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Physico-chemical characteristics of the biochars of Acacia sp, Bambusa sp, *Eichchornia crassipes* and *Hymenocardia acida*.

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ABSTRACT

Objective: In order to promote the rational use of the various biochars in the sandy soils of Kinshasa, a study was carried out to evaluate some physicochemical parameters of four types of biochars (*Acacia sp, Bambusa sp, Eichchornia crassipes and Hymenocardia acida*).
Methodology and results: four species of trees were used to make the biochars. These were analysed and the following parameters determined: cation exchange capacity, pH-water, nitrogen and total carbon, assimilable phosphorus, potassium, calcium and water retention capacity. With regard to the physico-chemical parameters analysed, the following conclusions were formulated; regarding pH, biochars from hardwoods (*Acacia sp* and *Hymenocardia acida*) showed an alkaline pH and those from less softwoods (*Bambusa sp* and *Eichchornia crassipes*) had neutral pH; the same results were found with the cation exchange capacity. All biochars used are generally rich in carbon and potassium content. On the other hand, nitrogen and exchangeable cation contents are low, except for the biochars of *Acacias* sp. The water retention capacity is very high on hardwood biochars than on those made from softer woods.
Conclusion and application of the results: To amend sandy and acidic tropical soils with biochars require the following recommendations. - The use of biochars from hardwoods because they contain high concentrations of plants nutriments and have a good pH (8.1) that could play the essential role in neutralizing soil acidity. - Biochar should be ground to obtain a particle size of less than 2 mm for good retention of water and mineral elements. The smallest particles induce faster effects; however, their impact is often short-lived.
Keywords: biochars, Acacia sp, Bambusa sp, *Eichchornia crassipes* and *Hymenocardia acida.*

RÉSUMÉ

Objectif : Dans le but de promouvoir l'utilisation rationnelle des différents biochars dans les sols sableux de Kinshasa, une étude a été menée pour évaluer certains paramètres physico-chimiques de quatre types des biochars (fabriqués à partir d'*Acacia sp, Bambusa sp, Eichchornia crassipes* et *Hymenocardia acida*) afin de préconiser ceux qui présentent les meilleurs caractéristiques.
Méthodologie et résultats **:** quatre espèces d'arbres ont été utilisées pour fabriquer les biochars ; ces derniers ont été analysés et les paramètres suivants ont été déterminés : la capacité d'échange cationique, le pH-eau, les teneurs en azote et carbone total, phosphore assimilable, potassium,

calcium et la capacité de rétention d'eau. Au regard des paramètres physico-chimiques analysés, les conclusions ci-après ont été formulées ; concernant le pH, les biochars issus des bois durs (*Acacia sp et Hymenocardia acida*) ont présenté un pH alcalin et ceux de bois moins durs (*Bambusa sp* et *Eichchornia crassipes)* ont le pH presque neutre ; et les mêmes résultats ont été remarqués avec la capacité d'échange cationique. Quant aux teneurs en nutriments, tous les biochars sont généralement riche en carbone et en potassium. Par contre les teneurs en azote et en cations échangeables sont faibles à l'exception des biochars d'*Acacias sp.* La capacité de rétention d'eau est très élevée sur les biochars de bois durs que ceux issus de bois tendres.
Conclusion et application des résultats : Pour utiliser raisonnablement les biochars dans les sols tropicaux sableux et acide, il convient de recommander ce qui suit ; utiliser les biochars issu des bois durs car ils contiennent des concentrations élevées en éléments minéraux et possède un bon pH (8,1) qui pourrait jouer le rôle capital pour neutraliser de son acidité. Il conviendrait de les broyer d'afin d'obtenir la granulométrie inférieure à 2 mm pour une bonne rétention d'eau et des éléments minéraux. Les particules très fines induisent des effets plus rapides ; toutefois, leur impact est souvent de courte durée.
***Mots clés**:* biochars, *Acacia sp, Bambusa sp, Eichchornia crassipes et Hymenocardia acida.*

