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Short-term effect of sawdust biochar and bovine manure on the physiological behavior of turnip (*Brassica rapa* L.) grown in open fields in the Algiers region

S. Nouar[1,*], M. Baha[2], M. Latati[1], R. Djebbar[3] and L. Reguieg[1]

[1]National School of Agronomy, Department of Plant Productions. Laboratory of Integrated Improvement of Agricultural Productions, Laboratory of Plant Production. Rue Hassen Badi, El Harrach DZ16200 Algiers, Algeria
[2]National School of Higher Education (ENS), Department of General Agronomy. Laboratory of Ecobiology animal. Post box 92 old Kouba1 DZ6308 Algiers, Algeria
[3]Université des Sciences et Technologies Houari Boumediene Faculty of Biological Sciences, Laboratory of Biology and Physiology of Organisms. Mailbox 32 El Alia Bab ezzouar DZ16111 Algiers, Algeria
[*]Correspondence: samnour207@gmail.com

Abstract. This study was designed to determine the effect of different doses of biochar (B) 5.10, 20 t ha^{-1} alone and mixed with manure (F) 10 t ha^{-1} on turnips. The results showed that the OM (organic matter) rate had a maximum of 93.7% for (B20*F) and a minimum of 14.5% for (F); the CEC (cation exchange capacity) showed a maximum of 32.2% for (B10*F) and a minimum of 0.2% with (B5*F) compared to the control (T) and finally the pH to be increased with a maximum value of 11.2% for (B20*F) and a minimum value of 1.7% for (F) compared to (T) (≤ 0.01).
For the chemical parameters of the turnip, the maximum nitrogen rate was 93.8% with (B10) and 2% for (B20). The highest value for phosphorus was recorded in (F) and a minimal value in (B5) (≤ 0.01). The potassium level was high 4.2% for the treatment (B20*F) with the lowest value of 4.4% for (B5) and (B10) compared to (T) (0.05).
For the yield components, the fresh weight of the most important bulb was obtained with (F) with the value of 116.8% and minimum weight of 0.4% in the treatment (B5). The highest bulb length value was 36.8% in (F) and the lowest was 0.5% obtained with (B20*F). The bulb diameter was the largest in the treatment (F) and the smallest was 4.8% in (B20). Finally, the fresh weight of the leaves showed a maximum of 106.9% in (F) and an increase of 6% in (B20) compared to (T) (≤ 0.01).

Key words: *Brassica rapa* L, bulb nutrients, wood biochar, cattle manure, soil.

INTRODUCTION

The progress made in crop intensification through the use of mineral fertilizers, new cultivation techniques, variety creations, etc., has not led to an increase in agricultural production. Yields of the main crops remain in decline due to soil depletion through leaching of mineral elements resulting in their depletion in organic matter (OM).

In the current context where environmentally friendly approaches are increasingly valued, global choices are moving towards sustainable agriculture that relies on the use of fewer chemical inputs and promotes the use of organic products that play an important role in addressing various environmental issues. Indeed, the conservation of the fertility of cultivable soils is one of the challenges that is becoming essential for obtaining satisfactory yields in terms of quality and quantity (Lehmann et al., 2006a ; Latati et al., 2016).

Soil organic carbon content plays an important role in soil fertility and is considered the main indicator of soil quality (Lehmann, 2007; Spokas et al., 2012). A loss of organic matter directly results in a decrease in their value, creating a vicious circle: soil degradation, lower yields, use of food imports, food insecurity, malnutrition and famine in some countries (Laird et al., 2010). In recent years, much progress has been made in understanding the impact of a 'biochar' amendment on soil carbon dynamics.

Indeed, burying bio-tanks in the soil could become one of the major ecological intensification techniques for 21st century agriculture. The usefulness of its application in soils has been deduced from observations made on black lands in the Amazon: Terra Preta, which have shown an improvement in physico-chemical and biological properties (Lehmann et al., 2006b; Lehmann, 2007).

