Agronomics of Land Application of Municipal Collected Shade Tree Leaves: I. Soil Properties

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ABSTRACT. Land application of municipal collected shade tree (MCST)-leaves is a permitted practice in New Jersey that may be useful in sustainable agriculture. The material helps build soil organic matter, but its overall impact on soil properties and nutrient levels needs to be determined. This study, conducted near Pittstown, NJ on a Quakertown silt loam (fine-loamy-mixed, mesic, Typic hapludult) from 1991 to 1994, examined the effects of MCST-leaves on soil organic matter content, pH, and soil test levels of nutrients and heavy metals, following three years of annual applications at 0, 22.5 and 45 Mg ha^{-1} yr^{-1}. Soil samples were collected four years after the initial application of MCST-leaves to evaluate treatment effects. Soil organic carbon levels increased from 13.9 g kg^{-1} in the unamended soil to 17.1 g kg^{-1} in the 22.5 Mg ha^{-1} yr^{-1} rate of MCST-leaves and to 18.4 g kg^{-1} for the 45 Mg ha^{-1} yr^{-1} rate. About 17% of the C that was added to the soil as MCST-leaves remained in the soil one year after the end of the three-year period of annual applications. Soil organic nitrogen levels increased from 1.0 g kg^{-1} for the unamended soil to 2.0 g kg^{-1} for the 45 Mg ha^{-1} yr^{-1} rate. Soil pH levels and Mehlich-3 extractable P, K, Cu, Mn, Zn, Co, Cd, Pb, Ni and Cr were unchanged by the applications of MCST-leaves while levels of Ca and B were increased. Percentage of

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exchangeable Ca increased in the amended soil while the exchangeable Mg decreased. The practice of land applying MCST-leaves is consistent with sustainable agriculture, to raise soil organic matter and Ca levels without causing an excessive buildup of soil test P.

KEYWORDS. Organic matter, calcium, nitrogen, boron, leaf litter

INTRODUCTION

Farmland may benefit from the application of MCST-leaves from urban areas as a source of organic material for soil improvement. In New Jersey, state regulations (New Jersey Register, NJAC 7:26-1.2, 7 Nov. 1988) allow MCST-leaves to be applied to agricultural land in a layer no higher than 15-cm (equivalent to approximately 45-Mg ha^{-1} of dry matter). The regulations require that tillage be used to incorporate the leaves into the soil. A study (Heckman and Kluchinski, 1996) of the chemical composition of MCST-leaves revealed that it has relatively low concentrations of most plant nutrients (1, −0.1, −0.4, NPK) and a mean carbon to nitrogen ratio of 50:1. Application rates of MCST-leaves are often greater than other organic materials including sewage sludges and manures, which typically have higher concentrations of N and P (Sommers, 1977). Heavier application rates of MCST-leaves may therefore be used to rapidly build up soil organic matter levels, but the impact on soil properties and crop production needs to be investigated to develop sustainable agronomic management practices for their use on agricultural land.

The present work examines the influence of application rates of MCST-leaves on soil organic matter content, and soil levels of nutrients and heavy metals. A following paper examines the influence of application rates of MCST-leaves on soybean and corn production.

MATERIALS AND METHODS

The experiment was conducted on a Quakertown silt loam (fine-loamy, mixed, mesic Typic Hapludult) at the Rutgers University Snyder Research and Extension Farm near Pittstown, New Jersey. The field had been cropped to sorghum-sudangrass cover crop in the previous growing season and had an initial soil pH of 6.4. Soil P and K levels at the initiation of the experiment in

1990 were 113 kg P ha^{-1} and 184 kg K ha^{-1} using the Mehlich-3 soil test (Mehlich, 1984). MCST-leaves were applied to plots each November of 1990 through 1992, using a manure spreader. The annual application rates of MCST-leaves on a dry basis were 0, 22.5, and 45-Mg ha^{-1}. Following their application, the leaves were incorporated with two passes of a chisel plow.

