Pedosphere **24**(3): 308–321, 2014
ISSN 1002-0160/CN 32-1315/P

Published by Elsevier B.V. and Science Press

PEDOSPHERE

www.elsevier.com/locate/pedosphere

Impact of Lignosulfonate on Solution Chemistry and Phospholipid Fatty Acid Composition in Soils[*1]

Å. R. ALMÅS[1,*2], A. K. AFANOU[2] and T. KROGSTAD[1]

[1] *Norwegian University of Life Science, Department of Environmental Sciences, P.O. Box 5003, N-1432 Ås (Norway)*
[2] *National Institute of Occupational Health, Department of Chemistry and Biology, P.O. Box 8149 Dep, N-0033 Oslo (Norway)*

(Received August 27, 2013; revised March 18, 2014)

ABSTRACT

An incubation experiment (Exp. 1) with three soils, two from Australia and one from Norway, was carried out to investigate the fate of dissolved BorreGro (a lignosulfonate, produced by Borregaard LignoTech Company, Norway) at different concentrations (0, 10 and 100 mg C L^{-1}) in soil solutions. A rhizobox experiment (Exp. 2) was also done in a Norwegian clay soil, mixed with four levels of BorreGro-carbon (BG-C) added (0, 2, 20 and 200 mg BG-C kg^{-1}) to test the impact of BorreGro on root growth, rhizosphere chemistry (pH, metals and dissolved organic carbon (DOC)) and the composition of phospholipid fatty acids (PLFAs). The BorreGro addition increased the concentration of Mn due to the high concentrations in BorreGro. The BorreGro addition to soil had an indirect but significant impact on the rhizosphere chemistry and PLFAs. The lowest amounts of added BorreGro facilitated the DOC excretion at plant roots, and thereby increased the bacterial and fungal biomass, likely as an effect of increased Mn solubility from BorreGro in the root zone.

Key Words: Ca, dissolved organic carbon, Mn, rhizosphere chemistry, WHAM/Model VI

Citation: Almås, Å. R., Afanou, A. K. and Krogstad, T. 2014. Impact of lignosulfonate on solution chemistry and phospholipid fatty acid composition in soils. *Pedosphere*. **24**(3): 308–321.

INTRODUCTION

Lignosulfonate (LS) is a by-product obtained from the sulfite pulping processes. This product is mainly used for concrete mixtures, and also as a binding additive in animal feed pellet production. In addition, LS is increasingly marketed as a soil conditioner and has shown to promote plant yield (Hesford, 2004). However, its physicochemical impact on soil solution is still not clear. The compound is an organic macro molecule carrying negatively charged carboxylic, phenolic, hydroxyl and sulfonate groups. During the sulfite pulping process, wood is treated with Ca or Mg sulfite, and the final product is thus rich in either one of these metals and other base cations like Na and K. Since LS is a by-product of different productions, the contents of trace metals varies, but the typically LS is rich in either as Zn (Goos *et al.*, 2000; Obrador *et al.*, 2002; Lopez-Valdivia *et al.*, 2002; Novillo *et al.*, 2002), Cu (Malhi *et al.*, 2005) and Fe (Goos and Germain, 2001). The contents of these metals in LS have shown to be of significance in raising the uptake of Cu, Zn or Fe and also the crop yield, as the above-cited studies reported. Lignosulfonate is easily dissolved in water due to the introduction of hydrophilic sulfonic acids for dissolving lignin during the pulping process. Thus, if 10 kg LS ha^{-1} (containing 40% carbon) is added to agricultural land together with a volume of water equivalent to 50 mm precipitation, the soil water will carry about 8 mg C L^{-1}, which is in the range of normal dissolved organic carbon (DOC) contents in soil solutions. If 100% dissolved, the addition of organic carbon and trace metals is substantial. Although additions of LS have shown to increase crop yield, the mechanisms involved are less clear. A number of different effects are reported. In addition to provide micro nutrients, the additions of LS has also shown to facilitate early interaction between ectomycorrhiza and host seedlings (Niemi *et al.*, 2005), release rooting hormone auxin (Kevers *et al.*, 1999), increase the fertilizer availability of N (Meier *et al.*, 1993; Xie *et al.*, 1993; Xie *et al.*, 1994; Alkanani and Mackenzie, 1996), and reduce the impact from pathogens and plant diseases (Lazarovits *et al.*, 2001; Abbasi *et al.*, 2002; Soltani *et al.*, 2002). It is not clear if all observations reported are due to direct or indirect effects from the LS treatments.

[*1] Support by the Borregaard LignoTech Company, Norway.

[*2] Corresponding author. E-mail: asgeir.almas@nmbu.no.

