Effect of Rice Hull Biochar on the Fertility and Nutrient Holding Capacity of Sandy Soils

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Abstract: In the Philippines, under an integrated and diversified system of farming called *Palayamanan*, rice hull biochar (carbonized rice hull) has a lot of uses. Among other things, it is popularly used as soil conditioner and as main ingredient in the production of organic fertilizers. It is also used as bedding or absorbent material to facilitate urine and manure collection as well as help eliminate foul odor in poultry, swine and livestock. Once saturated, it is collected and applied to the soil as fertilizer. This study tries to further explore more uses of biochar and was generally conducted to determine the effects of rice hull biochar on the growth of upland kangkong and peanut and its effects on residual properties of sandy loam soil. Specifically, it aimed to (a) determine the appropriate level of rice hull biochar for peanut and upland kangkong grown in sandy soils, (b) evaluate N, P and K uptake of peanut and upland kangkong with different rates of rice hull biochar grown in sandy soils, and (c) evaluate the nutrient holding capacity of rice husk biochar in sandy soil. The experiment was carried out in a sandy loam with the following particle size distribution: 71.22% sand, 20.41% silt, and 8.37% clay; had a pH_{KCl} of 4.93 , 0.64 % organic C, 0.16% total N, 1.53 mg kg^{-1} extractable P, 2.88 $cmol^{+}$ kg^{-1} soil exchangeable Al, 3.08 $cmol^{+}$ kg^{-1} soil exchangeable acidity, 0.25 $cmol^{+}$ kg^{-1} soil exchangeable K, 3.57 $cmol^{+}$ kg^{-1} soil exchangeable Ca, 1.38 $cmol^{+}$ kg^{-1} soil exchangeable Mg, and 0.25 $cmol^{+}$ kg^{-1} soil exchangeable Na. There were six treatment combinations from levels of amendment (0, 10, 20, 30, 40 and 50 g kg^{-1} soil). The processed biochar was applied at levels specified in the treatment on oven-dried weight basis. It was added and mixed well with the soil just immediately before filling the pots. The pots were allowed to stabilize for 3 days before planting. Blanket application of 70 mg each of N, P_2O_5 and K_2O kg^{-1} soil using urea, solophos and muriate of potash was done five days after seedling emergence. Urea and muriate of potash were applied as aqueous solution while solophos was applied as granules. A linear trend in the liming benefit and positive change in pH_{KCl} with biochar application were observed in two “plant biotest” especially at higher levels (30, 40 and 50 g kg^{-1} soil). On the other hand, the positive change in extractable P due to residual effect of rice hull biochar application was obtained even at 10 and 20 g kg^{-1} soil in both upland kangkong and peanut. In peanuts, direct effects of application of uncharred or charred poultry litter resulted in better plant growth, nodulation, biomass, and K uptake than the control plants. From the results of the study, it can be concluded that the application of biochar can enhance fertility of acid sandy loam soil. The rice hull biochar holds nutrient in place that is needed for plant growth and development. Application at 30-40 g kg^{-1} soil appears to be the most appropriate rate for both upland kangkong and peanut grown in acid sandy loam soils.

Keywords: biochar, nutrient-holding capacity, organic fertilizer, rice hull, sandy soil

Introduction

The Philippines is predominantly an agricultural country with 30% of its total land area is devoted to crop production (Guevarra, 2007). The country’s increasing population heightens the demand for food thus, adding pressure to agricultural lands. When intensified land utilization is not accompanied by appropriate soil and crop management strategies, most certainly soil fertility and productivity is adversely affected. Environmentally sound management of organic matter and nutrients that can improve physical, chemical and biological fertility of acidic sandy soils is a major challenge.

