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Influence of wood-derived biochar on the physico-mechanical and chemical characteristics of agricultural soils

Ahmed S.F. Ahmed and Vijaya Raghavan*

Department of Bioresource Engineering, McGill University, Sainte-Anne-de-Bellevue, Quebec, Canada

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Abstract. Amendment of soil with biochar has been shown to enhance fertility and increase crop productivity, but the specific influence of biochar on soil workability remains unclear. Select physico-mechanical and chemical properties of clay loam and sandy loam soils were measured after amendment with wood-derived biochar of two particle size ranges (0.5-425 and 425-850 µm) at five dosages ranging from 0.5 to 10% dry weight. Whereas the clay loam soil workability decreased when the finer wood-derived biochar was applied at rates of 6 or 10%, soil fertility was not enhanced. The sandy loam soil, due to Proctor compaction, significantly decreased in bulk density with 6 and 10% wood-derived biochar amendments indicating higher soil resistance to compaction.

Keywords: biochar, particle size, Proctor compaction, plasticity, soil workability

INTRODUCTION

Biochar is produced by pyrolysis, a process whereby biomass is decomposed in the absence of oxygen at temperatures of 250-700°C (Yuan *et al.,* 2014). Pyrolysis conditions and feedstock material influence the chemical composition and physical structure of biochar (Cimò *et al.,* 2014). Wood-derived biochar (WBC) with particle diameters < 2 µm had skeletal and particle densities of 1.96 and 0.60 g cm^{-3}, respectively (Brewer *et al.,* 2014; Mitchell *et al.,* 2015), and a surface area of 75 m^2 g^{-1}.

Application of WBC to soils could alter soil workability (*W*), as assessed through the soil plastic limit (θ_{pl}), optimum moisture content (θ_{opt}) for tillage, and aggregate tensile strength (σ_t). Soil *W* is directly linked to friability – the tendency of a mass of soil to crumble into smaller aggregates of certain size range under an applied stress (Utomo and Dexter, 1981). Soil aggregate σ_t and friability are indications of soil structural quality (Reis *et al.,* 2014). Friability could determine the damage done to the soil structure by tillage (Watts and Dexter, 1998). Soil *W* is inversely linked to aggregate σ_t (Arthur *et al.,* 2014) the force per unit area required to disrupt the aggregate. Thus, *W* combines friability and the energy needed to fragment the soil clods. The clay and silt contents of soils greatly increase the σ_t of soils (Imhoff *et al.,* 2002).

In addition, soil fertility has been shown to improve after WBC amendment; the degree of improvement depends on the amount of WBC applied and the incubation period of the mixture (Li *et al*., 2016).

Application of 6% dry weight. WBC decreased the soil liquid limit (θ_{ll}; the θ at which the soil changes from a plastic state to a liquid state), increased the θ_{pl} (the θ at which the soil changes from a semi-solid state to a plastic state) and consequently decreased the plasticity index ($PI = \theta_{pl} - \theta_{ll}$) of a clayey soil (Zong *et al.,* 2016). However, the effect on θ_{pl}, could become less significant as soil clay content increases, as noted by Qu *et al.* (2014) for rice-husk ash amendment. The amended clayey soil also showed lower cohesion (c) and higher internal friction (φ). Soil c is the result of the bonding between soil particles, whereas φ is the resistance to movement of soil particles when a shear force is applied (Zong *et al.,* 2016). Such changes have implications in farm management, since WBC amendment can reduce soil shear strength (τ) (Blanco-Moure *et al.,* 2012; Zong *et al.,* 2016).

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*Corresponding author e-mail: ahmed.ahmed@mcgill.ca

The objective of this research project was to determine the effects of amendment with different particle sizes of WBC on the *W* and fertility (organic matter (OM) content, nutrient composition, pH, cation exchange capacity (CEC), and ash content) of two soil types differing in texture, pore size distribution, and clay and sand content: a clay loam (CL) and a sandy loam (SL) soils.

MATERIALS AND METHODS

The CL and SL soils were collected from the A horizon (0-0.20 m) of two fields (45° 25' 35.5" N, 73° 55' 37.0" W and 45° 25' 35.8" N, 73° 56' 21.1" W) in the MacDonald Campus Farm, McGill University (Sainte-Anne-de-Bellevue, QC). The soil samples were air-dried at room temperature and ground to pass through a 2 mm sieve. The WBC, purchased from a local market (Charbon de Bois Feuille d'Érable Inc., Sainte-Christine d'Auvergne, QC), was produced by the thermal (at 500°C) decomposition of forest wastes, including maple (Acer sp.) wood. The WBC was ground to the desired particle sizes in a blender.