Some of the experimental outcome of LS treatments seems to be conditional to the mineral contents (*i.e.*, concentration of Zn, Cu or Fe) of LS applied in experimental trials. The alkaline nature of LS (the pH of BorreGro used in this experiment is pH 7.3) may also locally increase the soil pH. Overall, the agricultural use of LS seems to be a valuable low cost soil conditioner with the potential in promoting crop yield, particularly under non-optimal growth situations, *i.e.*, acid soils, low content of soil organic matter and insufficient supply of essential trace elements.

It is well known that seedlings of cultivated plants need an optimal pH for maximum root development and that Al ion activity is a critical factor in that context. The cultivation of sensitive crops, like barley and clover (lucerne), is optimal at pH near 6. Particularly in sandy soils, lower pH, caused root deformation and reduced the uptake of Mg and Ca as a result of Al-toxicity (Mengel and Kirkby, 1987). Seedlings are sensitive to Al^{3+} and $Al(OH)^{2+}$. Since organic matter binds Al very strongly (Evans, 1989), it is expected that in the acid range of soil pH, Al binds organically and is not controlled by inorganic Al precipitates and minerals. Due to the high metal binding capacity, LS may act in detoxifying Al ions in soil solution by complexation.

The impact of soil physicochemical properties on microbial communities can, for instance, be investigated by analysing the ^{3}H-thymidine incorporation (Bååth, 1992; Almås *et al.*, 2004) or the phospholipid fatty acid (PLFA) content of soil organisms (Frostegård and Bååth, 1996). For this investigation, we think testing the composition of PLFA as influenced by BorreGro treatments is most applicable. That is because when several types of biological and soil physicochemical parameters might interact positively or negatively at the same time on a complex measurement as the microbial community composition of PLFA, it can be statistically tested using principal component analysis (PCA). Additionally, the changes in microbial biomass can be estimated.

In general, the effect of applying LS on crop production seems ill-defined. At least the mechanistic impact seems conditional to how the experiments are focused. Little information exists on the biogeochemistry. More specifically, the LS impact on soil chemistry and microbiology in the rhizosphere is sparse. Hence, we designed two experiments to firstly test the hypothesis that BorreGro could detoxify Al ions by complexation for short periods of time after addition, in a scenario where dissolved BorreGro is in contact with slightly acid soils. This was important to investigate as some field trials with BorreGro had shown positive effects on crop production in slightly acid soils and Fe/Al oxide rich soils. The hypothesis was tested in a simple incubation experiment where the change in solution chemistry with time was investigated analytically and by modelling (WHAM/Model VI). Secondly, the impact of BorreGro on DOC and supply of trace elements in rhizosphere soils had to be investigated, in other words, in the presence of plants. It is well known that the interaction between plant roots and soil microbial communities in the rhizosphere are important for the attenuation of mineral nutrients, and the impact on LS in this context is not known. Hence, this hypothesis was tested in a rhizobox experiment by soil chemical extractions, metal speciation using WHAM/Model VI, and PLFA analysis as described later.

Thus, the aims of this study were to investigate the fate of dissolved BorreGro at different concentrations in solutions of three different soils and to test if the addition of different amounts of BorreGro to soils could affect the metal chemistry in soil solution and the composition of PLFAs in the rhizosphere.

MATERIALS AND METHODS

Soil samples

Two experiments were carried out in this study. Firstly, an incubation experiment (Exp. 1) was carried out preparing soil slurries to test the effect of BorreGro addition on metal and DOC solubility in three soils (Soils 1–3). Secondly, a rhizobox experiment (Exp. 2) was carried out to test the impact of BorreGro on PLFA, metal and DOC solubility in the rhizosphere using only one soil type (Soil 4).

Some of the important soil chemical properties are shown in Table I. A non-cultivated acidic clay loam (Soil 1) from Ås in Norway was sampled for Exp. 1 since the soil has not been limed or fertilized earlier. Due to low pH, another soil (Soil 4) in the same area but inside a cultivated field was later selected for Exp. 2. In addition to this soil, two non-BorreGro treated sandy soils (Soils 2 and 3) from Australia were sampled from field trial areas administrated by the Borregaard Company in Exp. 1. Soil samples were dried at 35 °C and sieved through 2-mm sieve and stored for chemical analyses. The mechanical analysis for soil particle size was carried out by the pipette method (Elonen, 1971). The pH of the soil was measured by the glass electrode method with 1:2.5 (w:v) of soil and water (Krogstad, 1992). The total organic carbon and total nitrogen contents were measured by combustion in an Leco CHN-1000 analyser (Tabtabai