Biological Forum – An International Journal 15(3): 625-631(2023)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Characterization of Wood and Bamboo Biochar, and their effect on Yield and Quality of Ricebean (*Vigna umbellata*) in Dystrudept

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(Received: 24 January 2023; Revised: 21 February 2023; Accepted: 25 February 2023; Published: 22 March 2023)
(Published by Research Trend)

ABSTRACT: Ricebean (*Vigna umbellata*) is a grain legume cultivated in the hilly areas of Northeastern India and may be adversely affected by soil acidity. Soil incorporation of biochar along with pig manure has the potential to mitigate soil acidity by decreasing soil exchangeable acid cations thereby improving soil fertility. A field experiment was conducted during 2019-2020 and 2020-2021 to study the effect of wood and bamboo biochar on ricebean yield, nutrient content and its uptake, and on soil properties under acidic soil conditions. Biochar produced from pyrolyzed wood of Teak (*Tectona grandis*) and bamboo (*Bambusa tulda*) was soil applied at the rate of 2.5 and 5.0 t ha^{-1}, with or without pig manure and recommended dose of fertilizer. Types of biochar, and the nutritional value of pig manure alongside RDF significantly enhanced the seed, stover yield, nutrient content and nutrient uptake of ricebean. Rising cost of commercial fertilizers added with increased environmental risk make the use of organic waste in agriculture an attractive method from the point of view of nutrient cycling. Thus, the present investigation hypothesized that wood and bamboo biochar along with pig manure application could enhance the productivity and nutrient concentration of ricebean by mitigating the acid soil.

Keywords: Biochar, ricebean, yield, nutrient content, base saturation, wood biochar and bamboo biochar.

INTRODUCTION

Ricebean (*Vigna umbellata*) is an underutilized annual leguminous crop widely distributed in the hills of the Himalayas. In India, it is mainly confined to the tribal regions of Northeastern States. It serves as an excellent cover crop and green manure, which prevents soil erosion and improves soil fertility by its ability to fix atmospheric nitrogen. The plant has an essential role in improvement of human, animal and soil health, being a good source of protein with up to 25% seed protein concentration, essential amino and fatty acids (Mohan *et al*., 1994). However, exposure of ricebean roots to excessive soil acidity may impair root growth, plant nutrients uptake, and shoot biomass which are important for plant growth (Haynes *et al*., 1981). Biochar is a carbon rich materials produced by thermal decomposition of biomass (woody and non-woody biomass) under limited supply or complete absence of oxygen (Lehmann *et al*., 2009). Feedstock include woody biomass primarily comprising of forestry and tree residue while non-woody biomass consists of agricultural and crop residues, animal waste and industrial solid waste (Jafri *et al*., 2018). Biochar are reported as an effective soil ameliorant to restore common problems associated with acid soils and improve soil fertility similar to lime application (Sarma *et al*., 2017). The potential benefits of biochar application include; improved soil properties, cation exchange capacity, increase microbial activity, water holding capacity or improving plant growth, and reduced availability of toxic metals, improving plant productivity (Chintala *et al*., 2014: Elangovan *et al*. 2022). The ameliorating effect of biochar on soil pH is similar to the lime application rate especially in highly weathered acidic soils. However, crop responses to biochar in a soil depend on the type of feedstock, temperature, plant species, soil type and nutrient concentration of biochar. Wood biochar, crop residue biochar, manure biochar and municipal waste biochar (produced at 350 to 550°C) applied at 2% of soil was found to enhance the crop productivity by 12.1, 2.6, 29.0 and 12.8%, respectively (Liu *et al*., 2013). The application of pig manure in the soil as organic manure is one of the most sustainable and alternative method of supplying plant nutrients. The use of animal waste as manure is a rational alternative and of great interest in terms of environmental, social and agronomic traits. Plant nutrients are removed from the soil in the harvested product fed to the animals and returned to the soil as manure, thereby continuing the cycle. Applying pig manure as fertilizer (N- 0.81%, P- 0.70%, K- 0.55%) in agricultural field also significantly improve productivity, soil fertility and quality thereby resulting in better yields (Hountin *et al.*, 2000). Therefore, a field experiment was carried out for two consecutive years (1) to investigate the effect of biochar and pig manure on yield, nutrient content and uptake of ricebean crop (2) to study its effect on soil properties in acid soil.