Soil particle size was analyzed according to the ASTM D7928 (ASTM International 2017). The smallest particle size of WBC (0.5 µm) was determined by a laser diffraction method, using a SympaTEC-HELOS/BF laser diffraction sensor (Clausthal-Zellerfeld, Germany) (Rees *et al.,* 2014). The ground WBC was sieved in a fumehood into two particles size ranges: 0.5-425 µm (PS_1), and 425-850 µm (PS_2), Thus, for each soil type, the design included 2 particle size ranges × 5 WBC dosages (Table 1).

To achieve the desired WBC content, dry soil and WBC were homogenized for 20 min in a soil mixer. Triplicate soil samples containing WBC of 0.5, 1.75, 3, 6, and 10% dry weight were used in the experiments (Table 1), which corresponds to field applications of 18.8, 65.6, 112.5, 225, and 375 t ha^{-1}, respectively, assuming a soil ρ in the field of 1.25 t m^{-3} and an application depth of 30 cm.

The uncompacted soil (loose and dry) bulk density (ρ_O) was determined by dividing the oven-dry mass of the soil, WBC, or WBC-amended soil by its volume. The soil maximum bulk density (ρ_{max}) and θ_{opt} were determined through a standard Proctor compaction test in line with ASTM D698-07 (ASTM International 2007), using a compaction effort of 25 rammer blows.

Soil consistency limits in terms of θ_{pl} and θ_{ll} were determined as the Atterberg limits by following ASTM D4318-10 (ASTM International, 2010).

The soil shear parameters (φ and c) were accertained by the standard shear box method (Lu *et al.,* 2014) and ASTM D3080 / D3080M-11 (ASTM International, 2005).

Soil aggregates were obtained from air-dried soil carefully fragmented by hand during the drying process, following the procedures outlined by Elmholt *et al.* (2008). Soil aggregate samples with a diameter of 30 or 50 mm were crushed (Dexter and Kroesbergen, 1985; Dexter and Bird, 2000) using a universal testing machine (INSTRON Model 5565) with a constant speed of 4 mm s^{-1}.

Equation (1) was used to calculate the σ_t (kPa) of each soil aggregate (Utomo and Dexter, 1981):

$$\sigma_t = \frac{0.576F}{d^2}, \tag{1}$$

where: *F* is the polar force (N) needed to fracture the aggregate, and *d* is the mean aggregate diameter (m).

Soil friability index (*FI*) values were calculated from the σ_t measurements of different aggregate sizes (Getahun *et al.,* 2016). The dimensionless *FI* is estimated from the variation of σ_t of various aggregate sizes about their mean, as shown in Eq. (2) (Watts and Dexter, 1998).

$$FI = \frac{\sigma_{\sigma_t}}{\sigma_t}, \tag{2}$$

where: $\sigma_{\sigma t}$ is the standard deviation of the tensile strength of various aggregates sizes, and σ_t is the mean tensile strength.

If $FI < 0.1$, the soil aggregate is not friable; if $FI = 0.1$-0.2, it is slightly friable; $FI = 0.2$-0.5, it is friable; if $FI = 0.5$-0.8, it is very friable; and if $FI \geq 0.8$, the aggregate is mechanically unstable (Imhoff *et al.,* 2002).

Soil *W* is calculated as the ratio of friability to mean σ_t, as shown in Eq. (3) (Arthur *et al.,* 2014):

$$W = \frac{FI}{\sigma_t}. \tag{3}$$

Low *W* values indicate unsuitability of soil for fragmentation at a given energy input (Getahun *et al.,* 2016).

The OM, nutrient composition, pH, CEC, and ash content of soil, WBC, and soil-WBC mixtures were determined by dry combustion (Slepetiene *et al.,* 2008), the Mehlich-3 extraction method (Mehlich, 1984), a pH me-

Table 1. Loose bulk density (ρ_o), maximum density (ρ_{max}), optimum moisture content (θ_{opt}), and relative increase in bulk density ((ρ_{max} -ρ_o)/ρ_o) of non-amended soils

Type	Characteristics	Physical properties			
		ρ_o (Mg m^{-3})	ρ_{max} (Mg m^{-3})	θ_{opt} (%)	$\frac{\rho_{max} - \rho_o}{\rho_o}$
Soil	Clay loam	0.987	1.532	17	0.55
	Sandy loam	1.195	1.674	11.9	0.40

ter (Carter, 1993), the $BaCl_2$ method (Hendershot *et al.,* 1993), and ASTM D1762-84 (ASTM International, 2013), respectively.

Analysis of variance (ANOVA) and the Duncan's Multiple Range Test were used for testing mean differences in the responses using the SAS software program (v. 9.2, SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

The CL and SL soils were well-graded. Hydrometer analysis showed that the CL soil contained 37% clay, 27% silt, and 26% sand. By comparison, the SL soil contained 5% clay, 20% silt, and 75% sand.