INTRODUCTION

For several decades, farmers around the world have applied simple techniques to improve the quality of their soils in order to increase their productivity (Pronatura, 2013). Therefore, the discovery in the Amazon of the too fertile black agricultural land, locally called Terra Preta, which produces yields 200 times higher compared to the typical oxisols of these regions has been the starting point of many scientific investigations since the 19th century in order to explain the process of this phenomenon (Ferhat 2018). However, the origin of Terra Preta comes from the agricultural practices of the Amazon people who incorporated enormous quantities of biochars in the soil. They were combined with manure and other organic fertilizers to improve crops yields, and to solve the Oxisoils fertility problem (Sohi, 2012). **Five hundred** years after the end of the agricultural practices that have contributed to black soil of Amazon, this soil remains fertile. The raison that contributed to their high fertility results to their physic chemistry properties. Their high nutrients contents, good cationic exchange capacity, well soil water retention; nutrients recycle on a longue period (Laird *et al.*, 2010; Lima *et al.*, 2002; Steiner *et al.*, 2008). By the way, some others report that the application of biochar on fragile tropical soils completely degraded improves physics, chemistries and biological properties of (Glaser *et al.,* 2002). To solve the problem of low fertility of soil and this of the organic matter to incorporate in the soil, biochar is proposed as an environmentally responsible solution and is at this time arousing particular interest in the scientific community. It is a vegetable charcoal that must be produced from a specific biomass, under well-defined pyrolysis conditions, and to be intended for agro-ecological use to meet this definition (Ferhat 2018). Biochar has been used to amend agricultural soils since many years around the world (Gagnon and Ziadi, 2012 ;). As for the other fertilizing residual materials rich in nutrients, their recycling by agricultural spreading constitutes a good management practice of these by-products. The use of biochar appears to be one of good alternatives to reduce greenhouse gases, by putting them in the ground (Manirakiza 2021). The growing interest in agricultural soil amendment by biochar comes from its potential to mitigate the effects of climate change by sequestering carbon and limiting greenhouse gas emissions (Ameloot *et al.* al., 2013; Hangs *et al.,* 2016;

Lentz *et al.,* 2014; Lévesque *et al.,* 2018; Manirakiza 2021). Another interest comes up to its influence on the sustainability of agriculture productivity by improving soil fertility (De Luca *et al.,* 2015; Olmo *et al.,* 2016; Singh *et al.,* 2015). The enthusiasm for biochar in agriculture and the environment is based on its interesting properties for plant growth, carbon sequestration and the interception of contaminants (Verheijen *et al.,* 2010, Montanarella, 2013). Furthermore, from the fact that biochars would improve soil fertility, water content and microbial life in soils, thus increasing plant yields whether in agricultural soils, artificial soils or degraded soils (Allaire and Lange, 2013). In developing countries such as DRC, biochar, with its interesting physics and chemical properties for agricultural purposes, could constitute an amendment to be popularized among farmers on sandy soils. However, due to a lack of information on the physicochemical characteristics of the available locally produced biochars, it would be wise to undertake research to know the different types, before making any recommendations to the farmers. Some characteristics of biochar would vary depending on the plant species they are derived from, so it is necessary to analyse the properties of each type. This study was initiated to evaluate certain physicochemical parameters of three types of most commonly produced biochars, from *Acacia sp*, *Bambusa sp*, and *Hymenocardia acida*. To these types of biochar was added that of *Eichchornia crassipes*, an invasive plant that produces a large amount of biomass.

MATERIALS AND METHODS

Materials: The materials used in this study were the biochars of *Acacia sp, Bambusa sp, Eichchornia crassipes and Hymenocardia acida.*

Chemical analysis of biochar: Different types of biochars have been analysed in the soil laboratory of the Faculty of Agronomic Sciences of the University of Kinshasa. Only the following parameters were determined: cation exchange capacity, acidity, nitrogen and total carbon, assimilable phosphorus, potassium and calcium contents. The water retention capacity of biochars was also evaluated.

Statistical analyses: To assess the weight of different biochars, ANOVA was used. Minitab software was used to determine significant differences between treatments.

RESULTS AND DISCUSSION

Physicochemical properties of biochars: The characteristics of biochars are extremely varied; they essentially change depending on the pyrolysis conditions (temperature, residence time, etc.) and the type of pyrolyzed biomass. Therefore, there is great diversity in the composition of biochars. Figures 1 to 4 show the different properties of biochars.

