MANAGEMENT OF SOIL FERTILITY AND GRASS-PINE INTERACTIONS IN SILVOPASTORAL SYSTEMS

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ABSTRACT
The objective of this work was to study the response of a silvopastoral system (soil fertility, pine and grass growth) to different levels of amendments and fertilizer and to evaluate the interaction between grass and pines. Since 1994, five treatments including two Linz-Donawitz (LD) slag doses, NPK fertilizer and a combination of LD slag and NPK fertilizer were applied every year on a pinewood stand (7-8 year old, and 4*4 average spacing), repeating the treatments in two areas, one, sown with productive grass and legume species, and, the other, maintaining the spontaneus species. Soil pH increased 0.46 units with application of LD slag. The joint application of LD slag and NPK fertilizer produced a higher increment of soil P (15.5 mg/kg from 0 mg/kg) than the application of NPK fertilizer alone. There is a slight accumulation of soil Mn (535 mg/kg) due to the high amounts of slag added. Pine height and diameter growth is enhanced by the slag but the NPK fertilizer produced the higher increments, being more important in response in the unsown area than in the sown area.

INTRODUCTION
In the Basque Country radiata pine is the most widely planted tree species and plantations are located usually on low fertility soils with steep slopes. The establishment of grass cover at the time of plantation may play an important role in protecting soil from erosion due to run off. Because pasture and trees are grown in association they will compete for space, light, water and available nutrients, thus is necessary to increase soil fertility to enhance pasture establishment under the tree and to study the ability of pasture species to become established alond tree plantations. Previous research by the authors (Pinto *et al*, 1995) has shown the ability of LD-slag (a by-product of the iron and steel-making industry composed mainly of 40% CaO, 20% Fe compounds, 8% MgO, 4% MnO) to be used as a liming agent suggesting the possibility of its use as a base for fertilizer mixtures to be applied in agroforestry systems established on acid soils.

MATERIALS AND METHODS
In 1994 a field assay was established in a young pinewood stand (7-8 years old) at Mendata (Bizkaia, Northern Spain). The soil was a Dystric Regosol (FAO, 1991) with a pH of 4.0, 88% Al saturation percentage, negligible P Olsen and low levels of K and Mg. This pinewood stand was cleaned of ferns and branches and thinned up to 4*4 m average spacing. It was split in two areas, one, sown with a mixture of cocksfoot (*Dactilys glomerata*), white clover (*Trifolium repens*), perennial ryegrass (*Lolium perenne*), Italian ryegrass (*Lolium multiflorum*), birdsfoot (*Lotus corniculatus*) and browntop (*Agrostis tenuis*) and, the other, unsown, spontaneous pasture dominated by *Agrostis curtisii*, *Molinia caerulea* and *Festuca rubra*. In both areas in a design of complete randomized blocks with four replicates, five fertilizer treatments were applied: (1) Control, (2) 750 kg CaO/ha as LD slag, (3) 1500 kg CaO/ha as LD slag, (4) 40-90-90 kg N, P_2O_5 and K_2O/ha, respectively and (5) treatment 4 (40-90-90) plus treatment 3 (1500 kg CaO/ha). In the second year (1995), the liming treatments were the same but the fertilizer treatment was reduced to 40-30-30 (N, P_2O_5 and K_2O respectively) because of the increase of soil nutrient levels due to the first year fertilizarion. Nitrogen was applied as ammonium sulphate, P as superphosfate (18% P_2O_5) and K as potassium chloride 60%. Soil samples were collected at the beginning of the trial and every autumn from 0-5 cm and 5-25 cm depth to determine pH, P, K, Ca, Mg, Al%, Fe, Mn, Cu, Zn. Pine height and diameter were measured every June and December. Herbage yield was measured by exclusion cages (0.5*1 m) cutting being done according to herbage growth.

RESULTS AND DISCUSSION
Soil parameters. Two year after the establishment, the treatments have a significant effect ($P<0.001$) on soil pH and percentage Al saturation, and P, Ca, Mg and Mn contents (Table 1). The high amount of Ca supplied with the LD slag produced a strong increment in soil exchangeable Ca and, consequently, Al % decreased notably. It must be noticed that in the Control and NPK treatments a decrease in soil pH (4.00 to 3.75) was recorded likely because cations uptake related to plant (pine and grass) growth and cation lixiviation were not compensated with the external application of Ca. In the present experiment, an application of 1500 kg CaO/ha increased an average of 0.54 soil pH and decreased in a 68.5% the Al percentage of saturation. However, in previous experiments in pastures, using the same liming material, showed a stronger increase in soil pH and, as in the present case, a slightly lower increase when the liming agent was applied with fertilizer (Pinto et al. 1995). Soil Ca and Mg increased when greater doses of LD slag were supplied, because greater amounts of Ca and Mg were added and this was reflected in their soil contents.

As it was expected, soil P increased with P application (Treatments 4 and 5) but the increment was clearer ($P<0.001$) when the liming treatment was applied together with the fertlizer. As slag LD does not contain any P, this significant difference must be due to the lower soil acidity which favours P availability in a very important way or to the lower tree growth for the Treatment 5 respect to Treatment 4 which would be related to a lower P uptake in the Treatment 5.

Soil Mn was measured because of its relatively high content in LD slag. In Table 1 the increment in soil can be seen. Manganese was very important, especially in the case of the highest LD slag doses together with the NPK fertilizer. The same effect was recorded in pastures where the Mn accumulation caused a slight toxicity in white clover, especially when the associated soil pH was low (< 5.5) and so the Mn availability conditions were enhanced (Rodríguez *et al.* 1994).

Pasture and Pine production. In Figure 1 is shown the effect of treatments on pine growth in both areas (sown and unsown). On one hand , the main effect was due to the NPK fertilizer which produced the higher increments for the diameter and for the height in both areas. Other authors have reported similar responses of pine to P supplies (Turner and Lambert, 1986). On the other hand, the liming agent had a positive effect on height and diameter, especially when the sown area was considered. It may be due to the extra N that white clover could supply or to the slightly lower herbage yields that have been recorded in this area (an average 2151 kg DM/ha vs 2538 kg DM/ha for the sown and unsown area, respectively). In the case of NPK treatment, the herbage yield in the unsown area was 2916 kg/ha and in the sown area 1961 kg /ha. This fact could justify a greater availability of nutrients for the pine in the sown areas and so, perhaps, larger pine growth, especially for the Treatment 5.

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Table 1
Soil P, Ca, Mg and Mn contents in the second year of the experiment

	Al%	P (mg/kg)	Ca (meq/100 g)	Mg (meq/100g)	Mn (mg/kg)
Control	59.3a	3.69c	2.24c	0.78a	25.51c
750 kg Ca/ha	34.5b	3.12c	6.60b	0.91a	212.1b
1500kg Ca/ha	21.3c	3.19c	9.53a	0.95a	332.1b
NPK	53.3a	10.75b	3.15c	0.49b	49.9c
1500+NPK	17.6c	15.65a	11.06a	0.94a	525.9a

Treatments with different letter are significantly different, P<0.05.

Figure 1
Increases in pine diameter and height due to LD slag and fertilizer applications in sown and unsown areas the second year of the experiment