Influence of application of sewage sludge and manure compost on crop ZN concentration and soil Zn availability index in a loamy sand soil in Ontario

Guang Wen[1], R. P. Voroney[2] J. J. Schoenau[1] and T. E. Bates[2]

[1]Dept. of Soil Science, Univ. of Saskatchewan, SASK, Canada S7N 5A8.
[2]Dept. of Land Resource Science, Univ. of Guelph, Ont., Canada NIG 2WI.

INTRODUCTION

An advantage of farm application of organic wastes, such as sewage sludges and manure is that organic wastes usually provide a number of nutritive elements to crops with little added cost. However, while manure application is, in general, considered safe, there are concerns about heavy metal contamination with application of wastes that may contain excessive amount of heavy metals, such as sewage sludges. With increased awareness about potential harmful effects, strict government regulations have been applied on industrial effluents draining to public sewage systems.

In Ontario, most sludges are treated with Al and Fe to reduce soluble P. Chaney (1990) suggested that application of sludges with low metal contents and high contents of hydrous Fe oxides and other adsorption sites may actually reduce metal uptake by crops. Under neutral to slightly alkaline conditions, hydrous Al and Fe oxides can lower the activity of metals in soil solution (Bruemmer et al. 1986). It has been reported that application of Al and Fe treated sludge reduced CH_3COONH_4-extractable soil Mg (Soon et al. 1978; Wen at al. 1999). Few studies have compared the effect of sewage sludge and other organic amendments on Zn availability. This poster describes a few experiments evaluate and compare the influences of sewage sludge and manure applications on crop Zn concentration and soil Zn availability index.

MATERIALS AND METHODS

Site: The experiment was conducted at Univ. Of Guelph Research Station (Cambridge, Ont.) on a Lisbon **loamy** sand with measured OC= 9 g **kg^{-1},** total N= 0.7 g kg“, **$NaHCO_3$-** extractable P= 79 mg **kg^{-1}, CH_3COONH_4-extractable K=136** mg kg“ and **pH=6.6.**

The soil Zn availability index=27. Soil Zinc was extracted by DTPA (Lindsay and Norvell 1978) and soil Zn availability index was calculated using following equation:

$Zn_{Index} = 203 + 4.5 \bullet Zn\ (mg\ kg^{-1}) - 50.7 \bullet pH + 3.33 \bullet pH^2$ (OMA 1990 a).

Organic Amendments

DSS: Anaerobically digested dewatered sewage sludge.

DISS: Anaerobically digested, dewatered, irradiated sewage sludge.

DICSS: Anaerobically digested, dewatered, irradiated and composted sewage sludge.

CLM: Composted livestock manure.

Experimental design: The four organic wastes were spread and incorporated into soil **(0- 15** cm) at four rates (10, 20, 30 and 40 Mg **ha^{-1}** dry weight) and each treatment replicated four times. Plot size: 4 •**4** m.

All treatments received adequate amounts of N and K fertilizer based on fertilizer recommendations (OMAF 1990 b). Treatments receiving less than the recommended amount of N and K from amendments, received fertilizer N or K as supplement. The Control Treatment (CT) received no amendments but fertilizer N and K.

In 1990, one half (2.4m) of each plot was planted to lettuce (cv. Grand Rapids), which was followed by snap bean (cv. Tender Green). The other half was planted to petunias (cv. Superior Red). In 1991, only one crop (lettuce) was grown, and two consecutive cuts were harvested. The DTPA-extractable soil Zn was measured in the samples collected after the second cut of lettuce.

RESULTS AND DISCUSSION

In 1990, the four organic amendments supplied approximately same amounts of total Zn within a same rate (Fig. 1). In 1991, sludge and sludge compost added more Zn than did manure compost. Crop yields with all treatments were approximately equal due to similarity in the supply of available N (a few treatments were excluded).

In 1990 in all three crops, the crop Zn concentration significantly increased with DSS and DISS applications at 20 Mg ha^{-1} rate (Table 1). Application of DICSS and CLM did not change Zn concentration in comparison with that of Control. The Zn concentrations in bean pod were only about half of those in lettuce. Bean pod is not as sensitive in accumulation of metals as lettuce (Korentajer 1991).

Table 1. Zinc concentration in crops grown in 1990.

Organic Source	Application rate (Mg ha^{-1})				
	0	10	20	30	40
			Lettuce leaves (mg kg^{-1})		
CT	50.3 b				
DSS		56.3 ab	68.3 a	‡	‡
DISS		59.3 ab	67.0 a	‡	‡
DICSS		53.5b	50.8 b	52.8 b	54. 5 ab
CLM		‡	53.0 b	54.3 ab	52.3 b
			CV%=13.1; L.S.D†=11.4		
			Bean pod (mg kg^{-1})		
CT	23.3 de				
DSS		25.5 bcde	25.9 abcde	26.1 abcd	26.7 abc
DISS		27.1 ab	27.2 ab	28.5 a	26.5abc
DICSS		24.7 bcde	24.5 bcde	23.2e	25.3 bcde
CLM		24.2 cde	24.8bcde	25.4bcde	25.7 abcde
			CV%=8.0; L.S.D†=2.91		
			Petunias (mg kg^{-1})		
CT	27.3 cdef				
DSS		26.8 cdef	3 1.7 abc	36.4 a	33.6 abc
DISS		28.1 cde	30.5abcd	30.2 abcd	35.1 ab
DICSS		27.8 cdef	20.8 f	22.6 ef	23.6 def
CLM		23.0 ef	29.0 bcde	24.0 def	24.2 def
			CV%=17.7; L.S.D†=7.0		

†L.S.D.(0.05) is for determining the difference among the treatments. Means followed by different letters are significantly different.
‡the treatment was excluded due to variable crop yield.