MATERIAL AND METHODS

Study area and physico-chemical characteristics of soil. The field experiment was conducted in the experimental farm of the Department of Agricultural Chemistry and Soil Science, School of Agricultural Sciences and Rural Development (SASRD), Nagaland University, Medziphema Nagaland, India (25˚45′30″ N, 93˚53′04″ E). Pre-experimentation composite soil sample (0–15 cm) was analyzed for initial soil physicochemical properties. The soil is sandy clay loam (50.4% sand, 19.1% silt and 30.5% clay) in texture, acidic in reaction (pH 5.10), high in organic carbon (16.8 g kg^{-1}), low in available N (215.1 kg ha^{-1}) and P (10.1 kg ha^{-1}), medium in available K (137.4 kg ha^{-1}), and have 33.1% base saturation. The wood and bamboo biochar feedstock was procured from the Forest Research Centre for Livelihood and Extension (FRCLE), Tripura, India. The biochar was produced from teak (*Tectona grandis*) and bamboo (*Bambusa tulda*) by heating at 700°C for 25-30 min, and had following properties (Table 1). The pig manure (PM) used in this experiment was collected from a local farmer and have the following properties: pH 6.4, EC 1.04 dSm^{-1}, 0.81% N, 0.70% P, and 0.55% K.

Experimental details. The field experiment was conducted during the *kharif* season of 2020 and 2021 with ricebean variety, Bidhan-1, as the test crop. The field was ploughed twice with the help of rotavator to make a final seed bed. A total of 5 seeds were sown in each row of a plot, the spacing of 45 cm × 30 cm and plot size of 2.25 × 2.10 m^2 were properly maintained. After 2 weeks of germination, thinning operation was carried out with a view to maintain optimum plant population in all plots. Nitrogen, phosphorus and potassium were supplied through urea, single super phosphate and muriate of potash, respectively. The treatments comprises of T_1: Control, T_2: Recommended dose of fertilizers (RDF) @ 20 kg Nha^{-1}, 40 kg Pha^{-1} and 30 kg K ha^{-1}, T_3: RDF + 2.5 t ha^{-1} wood biochar, T_4: RDF + 5.0 t ha^{-1} wood biochar, T_5: RDF + 2.5 t ha^{-1} bamboo biochar, T_6: RDF + 5.0 t ha^{-1} bamboo biochar, T_7: RDF + 2.0 t ha^{-1} pig manure, T_8: RDF + 2.0 t ha^{-1} pig manure + 2.5 t ha^{-1} wood biochar, T_9: RDF + 2.0 t ha^{-1} pig manure + 5.0 t ha^{-1} wood biochar, T_{10}: RDF + 2.0 t ha^{-1} pig manure + 2.5 t ha^{-1} bamboo biochar, T_{11}: RDF + 2.0 t ha^{-1} pig manure + 5.0 t ha^{-1} bamboo biochar, replicated thrice in randomized block design. Biochar was applied 14 days before sowing and pig manure was applied 30 days before sowing. Biochar and pig manure were broadcasted uniformly in the plot and mixed thoroughly with soils. At maturity, representative plant samples were collected from 1 m^2 area, away from the bunds. The stover and seed yield were estimated at 13% moisture content. After harvest of the crop, representative soil samples were collected from each plot randomly from 5 spots, away from the boundaries using screw auger, air dried and processed as per requirement.

