Effect of date of sewage sludge application on tree growth and pasture production in a *Pinus radiata* D. Don silvopastoral system

Mosquera-Losada M.R.[1*], Freitas A.P.[1;2], Ferreiro-Domínguez N.[1], Rigueiro-Rodríguez A.[1]
(1) Crop Production Departament. Escuela Politécnica superior. Universidad de Santiago de Compostela, 27002-Lugo, Spain.
(2) Faculdade de Ciências Agrárias e Veterinárias. Unesp, 14884-900 -Jaboticabal, Brasil
* Corresponding author: mrosa.mosquera.losada@usc.es

Abstract

Several studies have demonstrated that using sewage sludge as a fertilizer in silvopastoral systems increases both the production of pastures and the growth of trees. However, it is important to determine the appropriate period for sludge application. If sewage sludge is applied too early, nutrients can be leached and if it is too late, early use of nutrients is reduced and therefore growing season shortened. The objective of this study was to evaluate the effect of sewage sludge (100 kg N ha-1) at different dates (December, January, February and March) compared with the control treatments (with and without mineral fertilizer) on the growth of *Pinus radiata* D. Don trees and pasture production in Galicia (Spain). It was observed that if sewage sludge is applied on February this caused an increase pasture and tree growth, compared with those treatments fertilized in December.

Introduction

The integration of components livestock, agriculture and forestry is important for promoting sustainable development, animal welfare and increasing pasture production periods. Understanding how the tree component could contribute to existing production systems enables the development of technical work for the introduction and / or improvement of forestry practices and / or agroforestry on farms.

The trend in recent years of the distribution of land use in Galicia, northwest of Spain, indicates a continued growth of land devoted to forest use, demonstrating also that the area required for grazing suffers a slight increase [1] which, although not sufficient to sustain the increasing number of livestock in the region.

Fertilization practices are tools needed to compensate extractions made by the trees and pasture in silvopastoral systems while increasing the pasture production and quality. The evaluation of the effect of improving soil fertility on pasture production and tree growth is more important when trees are established, due to the high sensibility of trees in this time to pasture development.

The use of adequate doses of sewage sludge as fertilizer supplies the needed nutrients to the soil, thus ensuring increased productivity of pasture while alleviating the problem of deposit of waste through reuse and recycling of nutrients.

Proper management of sludge as fertilizer should be based on optimizing its use (dose and time of application), by balancing the needs of the pasture and trees, besides increasing nutrients to the soil, so that does not produce damage to the environment [2] [3].

The objective of this study was to study the effect of the sewage sludge application date at a dose of 100 kg N ha-1 on the soil, tree growth and pasture production in a silvopastoral system.

Material and Methods

The experiment was established in the Spring 2001, in Lugo (NW Spain 43º14'N, 7º 21' W, 450 metres above sea level). This area is within the Atlantic biogeographic region and it is characterised by an average annual rainfall of 1086 mm and an average annual temperature of 11.5 ºC. The soil in the area of the experiment was an abandoned agricultural soil with a sandy texture, an acid initial water pH of 5.2 and a high percentage of organic matter (8%). In 2001, the experimental area was divided into 30 plots of 150 m2 delimited by plantation lines, in which 25 one year old trees (5x5) of *Pinus radiata* D. Don were planted in March of 2001, at a density of 1,667 trees per hectare (frame of 3 x 2 m). Later, in October 2001 the area was hand with 12.5 kg ha-1 *Lolium perenne* variety Brigantia, 12.5 kg ha-1 *Dactylis glomerata* variety Ártabro and 4 kg ha-1 of *Trifolium repens* cv Huia.

At the end of 2001, six treatments were applied, arranged following a randomised block desing with three replicates. Treatments consisted o applying 1) no fertiliser (NF); and applications of sewage sludge with which 200 kg total nitrogen ha-1 incorporated on four different application dates: 2) December (F1), 3) January (F2), 4) February (F3) and 5) March (F4); and 6) mineral fertiliser (MIN), consisting of the application each year of 500 kg ha-1 of a compound mineral fertiliser 8:24:16 (N:P2O5 K2O) in March. The applications of sewage sludge and inorganic fertiliser were repeated during the three consecutive years 2002, 2003 and 2004. The fertilisation with sludge in the first application of the second year (December 2002 (F1)) could not be carried out due to technical problems (loading). Sewage sludge fulfil all Spanish (RD 1310/90) requirements to be used in agriculture. Results from the first years of this study can be seen in [4].

