The Review of Contemporary Scientific and Academic Studies
An International Multidisciplinary Online Journal
www.thercsas.com

ISSN: 2583-1380 Vol. 2 | Issue 10 | October 2022 Impact Factor: 4.736 (SJIF)

Effect of Rice Husk Biochar on Soil Physicochemical Properties and Performance of Cowpea (*Vigna ungiuculata*)

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 Crossref/DOI: https://doi.org/10.55454/rcsas.2.10.2022.002

Abstract: *Agricultural activities generate large quantities of crop residues such as rice husk, which are left unused. As the amount of nutrients for plant growth decline in soil, growth of crop is inhibited and yield reduced. This necessitates the need to find ways to amend poor soils and help maintain high yields, food stability and good soil health. The objective of this study was to evaluate the effects of rice husk biochar on soil physicochemical properties and performance of Cowpea. The experiment was carried out on a 35 m x 11 m (385 m²) area of land at the Teaching and Research Farms of Lagos State Polytechnic, Ikorodu and IAR&T sub-station Ikenne. Three levels of biochar application were used in this study viz, 0 t/ha, 1.25 t/ha, and 2.5 t/ha which was applied and incorporated into the soil two weeks before planting. The experiment was laid out in Randomized Complete Block Design (RCBD). Seeds were sown at a spacing of 70 cm x 20 cm with two seeds per hole. Six plants were tagged per treatment for growth parameters, while the entire plot was used for yield estimation. The growth data collected were: plant height, number of leaves, number of branches, and stem girth at 3, 5 and 7 weeks after planting. Number of pods and grain yield per hectare were the yield parameters collected. Soil properties evaluated includes soil pH, soil organic matter, total nitrogen, available phosphorus, exchangeable potassium, Soil exchangeable acidity, and Cation exchangeable capacity. Data collected were subjected to Analysis of Variance (ANOVA), and significant means of treatments were compared using Duncan Multiple Range Test (DMRT) at 5% level of probability using SAS statistical software version 9.4 of 2012. Rice husk biochar was found to have significant effects on performance of cowpea and soil properties.*

Keywords: Cations, Cowpea, Nitrogen, Rice Husk Biochar, Soil pH

Introduction

Cowpea is an important crop in the cereal-legume cropping systems and provides an inexpensive source of protein and minerals for the urban and rural populace [15]. It requires very few inputs, as the plant's root nodules are able to fix atmospheric nitrogen, making it a valuable crop for resource-poor farmers and well-suited to intercropping with others like sorghum, millet, maize, cassava, or cotton crops [17]. The whole plant can be used as forage for animals and the seeds can be cooked to make them edible for consumption by man [10] or can be processed into paste or flour [9]. Biochar is charcoal formed from the thermal decomposition of biomass in a low or zero oxygen environment at moderate temperature (>700 ^{0}C)[11]. Biochar application to soils is presently attracting universal attention due to its potential to improve water holding capacity, soil nutrient retention capacity, and sustainable carbon store, thus reducing greenhouse gas emissions [7]. Biochar application provides greater nutrient retention and availability than other nutrient sources, therefore, less conventional fertilizers needs to be applied to give a desirable crop yield. [8] in an assessment of biochar's ability to reduce greenhouse gases, estimated that 10%–30% reduction of nitrogen fertilizer use will be effective. [25] estimated that for approximately every tonne of nitrogeneous fertilizer that is used, 13.5 tonnes CO_2 is emitted into the atmosphere [16]. However, suggested the concept of using syngas from the pyrolysis process to replace the natural gas to produce nitrogen. Combining the biochar and nitrogen that is produced the same process can create a powerful carbon and nitrogen rich fertilizer [6].

