YIELD OF SUGAR BEET, SOYBEAN, CORN, FIELD BEAN AND WHEAT AS AFFECTED BY LIME APPLICATION ON A HIGH pH SOIL[1/]

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Abstract

Lime from sugar beet processing plants has been stockpiled for 100 years. Environmental regulations and limited storage space provide an impetus for the removal of the material. Land application on alkaline soils is one alternative for disposal of this material. This study was undertaken to evaluate the effect of applying sugar beet processing lime on crop production on these soils.

Studies were conducted at seven sites representing four alkaline soil series in Michigan. Lime was applied at rates of 0, 0.6. 1.2 and 2.5 tons/acre. The same rates were applied again after two or three years at two sites. Sugar beet (*Beta vulgaris* L.), soybean (*Glycine max* L.), corn (*Zea mays* L.), field bean (*Phaseolus vulgaris* L.) and wheat (*Triticum aestivium* L.) were grown.

Yield of root and sucrose of sugar beet as well as yield of soybean, corn, field bean and wheat were not affected by lime application. Mn and Zn concentration in leaves of sugar beet and soybean, and whole field bean plants decreased with increasing lime rate. Lime at rates up to 2.5 ton/acre (dry weight, 100% calcium carbonate equivalent) may be applied once every three years without negatively affecting the yield of sugar beet, soybean, corn, field bean or wheat. The nutritional status, particularly micronutrients, would have to be monitored to reduce probability of a nutrient deficiency.

Introduction

Factory waste lime, a by-product of beet juice purification, has been accumulating at some factories in Michigan for nearly 100 years. New environmental regulations require that this lime be removed. Land application is one choice for utilization of this material. However, many of the soils in the production region are alkaline with pH values as high as 8.2 and do not require lime application for optimum crop production. Transportation costs to regions in the state with greater lime needs is a limitation in the utilization of this material. Consequently, one possible tool would be to land apply the material on the alkaline soils in the sugar beet producing region.

One of the main concerns with the application of lime on these soils is the possible effect on availability of nutrients, particularly micronutrients. Adams and Pearson (1967) and McLean and Brown (1985) suggest that lime-induced nutrient deficiencies are probably due to incipient

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deficiencies prior to liming acid soils. Sanchez and Kamprath (1959) showed liming reduced the amount of exchangeable Mn in an acid soil. Mehlich (1957) showed that precipitation of Mn in solution by the addition of $Ca(OH)_2$ began to occur at pH 8.5, but in the presence of Al^{3+} and Fe^{3+} precipitation began at pH 5.8. He suggested that lime induced Mn deficiency on strongly acid soil is due to the supply of OH from the Fe/Al sesquioxide-hydrates. On less acid soils the sesquioxides are not present. Wear (1956) reported that a reduction of Zn availability as a result of liming a Norfolk sandy loam soil (pH 5.6) was due to conversion of Zn to less available forms. He suggested that it was a pH effect, not a Ca effect.

There are few reports concerning the effect of lime additions on alkaline soils. Hoeft and Sorensen (1969) reported that lime application on alkaline (pH 7.6 and 8.1) soil materials with low organic matter had little effect on yield and Zn, Fe and Mn uptake by corn. Wahhab and Shah (1952) reported that slaked lime applied at 1680 kg ha^{-1} to a calcareous soil with an initial pH of 8.0 did not have a significant effect on yield of green fodder of sorghum or oat. Uptake of N, P and Ca were unaffected by addition of lime. However, no long-term field experiments were found showing the effect of lime application on alkaline soils on yield or nutritional status of crops or on soil test values in relation to fertilizer needs.

This study was initiated to evaluate the effect of lime application to alkaline soils on 1) yield and quality of sugar beet, 2) yield of soybean, corn and field bean, 3) nutrient status of the four crops and 4) nutrient and pH status of the soil.

Methods

Liming material used in these studies averaged 91.8% calcium carbonate equivalent, 0.72% Mg and 31% moisture with a sieve analysis of 98.7, 78.9 and 62.4% passing an 8-, 60- and 100-mesh sieve, respectively.

Studies were conducted over a ten year period at seven locations representing four high pH soil series located in the sugar beet producing region of Michigan. The soil series were Misteguay silty clay, Londo loam, Parkhill loam, Kilmanagh loam and Tappan loam. Over 70% of the sugar beet produced in Michigan are grown on these soils.

Lime from sugar beet processing plants was applied at rates of 0, 0.6, 1.2 and 2.5 tons/acre on a dry weight basis and a calcium carbonate equivalent of 100%. On the Misteguay and one Londo site, rotations were established with each crop grown each year. This was accomplished by establishing contiguous blocks for each crop. Treatments were applied to each block in a randomized complete block design with four replications. A second application of lime was made after three and two years on the Misteguay and Londo soils, respectively. Lime was broadcast and moldboard plowed the fall prior to the growing of the first crops on these two sites. Similarly the second lime application was made in the fall before plowing.

