Influence of Application of Sewage Sludge, Sludge and Manure Compost on Plant Ca and Mg Concentrations and Soil Extractability

Guang Wen*, R. Paul Voroney and Thomas E. Bates

INTRODUCTION

Land application of organic wastes provides several nutrient elements to crops at little cost. When available N, P, and K in soils increase with fertilization, Ca and Mg could become insufficient. Additional supply of Ca and Mg to soil from organic wastes can increase crop yields (Hue, 1988).

Although theory implies that plant availability of Ca and Mg could be influenced by addition of organic materials, as the bonds between Ca and Mg and organic constituents may be different in strength and influenced by different decomposition dynamics, such a comparison has not been conducted.

Pathogenicity must be taken into consideration before sludge is applied. Composting and irradiation are often used to eliminate pathogens (US EPA, 1993). While composting changes the characteristics of organic matter, irradiation may inhibit biological decomposition of organic matter (Wen et al., 1995 & 1997). An understanding of the differences in the availability of Ca and Mg in different organic wastes is needed for proper use of the wastes.

The objective of this research was to compare different organic wastes as to their influences on Ca and Mg available to crops and soils.

MATERIALS AND METHODS

The field experiment was conducted over two growing seasons from April 1990 to July 199 1, at Univ. of Guelph, Ontario on a soil belonging to the Lisbon series (an Orthic Melanie Brunisol). Characteristics of the soil are shown in Table

1.

Four organic wastes were spread and incorporated in to soil (15 cm). Three of them involved the use of anaerobically digested, dewatered sewage sludge that received no further treatment (DSS), or were irradiated (DISS), or were composted after irradiation (DICSS). The DISS was prepared by exposing DSS to gamma irradiation at an absorbed dose of 6 kGy. A fourth waste involved the use of composted livestock manure (CLM). Properties of the wastes are shown in Table 2.

Each material was applied at 4 rates: 10, 20, 30 and 40 Mg solids ha" year-' with 4 reps. All treatments were designed to supply adequate amounts of N and K based on fertilizer recommendations (Ontario Ministry of Agriculture and Food, 1990). Treatments receiving less than the recommended amount of N or K from wastes, received fertilizer N or K as a supplement. A control treatment (CT) received no wastes but fertilizer N and K. Application of Ca and Mg with the wastes are shown in Fig. 1 a & b.

In 1990, one half (2 x 4 m) 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. CH_3COONH_4-extractable soil Ca and Mg were measured after second cut of lettuce.

RESULTS AND DISCUSSION

Crop yields with all treatments were approximately equal (extraordinary cases were excluded), due to approximate supply of available N. Crop responses to application of Ca and Mg were consistent with young plants appeared more sensitive than mature ones, and likely due to the cumulative applications (Fig. 1 a & b), the trends were more apparent in 199 1 than in 1990. This poster illustrates the changes occurred with the first cut of lettuce in 199 1 and the extractable soil Ca and Mg as affected by the waste application.

Crop Ca concentration and extractable soil Ca

Calcium concentration at 40 Mg ha^{-1} application of DSS was the highest among all treatments (Table 3), and the increase in crop Ca concentration was correlated with Ca application (Fig. 2 a). In contrast, Ca concentration at 40 Mg ha^{-1} application of CLM was low, and although CLM application at 10 Mg ha^{-1} significantly increased the extractable soil Ca to that of CT (Table 3), the increasing application rates decreased the extractable soil Ca (Fig 2 b).

Crop Mg concentration and extractable soil Mg

Application of Mg with DSS and DISS significantly increased Mg concentration in first cut of lettuce and the increases were correlated with application rates (Table 4 & Fig. 3 a). In contrast, Mg concentration decreased with increased application of CLM, and similar to Ca, a low concentration of crop Mg was found at 40 Mg ha^{-1}.

The low crop Ca and Mg concentrations with high rates of CLM may be related to the huge amount of K applied (1100 kg ha^{-1} accumulated at 40 Mg ha^{-1} rate, approximately thirteen times that of recommended). Plant and extractable soil K concentrations were significantly increased (data not shown). Potassium has antagonistic effect on Ca and Mg.

In contrast to decreased Mg concentration in crop, the extractable soil Mg linearly increased with increased CLM application (Fig. 3 b). In contrast to increased crop Mg concentration, application of DSS reduced extractable soil Mg at 40 Mg ha‘ ¹. Similar, but less significant reduction of extractable soil Mg occurred to other DSS and DISS treatments (Table 4). High concentration of hydrous oxides of Fe and Al in sludges could actually reduce uptake of metals (Chaney, 1990). Soon et al. (1978) reported that application of chemically treated (addition of Fe & Al) sludge, in which the contents of Al and Fe were similar to those in DSS and DISS (Table 2), reduced extractable soil Mg.