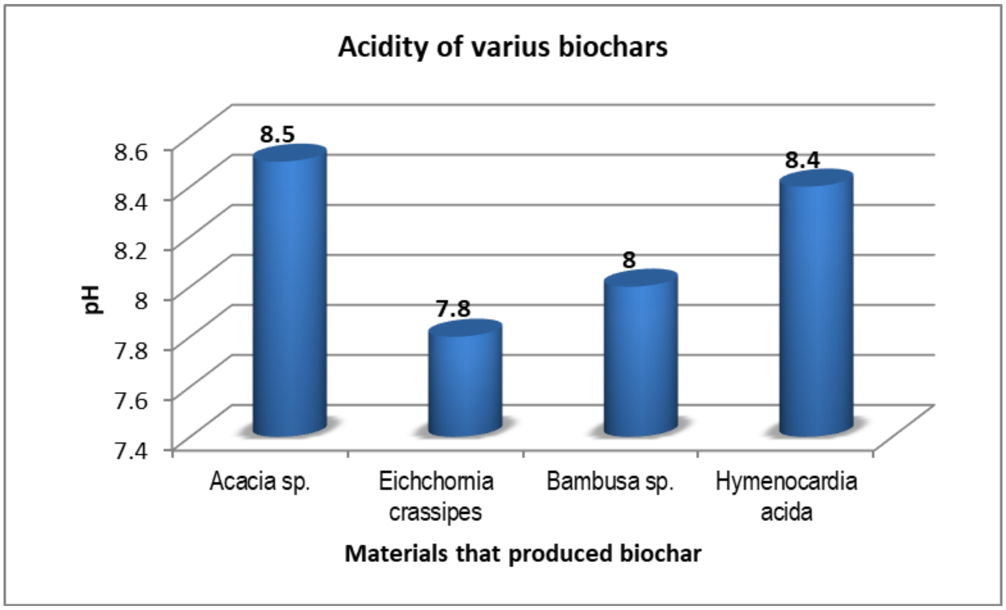

Figure 1: pH of the different biochars

It appears from Figure 1 that the pH of all biochars produced is alkaline, the average is 8; it is due to the manufacturing process of these. Similar results were found by Verheijen *et al.* (2009) which denote that the average of biochars pH varies around 8.1. The main raison is that the pH of biochars changes according to the species used. Chan and Xu (2009) found that pH could vary from 4 to 12 depending on the plant species used. According to Allaire *et al.* (2018) biochars from hardwood tend to have rather basic pH between 8 and 9, while those from soft coniferous wood tend to be a little more neutral, or even slightly acidic. Non-resinous softwood biochars and other materials also tend to be relatively basic with pH often above 7.5, primarily for those produced with vegetable residues with pH above 9.

