COMPARING EFFECTS OF MINERAL FERTILIZATION AND DAIRY SLUDGE APPLICATION ON SOIL METAL CONTENT IN SOWN MEADOWS

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1 INTRODUCTION

The dairy industry produces large volumes of wastewater containing cleaning products and milk residues, which usually undergo different treatments and yield a semi-liquid sludge as by-product. Recycling dairy sludges as fertilizers in agricultural land is a good method of disposal for these waste products, as they can provide the soil with N and P while having low K and metal content (Sommers, 1997). There is no specific legislation for dairy sludges and, by default, their use as fertilizers is governed by Directive 86/278/EEC, which encourages the use in agriculture and establishes strict limits on metal contents for sewage sludges (Commision of the European Communities, 1986).

In Galicia (NW Spain), the dairy sector produced 2280 million litres of milk in 2007, which represents almost 30% of the Spanish production (Ministerio de Medio Ambiente y Medio Rural y Marino, 2008). Main forage crops at dairy cattle farms in Galicia are sown meadows, Italian ryegrass and maize, which are usually fertilized with mineral fertilizers and/or cattle slurry. An agroindustrial sludge produced by a dairy plant has been regularly applied to sown meadows as fertilizer over the last 18 years, thus reducing the input of mineral fertilizers in receiving farms. In this sludge, K content is rather low, so that its use as fertilizer requires K supplementation (López-Mosquera et al., 2005). Although dairy sludges have low metal content (López-Mosquera et al., 2005), the possibility of metal accumulation in soil with regular use of these residues can not be discounted. In the present study, the effects of a dairy sludge applied to an acid soil, with or without K supplementation, on soil metal content were compared with those of mineral fertilization commonly used in sown meadows in northwestern Spain over a two-year period.

2 MATERIALS AND METHODS

A field trial was carried out at Goiriz-Lugo (NW Spain). The soil was a humic Umbrisol, which had been limed and fertilized with 600 kg ha^{-1} of a 8-24-16 NPK mineral fertilizer before sowing a mixture of perennial ryegrass (*Lolium perenne* cv. Barbestra) and white clover (*Trifolium repens* cv. Huia). Before establishing the experimental treatments, the soil had the following characteristics: pH (H_2O) 5.52, Olsen P 20.6 mg kg^{-1}, K 0.18 $cmol_c$ kg^{-1}, Ca 1.26 $cmol_c$ kg^{-1}, and Mg 0.66 $cmol_c$ kg^{-1}. It was very low in K and had a strong P retention.

At the beginning of the first growing season, sixteen plots of 400 m^2 were established in order to apply randomly four fertilizer treatments: an unfertilized control, dairy sludge, dairy sludge supplemented with K, and mineral fertilizers. Application dates and doses of fertilizers applied in each treatment are shown in Table 1. Metal contents in the dairy sludge used in each application were far below the limit values for metal concentrations in sludge for use in agriculture established in the Directive 86/278/EEC (Table 2).

During two growing seasons (first and second production year of the sown meadow), a silage cut was made in May. After mowing forage, in each plot soil samples were taken with a 7 cm diameter corer up to a 15 cm depth, then air-dried and sieved through a 2 mm mesh. The concentrations of Cd, Cr, Cu, Ni, Pb and Zn were determined by atomic absorption spectrometry in extracts obtained by digestion of soil samples with 70% nitric acid for 30 min in a Milestone Ethos 900 microwave oven (Tessier et al., 1979). The digestion procedure was quality-controlled by parallel analysis of the BCR-certified reference material BCR 143R. Results were subjected to a one way ANOVA and means were compared by the LSD test at $P<0.05$.

