Soil biological properties of two mining soils amended with mixtures of biochar and compost

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Introduction

Mining soils are categorized as Technosols which implies the modification of physical, chemical and biological soil properties due to industrial or artisanal human activities. The impacts of mining activities represents a threat to the ecosystem equilibrium, especially when is related to metal contamination. High amounts of metals in soils can produce losses of vegetation cover, alteration of soil biota (microorganisms) and even toxicity in plants and others levels of the trophic chain (Zhang *et al.*, 2010; Li *et al.*, 2019).

The use of soil biota to determine soil quality is a known strategy, because of the essential role of microorganisms in nutrient cycling, organic matter decomposition, ecosystem sustainability, among other functions. Some indicators: basal respiration, microbial structure, microbial biomass and enzyme activity, can provide enough information about the changes on soil community after an environmental disturb (Zhang *et al.*, 2010; Wang *et al.*, 2007). The use of organic amendments (i.e. biochar and compost) also impact soil microbiota. Soils amended with biochar have high nutrient content and carbon availability and as a result an increased effect of non- symbiotic microorganisms. Also, variations in soil pH, after biochar addition, affect fungi and bacteria biomass and most important biochar has a great sorption capacity of toxic compounds that allows an increase in microbial abundance (Lehmann *et al.*, 2011). In the case of the present investigation, the aim was to determine the changes in soil enzyme activities in two mining soils of Spain after the addition of organic amendments (biochar, compost and mixtures) with or without the combination with phytoremediation.

Experimental

The rabbit manure (MW) was obtained from the practice field of the Technical University of Madrid. Two biochars were prepared using MW as feedstock. The two biochars were prepared by heating the air-dried MW in a 2L steel reactor supplied by Demede S.L using a heating rate of 3ºC min^{-1} and N_2 flow of 0.5 L min^{-1} until 300 and 600ºC leading to BMW300 and BMW600, respectively. Later, biochars were sieved below 2 mm.

Then, two mixtures were prepared. First mixture was prepared mixing 50% (w/w) of the BMW300 and 50% of MW, named as B300+MW. For the second mixture, the same process was used with 50% of the BMW600 labelled as B600+MW. The two soils were selected from the south of Spain. The first correspond to a soil from the Portman bay, a well-known mining area (P2) and the second one correspond to a mining sludge from the same area (L32). The soils were amended with the follow amendments: MW, BMW300, BMW600, B300+MW and B600+MW at a rate of 10% (w/w). After that, all treatments were initially watered to 60% of field capacity and afterwards watered daily to account for moisture losses. Mixtures were introduced in corresponding pots (volume: 500 mL). The pots were provided first with a gravel layer, followed by the respective control or amended soil and in the superficial layer ten seeds of *Brassica napus or Sinapsis alba*. The controls treatments were maintained without seeds (no plant growth), in order to analyze the effect of the amendments by itself. Then, pots were introduced in an incubator with light cycles every 12 h at a controlled temperature from 20 °C for 60 days. Each treatment was replicated 3 times. After this time, shoots and roots were collected and dry weights were determined after drying at 80ºC during 24 h. The geometric mean (GMea) index was calculated as suitable measure of soil biochemical activity that integrated 3 enzymes: Phosphomonoesterase, β-glucosidase and Dehydrogenase (Paz-Ferreiro et al., 2012).

Results and discussion

Table 1 shows dry biomass weight of *Brassica napus* and *Sinapsis alba* growth in P2 and L32 soils. For *Brassica napus*, the addition of amendments significantly increased the vegetable biomass in L32 treatments, especially with the use of B600+MW. In the case of P2 soil, the highest values of *Brassica napus biomass* were obtained for the P2+BMW300 treatment. The MW addition to P2 soil also implied a better plant growth but the mixtures between biochar and MW did not seem to have a positive effect for plant growth. For *Sinapsis alba,* all treatments improved biomass production in the used in L32 soil with a significant increase after the addition of the mixture B600+MW and BMW300. For P2 soil, the highest value was obtained after BMW300 addition followed by the BMW600 application. On this last case, the plant growth was similar to the control soil (P2). In summary, *Sinapsis alba* showed higher plant growth than *Brassica napus* in almost all cases.

Table 1. Dry weight (g) of leaves, stems and roots of *Brassica napus* and *Sinapsis alba* in L32 and soil samples. L: leaves, St: stems, R: roots, S: soil.

