Content list available at http://epubs.icar.org.in, www.kiran.nic.in; ISSN: 0970-6429

Indian Journal of Hill Farming

June 2018, Volume 31, Issue 1, Page 141-145

Preparation and Characterization of Biochars for their Application as a Soil Amendment

Shaon Kumar Das[1*] • Goutam Kumar Ghosh[2] • R. K. Avasthe[1] • Manik Chandra Kundu[2]

[1]ICAR Research Complex for NEH Region, Sikkim Centre, Tadong, Gangtok 737102, Sikkim

[2]Palli-Siksha Bhavan, Visva-Bharati, Sriniketan731236, West Bengal

ARTICLE INFO

Article history:
Received 5 September 2017
Revision Received 20 January 2018
Accepted 21 February 2018

Key words:
Biochar; biomass; Weeds; pH; production efficiency

ABSTRACT

Biochar enjoys considerable interest due to its potential to alleviate numerous problems of environmental protection. Various types of biomass can be used as feedstock for biochar production. The kind of matter used as feedstock has an effect on biochar properties. Hence the importance is on proper selection of raw biomass, which will subsequently determine the properties of the biochar. Experiments were conducted to assess the recovery and characterization of biochar derived from six different weed biomass and three different plant biomass at ICAR Research Complex for NEH Region, Sikkim Centre. Charring was carried out in a portable metallic drum (kiln) to make the process simple, quick and low cost. Biochar production efficiency of *Lantana camera*, *Ageratum* spp., *Neyraridia* spp., *Artemisia vulgaris*,*Bidens* spp. *Chromolaenaodorata*, maize stalk, black gram stover and pine needle were 23.2, 13.2, 19.6, 15.1, 14.6, 16.4, 31.7, 27.3 and 18.9%, respectively. The soil reaction indicator pH was 9.21, 9.02, 8.87, 8.53, 8.11, 8.02, 9.38, 9.03 and 8.91, respectively for the above mentioned biochar. Total nitrogen content (g/kg) was highest in black gram stover (12.8) and lowest in *Lantana camara* biochar (7.2). Alkalinity was highest in maize (135.2) and lowest in *Chromolaenaodorata* biochar (90.6). Temperature 450^0C was best for the preparation of biochar. It was also found that maize biochar showed good quality properties as compared to other biochar. But all of them can be effectively used as potential source of soil amendment due to their alkalinity in nature.

1. Introduction

Biochar, an ancient soil conditioner or zero waste, is nothing but a carbon rich charcoal-like substance which is formed by heating the biomass in a limited oxygen condition, in a process known as pyrolysis. Biochar technology is called a geoengineering solution, as it has potential to actively reduce the atmospheric concentrations of green house gases (Das *et al.,* 2014 and Das 2014). The ability of biochar to increase or maintain soil pH as a fundamental element in the positive yield responses, especially in acid soils have already proven. Biochar can enhance plant growth by improving soil physical characteristics (*i.e.* bulk density, water holding capacity, infiltration, porosity), soil chemical characteristics (*i.e.* pH, nutrient retention, nutrient availability), and soil biological properties (*i.e.* microbial biomass carbon), all contributing to an increased crop productivity (Roy *et al.,* 2015; Khan *et al.,* 2016 and López-Cano *et al.,* 2016). Locally available weed biomass or plant biomass which are not economically important and cause considerable crop loss can be used as an important source of biomass for preparation of biochar. Thus, if we prepare biochar from locally available biomass then it is possible to reduce the weed population in the agricultural fields which is a serious problem in organic agriculture since the use of any chemical herbicide is not permitted especially since Sikkim is an organic state (Das and Avasthe 2015).