On the other sites, the lime was applied in the spring, field cultivated into the soil and the first crop was planted between three to six weeks after application.

Adequate N, P and K were applied for the production of each crop for row crops and 80 ft^2 for wheat. Weeds were controlled using appropriate herbicides, mechanical cultivation and hand removal.

Yield estimates were made by harvesting 40 to 60-feet of row. Appropriate moisture adjustments were made for corn, soybean, navy bean and wheat. Sugar beet roots were selected from each experimental unit at harvest and processed for quality analysis at the Michigan Sugar Company Agricultural Research Laboratory.

The following plant tissue was taken for analysis from the Misteguay and Londo sites: sugar beet, the youngest mature leaf blade at 12 weeks; corn, ear leaf at tasseling; soybean, youngest mature trifoliate at flowering; navy bean, whole plants at flowering. The tissue was washed, dried, ground and stored for analysis. Tissue was digested in H_2SO_4 - H_2O_2 and analyzed for P, K, Ca, Mg, Zn and Mn utilizing direct coupled plasma emission spectrometry.

Soil samples from each experimental unit were collected by compositing 20 cores (0.75 x 9-inch). After drying and grinding the samples were analyzed for pH, Bray-Kurtz P_1 extractable P, exchangeable K, Ca and Mg, and extractable Mn and Zn.

Yield and nutrient concentration data were analyzed as a randomized complete block using each site-year as a replication. Soil test results within a year from the Misteguay and Londo sites were analyzed as a randomized complete block combined over block. Soil pH at the other sites was analyzed for each year as a randomized complete block design. A Fishers protected LSD at $\alpha = 0.05$ was utilized to separate treatment means.

Results

Yield

Neither yield of sucrose nor of roots were significantly affected by lime rate (Table 1). The yield of root for the control was 23.1 compared to 23.7 tons/acre for the highest rate of lime. Yield of sucrose ranged from 6030 to 6200 lb/acre across lime rates.

Average yield of soybean, corn, field bean and wheat was not affected by lime rate (Table 1). Corn yield ranged from 150 to 153 bu/acre, while soybean ranged from 50 to 52 bu/acre across the lime rates. Field bean yielded 33 bu/acre for the control and 35 bu/acre for the 1.2 ton/acre lime rate. Wheat yield ranged from 71 to 74 bu/acre the one year it was included in the study.

Soil Test Values

There was a tendency for soil pH to be increased by lime application on all soils except those with an initial pH of 8.0 or 8.1 (Londo I and Kilmanagh) (Table 2). Treatment differences for Tappan I were not statistically significant.

Three years after the initial lime application on the Misteguay soil, pH had increased from 7.4 to 7.8

across lime rates (Table 2). After these soil samples were collected, a second lime application at the same rates was made. Soil pH three-years after the second application further increased pH 0.1 units.

As mentioned above there was no effect of lime on soil pH on the Londo I site two-years after the initial lime application. Furthermore, there is no further change three-years after the second application.

The amount of change in pH is directly related to the initial pH of the soil. For example, the pH change was 0.7 units for the Parkhill with an initial pH of 6.6, the change averaged 0.3 units for soil with a pH of 7.4 to 7.7 and was essentially zero for the two sites with a pH of 8.0 or above. This was not surprising considering the decreasing solubility of lime with increasing pH due to a lack of H^+ ions to replace Ca in the lime molecule (Barber, 1984).

This lime reacted fairly quickly with these soils. After one year, the pH of Londo II site was increased 0.3 units from 7.7 to 8.0. After 2 years the Parkhill soil was increased 0.6 units and the Misteguay was increased 0.4 units after 3 years. This is somewhat surprising giving the initial pH of these soils.

Application of lime had negligible effects on Bray and Kurtz P_1 P, exchangeable K and extractable Zn and Mn in samples taken at the termination of the Misteguay in the fall of 1998 (Table 3).

Exchangeable Ca was increased from 3500 to 3900 ppm with increasing rates of lime, while exchangeable Mg declined from 1030 to 990 ppm (Table 3). Neither of these changes would be expected to have a significant effect on fertilizer recommendations for the crops grown in this study.

On Londo I after 5 years, exchangeable Ca increased from 2430 to 2640 ppm due to lime application, but the soil test values for the other nutrients were not significantly affected by lime application (data not shown).

Nutrient Concentrations in Plant Tissue

The concentration of P, K, Ca, and Mg in the sampled plant tissue of sugar beet, soybean, corn and field bean were not significantly affected by increasing lime rate. There was no effect of lime rate on Mn and Zn concentration in corn leaf tissue.

Both Mn and Zn concentration in sugar beet leaf tissue were suppressed by applied lime (Table 4). Mn was reduced from 39.2 to 30.2 while Zn was reduced from 46.1 to 42.7 ppm.

In soybean leaf tissue, Mn decreased from 25.2 to 23.4 and Zn from 40.3 to 37.1 ppm with increasing lime rates (Table 4).