Plant (eg. peanut and kangkong) requires nitrogen (N), phosphorus (P) and potassium (K) in large amounts for its growth and development (Wiederholt and Johnson, 2005). Nitrogen is a constituent of all proteins, chlorophyll, nucleic acid, amines and amides. Its role in plant nutrition has been recognized to be connected to the production of chloroplast and promotion of photosynthetic carbohydrate in plants which results to vigorous vegetative growth associated with dark green leaf, higher yield and improved crop quality (Follet et al., 1981). Phosphorus, on the other hand, is important in energy storage and transfer. It influences plant growth by stimulating vigorous root growth which accounts for better utilization of the nutrients. In legumes, P plays a key role in various physiological processes concerning root production, nodulation, seed formation and improvement of seed quality (Pochlman, 1991). In addition, N fixation and survival of rhizobia in soil are particularly affected by low P (Graham and Vance, 2003). N and P requirement of plants can be met by applying fertilizers and manure. However, manures and commercial fertilizers have a vastly higher concentration of soluble N and P which easily dissolves and leaches into run off water as it passes over the surface of the field. The leached nutrients may contribute to ground water contamination especially in regions with intensive agriculture. This scenario is worsen in sandy soils because of its very low water and nutrient holding capacity thus, rendering N and P unavailable for plant uptake (Renck and Lehmann, 2004). Recognizing these limitations, other management options including the application of biochar (e.g. rice husk biochar) offers practical solutions to improve soil fertility of sandy soils.

Biochar is the carbon-rich product obtained when biomass such as woods, bark, leaves, and manures is heated in a closed container with little or no available air. It is a fine grained charcoal high in organic carbon produced through pyrolysis of carbon-based feedstock (biomass) in the absence or low supply of oxygen at temperatures between 350 and 700 ^{o}C (Lehmann et al. 2010; Jenkins and Jenkinson. 2009). The process of charring mirrors the production of charcoal. However, it distinguishes itself from charcoal by the fact that biochars are produced as a means of improving soil productivity and carbon (C) storage (Lehmann, 2006). The aromatic structure of biochar is responsible for its recalcitrance and potential for long-term C sequestration (Atkinson et al., 2010). As a soil amendment, biochar creates a recalcitrant soil C pool that is C-negative, serving as a withdrawal of atmospheric CO_2 stored in highly recalcitrant soil C stocks (Glaser et al., 2002). It can sequester or store C in the soil ranging from hundreds to millions of years (Lehmann et al., 2006). Char-amended soils also have shown 50-80% reductions in nitrous oxide emissions (Cox et al., 2001). In addition to increasing the stable C stocks in a soil, there is increasing evidence demonstrating that biochar as soil amendment also increases nutrient availability beyond a fertilizer effect (Chan et al., 2008). Biochar has been found to be much more efficient at improving soil quality than any other organic soil amendment (Lehman and Joseph, 2009). Oshio et a. 1981 discussed that rice husk charcoal has a porous structure which contributes to aeration and water retention, which in turn enhances water and nutrient (especially nitrogen and phosphorus) retention. In addition to improving soil fertility, biochar also improve the soil physical conditions.

Rice husks production amounted to 3.2 M mt per year. At present, the conversion of rice hull or husk into biochar. Rice hull had been used as fuel for heating (e.g. drying of palay). Its conversion into biochar is also popular to farmers practicing *Palayamanan*. *Palayamanan* is an integrated system of farming which highlights diversification of farm components such as rice and other crops, livestock and fish (Orge and Abon, 2011). In this model, rice husk biochar (RHB) plays important part as it used as soil conditioner and additives of organic fertilizer. While rice husk biochar or carbonized rice hull had been used by farmers and garden enthusiasts for decades, very few studies had been undertaken especially in Philippine settings. This study aims to evaluate the effectivity of RHB in peanut and upland kangkong growth. The CRH that will be used is a by-product of PhilRice continuous-type rice hull (CTRH). Appropriate level of RHB is very crucial in its application to plants. It is hypothesized that CRH helps in enhancing the fertility status of sandy soils.

Objectives

1. To determine the appropriate level of RHB for peanut and upland kangkong grown in sandy soils.
2. To evaluate N, P and K uptake of peanut and upland kangkong with different rates of rice hull biochar grown in sandy soils.
3. To evaluate the nutrient holding capacity of rice husk biochar in sandy soil.

Time and Place of the Study

This study utilized an alluvial sandy loam soil from Talavera, Nueva Ecija, Philippines. The pot experiment was conducted in a screen house of the Plant Breeding and Biotechnology Division, Central Experimental Station (CES) PhilRice, Science City of Muñoz, Nueva Ecija, Philippines. The analyses of soil and plant tissue samples were done at the Soils Research Testing and Plant Analysis Laboratory (SRTPAL) of the DASS and at the PhilRootcrops Central Analytical Service Laboratory.

