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USE OF MUNICIPAL WASTE IN VEGETABLE CROP PRODUCTION

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ABSTRACT

Increase in urban population has resulted in excess accumulation of municipal waste and less space for storage. A possible means of solving this waste problem is to recycle the material in activities like vegetable gardening which have also been increasing in urban areas. To determine the feasibility of recycling municipal waste as soil amendments in vegetable crop production, experiments were designed in which composted sewage, yard waste and horse manure were incorporated into a Christiana silt loam soil and used to grow vegetables, Swiss chard (Beta vulgaris, L.), string bean (Phaseolus vulgaris, L.) and tomato (Lycopersicon esculentum, Mill). In the first of two studies, composted sewage sludge was applied at rates of 143 Mg/ha and 72 Mg/ha to the silt loam soil from 1983-1987. To test possible accumulation of toxic heavy metals in the soil and subsequent uptake in vegetable crop plants, Swiss chard was planted in the sewage treated area in 1991 in rows 6.0m long and 1.0m wide. Results showed significantly higher soil organic matter content and pH levels in plots treated with the composted sewage sludge over plots in which recommended rates of commercial fertilizer were applied. Higher concentrations of Cd, Cu, Pb and Zn were found in soils treated with sludge compost, while higher levels of Cd, Ni and Zn were found in Swiss chard treated only with commercial fertilizer. Uptake of the heavy metals in plants was not at a level that was toxic to the plants or to humans who would consume them. In another study in which beans and tomatoes were planted in plots treated with composted sewage sludge, horse manure and yard waste, fresh market and total yield of both beans and tomatoes were comparable to and sometimes greater than that produced in plots which had commercial fertilizer as the soil amendment. In one year, yields were higher in the fertilizer treated plots but although these differences were significant statistically, they were so small that they may not be of economic significance. There were also some disease problems in some plots but these problems could possibly have been solved with the proper application of pesticides.

INTRODUCTION

As urban population increases, we find that urbanized land is coming closer to farming communities. Therefore, there is a need for closer interaction between the two entities in finding solutions to common environmental and agricultural production problems. Increasing urban population has resulted in the excessive accumulation of sewage, yard, and other solid waste materials with diminishing storage space for their safe disposal. A possible solution to this accumulating waste problem would be to recycle these waste materials as soil amendments in gardening operations. By recycling waste such as sewage sludge, yard and animal waste as soil amendments in urban gardening, we will be able not only to solve our waste storage problem but also provide an economical source of N-P-K for the growth of horticultural plants. Preliminary studies have shown that municipal waste enhances soil fertility by improving structure and providing available nutrients. Sewage sludge has also been used to grow vegetables such as turnip, radish, beet, onion, lettuce and cucurbits. However, depending on the source of the sludge and soil pH, toxic elements such as Cd, Hg, Pb and Zn may accumulate in the soil and then taken up by these crop plants at levels that may be harmful to humans when they are eaten.

In addition to the accumulation of toxic elements, there is also the possibility that sludge may

contain pathogenic organisms that may contaminate plants which when eaten by humans may cause disease. Studies have shown, however, that during the composting process these organisms are destroyed. Since there are indications that if properly used, waste generated by urban population can be safely recycled as soil amendments and since urban gardening has increased among this population, it becomes necessary to conduct research to determine how well plants will grow in urban gardens in which these materials are used as major soil amendments.

MATERIALS AND METHODS

To make preliminary determinations on the level at which heavy metals from composted sludge accumulate in some vegetable crops, Swiss chard (Beta vulgaris, L.) was planted in plots of Christiana silt loam soil treated with composted sewage at rates of 143 Mg/ha and 72 Mg/ha over a period of five years (1983-1987). In 1991, Swiss chard was planted in these plots in rows 6.0m long and 1.0m wide. Rows were overplanted and after germination thinned to 5.0cm apart. Plots were laid out as a randomized complete block design with three replications per treatment. At seven weeks, whole plants were harvested by severing stems at soil surface level, washed thoroughly to remove surface contamination, and dried in an oven at 70°C for 48 hours. After drying, plant tissue was ground in a Wiley mill using a 20 mesh screen. Further preparation for heavy metal determination followed the method of Preer et al. Concentrations of heavy metals were determined on a Perkin Elmer Model 2100 atomic absorption spectrophotometer. Soil metals were determined after extraction with hot 8N nitric acid, and represent total metal levels.

