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Chemical-physical characterization and bioassay on poplar and conifer biochar

Valagussa, M [a]*; Pozzi, A[b]; Tosca, A[c]

[a]MAC – Minoprio Analisi e Certificazioni, Viale Raimondi 54, Vertemate con Minoprio (CO), Italy; [b]AGT - Advanced Gasification Technology, Via Cesari 1/A, Cremona, Italy; [c]Fondazione Minoprio C.L.I.F.O.F., Viale Raimondi 54, Vertemate con Minoprio (CO), Italy
*E-mail: maclab@tin.it

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Introduction

Biochar produced from different types of biomass may greatly differ in its chemical and physical properties; moreover the process parameters and typology of biomass conversion technology influence the biochar final quality and characteristics [1].

In 2009 two different types of charcoal obtained from an Italian innovative gasification system (fixed-bed, down-draft, open core, small size) using two different kind of biomass (poplar and conifer woods) were analyzed for the following chemical and physical properties: pH, salinity, total and available nutrients, organic carbon content, humidity, ash, compacted bulk density, particle size distribution. Soil improvers and fertilizers standard methods were used and at least six replicates for chemical parameters were done to estimate coefficient of variation.

Moreover a bioassay was carried out using lettuce (*Lactuca sativa L.*) as a test plant [2]; conifer charcoal was tested for potential toxicity at different mixing rates with a reference sandy soil to obtain a growth index.

The different treatments were calculated to simulate field application and are listed in the Table 1.

Table 1. Bioassay treatments

Treatments (g fresh charcoal * kg^{-1} reference sandy soil)	Corresponding field application of fresh charcoal at 6% humidity (Mg ha^{-1})
0	0
5	23
10	45
15	68
20	90

The test was performed in growing room, with light and fixed temperature (22°C), using 250 ml pots with three seed plants/pot. Four replicates for each treatment were carried out, with a randomized design.

After 21 days aboveground biomass was cut and weighed, both fresh and dried at 105°C for 48 h,.

Dried production was analyzed by analysis of variance (ANOVA) and mean separation was done using Duncan test (P=95%).

Results and Discussions

Dry matter growth index obtained from bioassay is shown in Figure 1. Only corresponding fresh biochar field applications between 23 and 68 Mg ha^{-1} are significantly different and better than control.

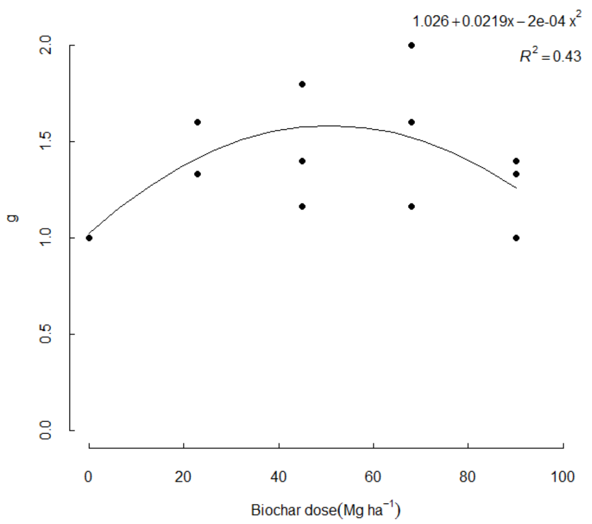

Figure 1. Conifer charcoal bioassay: lettuce dry matter production index (control index = 1).

Characterization data of conifer and poplar charcoal are shown in Table 2 (mean values).

Poplar charcoal has higher compacted bulk density (fresh matter) and humidity than conifer charcoal, because it was moistened during storage to prevent fire risk and to facilitate mechanical field application.

The pH value is higher in conifer than in poplar charcoal; however both are alkaline (> 9,0). The application of charcoal increases the pH of acid soils, but this effect is probably due to ash content [1]. As ash content (loss on ignition 600°C) is higher in poplar than in conifer charcoal, application of poplar charcoal may have more effect on soil acidity decrease.

Salinity is slightly higher in poplar charcoal, due to high water soluble nutrients content in fresh matter, especially for potassium and phosphorous. Even so salinity values are not toxic to plants when charcoal is used as soil improver.