Soil fertility management ranges from fertilizer applications to low external input agriculture based on organic sources of nutrients. As farmers are unable to meet the nutrient needs of all crops, they prefer to apply fertilizer to cereals and rarely target fertilizers directly to grain legumes which are mostly grown on residual fertility while in many African countries, the main use of fertilizer is on maize, sorghum/millet, and rice with cowpea receiving little attention from farmers in terms of fertilizer application. It is generally believed by most cowpea growers that the production of legumes does not require fertilizer application. This in modern agriculture depletes nutrients and reduces soil organic matter levels through continuous cropping. This decline in soil nutrient continues until management practices are improved, additional nutrients are applied, rotation with nitrogen-fixing crops is practiced, or until a fallow period occurs allowing a gradual recovery of the soil through natural ecological development. As the natural stores of the most important nutrients for plant growth decline in the soil, growth rates of crops are inhibited and yield reduced. This necessitates the need to find ways to amend poor soils and help maintain high yields and food stability hence, the main objective of this study was to evaluate the effects of rice husk biochar on soil physicochemical properties and performance of cowpea.

Materials and Methods

Experimental Location, Experimental Materials, Experimental Design and Treatments

The experiment was carried out at the Teaching and Research Farms of Lagos State Polytechnic, Ikorodu, Lagos State Nigeria and IAR&T Sub-station Ikenne, Ogun state. The cowpea seeds used for the research were Ife brown variety and it was gotten from Genetics Resource Center of International Institute of Tropical Agriculture (IITA) Ibadan, Oyo State. The feedstock that was used for biochar production was obtained from rice bran. The waste biomass was collected from a rice mill in Imota, Ikorodu, Lagos State and was processed into biochar using a pyrolyser. The experiment was laid out in Randomized Complete Block Design (RCBD) with three treatments (0t/ha, 1.25 t/haand 2.5 t/ha biochar) and replicated three times.

Crop Establishment and Maintenance

Cowpea seeds were sown at a spacing of 70 cm x 20 cm with two seeds per hole. Thinning to one plant per stand was carried out at two weeks after emergence (WAE). Weeding was done at two weeks interval manually and insect pests were controlled by spraying cypermethrin 10% EC at two week interval at the rate of 1.5 l/ha (7.2 ml/481 m^2) in 400 l/ha (19.2l/481 m^2) of water.

Preparation of Biochar

The biochar was processed by first removing the moisture content by sun drying, and then the material was loaded into the Reactor. Heat was applied for five hours at a temperature of >700^0C when there was no more smoke coming from the reactor, the content was unloaded from the reactor and then allowed to cool under ambient temperature.

Data Collection and Statistical Analysis

Six (6) plant stands was randomly sampled and tagged per plot for data collection. The data collected were: plant height, number of leaves, number of branches, and stem girth at 3, 5 and 7 weeks after planting as growth parameters, as well as number of pods, grain yield per hectare as yield parameters. Soil data collected are soil pH, soil organic matter, total nitrogen, available phosphorus, exchangeable cations, Soil exchangeable acidity, and Cation Exchangeable Capacity. Data collected were subjected to Analysis of Variance (ANOVA), and significant means of treatments were compared using Duncan Multiple Range Test (DMRT) at 5% level of probability using SAS statistical software version 9.4 of 2012.

Results

Pre-Planting Soil Physicochemical Properties and Biochar Analysis

Data presented in Table 2, shows the soil pre-planting soil physical, chemical and biochar analysis. In Ikorodu, the soil was slightly acidic (5.6), with organic carbon and total nitrogen of 1.81% and 1.96% respectively. The soil contained 5.96 mg/kg, 1.15 mg/kg, 129mg/kg, 185 mg/kg and 41.50 mg/ks of zinc, copper, iron, manganese and available phosphorus, respectively. The soil contained 1.06 cmol/kg sodium, 0.59 cmol/kg potassium, 0.55 cmol/kg calcium and 0.92 cmol/kg magnesium. The soil had a CEC of 8.89 cmol/kg.

