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The effects of biosolid application on soil chemical properties and *Zea mays* nutrition

Shahrzad Kabirinejad and Mehran Hoodaji*

Abstract

Background: The application of biosolid as a fertilizer in agricultural cultivation is a common practice in many countries. This study investigates the effects of sewage sludge and compost usage on soil chemical properties and *Zea mays* nutrition in comparison with those of iron and manganese sulfate solution. The experiment was carried out in a completely randomized block design with the following treatments: sewage sludge and compost with three levels (0, 25 and 50 $t\,ha^{-1}$) and iron and manganese sulfate solution (1 $g\,l^{-1}$ solution) with three replications.

Results: The application of sewage sludge (50 $t\,ha^{-1}$) had highly significant ($P < 0.01$) positive effects on cation exchange capacity and organic matter, total nitrogen, phosphorus, iron and manganese diethylenetetramine-penta-aceticacid-extractable in soil, and nitrogen, phosphorus, iron and manganese in plant. Also, compost application (50 $t\,ha^{-1}$) increased significantly ($P < 0.01$) the electrical conductivity in soil and potassium in soil and plant. Dry biomass increased significantly ($P < 0.01$) from 7.7 to 28.7 g per pot with sewage sludge application (50 $t\,ha^{-1}$).

Conclusions: Application of biosolid as fertilizer sources has become a common practice in Iran, especially in the agricultural lands. The reuse of these nutrients had some beneficial effects on soil fertility, such as increased cation exchange capacity, pH, organic matter, total nitrogen, phosphorous, iron and manganese. However, these benefits were limited by the presence of some potentially toxic trace metals in biosolid.

Keyword: Sewage sludge, Compost, Iron, Manganese, *Zea mays*, Plant nutrition

Background

Urbanization and industrialization processes always lead to increased production of waste, i.e., wastewater and solid waste such as sewage sludge and urban waste (compost). The advantages of reusing waste are providing a convenient disposal of waste products and having the beneficial aspects of adding valuable plant nutrients and organic matters to soil (Horswell et al. 2003). Sewage sludge and compost are beneficial soil amendments, especially for arable soils of inherently low organic matter content, as it may improve many soil properties, such as pH and the contents of organic matter and nutrients. The nutrient availability in soil depends on the nature of the chemical association between elements with the organic residual and soil matrix, the pH value of the soil, the concentration of the element in the compost and the sewage sludge, and the ability of the plant to regulate the uptake of a particular element (Smith 2009). Soil organic matter content from compost and sewage sludge has long been suggested as the single most important indicator of soil productivity (Haynes 2005).

Organic matter usage can cause positive effect on the physical, chemical and biological properties in the soil. Also, high attention to organic manure and replacing that with chemical fertilizer is necessary (Düring et al. 2003). In this respect, the use all of organic sources such as sewage sludge, compost and green fertilizer is necessary. The calcareous soil has more deficient macronutrients than acid soils, and low attention has been given to this subject. Therefore, the use of biosolid could be beneficial because they have large amounts of organic matter that can improve the soil structure and water-holding capacity (Giusquiani et al. 1995). As a resource, biosolid amendments present an attractive alternative for the improvement of agricultural land productivity due to its fertilizer value. Biosolid contain high proportions of nitrogen, phosphorus and organic matter (as much as six times more than that found in manure). The objective of this research was to quantify the effects of biosolid as nutrient

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sources by investigating the effects of sewage sludge and compost application on soil pH, electrical conductivity, organic matter, total nitrogen, phosphorus, potassium, iron, manganese and *Zea mays* nutrition in comparison with iron and manganese sulfate solution.

Results and discussion

The effects of treatments on soil chemical properties

The application of biosolid showed a tendency to increase organic matter (OM) (in percent), cation exchange capacity (CEC) and soil pH, an effect that was significant ($P < 0.01$) at the higher application rates (Table 1). Also, significant ($P < 0.01$) effect on electrical conductivity (EC) was found for the high compost application rates of 50 $t\,ha^{-1}$. The reason for the increasing soil pH and EC might be due to the increased soil organic matter and alkali metals at higher application rates of biosolid.

The effects of treatments on macro- and micronutrient concentrations in soil

The application of biosolid caused a significant ($P < 0.01$) increase of nitrogen, phosphorous and potassium contents in all treatments (Figure 1). The increase was related to the amount of biosolids applied. The highest N and P contents were obtained for the high sewage sludge application rates of 50 $t\,ha^{-1}$. Nitrogen and phosphorous contents increased from 9.5 and 44.5 mg kg^{-1} in the control to 22 and 73 mg kg^{-1} in the sewage sludge usage, respectively. Also, the K content increased significantly ($P < 0.01$) from 401 to 565 mg kg^{-1} for the high compost application rates of 50 $t\,ha^{-1}$. An increase in total organic matter and nitrogen through the application of biosolids has also been found in previous studies (Walter et al. 2000). However, (Garrido et al. 2005) did not find a significant increase in organic matter and total nitrogen, possibly because a lower biosolid rate (4.5 $t\,ha^{-1}$) was used in that study.

