Improving mining soil phytoremediation with *Sinapsis alba* by addition of hydrochars and biochars from manure wastes

E.Cárdenas-Aguiar[1], B. Ruiz[2], E. Fuente[2], G. Gascó[1], A.Méndez[3]

[1]Department of Agricultural Production, Technical University of Madrid, 28040 Madrid, Spain
[2]Biocarbon & Sustainability Group (B&S). Instituto Nacional del Carbón (INCAR), CSIC, 33011, Oviedo. Spain
[3]Department of Geological and Mining Engineering, Technical University of Madrid 28003 Madrid, Spain
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Presenting author email: begorb@incar.csic.es

Introduction

Mining and metallurgical plant activity has caused significant environmental damage. One of the most serious has been the pollution of soils by different metals and metalloids. Unlike organic substances, heavy metals are nondegradable and accumulate in the environment. Traditionally, soil remediation techniques involve destructive practices, such as soil excavation, metal immobilization or soil washing. However, there is growing interest in the development and use of cleaner, low-cost and ecological technologies like phytoremediation techniques that could facilitate not only the decontamination of soil but also the recovery of metals. In addition, phytoremediation is positively perceived by society and stakeholders and the growth of vegetation could prevent soil erosion or the leaching of metals (Paz-Ferreiro et al., 2014; Prasad, 2003). However, soil metal pollution has a pernicious effect on soil microbial properties and on the taxonomic and functional diversity of soils (Vacca et al., 2012) that impede the growth of plants to phytoremediation. In order to improve the properties of the soil and consequently plant growth, the addition of organic amendments as compost has been attempted.

More recently, several authors have focused their research on the phytoremediation of metal polluted soils in combination with biochar amendment (Paz-Ferreiro et al., 2014). The use of biochar for heavy metal immobilization is a low cost technique and long-lasting compared to other organic amendments due to the high stability of biochar. Biochar properties depend greatly on the characteristics of the feedstock and pyrolysis conditions such as temperature, heating rate or time. In the case of biochar produced by the pyrolysis of manure waste several essential factors make it a suitable option including nutrient content or high cation exchange capacity (Cely et al., 2015). This has led to an increase in interest in the treatment of mining soils. However, despite the positive effects of manure waste, its elevated water content precludes its use without a drying step before pyrolysis treatment. For this reason, the hydrothermal carbonization (HTC) of wet manure wastes could be an inexpensive alternative management method (Gascó et al., 2018). Hydrochars obtained from HTC of organic wastes have different physical and chemical properties to biochars and could have different effects on the soil. For this reason, the main objective of the present work is to study the effect of biochar and hydrochars in soil phytoremediation with *Sinapsis alba*.

Experimental

The manure waste (MW) was obtained from a farm located in the practice field of the Technical University of Madrid (Spain). Two biochars and two hydrochars were prepared using MW as raw material. The two biochars were prepared by heating the air-dried MW in a 2L steel reactor supplied by Demede S.L at a heating rate of 3ºC min^{-1} and under a N_2 flow of 0.5 L min^{-1} up to 450 and 600ºC giving rise to BMW450 and BMW600, respectively. The final temperature was maintained for 1 hour. Subsequently, the biochars were sieved to below 2mm.

The two hydrochars were prepared using 1.0 L of wet MW solution with 30% of solid content that was introduced in a Teflon recipient inside a Hastelloy autoclave supplied by Demede S.L. The solutions were heated at 190 and 240ºC and the final temperature was maintained for 6 hours under autogenous pressure giving rise to HMW190 and HMW240, respectively. After being cooled down to room temperature, the aqueous solutions were filtered and the hydrochars were dried at 90ºC for 24 hours and sieved to below 2 mm.

Mining soils were selected from two Spanish mining areas: Gamonedo (GAM) and Portamn (PORT). The soils were amended at a rate of 10% (w/w) with the raw material and the four chars. After that, all the treatments were initially watered down to 60% of field capacity and then watered daily to compensate for moisture losses. The mixtures were introduced into their corresponding pots (volume: 500 mL). 10 *Sinapsis alba* seeds were sowed in half of the mesocosm experiment while the other half were used as control without *Sinapsis alba* growth. The pots were then introduced in an incubator with light cycles every 12 h at a controlled temperature ranging from 20 to 25°C for 60 days. Each treatment was repeated 3 times. After this time, shoots and roots were collected and their dry weights were determined after drying them at 80ºC during 24 h. The metal content was also determined and related to biomass production and microbial activity. The soil microbial activity was estimated using the GMea index which is defined as the geometric mean of the next enzymatic activities: β-glucosidase, phosphomonoesterase and dehydrogenase.

The mining soils (GAM and PORT) and amendments (MW, BMW450, BMW600, HMW190 and HMW240) were characterised before and after phytoextraction (pH, metal content, cation exchange capacity, C, H, N, S, O and ash content, Hg porosimetry, SEM-EDX).