At Ikenne, the pH was strongly acidic (5.42) with organic carbon of 1.62% and total nitrogen of 1.76%. The soil contains 4.70 mg/kg, 1.01 mg/kg, 120 mg/kg, 165 mg/kg and 38.50 mg/kg of zinc, copper, iron, manganese and available phosphorus respectively. The soil contains 1.01 cmol/kg sodium, 0.49 cmol/kg potassium, 0.45 cmol/kg calcium and 0.72 cmol/kg magnesium. The soil had a CEC of 3.29 cmol/kg.

ISSN: 2583-1380 Vol. 2 | Issue 10 | October 2022 Impact Factor: 4.736 (SJIF)

The result from rice husk biochar analysis showed that the biochar had alkaline pH (8.13) and contains high organic carbon (63.71%) than the soils at the experimental locations but lower total nitrogen (0.86%) than both locations. The biochar also contains higher available phosphorus (75.35 mg/kg) than the soil at both locations. With regards to the exchangeable bases, the biochar had higher potassium (1.76 cmol/kg), calcium (11.70 cmol/kg) and magnesium (13.01 cmol/kg) but lower sodium (0.05) compared to the soil at both locations. The biochar also had higher CEC of 14.27 cmol/kg than the soils.

Table 1: Pre-planting soil chemical properties, particle size analysis and nutrient composition of biochar

Physicochemical Properties	Ikorodu	Ikenne	Biochar
pH	5.6	5.4	8.1
Organic Carbon (%)	1.81	1.62	63.71
Total Nitrogen (%)	0.19	0.17	0.08
Zn (mg/kg)	5.96	4.70	
Cu (mg/kg)	1.15	1.01	
Fe (mg/kg)	129	120	
Mn (mg/kg)	185	165	
Available Phosphorus (mg/kg)	41.50	38.50	75.35
Na (cmol/kg)	1.06	1.01	0.05
K(cmol/kg)	0.59	0.49	1.76
Ca (cmol/kg)	0.55	0.45	11.70
Mg (cmol/kg)	0.92	0.72	13.01
CEC (cmol/kg)	8.89	3.29	14.27

Effect of Biochar on Soil Chemical Properties at Ikorodu and Ikenne

Table 2 shows the effect of biochar on soil chemical properties at both Ikorodu and Ikenne. The result revealed thatsoil pH values were significantly (p≤0.05) influenced by biochar application at Ikenne, 2.5 t/ha biochar treated soils had the highest soil pH (4.81) while least (4.44) was observed in 0 t/ha biochar. However, Soil pH was not significantly (p≤0.05) influenced by biochar at Ikorodu.Soil organic matter was not significantly (p≤0.05) influenced by biochar application at both locations while total nitrogen (N) was significantly (p≤0.05) influenced by biochar application at only Ikenne with the highest soil N (0.19%) observed on 0 t/ha biochar while the least was observed on 1.25 t/ha biochar treated soils. Soil Total N was not significantly (p≤0.05) influenced by biochar application at Ikorodu. Available phosphorus (P) was significantly (p≤0.05) influenced by biochar application at Ikenne. The highest available P values (21.52 mg/kg) were obtained with 1.25 t/ha biochar, while the lowest (10.38 mg/kg) was observed with 0 t/ha biochar treatment. Soil available P values were not significantly (p≤0.05) influenced by application of biochar at Ikorodu. Exchangeable potassium (K) values were significantly (p≤0.05) influenced by biochar at Ikorodu but not at Ikenne. At Ikorodu, the highest soil exchangeable K (1.09 cmol/kg) was observed with 1.25 t/ha biochar (1.36 cmol/kg) while the lowest (0.92 cmol/kg) was observed with 0 t/ha biochar. Soil exchangeable acidity were not significantly (p≤0.05) influenced by biochar at both locations.

Soil cation exchangeable capacity was significantly (p≤0.05) influence by biochar at Ikenne with the highest observed in 1.25 t/ha biochar (12.26 cmol/kg) while the lowest (9.23 cmol/kg) observed in 0 t/ha biochar. Soil cation exchangeable capacity was not significantly (p≤0.05) biochar at Ikorodu.