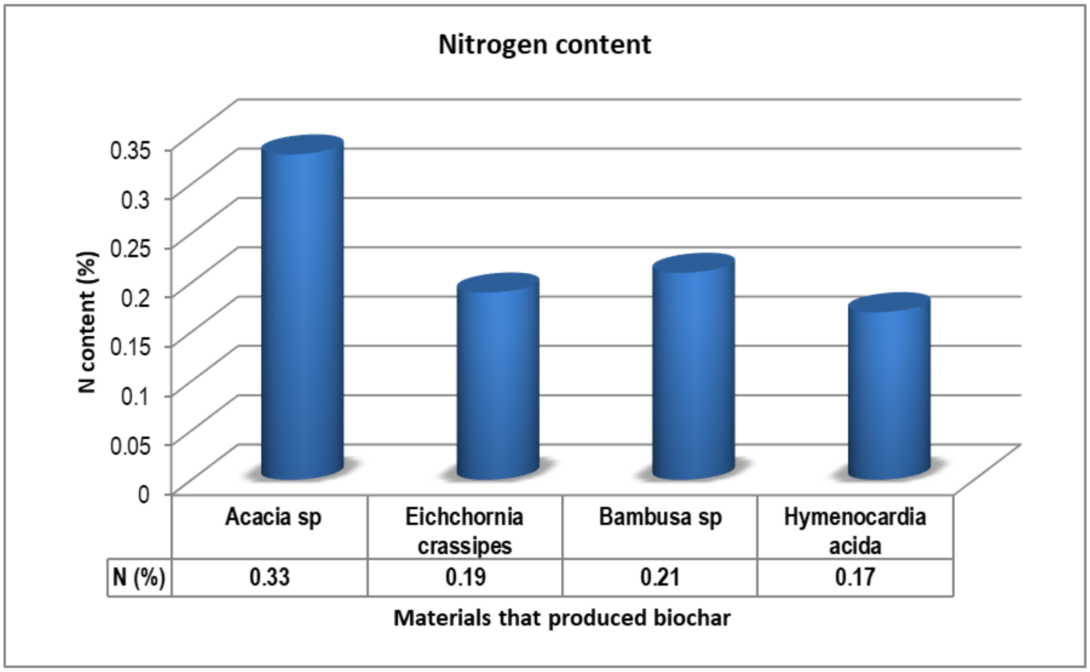

Figure 2: Total nitrogen of the different biochars

Nitrogen content of biochars is very low as shown in figure 2, except for Acacia sp, which represents a high nitrogen content; because it is a legume. This low content is because nitrogen generally volatilizes during pyrolysis process. As traditional millstones for the production of biochars are not very airtight, a large amount of nitrogen escapes. The results found by Allaire *et al.* (2018), pointed out the low concentrations of nitrogen are found in biochars. However, the N contents therefore cannot cause restrictions on the use of biochars in soil as an amendment.

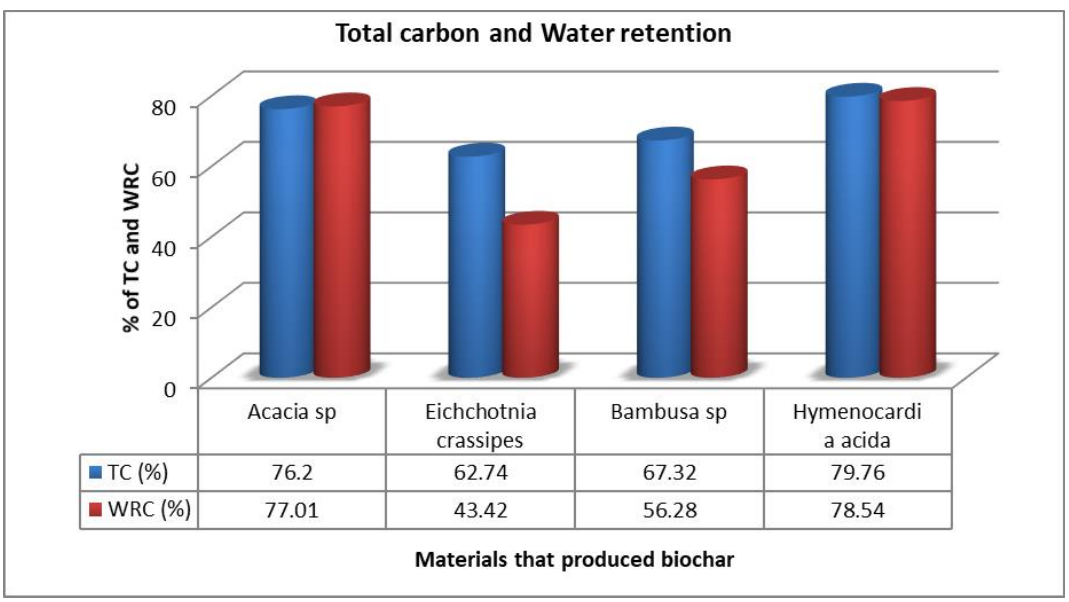

Figure 3: Total carbon and water retention capacity of the different biochars
Legend: -T.C: total carbon
-W R C: water retention capacity

Regarding to total carbon content, it is generally very high in all types of biochars, more than 50%; It is because of this carbon concentration that biochar is often used as an agricultural soil amendment. It always has high carbon content and a dominance of aromatic structures (Masiello, 2004; Reisser *et al.*, 2016). They are different points of view of several authors on biochars content and its process of gradual release into the soil; Lehmann et al, 2006; 2007a, b, showed that biochar would lead to better carbon sequestration in the soil. However, other results of scientific studies are contradictory, as well as rapid decomposition and slow decomposition of biochars has been observed respectively by Bird *et al.* (1999) and Shindo (1991). Water retention capacity is very high in all biochars used in general. However, that of hardwoods namely Acacia sp and *Hymenocardia acida* retain more water than those from softer woods such as *Bambusa sp* and *Eichchornia sp.*; similar results were found by Allaire 2015 using hard and soft wood.