Review of Literature

Biochar is the carbon-rich product obtained when biomass such as woods, bark, leaves, husk, and manures is heated in a closed container with little or no available air. It is a fine grained charcoal high in organic carbon produced through pyrolysis of carbon-based feedstock (biomass) in the absence or low supply of oxygen at temperatures between 350 and 700^{o}C (Lehmann et al. 2010; Jenkins and Jenkinson. 2009). The process of charring mirrors the production of charcoal. However, it distinguishes itself from charcoal by the fact that biochars are produced as a means of improving soil productivity and carbon (C) storage (Lehmann, 2006). The aromatic structure of biochar is responsible for its recalcitrance and potential for long-term C sequestration (Atkinson et al., 2010). As a soil amendment, biochar creates a recalcitrant soil C pool that is C-negative, serving as a withdrawal of atmospheric CO_2 stored in highly recalcitrant soil C stocks (Glaser et al., 2002). It can sequester or store C in the soil ranging from hundreds to millions of years (Lehmann et al., 2006). Char-amended soils also have shown 50-80% reductions in nitrous oxide emissions (Cox et al., 2001). In addition to increasing the stable C stocks in a soil, there is increasing evidence demonstrating that biochar as soil amendment also increases nutrient availability beyond a fertilizer effect (Chan and Xu, 2009). Biochar has been found to be much more efficient at improving soil quality than any other organic soil amendment (Lehman and Joseph, 2009).

Biochar additions to soil can significantly increase the levels of key plant nutrients such as N and P (Lehmann et al., 2006). The quantities of these nutrients added to the soil depend on the chemical and physical properties of the biochar and the quantity added (Atkinson et al., 2010). The effect on nutrient availability from biochar application has been attributed to changes in soil chemical, biological and physical properties (Tagoe et al., 2008; Novak et al., 2009; Lehman et al., 2010). Biochar soil applications increase soil pH, CEC and N retention, and decrease Al saturation of acid soils (Novak et al., 2009).

In nonlegumes, Enderes (2010) found that increasing rates at 0, 10 and 20 g kg^{-1}soil of biochar application resulted in a linear increase in plant height, biomass, and total N uptake of 49 day old corn.

Macro-and micro-faunal population and soil biogeochemistry can also be affected by biochar. Both biochar and organisms are important in various ecosystem services contributing to sustainable plant production, ecosystem restoration, and soil C sequestration and hence mitigation of global climate change (Warnock et al., 2007). Biochar can provide suitable habitat for microorganisms because of its high internal surface area and its ability to absorb soluble organic matter, gases and inorganic nutrients (Theis and Rillig, 2009). Hence, biochar application would likely favor high survival and activity of microbial inoculants such as rhizobia and mycorrhizal fungi and consequently, increases N and P availability. Rollon (2010) noted that application of peanut hull char at 20 g kg^{-1} soil in combination with *Rhizobium* sp. or arbuscular mycorrhizal fungi significantly increased plant N concentration and N uptake. Thus, the agricultural benefits from rhizobia and arbuscular fungi in sandy soils can be more enhanced with biochar application. It enhances population of *Rhizobium*, microsymbiont of legumes, nodulation and consequently affects amount of N fixed. A study by Rollon (2010) revealed a linear increase in nodule weight of peanut grown in strongly acidic soil with the application of increasing peanut hull char levels (0, 10 and 20 g kg^{-1}soil). In common beans (*Phaseolus vulgaris*), Rondon et al. (2007) found that the proportion of fixed N increased from 50% without biochar additions to 72% with 90 g biochar kg^{-1} soil added. The increase in the amount of N fixed was attributed to greater B, Mo, K, Ca, and P availability as well as higher pH and lower N availability and Al saturation with the application of biochar. Similarly, Nishio and Okano (1991) found that BNF determined by N difference was 15% higher when bio-char was added to soil at the early stages of alfalfa development and 227% higher when nodule development was greatest.

Biochar additions have been found to increase colonization rates of the host plant roots by AMF (Ishii and Kadoya, 1994). Biochar serves as a habitat for extraradical hyphae that sporulate in its micropores due to lower competition from saprophytes (Saito and Marumoto, 2002). Experiments conducted by Matsubara et al. (2002) proved that biochar addition increased the ability of AMF to assist their host in resisting infection by plant pathogens.

