Heavy Metal Accumulation in the Eggplant (*Solanum melongena*) Grown in MSW Compost Applied Soil

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Abstract

A pot experiment was conducted to investigate the effects of soil applications MSW (municipal solid waste) compost on the fruit yield and heavy metal accumulation in the leaf and fruit of eggplant plant (*Solanum melongena*). Red Mediterranean soil collected from the surface soil (0-30 cm) from the fields cropped in a wheat-corn rotation in Antalya Turkey was used as an experimental soil. The heavy metal content of untreated greenhouse soil was well within the accepted normal range of values. Pots containing different amounts (corresponding to 0, 25, 50, 100 and 200 T/ha, as dry weight basis) of MSW compost were used to grow eggplant plants under controlled greenhouse conditions. Fruit yield and Zn, Cu, Ni, Pb, Cd and Cr contents in the leaves and fruits of eggplant were determined. MSW compost applications led to greater fruit yield at low application rates, but higher application rates (100 and 200 T/ha) of MSW compost depressed plant growth and fruit yield. It was found that the MSW compost applications brought about a sharp increase for heavy metals in the plant material. At low MSW compost treatments, the concentrations of heavy metals in plants were below the phytotoxic levels. However, in high MSW compost treatments, according to background and toxicity limits, heavy metal status of leaves and fruits were ranged in high levels, and Pb concentrations in eggplant fruits were exceeded foodstuff index and limit values for edible vegetables. The resulting data demonstrate that the MSW compost was a source of heavy metals for the soil and MSW compost application caused an important accumulation of heavy metals in eggplant.

Key Words: MSW compost, heavy metals, eggplant

Introduction

Composting of municipal solid waste (MSW) and its subsequent application to agricultural land is gaining popularity because of environmental concerns associated with the disposal of this material in landfills. Several studies have shown that use of MSW compost in agriculture has many benefits to soil, crops and environment (Roe et al., 1993; Hicklelenton et al., 2001).

However, Heavy metal pollution of agricultural soils and crops through the applications of MSW (Municipal Solid Waste) compost and sewage sludge are of great concern. Although MSW compost provides nutrients for plant growth, its continual use over extended periods can result in the accumulation of heavy metals in soils and in the crops to levels that are detrimental to the food chain (Alloway and Jackson, 1991). As a matter of fact, pollution problems may arise if toxic metals are mobilized into the soil solution and are either taken up by plants or transported in drainage waters. Risk for human health may then occur through consumption of such crops and intake of contaminated waters. In the long term, the use of MSW compost can also cause a significant accumulation of Zn, Cu, Pb, Ni and Cd in the soil and plants (Mulchi et al., 1991). Contamination of soils by potentially toxic elements (e.g. Zn, Cu, Ni, Pb, Cd) from amendments of sewage sludge and MSW compost is subject to strict controls within the European Community in relation to total permissible metal concentrations, soil properties and intended use.

Information on the heavy metal loading potentials of MSW compost and its effects on the plants are scarce. The aim of this study was to assess the effects of MSW compost applications on the heavy metal accumulation in eggplant plant.

Materials and Methods

A pot experiment was carried out in the greenhouse and eggplant plant was grown in soil treated with MSW compost. Experimental soil was collected from the surface (0-30 cm) soil (Red Mediterranean, according to Soil Survey Staff, 1998) from fields cropped in a wheat-corn rotation in Antalya. The MSW compost was obtained from the Solid waste composting plant, Kemer, Antalya. Compost was produced by the composting of the organic fraction of unseparated municipal solid waste, selected mechanically at the plant. The soil and MSW compost were air-dried, mixed and sieved through a 2- mm-mesh sieve before filling to pots. The chemical properties of soil and MSW compost are summarised in Table 1.

Table 1. The analytical characteristics of the experimental soil and MSW compost before treatment, and their pollutant limits.

Parameters	Soil	Limit values in soil [1]	MSW compost	Limit values in organic materials[1]
Texture	Loam		-	
pH- H_2O (1:5 w/v)	7.34		7.66	
$CaCO_3$, %	7.70		-	
Total N, %	0.13		0.62	
Organic Matter, %	2.20		52	
EC (dS m^{-1})	0.03		8.88	
Zn, mg kg^{-1}	90[1]	150-300	1220[1]	2500-4000
Cu, mg kg^{-1}	23	50-140	105	1000-1750
Ni, mg kg^{-1}	16	30-75	43	300-400
Pb, mg kg^{-1}	46	50-300	196	750-1200
Cd, mg kg^{-1}	*	1-3	1.6	20-40

*: Below detection limit (< 0.02 mg kg^{-1}), [1]: Total concentrations (mg kg^{-1} dry wt), (C.E.C., 1986)

In the experiment, plastic pots containing 30 kg soil were used. MSW compost was applied to experimental soil. Treatments were consisted of five rates, 0 (control), 300, 600, 1200, 2400 g/pot amounts (corresponding to 0, 25, 50, 100 and 200 T/ha, respectively) as dry weight basis of MSW compost. Pots were arranged in a completely randomized design with four replicates. Before transplanting the plants, all treatments received supplemental fertilization at a rate of 160, 50 and 120 mg kg^{-1} of N, P and K, respectively.