The availability of nutrients for plants is becoming one of the obstacles to increasing crop production. Indeed, these soil nutrients are provided as fertilizers, some will be used by plants, some will be fixed by soil colloids and the rest will be lost through volatilization or leaching. Lehmann et al. (2011) reported that biochar can fix the nutrient content in the soil to limit these different forms of losses.

The biochar is one of the natural products that can answer this problem. It results from the pyrolysis of biomass under a relatively high temperature ≤ 700 °C and a limited supply of oxygen. It is not only a fertilizer, but also it is mainly a vector for the diffusion of nutrients and a habitat for the microorganisms due its high porosity and delete specific surface. Moreover increases the capacity of water retention of the grounds (Lehmann et al., 2011). Indeed, biochars are characterized by a strong cation exchange capacity (CEC), significantly improve the nutrition of plants and with its low density it confers a good root development (Glaser et al., 2002; Zhang et al., 2010). It is very recalcitrant to microbial decomposition and thus guarantees mediu²m and long term sequestration of organic carbon in order to make it available over time to the plant especially in degrading soils and even in temperate regions. Recent studies have shown that it is also of interest against global warming and reduces greenhouse gas emissions (Lehmann et al., 2006b).

In Algeria, the level of organic matter remains low (an average of 1.2%) because of inadequate, poorly exploited, cultivation techniques adopted such as plowing, non-compliance with crop calendars in some regions. The main question of our research is: how can we contribute to improving our yields by increasing the fertility of our soils ? so as to reduce our imports of fertilizers and/or foodstuffs in order finally to be able to ensure a certain food safety while preserving the environment.

It should be noted that the impacts of bio-tanks could vary depending on their nature, pyrolysis process and the soils to which they will be applied (Lehmann et al., 2006a; Spokas & Reicosky, 2009; Ippolito et al., 2012). We proposed to introduce it by combining it with cattle manure in our experiment to stimulate microbial life, increasing the availability of nutrients for turnips and enriching the soil with carbon. It should be noted that the impacts of biochars may vary according to their nature, pyrolysis process and soil types (Lehmann et al., 2006a; Spokas & Reicosky., 2009).

This study aimed to evaluate the effect of three doses of wood biochar and a single dose of cattle manure on certain physico-chemical properties of our soil and certain parameters of turnip growth, in order to determine if it is conceivable to introduce it into current farming practices as part of a perspective of contributing to the improvement of crop yields, in order to provide farmers with a sustainable and profitable farming system capable of improve the fertility of their soil and preserve the environment (limit the pollution of groundwater ....).

MATERIALS AND METHODS

Experimental site

Our experiment was conducted in the field during the 2015/2016 agricultural campaign at the experimental station of ENSA (El Harrach National Agronomic School) which is located in the North East of Algiers, located between latitude: 36° 43'North longitude: 30° 8' East altitude: 50 m bioclimatic floor: sub-humid to mild winter. The previous crop was a bean crop (*Vicia faba major* L).

Our experiment consisted of the study as follows

1-The biochar with the following doses: 5 t ha^{-1}, 10 t ha^{-1} and 20 t ha^{-1}

2-Manure with a dose of 10 t ha^{-1}

3- Witness (T)

The eight treatments were randomly organized with a device in total randomization with five blocks (repetitions). Each block consists of 8 plots of 1×1 m each. The blocks were spaced one meter apart and the plots were 0.5 m apart.

The different combinations are as follows:

T1 : B5	⟶ (5 t ha^{-1})	T5 : B20	⟶ (20 t ha^{-1})
T2 : B5*F	⟶ (5 t ha^{-1}+10 t ha^{-1})	T6 : B20*F	⟶ (20 t ha^{-1}+10 t ha^{-1})
T3 : B10	⟶ (10 t ha^{-1})	T7 : F	⟶ (10 t ha^{-1})
T4 : B10*F	⟶ (10 t ha^{-1}+10 t ha^{-1})	T8 :	⟶ witness

B : biochar

F : manure

According to a large number of bibliographic references (Laird et al., 2010 & Tammeorg et al., 2014), the long-term maintenance of soil fertility formerly amended in biochar compared to a growing number of trials in many countries, shows that the introduction of 5 t ha^{-1} to 20 t ha^{-1} of biochar per hectare can double productivity and create long-term fertility in the field from which the choice of these doses was proposed.