Biochemical analyses. Seeds and stover samples were oven dried at a temperature of 60–70°C to attain a constant weight, grounded and stored in a polythene bags with proper labeling for chemical analysis. The N content was estimated by Kjeldahl method (Bremner, 1996). For total phosphorus (P), potassium (K), sulphur (S), calcium (Ca) and magnesium (Mg) estimation, grounded plant samples were digested in diacid (HNO_3-$HClO_4$) (Jackson, 1973). Total P in the extract was determined vanadomolybdate-phosphate yellow colour. The K content was determined by flame photometer (Chapman and Pratt, 1961) and S content by turbidimetry method (Tandon, 1993). Ca and Mg content were determined by versenate (EDTA) method (Prasad, 1998). Nutrient uptake in seed and stover was calculated by multiplication of yield values with their respective nutrient content. Base saturation was calculated from the percentage of total CEC occupied by Ca^{2+}, Mg^{2+}, K^+ and Na^+.

Scanning electron microscope analysis. The surface morphology and textural structure of biochar was characterized by scanning electron microscope (SEM) [JSM-6360 (JEOL) with operating condition at 1 – 20kV accelerating voltage of 20 kV]. To generate the topographic SEM image, we have used low energy secondary electron (SEI) or high energy back scattered electrons (BEI) from the specimen for image formation with 8mm WD. The energy dispersive X-ray spectroscopy (Oxford EDS; Aztec software) was run to characterize elements and chemicals of biochar sample inside SEM.

Statistical analysis. The data related to each character were analyzed statistically by applying the techniques of analysis of variance and the significance of different source of variation was tested by 'F' test (Cochran and Cox, 1962). Correlation coefficient between different parameters was tested at 1% level of significance, determined from Pearson's critical correlation.

RESULTS AND DISCUSSION

Characteristics of biochar derived from wood and bamboo. The characteristics of biochars derived from wood (WB) and bamboo (BB) used in this experiment are presented in Table 1, and SEM images are illustrated in Fig 1. Both the biochars have comparable pH although WB has higher EC compared with BB. Total C content in WB is higher in BB and the reverse is true for volatile matter content. Elemental analysis showed that wood derived biochar have higher total N, P, K, Ca and Mg than bamboo derived biochar. Surface morphology from

SEM images showed that the WB and BB are highly porous, and had many mesoporous structures ranging from 10 to 30 µm. The result showed the hardwood biochar (WB) as a better candidate for neutralizing acid soil and nutrient enrichment as its pH and nutrient content are higher than BB. Similar results have been reported by Kasantikul *et al.* (2020). The use of biochar as a soil amendment is greatly facilitated by its highly porous structure which helps in water and nutrient retention Zakir *et al.* (2019).

Effect of biochar and pig manure on seed and stover yield of ricebean. The effect of biochar and pig manure on seed and stover yields of ricebean are presented in (Table 2). Application of biochar with or without pig manure significantly improved seed and stover yield during both the years of experimentation compared with control and RDF alone. Pooled data of seed (1271 kg ha^{-1}) and stover yield (2579 kg ha^{-1}) was highest in T_9. The treatment T_9 with RDF + 2.0 t ha^{-1} PM + 5.0 t ha^{-1} WB increased the seed yield by 86.3% and 76.1% during the first and second year of experimentation, respectively while pooled seed yield was enhanced to the extent of 81.0% over control. Stover yield was increased to the extent of 55.6 and 56.8% during the first and second year of experimentation over control with pooled value of 56.2%. However, effectiveness of wood and bamboo biochar was at par and there was no significant difference between differential biochar doses (2.5 and 5 t ha^{-1}), but higher seed and stover yield was obtained in WB treated plots. The seed and stover yield of ricebean could be enhanced by the addition of wood biochar at 5 t ha^{-1}, pig manure at 2 t ha^{-1} and recommended dose of fertilizer. Major *et al.* (2010) found that the liming effect of biochar may have eliminated the harmful effect of soil acidity thereby resulted in better crop growth and yield. Rondon *et al*. (2007) observed that combined application of biochar and fertilizer increase the yields, improved biological N fixation, and significantly enhanced biomass production and yield of common beans. Thus, from several field studies conducted it can be concluded that improved crop yield due to biochar addition is prominently witnessed in less fertile, acidic and weathered soils (Jones *et al*., 2012; El-Naggar *et al*., 2012) and this may be ascribed to its ability to neutralize the soil pH (liming effect) and improvement in physico-chemical and biological properties of soils (Cornelissen *et al*., 2013; Martinsen *et al*., 2014). The beneficial implications of biochar on crop production may be due to direct accessibility of fundamental essential nutrients such as N, P, K, Ca, and Mg, from biochar applied Dar *et al*. (2019).