The treatment plots were established as a randomized complete block design with 4 replications. Individual plot size was 15.2 × 45.6 m^2. Plots were separated by grass buffer strips to prevent soil mixing among treatments. The main plots were split into sub-plots that were cropped to either continuous corn, continuous soybean, a corn-soybean-corn rotation or a soybean-corn-soybean rotation. Details of the cropping practices are given in the following paper (Heckman and Kluchinski, 1999). Soil samples were collected in November 1993, after crops were harvested, to measure the amendment effects on soil properties. Composite soil samples were collected from the 0 to 17-cm depth by taking 64 cores from each application rate of MCST-leaves, within each replicate. Equal numbers of cores were taken from each cropping system within a MCST-leaf application rate treatment and mixed together as a composite soil sample. Soil samples were analyzed for pH on a 1:1 ratio of soil volume to water and for extractable P, K, Ca, Mg, B, Mn, Zn, Cu, Co, Cd, Pb, Ni, and Cr by the Mehlich-3 method (Mehlich, 1984). An organic C concentration was determined by the Walkley-Black method (Walkley and Black, 1934). Organic N concentration was determined by the Kjeldahl method. Cation exchange capacity was estimated by summing the cations extracted (by the NH_4OAc solution). The chemical analysis of the MCST-leaves was performed as described in Heckman and Kluchinski (1996) (Table 1). Analysis of variance was performed with SAS GLM (SAS Inst., 1991). Single degree of freedom contrasts were tested for treatment effects.

RESULTS AND DISCUSSION

Annual applications of MCST-leaves over the three-year period increased the organic C and organic N concentrations in the surface 17-cm of soil (Table 2). The C/N ratio of the soil organic matter was generally lower in soil where MCST-leaves were applied but it was not significantly lower than the unamended soil in the surface 17-cm. At the high application rate, the total amount of C and N added to soil over the three-year period was 63,815 kg C ha^{-1} and 1,350 kg N ha^{-1} (Table 1). At the high application rate the amended soil has 10,170 kg ha^{-1} more organic C than the unamended soil in the surface 17 cm. About 17.6% of the C that was added to the soil as MCST-leaves remained in the soil one year after the end of the three-year period of annual applications. Barber (1979) calculated the amount of C in

TABLE 1. Chemical composition of municipal collected shade tree (MCST)-leaves in New Jersey,[1] estimated application amounts of selected elements to soil from annual applications of MCST-leaves at 45 Mg ha^{-1} yr^{-1}, from 1990 to 1992.

Element	Minimum	Maximum	Mean	Total Element Applied to Soil
	----------- g kg^{-1}	-----------		kg ha^{-1}
C	362.8	516.1	472.7	63815
N	6.6	16.2	10.0	1350
P	0.2	2.9	1.0	135
K	0.9	8.8	3.8	513
Ca	1.3	30.4	16.4	2214
Mg	0.2	4.6	2.4	324
S	0.1	2.1	1.1	149
	---------- mg kg^{-1}	-----------		
B	7	72	38	5
Mn	19	1845	550	74
Zn	22	392	81	11
Na	36	325	110	15
Cu	2.8	31.5	9.2	1.2
Co	0.9	10.9	3.1	0.4
Cd	0.1	6.8	1.7	0.2
Pb	3.1	399.9	28.4	3.8
Ni	1.1	57.9	7.2	1
Cr	0.9	35.1	7.6	1

[1] Heckman and Kluchinski, 1996.

corn crop residues that was transformed into organic matter at 11%. The lower transformation value for corn residues may be related to its lower lignin content than that found in MCST-leaves. The lower C transformation value may also be related to the much larger volume of material added to soil with MCST-leaves and consequently the longer time needed to reach a new equilibrium for organic C content.

Applications of MCST-leaves did not increase the soil test level of P (Table 3). Repeated applications of manure or sewage sludge (Magdoff and Amadon, 1980; Sims, 1998) at rates that are determined by the crop N requirement, increase the soil test P to excessive levels. MCST-leaves typically have lower concentrations of N and P than livestock manures or sewage sludges (Heckman and Kluchinski, 1996). Thus, unlike manure or sludge, MCST-leaves can be applied at high rates to build soil organic matter content without rapidly raising soil test P to excessive levels.

Soil test K and Mg levels were not increased on MCST-leaf amended soil. Soil test Ca levels, however, were significantly increased on amended soil. MCST-leaves have a higher Ca concentration than any other plant nutrient (Heckman and Kluchinski, 1996). For the highest application rate, the total

TABLE 2. Soil organic carbon, organic nitrogen, and carbon to nitrogen ratio in November 1993 in relation to annual applications of MCST-leaves in November 1990 to 1992.

