INFLUENCE OF WATER TREATMENT LIME SLUDGE ON SOIL pH AND CROP YIELDS

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ABSTRACT

Soil pH levels are decreasing in extreme Eastern South Dakota. To test the effectiveness of water treatment lime sludge in raising soil pH and crop yields, a liming study was established at four locations with pH levels of 5.7 or less. The lime sludge applied at 3 tons per acre raised soil pH to neutral and maintained it at neutral for the 4 year duration of the study. Crops grown at the various sites included soybeans, corn, spring wheat, winter wheat and forage sorghum. Although there was a trend toward increasing yield at one location, liming had no significant influence on yield.

INTRODUCTION AND OBJECTIVES

Soil test summaries for 1988 - 1992 show 25% of South Dakota Soils tested at SDSU have a pH of 6.5 or less. This is substantially greater than 10 years ago when only 9% tested in that range. Six percent of samples statewide now test 6.0 or lower and in the extreme SE part of the state, 11% fall in this range.

Previous lime studies were conducted in the state over 20 years ago. At that time crop responses due to added lime were small and economically not justified. Since that time, however, soil pH levels are lower and a large source of inexpensive, excellent grade lime material has become available from water treatment facilities in cities and at rural water system treatment plants. In some locations, especially in larger cities, the disposal of this lime has become costly.

The objective of this study was to: 1) evaluate the influence of water treatment facility lime sludge on soil pH and 2) determine the effect of lime sludge on crop yield and nutrient uptake.

MATERIALS AND METHODS

Four experiment sites in southeast South Dakota which had an initial pH of 5.7 or less were selected for the lime study. Soil test levels and soil types are listed in table 1. The soils at these sites are medium to fine textured with varied origins. The Egan soils are glacial derived, the Estelline soils are loess and the Davis originated from alluvium. These are very common soils of Eastern South Dakota. The loess and glacial soils generally have free lime at 12 to 18 inches below the surface.

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Table 1. Initial Soil Test Levels[1] and Soil Type Used in Lime Study

Site	pH	O.M.	P	K	Soil Series
		%	---------ppm---------		
Brookings	5.5	3.5	21	195	Estelline silt loam
Moody 1	5.7	3.9	28	200	Egan silty clay loam
Moody 2	5.4	3.1	43	125	Davis loam
Clay	5.7	3.7	16	290	Egan silty clay loam

[1] 0 - 6 inch, 1989

The lime source used at all sites was the water treatment sludge from the Sioux Falls water treatment plant. The sludge is formed by softening the water with the use of hydrated lime (CaOH). This process raises the pH and precipitates out calcium and magnesium as carbonates.

Precipitated lime is usually very fine and of good purity from most water sources. A sample analysis of the Sioux Falls lime sludge is found in Table 2.

Table 2. Lime Sludge Analysis, Sioux Falls Water Treatment Plant

Parameter	analysis
Particle size	100 mesh - 0.95% retained 200 mesh - 1.50% retained 325 mesh - 4.30% retained
$CaCO_3$ equivalent	86%
Mg CO_3 equivalent	9%

The analysis shows a high calcium and magnesium carbonate content that is very finely divided. In the lagoons the moisture content of the lime is about 50%. The material used in these studies was taken from sludge that had been removed from the lagoons and allowed to dry somewhat, resulting in a moisture content of 25 to 33%.

The lime was applied to the experiment sties at approximately 3 tons of dry effective calcium carbonate material per acre. This rate was selected because it was a reasonable lime application rate and considered high enough so that soil pH would be significantly raised. The treatments used were either "with" or "without" the lime additions. Each treatment was replicated four times. Plot size was 25 feet by 50 feet.

Lime was applied in the spring of 1989 at the Brookings and Moody 2 sites and in 1988 at the other two locations. Lime was incorporated by the farm operators by chiseling and discing as part of their normal operations. All other nutrient applications and management practices were also preformed by the farm operators.

Plant samples for nutrient content were taken as follows: corn-ear leaf at silking, soybean - top fully developed trifoliate at pod set, wheat - whole plant at heading.

Yield estimates for corn were made by either hand harvesting 40 foot of row or combine harvesting the center 3 rows at the clay site. Wheat harvest was completed with a small plot combine. Soybeans were either hand harvested and threshed with a stationary plot thresher or harvested with a plot combine. Forage sorghum harvest was completed by hand harvesting whole plants from 10 foot of row. Grain yields were adjusted to similar moisture (corn - 15%, soybean - 13%, wheat - 9%). Forage sorghum yields were reported on a dry matter basis.

RESULTS AND DISCUSSION

The influence of lime treatment on soil pH over the four year period is shown in table 3. Lime applied in 1988 and in the spring of 1989 had raised the pH to nearly neutral by the fall of 1989 at all locations. Soil pH remained stable or increased slightly during the following 3 years. The rate of lime was adequate to change the pH for at least a four year period of time. Samples taken in 3 inch deep increments show pH was raised only in the top 6 inch of soil (data not shown). Soil pH below 6 inches remained unchanged after four years, indicating the relatively shallow tillage that is done in the area.

Table 3. Soil pH As Influenced By Time And Lime Treatment, 1989 - 1992

Site	Lime Treatment[1]	1989	1990	1991	1992
		pH[2]			
Brookings	+	6.8	6.7	7.0	7.1
	-	5.5	6.2	5.7	5.7
Moody 1	+	7.3	7.0	7.2	7.1
	-	5.7	6.1	5.9	6.1
Moody 2	+	6.6	6.5	6.7	6.9
	-	5.4	5.5	5.5	5.6
Clay	+	6.7	6.7	6.7	6.8
	-	5.7	5.8	5.9	5.8

[1] Applied 4/89, 10/88, 4/89, 5/88 respectively.
[2] Sampled in fall.