*Corresponding author:shaon.iari@gmail.com

Using locally available weed biomass for making biochar provides unique opportunity to landholders in organic agriculture to improve soil health for longer period of time. Biochar play a major role in organicagriculture for sustainable soil health by improving existing best management practices, not only by decreasing nutrient loss through leaching but also improving soil productivity (Das *et al.,* 2016 and Sánchez-García *et al.,* 2015). But little published information is available for conversion of weed biomass to biochar and their characterization. The weed biomass production in North East India is 20 t ha^{-1} has been observed. Every biochar has its own characteristic which influences ultimately in soil after field application. For example biochar produced from animal manures usually has smaller specific surface area compared to biochar derived from wood and plant biomass (Wiedner*et al.,* 2015). Thus, the objectives of this paper are to create some information regarding physical and chemical characterization of biochar from common biomass such as *Lantana camera*, *Ageratum* spp., *Neyraridia* spp., *Artemisia vulgaris*,*Bidens* spp., maize, pine needle, black gram and *Chromolaenaodorata*. These are abundant and naturally grown and survive in widely ranged climatic conditions and elevations under Sikkim mid hill ecosystem. Among many uses of these weeds, fuel wood supplement is the major one.

2. Materials and Methods

The experiment was conducted during the year 2016-17 at the experimental farm of ICAR-National Organic Farming Research Institute (formerly ICAR RC for NEH Region, Sikkim Centre) located in the Indian Himalayan region at Tadong (27˚20'N latitude and 88˚37'E longitude with 1350m amsl), in the state of Sikkim, India. Six different weed biomass *viz.Lantana camera*, *Ageratum* spp., *Neyraridia* spp., *Artemisia vulgaris*,*Bidens* spp. and *Chromolaenaodorata* and three different biomass from maize stalk, black gram stover and pine needle biochar were collected from nearby farm area of the ICAR Research Complex for NEH Region, Sikkim Centre and shredded to pieces of less than 12 inch. Shredded pieces were sun–dried before charring into biochar drum. Charring of all the biomass was carried out in a portable metallic charring kiln (drum) prepared by ICAR RC for NEH Region, Sikkim Centre. The picture of the low cost portable biochar kiln (drum) has been presented in Figure 1. Using the slow pyrolysis method all the biochar was prepared at 450°C for 1.2 h from the biomass. The temperature was standardized for the preparation of biochar. For that we carried out the experiment at three different temperature *viz.* 300, 450 and 600°C. The percentage of biochar yield was calculated using the equation described below-

$Yield_{biochar} = m_{biochar}/m_{raw} \times 100\%$; where $Yield_{biochar}$ = mass yield of biochar, %; $m_{biochar}$ = mass of biochar, kg; m_{raw} = mass of raw biomass, kg.

After preparing of biochar they were dried in a hot air oven at 110^{O}C for 24 h, pulverized to fine powder, sieved and used for further characterization. The pH, electrical conductivity and bulk density of the biochar samples were determined by procedures outlined by Ahmedna*et al.* 1997. For pH determination, 1% (w/w) suspension of biochar in de-ionized water was prepared and the suspension was heated to 90^{o}C with stirring for 20 min. The suspension was then allowed to cool to room temperature and the pH was measured using a pH meter. For bulk density, a glass cylinder (25 ml) was filled to a specified volume with 40 mesh powder biochar, dried in an oven at 80^{0}C overnight. The cylinder was tapped for 1–2 min to compact the char and the bulk density was calculated and presented as g/ml following the formula (Ahmedna*et al.,* 1997).