Unamended CL and SL soils had RID $((\rho_{max} - \rho_O)/\rho_O)$ values of 0.55 and 0.40, respectively (Table 2). The θ_{opt} for the ρ_{max} was higher in the CL soil – with higher clay content – than the SL soil, as reported by Larson *et al.* (1980), Craig (1974), and Barzegar *et al.* (2000). Therefore, the CL soil is more susceptible to compaction than the SL soil.

After amendment with PS_1 WBC, both the ρ_O and ρ_{max} decreased: at 6 and 10% dosages, the mean ρ_O decreased by 12.7 ($p = 0.05$) and 16.1% ($p = 0.05$) in CL soil, respectively, and by 4.1 ($p = 0.05$) and 3.9% ($p = 0.05$) in SL soil, respectively (Table 3, Fig. 1). At 6 and 10% WBC, the mean ρ_{max} decreased by 7.3 ($p = 0.05$) and 10.6% ($p = 0.05$) in CL soil, respectively, and by 10.1 ($p = 0.05$) and 13.9% ($p = 0.05$) in SL soil. Dosages of 0.5 and 1.75% PS_1 WBC (and in general the 3% dosage) did not affect the ρ_O, ρ_{max} or θ_{opt} of the two soil types ($p > 0.05$). Thus, the highest dosages of the fine WBC particles caused a more dramatic decline in ρ_O in CL soils than SL soils, but a similar magnitude decline in ρ_{max}. This meant that, whereas the RID increased in the CL soil by approximately 18% at 6 and 10% PS_1 WBC ($p = 0.05$), it actually decreased in the SL soil by 22 and 36%, respectively (Table 3). In CL soil, the θ_{opt} increased by 22 ($p = 0.05$) and 32% ($p = 0.05$) at 6 and 10% WBC PS_1, respectively, and by about double these values in SL soils.

With the exception of a 6.3% decrease in mean ρ_{max} ($p = 0.05$), the CL soil was not affected by amendment with the coarser WBC (PS_2) (Table 3). However, the SL soil was affected by a similar magnitude by PS_2 treatment as it was to PS_1: the SL soil ρ_O and ρ_{max} decreased at the two higher WBC dosages, the RID also decreased ($p = 0.05$), and the the θ_{opt} increased ($p = 0.05$). This difference in response related to soil texture could be attributed to the fact that the larger SL soil pores could accommodate more particles of PS_2 WBC, resulting in a significant decrease in ρ_{max} and increase in θ_{opt} for both particle size amendments (Fig. 2).

Table 2. Loose bulk density (ρ_o), maximum density (ρ_{max}), optimum moisture content (θ_{opt}), relative increase in bulk density (RID) of soils after amendment with WBC-PS_1 or WBC-PS_2 at different rates

Biochar amendment (% dry weight)	Biochar particle diameter							
	WBS-PS_1				WBC-PS_2			
	0.5-425 µm				425-850 µm			
	ρ_o	ρ_{max}	θ_{opt}	RID	ρ_o	ρ_{max}	θ_{opt}	RID
	(Mg m^{-3})		(%)		(Mg m^{-3})		(%)	
	Clay loam							
0.5	0.942	1.5	17.1	0.59	0.977	1.54	16	0.58
1.75	0.912	1.48	18.5	0.57	0.969	1.512	15.8	0.56
3	**0.896**	1.46	**19.5**	0.63	0.925	1.490	17	0.61
6	**0.862**	**1.42**	**20.7**	**0.65**	0.931	1.485	17.5	0.53
10	**0.828**	**1.37**	**22.5**	**0.65**	0.928	**1.436**	17.4	0.55
	Sandy loam							
0.5	1.185	1.65	12	0.39	1.194	1.67	15.5	0.4
1.75	1.188	1.606	12.8	0.35	1.187	1.64	16.2	0.38
3	**1.116**	**1.555**	**15.0**	0.35	1.145	1.63	16.8	0.42
6	**1.146**	**1.505**	**17.5**	**0.31**	**1.125**	**1.465**	**17.0**	**0.3**
10	**1.148**	**1.442**	**19.5**	**0.28**	**1.125**	**1.455**	**17.8**	**0.29**

Values in bold differ significantly ($p \leq 0.05$) from equivalent.

Table 3. Influence of WBC particle size and application rate on CL soil plasticity parameters

Biochar amendment (% dry weight)	Biochar particle diameter							
	PS_1				PS_2			
	0.5-425 µm				425-850 µm			
	θ_{pl}*	θ_{ll}*	PI*	ΔPI**	θ_{pl}	θ_{ll}	PI	ΔPI
	(%)							
0.5	19.8	49.3	29.5	3.2	20	51.0	31.0	4.7
1.75	20.8	50.0	29.25	2.9	20.0	44.4	24.4	1.9
3	22.0	**55.7**	**33.7**	7.4	21.0	53.0	**32.0**	5.7
6	**23.0**	**57.6**	**34.6**	8.3	20.7	**55.5**	**34.8**	8.5
10	**26.2**	**59.7**	**33.5**	7.2	**22.0**	**54.8**	**32.8**	6.5

*Relative % difference, **absolute difference, values in bold differ significantly ($p \leq 0.05$) from non amended CL soil, whose θ_{pl}, θ_{ll}, and PI are 21.9, 48.2 and 26.3%, respectively.

