Applying different rates of lime to alkaline soils and the effects on corn, navy beans and sugar beets

HUBBELL, LEE A.[2], and RICHARD R. LIST[2*], and CHRISTENSON, DONALD R.[1], [1]Crop and Soil Science Department, Michigan State University, East Lansing, MI 48824-1325, and [2]Monitor Sugar Company, 2600 S. Euclid, Bay City, MI 48706

Introduction

In the early 1990's, Monitor Sugar Company acknowledged a potential problem with the mountain of waste lime that had accumulated over the past 90 years. Many alternatives for disposal were studied, one being that farmers would take back one ton of lime for every acre of sugar beets grown. Monitor Sugar realized there could be concern with this plan because most soils surrounding Monitor's plant already had high pH values. Before this plan could be implemented, Monitor Sugar Company, along with Don R. Christenson and Michigan State University, needed to study the effects, to crop yields, by applying spent lime to alkaline soils. Research has shown that adding lime to acidic soils will help most cash crops. However, would there be an adverse effect to some cash crops by adding lime where pH in soils range from 7.5 to 8.0?

Monitor Sugar's site was established in the fall of 1993 on a Londo loam soil near Bay City, Michigan. This site was divided into three areas. Lime treatments were established on each area and placed in a randomized complete block design with four replications. Plots [experimental units] were 20' x 50' which accommodated 8-30" rows. Lime was applied in each area at five different rates: 1 ton every year, 1 ton every 3 years, 3 tons every 3 years, 5 tons every 3 years and a check. Initially lime was applied to all sections in the spring of 1994 and again in the fall of 1996. The application of 1 ton every year was also applied in the spring of 1995, fall of 1995, spring of 1998 and the fall of 1998. A moldboard plow, or Triple K, was used to incorporate the lime into the soil. Corn, navy beans and sugar beets were rotated each year to a new area. Normal farming practices were used during each growing season. Each fall, the center 30 ft. of the middle 4 rows were harvested for yields.

Lime applied at Monitor's site had the following physical and chemical properties.

Typical Analysis

Calcium	30%
Magnesium	.5 – 1%
Moisture	30%
Neutralizing Value	80-90%
$CaCO_3$ Equiv. lb./cu. Yard	1300 – 1500
Calcium Carbonate	77%
Magnesium Carbonate	1 – 3%

% Passing: Mesh Screen

8 Mesh	20 Mesh	60 Mesh	100 Mesh
98%	96.6%	92.4%	88.8%

The field at Monitor's site had Londo type soils with pH levels around 8.0. All crops were fertilized at the following rates for N, P & K. No micronutrients were applied, and weeds were controlled with approved herbicides, cultivation and hand removal.

1995

	CORN	SUGAR BEETS	NAVY BEANS
N	59# Broadcast (bc) + 120# Sidedress (sd)	59# Broadcast (bc) + 100# Sidedress (sd)	59# Broadcast (bc)
P	59# bc	59# bc	59# bc
K	178# bc	178# bc	178# bc

1996

N	20# bc. + 160# sd	20# bc. + 130# sd	20# bc
P	55# bc	55# bc	55# bc
K	235# bc.	235# bc	235# bc

1997

N	21# bc. + 160# sd.	21# bc + 130# sd	21# bc
P	59# bc	59# bc.	59# bc
K	250# bc	250# bc	250# bc.

1998

N	20# bc. + 160# sd	20# bc. + 130# sd	20# bc
P	55# bc	55# bc	55# bc
K	230# bc	230# bc	230# bc

1999

N	20# bc. + 160# sd.	20# bc. + 130# sd.	20# bc
P	54# bc	54# bc	54# bc
K	224# bc	224# bc	224# bc

Because this field was located next to a backwater area, in 1996 and 1997 portions of this field were flooded numerous times, which caused most results to be lost in those years. Sugar beet results were not used in 1998 because of poor stands. Cal Bricker and students from M.S.U. harvested the corn and navy beans by hand, and Monitor's research department harvested sugar beets. Sucrose, purity and yield in tons were used to determine recoverable sugar per acre.

Soil samples were taken from each small section using a hand probe. These samples were analyzed by Michigan State University. Results for pH, potassium (K), phosphorus (P), calcium (Ca) and magnesium (Mg) were obtained. Plant tissue was also analyzed by M.S.U. The following tissue was tested; sugar beets, the youngest mature leaf at 12 weeks; corn, ear leaf at tasseling; navy beans, whole plants at flowering. Plants were washed, ground and stored for analysis. Tissue was tested for P, K, Ca, Mg, Zn and Mn.