In the 1991 lettuce crops, the DSS and DISS application, particularly with DSS, also resulted in significant increase in lettuce Zn concentration at the high rates, (Table 2).

Table 2. Zinc concentration in crops grown in 1991 and soil Zn index after two-years waste application.

Organic Source	Application rate (Mg ha^{-1})				
	0	10	20	30	40
	First cut lettuce (mg kg^{-1})				
CT	41.0 ef				
DSS		52.0 abcdef	60.3 ab	61.5 a	58.3 abc
DISS		49.0 abcdef	51.0 abcdef	54.8 abcde	57.0 abcd
DICSS		43.8 cdef	42.0 def	45 bcde	‡
CLM		37.8 f	40.0 ef	375 f	42.5 def
	CV%=22.1; L.S.D†=15. 1				
	Second cut lettuce (mg kg^{-1})				
CT	51.8 cdef				
DSS		54.5 abcde	72.8 a	74.8 a	68.8 ab
DISS		52.0 bcdef	65.0 abcd	67.5 abc	68.0 abc
DICSS		50.5 def	43.5f	46.8 ef	‡
CLM		45.5 f	47.3 ef	45.5 f	48.0 ef
	CV%=18.7; L.S.D†=16.8				

†L.S.D.(0.05) is for determining the difference among the treatments. Means followed by different letters are significantly different.
‡the treatment was excluded due to lack of waste material.

Plant Zn concentrations in the first cut and second cut of lettuce in 1991 were significantly correlated with soil Zn indices (Fig. 2 a and b). Correlation between crop Zn uptake and the soil Zn index have been reported (Haq and Miller 1972). In our studies, the measured soil Zn availability index appeared to reflect the bioavailability of Zn as revealed in tissue contents..

No significant correlation relationship was found between crop Zn concentration and the amount of Zn applied with organic amendments. As soil contained sufficient available Zn prior to the start of the experiment (OMAF 1990 b), it is possible that the crop Zn accumulation potential was reached with high rate of DSS and DISS applications. Chaney (1990) observed that after Zn concentrations in lettuce increased to a plateau with sludge application, further increases in application rate did not increase crop Zn concentration.

The application of compost-DICSS or CLM did not increase crop Zn concentration vs the Control. For many metals in land applicable organic materials, the organic species is the dominant form and the release of Zn during decomposition has significant influence on soil Zn availability (Sterritt and Lester, 1984; Martens and Lindsay, 1990). The metal absorption capacity to organic matter is greatly influenced by the quality of organic matter (Corey et al. 1987). Witter (1988) and Deiana et al. (1990) showed that the humic acids extracted from sewage sludge contained a higher percentage of aliphatic carbon which are of lower molecular weight, and easier to be decomposed, while the humic acids extracted from composts are similar to those in soils with multiple bonding sites that complex and chelate Zn strongly.

There have been few studies comparing crop composition from application of organic amendments with different stages of stabilization. However, Kirkham (1978) reported that plants grown in soils receiving raw sludge had higher concentrations of K, Ca, and Mg than those grown with digested sludge. The opposite results were found for Fe, Zn, Cu, Ni Cr and Cd. Digestion is often used to reduce soluble organic mater in sewage sludge.

The soil pH was increased significantly with CLM application (the mean values measured after two years application were 6.25,6.47,6.75 and 6.83 for CT, DSS, DISS, DICSS and CLM, respectively) (Wen et al 1995), which may be another reason for the low Zn availability observed with DICSS and CLM applications. Increased soil pH has resulted in markedly lower concentrations of Zn in grass with sludge application (Rates et al. 1975).

Although application of DSS only resulted in higher soil Zn indices than DISS at rates of 30 and 40 Mg ha^{-1}, the crop Zn concentration with DSS consistently appeared higher than with DISS in almost all crops. The changes in the chemical behavior of metals in sludge due to irradiation would not be expected, however, irradiation may affect organo-metal complexes in sludges (Kirkham 1980). Irradiation can cause the degradation of organic matter through radical reactions, and the low molecular weight compounds formed during irradiation may act as soluble metal carriers. Campanella et al. (1989) reported that ***UV*** itradiation of sludges increased the mobility of Pb, Cu, and Zn. Rosopulo et al. (1975) reported higher K uptake in plants with irradiated than non-irradiated sludge. Opposite results that irradiation did not affect the plant availability of metals were also reported (Kirkham, 1980; Rosopulo et al., 1975; Suess et al., 1975; NMSU Agriculture Experiment Station, 1982). As Wen, et al. (1997) found that irradiation may inhibit organic matter decomposition in sludge, it is possible that decomposition has been rapid in DSS resulting releasing more plant available Zn that did DISS.