CONCLUSIONS

No significant changes were found with irradiation or cornposting treatments. However, while increasing rates of sludge application (DSS & DISS) increased crop Ca and Mg concentrations, increasing application of manure compost (CLM) decreased the crop Ca and Mg concentrations.

The CH_3COONH_4-extractable soil Mg was not a valid index of available soil Mg with application of the wastes.

Acknowledgment

The study was funded partially by Nordion International Inc. 447 March Rd., P.O. Box 13500, Kanada, Ontario K2K 1X8. The authors wish to thank cooperation from Ms. Swinwood, J. (Liaison Officer, Nordion International Inc.).

REFERENCES

Chaney, R.L. 1990. Twenty years of land application research. Biocycle. 3 1:54-59.

Hue, N.V. 1988. Residual effect of sewage-sludge application on plant and soil-profile chemical composition. Commun. in Soil Sci. Plant Anal. 19:1633-1643.

Ontario Ministry of Agriculture and Food. 1990. 1991-1992 Field crop recommendations. Publication 296. Canada.

Soon Y.K., T.E. Bates and L.R. Moyer. 1978. Land application of chemically treated sewage sludge: II. Effects on plant and soil phosphorus, potassium, calcium, and magnesium and soil pH. J Environ Qual 7: 269-273

US EPA. 1993. Environmental regulations and technology; Use and disposal of municipal wastewater sludge. US EPA 503.48. U.S. Gov. Print. Office, Washington, DC.

Wen, Guang, T.E. Bates and R.P. Voroney. 1995. Evaluation of nitrogen availability in irradiated sewage sludge, sludge compost and manure compost. J. Environ. Qual. 24:527-534.

Wen, Guang, R.P. Voroney, J.P. Winter and T.E. Bates. 1997. Effects of irradiation on sludge organic carbon and nitrogen mineralization. (In press. Soil Biology and Biochemistry).

Table 1. Relevant characteristics of the surface 15 cm soil.

Parameter	Unit	Value
Texture	Loamy sand	
pH		6.6
Organic carbon	g kg^{-1}	9.0
Total N	g kg^{-1}	0.68
$NaHCO_3$-extractable P	mg kg	79
CH_3COONH_4-extractable K	mg kg^{-}	136
CH_3COONH_4-extractable Ca	mg kg'	960
CH_3COONH_4-extractable Mg	mg kg	96

Table 2. Characteristics of digested sewage sludge (DSS), irradiated sewage sludge (DISS), irradiated composted sewage sludge (DICSS) and composted livestock manure (CLM) applied in 1990 and 1991.

		1990				1991			
Parameter	Unit	DSS	DISS	DICSS	CLM	DSS	DISS	DICSS	CLM
Dry Matter	g kg^{-1}	299	296	677	611	299	300	561	594
Total N	g kg^{-1}	20	22	10	11	28	26	17	10
$NH_4^+ + NO_3^-$	mg kg^{-1}	117	457	263	1446	627	878	521	1042
P	g kg^{-1}	12	16	12	6	32	36	22	4
K	g kg^{-1}	1.0	1.7	3.0	14.7	2.0	2.7	4.4	12.7
Al	g kg^{-1}	45	46	9	Nd	8	8	6	Nd
Fe	g kg^{-1}	61	60	135	Nd	237	238	245	Nd
pH		6.1	5.7	6.2	8.6	8.1	7.9	6.8	8.1

Table 3. Crop Ca concentration and CH_3COONH_4-extractable soil as affected by application of digested (DSS), irradiated (DISS), composted sewage sludge (DICSS) and composted livestock manure (CLM).

Organic Source	Application Rate (Mg ha^{-1})				
	0 (CT)	10	20	30	40
	Ca concentration in First cut of **lettuce† (g** kg")				
CT	16.2 b-e				
DSS		15.9 cde	17.1 bc	18.1 ab	19.7 a
DISS		16.0 cde	16.4 b-e	16.8 bcd	17.6 bc
DICSS		15.0 de	16.3 b-e	15.8 cde	‡
CLM		16.0 cde	14.8 de	14.9 de	14.5 e
	C.V.%=8.7 LSD.(0.05)=2.0				
	CH_3COONH_4 -extractable Soil **Cat** (mg kg")				
CT	959 d				
DSS		1037 cd	960 d	1140 a-d	1089 cd
DISS		999 cd	971 d	1222 a-d	1417 a
DICSS		956 d	1275 abc	1138 a-d	‡
CLM		1408 ab	1172 a-d	1106 bcd	1181 a-d
	C.V.%=17.5 LSD.(0.05)=282				

i-means not followed by same letter are different ($P \leq 0.05$).
‡value is not presented due to lack of the material.