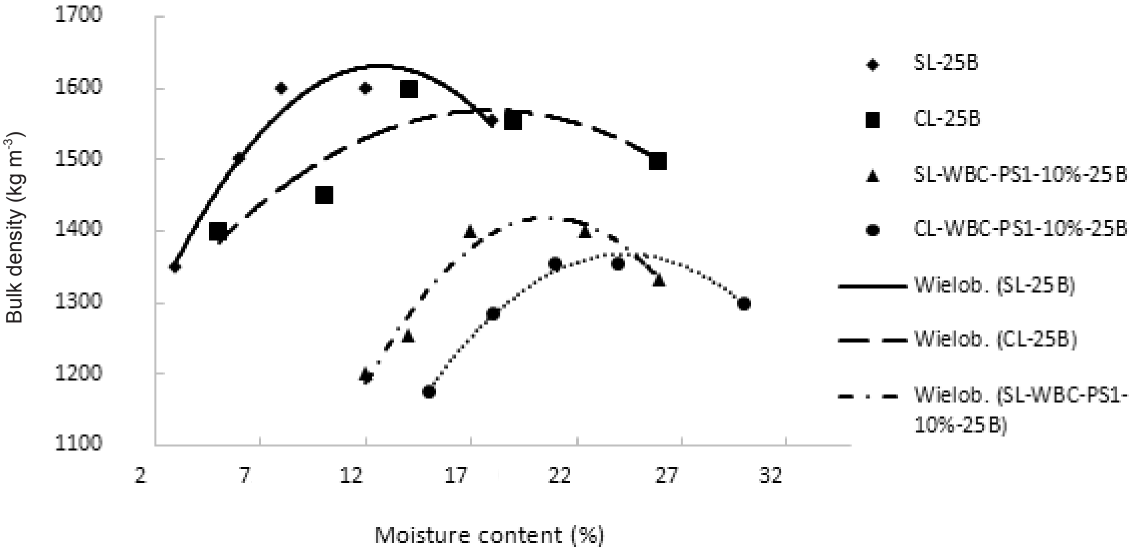

Fig. 1. Influence of WBC-PS_1 applied at a rate of 10% to clay loam and sandy loam soils on the compaction curves.

These results suggest that the addition of WBC PS_1 to CL soil could extend the range of the CL soil W, without causing compaction (Fig. 3). The relatively small particles of WBC could make the CL soil more prone to compaction.

The 10% PS_1 amendment decreased the ρ_O of the CL by 16% and decreased the ρ_{max} by 7.3%. but had an opposite trend in the SL, because it decreased the ρ_O to 3.9% and decreased the ρ_{max} to 10%. This means that the RID of the SL decreased by 22% (from 10 to 3.9%) and increased by 10% (from 7.3 to 16%) in the CL. This could only be attributed to the fact that the θ_{opt} of the SL increased by 70% whereas the CL increased only by 30% due to the 10% PS_1 amendment.

The θ_{pl}, θ_{ll}, and PI of the unamended CL soil were 21.9, 48.2, and 26.3%, respectively, whereas the SL soil showed no plasticity. Table 3 illustrates the variations in the consistency limits of the CL soil as amended with WBC-PS_1 and WBC-PS_2 at various rates. Amendment of the CL soil with 3, 6, or 10% of the WBC-PS_1 increased the PI by 0.1, 1.1 and 4.3%, respectively, relative to unamended soil. The θ_{ll} values for the same WBC-PS_1 amendments significantly ($p \leq 0.05$) increased with an increase in the application doses. For the same amendment rates, both WBC-PS_1 and WBC-PS_2 amendments led to a significant ($p \leq 0.05$) increase in the PI. The difference in the values of the PI between the WBC-PS_1 and WBC-PS_2 amended CL soil were not significant ($p \leq 0.05$). Furthermore, the effect

