

# The Effect of MSW Compost Application on the Growth and Heavy Metal Accumulation in Sugar Beet (*Beta Vulgaris L.*)

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**Abstract**— Municipal solid waste (MSW) compost was applied to pots at various rates (0, 20, 40, 80, and 160 tons/ha, corresponding to the application rate), and sugar beet plants were grown in greenhouse conditions. In relation to MSW compost application, DTPA extractable metal levels in the soil increased. The leaf and root dry matter content and Zn, Cu, Ni, Pb, and Cd content contents of the sugar beet increased with increasing levels of MSW compost. Heavy metal contents were found to be higher in the root tissues of sugar beets than in the leaf tissues. In all treatments, heavy metal concentrations in the plants were determined to be below phytotoxic levels. In MSW compost applications, based on basal and toxicity thresholds, heavy metals in plant leaves exhibited distribution at around normal and high levels. However, in the highest MSW compost application (160 tons/ha), Cd and Pb concentration in sugar beets exceeded the food codex limit values recommended for edible vegetables. The research results demonstrated that MSW compost caused a significant increase in heavy metal content in the plants.

**Keywords**— MSW compost, heavy metals, sugar beet

## I. INTRODUCTION

The use of composted organic waste to improve soil properties and provide nutrients has become a widespread practice. Composting municipal solid waste for use in agricultural fields appears to be an economical approach both for waste management and for enriching the soil with organic matter. Some researchers have reported positive effects of MSW compost on soil properties and crop quality. However, MSW compost may contain residues of undesirable plant and animal products, toxic elements, and heavy metals, and can cause contamination [1, 2]. Therefore, the presence of potentially harmful heavy metals in MSW compost raises concerns regarding its use [3]. The application of low-quality waste and the compost produced from it to soil poses risks of reduced soil fertility, adverse effects on groundwater, and the entry of heavy metals into the food chain.

The chemical characterization of compost is generally based on its agronomic value, nutrient content, and heavy metal content. In this regard, many countries have established legal regulations and imposed restrictions regarding the chemical characterization of compost and its heavy metal content. Restrictions have primarily been imposed on the application of organic waste materials, particularly sewage sludge, to agricultural and forest soils.

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The heavy metal limit values established for these wastes can also be applied to other organic wastes.

The sugar beet plant removes a significant amount of nutrients from the soil and can accumulate heavy metals at high levels. There are limited studies on the application of MSW compost to soil. In this study, the effect of MSW compost applied to soil on the Zn, Cu, N, Pb, and Cd contents in sugar beet plants was investigated.

## II. MATERIALS AND METHODS

The effect of MSW compost applied to soil on heavy metal accumulation in sugar beet plants was investigated through a greenhouse experiment. The greenhouse soil was collected from the 0–30 cm layer of a soil series belonging to the Red Mediterranean major soil group in the Antalya region [4]. The MSW compost was obtained from the Urban Solid Waste Treatment and Compost Preparation Facility in the Kemer district of Antalya. The soil sample and MSW compost used in the experiment were air-dried prior to the experiment and sieved to 2 mm. The limit values for certain physical and chemical properties of the experimental soil and MSW compost, as well as their heavy metal contents, are presented in Table 1.

TABLE 1. PRE-EXPERIMENT PHYSICAL AND CHEMICAL PROPERTIES OF THE EXPERIMENTAL SOIL AND MSW COMPOST, ALONG WITH LIMIT VALUES FOR HEAVY METAL CONTENT

Parameters	Experimental soil		Soil metal limits <sup>1</sup>	MSW Compost <sup>1</sup>	Heavy metal limit values in wastewater sludge <sup>1</sup>
Texture	Clayed loam			-	
pH, (1:2 w/v)	7,36			7,66	
CaCO <sub>3</sub> , %	7,7			0,88	
E.C., µS/cm	288			3750	
Organic matter, %	1,85			62	
Zn, µg g <sup>-1</sup>	88 <sup>1</sup>	1,8 <sup>2</sup>	150-300	1220	2500-4000
Cu, µg g <sup>-1</sup>	25	0,45	50-140	105	1000-1750
Pb, µg g <sup>-1</sup>	16	1,9	50-300	43	750-1200
Ni, µg g <sup>-1</sup>	45	1,2	30-75	196	300-400
Cd, µg g <sup>-1</sup>	< 0.001	< 0.001	1-3	1.6	20-40

1: Total concentrations (µg g<sup>-1</sup>, dry weight) [6]; 2: DTPA-extractable concentrations (µg g<sup>-1</sup>, dry weight)

Sugar beets were grown in plastic pots containing 25 kg of soil. MSW compost was applied at five levels corresponding to rates of 0 (control treatment), 20, 40, 80, and 160 tons/ha based on dry matter content, and the compost was thoroughly mixed

with the soil before the plants were transplanted. In the experiment, the pots were arranged in a randomized block design with four replicates. For all treatments, 60 kg ha<sup>-1</sup> of 15:15:15 compound fertilizer, equivalent to N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O, was applied as a basal fertilizer.

Sugar beet seedlings (*Beta vulgaris* L. var. Türkşeker) were transplanted into pots at a rate of two plants per pot. The experiment was conducted in a greenhouse under controlled conditions, and the water level in the pots was maintained at field capacity using distilled water throughout the experiment. The sugar beet plants were harvested 150 days after transplanting. Harvesting was performed by uprooting the plant from the soil along with its root system; after washing with distilled water, the plants were separated into leaves and roots. The leaf and root tissues were dried at 65 °C to determine dry matter content, ground, and digested in aqua regia (1:3 HNO<sub>3</sub> /HCl) [5] for heavy metal analysis. At the end of the experiment, soil samples were collected from the pots, processed according to standard procedures, and extracted by using Diethylenetriaminepentaacetic acid (DTPA). The concentrations of Zn, Cu, Ni, Pb, and Cd in the plant and soil extracts were determined by using ICP-MS under appropriate measurement conditions.

