Reclamation of acid soils with biomass ashes from pyrolytic wood liquefaction

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Fast Pyrolysis Bio-Oil (FPBO) is a 2nd generation bio-fuel produced employing a fast pyrolysis process in which organic material (mainly organic wastes streams) is heated in the absence of oxygen to about 500 °C within a few seconds. Under these conditions organic and aqueous vapours, pyrolysis gas and charcoal arise (https://www.residue2heat.eu/). The vapours are rapidly cooled and condensed into a highly viscous liquid, so-called pyrolysis oil or Fast Pyrolysis Bio-Oil (FPBO) (Leijenhorst et al., 2016). Additionally, the valuable by-products (charcoal (10-15%) and low calorific gases (15-20%)) can be recycled to generate energy by combustion, resulting in the production of ashes containing most of the minerals such as Ca, Mg, K and P, and micronutrients including Fe, Mn, Zn and Cu, originally present in the feedstock (Fernández-Delgado Juárez et al., 2016).

On the other hand, according to FAO (2018) acid soils cover a relevant surface of tropical and temperate areas and a proper management is necessary to reduce their potential toxicities (Aluminium) as well as deficiencies (Molybdenum). The application of lime into the cultivable soil layer is an effective and widespread method for amelioration of acid soils. Previous studies have shown that biomass ashes can be used as a substitute of lime, not only increasing soil pH, but also providing nutrients necessary for crop development (with the exception of N) and stimulating microbial activity (Bougnom et al., 2010). However, one of the potential effects of ash application is the increased N mineralization that might enhance plant development but also induce nitrate losses via leaching, and consequently contribute to groundwater eutrophication.

The main objective of this study was to investigate if the recovered ashes from the pyrolysis process can be used as a soil amendment without endangering soil microbial processes and plant development. A second objective was to observe potential effects on nutrient leaching as a result of the ash application into soil.

For this purpose, an acidic grassland soil (pH_{CaCl2} 5.23 and electrical conductivity (EC) 12.9 µS cm^{-1}) was sampled in Tyrol, Austria. The site had not been fertilized in the past 7 years. The soil (2kg), placed Perspex columns (11 cm Ø) was amended with 2% (w/w) FPBO fly ashes on basis of untreated pine wood chips. The applied ashes were sampled immediately after FPBO production in an air-tight container to avoid reactions with atmospheric CO_2 and were applied to the soil approximately 1 month after production. Unamended soil was used as control. A regional wheat variety was sown and the columns were placed in triplicate in a randomized block design in a greenhouse. They were sampled after 0, 60 and 100 days. A fourth set of columns was included in the randomised design in which wheat was harvested after 100 days, and after a 13-day period red clover was sown in each column to simulate the crop rotation and test the possible beneficial effects of the ashes on the crop yields. Red clover was chosen because of its common use as both a forage crop for livestock and a nitrogen-fixing plant in the crop rotation system. After an additional growth period of 150 days these columns were destructively sampled and referred as "250-day" treatment. After each sampling, soil samples were sieved (<2 mm) and stored (at 4°C and -20°C) for microbial (soil respiration, microbial biomass, nitrogen mineralization, nitrification, among others) and physico-chemical analyses (pH, EC, dissolved organic carbon (DOC), total and available phosphorus (Ptot and Pav), inorganic nitrogen (N)). Soil leachates were collected in small flasks during the 250-day period by watering the columns with 100 mL of water. EC and pH, together with the inorganic N content were measured in the soil leachates.

Amending with ashes induced a soil pH increase of almost 2 units over time and independently of the crop presence. Moreover, ash addition did also increase soil plant available P and soil nitrate. Moreover, an increase in DOC was observed at the initial stages of the experiment following ash application but was found to diminish over time. Moreover, parallel to these findings, the soil organic matter (SOM), was found to be lower in the ash-amended soils compared to the control, whereas the particulated soil organic matter (POM) was higher in the ash-treated soils.

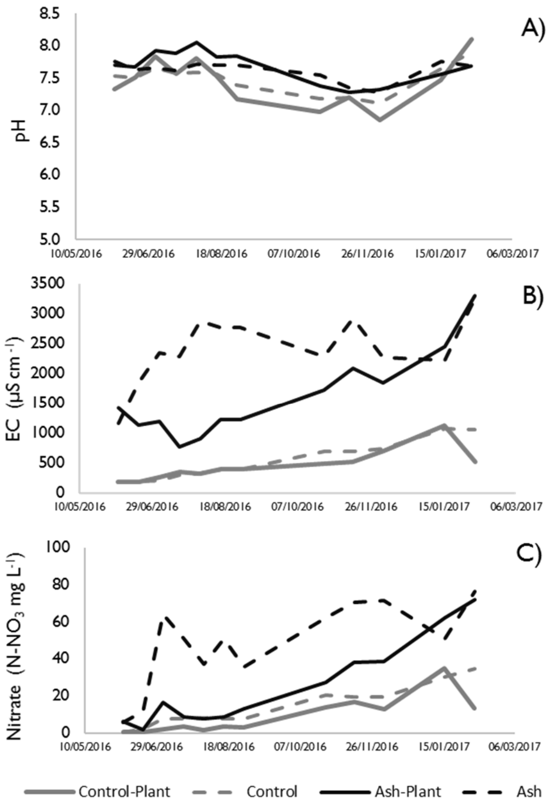

Figure 1. Soil leachate properties throughout the experimental period: pH (A), EC (B) and Nitrate (C).

Soil leachate properties were influenced the ash application to the soil. For pH (Fig 1A), the ash-treated columns showed a slight increase of approximately 0.5 units at some of the sampling times. However, these variations were not always detectable throughout the monitoring. The crop presence did not have a determinant influence on the leachate pH values.

For EC and nitrate content (Figs.1 B, C) the effect of ash amendment on the soil leachates was stronger.. In both cases, amending soil with ashes resulted in an increase of these two parameters compared to the control. In the case of ash-treated soils, crop presence drastically reduced nitrogen losses during the first stages of the experiment when wheat was present and took up the mineralized N for growth. Nonetheless, the change of crop to red clover (a nitrogen fixer) induced an increase of nitrate in soil leachate, indicating that the combination of N-fixing plants and FPBO ashes might not be optimal. We conclude that the choice of crop is important when reclaiming acid soils with FPBO ashes.

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