Incorporation of wood biochar and bovine manure

The biochar used in the experiment was obtained from a sawdust with a traditional method, which then sieved to 2 mm before application.

The manure used for our test was obtained from our school's central farm (ENSA), let it decay a few months. After soil preparation (plowing and harrowing). The quantities of biochar and manure from the different treatments were weighed and distributed evenly over the different micro-plots according to the conditions required on the soil. The incorporation of the two amendments was done manually at a depth of about 10 cm

2 weeks before sowing turnip seeds.Turnip *(Brassica rapa* L.) variety 'hammer', grown for its large, swiveling, bulbous and succulent root (ITCMI, 2010) was sown on 17 January 2016. Direct seeding was conducted in-line with spacing between rows of 20 cm and 15 cm between plants. Thinning was done afterwards; weeding was done on a weekly basis and manually; Irrigation was applied throughout the experiment.

The physical and chemical properties of the soil

A diagonal soil sample was taken before the crop was planted at a depth of about 20 cm approximately.The collected soil samples pooled, air-dried and sieved with a 2 mm sieve and analyzed for nitrogen, phosphorus, potassium, CEC, particle size, organic matter, and pH.

– Organic carbon (Matieu & Pieltain, 2003).
– The pH with distilled water (2v/5v) (Baize, 1988).
– The salinité with distilled water (1v/5v) (Baize, 1988).
– Total nitrogen by Kjeldahl method (Matieu & Pieltain, 2003).
– Exchangeable potassium extracted using 1M ammonium acetate (flame spectrophotometer) (Baize, 1988).
– The assimilable phosphorus (Olsen et al., 1954).
– The CEC carried out with sodium acetate and potassium acetate (Matieu & Pieltain, 2003).

The total limestone measured with Bernard calcimeter (Matieu & Pieltain, 2003).

The picking of the fruit was done manually by hand, once uprooted the tubers are washed in tap water to remove any trace of soil then weighed on a precision scale to determine their fresh weight. The length was measured using a ribbon meter and the diameter using a vernier caliper.

Analysis of wood biochar and bovine manure

– The chemical composition of our biochar and bovine manure used was analyzed after drying then grinding and sieving to be ready for analysis.The organic carbon content of the substrates was measured by calcination in the calcination furnace (30 minutes at 500 °C and then 6 hours at 600 °C).

During the harvest of the turnip in 2015/2016, five samples are taken per micro-parcel weighed, washed then dried at 60–70 °C for 48 h and finally milled in a vegetable mill for the analyzes which are:

– Total nitrogen (Kjeldahl method) (Matieu & Pieltain, 2003).
– Vegetable phosphorus revealed by the vanadomolibdique reagent (AFNOR, 1969).
– Vegetable potassium extracted with 0.1N nitric acid (El mekaoui, 1987).

Statistical analysis

The data collected for each experiment was analyzed by the Statistical Package Version 8 (ANOVA) and the treatment facilities were compared using the Tukey Test at probability level $p = 0.05$.

RESULTS AND DISCUSSION

Chemical analyses of the soil before seeding and of manure and biochar are illustrated in Tables 1 and 2. The soil of our experimental site is of a fine-argillaceous silt texture, neutral at low organic matter content, quite rich in total nitrogen, low rate of assimilable phosphorus, moderately rich in exchangeable potassium.

The pH of the biochar was alkaline, rich in organic carbon and poor in total nitrogen resulting in a high content of C/N, a low level of available phosphorus but sufficiently rich in exchangeable potassium. The manure was characterized by a neutral pH, with higher concentrations of total nitrogen, available phosphorus and exchangeable potassium compared to biochar.