Bulk density g/ml) = Weight of dry material (g) / Volume of packed dry materials (g/ml) × 100

Total organic carbon content of different biochar samples were analyzed using total organic carbon (TOC) analyzer. Water holding capacity was determined by following the methodology detailed by Dugan *et al.* (2010). Volatile Organic Carbon (VOC) was determined as the mass loss from dried samples in covered crucibles at 700 °C for 20 min. Phosphorus was determined by molybdophosphoric acid method. K was determined by flame photometer. Compositions of Ca, Mg and Na in the biochar were analyzed with an inductively coupled plasma spectrometer. Cation

Figure 1. Preparation of biochar by low cost portable drum (kiln)

exchange capacity was determined according to a modified barium chloride compulsive exchange method. All the experiments were carried out in triplicate and the results were expressed in average values. Water holding capacity was determined as per the procedure of Mukherjee and Das (2016). Ash content was determined as

Ash content (%) = (wt.ash / wt. biochar) × 100 (Yuan *et al.,* 2011)

3. Results and Discussion

Biochar production efficiency from different biomass has been shown in Table 1. Results revealed that biochar production efficiency of *Lantana camera*, *Ageratum* spp., *Neyraridia* spp., *Artemisia vulgaris*,*Bidens* spp. and *Chromolaenaodorata*, maize stalk, black gram stover and pine needle biochar were 23.2, 13.2, 19.6, 15.1, 14.6, 16.4, 31.7, 27.3 and 18.9%, respectively. Production efficiency was highest in maize (31.7 %) and lowest in *Ageratum* spp. (13.2 %). The varying production efficiency could be attributed to variable moisture content in each biomass. Among the temperature it was found that at 450^{0}C the production was satisfactory and that's why the experiment was conducted at that temperature and also time 1.2 h is best.

Table 1. Biochar production efficiency from different biomass

Biomass	Moisture content (%)	Production efficiency (%)
Lantana spp.	10.3	23.2
Ageratum spp.	9.9	13.2
Neyraridia spp.	10.2	19.6
Artemisia vulgaris	10.1	15.1
Bidens spp.	9.7	14.6
Chromolaenaodorata	10.6	16.4
Maize stock biochar	12.9	31.7
Pine needle biochar	8.6	27.3
Black gram stover biochar	9.8	18.9

The soil reaction indicator pH for *Lantana camera*, *Ageratum* spp., *Neyraridia* spp., *Artemisia vulgaris*,*Bidens* spp. and *Chromolaenaodorata*, maize stalk, black gram stover and pine needle biochar were 9.21, 9.02, 8.87, 8.53, 8.11, 8.02, 9.38, 9.03 and 8.91, respectively (Table 3 and 4). All the soil reaction (pH) was alkaline in nature which indicated that these biochar amendments can be utilized as soil ameliorating agent for management of acid soil (Figure 2). Among plant biomass derived biomass black gram biochar had highest bulk density (0.41) and maize biochar had lowest bulk density (0.31). The lower the bulk density of the amendment the greater benefit for soil bulk density. Lower bulk density indicates an increase in pore space which enhances the potential for soil aeration and increase water holding capacity. Total nitrogen content (g/kg) were *Lantana camera* (7.2), *Ageratum* spp. (8.3), *Neyraridia* spp. (7.8), *Artemisia vulgaris* (7.7),*Bidens* spp. (9.5) and *Chromolaenaodorata* (8.9) maize stalk (11.3), black gram stover (12.8) and pine needle (6.8). Highest nitrogen content was for black gram and lowest for pine needle. The highest nitrogen content in black gram may be due to the fact that the crop is leguminous. Among the weed biomass highest C: N ration was for *Lantana camara* (102) and lowest for Bidens spp. (74) biochar (Table 2). Total carbon content was highest in *Ageratum* spp. (750 g/kg) and lowest in black gram biochar (703 g/gm). The high C: N ratio indicates that it has longer stability in soil system and resistant to degradation by microbes. The CEC (cmol kg^{-1}) was higher in maize biochar (37.6) and lower in black gram (18.3). The higher CEC indicates that it has greater potential to exchange nutrient in soil solution. Such type of study has been carried out by Mondal*et al.* 2013; Srinivasan *et al.* 2015 and Windeatt *et al.* 2014.

Conclusion

The above mentioned biomass can be effectively used as potential source of biochar preparation for management of soil health. Assuming that the science of biochar addition in soil is *unambiguously beneficial*, the soil scientists support the view that agriculture should be rewarded for carbon sequestration through biochar application.