Table 4. Crop Mg concentration and CH_3COONH_4-extractable soil Mg as affected by application of digested (DSS), irradiated (DISS), composted (DICSS) sewage sludge and composted livestock manure (CLM).

Organic Source	Application Rate (Mg ha“)				
	0 (CT)	10	20	30	40
	Mg concentration in first cut of lettuce† (g kg“)				
CT	3.83 ghi				
DSS		4.10 d-h	4.65 cd	4.98 bc	5.63 a
DISS		4.35 c-g	4.60 cde	4.53 c-f	5.48 ab
DICSS		3.75 g-j	3.65 hij	3.98 e-h	‡
CLM		3.90 f-i	3.33 ij	3.53 hij	3.13 j
		C.V.%=10.5	LSD.(0.05)=0.63		
	CH,COONH,-extractable Soil Mg† (mg kg^{-1})				
CT	91 bcd				
DSS		74 ed	80 ecd	83 ecd	66 e
DISS		78 ecd	77 ecd	83 ecd	76 ed
DICSS		79 ecd	95 bc	101 ab	‡
CLM		95 bc	114 a	105 ab	115 a
		C.V.%=14.2	L.S.D.(0.05)=18		

†means not followed by same letter are different ($P \leq 0.05$).
‡value is not presented due to lack of the material.

