Surface Applied Lime Impacts on North Dakota No-till Soils

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Objective

Soils become acidic from the mineralization of ammonium-based fertilizers. No-till soils are particularly susceptible to acidification from the lack of mixing subsurface alkaline products and the tendency to apply ammonium-based fertilizers at or near the soil surface. As a result, the zone of acidification is at the depth of fertilizer placement[2,4].

Soil pH controls chemical weathering and soil solution chemical activity. Phosphorus (P) and aluminum (Al) are two elements that greatly impact crop production and are dependent on soil pH. Phosphorus is most readily plant available when the soil pH is approximately six to seven. When soil pH is less than 5.5, Al becomes soluble, binds to P, and renders P unavailable to plants. Additionally, Al can have a toxic effect to plants that stunt and deform root growth and reduces seed germination (Figure 1). Free Al in the soil solution hydrolyzes water which further acidifies the soil[8]. Soil pH less than 5.5 can reduce bacteria activity and increase nitrogen deficiencies[6].

Calcium-carbonate (lime) neutralizes acidity and is a common liming amendment[11]. Agriculture lime is not readily available in North Dakota. However, a waste product of the sugarbeet refining process (SBWL) is comprised of lime[11].

Lime requirement recommendations have not been developed for North Dakota[11]. Soil acidity is new and growing issue to North Dakota soils. This project investigated the impacts of surface applied SBWL on acidic no-till soils in North Dakota.

Figure 1. Aluminum toxic canola (top) with soil pH of 4.5 and 51 ppm Al. Healthy canola (bottom) with a soil pH of 5.8 and 3 ppm Al.

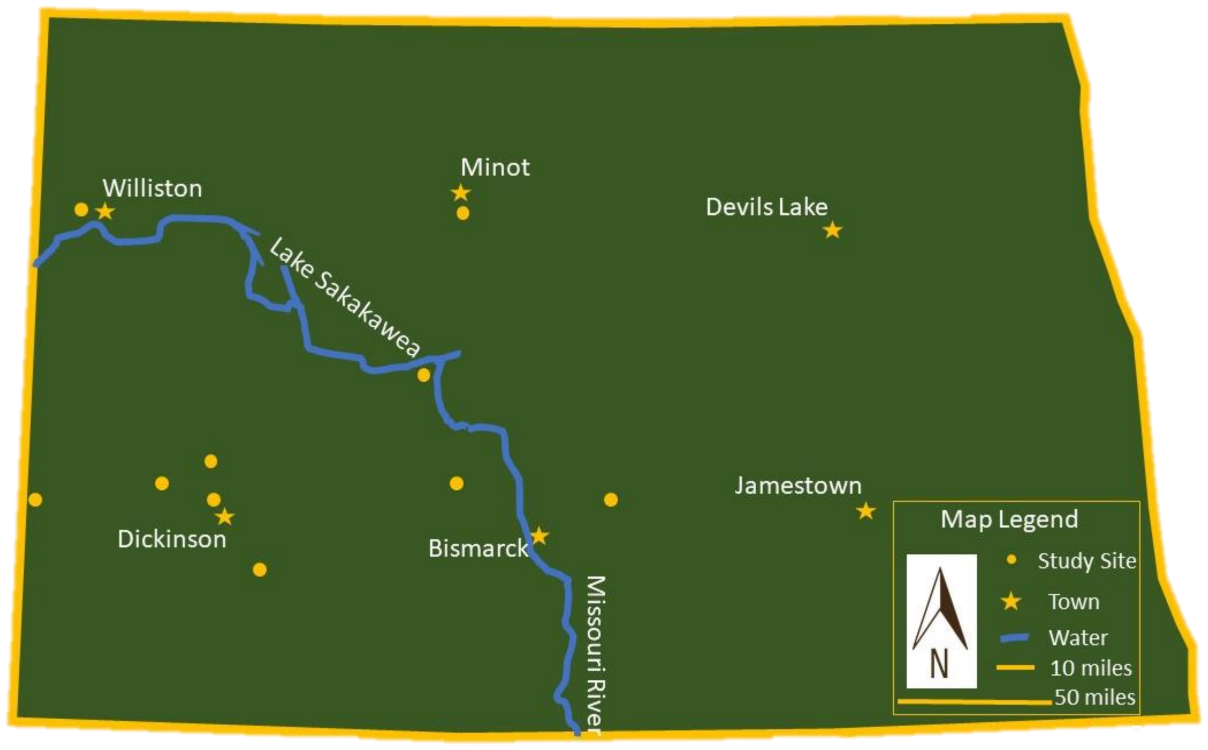

Figure 2. Locations of experimental sites in North Dakota[7].