Table 2. Chemical properties of biochar derived from different weed biomass

Sources	Volatile organic content (%)	pH	Total N (g/kg)	Total P (g/kg)	Total C (g/kg)	C:N ratio	Ash (%)	CEC (cmol kg^{-1})	Alkalinity
Lantana spp.	15.7	9.21	7.2	1.81	735	102	25.7	29.7	121.3
Ageratum spp.	16.9	9.02	8.3	1.95	750	85	27.9	26.2	110.5
Neyraridia spp.	19.6	8.87	7.8	1.78	730	94	30.5	23.4	102.7
Artemisia vulgaris	19.1	8.53	7.7	1.81	715	93	33.2	22.7	99.7
Bidens spp.	17.8	8.11	9.5	1.92	708	74	36.4	21.6	94.7
Chromolaenaodorata	18.4	8.02	8.9	1.83	727	82	39.6	20.7	90.6

Table 3. Chemical properties of biochar derived from different plant biomass

Parameters	Maize stock biochar	Pine needle biochar	Black gram stover biochar
VOC (%)	19.6	13.6	17.6
pH	9.38	9.03	8.91
Total N (g/kg)	11.3	6.8	12.8
Total P (g/kg)	1.93	1.53	1.73
Total C (g/kg)	715	724	703
Ash (%)	21.5	29.7	34.3
CEC (cmol kg^{-1})	37.6	24.2	18.3
Alkalinity	135.2	115.9	109.3
Ca (g kg^{-1})	7.52	7.39	7.12
Mg (g kg^{-1})	5.36	5.02	4.97
K (g kg^{-1})	21.8	19.8	19.1
Na (g kg^{-1})	7.3	6.9	6.7
Bulk density (g/ml)	0.31	0.37	0.41
Water holding capacity	179	157	151
Surface area (m^2 g^{-1})	2.1	1.7	1.4
Total pore volume (mL g^{-1})	0.95	0.91	0.87

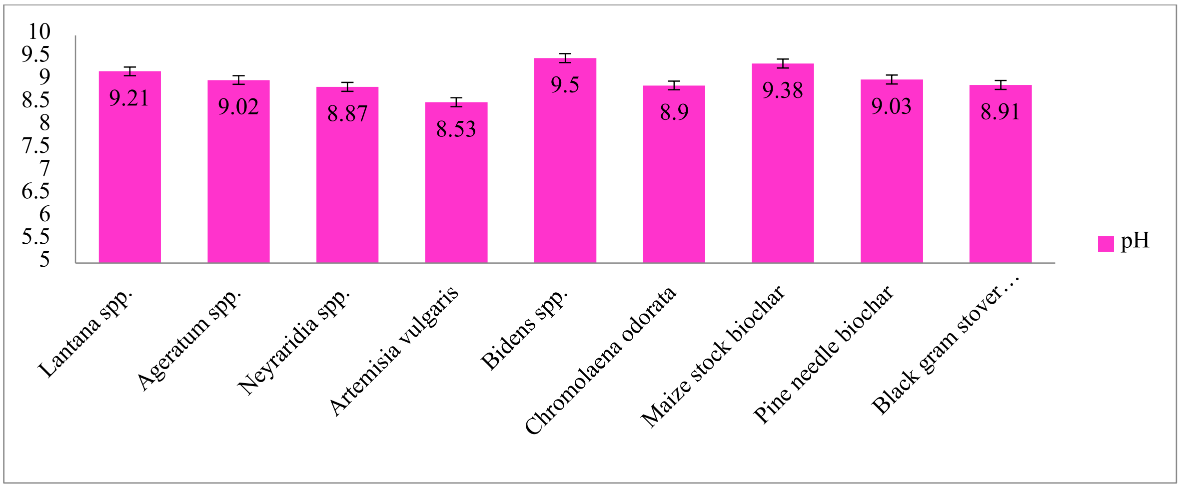

Figure 2. pH of different biochar derived from different biomass

Acknowledgements

The first author is thankful to the Director, ICAR Research Complex for NEH Region, Umiam, Meghalaya for providing necessary facilities to undertake the Ph.D (Soil Science and Agricultural Chemistry) research works.

