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

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Abstract

Background: The application of biosolids as a fertilizer in agricultural cultivation is common practices 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 iron and manganese sulfate solution. The experiment was carried out in a completely randomized block design with 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 , organic matter, total nitrogen, phosphorus, iron and manganese DTPA extractable in soil and nitrogen, phosphorus, iron and manganese in plant. Also compost application (50 t. ha^{-1}) increased significantly ($p< 0.01$) electrical conductivity in soil and potassium in soil and plant. Dry biomass increased significantly ($p< 0.01$) from 7.7 to 28.7 g pot^{-1} with sewage sludge application (50 t. ha^{-1}).

Conclusion: Application of biosolids 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 potential toxic trace metals in biosolids.

Key word: *Sewage sludge, Compost, Iron, Manganez, 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 that it provides a convenient disposal of waste products and has the beneficial aspects of adding valuable plant nutrients and organic matters to soil (Horewell et al.2003). Sewage sludge and compost are beneficial soil amendment, 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 nutrients 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 (Stephen and Smith 2008). Soil organic matter content from compost and sewage sludge as has long been suggested as the single most important indicator of soil productivity (Haynes 2005).

Organic matter usage can cause positive effect on physical, chemical and biological properties in the soil. Also the high attention to organic manure and replacement those with chemical fertilizer are necessary (During et al. 2003). In this respect, use all of the organic sources such as sewage sludge, compost and green fertilizer is necessary. The calcareous soil has more macro nutrients deficient than acid soils and low attention has to this subject. Therefore the use of biosolids could be benefit, 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, biosolids amendments present an attractive alternative for the improvement of agricultural land productivity due to its fertilizer value. Biosolids contain high proportions of nitrogen, phosphorus, and organic matter (as much as six times that found in manure). The objective of this research was to quantify the effects of biosolids as nutrient sources by investigating the effects of sewage sludge and compost application on ;(i) soil pH, EC, organic matter, total nitrogen, phosphorus, potassium , iron and manganese and *Zea mays* nutrition in comparison with iron and manganese sulfate solution

Results and discussion

1. The effects of treatments on soil chemical properties

The application of biosolieds showed a tendency to increase of organic matter (OM %), cation exchange capacity (CEC) and soil pH, an effect that was significant ($P < 0.01$) at the higher application rates (Table 2). Also significant ($P < 0.01$) effect on electrical conductivity (EC) was found for the high compost application rates of 50 ton ha^{-1}. The reason of increasing soil pH and EC might is due to increased soil organic matter and alkali-metals at higher application rates of biosolids.

Table 2. The effects of treatments on soil chemical properties. Different superscript letters indicate significant Differences between treatments (P<0.01)