Effect of biochar and pig manure on nutrient composition, protein content and protein yield of ricebean. Biochar application with or without PM significantly improved nutrient content of ricebean (Table 3). The N, P and S content were higher in seed as compared with stover, while the reverse is true for K, Ca and Mg content. The application of RDF + 2.0 t ha^{-1} PM + 5.0 t ha^{-1} WB (T_{11}) resulted in maximum N, P, K, S content in seed and stover of ricebean in this experiment. In seed, the highest N content was observed with treatment T_9 with 3.44 and 3.46% and in stover with 1.36 and 1.38%, P content in seed ranged from 0.24 to 0.42%, and P content in seed was found to increase by 70.8% over control with application of RDF + 2.0 t ha^{-1} pig manure + 5.0 t ha^{-1} wood biochar. Similarly, in stover, the P content was highest in RDF + 2.0 t ha^{-1} PM + 5.0 t ha^{-1} WB with 0.20 and 0.21%. Further evaluation of pooled data indicated that P content in stover increased to the extent of 75.0% over control. From the pooled data it was observed that K content in seed increased by 18.2% and 11.5% in stover over control. Maximum S content in seed was recorded in treatment RDF + 2.0 t ha^{-1} pig manure + 5.0 t ha^{-1} wood biochar however S content in seed and stover during both the years of experimentation was found to be non-significant. The Ca content in seed recorded was highest with the application of RDF + 2.0 t ha^{-1} pig manure + 5.0 t ha^{-1} wood biochar while the effect of the treatment was found non-significant. However, the Mg content in seed and stover of ricebean was recorded non-significant. The results showed that application of biochar and pig manure could enhance the nutrient content as well as uptake in ricebean, which is in agreement with some of the previously published studies. The addition of WB may have improved the nutrient availability in and around plant roots thereby attributing to increase nutrient content in both seed and stover Mia *et al*. (2014). Biochar is rich in organic carbon and minerals which play an important role in supplying additional nutrient to the soil that is available for plant growth, enhancing the plant nutritional status thus helping in the plant development (Syuhada *et al*. 2016; Gao *et al*. 2019). These results are in agreement with Mohammad *et al.* (2017) who observed that addition of biochar in acid soil increased the nutrient content in faba beans. Significant improvement in the content of sulphur in ricebean seed could be attributed to the presence of numerous micropores on the surface of the biochar which act as a favorable habitat for the growth of microbes when added to the soil, and easily access plant unavailable sources of S and P from the soil or the biochar directly, ultimately making S content available for plants Warnock *et al.* (2007). The increase in the content of Ca in seed might be due to increase in the soil pH as a result of biochar addition and therefore nutrients especially basic cations like Ca and Mg are made available and their concentration increased for the plant uptake Uzoma *et al*. (2011).

Protein content and yield of ricebean. The pooled data of seed protein content and yield showed that both biochar and PM application significantly improved the protein content and yield in seed (Table 3). Protein content (19.6%) and yield (137.9 kg ha^{-1}) was lowest in control. Combine usage of biochar and PM application do not improve the protein content. Highest protein yield was observed in T_9 that increased the protein yield by 98.5 and 47.4% from control and RDF, respectively. No significant difference was observed with the plots amended with combined application of RDF, biochar and pig manure (T_8 to T_{11}). Biochar contain nutrients, such as K, Ca, Mg and S which act as activator in synthesis of protein, thereby increasing the protein content and yield Tessfaw *et al*. (2021).