In whole field bean plants, Mn decreased from 33.3 to 26.4 and Zn from 34.0 to 32.7 ppm. The differences in treatment means for Zn concentration are not statistically significant. Since there is a long history of Zn deficiency in Michigan field bean production Zn requirements of this crop would have to be monitored closely if lime were applied on these soils.

Discussion

This study was conducted to measure the effect of lime application to high pH soils on yield and nutrition of soybean, sugar beet, corn and field bean. We didn't expect to see any effect on yield of crops from increasing rates of lime on these medium and fine textured soils. The lack of effect was consistent from site-year to site-year and from the amount of time between lime application and when the crop was grown. For example, on the Misteguay soil all crops were grown every year and there were no differences in effect on any of the crops in any year of the study.

Reduction in concentration of Mn and Zn in sugar beet, soybean and field bean plant tissue suggests that these nutrients need to be monitored if lime were to be applied to these alkaline soils. In the case of sugar beet, soybean, field bean, and wheat grown under Michigan conditions, we often see Mn deficiency and a response to applied Mn. In addition, field bean is susceptible to Zn deficiency. Even though there is no evidence of Mn or Zn deficiency in this study, these results indicate the need to monitor the nutritional status of crops grown after the application.

This study focused on the effects of liming primarily on Zn and Mn nutrition of the crops grown. Other micronutrients which may be affected are B, Cu and Fe. There is no indication of Cu and Fe deficiencies developing on these crops grown on these soils. For example, where tile drainage has been installed and calcareous subsoil is brought to the surface, there is no history of Cu or Fe deficiency developing, but there are cases of Mn and Zn deficiency developing due to this disturbance.

Soil application of B for sugar beet production on alkaline soils has been a common practice in Michigan as well as in other sugar producing areas (Draycott, 1993). In addition to monitoring the Mn status of sugar beet, B status should be also.

These results suggest that growers could apply lime at up to 2.5 tons/acre (dry weight, 100 % calcium carbonate equivalent) once per rotation on medium and fine textured soils without negatively affecting crop yields. Careful monitoring of the nutritional status of the crops would be needed.

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Table 1. Effect of increasing lime rate on recoverable sucrose and root yield of sugar beet, and on yield of soybean, corn, field bean, and wheat, averaged across all site-years.

Lime Rate	Recoverable Sucrose	Root Yield	Soybean	Corn	Field Bean	Wheat
ton/acre	lb/acre	ton/acre	-------------	bu/acre	-------------	
0	6030	23.1	50	151	33	71
0.6	6200	23.6	50	151	35	74
1.2	6150	23.4	51	153	35	71
2.5	6110	23.8	52	150	34	74
LSD (5%)	NS	NS	NS	NS	NS	NS
Site-Years	14	14	11	6	16	1

Table 2. Comparison of soil pH values at various lengths of time after lime application for four soil series at seven locations.

Soil Series	Time After Lime Application	Lime Rate (ton/acre) 0	0.6	1.2	2.5	LSD (5%)
Misteguay	3 years	7.4	7.5	7.7	7.8	0.13
	6 years†	7.4	7.6	7.8	7.9	0.09
Londo I	2 years	8.1	8.1	8.1	8.1	NS
	5 years†	8.0	8.0	8.0	8.1	NS
Londo II	1 year	7.7	8.0	8.0	7.9	0.14
Parkhill	2 years	6.6	6.9	7.2	7.3	0.41
Kilmanagh	2 years	8.0	8.0	8.0	8.1	NS
Tappan I	5 years	7.5	7.6	7.7	7.6	0.17
Tappan II	4 years	7.5	7.6	7.8	7.9	0.23

† pH 3 years after the second application of lime.

Table 3. Bray and Kurtz P_1 extractable P, exchangeable K, Ca and Mg, and extractable Zn and Mn from soil samples taken in the fall of 1998 as affected by lime applied in the fall of 1992 and again in the fall of 1995 for the Misteguay soil.

Lime Rate	P	K	Ca	Mg	Zn	Mn
ton/acre			ppm			
0	42	236	3500	1030	44	8.8
0.6	43	236	3590	1030	43	8.9
1.2	44	243	3740	997	48	10.0
2.5	44	234	3900	990	45	9.2
LSD (5%)	NS	NS	70	34	NS	NS

Table 4. Effect of lime rate on Mn and Zn concentration in the youngest mature sugar beet leaf blade at 12 weeks, youngest mature trifoliate of soybean at flowering and whole field bean plants at flowering, averaged across site-years.

Lime	Sugar beet		Soybean		Field Bean	
Rate	Mn	Zn	Mn	Zn	Mn	Zn
ton/acre			ppm			
0	39.2	46.1	25.2	40.3	33.3	34.0
0.6	36.6	45.3	24.6	39.3	28.8	31.6
1.2	33.1	43.1	23.2	37.6	28.3	33.3
2.5	30.2	42.7	23.4	37.1	26.4	32.7
LSD (5%)	4.2	2.6	1.6	2.4	4.8	NS
Site-years	9		6		8	

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