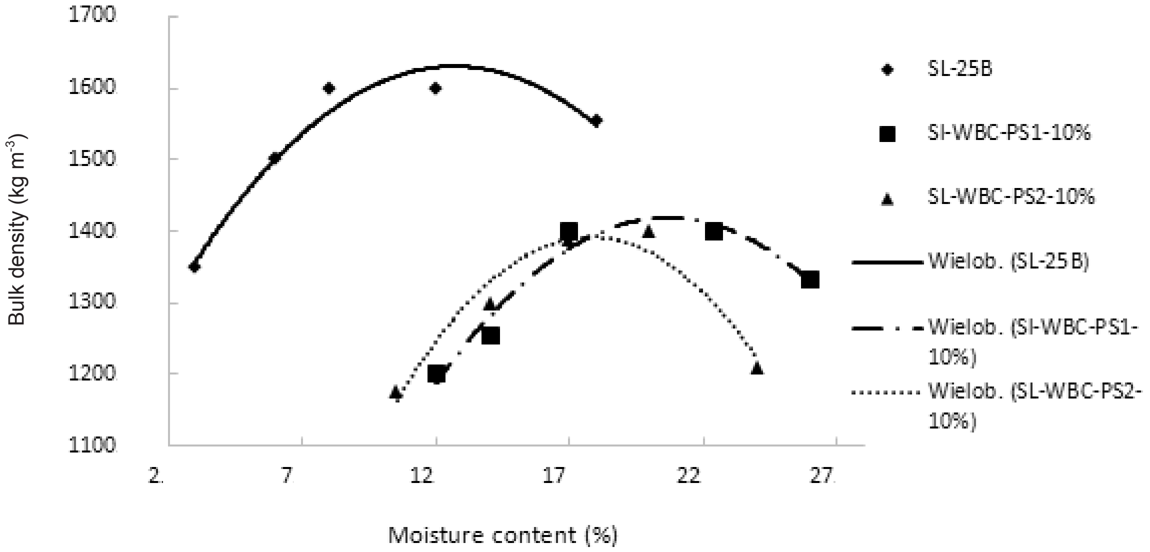

Fig. 2. Influence of WBC particle sizes applied at a rate of 10% to the SL soil on the compaction curves.

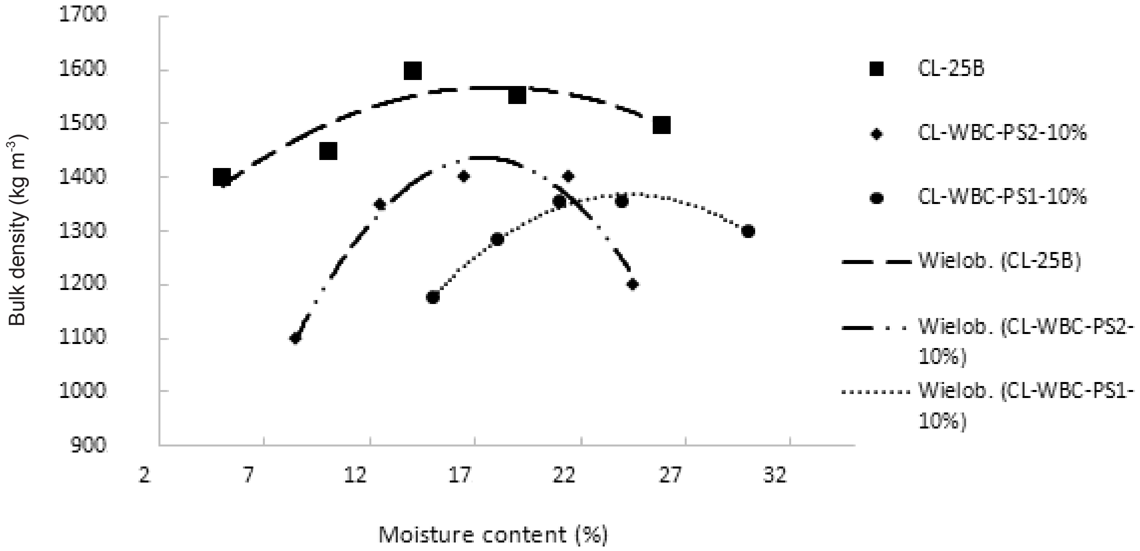

Fig. 3. Influence of WBC particle sizes applied at a rate of 10% to the CL soil on the compaction curves.

of increasing the WBC-PS$_2$ application dose on the CL soil *PI* was not consistent. Given the important role of the value of the θ_{ll} on the *PI*, the similarity of the *PI* response can be attributed to the relatively small increase in θ_{pl} of the WBC-PS$_2$ amended soils compared to that of the WBC-PS$_1$. The increase in θ_{pl} for the WBC-PS$_1$ was significant at 6% and 10% amendment rates only, whereas, the increase in θ_{ll} for the WBC-PS$_1$ amendment was greater than that for WBC-PS$_2$ amendments. This inconsistency minimized the significant differences in the *PI* values of the soils amended with WBC-PS$_1$ and WBC-PS$_2$. According to Mapfumo and Chanasyk (1998a) a $PI < 7$ indicates a soil of low plasticity, whereas $7 < PI < 17$ indicates medium plasticity, and $PI > 17$ indicates high plasticity. Since clayey soils exhibit high plasticity and are therefore highly prone to compaction, the CL soil amended with WBC has higher *PI*-given the larger moisture range within which deformation could occur – does not render soil more prone to compaction than unamended soil.