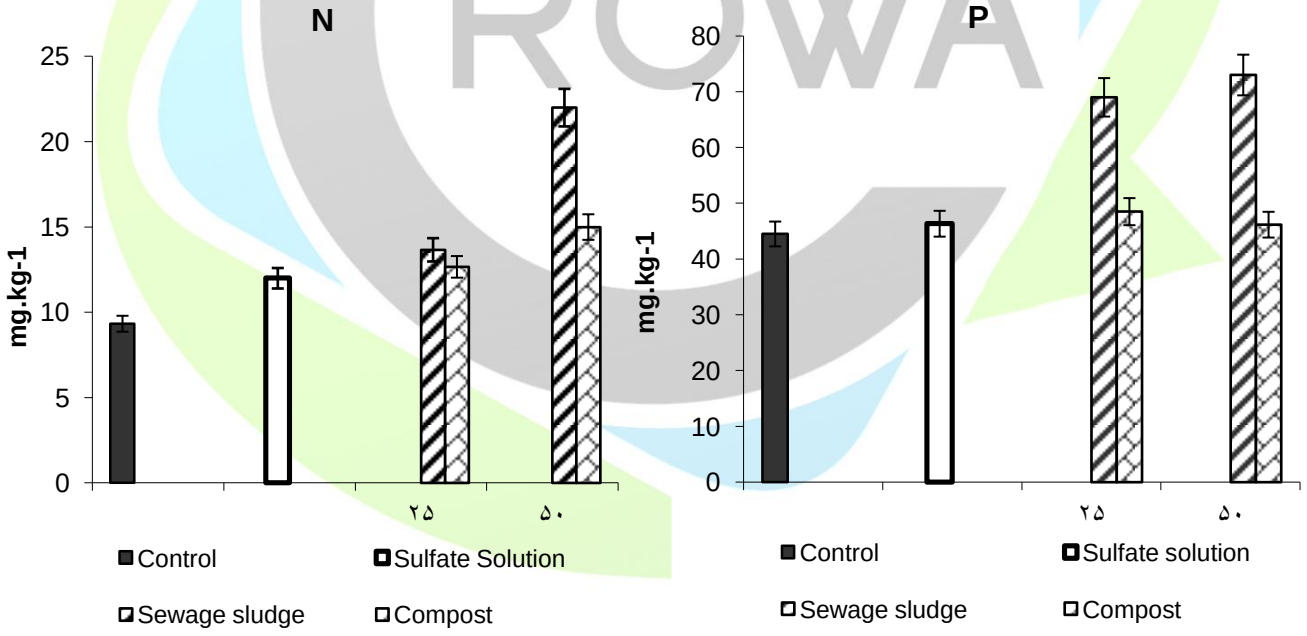
Treatments	*Rates (ton ha^{-1})*	*OM (%)*	*CEC ($Cmol^{+}kg^{-1}$)*	*pH*	*EC (dSm^{-1})*
Sewage sludge	25	2.2^{a}	17^{ab}	7.8^{a}	2.1^{b}
	50	2.4^{a}	18.3^{a}	7.6^{a}	2.1^{b}
Compost	25	2.3^{a}	9.9^{d}	7.5^{a}	2.1^{b}
	50	2.3^{a}	16.5^{bc}	7.9^{a}	3.9^{a}
iron and manganese sulfate	–	1.5^{b}	17.7^{ab}	7.8^{a}	2.1^{b}
control	–	1.7^{b}	15.8^{c}	6.9^{b}	2.8^{b}

2. The effects of treatments on macro and micro nutrients concentrations in soil

The application of biosolids caused a significant ($P < 0.01$) increase of nitrogen, phosphorous and potassium contents at all treatments (Fig. 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 ton ha^{-1}. Nitrogen and phosphorous contents increased from 9.5 and 44.5 $mg.kg^{-1}$ in control to 22 and 73 $mg.kg^{-1}$ in sewage sludge usage respectively. Also the K content was increased significantly ($P < 0.01$) from 401 to 565 $mg.kg^{-1}$for the high compost application rates of 50 ton ha^{-1}. An increase in total organic matter and nitrogen through application of biosolids has also been found in the 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 biosolids rate (4.5 t ha-1) was used in that study.

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

The short-term nature (one time) of biosolids 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 biosolids matrix. Thus, trace metals added to soil with biosolids are less phytoavailable than those added as simple inorganic salts.



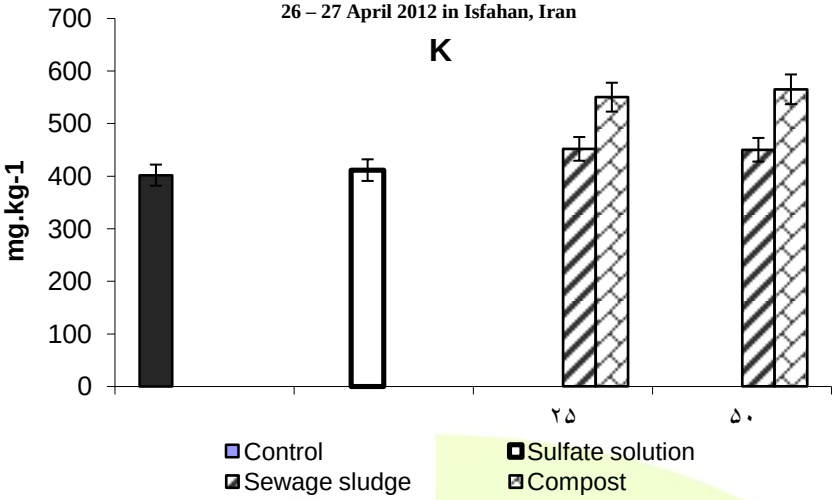


Figure1: The effects of treatments on macronutrients contents in soil.