TABLE 1 **Application dates, and types and doses of fertilizers applied in treatments.**

Treatment	**Spring 1st year**		**Spring 2nd year**
	17th March	22nd June	22nd March
Control	---	---	---
Mineral	675 kg ha $^{-1}$ 15-15-15 NPK fertilizer	292.5 kg ha $^{-1}$ calcium ammonium nitrate (20.5 %N) 120 kg ha $^{-1}$ K_2SO_4 (50%)	675 kg ha $^{-1}$ 15-15-15 NPK fertilizer
Dairy sludge	80 m^3 ha $^{-1}$ dairy sludge	80 m^3 ha $^{-1}$ dairy sludge	160 m^3 ha $^{-1}$ dairy sludge
Dairy sludge + K	80 m^3 ha $^{-1}$ dairy sludge 175 kg ha^{-1} K_2SO_4 (50%)	80 m^3 ha $^{-1}$ dairy sludge 120 kg ha $^{-1}$ K_2SO_4 (50%)	160 m^3 ha $^{-1}$ dairy sludge 137.5 kg ha $^{-1}$ K_2SO_4 (50%) 235 kg ha $^{-1}$ superphosphate (18%)

TABLE 2 **Metal contents (mg kg^{-1}) of the dairy sludge applied over the study period on a dry matter basis, and EU limit values for metal concentrations in sludge for use in agriculture applied in soils with pH<7 (Directive 86/278/EEC).**

		Metal content (mg kg^{-1})					
		Cd	Cr	Cu	Ni	Pb	Zn
Spring 1st year	**17th March**	0.2	17.3	47.8	8.9	13.7	427
	22nd June	0.4	20.2	65.9	12.9	15.3	475
Spring 2nd year	**22nd March**	1.0	12.7	28.5	19.0	19.0	444
EU limit values for metal concentrations		20	1000	1000	300	750	2500

3 RESULTS AND DISCUSSION

Dairy sludge was effective as fertilizer, as its application resulted in similar or higher forage production than mineral fertilizers (data not shown). In spite of different soil fertility conditions under the four treatments, there were no significant differences in soil metal contents neither the first nor the second year (Tables 3 and 4).

Results showed that application of dairy sludge did not even increase soil contents of Cd, Cr, Cu, Ni, Pb or Zn respect to the control, what can be explained by the low metal content of this agroindustrial residue.

TABLE 3 **Cd, Pb, Cu, Cr, Ni and Zn content in soils from plots under the different fertilization treatments after the silage cut of the first year. Within each soil, values of a parameter followed by a different letter are significantly different for p<0.05.**

	Cd	**Cr**	**Cu**	**Ni**	**Pb**	**Zn**
			mg kg^{-1}			
Control	0.45	22.85	3.72	10.87	11.00	32.33
Mineral	0.45	21.01	2.90	10.57	9.70	28.77
Dairy sludge	0.49	21.21	2.20	10.75	9.37	30.29
Dairy sludge + K	0.44	21.64	3.26	10.24	11.12	29.78

TABLE 4 **Cd, Pb, Cu, Cr, Ni and Zn content in soils from plots under the different fertilization treatments after the silage cut of the second year. Within each soil, values of a parameter followed by a different letter are significantly different for p<0.05.**

	Cd	Cr	Cu	Ni	Pb	Zn
			mg kg^{-1}			
Control	0.47	24.97	2.76	12.29	6.37	24.08
Mineral	0.43	24.11	3.81	12.26	7.12	23.72
Dairy sludge	0.37	22.90	3.46	12.25	8.50	24.82
Dairy sludge + K	0.46	22.59	3.25	11.44	6.87	20.29

The effects of dairy sludge on soil metal concentrations were thus far different to those produced by the application of sewage sludge. In field experiments, Wang et al. (2008) found that application of sewage sludge increased grass biomass, but also Cu, Pb, Zn and especially Cd concentrations in soil compared to the untreated control, concluding that the sludge was suitable for application to forestry and grasslands or nurseries where food chain contamination with cadmium is not a concern. These limitations can be ruled out when using dairy sludges as fertilizers.

4 CONCLUSIONS

Application of dairy sludge did not increase soil contents of Cd, Cr, Cu, Ni, Pb or Zn respect to the control during the two years studied, which can be explained by the low metal content of this agroindustrial residue.

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