The concentrations of diethylenetetramine-pentaaceticacid (DTPA)-extractable Fe and Mn in soils were increased significantly by application of sewage sludge (50 $t\,ha^{-1}$) from 7.4 and 41 mg kg^{-1} in the control to 10.7 and 52.2 mg kg^{-1}, respectively (Figure 2). This was probably due to the high concentrations of Fe and Mn in the biosolids (Table 2).

The short-term (one-time) nature of biosolid application in these experiments may have contributed to the lack of a significant effect on these elements. Trace metals in biosolids are generally strongly sorbed to the biosolid matrix. Thus, trace metals added to soil with biosolids are less phytoavailable than those added as simple inorganic salts.

The effects of treatments on macro- and micronutrient concentrations in plant

The application of biosolids caused a significant ($P < 0.01$) increase of nitrogen, phosphorous and potassium contents in the plant shoot in all treatments (Figure 3). The increase was related to the amount of biosolids applied. The highest N and P contents were obtained for the high sewage sludge application rates of 50 $t\,ha^{-1}$. Nitrogen and phosphorous contents increased from 32 and 69 mg kg^{-1} in the control to 74 and 102.6 mg kg^{-1}, respectively. Also, the K content increased significantly ($P < 0.01$) from 375 to 579.1 mg kg^{-1} for the high compost application rates of 50 $t\,ha^{-1}$.

The concentrations of Fe and Mn in the plant shoot were increased significantly by the application of sewage sludge (50 $t\,ha^{-1}$) from 86.7and 60 mg kg^{-1} in the control to 125.4 and 81.7 mg kg^{-1}, respectively (Figure 4). This was probably due to the high concentrations of Fe and Mn in the biosolids (Table 2).

The effect of treatments on dry biomass

Biosolid application increased the dry matter of *Z. mays* (Figure 5). These growth parameters were obtained with increase as biosolid rates. The highest dry biomass was obtained for the high sewage sludge application rate of 50 $t\,ha^{-1}$. Application of sewage sludge (50 $t\,ha^{-1}$) significantly ($P < 0.01$) increased the shoot dry matter from 7.7 to 28.7 g per pot.

Conclusions

Application of biosolids as fertilizer sources has become a common practice in agricultural lands. The reuse of these materials had some beneficial effects on soil

Table 1 The effects of treatments on soil chemical properties

Treaments	Rate ($t\,ha^{-1}$)	OM (%)	CEC (Cmol kg^{-1})	pH	EC (dS m^{-1})
Sewage sludge	25	2.2^{a}	17^{ab}	7.8^{a}	2.1^{b}
	50	2.4^{a}	18.3^{a}	7.6^{a}	2.1^{b}
Compost	25	2.3^{a}	9.9^{d}	7.5^{a}	2.1^{b}
	50	2.3^{a}	16.5^{bc}	7.9^{a}	3.9^{a}
Iron and manganese sulfate	-	1.5^{b}	17.7^{ab}	7.8^{a}	2.1^{b}
Control	-	1.7^{b}	15.8^{c}	6.9^{b}	2.8^{b}

Different superscript letters indicate significant differences between treatments ($P < 0.01$). *CEC*, cation exchange capacity, *EC* electrical conductivity, *OM* organic matter.