It can be inferred from Tables 3 and 4 that the θ_{pl} of the CL soils increased due to the increase in θ_{opt} with increasing WBC PS$_1$ dosage. By simple linear regression, the relationship ($R^2 = 0.94$; p =0.05) between θ_{pl} and θ_{opt} for CL soil amended with 3, 6, and 10% WBC PS$_1$ is found as:

$$\theta_{opt} = 0.68\ \theta_{pl} + 4.8\ . \qquad (4)$$

The simple regression analysis with the WBC-PS_2 did not show a strong correlation between the θ_{pl} and the θ_{opt} ($r = 0.41$).

Untreated SL soil had 64% lower *c* than CL soil (Fig. 4). The 6 and 10% PS_1 WBC amended CL soils had lower *c* values ($p = 0.05$ and 0.05, respectively) than unamended CL soils, whereas the 3, 6, and 10% PS_1 WBC amended SL soils had lower *c* values ($p = 0.05$, 0.05, and 0.05, respectively) than unamended SL soils.

Compared to an unamended SL, an increase ($p \leq 0.05$) in φ was found upon amendment of the soil with WBC-PS_1 at dosages of 1.75, 3, 6, and 10% dry weight and with WBC-PS_2 at a rate of 10%. There was an increase ($p<0.05$) in the φ of the CL soil when it was amended with WBC-PS_1 at rates of 1.75, 3, 6, and 10% dry weight (Fig. 5).

Given the influence on soil failure of the thrust force under tractor tires and in front of a tillage tool, a decrease in the soil *c* and an increase in soil φ would require alternating agricultural machinery and practices. For example, since an increase in φ would be beneficial under high tractor loads, amendment with finer WBC would be recommended when heavy tractors are used (large-scale farms). Conversely, a decrease in the soil *c* would require wider tractor tires to overcome the reduced *c* of soil. Therefore, relatively coarse WBC amendment would be recommended in small-scale farms or wider wheels when smaller WBC particle sizes are applied. Conversely, in front of a tillage tool, the force required to cut the soil will be reduced when finer WBC is applied to CL soil at dosages of 6 or 10%. This is because a decrease in the value of *c* and φ would have a minimal effect on the cutting action.

Untreated CL soil aggregates exhibited nearly 10-fold higher ($p = 0.05$) σ_t than SL soil aggregates (Fig. 6). The presence of PS_1 WBC at dosages of 0.5-10% reduced the mean σ_t of CL soil aggregates by 10-47% ($p = 0.05$), with the maximum change observed for the 10% treatment. For the coarser WBC, only the 3, 6, and 10% treatments decreased the mean σ_t in the CL soil. By comparison, the σ_t of SL soil aggregates was less sensitive to WBC amendment, only showing a decrease ($p = 0.05$ and 0.05) at 6 and 10% amendment with WBC PS_1 and no change ($p > 0.05$) with WBC PS_2.

The *FI* of untreated CL soil was nearly 8-fold higher than the *FI* of untreated SL soil (Table 5). 10% WBC PS_1 amendment decreased the *FI* of CL soil by 48% ($p = 0.05$), but did not change ($p = 0.05$) the *FI* of SL soil. By comparison, whereas 10% WBC PS_2 amendment, did not change the *FI* of CL soil, the *FI* of SL increased by 133% ($p = 0.05$). Friability and aggregate σ_t are an indication of soil *W*. Therefore, the CL soil *W* decreased from 691 to 102.6 kPa with the application of 10% WBC-PS_1, and no significant changes in the *W* of the CL soil was observed with the addition of WBC-PS_2 at the same application rate.

There was no significant differences in the pH of the WBCs of different particle sizes, but the WBC with smaller particle size had a significantly higher P, K, Ca and Mg levels than the WBC with larger particle size ($p \leq 0.01$). This difference in nutrients release is attributed to the relatively high surface area of the smaller particle size of WBC compared to the larger particle size of the WBC. The unamended SL soil had a higher pH, P and Al but lower K and Mg nutrient levels than the CL soil (Table 6).