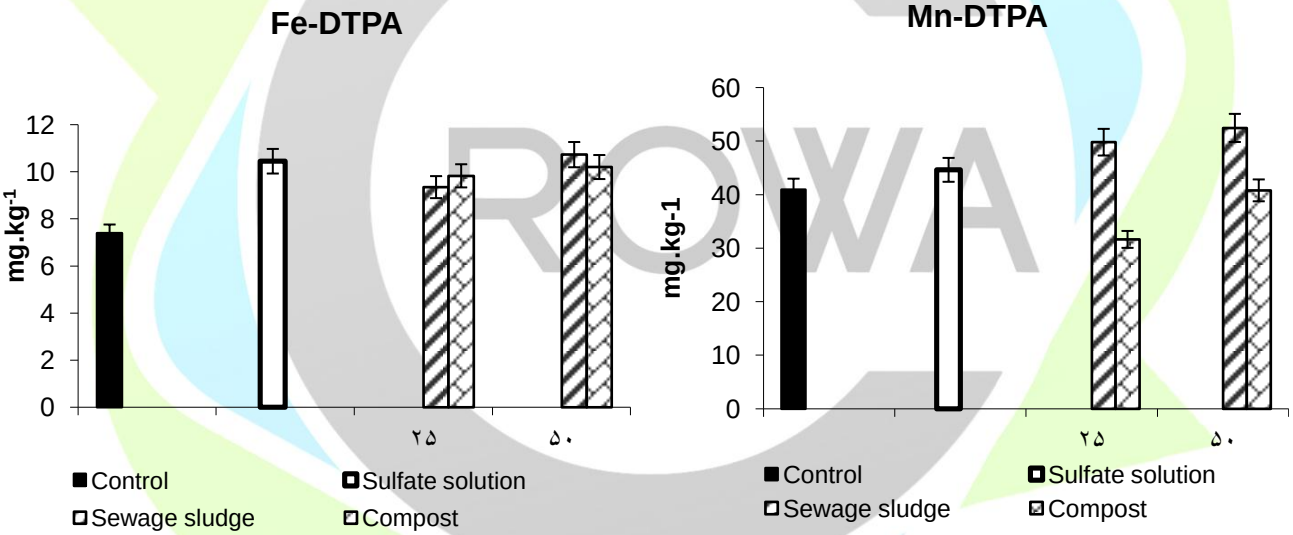


Figure2: The Effects of treatments on DTPA-extractable concentrations of Fe and Mn in soil.

3. The effects of treatments on macro and micro nutrients concentrations in plant

The application of biosolids caused a significant ($P < 0.01$) increase of nitrogen, phosphorous and potassium contents in plant shoot at all treatments (Fig. 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 ton ha^{-1}. Nitrogen and phosphorous contents increased from 32 and 69 $mg.kg^{-1}$ in control to 74 and 102.6 $mg.kg^{-1}$ respectively. Also the K content was increased significantly ($P < 0.01$) from 375 to 579.1 $mg.kg^{-1}$for the high compost application rates of 50 ton ha^{-1}.