References

Ahmedna M., Clarke SJ, Rao RM, Marshall WE, M. Johns (1997). Use of filtration and buffers in raw sugar color measurements. *J Sci Food Agric* 75:109–116. doi:10.1002/(SICI)10970010(199709)75:1

Das SK., Avasthe RK, M.Singh (2016). Carbon-negative biochar from weed biomass for agricultural research in India.*Current Science* 110(11): 2045-2046

Das SK., Avasthe RK, Singh R, S.Babu(2014). Biochar as carbon negative in carbon credit under changing climate. *Current Science* 107(7): 1090-1091

Das SK., RK.Avasthe(2015). Carbon farming and credit for mitigating greenhouse gases. *Current Science* 109 (7): 1223

Dugan E., Verhoef A, Robinson JS, S. Sohi(2010). Bio-char from sawdust, maize stover and charcoal: impact on water holding capacities (WHC) of three soils from Ghana. World Congress of Soil Science, Soil Solutions for a Changing World, Brisbane, pp 1–6

Das SK. (2014). Role of micronutrient in rice cultivation and management strategy in organic agriculture-A reappraisal. *Agricultural Sciences* 5(09): 765

Khan N., Clark I, Sánchez-Monedero MA, Shea S, Meier S, Qi F, Kookana RS, N Bolan (2016). Physical and chemical properties of biochars co-composted with biowastes and incubated with a chicken litter compost. *Chemosphere* 142:14–23

López-Cano I., Roig A, Cayuela ML, Alburquerque JA, Sánchez- MA Monedero(2016). Biochar improves N cycling during composting of olive mill wastes and sheep manure. *Waste Management* 49:553–559

Mandal S., Singh RK, Kumar A, Verma BC, SV. Ngachan(2013). Characteristics of Weed Biomass-derived Biochar and Their Effect on Properties of Beehive Briquettes. *Indian J Hill farming* 26(1): 8-12

Mukherjee I., Das SK, A, Kumar (2016). Degradation of flubendiamide as affected by elevated CO_2, temperature, and carbon mineralization rate in soil. *Environmental Science and Pollution Research* 23(19): 19931-19939

Roy A., Das SK, Tripathi AK, NU.Singh (2015). Biodiversity in North East India and their Conservation. *Progressive Agriculture* 15(2):182-189

Sánchez-García, M., Alburquerque, J.A., Sánchez-Monedero, M.A., Roig, A., M.L.Cayuela, (2015). Biochar accelerates organic matter degradation and enhances N mineralization during composting of poultry manure without a relevant impact on gas emissions. Bioresource Technology 192: 272–279

Srinivasan P., Sarmah AK, Smernik R, Das O, Farid M, W.Gao (2015). A feasibility study of agricultural and sewage biomass as biochar, bioenergy and biocomposite feedstock: production, characterization and potential applications. *Science of Total Environment* 512:495–505

Wiedner K., Fischer D, Walther S, Criscuoli I, Favilli F, Nelle O, B, Glaser (2015). Acceleration of biochar surface oxidation during composting? *J Agriculture Food Chem* 63:3830–3837

Windeatt JH, Ross AB, Williams PT, Forster PM, Nahil MA, S. Singh (2014). Characteristics of biochars from crop residues: potential for carbon sequestration and soil amendment. *J Environ Manag* 146:189–197

Yuan JH, Xu RK, H. Zhang (2011). The forms of alkalis in the biochar produced from crop residues at different temperatures. *Bioresource Technology* 102:3488–3497