Tree heights were measured in the nine inner trees of each experimental unit in order to avoid the "border effect" by using a pole in 2006.The production of pasture was estimated by collecting four random samples from each plot (between the central trees), using a 0.30 x 0.30 surface square and battery driven hand shears. These samples were transported to the laboratory and weighed whilst fresh. Afterwards, 100 grams were separated from each sample and oven-dried to determine their dry weight (60 ºC x 48 hours) and dry matter production. The dates of the sampling in 2002 and 2003 were June and November, coinciding with summer and autumn. In the third, fourth and fifth year (2004, 2005 and 2006), three harvests of grass were made (May, July and November) coinciding with spring, summer and autumn. Once the plots had been sampled, the grass was mowed and removed from all the experimental units.

The results obtained were statistically processed using ANOVA and the measurements were separated using the LSD Test with the Statistical Packet SAS.

Results

A very long period of drought was found in 2006 lasting from May to July. Figure 1 shows that tree growth was promoted when sewage sludge was applied in February when compared with control or with the first date of sewage sludge application (December). However, tree height growth was similar when sewage sludge was applied in January, February or March or when mineral fertilization was added to the soil.

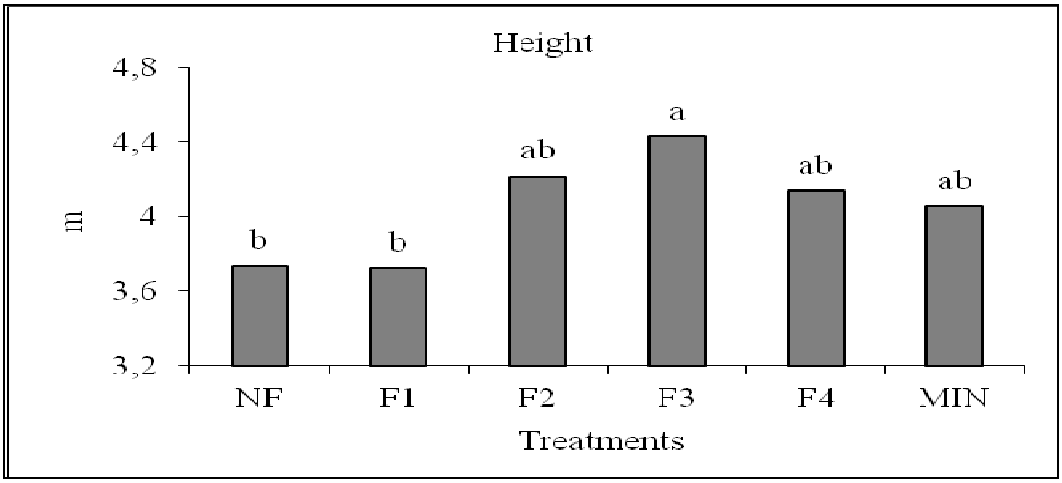

Figure 1. Height (meters) of *Pinus radiata* trees measured in 2006. Means with the same letters in columns do not differ among themselves by Tukey test (5%). NF: No fertilization; F1: sewage sludge applied in December; F2: sewage sludge applied in January; F3: sewage sludge applied in February; F4: sewage sludge applied in March; MIN: Mineral fertilizer

Annual pasture production was low in 2006 when compared with the previous years due to the long drought period found during the summer, but also due to the shade generated by the development of the trees which reached 4 m of height in all treatments with the exception of NF and F1. Figure 2 shows that annual pasture production was significantly higher if sewage sludge was applied in December or if MIN was added to the soil. NF treatmens also provided high pasture production.