In 1992, a second study was initiated in which a set of experimental plots were established where the composted waste materials, sewage, horse manure and yard waste (leaves and grass) were applied at a rate of 53 Mg/ha. Control plots received 10-10-10 fertilizer at a rate of 2.2 Mg/ha. Plots were laid out as a randomized complete block with three replications per treatment. Main plots were compost treatments and sub-plots were crop plants. Each composted material was broadcast on plot surfaces and incorporated by light discing. Crops used were string beans and tomatoes. Bean seeds were overplanted in rows and after emergence thinned to 15cm apart. For tomatoes, greenhouse grown seedlings 15cm tall were transplanted 60cm apart. Planting date was May 27 for both 1992 and 1993. There were three rows per plot and plots were 3m x 3m. During the growing season weeds were controlled by hand hoeing. No pesticides were applied. Harvesting began the last week in July for beans and the first week in August for tomatoes in both years. Frequencies of harvest were three and four days for beans and tomatoes, respectively. Fresh weight yield data was analyzed using standard statistical methods.

RESULTS AND DISCUSSION

Application of composted sewage sludge to a silt loam soil over a five year period (1983-1987) resulted in a significant increase in soil organic matter and soil pH (Table 1). While an application rate of 73 Mg/ha of composted sewage increased percentage organic matter and pH significantly over controlled plots which received only recommended rates of commercial fertilizer, doubling the application rate to 143 Mg/ha did not show further significant enhancement of these two soil properties (Table 1). Higher accumulation of heavy metals Cd, Cu, Pb and Zn in soil was greater in composted sewage treated plots than those receiving fertilizer only (Fig. I). Concentration of these metals was also higher in plots receiving the higher rate of sludge compost. Swiss chard planted in the experimental plots in 1991 showed highest concentration of Cd, Ni and Zn in control plots (Fig. II). These plots had low pH levels which are thought to have caused the heavy metals to be more available thus producing greater uptake in the Swiss chard plants. Based on toxicity levels already established in other studies (2, 3) results from this study showed that if pH levels are maintained near neutral, heavy metals are not taken up by plants in toxic proportions and therefore offer no danger to humans when consumed.

The second phase of the study in which snap beans and tomatoes were grown in field plots treated with composted horse manure, yard waste and composted sludge, results showed significant differences in both marketable and total yield for both crops. In 1992 marketable yield of beans in plots treated with composted horse manure and yard waste was comparable to that with commercial fertilizer as the soil amendment (Table 2). There was no significant production of unmarketable beans until the fourth harvest where there were some losses due to disease problems. For tomatoes, in 1992 highest marketable yield was produced in horse manure treated plots with peak production at harvests five and six (Table 3). Non-marketable tomato production was high especially in the sludge treated plots. The high incidence of non-marketable tomatoes was caused by severe disease problems. It should be pointed out that there were no pesticide applications to control disease and insect infestation in these plots.

In 1993 the highest marketable yield of beans was produced in plots treated with yard waste (Table 4). Most non-marketable yield for beans was also produced in yard waste treated plots, mostly at the second harvest (Table 4). Marketable yield for tomatoes in 1993 peaked at harvest #5 (Table 5). This period was mid-August when temperatures were high and fruits were ripening faster than when the initial harvest began. Non-marketable yield was higher than that of 1992 for all compost treatments. Since these were the same plots that were used in 1992 it is assumed that higher non-marketable yield was caused by an accumulation of disease organisms in the field plots. In addition, as in 1992, no pesticides were applied.

In general, the highest total yield for beans in 1992 was produced in plots treated with horse manure while in 1993 it was the fertilizer treated plots that had highest total yields (Table 6). However, while total yield of beans was higher in 1993 than in 1992, that of 1993 had a greater amount of the non-marketable category. For tomatoes, plants in plots treated with both sludge and horse manure produced significantly more marketable yield than control plots in which commercial fertilizer was applied in 1992 (Table 7). In 1993, fertilizer treated plots produced the highest in both marketable and total yield. However, although significant, yield in the sludge treated plots were only slightly lower. As a whole, yield results indicated that with proper application of lime and pesticides, vegetable crops such as beans and tomatoes can be successfully grown on garden plots in which composted yard and animal waste are used as soil amendments. If pH levels are near neutral there is no fear of heavy metal toxicity problems for the plants grown in plots treated with these waste materials or to humans who consume edible portions of the plants grown in soils to which these waste materials were applied.