When the CL and the SL soils were amended with WBC at various rates of either WBC-PS_1 or WBC-PS_2, the pH values were changed significantly ($p \leq 0.05$) (shown in bold in Table 5). In contrast, the P, K, Ca, Mg and Al values were not changed significantly when WBC-PS_1 or WBC-PS_2 were amended to the CL soil (Table 6). In another study, CL

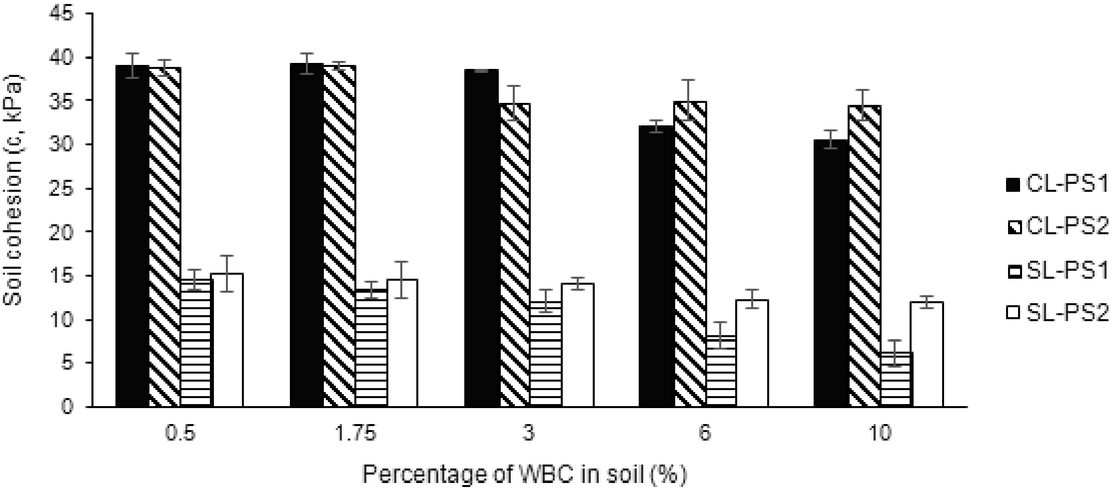

Fig. 4. Influence of the amendment of the SL and CL soils with different rates (% dry weight) of small (PS_1) or large (PS_2) particle size WBC on soil cohesion.

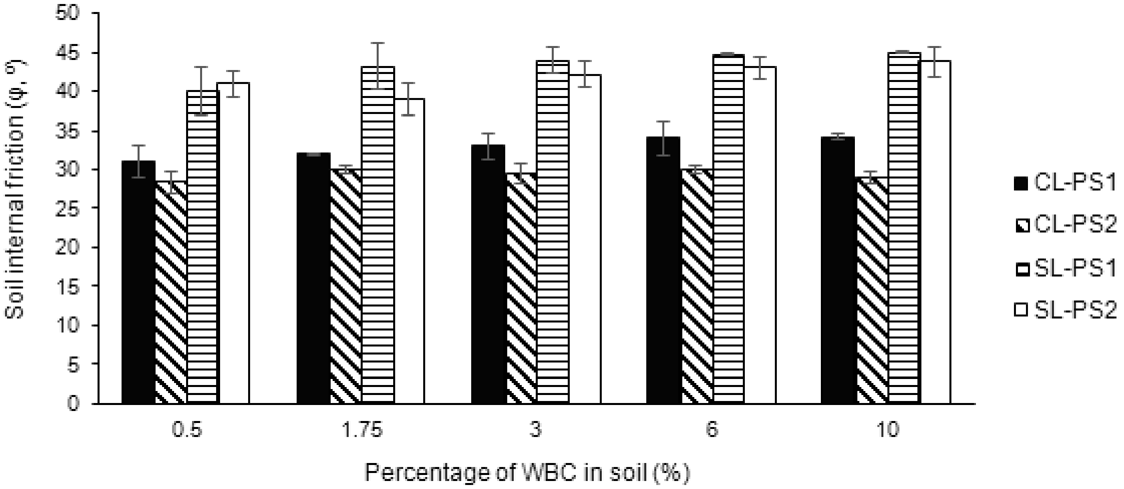

Fig. 5. Influence of the amendment of the CL soil with different rates (% dry weight) of small (PS_1) or large (PS_2) particle size WBC on soil internal friction.