Effect of biochar and pig manure on total nutrient uptake. The nutrient uptake scenario of ricebean showed that WB at 5 t ha^{-1}, PM at 2 t ha^{-1} with RDF was significantly superior in enhancing the total N (201.6 kg ha^{-1}), P (26.4 kg ha^{-1}), K (117.3 kg ha^{-1}), S (19.6 kg ha^{-1}), Ca (18.9 kg ha^{-1}) and Mg (12.4 kg ha^{-1}) uptake (Table 3). The total N, P, K, S, Ca and Mg uptake increased by 32.2, 59.6, 25.9, 28.4, 29.7 and 33.3%, respectively in RDF compared to the control. Between the two biochar, WB is significantly more effective in improving total nutrient uptake. Results revealed that biochar and pig manure incorporation enhanced the nutrient uptake of ricebean under the acidic conditions Kleber *et al*. (2015) which might be attributed to biochar's porous surface and structure which has the capacity to hold nutrients leading to improved nutrient availability and uptake. This result is supported by Milla *et al.* (2013) who observed higher N, P, and K uptake by cowpea in the biochar treated soil maintained higher concentration of these nutrients in soil solution. Schulz *et al.* (2013) also found that biochar amendment provides biota for microbial populations and thereby enhances mobilization allowing plants to uptake more Agegnehu *et al*. (2016) reported that Ca becomes readily available in the soil after biochar application, which enables the plant to largely dependent on the root cation exchange capacity. The Ca content in biochar replaces monomeric Al species on soil mineral or organic matter exchange sites which may have helped in enhancing Ca availability for plant uptake. Fox *et al*. (2014) observed increment in Mg uptake in maize grain when biochar was soil applied compared to control.

Effect on soil base saturation. The effect of biochar and pig manure on soil base saturation is presented in Table 5. Application of fertilizer, biochar and pig manure significantly increased the base saturation after crop harvest during both the years of experimentation. The highest base saturation was recorded in T_9 treatment and base saturation was 44.9 and 45.6% during 2019 and 2020, respectively, with pooled value of 45.3%. Lowest base saturation was observed from control with in both years of experimentation (34.1% in 2019 and 36.1% in 2020). Increasing rate of wood and bamboo biochar application (2.5–5.0 t ha^{-1}) significantly increased the base saturation over RDF (T_2). Han *et al*. (2016) stated that biochar has a loose and porous structure due to its large surface area which is rich in functional groups which help in adsorbing more base ions thereby increasing the soil base saturation. This result is supported by Singh *et al*. (2010) who reported that when freshly added biochar gets exposed to water and oxygen in soil, biochar may have undergone surface oxidation reactions leading to a rise in the net negative charge which results in higher CEC and base saturation.

Pearson's Correlation Analysis. A correlation studies were performed among the studied traits is depicted in Table 6. There exist a significant and positive correlation between seed, stover yield to protein content, protein yield, total nutrient uptake in N, P, K, S, Ca and Mg and base saturation in soil (Table 6). The nutrient uptake is a function of nutrient content and biomass production.