Materials and Methods

Soil Collection, Preparation and Analyses

Bulk samples of alluvial sandy loam soil from 0-20 cm depth was collected from Talavera, Nueva Ecija, Philippines. Prior to any treatment, the bulk soil samples were air-dried, pulverized and passed through a 4-mm sieve. The soil texture was sandy loam with particle size distribution of 71.22% sand, 20.41% silt, and 8.37% clay. Subsamples were taken subsequently for chemical analyses and the rest were prepared for bagging. The subsamples for chemical analyses were again passed through a 2-mm sieve for the following analyses:

1. Soil pH. This was analyzed following the potentiometric method using 0.01 M KCl_2 as diluent (pH $CaCl_2$) respectively (PCARR, 1980).
2. Organic carbon (OC). This was determined using the modified Walkley-Black method (Nelson and Sommers, 1982).
3. Total N. This was determined using the Micro-Kjeldahl method (Bremner and Mulvany, 1982).
4. Extractable P. This was determined through the Bray P-2 extraction method using 0.1 N HCl and 0.03 N NH_4F extractant (Olsen and Somners, 1982). The amount of P in the extract was quantified by the ascorbic-molybdate method (Murphy and Riley, 1962).
5. Exchangeable K, Ca, Mg, and Na. The exchangeable bases was extracted using the Ammonium Acetate Method (ISRIC, 1995) and was quantified using the Atomic Absorption Spectrometry (AAS).
6. Exchangeable Al and Acidity. These were determined using the Potassium Chloride method of Thomas (1982).

Plant and soil samples were taken from each of the pots and air dried. After air drying, soil samples were sieved (2-mm) and 20 g subsamples from each of the two pots per treatment per replication were mixed thoroughly to make the composite sample and analyzed for soil pH, OC, total N and extractable P using the previously described methods. Initial soil properties

For determination of initial characteristics of soil, the air-dried subsample was analyzed for .pH, organic C, total N, extractable P exchangeable acidity and exchangeable levels of Al, K, Ca, Mg and Na, and cation exchange capacity. The methods and results of these analyses are summarized in Table 1.

Experimental Design

There were 6 treatment combinations with different levels of rice husk biochar (0, 10, 20, 30, 40 and 50 g biochar kg^{-1} soil). Each treatments were replicated 4 times and were arranged in randomized complete block design. Two plant `biotest` were used (peanut and upland kangkong).

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Table 1. Initial properties of the soil

Property	Method	Value
pH (1:2.5 soil to 0.01 M KCl_2)	Potentiometric (PCARR, 1980)	4.93
Exchangeable Al ($cmol^+ kg^{-1}$ soil)	Potassium chloride (Thomas, 1982)	2.88
Exchangeable Acidity ($cmol^+ kg^{-1}$ soil)	Potassium chloride (Thomas, 1982)	3.08
Organic C (%)	Modified Walkley Black (Nelson and Sommers, 1982)	0.64
Total N (%)	Modified micro-Kjeldahl (Bremner and Mulvaney, 1982)	0.16
Extractable P (mg kg^{-1} soil)	Olsen extractant (Olsen and Sommers, 1982) and quantified by Ascorbic acid method (Murphy and Riley, 1962)	1.53
Exchangeable bases ($cmol^+ kg^{-1}$ soil)	Ammonium acetate method (ISRIC, 1995)	
K		0.25
Ca		3.57
Mg		1.38
Na		0.15
$CEC_{Effective}$ ($cmol^+ kg^{-1}$ soil)		8.43

The carbonizer used in the study

Figure 1 shows the PhilRice continuous-type rice hull (CtRH) carbonizer which was used in the study. This is made of 2mm thick BI metal sheets with body dimension of 1.5 m x 0.8 m x 0.8 m. The carbonizer has a fully enclosed hopper to make it able to operate during windy conditions. The hopper houses the inverted V-partition (made of the same 2mm thick metal sheet used for the sidings) which forms an empty space once it is filled with rice hull. This empty space serves as the combustion chamber where combustion takes place as the ambient air mixes with the pyrolytic gases and those that are products of incomplete combustion. It is also where the material to be carbonized is initially ignited during the start of the operation. The inverted V partition is designed to be easily detachable to facilitate repair or replacement since it is the one that has the greatest chance of failure being the one exposed to extreme heat. Also the air inlet where the ambient air enters is detachable to facilitate during start up operation or when re-igniting the combustion while already in operation (Orge and Abon, 2012).