The use of biochar and manure alone and in mixture generally caused an increase in the soil component ie organic carbon and CEC relative to witness. Indeed, (Table 3) shows the effect of bovine manure alone on the soil chemical properties. During this test, the manure individually slightly increased the rate of some soil elements studied as organic matter and CEC relative to the control in a very highly significant ($p \leq 0.001$) with a rate of 1.1% and of 4.35 cmol kg^{-1} soil respectively. In addition, the application of different doses of Biochar individually increased in a very highly significant ($p \leq 0.001$), soil pH values increased by an average of about 1.2 units compared to the control. The organic matter showed a very highly significant difference ($p \leq 0.001$) with a maximum of 1.64% compared to the control and a maximum value of 5.39 cmol kg^{-1} for the CEC.

Table 1. Soil properties of the site before experimentation

Property	Value
pH (water)	7.1
N Total ($NH^{4+)}$ ppm	0.87
$CaCO_3$%	1.03
k^+ (meq100^{-1}g soil)	0.45
p (ppm)	5.98
CEC (cmol kg^{-1} soil)	4.19
C %	0.37
OM %	0.63
N assimilable (ppm)	12.05
EC 10^{-3}ms cm^{-1}	123.44
Sand (%)	17.22
Silt (%)	54.55
Clay (%)	28.23
Textural class	Loam clay

Table 2. Chemical composition of biochar and manure

Property	Biochar	manure
pH	8.29	7.4
N Total (NH^{4+}) (%)	0.28	0.61
C Pendéral (%)	93.5	23
K^+ (meq $100g^{-1}$ soil)	0.51	0.81
P (ppm)	2.01	40.79
CEC (cmol kg^{-1} soil)	3.3	5.28

(Table 3) shows the effect of mixing manure with biochar on the soil chemical properties.

For the soil parameters, statistical analysis showed that there were very significant differences between the tratements, particularly for pH. Indeed, (B20) and (B20*F) gave the highest pH compared to the other treatments, the (F) and (T) in last position ($p \leq 0.001$).

During this test, for organic matter the results showed that the best results were obtained with (B10), (B10*F), (B20) and (B20*F) treatments compared to other treatments. For the CEC, the results showed that these same treatments have given the best results ($p \leq 0.001$).

Table 3. Effect of biochar and manure on soil

± Treatment	PH	OM (%)	CEC (cmol per kg soil)
B5	7.74 ± 0.03 [c]	1.05 ± 0.05 [b]	4.04 ± 0.14 [b]
B5*F	7.61 ± 0.03 [c]	1.12 ± 0.02 [b]	4.20 ± 0.12 [b]
B10	8.16 ± 0.01[b]	1.61 ± 0.15 [a]	5.24 ± 0.23 [a]
B10*F	8.15 ± 0.01[b]	1.73 ± 0.22 [a]	5.55 ± 0.18 [a]
B20	8.28 ± 0.00 [a]	1.64 ± 0.1 [a]	5.39 ± 0.2 [a]
B20*F	8.28 ± 0.01 [a]	1.86 ± 0.13 [a]	5.53 ± 0.22 [a]
F	7.31 ± 0.03 [d]	0.97 ± 0.02 [b]	4.35 ± 0.24 [b]
T	7.44 ± 0.03 [d]	1.07 ± 0.02 [b]	4.2 ± 0.16 [b]
p value	≤ 0.001	≤ 0.001	≤ 0.001

F: manure; B: biochar with B5: 5 t ha^{-1}, B10: 10 t ha^{-1}, B20: 20 t ha^{-1}; OM: organic matter; CEC: cation exchange capacity; Means with the different letter are highly significantly different acordind to the Tukey's test ($P \leq 0.001$) Value with ± represent the standard errors.

Results on the effect of Biochar and manure on the nutrient concentration of the turnip tuber are presented in (Table 4). In general, treatment of manure alone influenced very highly ($p \leq 0.001$) and significantly increased the concentrations of nitrogen, phosphorus ($p \leq 0.001$) and potassium ($p \leq 0.05$) in tissues turnip tuber.