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

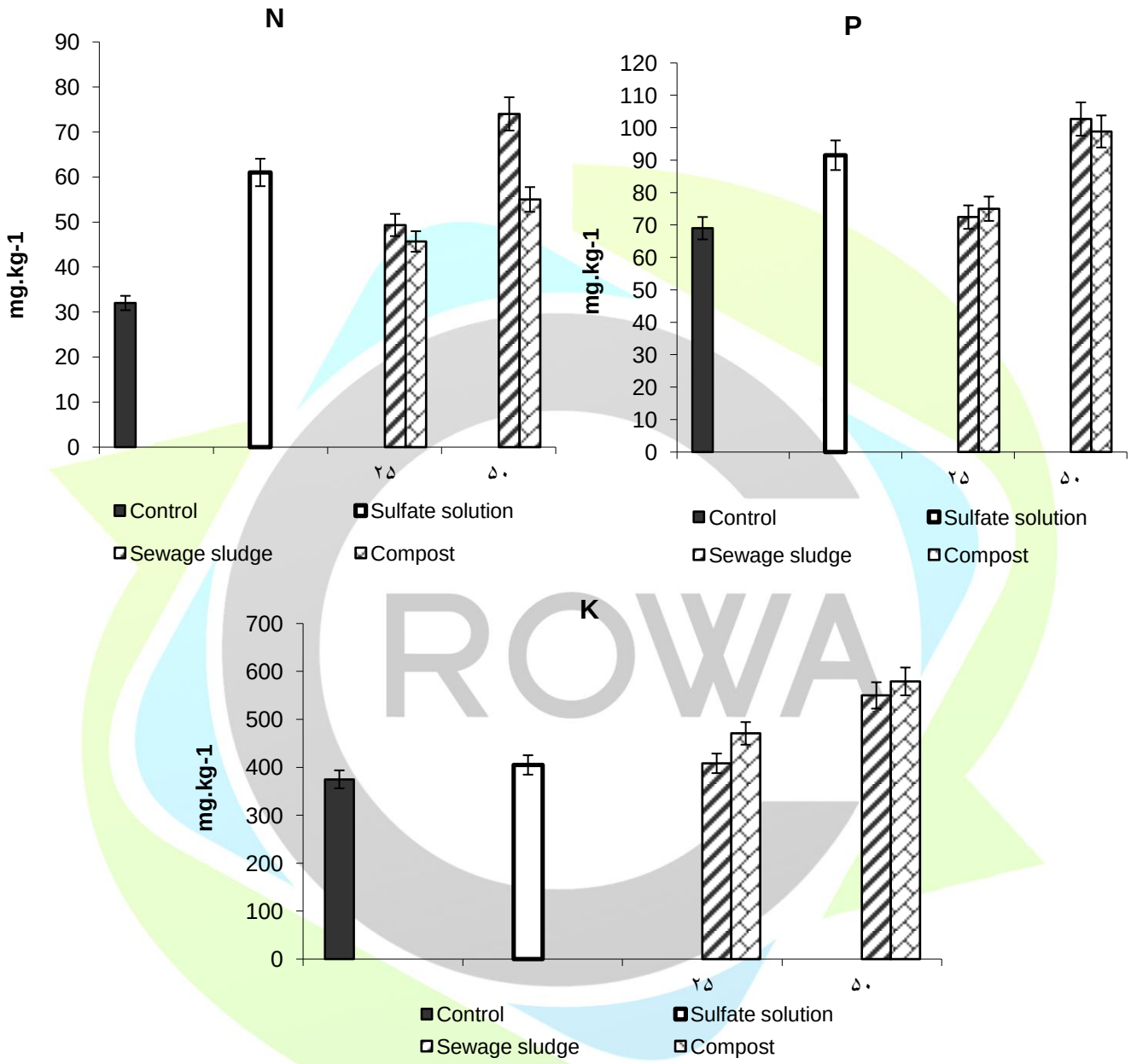


Figure3: The effects of treatments on macronutrient contents in plant shoot.