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Table 1. Soil properties of field plots treated with composted sewage sludge over a period of four years.

	Rates of application		
Soil Properties	High (143 mt/ha)	Low (73 mt/ha)	Control (Fertilizer only)
Bulk Density (g/cm^3)	1.4[a1]	1.4[a]	1.4[a]
Organic Matter (%)	6.2[a]	5.5[a]	3.2[b]
pH	6.2[a]	5.9[a]	4.7[b]

[1]Means followed by the same letters are not significantly different from others in the same row at P=.05.

Table 2. Harvest intervals and effect on marketable and non-marketable yield of snapbeans grown in plots treated with composted waste, 1992.

Composted Materials	Marketable yield (kg/ha)						Total
	H_1[a]	H_2	H_3	H_4	H_5	H_6	
Horse manure	1.9	0.0	0.9	0.0	1.0	2.3	6.7
Yard (leaf+grass)	1.8	0.5	0.8	0.4	0.3	0.6	4.4
Sludge	1.7	0.4	0.5	0.8	0.3	1.3	5.0
Yard+Sludge	1.3	1.1	1.1	1.3	0.3	0.2	5.3
Fertilizer 10-10-10	1.1	0.9	0.8	0.1	0.5	1.8	6.4
$LSD_{.05}$			0.6				0.5

[a]H_1-H_6 Harvests 1-6

Table 3. Harvest intervals and their effect on marketable and non-marketable yield of tomatoes grown in plots treated with composted waste, 1992.

Composted Materials	Yield (Mt/ha)														Total
	Marketable							Non-Marketable							
	H_1[a]	H_2	H_3	H_4	H_5	H_6	H_7	H_1	H_2	H_3	H_4	H_5	H_6	H_7	
Horse manure	3.4	3.6	2.0	3.4	13.9	29.0	7.4	0.1	2.9	0.0	1.6	1.1	0.0	0.7	43.8
Yard (leaf+grass)	1.0	0.8	0.5	0.8	2.2	0.6	1.3	0.3	0.0	0.0	0.2	0.0	0.0	0.5	8.2
Sludge	1.3	3.7	3.5	2.6	7.2	15.8	6.2	0.4	1.7	0.6	0.4	0.8	1.1	0.5	45.8
Yard+Sludge	1.0	2.5	1.1	1.8	6.3	11.8	6.3	0.3	0.9	0.0	0.6	0.6	0.2	1.6	35.1
Fertilizer 10-10-10	1.4	2.8	1.7	0.3	4.4	8.1	7.3	1.4	1.1	0.6	0.0	0.4	1.1	0.7	31.4
LSD^{05}			0.5							0.1					0.5

[a]H_1-H_7=Harvests 1-7

Table 4. Harvest intervals and their effect on marketable and non-marketable yield of bean grown in plots treated with composted waste, 1993.

	Yield (Mt/ha)												
	Marketable						Non-Marketable						Total
Composted Materials	H_1[a]	H_2	H_3	H_4	H_5	H_6	H_1	H_2	H_3	H_4	H_5	H_6	
Horse manure	0.1	1.4	0.7	1.3	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5
Yard (leaf+grass)	0.3	1.3	0.8	1.1	0.2	0.7	0.0	0.0	0.2	0.0	0.0	0.0	4.6
Sludge	0.1	0.3	0.7	0.7	0.2	1.3	0.0	0.0	0.0	0.0	0.0	0.0	3.3
Yard+Sludge	0.2	0.7	0.3	1.1	0.4	0.2	0.2	0.0	0.0	0.0	0.0	0.0	3.1
Fertilizer 10-10-10	0.0	0.9	0.7	0.7	0.4	0.0	0.0	0.0	0.0	0.5	0.4	0.0	3.6
$LSD_{.05}$			0.6						0.3				0.6

[a]H_1-H_6=Harvests 1-6

Table 5. Harvest intervals and their effect on marketable and non-marketable yield of tomatoes grown in plots treated with composted waste, 1993.