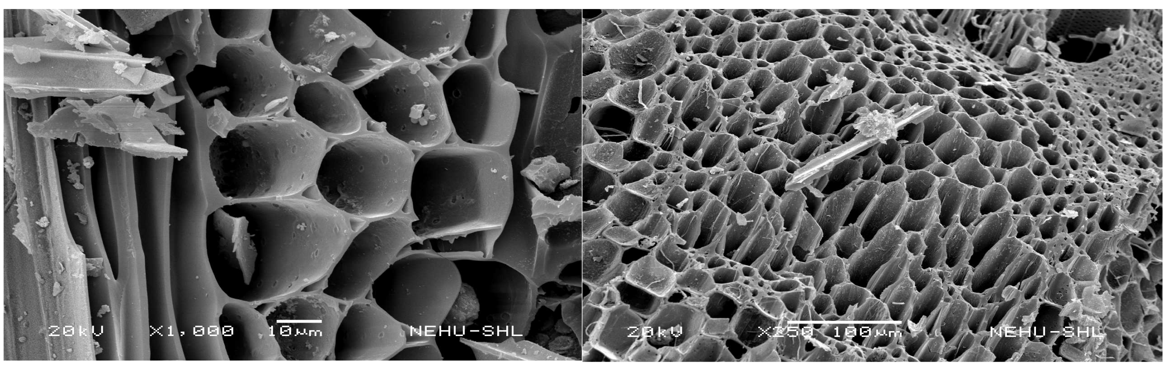

Fig. 1. SEM image of biochars derived (a) wood and (b) bamboo.

Table 1: Basic chemical properties of biochar used in the experiment.

Particulars	Wood biochar (WB)	Bamboo biochar (BB)
pH	7.91	7.70
EC	3.58 dS m^{-1}	1.68 dS m^{-1}
Carbon	86.9 %	83.4 %
Hydrogen	1.17 %	3.85 %
Moisture	3.81 %	3.60 %
Ash	6.78 %	6.54 %
Volatile matter	17.8 %	32.0 %
Fixed carbon	71.6 %	57.8 %
Total N	0.76 %	0.57 %
Total P	0.89 %	0.72 %
Total K	0.81 %	0.23 %
Total Ca	2.35 %	0.37 %
Total Mg	0.45 %	0.36 %

Table 2: Seed and stover yield as affected by biochar and pig manure applications (pooled data of two years).

Treatment	Seed yield (kg ha^{-1})			Stover yield (kg ha^{-1})		
	2019	2020	Pooled	2019	2020	Pooled
T_1	678.43	725.22	701.82	1649.77	1651.61	1650.69
T_2	903.43	928.59	916.01	1922.06	1929.21	1925.64
T_3	1062.05	1137.25	1099.65	2362.83	2368.68	2365.76
T_4	1149.08	1147.10	1148.09	2430.04	2436.76	2433.40
T_5	1023.50	1051.40	1037.45	2159.91	2163.45	2161.68
T_6	1108.72	1141.60	1125.16	2314.85	2319.80	2317.32
T_7	1125.15	1139.82	1132.49	2332.28	2340.88	2336.58
T_8	1238.78	1258.09	1248.44	2473.16	2478.50	2475.83
T_9	1264.42	1277.12	1270.77	2567.31	2590.82	2579.06
T_{10}	1118.64	1217.74	1168.19	2480.03	2450.22	2465.12
T_{11}	1182.41	1228.33	1205.37	2544.88	2555.50	2550.19
SEm±	39.99	34.97	26.56	41.36	43.59	30.04
CD (p< 0.05)	117.96	103.16	75.92	122.01	128.59	85.88

Table 3: Effect of biochar applications on nutrient content (%) in seed and stover of ricebean (pooled data of two years).