Table 2: Effect of biochar on soil chemical properties at Ikorodu and Ikenne

Treatments	pH		SOM (%)		N (%)		P (PPM)		K (cmol/kg)		Exch. Acid (H^+&$Al3^+$)		CEC (cmol/kg)	
	Ikorodu	Ikenne	Ikorodu	Ikenne	Ikorodu	Ikenne	Ikorodu	Ikenne	Ikorodu	Ikenne	Ikorodu	Ikenne	Ikorodu	Ikenne
0	6.04	4.44c	3.44	3.53	0.10	0.19a	10.22	10.38c	0.92b	0.72	0.17	0.16	14.93	9.23b
1.25	6.36	4.81a	3.59	3.77	0.10	0.14b	10.26	18.45b	1.09ab	0.74	0.17	0.15	17.22	12.26a
2.5	6.05	4.64b	4.04	3.87	0.12	0.13b	10.27	21.52a	1.36a	0.75	0.15	0.17	15.02	10.53b
S.E.	0.09	0.09	0.14	0.08	0.01	0.02	0.01	0.03	0.1	0.01	0.01	0.01	0.61	0.72
Significance	Ns	*	ns	ns	ns	*	Ns	*	*	ns	ns	ns	ns	*

 https://doi.org/10.55454/rcsas.2.10.2022.002

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ISSN: 2583-1380 Vol. 2 | Issue 10 | October 2022 Impact Factor: 4.736 (SJIF)

Effects of Rice Husk Biochar on the Growth and Yield of Cowpea in Ikorodu and Ikenne

Tables 3 to 7 present the effects of rice husk biochar on the growth and yield of cowpea in Ikorodu and Ikenne. Plant heights of cowpea were significantly ($p \leq 0.05$) affected by biochar at 5 WAS and 7 WAS at Ikene (Table 3). At 5 WAS and 7WAS, 1.25 t/ha of biochar had the tallest plants (60.14 cm and 143.01 cm) as compared to other rates of biochar application. There was no significant difference observed in the rates of biochar at all weeks of consideration in Ikorodu and 3WAS at Ikenne. Number of leaves of cowpea were significantly ($p \leq 0.05$) affected by biochar at 3, 5, and 7 WAS at Ikenne (Table 4). At 3 WAS, 0 t/ha biochar had the highest number of leaves (14.18) followed by 1.25 t/ha biochar. At 5 WAS, 1.25 t/ha biochar had the highest number of leaves (69.66) followed by 0 t/ha biochar (65.29) with 2.5 t/ha biochar having the least number of leaves (57.94). At 7 WAS, 2.5 t/ha biochar had the highest number of leaves (141.99) followed by 0 t/ha lime (134.88), with 1.25 t/ha biochar having the least number of leaves. There were no significant ($p \leq 0.05$) differences in the number of leaves of cowpea as affected by biochar at 3, 5, and 7 WAS at Ikorodu. Number of branches of cowpea were significantly ($p \leq 0.05$) affected by biochar at 3 WAS at Ikorodu and 7 WAS at Ikenne, and NPK fertilizer at 5 WAS at Ikorodu. At 3 WAS in Ikorodu 1.25 t/ha biochar had the highest number of branches (5.00) followed by 0 t/ha biochar (4.56) with 2.5 t/ha biochar having the least number of branches (4.39). At 7 WAS at Ikenne, 1.25 t/ha biochar had the highest number of branches (86.84) followed by 0 t/ha biochar (63.93) with 2.5 t/ha biochar having the least number of branches (59.14). There were no significant ($p \leq 0.05$) differences in the number of branches of cowpea as affected by biochar at 5, and 7 WAS at Ikorodu and 3 and 5 WAS at Ikenne (Table 5).Cowpea stem girth was significantly ($p \leq 0.05$) increased by, biochar at 3 WAS at Ikorodu, (Table 6). At 3 WAS, plant treated to 1.25 t/ha biochar had the thickest stem (1.93 cm) in Ikorodu. There were no significant ($p \leq 0.05$) differences in the stem girth of cowpea as affected by biochar at 5, and 7 WAS at Ikorodu and 3, 5 and 7 WAS at Ikenne.There was no significant different observed in the number of pods, days to 50% flowering and number of pods as influenced biochar at both locations (Table 7).