Yield

Recoverable sugar per acre (RWSA), % sugar, recoverable sugar per ton (RWST) and % Purity for sugar beets were not significantly affected by the different lime rates. Yields for corn and navy beans were not affected by these same rates of applied lime.

SUGAR BEET YIELDS
AVERAGE OF 4 YEARS

TREATMENT	RWSA	% SUGAR	RWST	TON/A	% PURITY
5 Ton/Acre Every 3 Years	4595	18.59	269.6	17.17	93.97
3 Ton/Acre Every 3 Years	4407	18.64	272.4	16.23	94.30
1 Ton/Acre Every 3 Years	4712	18.91	275.4	17.36	94.05
1 Ton/Acre Every Year	4549	18.89	274.5	16.71	93.98
0 Tons	4485	18.75	272.1	16.62	93.91
GM	4550	18.76	272.8	16.82	94.04
LSD (5%)	N/S	N/S	N/S	N/S	N/S
CV%	11.6	2.97	3.3	11.60	0.76

NAVY BEANS
HIGH pH LIME TEST
AVERAGE OF 3 YEARS

	Cwt/ Acre*	% Moisture	Cwt/ Acre*	% Moisture	Cwt/ Acre*	% Moisture	Cwt/ Acre*	% Moisture
	1995		1998		1999		Avg. of 3 Years	
5 Ton/A/3 Yrs.	12.9	19.2	10.5	17.5	12.4	12.9	11.9	16.5
3 Ton/A/3 Yrs.	12.8	18.7	12.5	16.6	12.6	13.1	12.6	16.1
1 Ton/A/3 Yrs.	14.1	19.4	11.8	16.8	10.2	12.8	12.0	16.3
1 Ton/A/Yr.	11.9	19.3	11.8	16.0	12.8	14.2	12.2	16.5
0 Ton	12.6	18.0	11.9	15.6	13.5	12.8	12.7	15.5
GM	12.9	18.9	11.7	16.5	13.2	13.2	12.3	16.2
LSD (5%)	N/S	N/S	N/S	N/S	N/S	1.3	N/S	1.07
CV%	28.8	9.6	43.6	15.4	23.4	6.6	8.9	3.5

*Adjusted to 18 percent moisture.

CORN

HIGH pH LIME TEST

AVERAGE OF 4 YEARS

	Bushels /Acre*	% Moisture	Bushels /Acre*	% Moisture	Bushels /Acre*	% Moisture	Bushels /Acre*	% Moisture	Bushels /Acre*	% Moisture
	1995		1996		1998		1999		Avg. of 4 Years	
5 Ton/A/3 Yrs.	158.8	20.7	146.5	25.0	100.3	35.8	167.6	23.0	143.3	26.1
3 Ton/A/3 Yrs.	156.2	20.9	167.5	24.4	100.9	35.8	176.7	23.1	150.3	26.0
1 Ton/A/3 Yrs.	157.7	20.9	162.8	25.2	102.9	35.4	166.0	23.3	147.3	26.2
1 Ton/A/Yr.	154.5	20.9	163.5	24.2	98.9	35.6	166.1	22.3	145.8	25.8
0 Ton	160.2	20.7	158.9	24.0	96.0	36.9	163.2	22.5	144.6	26.0
GM	157.5	20.8	159.8	24.6	99.8	35.9	167.9	22.8	146.3	26
LSD (5%)	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S
CV%	4.7	1.9	14.9	3.9	21.1	4.6	17.7	6.4	3.4	1.8

*Yields converted to 15.5% moisture.

Soil Tests

pH did not change measurably because our spent lime has a pH of about 7.8 and fields were 8.0 when first tested.

CHANGES IN pH

RATE APPLIED	1994	1995	1996	1997	1998	1999	94-99 CHANGE
5 TON Every 3 Years	8.07	8.16	8.08	8.19	7.98	8.04	-.033
3 TON Every 3 Years	8.09	8.18	8.08	8.18	8.00	8.03	-.058
1 TON Every 3 Years	8.08	8.14	8.08	8.15	7.95	8.04	-.042
1 TON Every Year	8.10	8.15	8.09	8.14	7.96	8.08	-.017
0 TON	8.08	8.14	8.07	8.12	7.95	8.03	-.042
GM	8.09	8.15	8.08	8.16	7.97	8.05	-.038
LSD (5%)	N/S	N/S	N/S	.052	.046	N/S	N/S
CV%	.57	.81	.59	.82	.72	.85	

Some higher values in calcium could have been the result of lime not dissolved in the soil. No reason can be given for increases in the check area other than unexplained variability.

