CORN, SOYBEAN, AND ALFALFA RESPONSE TO DOLOMITIC AND CALCITIC LIME

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Introduction

Renewed interest in soil pH and liming on some of south-central Minnesota's most productive glacial till soils has occurred recently because: (1) intensive "grid" soil sampling has identified areas of fields that are generally considered below optimum pH (< 6.0) for soybean production, (2) the availability of site-specific application technology to treat only below-optimum pH soils in fields that contain significant variability in soil pH, and (3) near neutral pH is believed to be necessary for achieving exceptionally high yields. A research study was initiated at Waseca on a Nicollet clay loam in August of 1998 to determine the effect of lime source (dolomite vs. calcite) and rate on soil pH and corn, soybean, and alfalfa production.

Materials and Methods

A 1.2-acre research site with a surface (0 to 6 in.) soil pH (water) of 5.4 was identified in 1997 at the Southern Research and Outreach Center at Waseca. After harvesting oats, the site was disked and the experimental plots were established in August of 1998. Each plot is 15 ft. wide by 28 ft. long with 8 replications (4 reps for corn and 4 for soybean) of 12 treatments (Table 1). Before treatment application, all plots were soil sampled to a depth of 6 in. to characterize the variability in pH among all 96 plots. Lime treatments consisted of five rates (0.5, 2.0, 4.0, 6.0, and 10.0 T/A) of dolomite ($CaMgCO_3$, ag lime) and four rates [0.2, 0.5, 1.0, and 0.2 (annual) T/A] of calcite ($CaCO_3$, pell lime). The effective neutralizing power (ENP) of these products was determined to be 1030 and 1800 lb ENP/T for the dolomite and calcite, respectively (Rehm et al., 1992). Two additional materials, gypsum ($CaSO_4$) and road salt ($CaCl_2$) that have zero ENP, were included to compare the effects of sulfur and calcium, respectively. Lime treatments were hand applied on August 13, 1998 and immediately incorporated with a rototiller to a depth of 5 in. This method of incorporation was chosen to ensure thorough mixing of the materials with the soil and to minimize lateral movement of materials to nearby plots. After evaluating soil pH data taken in July of 2000 (Table 2), it was determined that many of the lime treatments had minimal affect on pH on this highly buffered soil. Thus, all treatments were applied and incorporated with a rototiller again on October 11, 2000. The annual treatments were also applied in the fall of 1999, 2001, 2002, and 2003.

Corn (Cargill 4111 in 1999, Pioneer brand 36R10 in 2000 and 36R11 in 2001 and 2002) was planted at 32,000 plants/A in 30-in. rows following preplant tillage (one-pass field cultivation). Nitrogen was preplant applied as urea at a rate of 120 lb N/A. Excellent weed control was achieved with a combination of pre- and post- emerge herbicides and row cultivation. Soybeans (Asgrow 2101 in 1999, Pioneer brand 91B64 in 2000 and 2001, and Northrup King S19-V2 in 2003) were also planted in 30-in. rows following a fall chiseling of corn and spring field cultivation. Crops were harvested with a small plot combine, and yields were corrected for moisture. Data were analyzed using traditional ANOVA, and LSD's at α=0.10 are used where appropriate. Linear contrast statistics were used to measure the effects of (dolomite) ag lime.

Alfalfa (Dairyland Magnum V) was established by direct seeding 14 lb/A on May 1, 2002 following fall chisel plowed and spring disked corn. Weeds were controlled with post-emerge herbicides on June 17, 2002 and by clipping on July 12, 2002. Pests (potato leaf hoppers) were controlled with timely cutting and insecticides as determined by scouting. A single harvest was taken on August 20, 2002. Four cuttings were taken in 2003 (May 29, June 30, July 31, and September 3) and in 2004 (May 28, June 25, August 6, and September 21). Alfalfa yields are expressed on a dry matter basis.

