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SEWAGE SLUDGE COMPOST FERTILIZER EFFECT ON MAIZE YIELD AND SOIL HEAVY METAL CONCENTRATION

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ABSTRACT

Studies were conducted to determine the use of an organic residue (sewage sludge compost) for four years (1996-1999), to study effects of sewage compost on crop yield and chemical properties of soil under field condition. Productivity studies showed that the greatest growth is obtained in mixed II treatment (12000 kg/ha sewage sludge compost plus 350 kg/ha urea) with 20 % more than mineral fertilization, followed by mixed I (8000 kg/ha sewage sludge compost plus 350 kg/ha urea) with 10 % more than mineral fertilization. No toxic effects arising from the heavy metals in the plant were observed. Moreover, the concentration of heavy metals in the soil are below Spanish and European legal limits.

Palabras clave: lodo biodegradado, reutilización, fertilización, producción, metales pesados, maíz

RESUMEN

Se realizaron ensayos con residuos orgánicos (biodegradados de sedimentos de aguas residuales) durante 4 años (1996-1999) para determinar el efecto del lodo biodegradado sobre la producción y las propiedades químicas del suelo. Estudios de productividad han demostrado que el mayor crecimiento se ha obtenido con el tratamiento mixto II (12000 kg/ha de lodo biodegradado más 350 kg/ha de urea) con 20 % más que la fertilización mineral, seguido del mixto I (8000 kg/ha lodo biodegradado más 350 kg/ha de urea) con 10 % más que la fertilización mineral. Con respecto al contenido en metales pesados, en ningún momento la aplicación de lodo biodegradado en un cultivo de maíz ha constituido un riesgo para la planta. La concentración de metales pesados en el suelo está por debajo de los límites legales permitidos en España y en el resto de Europa.

INTRODUCTION

Knowing of chemical composition of sewage sludges is of great importance when developing recommendations for the rates of sludge applications on agricultural land (Beltrán *et al*. 1999). At the present time, recommendations for sludge applications rates on land are based on the fertilizer values (N, P and K) and on the concentrations of trace metals present in sludge (Delgado *et al*. 1999). The metals of primary concern are Zn, Cu, Pb, Ni and Cd which, when applied to soils in excessive amounts, may reduce plant yields or impair the quality of food or fiber produced (Parr *et al*.1989).

On the other hand, repeated applications of compost from sewage sludges on agricultural soil have significant effects on the physical and chemical properties of soil (Redy and Overcash 1981, Okereke 1985). A considerable amount of research has been carried out in Europe in order to evaluate the effects of compost from sewage sludge on soil properties (Williams and Goh 1982, Sheiikh *et al.* 1990).

Organic matter deficit in Spanish soils has reached alarming levels, which are not higher than 1 % due to agricultural practices (Beltrán *et al.* 2000). Hence, a greater effort is needed to promote the conservation and enrichment of organic matter (Berry 1987). Nowadays sewage sludge recycling is one of the main options adopted in agriculture because sewage sludge compost is plenty of plant nutrients, especially N and P, and are an effective long-lasting amendment.

The purpose of present study was to determine the effect of sewage sludge compost on maize crop yield and on the chemical properties of the soil under field condition.

MATERIALS AND METHODS

The study was conducted for four years (1996-1999), at a cultivation area located in the province of Madrid, Spain. Maize (*Zea mays* L. var. Juanita) was grown in soil amended with a compost of sewage sludge obtained after an aerobic fermentation process of sewage sludges mixture from six waste water treatment plants in Madrid (Valdebebas, China Butarque, Rejas, Sur and Sur Oriental).

Three different treatments were applied (bottom dressing in March and cover dressing in May) to soil surface: mineral treatment (control) (Barrantes *et al.* 1992, Domínguez 1997), mixed I treatment and mixed II treatment (sewage sludge compost plus urea). The characteristics of treatments used were:

- Mineral treatment (Control) with basal dressing: 800 kg/ha of N (NH_4NO_3)-P ($CaHPO_4$)-K (KCL) (15-15-15) and top dressing: 350 kg/ha urea (46 %).
- Mixed I treatment with basal dressing: 8000 kg/ha sewage sludge compost and top dressing : 350 kg/ha urea (46 %).
- Mixed II treatment with basal dressing: 12000 kg/ha sewage sludge compost and top dressing: 350 kg/ha urea (46 %).