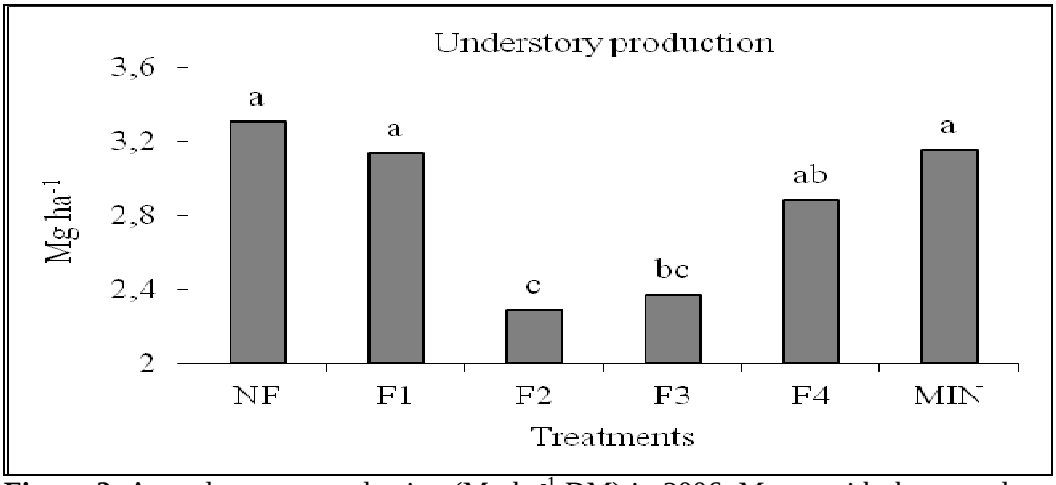

Figure 2. Annual pasture production (Mg ha^{-1} DM) in 2006. Means with the same letters in columns do not differ among themselves by Tukey test (5%). NF: No fertilization; F1: sewage sludge applied in December; F2: sewage sludge applied in January; F3: sewage sludge applied in February; F4: sewage sludge applied in March; MIN: Mineral fertilizer

The lack of fertilization caused a reduction of tree growth in NF fertilizer which improved the amount of light reaching the soil, therefore increasing pasture production five years after plantation. The use of early dates for applying sewage sludge increased the availability of nutrients which was used by the pasture reducing initially tree growth. This also caused an improvement of the light reaching the soil and therefore causes an increase of pasture production five years after plantation. Shade reduced the amount o pasture production when the sewage sludge was applied later because o tree growth increases. Both F4 and MIN behaved intermediately as tree growth was not significantly higher than NF of F1 treatment and therefore pasture production was not so negatively affected when compared with F2 and F3.

Conclusion and perspectives

The use of fast growing species like *Pinus radiate* D. Don and its promotion through the adequate use of fertilizer decrease pasture production by 42% five years after planting, which makes advisable to use low tree initial density to make more compatible pasture and tree production from the same piece of land.

Acknowledgements

We are grateful to the CICYT, to the Escuela Politécnica Superior de Lugo for facilities; and to José Javier Santiago Freijanes, Teresa Piñeiro López, Divina Vázquez Varela, and Pablo Fernández Paradela for their help in processing and laboratory work.

References

[1] RIGUEIRO-RODRÍGUEZ, A. Sistemas silvopastorales en la Iberia Atlántica. XL Reunión Científica de la Sociedad Española para el Estudio de los Pastos. p. 649-657, 2000.

[2] MOSQUERA LOSADA, M. R., RIGUEIRO-RODRÍGUEZ, A., LÓPEZ-DÍAZ, M. L. Sewage sludge fertilization of a silvopastoral system with pines in northwestern Spain. **Agroforestry Systems**. n. 53, p. 1-10, 2001a.

[3] EGIARTE, G., CAMPS, M., ALONSO, A., RUÍZ-ROMERA, E., PINTO, M. Effect of repeated applications of sewage sludge on the fate of N in soils under Monterey pine stands. **Forest Ecology and Management**; n. 216, p.257-269, 2005.

[4] RIGUEIRO-RODRÍGUEZ A, CASTRO, S., MOSQUERA-LOSADA, M.R. Effects of dose and period of sewage sludge application on soil, tree and pasture components in a Pinus radiata D. Don silvopastoral system **Agroforestry Systems**. N 79, P.237-247, 2010.