Table 3: Effects of Rice husk biochar on plant height (cm) of cowpea in Ikorodu and Ikenne

	Weeks after Sowing					
	3		5		7	
Biochar(t/ha)	**Ikorodu**	**Ikenne**	**Ikorodu**	**Ikenne**	**Ikorodu**	**Ikenne**
0	13.65	14.16	42.18	53.88b	104.39	134.28ab
1.25	14.21	15.23	48.35	60.14a	114.97	143.01a
2.5	13.82	13.92	42.98	56.27ab	103.18	131.62b
S.E.	0.14	0.33	1.58	1.49	3.06	2.81
Significance	ns	ns	Ns	*	ns	*

S.E: Standard error, ns: not-significant at $p \leq 0.05$ *: Significant at $p \leq 0.05$

Table 4: Effects of Rice husk biochar on number of leaves of cowpea in Ikorodu and Ikenne

	Weeks after Sowing					
	3		5		7	
BIOCHAR (t/ha)	**Ikorodu**	**Ikenne**	**Ikorodu**	**Ikenne**	**Ikorodu**	**Ikenne**
0	15.00	14.18a	74.79	65.29ab	129.06	128.67b
1.25	16.01	13.64ab	80.22	69.66a	139.92	119.59b
2.5	14.50	13.17b	74.39	57.94b	138.22	141.99a
S.E.	0.36	0.24	1.54	2.79	2.75	5.31
Significance	ns	*	ns	*	ns	*

S.E: Standard error, ns: not-significant at $p \leq 0.05$*: Significant at $p \leq 0.05$

Table 5: Effects of Rice husk biochar on number of branches of cowpea in Ikorodu and Ikenne

	Weeks after Sowing		
	3	5	7

BIOCHAR (t/ha)	Ikorodu	Ikenne	Ikorodu	Ikenne	Ikorodu	Ikenne
0	4.56ab	5.20a	25.94	29.06	45.39	63.93b
1.25	5.00a	5.22a	28.06	30.19	49.50	86.84a
2.5	4.39b	5.22a	26.00	30.00	47.22	59.14b
S.E.	0.15	0.01	0.57	0.29	0.97	6.98
Significance	*	ns	ns	ns	ns	*

S.E: Standard error, ns: not-significant at p≤0.05*: Significant at p≤0.05

Table 6: Effects of Rice husk biochar on stem girth (cm) of cowpea in Ikorodu and Ikenne

	Weeks after Sowing					
	3		5		7	
BIOCHAR (t/ha)	Ikorodu	Ikenne	Ikorodu	Ikenne	Ikorodu	Ikenne
0	1.77b	1.89	2.36	2.54	3.09	2.87
1.25	1.93a	1.22	2.37	1.95	3.01	2.77
2.5	1.83b	1.83	2.26	2.48	3.03	2.86
S.E.	1.40	2.82	0.03	0.69	0.02	0.03
Significance	*	ns	ns	ns	Ns	ns

S.E: Standard error, ns: not-significantat p≤0.05*: Significant at p≤0.05

Table 7: Effects of Rice husk biochar on number of pods, pod weight and days to 50% flowering of cowpea in Ikorodu and Ikenne

	Number of pods		Pod weight (g)		Days to 50% flowering	
Treatments	Ikorodu	Ikenne	Ikorodu	Ikenne	Ikorodu	Ikenne
0	26.56	30.93	0.22	0.24	40.17	39.83
1.25	25.67	30.33	0.21	0.24	38.94	39.61
2.5	26.50	29.85	0.18	0.23	40.06	39.50
S.E.	0.23	0.26	0.01	0.00	0.32	0.08
Significance	ns	Ns	ns	Ns	ns	ns

Discussion

Results from Ikenne shows that plots treated with 1.25 t/ha biochar had a considerable increase in soil pH as compared to the treatments with no biochar applications, this can be attributed to the ability of biochar to increase soil pH and reclaiming acidic soil, this is in line with the findings of [13], who observed that the application of biochar to soils resulted in changes in soil chemical and physical properties such as an increase in soil pH, CEC, and water retention capacity.