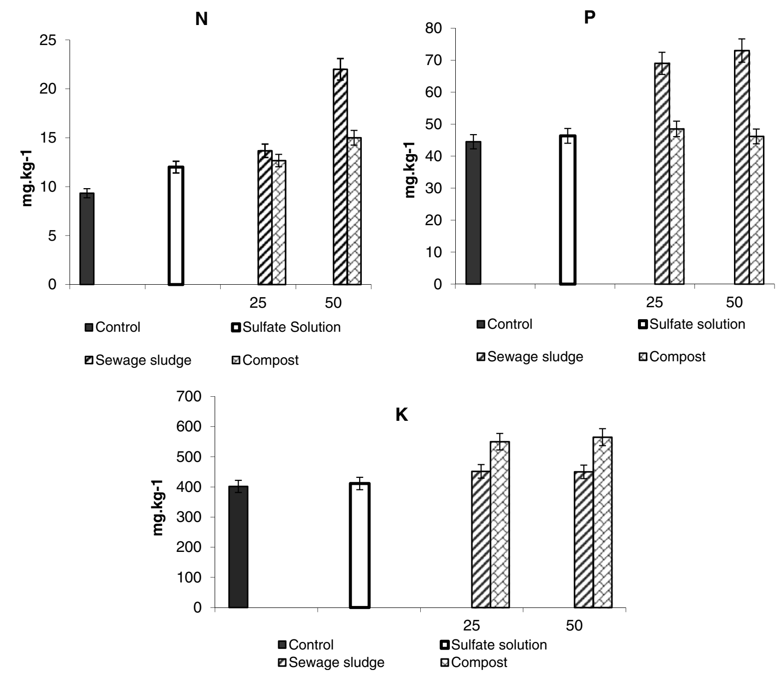

Figure 1 **The effects of treatments on macronutrient contents in soil.**

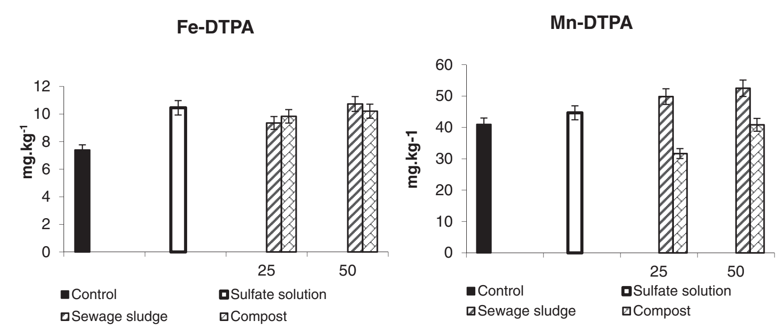

Figure 2 **The effects of treatments on the DTPA-extractable concentrations of Fe and Mn in soil.**

Table 2 Chemical properties of soil and biosolids

	pH	EC	CEC (Cmol kg^{-1})	OM (%)	N_T	P_{ava}	K	Fe	Fe_{DTPA}	Mn	Mn_{DTPA}
		(dS m^{-1})			(mg kg^{-1})						
Soil	7.6	1.4	14.3	1.1	13	52	600	255	6.8	439	34
Compost	7.5	11.5	23.6	35.6	130	1,430	3,900	915	-	42	-
Sewage sludge	6.4	8.5	35.7	48	240	3,400	3,100	3,425	-	76	-

CEC cation exchange capacity, *EC* electrical conductivity, *OM* organic matter.

fertility, such as increased organic matter, macro- and micronutrients. This study found that cation exchange capacity, pH, organic matter content, and total nitrogen, phosphorous, potassium, Fe and Mn were improved in soils treated with sewage sludge and compost. However, these benefits were limited by the presence of some potentially toxic trace metals in biosolids. The addition of biosolids, in the form of compost, also increased the soil EC. This was probably due to the short-term nature of biosolid application and the relatively low concentrations of these trace metals in the biosolids. International data on the total concentrations of macro- and micronutrients in biosolids were compiled and showed that all types of biosolids such as sewage sludge and compost