Treatments	N		P		K		S		Ca		Mg		Protein content (%)	Protein yield (kg ha^{-1})
	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover		
T_1	3.14	1.15	0.24	0.12	0.82	1.39	0.26	0.12	0.11	0.21	0.06	0.15	19.6	137.9
T_2	3.25	1.25	0.32	0.14	0.86	1.43	0.27	0.13	0.12	0.23	0.07	0.16	20.3	185.8
T_3	3.32	1.29	0.36	0.17	0.88	1.48	0.29	0.13	0.13	0.23	0.08	0.17	20.7	227.9
T_4	3.34	1.31	0.38	0.18	0.90	1.49	0.30	0.15	0.14	0.25	0.08	0.17	20.6	239.4
T_5	3.32	1.27	0.35	0.17	0.87	1.46	0.27	0.14	0.11	0.22	0.07	0.17	20.7	214.9
T_6	3.33	1.29	0.36	0.18	0.88	1.47	0.28	0.14	0.12	0.23	0.07	0.17	20.8	234.2
T_7	3.42	1.33	0.38	0.18	0.92	1.50	0.29	0.14	0.12	0.23	0.08	0.18	21.7	242.7
T_8	3.43	1.36	0.40	0.20	0.95	1.52	0.30	0.15	0.14	0.24	0.08	0.18	21.4	267.8
T_9	3.45	1.37	0.41	0.21	0.97	1.55	0.31	0.15	0.15	0.25	0.08	0.19	21.6	273.9
T_{10}	3.43	1.33	0.38	0.18	0.94	1.52	0.29	0.14	0.12	0.22	0.07	0.18	21.4	249.7
T_{11}	3.43	1.35	0.39	0.18	0.95	1.54	0.29	0.14	0.14	0.24	0.07	0.18	21.7	258.7
SEm±	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.11	5.83
CD(p<0.05)	0.05	0.06	0.02	0.02	0.03	0.03	0.02	NS	NS	0.02	NS	0.02	0.31	16.6

Eleven treatments (T_1= Control, T_2= RDF, T_3= RDF + 2.5 t ha^{-1} wood biochar, T_4= RDF + 5.0 t ha^{-1} wood biochar, T_5= RDF + 2.5 t ha^{-1} bamboo biochar, T_6= RDF + 5.0 t ha^{-1} bamboo biochar, T_7= RDF + 2.0 t ha^{-1} pig manure, T_8= RDF + 2.0 t ha^{-1} pig manure + 2.5 t ha^{-1} wood biochar, T_9= RDF + 2.0 t ha^{-1} pig manure + 5.0 t ha^{-1} wood biochar, T_{10}=RDF + 2.0 t ha^{-1} pig manure + 2.5 t ha^{-1} bamboo biochar, T_{11}= RDF + 2.0 t ha^{-1} pig manure + 5.0 t ha^{-1} bamboo biochar)

Table 4: Effect of biochar and pig manure on total nutrient uptake, protein content and yield uptake in ricebean (pooled data of two years).

Treatments	Total nutrient uptake (kg ha^{-1})					
	N	P	K	S	Ca	Mg
T_1	103.5	8.9	62.6	9.5	9.4	6.0
T_2	136.8	14.2	78.8	12.2	12.2	8.0
T_3	169.0	20.0	98.6	15.9	15.5	10.5
T_4	178.6	22.1	104.4	17.6	16.9	10.6
T_5	157.2	17.1	89.3	14.2	13.0	9.7
T_6	172.0	20.4	97.9	15.6	14.7	10.4
T_7	177.5	21.4	100.9	16.5	14.9	10.9
T_8	196.3	24.7	111.1	18.6	16.8	12.2
T_9	201.6	26.4	117.3	19.6	18.9	12.4
T_{10}	187.4	22.7	108.8	17.2	15.8	11.9
T_{11}	192.2	23.5	112.7	17.6	17.0	11.8
SEm±	1.05	0.12	1.32	0.15	0.22	0.24
CD(p <0.05)	3.00	0.35	3.76	0.44	0.63	0.67

Table 5: Effect of biochar and pig manure on post-harvest soil base saturation.

Treatments	Base saturation (%)		
	2019	2020	Pooled
T_1	34.9	36.1	35.5
T_2	39.2	39.3	39.2
T_3	40.8	41.3	41.0
T_4	41.2	41.7	41.5
T_5	39.1	40.9	40.4
T_6	40.1	41.3	40.7
T_7	42.1	41.8	42.0
T_8	44.7	45.2	44.9
T_9	44.9	45.6	45.3
T_{10}	43.4	43.1	43.7
T_{11}	43.7	44.2	44.0
SEm±	0.76	0.46	0.45
CD (p<0.05)	2.25	1.37	1.28

Table 6: Correlation co-efficient between seed, stover yield, total nutrient uptake, protein content, protein yield and base saturation.