Results and discussion

Figure 1 shows the dry weight corresponding to *Sinapsis alba* growth in the GAM and PORT soils. The addition of amendments significantly increased the growth of the leaves, stems and roots of the plants. The greatest increase was obtained after the addition of the MW. However, the greatest increase was recorded in the GAM soil according to the GMea index as a result of the addition of the 2 hydrochars.

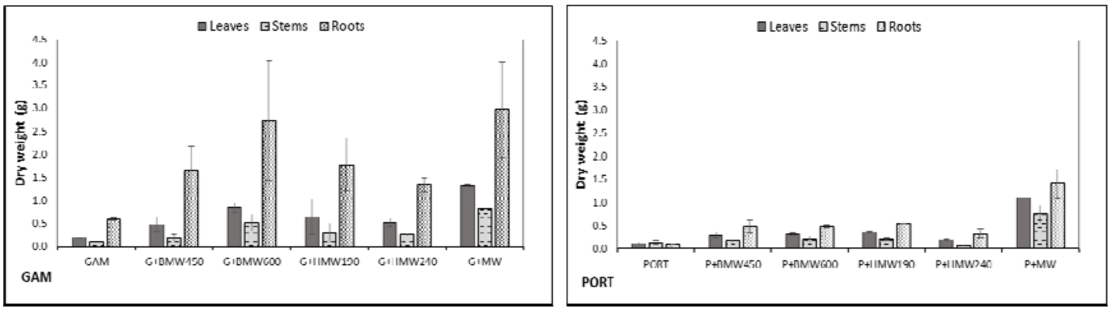

Fig. 1. Dry weight (g) of leaves, stems and roots in the GAM and PORT soil samples

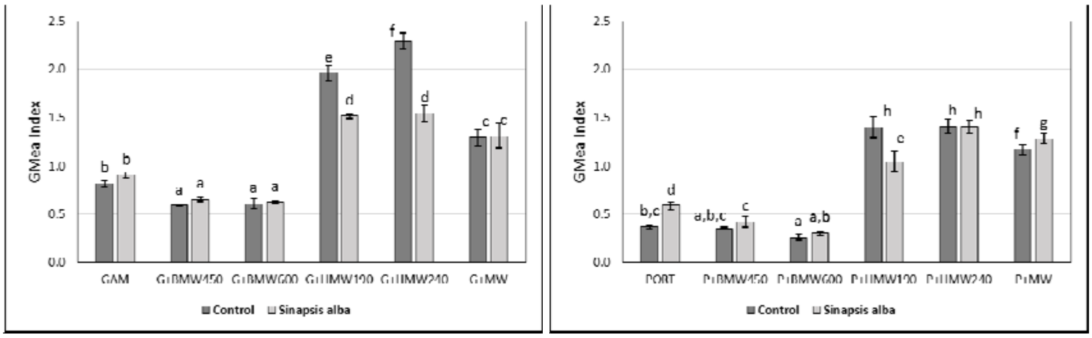

Fig. 2. GMea of the GAM and PORT soil samples

According to the bioconcentration factor (BCF), *Sinapsis alba* acted as an accumulator for As in the presence of BMW600 and HMW190 in the PORT samples but in the case of the GAM treatments the addition of amendments did not entail any improvement in the capacity for metal accumulation. The same trend was noticed for Pb with an increase in the BCF in the P+BMW600 sample, although the value did not exceed 1. Values of BCF greater than one indicate a good accumulation efficiency and a potential accumulator plant (Diwan et al., 2010). In conclusion, a heavy metal uptake depends on plant ability, the type of soil, the amendment added and the targeted metal.

References

Cely, P., Gascó, G., Paz-Ferreiro, J., Méndez, A. 2015. Agronomic properties of biochar from different manure wastes. Journal of Analytical and Applied Pyrolysis 111: 173-182**.**

Diwan, H., Ahmad, A., & Iqbal, M. (2010). Uptake-related parameters as indices of phytoremediation potential. Biologia, 65(6), 1004-1011.

Gascó, G, Paz-Ferreiro, J., Álvarez, M.L., Saa, A., Méndez, A., 2018. Biochars and hydrochars prepared by pyrolysis and hydrothermal carbonisation of pig manure. Waste management 79: 395-403

Paz-Ferreiro, J., Lu, H., Fu, S., Méndez, A., Gascó, G., 2014. Use of phytoremediation and biochar to remediate heavy metal polluted soils: a review. Solid Earth 5, 65–75

Prasad, M.N.V., 2003. Phytoremediation of metal-polluted ecosystems: hype for commercialization. Russ. J. Plant Physiol. 50, 686–700.

Vacca, A., Bianco, M. R., Murolo, M., & Violante, P. (2012). Heavy metals in contaminated soils of the Rio Sitzerri floodplain (Sardinia, Italy): characterization and impact on pedodiversity. Land Degradation & Development, 23(4), 350-364.

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