Table 4. Effect of Biochar and manure on the chemical elements of the turnip bulb

± Treatment	P (P mg per 100g ps)	N (%)	K (k^+mg per 100 g ps)
B5	302.69 ± 17.13 [bc]	0.44 ± 0.04 [d]	2,866.66 ± 169.97 [c]
B5*F	372.37 ± 28.09 [ab]	0.65 ± 0.02 [bc]	3,666.66 ± 182.57 [b]
B10	258.38 ± 2.58 [cd]	0.95 ± 0.06 [a]	3,133.33 ± 133.33 [bc]
B10*F	298.46 ± 5.09 [c]	0.75 ± 0.06 [ab]	3,933.33 ± 286.74 [a]
B20	233.41 ± 7.57 [d]	0.50 ± 0.03 [cd]	3,266.66 ± 323.18 [bc]
B20*F	227.26 ± 7.61 [d]	0.55 ± 0.04 [cd]	4,266.66 ± 476.1 [a]
F	436.22 ± 19.10 [a]	0.81 ± 0.03 [ab]	3,866.66 ± 583.1 [b]
T	315.25 ± 22.86 [ab]	0.5 ± 0.04 [cd]	2,999.99 ± 105.41 [c]
p value	≤ 0.001	≤ 0.001	≤ 0.05

F: manure; B: biochar with B5: 5 t ha^{-1}, B10: 10 t ha^{-1}, B20: 20 t ha^{-1}; P: phosphorus; N: nitogen; K: potassium; PS: dry weight; Means with the different letter are highly significantly and significantly different acordind to the Tukey's test ($P \leq 0.001$) and ($P \leq 0.05$) Value with ± represent the standard errors.

In this test, the effect of the biochar applied alone and mixed with manure had a very highly significant effect. For phosphorus, the results showed very highly significant differences ($p \leq 0.001$). Indeed, it decreased significantly for the dose of (B20*F) and (B20). The manure (F) was distinguished from other treatments by ranking first with the best phosphorus concentrations compared to other treatments.

For the total nitrogen, the results showed that for all the different doses applied, the effect was significant ($p \leq 0.01$) compared to the control with (B10) which gave the best results and led the groups. (B5) is in last position with the lowest nitrogen concentration.

For potassium, the results showed that for all the different doses applied the effect was significant ($p \leq 0.05$) compared to the control in the tissues of the turnip tuber with (B20*F) at the top of the ranking.

Our results revealed an interactive effect between the different doses of Biochar and the manure dose, which were very highly significant ($p \leq 0.001$) for all the chemical elements studied, namely nitrogen and phosphorus, and significant ($p \leq 0.05$) for potassium.

Results on the effect of Biochar and manure on turnip yield components are as follows:

Presented in (Table 5); when wood biochar and manure are studied on biometric parameters related to turnip yield; bovine manure was found to be very highly ($p \leq 0.001$) increased fresh weight bulbs, diameter, bulb length and fresh weight leaves with the highest values with the best yield compared to all other treatments.

Table 5. Effect of biochar and manure on turnip yield components

± Treatment	FWB (g)	Diameter (cm)	BL (cm)	FWL (g)
B5	59.00 ± 4.43 ^{cd}	4.24 ± 0.22 ^{b}	8.97 ± 0.5 ^{c}	12.47 ± 1.78 ^{bc}
B5*F	97.80 ± 9.15 ^{b}	4.62 ± 0.19 ^{ab}	11.89 ± 0.45 ^{a}	22.08 ± 5.17 ^{ab}
B10	81.76 ± 7.22 ^{bc}	4.42 ± 0.16 ^{ab}	11.12 ± 0.65 ^{ab}	14.42 ± 1.90 ^{abc}
B10*F	86.36 ± 4.90 ^{b}	4.47 ± 0.19 ^{ab}	11.40 ± 0.23 ^{a}	15.68 ± 1.51 ^{abc}
B20	50.24 ± 5.04 ^{d}	4.08 ± 0.32 ^{b}	8.83 ± 0.40 ^{c}	10.52 ± 1.63 ^{c}
B20*F	56.52 ± 3.65 ^{cd}	4.27 ± 0.20 ^{b}	9.37 ± 0.38 ^{b}	12.3 ± 1.09 ^{bc}
F	127.30 ± 5.24 ^{a}	5.24 ± 0.1 ^{a}	12.75 ± 0.32 ^{a}	23.19 ± 1.38 ^{a}
T	58.72 ± 2.54 ^{cd}	3.89 ± 0.1 ^{b}	9.32 ± 0.31 ^{b}	11.20 ± 1.15 ^{c}
p value	≤ 0.001	≤ 0.001	≤ 0.001	≤ 0.001