Seedlings of eggplant (*Solanum melongena var. Pala-Yalova49*) were transplanted as one plant per pot. All pots were located in the greenhouse under controlled climatic conditions. Pots were maintained around field capacity by daily watering with distilled water. Leaf samples were taken at flowering period. Sixty days after transplanting, eggplant fruits were reached maturation. Total fruit yield of per pot was recorded till the end of harvest. Leaf and fruit samples of eggplant were dried at 65 ºC for 48 h for determination of plant mineral analysis . Plant tissues were ground and then digested in aqua regia (1:3 HNO_3/HCl). Zn, Cu, Ni, Pb, Cd and Cr concentrations in plant samples were determined by flame atomic absorption spectrometry (FAAS) under optimised measurement conditions.

Data were analyzed by standard ANOVA procedures for a randomized complete block design and least significant difference (LSD) at $P<0.05$ was used.

Results and discussion

The heavy metal contents of untreated greenhouse soil and MSW compost (Table 1) are well within the accepted normal range of values. A comparison of metal contents of MSW compost with that of untreated soil showed that the metals Zn, Cu, Ni, Pb and Cd were present in MSW compost in greater concentrations than in the soil. The heavy metal concentrations of MSW compost is below the levels indicated by the EU (CEC, 1986) for the agricultural use of waste organic material (sewage sludge).

Dry matter yield and concentrations of Zn, Cu, Ni, Pb, Cd and Cr in the leaves and fruits of eggplant plant grown in MSW compost treatments, and also background (Davis and Carlton-Smith, 1980) and phytotoxic metal limits as defined by Kabata-Pendias (2000) are presented in Table 2.

Table 2. Fruit yields and leaf and fruit metal concentrations of eggplants amended with MSW compost

Plant Tissue	Treatments, g/pot	Fruit yield g/pot	Zn	Cu	Ni	Pb	Cd	Cr
			mg kg^{-1}					
Leaf	0 (Control)	-	22 d	5.2 d	1.5 c	2.0 d	<0.02 d	0.05 d
	25	-	30 d	9 c	3.7 c	10.2cd	0.04 c	0.09 c
	50	-	58 c	10 bc	6.0 b	17.2 bc	0.35 b	0.10 c
	100	-	118 b	13 b	8.2 ab	24.2 ab	0.88 a	0.17 b
	200	-	255 a	16 a	13.0 a	35.4 a	0.91 a	0.33 a
Fruit	0 (Control)	1552 c	29 d	5.3 d	1.4 c	2.2 d	<0.02 d	0.05 c
	25	1570 c	51 d	7 c	3.6 c	13.6 c	0.08 c	0.18 b
	50	1770 b	69 c	15 b	6.8 b	24.4 b	0.41 b	0.22 b
	100	2280 a	128 b	17 b	8.1 ab	31.7 ab	0.71 b	0.38a
	200	1680 b	266a	20 a	11.0 a	40.2 a	0.94 a	0.39 a
Background level [2]		-	40	8	2	3	<0.50	-
Phytotoxic level [3]		-	100-400	20-100	10-100	30-300	5-30	5-30

***: P<0.001, [1] :Means within an amendment followed by the same letter are not significantly different at the 005 level. [2]:Davis and Carlton-Smith (1980), [3]: Kabata-Pendias (2000)

MSW compost treatments increased leaf and fruit dry matter yield, and heavy metal concentrations (P< 0.05) both in leaf and fruit tissues of eggplant plant (Table 2). Concentrations of Zn, Cu, Ni, Pb and Cd in the control treatment were small and representative of background levels (Davis and Carlton-Smith, 1980) (Table 2). Heavy metal concentrations in the leaf and fruit tissues of eggplant in MSW compost treatments were higher than that of control. Zn, Cu, Ni, Pb and Cd concentrations in eggplant were increased by increasing applications of MSW compost. According to background and toxicity limits, metal status of leaves was generally ranged in normal and high levels.

Compared with metal limits at the highest application of MSW compost (192 g/pot), Zn, Cu, Ni and Pb contents of eggplant were found in high levels. Nevertheless, all metal concentrations were below the phytotoxic maximum limits. The concentration of Cd in the leaf and fruit tissues of eggplant grown in control treatment was small and below the detection limit of analytical apparatus. Although concentration of total Zn, Cu, Ni and Pb in the highest MSW compost treatments was particularly large and near to toxic level, there was no evidence that plant growth was affected detrimentally.

Fruit tissue of eggplant contained higher metal concentrations than that of leaf tissue. This is important because of edible fraction of plant. Limit values of Pb in edible vegetables were suggested as 0.25 mg kg^{-1} in fresh material (CEC, 2001) (corresponding about 2.5 mg kg^{-1} dry weight basis). Therefore based on the results of current experiment, Pb concentrations of eggplant in MSW compost treatments were exceeded foodstuff index and limit values for edible vegetables (CEC, 2001).

Conclusion

This study suggests that MSW compost was a source of heavy metals for the soil and application of MSW compost to soil, lead to harmful accumulation of heavy metals in the plant. In this short-term study no phytotoxic effects of MSW compost on eggplant plant were detected. However, safety food metal limit values for edible vegetables were exceeded by MSW compost applications. Taking into consideration the long-term applications of MSW compost would carry a risk of progressive of heavy metals to toxic levels. Thus regular sludge, soil and plant analysis are needed to check for low levels of MSW compost-borne metals used as soil amendments.

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