MCST-Leaves	Organic Carbon	Organic Nitrogen	Carbon/Nitrogen Ratio
Mg ha^{-1} yr^{-1}	----------g kg^{-1}	---------	
0	13.9	1.0	13.9
22.5	17.1	1.4	12.2
45	18.4	2.0	9.2
Statistical Analysis	$P > F$		
Treatment	0.07	0.06	0.28
Check vs. Amended	0.03	0.05	0.21

TABLE 3. Mehlich-3 soil test levels of major nutrients in soil sampled in November 1993, following annual applications of MCST-leaves in November 1990 to 1992.

MCST-Leaves	Mehlich-3 Extractable			
	P	K	Ca	Mg
Mg ha^{-1} yr^{-1}	---------------	kg ha^{-1} dry soil	---------------	
0	142	398	2489	632
22.5	164	486	2847	549
45	130	486	3079	622
Statistical Analysis		$P > F$		
Treatment	0.37	0.31	0.08	0.12
Check vs. amended	0.79	0.13	0.04	0.19

amount of Ca added to the soil from MCST-leaves was 2214-kg ha^{-1}. In addition to an increase in Mehlich-3 extractable Ca, the percentage of exchangeable Ca was increased (Table 4).

The three years of MCST-leaf application caused no decrease in soil pH compared to unamended soil (Table 4). Although MCST-leaves do not appear to significantly change the agricultural limestone requirement, the selection of the appropriate liming material for future maintenance of a balance between Ca and Mg (Table 3) in the soil may be a consideration for crops that are sensitive to Mg deficiency.

The enrichment of soils with essential and non-essential microelements is a major concern with application of industrial by-products and waste materials to agricultural land. The Mehlich-3 soil test has been proposed (Sims et al., 1991) as a test to monitor waste amended soils for heavy metal accumulation. Mehlich-3 extraction of the soils in this study detected no significant increases in heavy metal accumulation from the application of MCST-leaves (Table 5). The only microelement that was increased on MCST-leaf amended soil was B, but the soil test level of this nutrient remained in a range that was favorable for crop production.

SUMMARY

MCST-leaf material is a rich source of Ca. Heavy applications of this material to soil tends to increase exchangeable Ca and decrease exchangeable Mg. Although there is little impact on soil pH from applications of MCST-leaves to soil, the selection of type of liming material is a consideration for future maintenance of a balance between Ca and Mg. Because the concentrations of N and P are relatively low, MCST-leaves may be applied to land without causing rapid buildup of soil test P, while permitting large applications of MCST-leaves to agricultural land for the purpose of effectively increasing the soil organic matter content. Following three years of annual applications of MCST-leaves, soil organic C content was increased by nearly a third and soil organic N content was doubled. Thus, leaf litter from city shade trees is a resource for soil improvement when applied to farmland.

TABLE 4. Soil pH, cation exchange capacity, and base saturation percentages in November 1993, following annual applications of MCST-leaves in November 1990 to 1992.

MCST-Leaves	Soil pH	CEC	Base Saturation			
			Ca	Mg	K	Na
Mg ha^{-1} yr^{-1}		cmol kg^{-1}	-------------- % --------------			
0	6.2	10.3	53.8	22.8	4.4	1.1
22.5	6.3	10.8	58.7	18.9	5.1	0.9
45	6.4	11.4	60.0	20.2	4.8	1.0
Statistical Analysis			P > F			
Treatment	0.49	0.22	0.09	0.01	0.34	0.30
Check vs. amended	0.37	0.13	0.04	0.004	0.19	0.19

TABLE 5. Mehlich-3 soil test levels of microelements in soil sampled in November 1993 in relation to annual applications of MCST-leaves in November 1990 to 1992.

MCST-Leaves	Mehlich-3 Extractable								
	B	Mn	Zn	Cu	Co	Cd	Pb	Ni	Cr
Mg ha^{-1} yr^{-1}	------------------- mg kg^{-1} dry soil -------------------								
0	0.39	138	3.8	23	1.2	0.14	21	0.37	0.69
22.5	0.63	163	4.6	25	1.3	0.13	21	0.49	0.76
45	0.64	158	4.6	21	1.4	0.18	20	0.46	0.85
Statistical Analysis					P > F				
Treatment	0.01	0.20	0.26	0.49	0.25	0.55	0.66	0.60	0.16
Check vs. amended	0.006	0.09	0.12	0.91	0.22	0.52	0.60	0.34	0.11

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