F: manure; B: biochar with B5: 5 t ha^{-1}, B10: 10 t ha^{-1}, B20: 2 0t ha^{-1}; FWB: Fresh weight bulbs; D: Diameter; BL: Bulb length; FWL: Fresh weight leaves Means with the different letter are highly significantly different acordind to the Tukey's test ($P \leq 0.001$) Value with ± represent the standard errors.

nb: these results are similar to those of another potted trial carried out with a sandy soil not yet published and with the same variety of turnip (hammer) where the yield components were low for high doses in biochar alone and mixed with manure; the best results were obtained with the manure dose alone.

Biochar vary greatly in composition, pH and physical properties (Chan et al., 2007; Lehmann., 2007). Before applying them, it is important to note that during pyrolysis all the nitrogen contained in the original biomass is either trapped in the aromatic structure or volatilized (Steiner et al., 2010). The addition of 'fresh' biochar alone to soils often results in what is called a 'nitrogen shock', limiting its bioavailability for plants (Alexis et al., 2007; Chan et al., 2008; Sanchez-Garcia et al., 2015), hence the need to associate a nitrogen source such as manure with it to avoid immobilization. Our results showed that the values of the different treatments, namely (B20*F), (B20) and (B5) of biochar alone, were close to the control, with the exception of the treatment (B10) and (F), which showed the highest values compared to the control and the remains of the treatments.

According to Lehmann et al. (2003); Chan et al. (2008); Steiner et al. (2010); Steiner et al. (2010) biochar reduces nitrogen losses in the soil by leaching, so it is conducive to better soil fertility and reduced environmental impacts (groundwater pollution); also Laird et al. (2010); Zheng (2013) noted a significant 30% reduction in NO_3^- losses by leaching into amended soils into biochar, resulting in better nitrogen availability. This could explain the increase in nitrogen rate for treatments (B10) and (B10*F) compared to other treatments.

In a laboratory study where biochar was applied without manure (Ippolito et al., 2014) showed that the application rate of 10% biochar significantly reduced NO_3^- concentrations in the soil. While Foster et al. (2016) demonstrated that with a dose of 30 t ha^{-1} biochar, no decrease or increase in nitrogen in soil at alkaline pH in maize was observed.

The results of this test are consistent with those obtained by (Ippolito et al., 2016), where the joint application of the biochar-manure mixture to limestone soil at different rates resulted in beneficial effects on soil properties. In another field study, the application of biochar and manure at doses of 22.4 and 42 t ha^{-1} respectively resulted in a decrease in NO_3^- content in the soil during the first year at alkaline pH (Ippolito et al., 2016). According to Lentz & Ippolito (2012), over time soil NO_3^- increases with all applied biochar rates when mixed with 2% manure, probably due to manure mineralization and nitrification.

The treatment deferents increased the soil pH except for manure and control, which created an unfavourable environment for the development of our crop, knowing that the optimal pH of turnip is 6–6.5 (ITCMI, 2010). The soil pH increased from about 1.0 to 1.4 units for all treatments except (F) and the control, this could surely be related to the alkaline effect of our biochar because of its chemical composition (related to the liming of the soil).

Generally, bacteria and fungi respond differently to a change in pH in the soil, microbial biomass increases with a pH increase from 3.7 to 8.3 (Novak et al., 2012). Indeed, bacteria respond positively to a pH increase above 7 while fungi show no significant change in their total biomass (Steinbeiss et al., 2009). Thus, microbial abundance would be influenced by adhesion to the biochar (Glaser et al., 2002; Steinbeiss et al., 2009). This suggests that increasing the pH creates a favourable environment for the survival and development of soil fauna. According to DeLuca et al. (2009), the alkaline pH of soils is due to the ash and carboxylic groups contained in the biochar, depending on the nature of the biomass treated.