Soil samples were taken annually from all plots in late June or early July of 1999 through 2002. Six random cores to a depth of 6 in. were composited and soil water pH and buffer index, when pH < 6.0, were determined by a research analytical laboratory. In October of 2000 deep soil samples were taken to a depth of 48 in. in 6 in. increments. These samples were used to characterize the subsoil pH of the site.

Input cost calculations (Table 1) of liming materials included product cost, trucking approximately 20 miles, and application. The material costs used in this report were as follows: dolomite was $12.40/T applied; calcite "pell lime" was $100/T plus $4.50/A per application; and gypsum was $120/T plus $4.50/A per application.

Results and Discussion

Soil pH of this Nicollet clay loam profile increases from 5.4 at the surface to 7.0 at 24 in. and remains calcareous to 48 in., where the pH is 8.1 (Figure 1). In July 2000, soil pH in the surface 6 in. was increased linearly from 5.4 to 6.2 with increasing rates of dolomitic (Ca and Mg) lime up to 10 T/A (Table 2). Calcitic lime (Ca only) increased soil pH from 5.3 to 5.6 with the 1.0 T/A rate. Gypsum and road salt did not affect pH.

Because soil pH was not raised above 6.2 with the initial 10 T/A rate after two years on this highly buffered soil, all treatments were applied again in October 2000. Soil pH measurements taken in July 2002 increased linearly with increasing dolomitic lime rate from 5.4 to 6.4. The 0.2, 0.5, and 0.2 (annual) T/A calcite treatments had little to no effect on soil pH compared to July 2000 levels and/or the control. One T/A of calcite increased soil pH similarly to 2.0 T/A of dolomite, which is in agreement with their measured ENP values (1020 for dolomite vs. 1800 for calcite).

Soybean yields were significantly different (LSD 0.10) in 2 of 4 site years and for the 4-yr average (Table 3). However, in 2001 differences were not statistically (greater or less) than the control plot for any of the treatments. The 6 and 10 T/A dolomitic lime treatments applied twice, and the annual 0.2 T/A calcitic lime treatment were the only treatments that statistically increased soybean yield above the 0 T/A control in 2003 and for the 4-yr average. A linear contrast for dolomitic lime rate was significant in 1999 and for the 4-yr average.

Corn yields were significantly different in 2 of 4 years, but not the 4-yr average (Table 4). In 2001 the 10 T/A dolomitic lime treatment (175 bu/A) increased yields compared to the control (162 bu/A). Whereas in 2002, yields were lower for the 2 and 10 T/A dolomitic lime treatments (172 bu/A) compared to the control (189 bu/A). The linear contrast for dolomitic lime rate was highly significant in 2001 and for the 4-yr average.

Alfalfa dry matter yields (Table 5) were significantly different in both the establishment year (2002) and the first, full year of production (2003), but not in 2004. Dry matter yields increased with increasing lime rate for both dolomite and calcite. Greatest yields were obtained with the 10 T/A rate of dolomitic lime (1.79, 7.47, and 6.73 T/A, in 2002, 2003, and 2004 respectively). However, sizable yield responses in the first full production year, ranging from 0.74 to 0.93 T/A, were obtained with reduced rates of dolomitic (2 T/A) and calcitic [1 and 0.2 (annual) T/A] lime.

