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Evaluation of Crop Availability of K and Mg in Organic Materials under Greenhouse Conditions

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Abstract

A greenhouse investigation using sorghum sudan [(*Sorghum bicolor* (L.) Moench] was conducted to evaluate the availability of K and Mg added in organic materials applied to a Leadvale (fine-silty, siliceous, thermic typic Fragiudult) and Taloka (fine, mixed, thermic mollic Albaqualf) soil series. Organic materials were compared to an N-P_2O_5-K_2O (13-13-13) fertilizer during a 70 days greenhouse study. They were added based on two N rates: 25 and 50 mg N kg^{-1} soil. Percent Mg recovery from added organic materials was substantially lower than that of K. Soybean, corn and wheat residues were found to be important sources of K, as about 40-50 % of K was available from these residues in a 70 days period. Therefore, we recommend that the contribution of these organic materials should be taken into account when formulating K fertilizer programs.

Introduction

Most studies on organic residue decomposition have been done on N, and to some extent P and S mineralization (Kaboneka *et al.*, 1997; Blackmer and Green, 1995; Aoyama and Nozawa, 1993; Janzen and Kucey, 1988; Enwezor, 1976). The few studies on K and Mg release have been performed on foliar litter decomposition in forestry (Bockheim and Leide, 1986; Blair, 1988). Little is known on the availability of K and Mg from organic materials applied to soils of different fertility levels.

The objectives of this greenhouse study were:

i) to evaluate plant uptake of K and Mg from soil-incorporated cattle manure, soybean [*Glycine max* (L.) Merr.], wheat (*Triticum aestivum* L.) and corn (*Zea mays* L.) residues;
ii) to evaluate the effect of soil fertility status on K and Mg release from added organic materials.

Materials and Methods

Soil physical and chemical properties have been described elsewhere (Kaboneka *et al.*, 1997; Kaboneka and Sabbe, 1995) and are summarized in Table 11.1. The Leadvale soil was limed with 9.0 g of limestone per pot (2.5 metric tons ha^{-1}) and pots were regularly watered to approximately field capacity for three weeks prior to sorghum-sudan planting to activate the added limestone. Characterization of residues was done by analyzing them for total N by digestion with H_2SO_4 and H_2O_2, followed by steam distillation of appropriate aliquots (Bremner and Mulvaney, 1982). Total plant P, S, Ca, Mg and K were analyzed by inductively coupled plasma (ICP) spectrometry after digestion with HNO_3 and H_2O_2 of a 0.2 g sample at 120° C (Zarcinas *et al.*, 1987). Ash content of residues was determined by dry combustion in a muffle furnace at 550° C for 4 hours.

Results of the analyses expressed on a dry weight basis are presented in Table 11.2. Of these organic materials, cattle manure provided the highest total amount of Ca and Mg, whereas corn and wheat residues provided the highest amount of K.

Polyethylene pots were filled with 3.53 kg of 2-mm sieved air-dried Taloka and Leadvale soil series. Residues were added based on two N rates: 25 mg N kg^{-1} soil and 50 mg N kg^{-1} soil (56 and 112 kg N ha^{-1}, respectively). They were compared to an N-P_2O_5-K_2O (13-13-13) fertilizer. A control (soil only) treatment was also included.

Table 11.1: Selected physico-chemical properties of Taloka and Leadvale soil series

	Soil	
Parameter	Taloka	Leadvale
PH (H_2O)	5.9	4.6
K (mg kg^{-1})	121	20
Ca (mg kg^{-1})	976	188
Mg (mg kg^{-1})	63.5	46.5
Clay (%)	5.9	6.7
Silt (%)	68.8	75.4
Sand (%)	25.3	17.9
O.M. (g kg^{-1})	20	20

Source: Kaboneka and Sabbe, 1995.

Table 11.2: Chemical composition of the plant residues, manure and inorganic fertilizer

			Material		
Parameter	manure	wheat	soybean	corn	Fertilizer
			g kg^{-1}		
N	3.43	9.03	28.47	15.98	130.00
P	0.97	1.33	3.19	2.29	56.80
S	0.49	1.38	2.33	1.24	130.00
K	1.75	9.75	17.40	15.45	107.90
Ca	6.40	4.30	15.30	3.70	9.00
Mg	1.70	0.80	2.65	1.75	3.00

Two successive sorghum-sudan crops were harvested from each pot after 35 days of growth, corresponding to a total of 70 days of nutrient uptake. Twenty seeds of sorghum-sudan were planted each time. Plants were thinned to 10 plants after germination. During plant growth, pots were regularly watered to approximately field capacity. After 35 days, above-ground plant tissues were harvested, dried for 48 hours at 70° C and the dry weight recorded. Dry plant samples were ground for chemical analyses. Experimental treatments consisted of a control (soil only) and five sources of nutrients (chemical fertilizer, manure, corn, wheat, and soybean residues). Treatments were applied to Leadvale and Taloka soil series in a completely randomized design with three replications. Statistical analyses were performed on each of the two sorghum-sudan harvests and on their combination by using the SAS-GLM procedures of the Statistical Analysis System (SAS, 1985). Treatment mean separation was performed by using LSD at the 0.05 level of probability. The LSD values indicated in different tables were used to compare treatments within and across soil series.