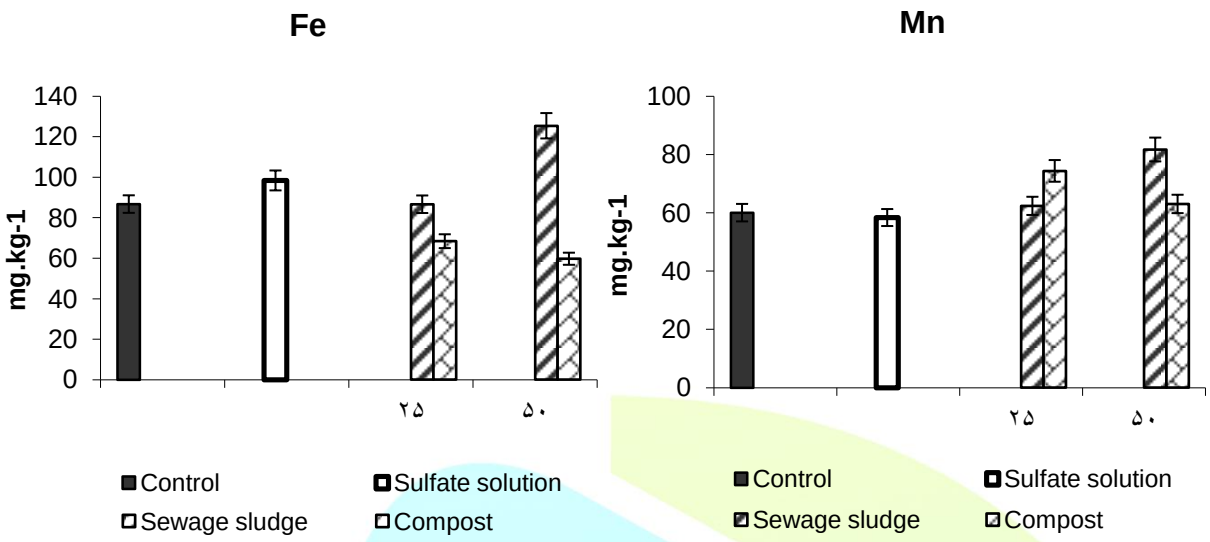


Figure4: The effects of treatments on concentrations of Fe and Mn in plant shoot.

4. The effect of treatments on dry biomass

Biosolids application increased the dry matter of *Zea mays* (Fig. 5). These growth parameters were obtained with increase as biosolids rates. The highest dry biomass was obtained for the high sewage sludge application rates of 50 ton ha^{-1}. Application of sewage sludge (50$t.ha^{-1}$) significantly ($P < 0.01$) increased shoot dry matter from 7.7 to 28.7$g\ pat^{-1}$.

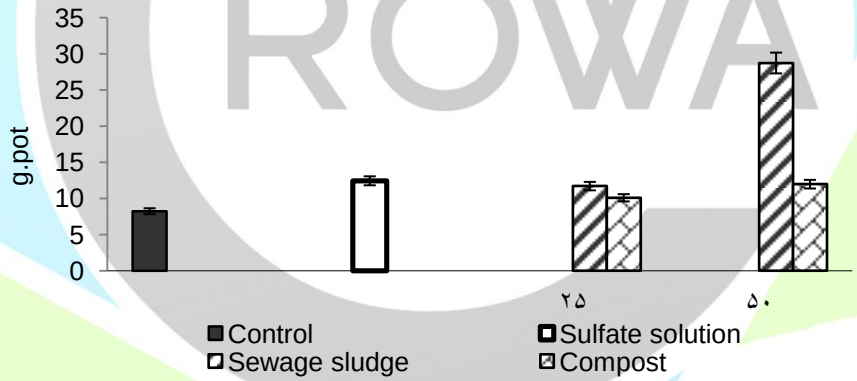


Figure 5- The effect of treatments on dry biomass

Canclusions

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 fertility, such as increased, organic matter, macro and micro nutrients. This study found that, cation exchange capacity pH, organic matter content, 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 potential 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

biosolids application and the relatively low concentrations of these trace metals in the biosolids. International data on the total concentrations of macro and micro nutrients in biosolids are compiled and show that all types of biosolids such as sewage sludge and compost contain high concentrations of macro and micro nutrients. Therefore these elements will slowly accumulate in 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 micro nutrients in crop tissues that rise application of biosolids to soil for increase 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 micro nutrient in biosolid-amended soil increases with high levels of biosolide 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. The biosolid, provided the best results in terms of plant biomass and concentrations of macro and micro nutrients. Although biosolids have been demonstrated to be an 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 greenhouse condition are needed to confirm the results obtained in this study.

Material and Methods

1. Greenhouse Study

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

2. Soil and fertilizer sampling

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

Table 1. Chemical properties of soil and biosolids.

	pH	EC	CEC	OM	N_T	P_{ava}	K	Fe	Fe_{DTPA}	Mn	Mn_{DTPA}
		$(dS.m^{-})^{1}$	$(Cmol.kg^{-})^{1}$	(%)			$(mg\ kg^{-1})$				
Soil	7.6	1.4	14.3	1.1	13	520	600	255	6.8	439	34
Compost	7.5	11.5	23.6	35.6	130	1430	3900	915	-	42	-
Sewage sludge	6.4	8.5	35.7	48	240	3400	3100	3425	-	76	-

3. Plant analysis

Four seeds (*Zea mays*) were sown into pots (27 cm height × 25 cm diameter) and were irrigated with deionized water at field capacity. Plants shoot were harvested after 70 days, washed thoroughly with deionized water and oven-dried for 48 hours 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 , PerkinElmer, 3030) (Allen and Blackwell 1989).