	Yield (Mt/ha)														
	Marketable							Non-Marketable							Total
Composted Materials	H_1[a]	H_2	H_3	H_4	H_5	H_6	H_7	H_1	H_2	H_3	H_4	H_5	H_6	H_7	
Horse manure	0.1	4.6	5.6	9.4	14.2	13.0	4.7	0.1	0.4	4.3	5.1	4.6	6.7	6.7	79.5
Yard (leaf+grass)	0.5	2.4	4.1	11.9	16.5	9.4	3.2	0.3	0.9	4.0	5.2	3.9	3.9	3.1	61.7
Sludge	1.2	1.6	6.4	10.2	21.1	12.7	7.8	0.8	0.9	4.1	10.0	5.9	5.9	3.2	89.0
Yard+Sludge	2.2	6.1	5.0	8.1	6.0	0.0	0.0	4.1	1.2	5.1	7.6	8.2	8.2	0.0	61.3
Fertilizer 10-10-10	0.2	3.3	5.0	14.7	25.5	18.7	11.7	0.1	1.9	4.6	9.9	8.3	8.3	5.4	115.0
$LSD_{.05}$			0.6							0.1					0.5

[a]H_1-H_7=Harvests 1-7

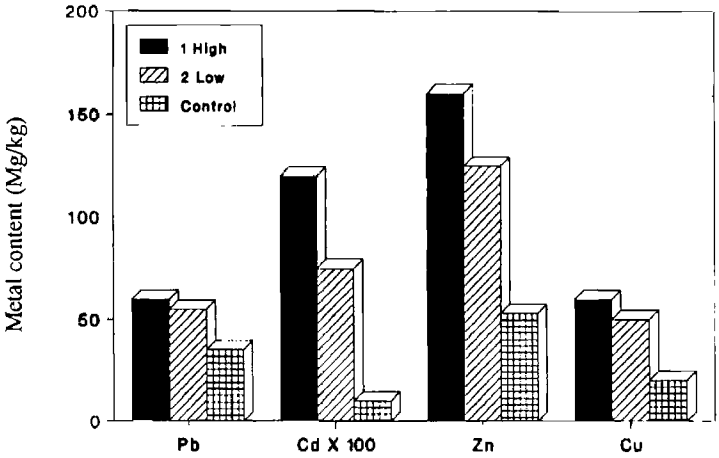

Fig. 1. Heavy metal composition in soils of field plots treated with sewage sludge (1983-1987).
[1,2] Rates of composted sewage application.
[3] Values followed by the same letters are not significantly different at p=.05.

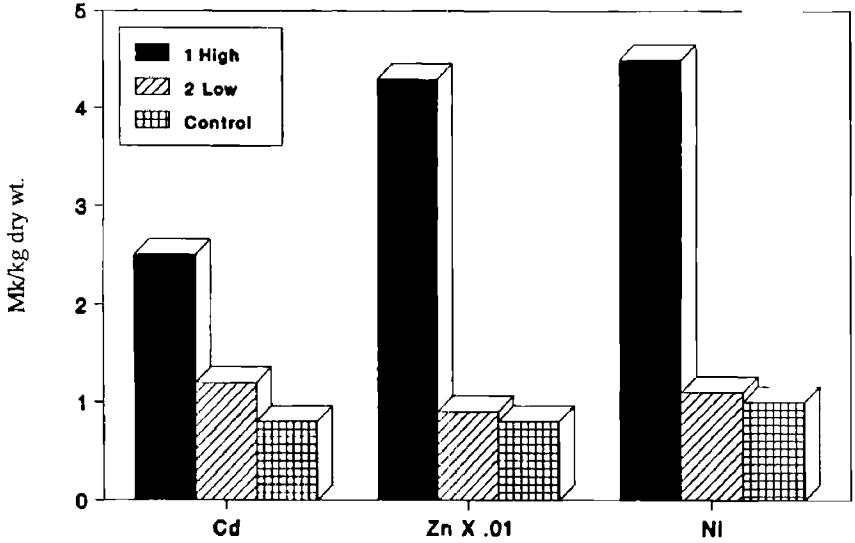

Fig. 2. Uptake of heavy metals by swiss chard grown on a soil treated with composted sewage.
[1,2] Rates of sewage application.