Economic analysis of lime application for corn, soybean and alfalfa is presented in Table 6. Total input costs (lime treatment costs) are taken from Table 1. Gross **income** for each crop was calculated by subtracting the check plot yield from treatment yields and then multiplying by crop value (2 and 5 $/bu for corn and soybean, respectively and $105/T of dry matter for alfalfa). These data are presented in dollars per acre per year, based on 4-yr average yields for corn and soybean and for years 2002 to 2004 for alfalfa. Gross **income** for lime (dolomitic and calcitic) treatments ranged from –4 to 12 and –7 to 14 $/A/yr for soybean and corn, respectively. Gross **income** of alfalfa from lime treatments ranged from –1 to 51 $/A in 2002 (establishment year), 6 to 131 $/A in 2003, and –16 to 51 $/A in 2004. Net **return** for lime treatments (dolomitic and calcitic) in a corn-soybean rotation ranged from –5 to –39 $/A when input costs were amortized over 5 yr. When amortized over 10 yr, net returns ranged from 0 to –16 $/A. These data show that obtaining a profitable economic return to liming in a corn-soybean rotation on this site is unlikely. Based on the gross income from 3-yr of alfalfa (one establishment and two production yr), these data indicate that total dolomitic lime rates of 1.0 and 4.0 T/A will generate a significant profit while dolomitic lime rates from 8 to 20 T/A will fail to provide a profit to the grower during the 3-yr period. Calcitic lime applied twice at total rates from 0.4 to 2.0 T/A clearly will not generate a profit, but the 0.2 T/A annual treatment would generate a $30/A profit over 3-yr. Gypsum, while not a liming material, can be used as a source of sulfur for corn. Gypsum, applied at this higher rate, resulted in net losses of 25 and 11 $/A when amortized over 5 and 10 yr, respectively.

Conclusions

The value of continuous, long-term evaluation of various lime treatments was shown during the 6 yr of this study at Waseca. In the first two yr, neither soybean nor corn yields were affected significantly by the lime treatments. However, in 2001 – 2003 significantly different yields were found for both crops. Averaged across 4 yr, soybean yields were increased by the 6 and 10 T/A dolomitic and 0.2 (annual) T/A calcitic lime treatments. Corn yields, averaged across 4 yr, were 5 to 6 bu/A greater with some of the dolomitic and calcitic lime treatments, and the gypsum treatment, however, these differences were **not** statistically significant. Lime treatments increased alfalfa total dry matter yields by as much as 38 and 20% in 2002 (establishment yr) and 2003, respectively.

A positive economic return to liming on highly-buffered glacial till soils with very acid surface soils in south-central Minnesota appears likely only for alfalfa. The small yield responses of corn and soybean obtained in this experiment would not recoup the input costs associated with these treatments based on our assumptions (lime material, trucking, and application costs, and crop value) at Waseca. This experiment will need to be continued indefinitely to determine if these results change markedly over time. Farmers considering lime applications should calculate their costs based on their circumstances (lime sources available in their area, application costs including trucking, grid sampling (if needed) to identify low pH soils, and possible variable rate application).

References

Rehm, G., R. Munter, C. Rosen, and M. Schmitt. 1992. Lime Materials for Minnesota Soils. University of Minesota Extension Service Bulletin FO-5957-GO. *at http://www.extension.umn.edu/distribution/cropsystems/DC5957.html*

Figure 1. Soil water pH as affected by soil depth at Waseca.

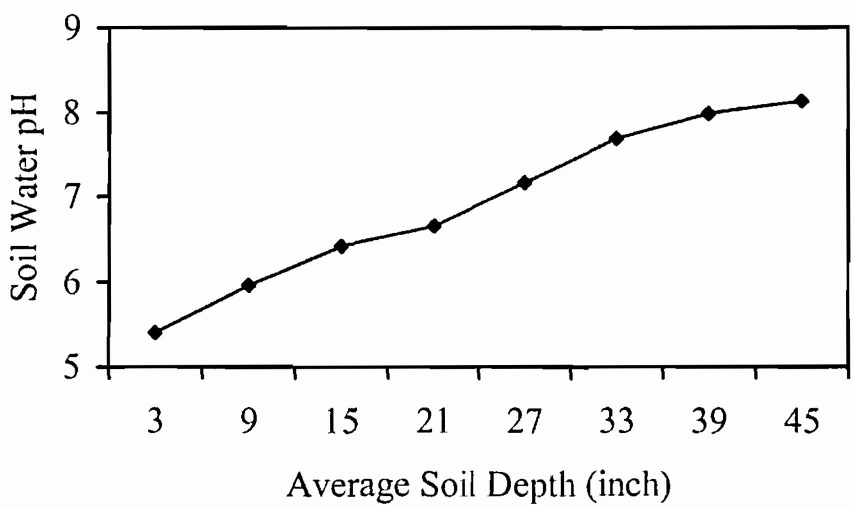

Table 1. Lime source, rate, time of application and approximate cost for lime treatments.