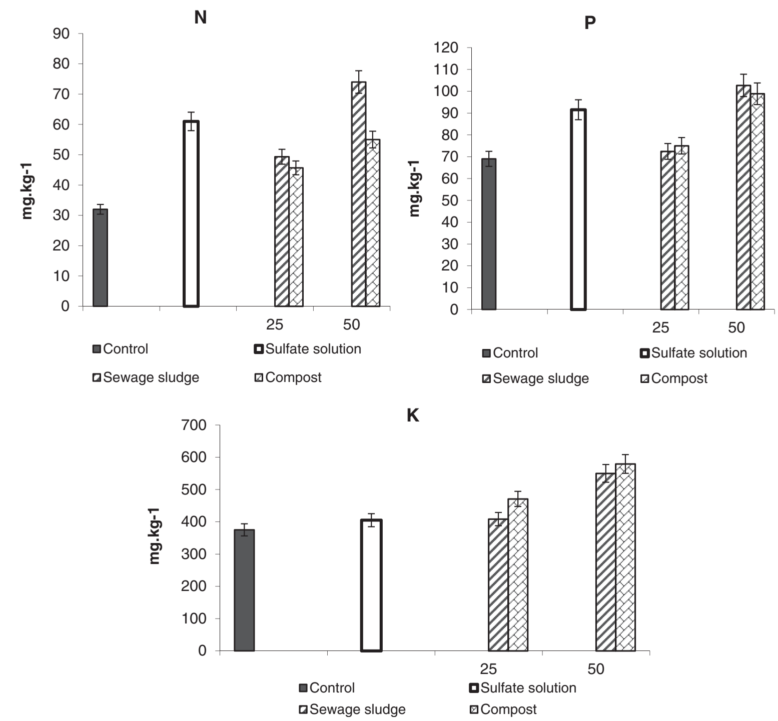

Figure 3 **The effects of treatments on macronutrient contents in plant shoot.**

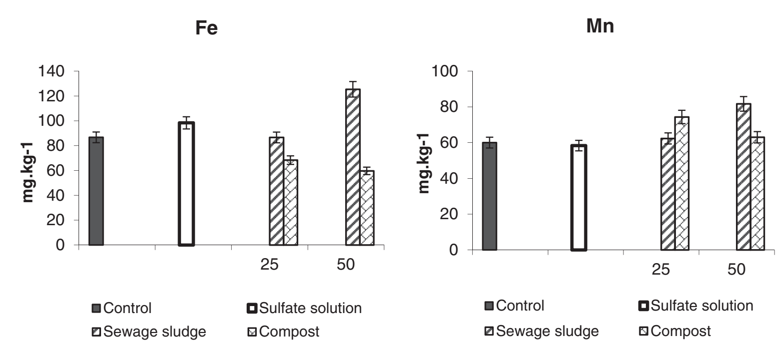

Figure 4 **The effects of treatments on the concentrations of Fe and Mn in the plant shoot.**

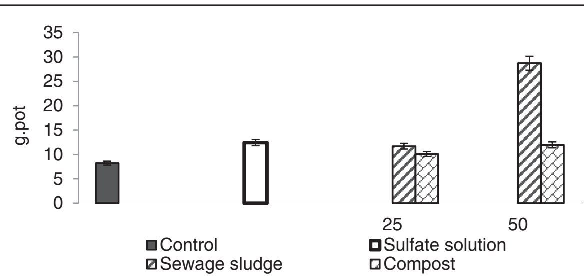

Figure 5 **The effect of treatments on dry biomass.**

contain high concentrations of macro- and micronutrients. Therefore, these elements will slowly accumulate in the soil following the long-term application of all types of composted biodegradable waste materials, and they can increase plant biomass. Consequently, there is evidence of accumulations of macro- and micronutrients in crop tissues which increase the application of biosolids to soil for increased plant yield. Micronutrients such as Fe and Mn may have a strong association with crop yield; however, there is evidence from short-term greenhouse studies that the bioavailability of macro- and micronutrients in biosolid-amended soil increases with high levels of biosolid instead of iron and manganese sulfate. There is good experimental evidence that bioavailability and plant uptake of micronutrients from biosolids were higher than other fertilizers such as iron and manganese sulfate. Biosolid provided the best results in terms of plant biomass and concentrations of macro- and micronutrients. Although biosolids have been demonstrated to be a useful nutrient source for agricultural soils, the beneficial properties of biosolids can, depending on their origin, be limited by their contents of potentially harmful substances. However, further researches under farm condition are needed to confirm the results obtained in this study.

Methods

Greenhouse study

Pot experiments were conducted in a randomized complete block design with three replications at the greenhouse of Islamic Azad University, Khorasgan branch. Experimental treatments were the following: sewage sludge and compost, with three levels (0, 25 and 50 $t\,ha^{-1}$), and compound of iron and manganese sulfate (1 $g\,l^{-1}$) in clay loam soil. Some soil chemical and biosolid properties were shown in Table 2.

Soil and fertilizer sampling

Soil samples were air dried, ground and passed through a sieve (2 mm) before analysis for the following parameters: pH and electric conductivity (solid/deionized water = 1:2 *w*/*v*); texture (hydrometer method); and organic matter (Walkley-Black wet digestion) (Lindsay and Norvell 1978), total nitrogen (Kjeldahl method) (Baumann 1885), potassium (flame photometry) (Chapman 1965), phosphorus (Olsen method) (Olsen and Sommers 1982), and the available Fe and Mn in soil, which were extactable by diethylenetetramine-penta-aceticacid (Pyddtt 1999). In biosolid, total N was determined by the micro-Kjeldahl method, K by flame photometry, P by the vanado-molybdate spectrophotometric method and Fe and Mn by atomic absorption spectrophotometer.

Plant analysis

Four seeds (*Z. mays*) were sown into pots (27 cm height × 25 cm diameter) and were irrigated with deionized water at field capacity. Plant shoots were harvested after 70 days, washed thoroughly with deionized water, oven-dried for 48 h at 75°C (Campbell and Plank 1998), weighed and then ground with an agate mortar to pass through a 2-mm sieve. Plant samples were digested using a mixture of acid ($HNO_3 + HClO_4$ (3:1, *v*/*v*)) (Ryan et al. 2001). Fe and Mn concentrations in the plant samples were determined by flame atomic absorption (FAAS, 3030, PerkinElmer, Waltham, MA, USA) (Allen 1989).

Statistical analysis

Statistical analyses were performed using SPSS 16 software, and comparison of means was done with Duncan test at 5% level.

Abbreviations

CEC: cation exchange capacity; DTPA: diethylenetetramine-penta-aceticacid; EC: electrical conductivity; OM: organic matter.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

SK performed the experiments and data collection. MH designed the experiment, gave supervision, analyzed the data and wrote the manuscript. All authors read and approved the final manuscript.

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