.biochar-international.org/characterization standard

[9] Jindo, H; Mizumoto, Y; Sawada , M. A; Sanchez, M; Sonoki, T. Physical and chemical characterization of biochars derived from different agricultural residues Biogeosciences 2014, 11, 6613–6621, doi:10.5194/bg-11-6613-2014

[10] Lehmann, J. A handful of carbon. Nature 2007, 447:143–144

[11] Liu, X; Zhang, Y; Li, Z; Feng, R.; Zhang, Y. Characterization of corncob-derived biochar and pyrolysis kinetics in comparison with corn stalk and sawdust. Bioresour. Technol 2014, 170, 76–82.

[12] Ahmad, M; Sang Soo, L; Xiaomin, D; Dinesh M; Jwa-Kyung, S; Jae E. Y, Yong, S. Effects of pyrolysis temperature on soybean stover- and peanut shell-derived biochar properties and TCE adsorption in water. Bioresour Technol 2012, 118:536–544

[13] Marmiroli, M; Bonas, U; Imperiale, D; Lencioni, G; Mussi, F; Marmiroli, N; Maestri, E. Structural and Functional Features of Chars From Different Biomasses as Potential Plant Amendments. Front. Plant Sci 2018, 9:1119. doi: 10.3389/fpls.2018.01119

[14] McElligott, K; Page-Dumroese, D; Coleman, M. Bioenergy production systems and biochar application in forests: potential for renewable energy, soil enhancement, and carbon sequestration. Res. Note RMRS-RN-46. Fort Collins, CO; U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station 2011. 1-14

[15] Mengfan, H; Limei, Z; Zhongxin, T; Qiaoyun, H. Effect mechanism of biochar's zeta potential on farmland soil's cadmium immobilization. Environmental Science and Pollution Research 2019, 26:19738–19748 https://doi.org/10.1007/s11356-019-05298-5

[16] Tan, X. F.; Liu, S.B.; Liu, Y.G.; Gu, Y. L.; Zeng, G. M.; Hu, X. J. ; Wang, X.; Liu, S. H.; Jiang, L.H. Biochar as potential sustainable precursors for activated carbon production: Multiple applications in environmental protection and energy storage. Bioresource Technology 2017, 227: 359–372.

[17] Purakayastha, T.J.; Savita, K.; Pathak, H. Characterization, stability, and microbial effects of four biochars produced from crop residues Geoderma 2015, 239–240 http://dx.doi.org/10.1016/j.geoderma.2014.11.009

[18] Berihun, T; Shiferaw T.; Muluken, T.; Firew, K. Effect of Biochar Application on Growth of Garden Pea (Pisum sativum L.) in Acidic Soils of Bule Woreda Gedeo Zone Southern Ethiopia. Hindawi International Journal of Agronomy Volume 2017, Article ID 6827323, 8 pages https://doi.org/10.1155/2017/6827323

[19] Klasson, T. Biochar characterization and a method for estimating biochar quality from proximate analysis results Biomass and Bioenergy 2017, 96, 50-58

[20] Chen T.; Ronghou, L.; Norman, R. S. Characterization of energy carriers obtained from the pyrolysis of white ash, switchgrass and corn stover Biochar, syngas and bio-oil. Fuel Processing Technology 2016, 142 124–134

[21] Samsuri, W.; Sadegh-Zadeh, F.; Seh-Bardan B. J. Characterization of biochars produced from oil palm and rice husks and their adsorption capacities for heavy metals. Int. J. Environ. Sci. Technol. 2014, (17) 60375-811:967–976 DOI 10.1007/s13762-013-0291-3

[22] Lu ,W.; Weixin, D.; Junhua, Z.; Yi, L.; Jiafa, L.; Nanthi, B.; Zubin, X.W. Biochar suppressed the decomposition of organic carbon in a cultivated sandy loam soil: A negative priming effect, Soil Biology & Biochemistry 2014, http://dx.doi.org/10.1016/j.soilbio.2014.04.029

[23] Lee, X. J.; Lai Y. L.; Suyin, G.; Thangalazhy-Gopakumar. S.; Ng H.K. Biochar potential evaluation of palm oil wastes through slow pyrolysis: Thermochemical characterization and pyrolytic kinetic studies Bioresource Technology 2017, 236 155–163.

[24] Zhou,Y.; Xiaocheng, L.; Yujia, X.; Wang, P.; Zhang J.; Fengfeng, Z.; Jianhong, W.; Lin, L.; Ming L.; Tang, L. Modification of biochar derived from sawdust and its application in removal of tetracycline and copper from aqueous solution: adsorption mechanism and modelling, Bioresource Technology 2017, doi: http:// dx.doi.org/10.1016/j.biortech.2017.08.178