Lime Source †	Lime Rate	Time of Application	Total Rate	Total Cost ‡
	Ton/A/Application		Ton/A	\$/A
None (check)	0.0	None	0.0	0
$CaMgCO_3$ (dolomite)	0.5	Aug 98 and Oct 00	1.0	12
"	2.0	"	4.0	50
"	4.0	"	8.0	99
"	6.0	"	12.0	149
"	10.0	"	20.0	248
$CaCO_3$ (calcite)	0.2	"	0.4	49
"	0.5	"	1.0	109
"	1.0	"	2.0	209
"	0.2	Annually since Aug 98	1.0	122
$CaCl_2$ (road salt)	0.2	Aug 98 and Oct 00	0.4	NA
$CaSO_4$ (gypsum)	0.2	Annually since Aug 98	1.0	142

† Average ENP of dolomite and calcite was 1020 and 1800 lb/ton, respectively.
‡ Total costs are for total lime applied for crops grown from 1999 - 2003 and include hauling and (multiple) applications.

Table 2. Soil water pH (0-6 inch depth) in 2000 and 2002 as affected by lime treatments.

			Soil Water pH	
Lime Source †	Lime Rate	Time of Application	7 July 2000	12 July 2002
	Ton/A/Application			
None	0.0	None	5.4	5.4
Dolomite	0.5	'98 and '00	5.4	5.5
"	2.0	"	5.7	6.0
"	4.0	"	6.0	6.2
"	6.0	"	6.0	6.3
"	10.0	"	6.2	6.4
Calcite	0.2	"	5.3	5.3
"	0.5	"	5.4	5.5
"	1.0	"	5.6	5.9
"	0.2	Annually	5.6	5.6
Salt	0.2	'98 and '00	5.4	5.4
Gypsum	0.2	Annually	5.3	5.2

† Average ENP of dolomite and calcite was 1020 and 1800 lb/ton, respectively.

Table 3. Soybean seed yield from 1999 – 2003 as affected by lime treatments.

Lime Source †	Lime Rate	Time of Application	Soybean Seed Yield 1999	2000	2001	2003	4-yr Avg.
	Ton/A/Application		bu/A				
None	0.0	None	59.0	58.2	53.0	52.3	55.7
Dolomite	0.5	'98 and '00	57.0	61.0	51.7	53.5	55.8
"	2.0	"	56.5	60.9	55.0	55.5	57.0
"	4.0	"	59.9	59.1	53.8	54.4	56.8
"	6.0	"	59.2	61.5	54.3	55.8	57.7
"	10.0	"	59.9	61.3	54.4	55.5	57.8
Calcite	0.2	"	58.4	61.7	52.6	51.3	56.0
"	0.5	"	59.3	61.3	49.0	50.1	54.9
"	1.0	"	59.3	58.4	54.9	54.5	56.8
"	0.2	Annually	57.9	61.8	54.4	58.0	58.0
Salt	0.2	'98 and '00	59.9	60.9	52.9	51.1	56.2
Gypsum	0.2	Annually	58.4	58.7	50.7	50.3	54.5
		LSD (0.10):	NS	NS	2.6	3.2	1.5
		Contrast 'Dolomite Linear' (P>F):	0.10	NS	NS	NS	<0.01

† Average ENP of dolomite and calcite was 1020 and 1800 lb/ton, respectively.

Table 4. Corn grain yield from 1999 – 2002 as affected by lime treatments.