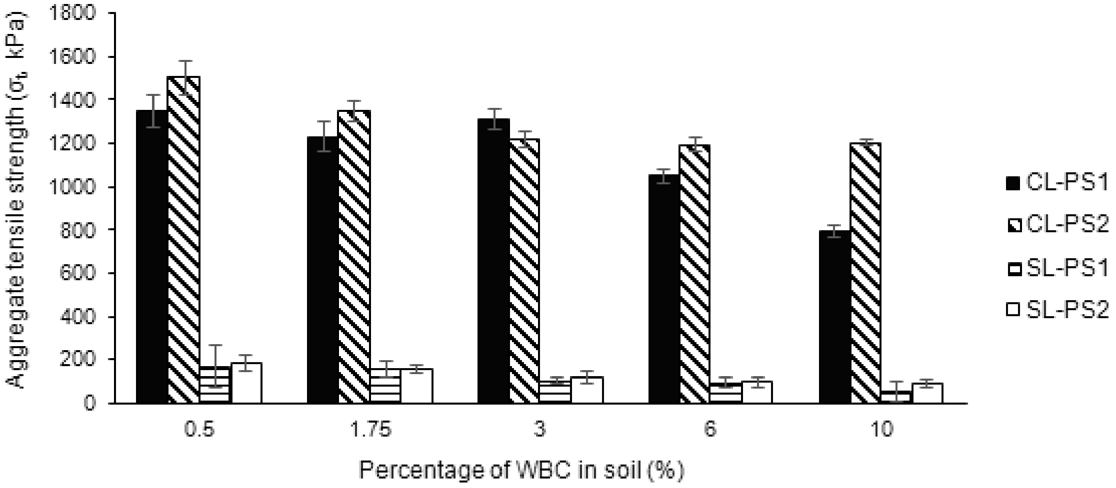

Fig. 6. Aggregate tensile strength (σ_t) of CL and SL soils amended at different rates with small particle size (WBC-PS_1) and large particle size (WBC-PS_2) WBC.

Table 4. The TS, *FI* and W of the CL and SL soils as amended with 10% WBC of various particle sizes

Treatment	Tensile strength	*FI*	Classification	Workability
CL	1499.5	0.46	Friable	691
CL-WBC-PS_1-10%	427.5	0.24		102.53
CL-WBC-PS_2-10%	1204	0.47		658.32
SL	177.5	0.06	Non Friable	10.61
SL-WBC-PS_1-10%	58.5	0.08		4.95
SL-WBC-PS_2-10%	182.5	0.14		24.75

Table 5. Chemical composition of WBC of two particle size ranges, and of the two experimental soils (clay loam and sandy loam)

Treatment	Particle size range	pH	OMC%	P	K	Ca	Mg	Al
				mg kg^{-1}				
WBC	0.5-425 μm	8	NA	65.5	783	1353	95.6	96.4
	425-850 μm	7.9	NA	28.1	527	626.4	53.5	126
Soil	Clay loam	5.8	4.1	66	165	1318	251.1	1143.4
	Sandy loam	6.3	5.4	148	31.1	1316	79.4	1369

Table 6. Chemical composition of mixtures of WBC of two particle size ranges, applied at different rates to the clay loam or sandy loam soils

Biochar amendment (% dry weight	Biochar particle diameter													
	0.5-425 μm – PS$_1$							425-850 μm – PS$_2$						
	pH	OMC %	P	K	Ca	Mg	Al	pH	OMC %	P	K	Ca	Mg	Al
			mg kg^{-1}							mg kg^{-1}				
	Clay loam													
3	5.7	4.6	47	114	1323	241.5	1094	5.8	4.9	48.8	125.0	1298	240.6	1105
6	5.8	6	47.8	123.2	1331	237.4	1119	5.8	5.8	46.9	125.2	1304	236.8	1071
10	5.8	7.2	52.5	135.5	1323	234.6	1096	5.7	7.1	47.3	125.6	1288	228.5	1060
	Sandy loam													
3	6.6	5.8	150	39.5	1326	73	1332	6.4	5.7	157	29.4	1319	76.1	1372
6	6.6	6.6	164.4	42.4	1340	71.2	1475.7	6.3	6.4	184.6	43.8	1360	50.4	1509.5
10	6.7	8.4	154.2	67.6	1340	76.8	1391	6.6	7.3	175.4	46.2	1343	52.1	1425.6

soil OM content increased from 21.5 to 36.26 g kg^{-1}, and the available P and K showed no significant changes when 2% WBC was added to the soil and the mixture was incubated for 135 days (Li *et al.,* 2016). However, Lehmann *et al.* (2003), Novak *et al.* (2009), Steiner *et al*. (2008), and Zong *et al.* (2016) reported that WBC addition to soil significantly increased the soil pH, and total C and available K and P concentrations. These differences could be attributed to the fact that the soil in this study was incubated for only a week.

CONCLUSIONS

1. The workability increased when relatively coarse wood-derived biochar was applied to clay loam soil at dosages of 6 or 10%. It is recommended that coarser wood-derived biochar is applied to clay loam soil to prevent destruction of the soil structure because finer wood-derived biochar particles render clay loam soil less friable.

2. Wood-derived biochar addition could improve fertility depending on the particle size of the wood-derived biochar and the soil texture. The clay loam fertility was not affected by particle size.

3. Wood-derived biochar amendment increased the plasticity index of the clay loam soil, thereby increasing the range of moisture within which the clay loam soil is most susceptible to compaction. Wood-derived biochar amendment increased the affinity of the clay loam soil for water requiring more water to behave in a plastic or liquid manner. Moreover, increasing the water content at optimum moisture content and plastic limit may imply that soil could exhibit same deformation and a similar workable range.

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