Total organic carbon content has been determined both by dichromate oxidation-titration techniques (oxidation with heating time and temperature 10 min and 150°C respectively) and by dry combustion (elementary analysis using a correction for carbonates). Values range from 53 % for poplar charcoal to 70% for conifer charcoal (Dumas method), in line with the major bibliographical data [3].

C/N ratio is very high in conifer charcoal, due to higher carbon content and lower nitrogen value.

Poplar charcoal shows the highest values in total nitrogen, phosphorus and potassium content. As to available bases (exchangeable cations), the different values for potassium (lower in conifer charcoal) and calcium (lower in poplar charcoal), are related to feedstock and charring conditions.

Particle size distribution shows that conifer charcoal is coarse and it has an homogenous division between 1, 2 and 5 mm.

Both have particle size near 100% < 5 mm.

Table 2. Conifer and poplar charcoal characterization (mean values – coefficient of variation always < 0,5)

Parameter	Conifer biochar	Poplar biochar	Reference method
Compacted bulk density (g l^{-1} fm)	196	421	UNI-EN 13037:2002
Humidity (%)	6,0	50,5	UNI-EN 13040:2008
pH (H_2O)	10,3	9,6	UNI-EN 13037:2002
Salinity (mS m^{-1})	28	39	UNI-EN 13038:2002
Nitrate $_{(N\ water\ soluble)}$ (mg l^{-1} fm)	< 1,0	< 1,0	UNI-EN 13652:2001
Ammonium $_{(N\ water\ soluble)}$ (mg l^{-1} fm)	32,2	35,9	UNI-EN 13652:2001
Potassium $_{(K\ water\ soluble)}$ (mg l^{-1} fm)	245,0	510,0	UNI-EN 13652:2001
Phosphorus $_{(P\ water\ soluble)}$ (mg l^{-1} fm)	2,9	99,7	UNI-EN 13652:2001
Organic Carbon (% dm)	63,8	58,0	DM* 21/12/00 Add. 6 (Springer-Klee)
Organic Carbon (% dm)	69,5	53,0	DM* 13/09/99 met. VII.1 (Dumas)
C/N (Dumas method)	173,8	37,9	DM* 13/09/99 met. VII.1 (Dumas)
Nitrogen $_{(N\ Total)}$ (% dm)	0,4	1,4	UNI-EN 13654-2:2001 (Dumas)
Phosphorus $_{(P\ Total)}$ (% dm)	< 0,1	0,4	UNI-EN 13650:2002 (aqua regia)
Potassium $_{(K\ Total)}$ (% dm)	0,4	1,0	UNI-EN 13650:2002 (aqua regia)
Ash $_{(loss\ on\ ignition\ at\ 600°C)}$ (% dm)	8,0	22,0	UNI-EN 13039:2002 (loss on ignition)
Ca^{2+} $_{(exchang.-BaCl2)}$ (mg kg^{-1} dm)	4972	1580	DM* 13/09/99 met. XIII.5
Mg^{2+} $_{(exchang.-BaCl2)}$ (mg kg^{-1} dm)	586	522	DM* 13/09/99 met. XIII.5
K^{+} $_{(exchang.-BaCl2)}$ (mg kg^{-1} dm)	2957	5207	DM* 13/09/99 met. XIII.5
Na^{+} $_{(exchang.-BaCl2)}$ (mg kg^{-1} dm)	200	446	DM* 13/09/99 met. XIII.5
Particle size < 1,00 mm (%)	29	56	UNI-EN 15428:2008
Particle size < 2,00 mm (%)	60	77	UNI-EN 15428:2008
Particle size < 5,00 mm (%)	97	96	UNI-EN 15428:2008
Particle size < 10,00 mm (%)	100	100	UNI-EN 15428:2008

* Ministerial Decrees for official methods

Conclusions

Biochar produced from different types of biomass varies in its properties, as much as charring conditions.

A databank for different kinds of biochar is useful and desirable.

Moreover, as to assess the agronomic values of the different biochars, we need to define parameters, standard harmonized methods and bioassays, in order to allow different data comparison.

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