Reuse of municipal sewage sludge in agriculture: the case of maize crop

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Keywords: recycling, arable crops, trace elements.

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Sewage sludge (SS), a common by-product of the municipal wastewater treatments, contains macronutrients and micronutrients essential for plant growth and is a potentially valuable source of organic matter for most agricultural soils (Tester *et al*, 1982). The application of SS to agricultural land is of particular importance in the Mediterranean area, where soils have been intensively cultivated for centuries and have typically low fertility and organic matter content. Although several studies on reuse of municipal SS in agriculture have been reported, the adoption of a plan for applying organic amendments to agricultural soils requires information regarding the effect of such amendments on any particular crop or environment. However, to our knowledge there is a void in the literature on field studies in dry, semi-arid Mediterranean-type environments (described as *xeric* in the Soil Taxonomy classification protocol), concerning the evaluation of the fertilizer value of organic amendments as compared to conventional fertilizer in maize, one of the common and very nutrient demanding crops in the area.

The purpose of this study was to investigate the response of maize to SS application, in terms of growth, productivity and nutrient accumulation under Mediterranean conditions, in comparison to the recommended inorganic fertilization for maize production in the area. In addition, the effect of SS application on trace element concentrations in soil and maize plants was examined.

Materials and methods

Two field experiments were conducted in Lepti, near Orestiada, in the area of North Evros in Greece during the 2012 and 2013 growing seasons. A representative soil sample from the selected field and a SS sample obtained just before each annual application were analyzed for the determination of selected physical and chemical properties.

The commercial maize hybrid 'Dekald 6040' (Monsanto) was used. Treatments consisted of three rates of SS, i.e. 20 (SS1), 40 (SS2), and 60 (SS3) Mg dry weight ha⁻¹ yr⁻¹ (corresponding to 150, 300 and 450 kg of N ha⁻¹ yr⁻¹, respectively), one rate of inorganic fertilizer (IF, 300 kg N ha⁻¹ yr⁻¹ plus 80 kg P_2O_5 ha⁻¹ yr⁻¹), and an unamended control (C, no addition of any type of fertilization). Sewage sludge was obtained from the wastewater treatment plant of the town of Orestiada, where waste waters are anaerobically treated, and was distributed and incorporated into the soil manually 2 weeks before sowing. The experiments were arranged in a randomized complete block design with four replications per treatment. Plots were 100 m² (10 x 10 m) and consisted of 13 rows spaced 0.75 m apart. The sowing was done on 24 April 2012 and 12 May 2013. Common agricultural practices for maize production in the area were used (e.g. weed control, artificial irrigation etc.).

Plant samples, composed of a row 1 m long, were taken at anthesis and maturity from each plot. Dry matter and nutrient concentrations in maize was determined. All plant samples were oven-dried at 70 °C to constant weight, weighed and ground in a Wiley Mill to pass through a 0.4 mm screen. Nitrogen concentration in plant samples was determined by the standard macro-kjeldahl procedure. Soil samples (one composite sample obtained from 3 core subsamples per plot, at 0-20 cm depth) were also obtained after maize harvesting the first year. Trace element concentrations from soil and plant samples were determined by atomic absorption spectrophotometry.

Results and Discussion

The application of SS showed a beneficial effect on maize growth and productivity as indicated by the greater dry matter accumulation and grain yield compared with the unamended control (Table 1). Comparing the soil amended treatments, maize grain yields obtained with SS application were similar (SS1 and SS2) or greater (SS3) than those of IF. In the case of the greater SS application rate (SS3), the superiority of grain yield obtained was 57% in 2012 and 78% in 2013 compared with the addition of IF. These results are in agreement with those reported for wheat grown in soils amended with SS in the same area (Koutroubas *et al*, 2014). On the contrary, Fernández *et al*. (2009) reported that high rates (80 Mg ha⁻¹) of composted or thermally dried SS caused a significant decrease in barley yield. The discrepancy between the results may be due to the different types of sludge used in the two studies. The application of SS resulted in marginal differences among treatments in grain N concentration at maturity (Table 1). However, total N uptake at maturity (i.e. the product of dry matter accumulation and N concentration) showed a significant response to SS application (data not shown), similar to that observed for dry matter. The beneficial effect of SS application on plant growth and N uptake may be attributed to enhanced nutrient supply and improvement of the overall soil conditions for plant growth such as soil water holding capacity and aeration (Samaras *et al*, 2008).