Concerning phosphorus, this element plays a major role in root development, leading to an increase in tomato fruit production (Hossain et al., 2010). Note that phosphorus is blocked at pH below 6 and above 7.5, it is bioavailable at pHs between 6 and 7.5 (Zhang et al., 2010; Ippolito et al., 2014; Houben et al., 2014). In addition, when Ca^{2+} is in excess in the soil, phosphorus release is reduced due to the formation of poorly soluble phosphates (Nelson et al., 2011; Foster et al., 2016). This could explain the low phosphorus levels observed in turnip tissues obtained with almost all treatments except (F) compared to the control and also the low concentration of phosphorus in soil and biochar. The general trend shows a significant decrease in tuber size (yield), so it is difficult to conclude on the 'fertilizing' effect of biochar alone in turnips under our conditions.

In temperate systems, field trials without phosphorus fertilization have shown that pine biochar has decreased the available phosphorus in the soil, this decrease has been attributed to soil alkalinization (Nelson et al., 2011). According to Laird et al. (2010); Foster et al. (2016), the fixation of phosphorus by calcium and its adsorption on biochar surfaces has made it less available to the plant. Xu et al. (2014); Foster et al. (2016); Ige et al. (2005) demonstrated that there was a significant decrease in phosphatase activity in maize and hypothesized that pine biochar interacted with the production signals of this enzyme. They also reported that the effect of biochar on phosphorus adsorption is highly influenced by soil pH. Indeed, at a pH around 7–7.5, phosphorus is fixed by calcium and thus becomes less available, especially when calcium is in excess in the soil, its release is reduced because of the formation of poorly soluble phosphates. Thus, the fixation of phosphorus in soils amended with biochar can therefore be explained by their high calcium content.

Concerning potassium, the losses of this element by leaching seem to be less significant in the presence of biochar compared to the control because of its presence in turnip tissues, particularly for treatments (B10*F) and (B20*F).

There was an increase in potassium levels in our turnips as a result of the application of biochar or manure. This increase was greater with the mixing of the two compared to the control. This could be related to the presence of potassium in both amendments and in our soil for almost all the treatments studied. This can be explained by the fact that adding manure to biochar can increase oxidation of the biochar surface under favourable conditions (sufficient moisture, favourable temperature), to release existing potassium and make it available to the turnip (Adekiyaa, et al., 2016; Biederman et al., 2017).

Research has shown that applying biochar to the soil can improve the cation exchange capacity (CEC) of soils, resulting in reduced nutrient leaching and thus improved availability (Liang et al., 2006). Indeed, biochar has a porous structure with a large exchange surface and a negative surface charge, giving it a high capacity for cation exchange in the soil for good nutrient retention (Zhang, et al., 2014). This CEC would likely increase over time due to aging and incubation of the biochar in the soil, oxidation of its surfaces and/or adsorption of organic acids (Spokas & Reicosky, 2009). Indeed, just like the chemically active colloidal fraction of soils, over time it can begin to show a larger loading surface and can therefore increase the CEC of soils (Laird et al., 2010).

Regarding the comparison between treatments, the results showed an improvement in CEC compared to the control, especially with the treatment (B10), (B20), (B10*F) and (B20*F). The very low CEC of our soil is an indication that it contains low nutrient reserves. This could be related to soil mineralogy, including the very low clay fraction (Liang et al., 2006; Major et al., 2012) and the low organic matter content.

The decreases in mineral elements observed in the control are mainly due to the reduction in the soil carbon content. Indeed, organic matter is directly related to soil CEC; this has been highlighted by several authors (Lehman et al., 2006a; Atkinson et al., 2010; Laird et al., 2010; Zhang et al., 2010).