Figure 1. The CtRH carbonizer.

To start the operation, small amount of kerosene is sprinkled into the combustion chamber and then ignited. Once the flame has become vigorous and stabilized, the air inlet is put in place. The heat generated at the combustion chamber carbonizes the rice hulls in the immediate vicinity. Pyrolysis and partial combustion takes place and progresses radially. Because of the suction effect of the chimney, the pyrolytic gases and those generated due to partial combustion (most of which are combustible) are drawn into the combustion chamber where they get combusted as the ambient air, coming in from the air inlet holes mixes with them, thus smokeless emission are usually observed at chimney.

The opening at the bottom allows harvesting of the charcoal once the carbonization zone has already reached the bottom part of the machine. The carbonizer can accommodate 6 sacks ~ (60 kgs) of rice hull with an average capacity of 24.2 kg/hr (Orge and Abon, 2012).

Pot Preparation and Bagging

Forty eight polyethylene bags (measuring 8 x 8 x 12) were used and referred to as pots in the succeeding sections. Each pot was filled with 8 kg of non-sterilized soil on air-dried weight basis.

Planting

For peanut, three seeds of peanut (UPL-Pn 2) were sown in each of the pots. Five days after emergence, the seedlings were thinned to one plant per pot. For upland kangkong, five seeds will be sown in each of the pots. Four days after emergence, the seedlings will be thinned to three plants per pot.

Figure 1. Peanut plant planted in polyethyelene bags in the screenhouse

Figure 2. Uplang kangkong planted in polyethylene bags in the screenhouse

Care and Management

Plants were watered whenever necessary. Weeds in each pot were removed manually immediately after the emergence. Insects were also removed by handpicking.

Harvesting

Peanut was harvested 43 days after planting while upland kangkong was harvested 25 days after planting. The plant in each pot was cut close to the soil surface. The soils adhering to the roots were removed carefully. The shoot and roots were washed with tap water, rinsed with distilled water and blot-dried using paper towel. The nodules of peanuts were detached from the roots and set aside for counting and weighing. The remaining shoots and roots were weighed. The different plant parts were air-dried prior and then oven dried for three days in a forced draft oven set at 70^0 C.

Plant Tissue Analysis

The oven dried samples were weighed and ground to particle size of < 1 mm using a blender and were placed in paper bags until used for analyses. Two gram subsamples from each plant of the two pots per treatment per replication will be mixed thoroughly prior to tissue analysis.

Plant Parameters Gathered

1. Plant Height (cm). This was determined weekly by measuring the height from the soil surface up to the tip of the longest leaf until harvest.
2. Dry matter yield (mg plant^{-1}). This was obtained by weighing the shoots, roots and nodules after oven drying at (70°C) for two to three days until constant weight was obtained. Dry weight of shoots, roots and nodules were combined to obtain the total dry matter yield per plant.
3. N, P and K uptake (mg plant^{-1}). The amount of N and P uptake was determined by taking the product of total dry matter yield and their respective N and P contents.

Data Analyses

Statistical analysis was conducted using Statistical Tool for Agricultural Research (STAR) version 2.0.1. If found significant, the treatment means were compared using Tukeys's Honest Significant difference at 5% level of significance.

Results and Discussions

Effects of Rice Husk Biochar on Growth, Biomass and N, P, K uptake of Upland *Kangkong* and Peanut

Plant biomass response to the application of rice husk biochar and was observed to be statistically significant (Table 1 and 2) which have probability values of 0.0000 to 0.0002. This implies that even at high application of RHB, plants can still grow well.

For upland kangkong, application of RHB did not significant affect N, P and K concentration. It could be possible that the agronomic benefit of RHB was not yet evident at the time the plants were sampled. While in peanut application of RHB even at lower low application (10 g kg^{-1}) significantly affect K concentration in plants and no significant increase as levels increase. This implies that 20 g kg^{-1} soil is already the threshold level.