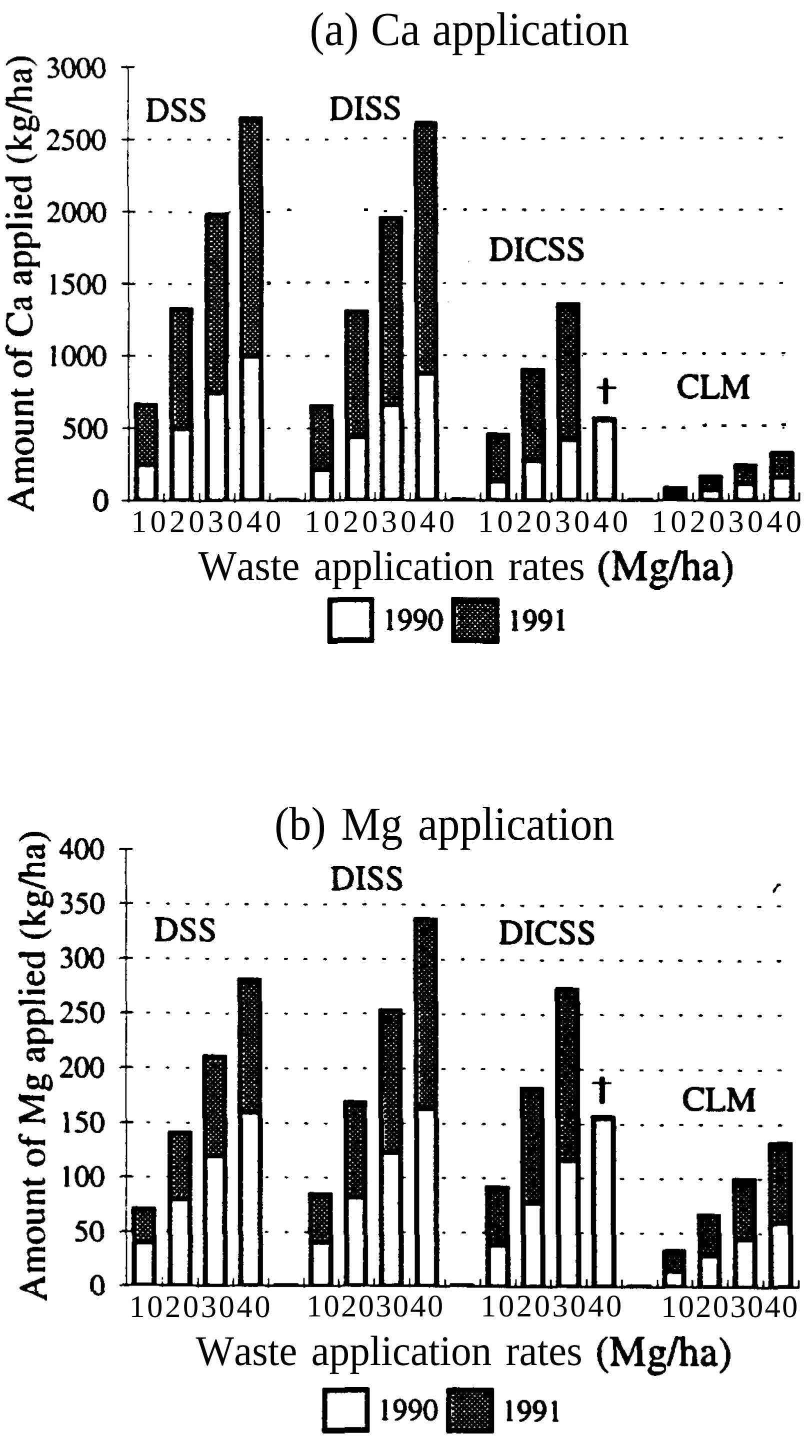

Fig. 1. Application of Ca and Mg from digested (DSS), irradiated (DISS), composted (DICSS) sewage sludge and composted livestock manure (CLM). †value is not presenteddue to lack of the material.

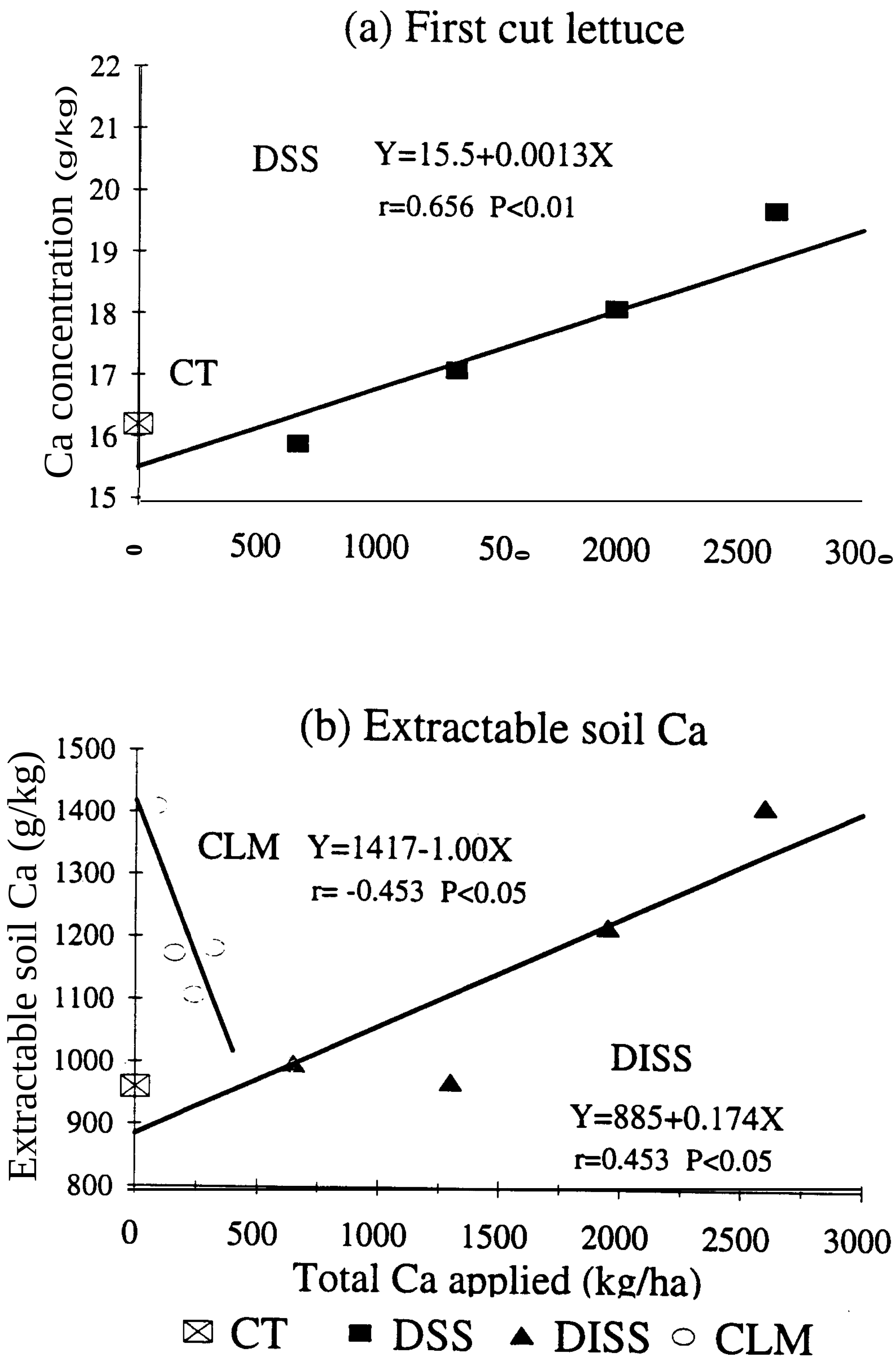

Fig. 2. Significant correlation between (a) Ca concentration in first cut of lettuce in 1991, (b) CH_3COONH_4-extractable soil Ca and the amount of Ca applied.