Results from Ikenne sites show that the application of 2.5 t/ha biochar had the lowest total nitrogen as compared to the other rate and the control (no application). This result might be due to the increase in nutrient use efficiency influenced by biochar application. This increase in nutrient use efficiency has been found to be facilitated by increase in soil pH resulting in plants using more of the nitrogen in the soil. Also alkaline materials like biochar can volatize nitrogen that is in form of ammonia. All of these could be responsible for the low nitrogen content in treatments with biochar application. This result is supported by the findings of [24], who observed a significant increase in yield and availability of nutrients as a result of biochar application.

Application of 1.25 t/ha biochar led to an increase in the soil available phosphorus at Ikenne as compared to other rates of biochar. This is because biochar is a potential material for making slow-releasing phosphorus (P) fertilizers for the sake of increasing soil P use efficiency and mitigating P losses [24, 21], thereby improving soil available phosphorus content [20].

ISSN: 2583-1380 Vol. 2 | Issue 10 | October 2022 Impact Factor: 4.736 (SJIF)

Biochar at the rate of 2.5 t/ha in Ikorodu had high soil exchangeable potassium which might be due to the fact that biochar in itself is rich in potassium. This is in line with the findings of [24], who found out that the addition of biochar to soils resulted in increased soil phosphorus (P), soil potassium (K), total soil nitrogen (N), and total soil carbon (C). Application of 1.25 t/ha Biochar had the highest CEC which is hypothesized to be due to the fact that biochar in itself is rich in potassium and other exchangeable cations. Furthermore biochar is a colloidal material and has the ability to hold onto cations keeping them from leaching. This is in agreement with the findings of various authors that biochar application leads to increased potassium and other exchangeable cations [5, 12, 23, 13]. Application of biochar at the rate of 1.25 t/ha performed best in improving the growth of cowpea at both locations especially at ikenne. This might be due to the fact the biochar is from organic source which not only helps to reduce the pH of the soil to make nutrients more available for crop growth but also help release organic matter which is rich in nutrients into the soil, this hypothesis is supported by the findings of [5, 12, 23]. Application of biochar at the rate of1.25 t/ha of Biochar performed best in improving the growth of cowpea at both locations especially at ikenne. This might be due to the fact the biochar is an organic material which not only helps to improve the pH of the soil to making nutrients available for crop growth, this hypothesis is supported by the findings of [5, 12, 23, 13].From literatures, different authors found out that biochar application leads to improved cation exchange capacity, reduces nitrogen leaching [18]. Established that biochar can help in increasing nitrogen use efficiency and [14] observed that biochar application improved biological nitrogen fixation.

The non-significant effect observed in days to 50% flowering, number of pods and pod weight of cowpea might be due to other reason as it has been reported by [4] that biochar application enhances soil fertility and crop yields and [24] who reported that biochar application increases the fruit yield of tomato.

Conclusion

It can be concluded statistically, based on the outcome of this study that 1.25 t/ha of biochar has a very good potential at increasing the soil physiochemical properties, growth and yield of cowpea as it was observed to perform best as compared to other rates of application.

From the results observed in this study, it is recommended that Biochar at the rate of 1.25 t/ha should be adopted as an organic substitute for chemical lime as it was observed in this current research to not only improve soil pH but also make nutrient available for good crop performance. Further research is however recommended with more focus on more rates of application.

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