Table I shows the chemical composition of sewage sludge compost used in the trials (dry weight), the pH was obtained with the glass electrode, using a soil water suspension of 1:2.5 (w/v), electric conductivity was determined in conductivimeter (soil/water ratio, 1:5.0) 25 ºC, oxidable carbon by the Walkley-Black method (APHA, AWWA, WPCF 1992), total Kjeldahl nitrogen by Kjeldahl method (Hesse 1971) and P, K, Ca, Fe, Mg and heavy metals Cu, Pb, Cr, Zn, Ni and Cd concentrations were determined by atomic absorption spectroscopy (AAS) after mineralization with HNO_3 + $HCLO_4$ solution (Sims and Kline 1991).

TABLE I. CHEMICAL ANALYSIS OF THE SEWAGE SLUDGE COMPOST USED (1996, 1997, 1998 and 1999)

Characteristics	Sewage Sludge Compost*
Humidity (%)	21.5
pH (H_2O)	7.9
E.C. (dS/m)	4.6
Organic Matter (%)	36.6
Oxidable Carbon(%)	13.2
Total Kjeldahl Nitrogen (%)	2.5
Phosphorus (%)	3.0
Potassium (%)	0.4
Calcium (%)	7.1
Iron (%)	1.7
Magnesium (%)	0.9
Copper (mg/kg)	293.5
Lead (mg/kg)	194.0
Chromium (mg/kg)	279.5
Zinc (mg/kg)	1205.5
Nickel (mg/kg)	55.0
Cadmium (mg/kg)	3.5

* Mean of four years

Harvested plants were oven dried at 65 ºC, weighed for dry matter yield, ground and stored for analysis. The production and metal uptake of grain maize were analyzed after annual treatment (Chae and Tabutabai 1986).

Soil samples were brought from the field at depth 0-30 and 30-60 cm were taken from 30 sites (10 samples mineral treatment, 10 samples mixed I treatment and 10 samples mixed II treatment) for each depth in the winter of 1999, the samples were air-dried, passed through a 2 mm sieve and stored at 4 ºC.

RESULTS AND DISCUSSION

The factors studied were those related to production and quality of the maize grain and to the properties of the soil. Special importance was conferred to the possible contamination with heavy metals (factor that limits its use), especially in the plots with annual application of compost.

Table II shows the yield maize grain (kg/ha) in different treatments througout for the four years of the experiment.

TABLE II. MAIZE GRAIN YIELD IN DIFFERENT TREATMENTS DURING 1996 TO 1999 (kg/ha)

	1996	1997	1998	1999	Average production
Mineral	10148	13597	10006	11852	11401
Mixed I	11545	14117	11947	13565	12793
Mixed II	13818	15708	12840	13954	14080

TABLE III. ANALYTICAL CHARACTERISTICS OF MAIZE GRAIN IN 1999

Amended	Zn*	Cu*	Cr*	Pb*	Cd*	Ni*	P (%)	K (%)	Ca (%)
Mineral	18.83	2.46	2.29	0.50	0.0052	3.22	0.27	0.29	0.004
Mixed I	15.67	3.86	2.12	0.54	0.0050	3.01	0.22	0.26	0.003
Mixed II	14.33	4.36	2.75	0.67	0.0053	2.99	0.21	0.20	0.003

*heavy metals (mg/kg)

Production results showed that in mixed II treatment (12000 kg/ha sewage sludge compost + 350 kg/ha urea) average grain yield was 14080 kg/ha, a 23.5 % increase with respect to mineral treatment in mixed I grain yield that was 12793 kg/ha, a 12.2 with respect to the standard (Hernández *et al*. 1991).

Table III shows analytical characteristics of maize grain; no toxic effects arising from the heavy metals in the plant were observed.

Also, the purpose of the present study was to determine the effect of sewage sludge compost on several soil parameters (pH, E.C., organic matter, N, P, K, humic acids, fulvic acids and heavy metals). Although the annual application of the rate mixed II resulted in an important accumulation of heavy metals in the soil, never exceeded Spanish nor European limits (**Table IV**) (Guidi *et al.* 1990, Wagner 1993).