Total plant uptake of K and Mg was estimated by multiplying the respective concentration of nutrients by above ground dry matter yield. Net uptake of the two cation nutrients were estimated by difference between the nutrient uptake from respective materials and the control treatment. Percentage recovery of each nutrient was estimated as follows :

$$\text{Recovery (\%)} = [(X - Y) / Z] \times 100$$

where
X = Nutrient uptake from fertilized or amended treatments;
Y = Nutrient uptake from the control treatment;
Z = Total amounts of nutrients added in organic or mineral fertilizer materials.

Results and Discussion

Nutrient uptake and recovery did not include nutrients in roots. It was assumed that addition of root biomass and their nutrient content would not affect treatment differences, as was suggested by Broadbent and Nakashima (1965). Effects of soil series, residue type, rate of residue application and their interactions on K and Mg uptake were evaluated by using orthogonal contrast comparisons (Table 11.3).

Table 11.3. Selected orthogonal contrast comparisons and effect of soil, residue, application rate and their interactions on total K and Mg uptake from added residues.

	Pr > F	
Contrast	K	Mg
NPK vs residue	0.0001	0.0001
Control vs others	0.0026	0.6440
Soil	0.0001	0.0001
Residue	0.5420	0.0001
Rate	0.0001	0.3970
Soil * residue	0.0001	0.2490
Soil * rate	0.2310	0.4600
Residue * rate	0.8320	0.5920
Soil * residue * rate	0.0340	0.3050

Potassium Uptake

Potassium uptake for individual and combined harvests are presented in Table 11.4, which indicates higher K uptake in the first harvest. A two-to three-fold decrease between the first and the second harvest was observed for both soils, with the greater decrease occurring in Taloka soil. A similar trend was recorded with sorghum-sudan dry matter yields (Kaboneka and Sabbe, 1995). Analysis of variance and orthogonal contrast comparisons performed on combined K uptake showed significant effects of soil series, residue application rate, soil series × residue type and soil × residue type × application rate interactions on total K uptake. Total K uptake from chemical fertilizer was significantly higher than that from residue treatments. Both fertilizer and residue effects on total K uptake were significantly higher in Taloka than in Leadvale soil. These differences were probably due to the initial exchangeable high K levels in Taloka soil, which was originally six times higher than that of Leadvale soil. K net uptake from all added materials was uniformly positive in Leadvale soil, suggesting an important K release from residues in this soil series. On the contrary, the only positive net K uptake values in Taloka soil occurred with chemical fertilizer and with the higher manure and soybean residue rates.

Table 11.4: Effect of plant residues, manure and chemical fertilizer on K uptake by sorghum-sudan

			Harvest I		Harvest II		Total Harvest	
Material	N rate	K applied	Leadvale	Taloka	Leadvale	Taloka	Leadvale	Taloka
Control	0	0	50.5	199.9	29.5	62.9	80.0	262.8
NPK	25	75.4	126.1	253.4	40.3	61.8	166.4	335.2
	50	150.8	148.3	290.5	59.5	68.5	208.8	359.0
Corn	25	87.8	87.8	168.4	29.7	64.1	117.5	232.5
	50	175.6	108.1	185.9	53.6	71.9	161.7	257.8
Manure	25	46.3	74.3	184.6	26.7	60.3	101.0	244.9
	50	92.6	80.7	232.8	27.8	69.8	108.5	302.6
Soybean	25	55.0	79.7	170.9	29.9	91.1	109.6	262.0
	50	110.0	96.1	185.6	39.7	88.4	135.8	274.0
Wheat	25	98.0	78.0	154.6	38.0	68.7	116.0	223.3
	50	196.0	122.6	145.5	54.0	61.8	176.6	207.3
LSD (5 %)			41.5		23.5		40.4	

The high K uptake in the limed Leadvale soil could be due to the complementary effect of the two cation nutrients on soil cation exchange sites. It has indeed been demonstrated that lime and the Ca ion in general increases soil solution K by exchanging K from soil exchange sites (Tisdale *et al.*, 1985).

Total K recovery from the lower fertilizer rate was 96 % or more in both soils, with the higher percent in Leadvale soil (115 %). K recoveries were 85 % and 64 % with the higher fertilizer rate, respectively. No K was recovered from the lower manure rate nor from other residues in Taloka soil, with the exception of the higher manure rate (43 %). K percent recovery occurred in all residue treatments in Leadvale soil. However, it decreased from 45 to 31 % from the lower to the higher manure application rates. A similar trend was observed with the soybean residues where K recovery decreased from 54 to 51 % from the lower to the higher residue application rate. On the contrary, the opposite trend was observed with corn and wheat residues in the same soil, where high K recoveries occurred with higher residue rates. As a matter of fact, K recovery from corn residue was 43 and 47 % in Leadvale soil, whereas 37 and 49 % of wheat K were taken up by sorghum-sudan from the same soil. However, the data were not significantly different.