Sewage sludge can contain trace elements that may adversely affect crops and also could transfer through the soil to plants and the food chain. In the present study, although the concentrations of total and DTPA-extractable trace element in the soil at the end of the first year of experimentation tended to increase with SS application, particularly at the high rates (data not shown), they were much lower than the regulation limits in all cases. In addition, concentrations of Fe and Mn in wheat plants were similar across treatments, or in the case of Zn did not exceed those obtained with IF

(Table 1). Other non-essential trace elements (i.e., Cr, Pb and Cd) were also measured in sewage sludge, but their concentrations were rather minimal, as would rather be expected for a small country town-derived sewage sludge. Thus, such elements were not further investigated.

Table 1. Dry matter accumulation at maturity,	, grain yield, gra	in N and Zn concer	tration for maize	grown under three
levels of sewage sludge (SS) application and v	vith inorganic fe	rtilizer (IF) for two	growing seasons i	n 2012 and 2013.

Dry matter				Grain N		Grai	Grain Zn		
	accumulation		Grain yield		concentration		concen	concentration	
Treatments	2012	2013	2012	2013	2012	2013	2012	2013	
	kg ha ⁻¹				mg kg ⁻¹				
Control	13439 c	12255 e	5741 c	4919 d	11.35 ab	11.48 ab	14.77 ab	19.18 ab	
SS1	24311 b	28561 c	9778 bc	11919 bc	12.45 a	12.45 a	10.54 b	12.77 b	
SS2	28168 ab	31712 b	13553 ab	13906 b	9.88 b	9.88 b	18.92 a	26.08 a	
SS3	32821 a	36593 a	16731 a	17988 a	11.25 ab	11.40 ab	12.00 b	17.13 ab	
IF	24003 b	23200 d	10674 b	10088 c	10.65 ab	11.05 ab	18.01 a	23.15 a	
Mean	24548	26464	11296	11764	11.12	11.25	14.85	19.66	

Different letters within each column indicate statistically significant differences at P=0.05.

In conclusion, results indicated that the application of SS, even at the lower rate (20 Mg dry weight ha⁻¹ yr⁻¹) resulted in grain yield similar to that obtained with the addition of IF. This SS application rate was proved to be agronomically efficient for maize crop in the area, while at the same time it could be more acceptable by the farmers and the public opinion compared to the higher rates. Thus, SS could successfully replace IF needed to meet the nutrient demands of maize crop in the area, without increasing trace elements concentration in soil and in plant tissues. However, more research is required to study potential health safety issues based on a long-term evaluation.

References

Fernández JM, Plaza C, García-Gil JC, Polo A (2009) Biochemical properties and barley yield in a semiarid Mediterranean soil amended with two kinds of sewage sludge. Appl Soil Ecol 42:18–24

Koutroubas SD, Antoniadis V, Fotiadis S, Damalas CA (2014) Growth, grain yield and nitrogen use efficiency of Mediterranean wheat in soils amended with municipal sewage sludge. Nutr Cycl Agroecosys 100:227–243

Samaras V, Tsadilas CD, Stamatiadis S (2008) Effects of repeated application of municipal sewage sludge on soil fertility, cotton yield, and nitrate leaching. Agron J 100:477–483

Tester CF, Sikora LJ, Taylor JM, Parr JF (1982) Nitrogen utilization by tall fescue from sewage sludge compost amended soils. Agron J 74:1013–1018

Acknowledgments

The research was funded by the Region of Eastern Macedonia & Thrace. The authors thank the Municipal Wastewater Treatment of the town of Orestiada for providing sewage sludge.