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Table 1. Means of plant biomass, N, P, and K concentration of upland kangkong as affected by the levels of rice husk biochar application

Level of biochar application (g kg^{-1})	Biomass (g plant^{-1})	N Concentration (%)	P Concentration (%)	K Concentration (%)
0	3.83c	6.05	0.0474	3.95
10	5.70abc	6.31	0.0526	3.90
20	4.31bc	6.80	0.0535	4.01
30	7.77ab	6.84	0.0563	4.22
40	6.82abc	6.28	0.0566	4.24
50	8.51a	6.46	0.0556	4.36
Probability Value	0.0026	0.5662	0.18	0.1707
HSD (5%)	3.46	ns	ns	ns
c.v. (%)	24.47	10.73	4.47	6.92

Means with the same letter are not significantly differet at 5% level of significance using Tukeys's Honest Significant Difference (HSD) Test

Table 2. Means of plant biomass, N, P, and K concentration of peanut as affected by the levels of rice husk biochar application

Level of biochar application (g kg^{-1})	Biomass (g plant^{-1})	N Concentration (%)	P Concentration (%)	K Concentration (%)
0	12.67b	5.18	0.0564	1.44b
10	23.65a	4.98	0.0521	2.08ab
20	21.67a	4.79	0.0550	2.35a
30	23.00a	4.86	0.0550	2.30a
40	24.02a	4.94	0.0554	2.56a
50	23.02a	4.91	0.0560	2.51a
Probability Value	0.0000	0.5767	0.2077	0.0009
HSD (5%)	3.97	ns	ns	0.68
c.v. (%)	8.06	3.99	4.30	13.47

Means with the same letter are not significantly differet at 5% level of significance using Tukeys's Honest Significant Difference (HSD) Test

Nodulation was enhanced by the application of RHB especially at higher rate of application. The rate of application affected the nodule formation with very high probability values of 0.0003 and 0.0001 for number and weight of nodule respectively (Table 3). The improved nodulation i.e. production of heavier nodules due RHB application could be attributed to the increase in soil pH, exchangeable Ca, reduced availability of exchangeable Al, and increased availability of P. Numerous studies had reported reduced nodulation in acid soils (O'Hara and Glenn 1994, Ibekwe et al., 1997; Taurian et al. 1998). Also, low pH affects the production and excretion of Nod metabolites (Oldroyd, 2001). The pH sensitive stage in nodulation occurs early in the infection process and attachment to root hairs is adversely affected by acidic conditions.

Moreover, the increased P availability from RHB application had contributed in nodule development and functioning. Upon detaching the nodules, it was observed that nodules in RHB amended treatments were either pink or red in color while control treatments had white to brown color. According to van Rhijn and Vanderleyden (1995), effective nodules are pink while white nodules are ineffective nodules. The production of effective nodules in RHB treated plants can be explained by the increased availability of P brought about RHB application. Phosphorus is essential for the development and function of the nodules formed (Waluyo et al, 2004).

Table 3. Means of nodule number and weight of peanut as affected by the levels of rice husk biochar application

Level of biochar application (g kg^{-1})	Nodule Number	Weight of nodule (mg plant^{-1})
0	111.75b	42.15c
10	276.50ab	81.25bc
20	374.00a	207.75ab
30	369.50a	254.85a
40	444.25a	333.90a
50	454.75a	278.10a
Probability Value	0.0003	0.0001
HSD (5%)	191.78	156.24
c.v. (%)	24.66	24.06

Means with the same letter are not significantly differet at 5% level of significance using Tukeys's Honest Significant Difference (HSD) Test

Effects of Rice Husk Biochar on Soil Chemical Properties after Plant Harvest

Analyses on soil samples collected after harvesting upland kangkong and peanut showed that soil pH$_{KCl}$, extractable P, exchangeable K and organic C were significantly affected by levels of application of RHB (Tables 4 and 5). Regardless of the "plant biotest", all these soil chemical properties have a linear trend as levels of application increases. The observed results revealed that soils with RHB holds nutrient in place and will not be leached easily. It also shows its ameliorating capacity in acid sandy soils.