	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	N total uptake (kg ha^{-1})	P total uptake (kg ha^{-1})	K total uptake (kg ha^{-1})	S total uptake (kg ha^{-1})	Ca total uptake (kg ha^{-1})	Mg total uptake (kg ha^{-1})	Protein content (%)	Protein yield (kg ha^{-1})	Base saturation (%)
Seed yield (kg ha^{-1})	1.000										
Stover yield (kg ha^{-1})	0.983**	1.000									
N total uptake (kg ha^{-1})	0.996**	0.987**	1.000								
P total uptake (kg ha^{-1})	0.995**	0.983**	0.995**	1.000							
K total uptake (kg ha^{-1})	0.987**	0.992**	0.996**	0.992**	1.000						
S total uptake (kg ha^{-1})	0.984**	0.979**	0.988**	0.995**	0.989**	1.000					
Ca total uptake (kg ha^{-1})	0.956**	0.966**	0.959**	0.973**	0.973**	0.981**	1.000				
Mg total uptake (kg ha^{-1})	0.992**	0.984**	0.995**	0.998**	0.995**	0.993**	0.975**	1.000			
Protein content (%)	0.951**	0.934**	0.967**	0.952**	0.958**	0.937**	0.885**	0.955**	1.000		
Protein yield (kg ha^{-1})	0.998**	0.981**	0.999**	0.996**	0.990**	0.985**	0.954**	0.994**	0.967**	1.000	
Base saturation (%)	0.962**	0.935**	0.971**	0.966**	0.967**	0.958**	0.931**	0.973**	0.965**	0.972**	1.000

**= Significance at 1% level

CONCLUSIONS

Findings of the present investigation revealed the positive influence of biochar application along with RDF and pig manure, which improved the soil base saturation, increased nutrient uptake, mineral composition that have bettered the yield of ricebean under acidic conditions. Yield increment in ricebean could be pertinent to the liming effect of biochar, meanwhile the higher nutrient content and uptake is evidence of the bioavailability of nutrients post biochar application. As observed from the outcome of the investigation, combined application of RDF + 2.0 t ha^{-1} pig manure + 5.0 t ha^{-1} wood biochar may be recommended for getting better yield of ricebean in Dystrudepts of Nagaland.

FUTURE SCOPE

Biochar show a great potential in terms of soil health and crop yields improvement as well as decreasing GHG emissions and carbon sequestration for much longer period. Although, biochar as soil amendments for improving soil quality and soil carbon sequestration has attracted wide scale global attention, the fundamental mechanisms by which biochar could provide beneficial function to soil and the wider function of the agro-ecosystem are sometime poorly described and need to be researched further. There is a need to monitor the changes in physical, chemical, hydrological and ecological settings of soil under the long term application of biochar.

Acknowledgment. I extend my sincere thanks to the Forest Research Centre for Livelihood Extension, Tripura, Agartala, CSIR- North East Institute of Science and Technology, Jorhat, Assam, SAIF- North-Eastern Hill University, Shillong, Meghalaya, India for their support. I also sincerely thank the Ministry of Tribal Affairs, Government of India for supporting the research financially by awarding me NFST scholarship (201819-NFST-ARU-02226).

Conflict of Interest. None.

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How to cite this article: Yabi Gadi, Y. K. Sharma, A.P. Singh, Avini-e Nakhro, M.M. Shulee Ariina and Sibino Dolie (2023). Characterization of Wood and Bamboo Biochar, and their Effect on Yield and Quality of Ricebean (*Vigna umbellata*) in Dystrudept. *Biological Forum – An International Journal, 15*(3): 625-631.