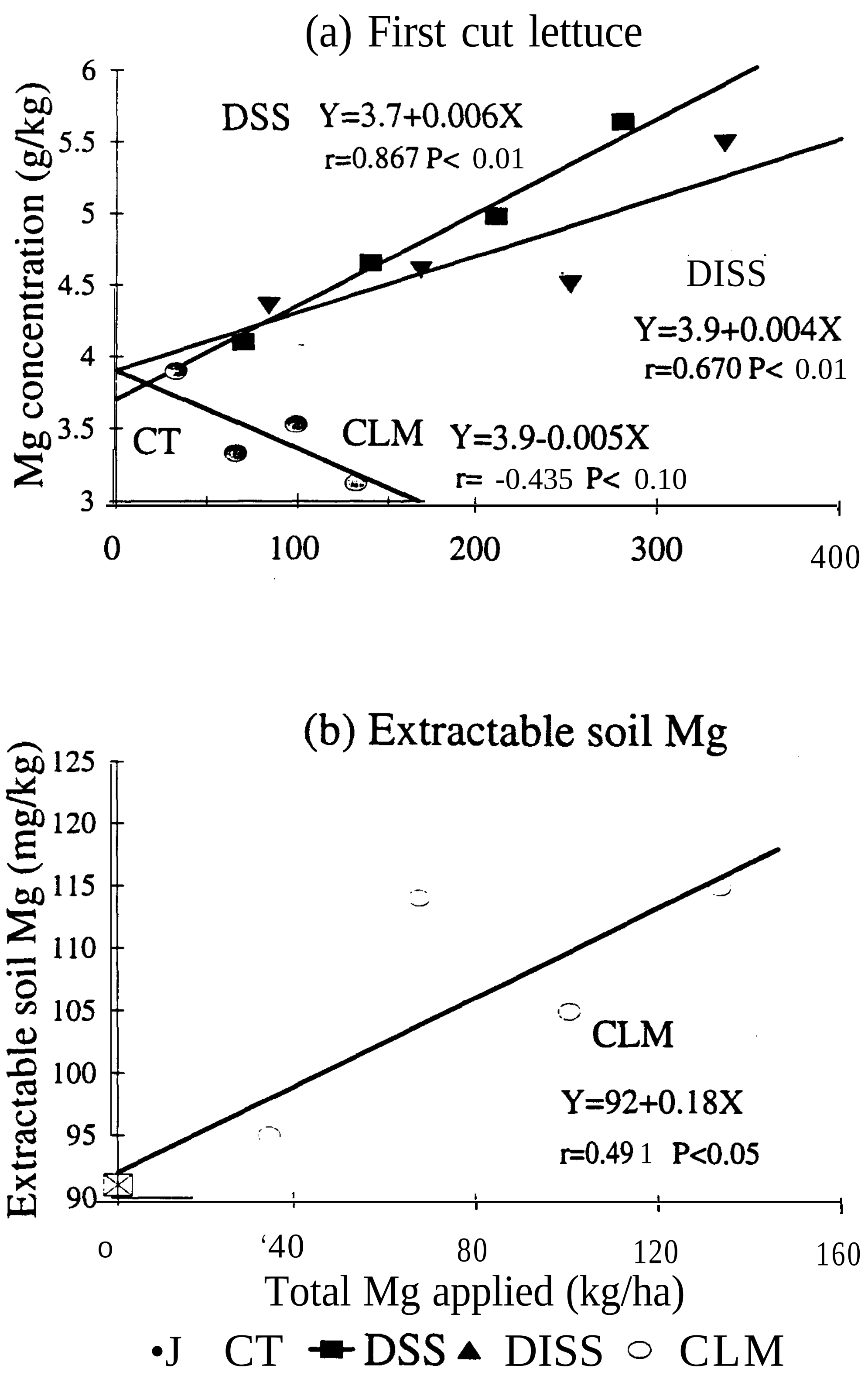

Fig. 3. Significant correlation between (a) Mg concentration in first cut of lettuce in 1991, (b) CH,COONH,-extractable soil Mg and the amount of Mg applied.