CHANGES IN CALCIUM

RATE APPLIED	1994	1995	1996	1997	1998	1999	94-99 CHANGE
5 TON Every 3 Years	5072	5766	6339	6149	7840	5233	161
3 TON Every 3 Years	4918	5653	6230	6056	7560	5245	327
1 TON Every 3 Years	5050	5523	5990	5973	7020	5151	101
1 TON Every Year	5094	5616	6030	6064	7281	5068	-25
0 TON	5110	5467	5903	5849	6891	4902	-208
GM	5049	5605	6098	6018	7319	5120	71
LSD (5%)	N/S	221	394	295	495	255	348
CV%	7.7	5.3	8.7	6.6	8.1	6.73	

Magnesium had a downward trend, probably resulting from the lack of magnesium in the waste lime spread on this field.

CHANGES IN MAGNESIUM

RATE APPLIED	1994	1995	1996	1997	1998	1999	94-99 CHANGE
5 TON Every 3 Years	655	681	618	628	650	628	-26
3 TON Every 3 Years	665	705	626	649	649	627	-38
1 TON Every 3 Years	700	704	637	693	659	651	-49
1 TON Every Year	701	709	639	694	677	643	-59
0 TON	711	725	646	700	689	648	-63
GM	686	705	633	673	665	639	-47
LSD (5%)	37	36	N/S	45	N/S	N/S	N/S
CV%	7.2	6.9	6.9	9	9.8	7.27	

Phosphorus and Potassium had upward trends, probably resulting from excess fertilizer applied.

CHANGES IN PHOSPHORUS

RATE APPLIED	1994	1995	1996	1997	1998	1999	94-99 CHANGE
5 TON Every 3 Years	136	139	147	155	170	161	25
3 TON Every 3 Years	148	143	149	149	173	164	16
1 TON Every 3 Years	147	144	156	155	182	166	19
1 TON Every Year	146	144	145	152	169	159	13
0 TON	148	149	154	162	178	163	15
GM	145	144	150	155	174	162	17.4
LSD (5%)	N/S	N/S	N/S	11	N/S	N/S	9
CV%	14.9	11.9	11.8	9.9	11.3	11.1	

CHANGES IN POTASSIUM

RATE APPLIED	1994	1995	1996	1997	1998	1999	94-99 CHANGE
5 TON Every 3 Years	195	198	230	321	360	370	176
3 TON Every 3 Years	201	201	229	332	351	384	184
1 TON Every 3 Years	194	199	238	331	377	380	187
1 TON Every Year	208	206	232	342	366	372	164
0 TON	202	212	246	354	383	368	166
GM	200	203	235	336	368	375	175
LSD (5%)	N/S	N/S	N/S	26	N/S	N/S	N/S
CV%	10.1	10.3	14.7	10.6	10.9	8.4	19.9

Nutrient Concentrations in Plant Tissue

Concentration of P, K, Ca and Mg in sugar beets, corn and navy beans were not significantly affected by different lime rates. (data not shown). There was no effect of lime rate on Mn and Zn concentration in corn leaf tissue. However, both Mn and Zn concentrations in sugar beet leaf tissue and navy bean plants were reduced, but never reached deficient levels. Although the differences were not statistically significant, monitoring of these plants should occur if lime is applied at these higher rates.

Discussion

This study was a small part of a larger test done by Don Christenson at M.S.U. Its main emphasis was on measuring the yield on corn, soybeans, navy beans, wheat and sugar beets when applying different rates of lime to alkaline soils. Over the six-year study, there was no difference in yield in any of the crops studied.

There were changes in extractable nutrients due to increased lime rate; however, the changes were small. These changes should have little or no effect on yield. Leaf tissue analysis saw a reduction in Mn and Zn concentration in sugar beets and navy beans. Farmers should watch and test for this problem where lime is applied to their alkaline soils. Sugar beets and navy beans can have yield losses with Mn deficiencies and navy beans can also be affected by Zn deficiency. Other micronutrients could also be affected by liming, but no indication of deficiencies was found. However, from other research reports, boron (B) should also be monitored.

Conclusions

Final results show that farmers could apply lime up to five tons per acre once every three years on Londo soils without having any adverse effects on crop yields. However, testing of nutrients in the soil and plant tissue would be advised.

References

Christenson, D.R. , P.B. Brimhall, L. Hubbell, and C.E. Bricker. 2000. Yield of sugar beet, soybean, corn, field bean, and wheat as affected by lime application on alkaline soils. Communications in Soil Science and Plant Analysis 32 (9+10), 1145-1154.