Table 4. Means of soil pH $_{KCl}$, extractable P, total N and exchangeable K after harvest of upland kangkong as affected by the levels of rice husk biochar application

Level of biochar application (g kg^{-1})	pH $_{KCl}$	Extractable P (mg kg^{-1})	Total N (%)	Organic C (%)	Exchangeable K (mg kg^{-1})
0	5.20ab	34.05 c	0.0470	0.1165	20.42c
10	5.12ab	38.18 bc	0.0725	0.1860	21.35c
20	5.06b	41.33 abc	0.0740	0.1762	31.48cb
30	5.28ab	43.38 abc	0.0850	0.2313	87.86a
40	5.33ab	46.52 ab	0.0935	0.1970	107.29a
50	5.45a	48.32 a	0.0915	0.2288	109.85a
Probability Value	0.0262	0.0021	0.1404	0.0263	0.0000
HSD (5%)	0.34	9.57	ns	0.10	13.91
c.v. (%)	2.45	9.93	31.61	23.68	9.61

Means with the same letter are not significantly differet at 5% level of significance using Tukeys's Honest Significant Difference (HSD) Test

Table 5. Means of soil pH $_{KCl}$, extractable P, total N and exchangeable K after harvest of peanut as affected by the levels of rice husk biochar application

Level of biochar application (g kg^{-1})	pH $_{KCl}$	Extractable P (mg kg^{-1})	Total N (%)	Organic C (%)	Exchangeable K (mg kg^{-1})
0	5.29ab	30.09c	0.8700	0.2450b	20.23c
10	5.19b	34.03bc	0.0700	0.2635b	21.92c
20	5.16b	40.66ab	0.0653	0.3317a	24.89c
30	5.42a	40.47ab	0.0670	0.2820ab	30.64bc
40	5.44a	41.70ab	0.0535	0.2795ab	63.75ab
50	5.50a	44.69a	0.0655	0.2853ab	82.33a
Probability Value	0.0004	0.0005	0.5767	0.0466	0.0003
HSD (5%)	0.2182	3.19	ns	0.07	4.59
c.v. (%)	1.78	9.62	36.06	11.97	4.29

Means with the same letter are not significantly differet at 5% level of significance using Tukeys's Honest Significant Difference (HSD) Test

Summary, Conclusion and Recommendations

Two sets pot experiments were conducted to determine the effects of rice husk biochar (RHB) on the growth of upland kangkong and peanut and RHB effects on residual properties of sandy loam soil.

There were six treatment combinations from levels of amendment (0, 10, 20, 30, 40 and 50 g kg^{-1} soil). The soil used was sandy loam with the following particle size distribution: 71.22% sand, 20.41% silt, and 8.37% clay; had a pH$_{KCl}$ of 4.93 , 0.64 % organic C, 0.16% total N, 1.53 mg kg^{-1} extractable P, 2.88 cmol^{+} kg^{-1} soil exchangeable Al, 3.08 cmol^{+} kg^{-1} soil exchangeable acidity, 0.25 cmol^{+} kg^{-1} soil exchangeable K, 3.57 cmol^{+} kg^{-1} soil exchangeable Ca, 1.38 cmol^{+} kg^{-1} soil exchangeable Mg, and 0.25 cmol^{+} kg^{-1} soil exchangeable Na.

The processed RHB was applied at levels specified in the treatment on oven-dried weight basis. It was added and mixed well with the soil just immediately before filling the pots. The pots were allowed to stabilize for 3 days before planting.

Blanket application of 70 mg each of N, P_2O_5 and K_2O kg^{-1} soil using urea, solophos and muriate of potash was done five days after seedling emergence. Urea and muriate of potash were applied as aqueous solution while solophos was applied as granules.

A linear trend in the liming benefit and positive change in pH$_{KCl}$ with RHB application were observed in two "plant biotest" especially at higher levels (30, 40 and 50 g kg^{-1} soil). On the other hand, the positive change in extractable P due to residual effect of RHB application was obtained even at 10 and 20 g kg^{-1} soil in both upland kangkong and peanut. In peanuts, direct effects of application of uncharred or charred poultry litter resulted in better plant growth, nodulation, biomass, and K uptake than the control plants.

Application of RHB can enhance fertility of acid sandy loam soil. RHB holds nutrient in place that is needed for plant growth and development. Application at 30-40 g kg^{-1} soil appears to be the most appropriate rate for both upland kangkong and peanut grown in acid sandy loam soils.

RHB application can improve the chemical fertility of acidic sandy loam soil. However, a long-term follow up study in field level is recommended to better understand the role of this organic amendment in improving soil quality and in climate change mitigation.

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