Magnesium Uptake

Similarly to K, total Mg uptake decreased from the first to the second harvest, particularly in Taloka soil. Analysis of variance and orthogonal contrast comparisons performed on combined Mg uptake showed significant effects of soil series and residue application on total Mg uptake (Table 11.3). Total Mg uptake from chemical fertilizer was significantly higher than that recorded from residue treatments. Fertilizer effect on total Mg uptake was significantly higher than residue treatments in Leadvale soil. Net Mg uptake was positive with manure in both soils and with the higher soybean rate in Leadvale soil. All other treatments were characterized by negative net Mg uptake, suggesting that Mg immobilization possibly occurred during microbial degradation of added residues. Residue Mg was recovered from manure at both application rates in Leadvale soil and with the lower soybean application rate in the same soil. In particular, as much as 24 and 6 % Mg were recovered from the lower and the higher manure rates in Leadvale soil, respectively. Substantial Mg (31%) was also recovered from the lower soybean residue rate in Leadvale soil. No Mg was recovered from Taloka soil from either applied organic material. In general, percent Mg recovery from added organic materials was substantially lower than that of K.

Although the chemical fertilizer contained little Mg (Table 11.5), the highest Mg uptake was observed with the fertilized treatments as compared to treatments receiving organic materials. One can hypothesize that fertilizer application released Mg from available forms into soil solution. The competition theory as discussed for K can also be applied to Mg. K applied in the chemical fertilizer could have displaced Mg from soil exchange sites into soil solution, where it would have been actively absorbed by the sorghum-sudan crops. The same competition theory could also explain the higher Mg uptake from the fertilizer in Leadvale soil, since this soil received Ca from applied lime. Therefore, we suspect that a double competition between Mg and both Ca and K for exchange sites would have resulted in higher available Mg in soil solution in fertilized and limed Leadvale soil series (Tisdale *et al.*, 1985).

Table 11.5: Effect of plant residues, manure and chemical fertilizer on Mg uptake by sorghum-sudan

			Harvest I		Harvest II		Total Harvest	
Material	N rate	Mg applied	Leadvale	Taloka	Leadvale	Taloka	Leadvale	Takola
Control	0	0	13.8	19.7	22.1	7.8	35.9	27.5
NPK	25	2.1	38.6	21.2	21.8	8.0	59.4	29.2
	50	4.2	29.9	31.2	27.0	5.5	6.9	36.7
Corn	25	9.9	17.3	12.0	12.7	4.9	30.0	16.9
	50	19.8	16.1	10.3	19.3	7.6	35.4	17.9
Manure	25	45.0	6.5	17.3	20.1	6.6	46.6	23.9
	50	90.0	25.1	19.9	16.4	8.8	41.5	28.7
Soybean	25	8.5	17.4	12.4	21.1	8.7	38.5	21.1
	50	17.0	16.9	15.1	12.7	7.9	29.6	23.0
Wheat	25	8.0	10.5	11.7	11.2	5.2	21.7	16.9
	50	16.0	3.9	10.0	13.6	5.9	27.5	15.9
LSD (5 %)			9.6		8.6		10.6	

From our data, we observed that K and Mg release from applied residues followed the order K > Mg. Our results agree with those reported by other investigators. For example, in a decomposition study of dogwood (*Cornus florida* L.), red maple (*Acer rubrum* L.) and chestnut (*Quercus prinus* L.) forest litter, Blair (1988) found that 91 % of K and 58 % of Mg were released after 2 years of decomposition. For all three species, nutrients were released in the order K > Mg. In a similar study on foliar litter and forest floor dynamics in a *Pinus resinosa* stand, Bockheim and Leide (1986) found that cation nutrients were also released in the order K > Mg.

The difference in the two cation nutrient release pattern from plant materials is governed by their structural nature in the plant matrix. Whether a nutrient is a structural or non-structural component of plant tissues will affect its release dynamics during residue decomposition (Blair, 1988; Budelman, 1988). Among the six major plant nutrients, namely N, P, K, Ca, Mg and S, K is the only non-structural component of plant tissue. It is present as a cation freely moving in the cell fluid. Therefore, K release from crop residues is less correlated with biotic factors as compared to other nutrients. Thus, it is easily leached out and rendered available to crops when the cell membranes disintegrate during residue decay.

Conclusion

This study indicated that direct soil application of organic materials could provide substantial amounts of K. In particular, soybean, corn and wheat residues were found to be important sources of K, as about 40-50 % of K was available from these residues in a 70 days period. From the findings of this study, we recommend that K added as crop residues is readily available for plant uptake and should definitely be taken into account when formulating K fertilizer programs.

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