The effects of fertilization with anaerobic, composted and pelletized sewage sludge on soil cations and pasture production in a silvopastoral system under *Quercus rubra* L.

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Abstract

In Europe, sewage sludge has to be stabilized before being used as fertilizer in agriculture. Depending on the stabilization process that is used, sewage sludge has different characteristics, nutrient contents and soil nutrient incorporation rates. This study aimed at evaluating the effect of municipal sewage sludge stabilized using anaerobic digestion, composting and pelletization on saturation percentage of cations in the soil exchange complex and pasture production compared with control treatments (mineral and no fertilization) in a silvopastoral system established under *Quercus rubra* L. in Galicia (Spain). The application of the dose of pelletized sewage sludge in several times implied an increase of pasture production in the understory which reduced the Ca saturated percentage in the soil exchange complex and therefore increased the Al saturated percentage compared with the other types of sewage sludge evaluated.

Keywords: agroforestry, waste, mineral, sowing, afforestation

Introduction

Change in land use is one of the main modifications that occurred in Galicia (Spain) in the last years due to the reforestation promoted by the Common Agricultural Policy (CAP) through direct payments [1]. Trees were planted in either agronomic or forest soils, depending on the potential growth of trees and soil characteristics. Recently, silvopastoral systems are promoted by the EU (Council Regulation 1698/2005) [1] as a sustainable way of land management, where trees, pasture and animals are integrated [2].

On the other hand, in recent years the production of sewage sludge was increased in the EU countries, due to the implementation of European Directive 91/271/EEC [3] which it makes necessary to find an adequate disposal for these residues in compliance with environmental EU policy. One option adopted in many countries around the world is the use of sewage sludge as fertilizer in agriculture due to its specific organic matter and content of macronutrients, particularly N [4]. Moreover, several studies have shown that the use of sewage sludge as fertilizer in silvopastoral systems increase the tree and pasture production [5] [6] which in Galicia (Spain) is limited by the soil acidity.

In Europe, sewage sludge has to be stabilized before using them as fertilizer in agricultural systems. Anaerobic digestion and composting are two types of sludge stabilization promoted by the EU [7]. However, sewage sludge stabilized by these processes contains a high proportion of water. Pelletized sewage sludge is derived from the thermic treatment of anaerobic digested sewage sludge in order to reduce water content to 2%, which consequently reduces storage, transport and spreading costs compared with anaerobic or composted sludge [8]. These processes of stabilization can alter both the proportions of macronutrients and of micronutrients in the sludge [8] and rates of incorporation into the soil [9].

The objective of this study was to evaluate the effect of municipal sewage sludge stabilized using anaerobic digestion, composting and pelletization on saturation percentage of cations in the soil exchange complex and pasture production compared with control treatments (mineral and no fertilization) in a silvopastoral system established under *Quercus rubra* L.

Material and Methods

The experiment was established in Lugo (NW Spain) on an abandoned agricultural land at an altitude of 470 m above sea level. At the beginning of the experiment (2004) the pasture was sown with a mixture of *Dactylis glomerata* L. var. Artabro (12.5 kg ha^{-1}), *Lolium perenne* L. var. Brigantia (12.5 kg ha^{-1}) and *Trifolium repens* L. var. Huia (4 kg ha^{-1}). *Quercus rubra* L. were planted at a density of 833 trees ha^{-1} after pasture sowing in February 2005.The experimental design was a randomized block with three replicates and five treatments distributed in experimental units of 192 m^2 with 25 trees arranged in a frame of 5×5 trees. The treatments consisted of (a) no fertilization (NF); (b) mineral fertilization (MIN) with 500 kg ha^{-1} 8:24:16 compound fertilizer ($N:P_2O_5:K_2O$) at the beginning of the growing season and 40 kg N ha^{-1} before first harvest (MIN); (c) fertilization with anaerobically digested sludge with an input of 320 kg total N ha^{-1} before pasture sowing (ANA); (d) fertilization with composted sewage sludge with an input of 320 kg total N ha^{-1} before pasture sowing (COM) and (e) application of pelletized sewage sludge, split into 134 kg total N ha^{-1} before pasture sowing in 2004, and 93 kg N ha^{-1} in spring of 2006 and 2007 (PEL). Sewage sludge was applied superficially and the calculation of the required amounts was conducted according to the percentage of total N and dry matter contents [8] and taking into account the Spanish regulation (R.D 1310/1990) [9] regarding the heavy metal concentration for sewage sludge application. To estimate the effective exchange capacity (EEC) a composite soil sample per plot was collected at a depth of 25 cm, as described in the RD 1310/1990 [7] in January 2007. In the laboratory the soil samples were air-dried, passed through a 2 mm sieve and ground with an agate mortar. Then, an extraction with 0.6 N $BaCl_2$ was used to determine the concentrations of Al and the exchangeable cations (K, Ca, Mg and Na) [10]. The K, Ca, Mg and Na exchangeable concentrations were measured with a VARIAN 220FS Spectrophotometer using the atomic emissions for K and Na and the absorptions for Ca and Mg. The Al concentrations were analysed after valoration with 0.01 N NaOH using phenolphthalein (1%) in an alcohol-based solution as an indicator [10]. The EEC was determined by taking the sum of K + Ca + Mg + Na + Al and the saturation percentage of Al, K, Ca, Mg and Na using the quotients Al/EEC, K/EEC, Ca/EEC Mg/EEC and Na/EEC, respectively [10]. Annual pasture production was determined by taking four samples of pasture per plot at random (0.3 × 0.3 m^2) in April, June and November 2006. Data were analysed using ANOVA and differences between averages were shown by the LSD test, if ANOVA was significant [11].