CONCLUSIONS

Application of sewage sludges consistently increased crop Zn concentrations while application of sludge compost and manure compost did not. Although the amount of available Zn in sludges can not be adequately estimated by measuring total Zn content, the influence of organic amendments on soil Zn fertility was reflected in both soil Zn availability index measurement and plant Zn tissue concentration Irradiation treatment for sewage sludge appeares to reduce the availability of Zn.

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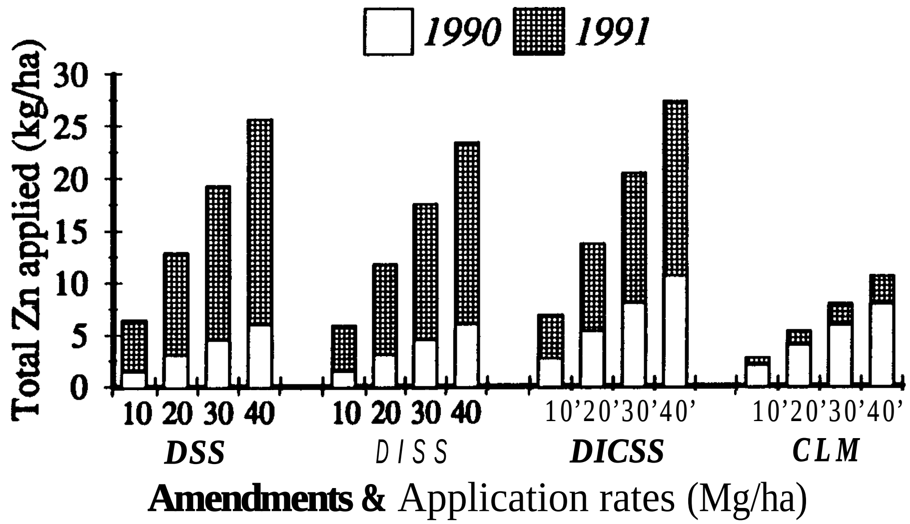

Fig. 1. Amount of Zn applied in two years with organic amendments.

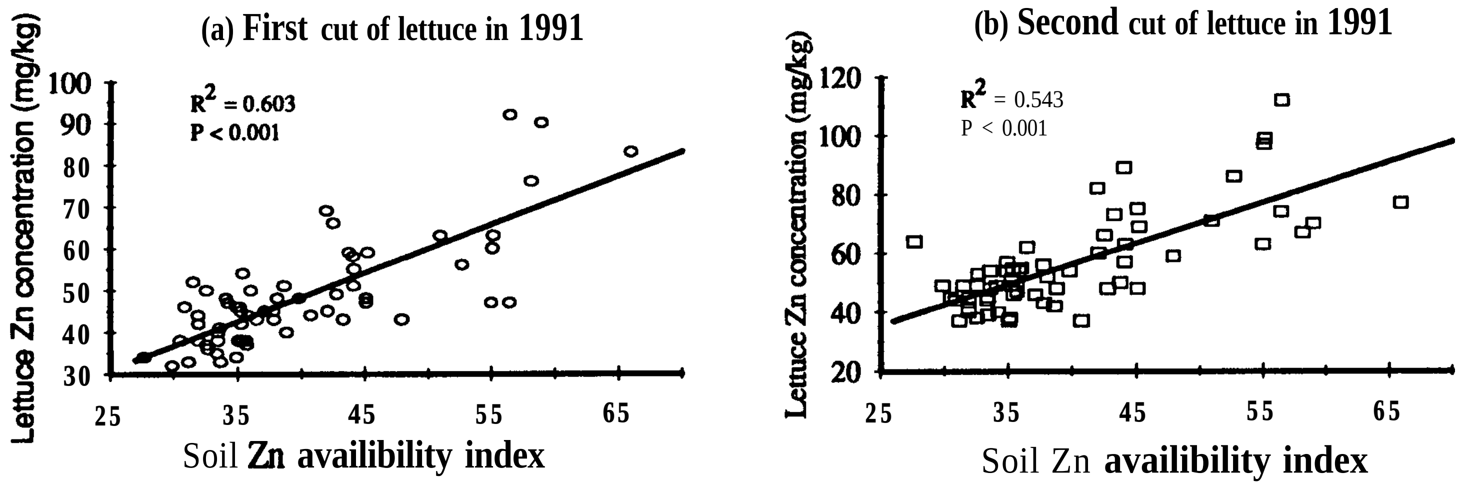

Fig. 2. Correlation relationship between crop Zn concentration and soil Zn availability index measured after two years application (a). First cut of lettuce in 1991: Y=2.13+1.15•X; (b). Second cut of lettuce in 1991: Y=0.953+1.39•X.