Standard ANOVA and LSD tests ( $P < 0.05$ ) were applied to the data obtained from the experiment.

### III. RESULTS AND DISCUSSION

The heavy metal contents of the experimental soil and MSW compost were found to be below the reported limit values [6]. In the experimental soil, the levels of metals extractable with DTPA from the applied MSW compost

increased with increasing application rates. It was determined that Zn was the predominant metal among those extractable with DTPA (Table 2). These results indicate that the application of MSW compost to soil not only increases the total metal content in the soil but also significantly increases the fraction of metals forms readily available to plants. On the other hand, it is also understood that the metals present in the MSW compost are largely in a form readily available to plants.

TABLE II. EFFECT OF SEWAGE SLUDGE APPLIED TO SOIL ON THE DTPA-EXTRACTABLE METAL CONTENT IN THE EXPERIMENTAL SOIL AFTER INCUBATION

Treatments, g kg <sup>-1</sup>	Zn	Cu	Ni	Pb	Cd
0 (Control)	1,96	0,35	1,02	2,13	<0,001
20	9,56	0,46	1,32	7,21	0,018
40	24,25	0,58	3,34	14,56	0,034
80	32,65	0,62	6,25	32,6	0,096
160	69,25	0,81	8,25	45,6	0,125
Significancy	**	*	**	**	**

\*\* : P<0.01, \* : P<0.05, ns: no significancy.

It was observed that the electrical conductivity and heavy metal contents of the MSW compost were significantly higher than those of the experimental soil (Table 1). Regarding the application of MSW compost to the soil, the findings on the dry matter content of the sugar beet plant and the Zn, Cu, Ni, Pb, and Cd contents in the leaf and root tissues are presented in Table 3 and Table 4, respectively. Table 2 also presents the basal levels and phytotoxic levels of heavy metals in sugar beet plants.

TABLE III. DRY MATTER CONTENT AND HEAVY METAL LEVELS IN SUGAR BEET LEAVES

Applications, ton/ha	Leaf dry matter g/pot	Zn	Cu	Ni mg kg <sup>-1</sup>	Pb	Cd
0 (Control)	14.2 c	26 d	4.8 b	1.7 d	2.5 d	<0.02 d
20	14.6 c	34 d	5.4 a	1.9 d	7.4 c	0.09 c
40	14.6 c	57 c	5.4 a	2.6 c	8.8 c	0.11 c
80	15.2 b	85 b	5.6 a	3.9 b	11.2 b	0.16 b
160	19.4 a	151 a	5.6 a	7.5 a	17.7 a	0.24 a
Significancy (P<0.05)	*	**	*	**	**	**
Basal level [7]	-	40	8	2	3	<0.50
Phytotoxic level [8]	-	100-400	20-100	10-100	30-300	5-30

1: There is no statistically significant difference ( $P < 0.05$ ) between the means denoted by the same letter.

TABLE IV. DRY MATTER CONTENT AND HEAVY METAL LEVELS IN SUGAR BEET ROOTS

Applications, ton/ha	Root dry matter g/pot	Zn	Cu	Ni mg kg <sup>-1</sup>	Pb	Cd
0 (Control)	12.0	28	4.9 b	2.8 c	2.8 c	<0.02 d
20	12.1	36	5.7 a	3.6 c	8.7 b	0.09 c
40	13.6	47	5.7 a	4.7 c	9.6 b	0.16 b
80	16.6	79	5.9 a	9.9 b	10.1 b	0.19 b
160	25.1	165	5.9 a	15.6 a	18.1 a	0.24 a
Significancy (P<0.05)	*	**	*	**	**	**

1: There is no statistically significant difference ( $P < 0.05$ ) between the means denoted by the same letter.

The application of MSW compost to the soil increased the dry matter content of leaves and roots as well as heavy metal concentrations in sugar beet plants ( $P < 0.05$  and  $P < 0.01$ ). In the control treatment, heavy metal concentrations were low and within baseline levels. As expected, heavy metal concentrations

in sugar beet plants increased with MSW compost applications and were found to be higher than in the control treatment. Statistically significant differences were observed between the treatments. Higher increases in dry matter and metal content were observed with increasing amounts of MSW compost. In the leaves and root tissues of sugar beets following MSW

compost applications, Zn, Ni, and Pb contents were determined to be significantly above background levels. However, with the exception of Zn, all heavy metal concentrations were found to be below phytotoxic levels. Significant differences in heavy metal content were observed in the leaf and root tissues of sugar beets, with the root tissue containing higher levels of heavy metals than the leaf tissue.

The Cd content of sugar beets grown in the control treatment was quite low and remained below the limit of quantification. However, in the highest MSW compost application (160 tons/ha), the Cd and Pb contents in sugar beet plants exceeded the food codex limit values recommended for leafy vegetables/forages [9]. Although Zn, Ni, and Pb contents were quite high and close to the phytotoxic threshold at high application rates of MSW compost, no adverse effects were observed in sugar beet plants. This situation has been attributed to the low bioavailability of metals in organic materials [2].

#### IV. CONCLUSION

High-level MSW compost applications significantly increased both DTPA-extractable metal contents in the soil. The application of MSW compost to the soil increased both the dry matter content and heavy metal concentrations in sugar beet plants. In the short-term pot experiment, no phytotoxicity was observed in the plants at high application rates of MSW compost. However, it appears that when MSW compost is applied to the soil, it can serve as a source of heavy metals and may lead to harmful accumulation in the soil and plants, particularly at high application rates.

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