Results and discussion

Figure 1 shows that the Ca saturated percentage in the soil exchange complex was lower when the pelletized (PEL) sewage sludge was applied compared with the other treatments (NF, MIN, ANA and COM) ($p<0.05$). The reduction of the Ca saturated percentage in the PEL treatment implied a higher Al saturated percentage in this treatment than in the NF treatment and when the composted (COM) sewage sludge was applied ($p<0.05$). These results could be explained mainly by the higher pasture production observed in the PEL treatment than in the rest of the treatments ($p<0.05$) (Figure 2) which increased the extraction of cations from the soil in the PEL treatment, being the cations of the exchangue complex replaced by the Al as observed [12] in a silvopastoral system established under *Pinus radiata* D. Don in a acid soil fertilized with different doses of anaerobic sewage sludge (160, 300 and 480 kg N ha^{-1}). In this experiment, the increase of the pasture production associated to the PEL treatment could be due to the fact that pelletized sludge (PEL) was applied splitted in different years, which probably implied a better incorporation into the soil, increasing availability of cations to plants and reducing losses of nutrients. The positive effect of the fertilization with pelletized sewage sludge on pasture production compared with anaerobic and composted sludge was previously described by other authors in silvopastoral systems established in the same area with *Fraxinus excelsior* L. [13]. Moreover, the variation of the Ca saturated percentage in the soil exchange complex found between the three types of sludge analysed in this study could be also explained by its different composition and rate of mineralization [8]. The dose of composted sludge applied was higher to meet the N required by crops [8] than the dose of anaerobic or pelletized sludge which implied that the COM treatment added to the soil around 1770.34 kg Ca ha^{-1}; meanwhile, only 90.53 and 849.11 kg Ca ha^{-1} was added with the ANA and PEL treatments, respectively. Finally, it is important to be aware that in spite of the higher levels of Ca inputs in those plots receiving pelletized sludge than anaerobic sludge, these plots had a lower Ca saturation percentage in the soil exchange complex, probably due to the higher pasture cation extraction because the pasture production was almost double in the PEL treatment than in the ANA treatment.

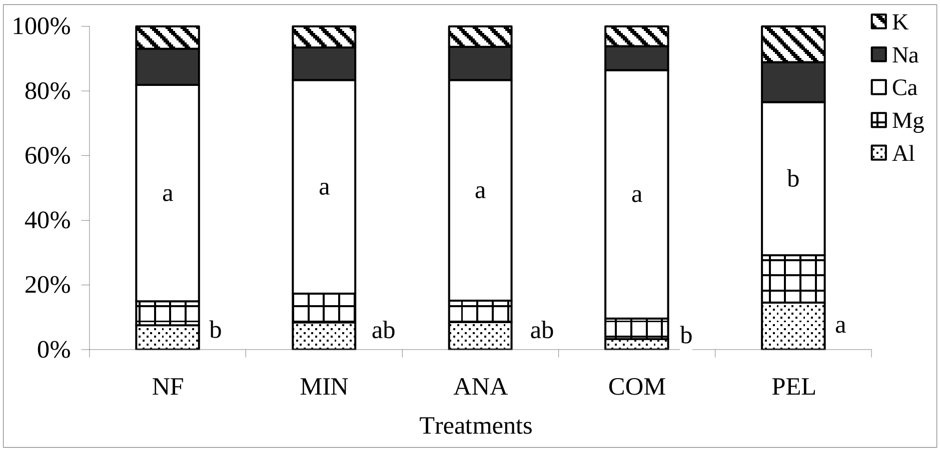

Figure 1. Saturation percentage of Al, K, Ca, Mg and Na in soil exchange complex (%) under each treatment. NF: no fertilization, MIN: mineral; ANA: anaerobic sludge, COM: composted sludge and PEL: pelletized sludge. Different letters indicate significant differences between treatments.

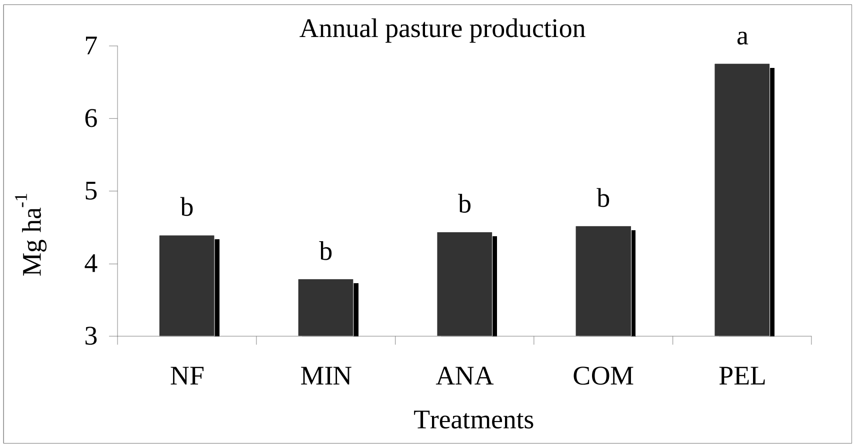

Figure 2. Annual pasture production in 2006 (Mg ha^{-1}) under each treatment. NF: no fertilization, MIN: mineral; ANA: anaerobic sludge, COM: composted sludge and PEL: pelletized sludge. Different letters indicate significant differences between treatments.

Conclusion

The application of the dose of pelletized sewage sludge in several times implied an increase of pasture production in the understory which reduced the Ca saturated percentage in the soil exchange complex and therefore increased the Al saturated percentage compared with the other types of sewage sludge evaluated. Pelletized sludge should be recommended among all the types of sludge tested, as it increases pasture production and its lower proportion of water than anaerobic sludge and composted sludge reduces application and storage costs.

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