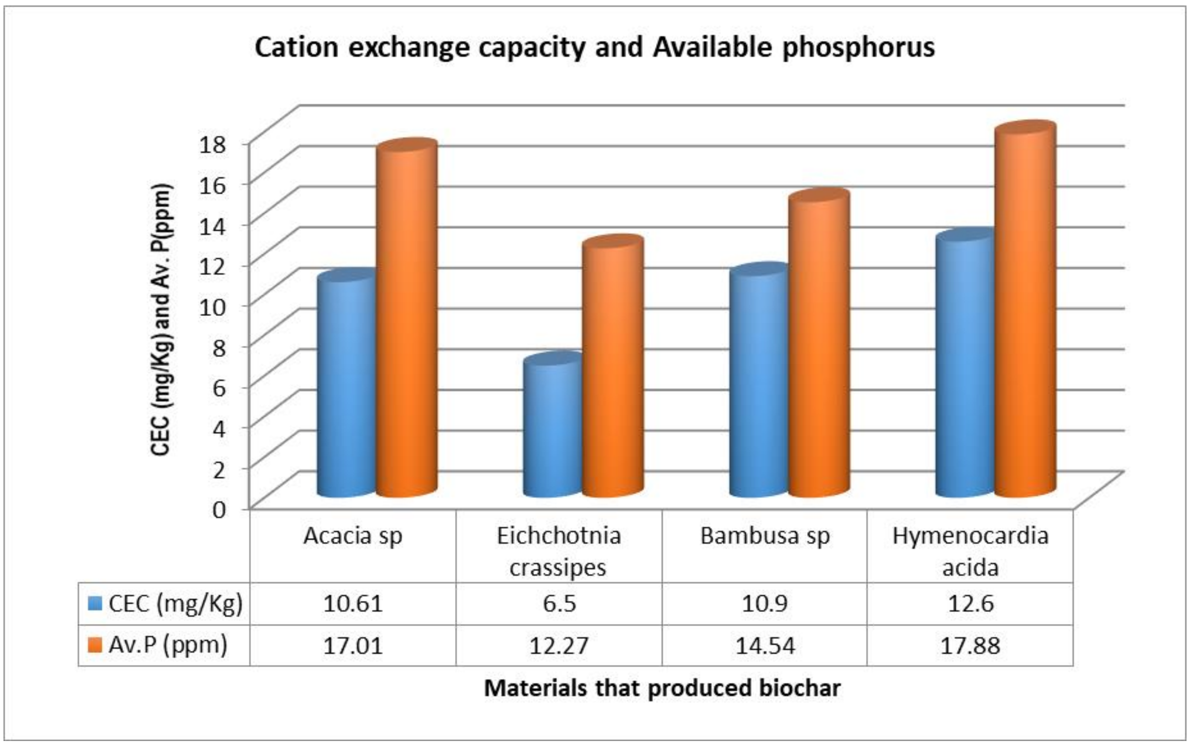

Figure 4: Available phosphorus and the cation exchange capacity of the different biochars.
Legend: - C.E.C.: cation exchange capacity
- Ava. Phos. : Available phosphorus

Contrasting to nitrogen content, biochars have enough phosphorus. These results prove that biochar is a good amendment for crops, which require high quantity of phosphorus. Biochars of hardwoods such as Acacia sp. and *Hymenocardia acida* can therefore be used as a phosphorus amendment for plants, to avoid the problem of phosphorus in the environment such as pointed out Allaire *et al.* (2018). Data of the CEC presented an enormous variability. Hardwood biochars have a higher cation exchange capacity than to softer woods. These results show that biochar is a good soil amendment able to improve the CEC of soil. Indeed, Lehmann (2007b) found that there is a big variation on the CEC of biochar particles; it can **exceed** 40 cmol / kg; and the main reason is that the cation exchange capacity and the pH of biochars increase with the production temperature.