The influence of lime on crop yields over the four year period is shown in table 4. There was no significant (0.05 level) yield response measured in any site year due to lime. There was a trend toward increasing corn yield (0.15 level) at the Brookings site in 1990. However, the operator did not apply nitrogen due to wet conditions at the site. The influence of treatment on yield was likely due to lime enhanced mineralization which provided additional nitrogen to the N deficient crop. There was also a trend for increased yields in 3 of 4 years at the Clay site (table 4).

Table 4. Influence Of Applied Lime Sludge On Crop Yield, 1988 - 1992

		Treatment		Significance	
Site	Crop	No Lime	Lime	of F test	C.V.[1]
		---------bu/A---------			%
1989					
Brookings	Corn	100	105	0.59	12.6
Moody 1	Soybean	55	53	0.58	6.8
Moody 2	Soybean	31	30	0.25	3.6
Clay	Soybean	25	28	0.13	7.1
1990					
Brookings	Corn	59	79	0.15	20.5
Moody 1	W. Wheat	38	39	0.85	12.2
Moody 2	Soybean	33	33	0.76	4.8
Clay	Corn	98	101	0.17	2.7
1991					
Brookings	Corn	85	92	0.32	9.6
Moody 1	Soybean	57	56	0.49	3.4
Moody 2	Soybean	40	40	0.81	3.7
Clay	Soybean	30	29	0.43	5.4
1992					
Brookings	Forage Sorghum	8831[2]	8870[2]	0.93	8.3
Moody 1	Sp. Wheat	58	57	0.82	12.0
Moody 2	Corn	148	136	0.52	11.5
Clay	Corn	147	157	0.08	3.4

[1] Coefficient of variation

[2] Lbs dry matter per acre

The influence of added lime on plant nutrient uptake in 1990 and 1991 is shown in tables 5 and 6. In 1991 (table 6) the significant (0.10 level) differences tend to be an increase in plant calcium and magnesium levels with liming. This would be expected since the liming material contained significant amounts of these cations. There is also a trend for decreasing plant potassium levels with liming. This is probably due to the competition effect from the Ca and Mg ions. In addition, there is a trend for lower plant micronutrient levels due to liming. This was noted in 1990 (table 5) and is likely due to lower plant availability of the soil micronutrients because of the higher pH. In 1989, liming had no significant effect (0.10 level) on plant nutrient content (data not shown).

Table 5. Influence Of Lime Sludge Application On Plant Nutrient Content From Four Sites, 1990

			Element[1]								
Site	Crop	Lime	N	P	K	Ca	Mg	S	Mn	Zn	Cu
			%						ppm		
Brk	C[1]	+	2.01	0.23	1.74	0.52	0.25	0.21	60.5	20.3	6
Brk	C	-	2.01	0.22	1.80	0.51	0.25	0.21	68.8	21.0	8
Moo1	W	+	2.35	0.25	2.04	0.33	0.16	0.23	34.8	18.3	4
Moo1	W	-	2.48	0.25	2.09	0.31	0.14	0.24	42.5	23.0	5
									*	*	*
Moo2	S	+	5.37	0.40	1.72	1.08	0.48	0.37	78.3	32.7	13
Moo2	S	-	4.64	0.40	1.74	0.96	0.43	0.31	94.0	36.3	13
SE	C	+	2.61	0.21	1.67	0.49	0.36	0.22	80.8	23.5	10
SE	C	-	2.43	0.20	1.71	0.46	0.39	0.22	88.0	20.3	10

[1] C = corn (ear leaf), W = winter wheat (whole plant at heading), S = soybean (top trifoliate).

* Indicates the difference between treatments was significant at the 0.10 level.

Table 6. Influence Of Lime Sludge Application On Plant Nutrient Content From Four Sites, 1991

			Element[1]								
Site	Crop	Lime	N	P	K	Ca	Mg	S	Mn	Zn	Cu
			%						ppm		
Brk	C[1]	+	2.84	0.24	1.83	0.69	0.32	0.16	78.5	17.8	11.5
Brk	C	-	2.90	0.23	1.90	0.51	0.25	0.15	99.5	20.3	11.0
					*	*	*		*	*	
Moo1	S	+	5.12	0.29	1.79	1.27	0.41	0.26	76.5	29.8	8.3
Moo1	S	-	5.06	0.27	1.80	1.19	0.43	0.26	84.3	32.5	8.8
Moo2	S	+	5.29	0.37	1.65	1.31	0.50	0.30	88.0	41.3	12.3
Moo2	S	-	5.09	0.34	1.63	1.33	0.38	0.30	93.0	41.0	12.8
			*	*			*				
SE	S	+	4.60	0.29	1.81	1.23	0.37	0.25	50.5	32.0	10.0
SE	S	-	4.50	0.28	1.86	1.18	0.37	0.25	56.3	33.3	10.8
					*					*	

[1] C = corn (ear leaf), S = soybean (top trifoliate)
* Indicates the difference between treatments was significant at the 0.10 level.

CONCLUSIONS

Based on these results, application of liming materials would not be recommended to improve soybean or corn yields in eastern South Dakota. Other benefits of higher soil pH such as improved herbicide performance were not evaluated but may be important. One disadvantage of liming is reducing plant availability of micronutrients. This would only be a problem for those soils already somewhat limited in these nutrients or if the soil was severely overlimed. At reasonable rates (1-2 ton/acre of effective calcium carbonate equivalent), water treatment lime sludge can be used on many of the states' slightly acid soils with no detrimental effects. However, yield advantages with corn or soybean should not be expected with lime applications.

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