For organic carbon, it increased significantly with a biochar amendment (B10) and (B20) compared to (F) and the control confirming its sequestration potential. These results are consistent with those of Adekiyaa et al. (2019) and Foster et al. (2016). Although it is resistant to microbial decomposition, it guarantees long-term soil fertility (Steiner et al., 2007; Sohi, 2012; Zhang, 2014). According to Steinbeiss et al. (2009), the nature of biochar has a real influence on soil organic carbon losses, its measurement makes it possible to monitor its evolution with different amendments in different soil types.

The highest organic matter rate obtained is 1.86% with the treatment (B20*F). Although our soil is poor in organic matter and even after organic matter inputs, our results remain low compared to other work. This may be due to the recalcitrance of the biochar (Lehmann et al., 2003), or may be related to the analytical method used because according to (Blanc, 2013), it is likely that the calcination method detects about 70% organic matter in a pure biochar while the potassium dichromate method only 6%. In addition, potassium dichromate reacts more with fine biochar particles. This is certainly related to the much larger attack surface for fine particles than for coarse particles, whereas with the calcination method, coarse particles have a higher organic matter content than fine particles; organic matter analyses are therefore biased for samples containing biochar.

The application of biochar alone or mixed with manure had a negative influence on turnip yield (low weight stunted tubers) especially at high doses of (B20) and (B20*F) compared to the control and treatment remains. This could be explained by its nature (high pH,...) necessary for root development, knowing that turnips prefer humus-bearing, slightly acidic or neutral soils with an optimal pH (6–6.8), they have difficulty tolerating alkaline soils, which is the case for most soils in temperate regions (Lentz & Ippolito, 2012). On the other hand, biochar improves penetration depth by its ability to reduce soil compaction (Glaser et al., 2002; Atkinson et al., 2010), this has been demonstrated in asparagus where the number of roots has increased with the addition of coconut biochar in tropical soil (Matsubara et al., 2002; Lehman et al., 2011); also, in rice where root length has increased with biochar additions (Noguera et al., 2010; Lehman et al., 2011).

According to our study, the contribution of manure alone did not increase organic carbon and soil CEC like biochar, however the improvement in turnip performance by manure was attributed to its neutral pH, low C/N content, richness in minerals available to our crop that increased tuber size and weight compared to the control and biochar alone. Indeed, the manure supply significantly improved the quality of the fruit in the treatments amended to manure alone or in a mixture for treatment (B5*F) compared to the control and the remains of the treatments. This result can be explained by better soil biological activity due to an ideal pH for good mineralization of organic matter, thus allowing better bioavailability of mineral elements for turnips, resulting in acceptable fruit quality contributing to satisfactory yields (Biederman et al., 2017; Adekiyaa et al., 2019).

Our results are consistent with those of Foster et al. (2016) and Ippolito et al. (2016) who hypothesized that relatively low biochar application rates would not cause a negative effect while excessive biochar applications (10% and more) would cause a negative priming effect even if in the presence of manure this remains related to each crop and soil type.

CONCLUSION

This trial found that, in the short term, the addition of wood biochar and bovine manure alone or as a mixture to the soil helped to improve some soil parameters such as CEC and organic matter.Although biochar has several benefits to our soil that can be appreciated in bulb vegetables and that have a direct impact on their growth and development because of the improvement in their depth of penetration by its ability to reduce the soil compaction by increasing porosity resulting in better water retention and nutrients.

Overall, the development of sustainable agriculture involves the identification and development of new strategies to maintain long-term returns. In the future, biochar could be associated with manure or other organic sourcesfrom farms or agro-food industries or to another inorganic one, which could be one of the possible future solutions for the sequestration of organic carbon in degraded soils (Lehmann, 2007; Sohi, 2012). Indeed, it is important to mention that the effects of biochar can not be generalized since they are specific to the type of biochar to use, to the selected crop, nature of the soil and to the technical route to adopt; the ideal would be to establish a rate for each soil and for each plant species because it is not the contribution of carbon as such which is important for soil fertility, but rather the monitoring of its decomposition and its impact on the agro system.

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