4. Statistical analysis

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

List of abbreviations used

DTPA: Diethylenetetramine-penta-aceticacid

CEC: Cation exchange capacity

EC: Electrical conductivity

OM: Organic matter

Competing interests

1. Do you hold any stocks or shares in an organization that may in any way gain or lose financially from the publication of this manuscript, either now or in the future? No
2. Do you hold or are you currently applying for any patents relating to the content of the manuscript? Have you received reimbursements, fees, funding, or salary from an organization that holds or has applied for patents relating to the content of the manuscript? No
3. Do you have any other financial competing interests?No

Authors' contributions

S. Kabirinejad: Doing experiments and data collection

M. Hoodaji : Design experiment ,Supervision , Data analysis and Writing.

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References

1. Allen, S.E. Blackwell.1989. Chemical analysis of ecological materials (2nd ed.). Oxford:
2. Baumann A. 1885. Das Verhalten von Zinksatzen gegen pflanzen and in Boden landwirtsch . vers . Statn 31 . pp:1 – 5.
3. Campbell C R and Plank C O. 1998. Preparation of plant tissue for laboratory analysis. p 37 - 49 . In Y. P. Kalra (ed) Handbook of Reference Methods for Plant Analysis. CRC Press, Boca Raton, FL
4. Chapman HD. 1965. Total Exchangeable Bases. Ch. 58. In C. A. Black (ed.)Methods of Soil Analysis, Part 2. Soil Sci. Soc. of Amer., Madison, WI.
5. During R A, HoB T and Gath S. 2003. Sorption and bioavailability of heavy metals in long – term differently tilled soils amended with organic wastes. Sci. total Environ. 313 .pp: 227 – 234.
6. Garrido S., Del Campo G.M, Esteller M.V,Vaca R., Lugo J.2005. Heavy metals in soil treated with sewage sludge composting, their effect on yield and uptake of broad bean seeds (*Vicia faba* L.),Water, Air, & Soil Pollution 166 , 303.
7. Giusquiani P L. Pagliais M, Giyliotti G, Businell D and Benetti A. 1995. Urban waste compost effect on physical, chemical and biochemical soil properties. J. Environ Qual. 24.pp:175-182.
8. Haynes R J. 2005. Labile organic matter fractions as central components of the quality of agricultural soils, an overview. Adv. Agron. 85, 221–268.
9. Horswell J, Speir T W, Schaik A.P van.2003. Bioindicators to assess impacts of heavy metals in land-applied sewage sludge .Soil Biology and Biochemistry.35, 1501.
10. Lindsy W L and Norvell W A. 1978. Development of a DtpA soil test a for zinc, iron, and mangenez capper Soil Sci Soc. A. M. J. 42 . pp:421 – 428.
11. Olsen S R and Sommers L E. 1982. Methods of soil and analysis, part 2 : chemical and microbiological properties, 2nd ed. Soil Sci Soc. A. M.

12. Pyddtt F B. 1999. Comparison of foliar and stem bioaccumulation of heavy metals by Corsican pines in the mount Olympus area of Cyprus, Ecotoxicol. Environ 42. pp: 57 – 61.

13. Ryan, J., Estefan, G., Rashid, A. 2001. Soil and Plant Análisis Laboratory Manual. International Center for Agricultural Research in the DryAreas(ICARDA) and the National Agricultural Research Center(NARC). Available from ICARDA,Aleppo,Syria.

14. Smith SR. 2008.A critical review of the bioavailability and impacts of heavy metals in municipal solid waste composts compared to sewage sludge. Environment International, EI-01795; 15.

15. Walter I., Cuevas G., Garcia S., Martinez F. 2000. Biosolid effects on soil and native plant production in a degraded semiarid ecosystem in central Spain, Waste Management and Research 18, 259.