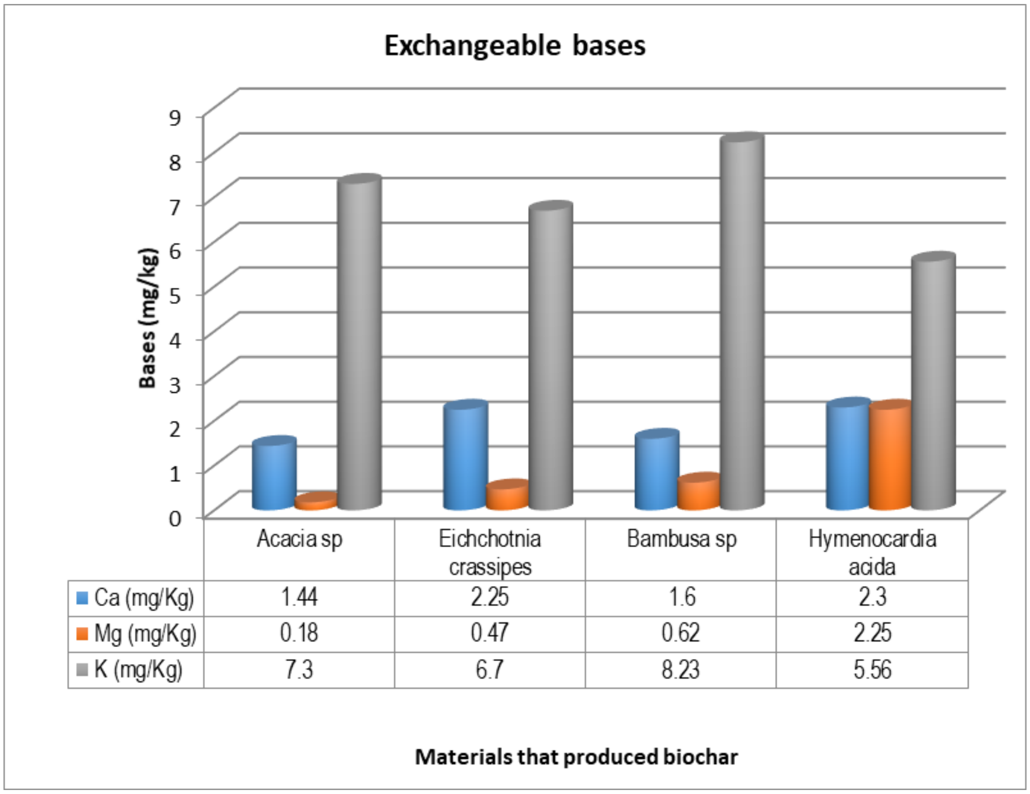

Figure 5: The exchangeable bases of the different biochars

<u>Legend</u>: -Ca^{2+}: Calcium

-Mg^{2+} : Magnesium

- K^{+} : Potassium

Biochars from *Bambusa sp*. and from *Acacia sp*. have the highest potassium (K) content, while those of *Hymenocardia sp* and *E. crassipes* have the lowest values. The Ca content shows great variability between the biochars analysed; some tend to contain a little more than others as shown in fig 4. For Mg, biochar is *Hymenocardia* is the only one that has the highest content.

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CONCLUSION AND APPLICATION OF RESULTS

Biochar is an organic amendment, however, its decomposition is very difficult. It is useful for improving some properties of soils such as: reducing the acidity of acidic soils, improving the exchange capacity of several essential nutrients for plant growth and production, increasing the capacity to retain water. This study allowed evaluating some chemical properties of different biochars. The results showed that biochars from hardwoods tend to be more alkaline and those from softwoods, and for the cation exchange capacity of biochars. The average content of potassium and carbon are high in all of the biochars studied. The nitrogen content remains low except that of Acacia sp, which is a legume. The water retention capacity of all biochars is very good. On the other hand, the magnesium and calcium content is low unlike potassium, which was quite high. For the best management of sandy and acidic tropical soils, the following recommendation can be made: - a) the use of biochars from hardwoods, because of their high concentrations of nutrients and have a good pH (8.1); that could play the essential role in neutralizing soil acidity. - b) Biochars should be ground to obtain particles size less than 2 mm for good retention of water and mineral elements. On the other hand, the finest particles induce faster effects; but their impact is often short-lived.

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