Lime Source †	Lime Rate	Time of Application	Corn Grain Yield 1999	2000	2001	2002	Avg.
	Ton/A/Application		bu/A				
None	0.0	None	182	146	162	189	170
Dolomite	0.5	'98 and '00	170	157	160	179	166
"	2.0	"	187	166	156	172	170
"	4.0	"	178	162	154	189	171
"	6.0	"	176	161	173	196	176
"	10.0	"	190	161	175	172	175
Calcite	0.2	"	171	164	167	180	171
"	0.5	"	175	166	158	182	170
"	1.0	"	182	161	162	183	172
"	0.2	Annually	175	166	162	199	175
Salt	0.2	'98 and '00	188	159	158	179	171
Gypsum	0.2	Annually	183	167	168	184	176
		LSD (0.10):	NS	NS	12	15	NS
		Contrast 'Dolomite Linear' (P>F):	NS	NS	<0.01	NS	0.01

† Average ENP of dolomite and calcite was 1020 and 1800 lb/ton, respectively.

Table 5. Alfalfa yield in 2002 (establishment year), 2003 and 2004 as affected by lime.

Lime Source †	Lime Rate	Time of Application	Total Dry Matter Yield 2002	2003	2004
	Ton/A/Application		----------- Ton/A -----------		
None	0.0	None	1.30	6.22	6.24
Dolomite	0.5	'98 and '00	1.46	6.45	6.33
"	2.0	"	1.69	7.15	6.61
"	4.0	"	1.64	6.71	6.09
"	6.0	"	1.56	7.17	6.50
"	10.0	"	1.79	7.47	6.73
Calcite	0.2	"	1.29	6.27	6.47
"	0.5	"	1.30	6.62	6.40
"	1.0	"	1.57	7.02	6.22
"	0.2	Annually	1.60	6.96	6.64
Salt	0.2	'98 and '00	1.31	6.46	6.37
Gypsum	0.2	Annually	1.17	6.26	6.40
		LSD (0.10):	0.16	0.44	NS
	Contrast 'Dolomite Linear' (P>F):		<0.01	<0.01	0.16

† Average ENP of dolomite and calcite was 1020 and 1800 lb/ton, respectively.

Table 6. Economics of corn, soybean, and alfalfa production as affected by lime treatments at Waseca.

Lime Source †	Lime Rate	Time of Application	Gross Income Over Control ‡ Beans 4-yr Average	Corn 4-yr Average	Alfalfa 2002	Alfalfa 2003	Alfalfa 2004	Alfalfa 3-yr Total	Total Input Costs	Return for C-Sb § Amortized Over 5-yr	10-yr
	Ton/A/Application		$/A/yr						$/A		
None	0.0	None	---	---	---	---	---	---	0	---	---
Dolomite	0.5	'98 and '00	1	-7	17	24	9	50	12	-5	-2
"	2.0	"	7	1	41	97	39	177	50	-6	-1
"	4.0	"	6	2	35	51	-16	70	99	-16	-6
"	6.0	"	10	14	27	99	27	153	149	-18	-3
"	10.0	"	11	10	51	131	51	233	248	-39	-14
Calcite	0.2	"	2	2	-1	6	24	29	49	-8	-3
"	0.5	"	-4	1	0	42	17	59	109	-23	-12
"	1.0	"	6	5	28	84	-2	110	209	-37	-16
"	0.2	Annually	12	12	32	78	42	152	122	-13	0
Gypsum	0.2	Annually	-6	12	-14	4	17	7	142	-25	-11

† Average ENP of dolomite and calcite was 1020 and 1800 lb/ton, respectively.

‡ Net income for each crop = (treatment yield – check plot yield) x crop value (5 and 2 $/bu for corn and soybean and $105/ton of dry matter for alfalfa).

§ Five and 10 year amortized returns are calculated by taking the average of gross returns for corn and soybean, based on the 4-yr average corn and soybean yields, and multiplying it by 5 or 10. Then subtracting the total input costs associated with each treatment and finally dividing that difference by 5 or 10. Interest is not included in any of the calculations.

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