Treatments	**L32**						**P2**					
	Brassica napus			***Sinapsis alba***			***Brassica napus***			***Sinapsis alba***		
	L	**St**	**R**	**L**	**St**	**R**	**L**	**St**	**R**	**L**	**St**	**R**
Soil	0.05	0.02	0.25	0.13	0.04	0.43	0.12	0.07	1.17	0.15	0.08	0.51
S+BMW300	0.24	0.10	0.65	0.24	0.07	0.51	0.48	0.22	1.42	0.33	0.12	0.48
S+BMW600	0.10	0.04	0.29	0.19	0.08	0.51	0.23	0.12	1.01	0.15	0.09	0.51
S+B300+MW	0.39	0.15	0.35	0.35	0.11	0.33	0.28	0.16	0.37	0.14	0.05	0.15
S+B600+MW	0.48	0.22	1.26	0.36	0.13	0.57	0.23	0.13	0.30	0.22	0.08	0.23
S+MW	0.53	0.25	0.57	0.20	0.08	0.36	0.53	0.30	1.46	0.21	0.08	0.21

Finally, soil biochemical activity (GMea) was determined. GMea significantly increases after addition of MW, the mixtures of MW and biochars and BMW300 following the same trend when the amendment was combined with *Brassica napus and Sinapsis alba*.

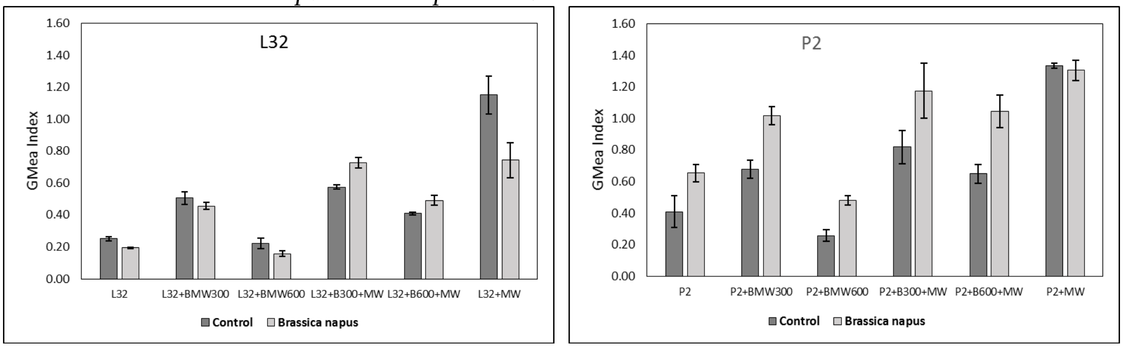

Figure 1. GMea index for *Brassica napu*s in L32 and P2 soil samples.

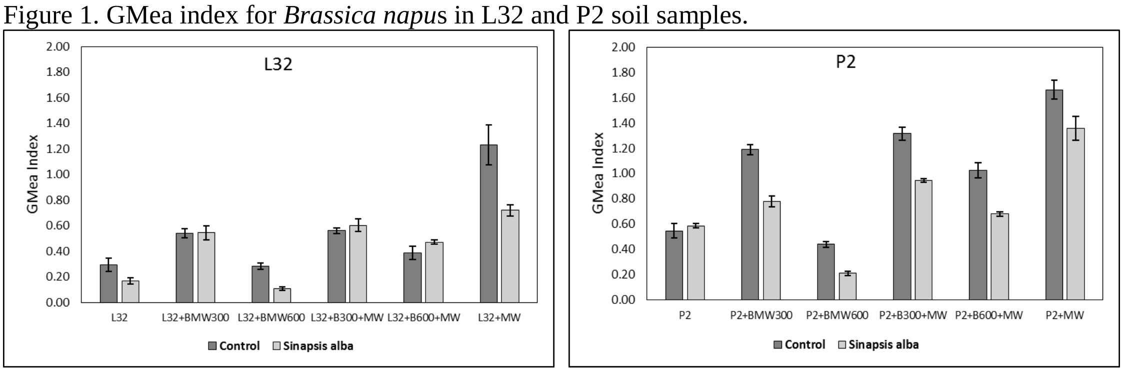

Figure 2. GMea index for *Sinapsis alba* in L32 and P2 soil samples.

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