In **table IV** within each heavy metal, the means followed by the same letter are not significantly different (p>0.05), based on analysis of variance (ANOVA) multiple range tests. There are no significant differences for heavy metals lead, cadmium and chromium in anything for profile soil 0-30 and 30-60 because the results in all the treatments were: Pb < 3 mg/kg, Cd < 0.1 mg/kg and Cr < 3 mg/kg.

TABLE IV. HEAVY METALS IN SOIL PROFILE (mg/kg) IN 1999*

Amended	Mineral	Mixed I	Mixed II
		Cu	
0-30	5.30[a]	7.90[b]	10.70[c]
30-60	3.30[a]	3.35[a]	6.15[b]
		Zn	
0-30	31.40[a]	53.10[b]	70.90[c]
30-60	22.90[a]	24.00[b]	39.80[c]
		Ni	
0-30	6.65[a]	8.55[b]	10.45[c]
30-60	6.25[a]	6.15[a]	8.20[b]

* Each value represents the mean of 10 pots

Within each agronomic parameter (pH, E.C., total K-N, P, K and Ca), means followed by the same letter are not significantly different (p>0.05), based on analysis of variance (ANOVA) multiple range tests.

Within each type of organic matter (**Table V**), the means followed by the same letter are not significantly different (p>0.05), based on analysis of variance (ANOVA) multiple range tests.

TABLE V. AGRONOMIC PARAMETERS IN SOIL PROFILE (mg/kg) IN 1999*

	Depth (cm)	Mineral	Mixed I	Mixed II
pH 1:2.5 H_2O	0-30	8.59[a]	8.46[a]	8.26[b]
	30-60	8.25[a]	8.49b	8.40[b]
E.C.dS/m:1:5 H_2O	0-30	0.22[a]	0.27[b]	0.31[c]
	30-60	1.42[a]	0.47[a]	0.38[b]
Total K-Nitrogen (%)	0-30	0.13[a]	0.13[a,b]	0.15[b]
	30-60	0.07[a]	0.09[a,b]	0.11[b]
Phosphorus (%)	0-30	0.05[a]	0.11[b]	0.16[c]
	30-60	0.03[a]	0.04[b]	0.06[c]
Potassium (%)	0-30	0.50[a]	0.51[a]	0.52[a]
	30-60	0.44[a]	0.48[b]	0.49[b]
Calcium (%)	0-30	16.85[a]	17.37[a]	17.78[a]
	30-60	17.57[a]	17.93[a]	18.32[a]

* Each value represents the mean of 10 pots

The sewage sludge compost (**Table VI**) increases oxidable carbon and humic acids in the soil (Pagliai *et al*. 1981, Smith *et al*. 1993). No significant organic matter was detected in 30-60 cm depth.

TABLE VI. ORGANIC MATTER IN SOIL PROFILE (0-30 cm of depth) IN 1999*

	Mineral	Mixed I	Mixed II
Oxidable Carbon (%)	1.14[a]	1.29[b]	1.41[c]
Humic Acids (mg/kg)	1.39[a]	1.64[b]	1.74[b]
Fulvic Acids (mg/kg)	1.22[a]	1.22[a]	1.23[a]

* Each value represents the mean of 10 pots

ANALYSIS OF DATA

A statistic analysis of variance multiple range tests from agronomic factors, heavy metals and organic matter in soil profile was carried out for 1999 (**Tables IV**, **V** and **VI**). The conclusions from these analysis were:

For 0-30 cm depth: denotes a statistically significant difference ($p<0.05$) for nitrogen, pH, electric conductivity, oxidable carbon, humic acids, fulvic acids and heavy metals means (nickel, copper and zinc), and there is no statistically significant difference ($p>0.05$) for phosphorus, calcium and potassium.

For 30-60 cm depth: denotes a statistically significant difference for pH, electric conductivity, nitrogen, phosphorus, potassium, oxidable carbon, calcium and heavy metals (nickel, copper and zinc), and there is no statistically significant difference for lead, cadmium and chromium.

The results obtained show the effect of sewage sludge compost on chemical properties of the soil under field condition and confirm the possibility to use sewage sludge compost as fertilizer on maize.

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