Methodology

Eleven sites (Figure 2) were established in April/May of 2021. Soil pH at the 0-3 in depth was less than 5.5. Collaborating producers planted and managed their crop. Experimental design was a randomized complete block design.

Plastic hoops with a 36 in diameter were placed in the field and spaced at least 10 ft away from adjacent hoops. Soils were collected within 1 ft outside of the hoop. Soil was sampled by a hand probe at the 0-3, 3-6, and 0-6 in depths . Sugarbeet waste lime treatments were hand applied (Figure 3) within the hoop after initial soil sampling. Treatments were 0, 2, 4, 8, and 16 tons lime/ac. The SBWL contained 0.6 lbs nitrate/ton, 5.2 lbs P/ton, 0.9 lbs potassium/ton, 75.5 % calcium carbonate equivalence, and 14% moisture.

Post harvest, October/November, soil samples were collected by a hand probe within the hoop at the 0-3, 3-6, and 0-6 in depths.

Soils were analyzed for nitrate, Olsen P, potassium, calcium carbonate equivalent, pH, buffer pH, salinity, organic matter, cation exchange capacity, zinc, sodium, manganese, magnesium, aluminum. Soil analysis was completed by AGVISE Labs[1]. Comparison of means and regression analysis was conducted by Statistical Analysis Software[9].

Figure 3. Hand application of SBWL.

Table 2. Regression analysis and predicted lime needed to raise soil pH at the 0-3 in depth.

Buffer pH[10]	Desired pH (0-3 in depth)			Equation**	r^2
	5.5	6	6.5		
	Tons of Calcium Carbonate/Acre				
6.2 n=5†	5.6	9.5	14.0	$y = 1.271x^2 - 6.8828x + 5.0276$	0.99*
6.3 n=7	10.0	11.0	8.5	$y = -7.0431x^2 + 82.954x - 233.15$	0.60
6.4 n=20	0.7	3.4	8.6	$y = 5.1047x^2 - 53.374x + 139.86$	0.81*
6.5 n=24	2.7	5.2	8.6	$y = 1.5829x^2 - 13.1x + 26.826$	0.60*
6.6 n=29	2.0	4.5	8.1	$y = 2.0756x^2 - 18.833x + 26.826$	0.67*
6.7 n=19	1.5	5.5	9.2	$y = -0.6377x^2 + 15.394x - 63.884$	0.57*
6.8 n=27	0.9	2.4	5.1	$y = 2.3551x^2 - 24.025x + 61.806$	0.54*
6.9 n=22	0.1	1.2	3.8	$y = 2.9871x^2 - 32.222x + 86.998$	0.61*
7.0 n=16	-0.1	0.5	2.5	$y = 2.9062x^2 - 32.259x + 89.428$	0.59*
7.1 n=5	1.1	4.2	7.3	$y = -0.1207x^2 + 7.6291x - 37.184$	0.56

*r^2 was significant at the 0.05 level.
**x variable is desired soil pH at the 0-3 in depth. y variable is tons of lime/ac.
†n is the number of samples from each soil environment.

Table 3. Beet lime impacts on soil nutrients at the 0-6 in depth.

Lime	Salts	Phosphorus (Olsen)	Calcium	Manganese	Aluminum	Calcium Carbonate Equivalence
tons/ac*	mmhos/cm	ppm				%
0	0.3b**	18d	1,781c	18a	5a	0.6c
2(2.6)	0.3b	19d	1,999c	14ab	2b	0.6c
4 (5.3)	0.4ab	20c	2,286c	11ab	2b	0.8b
8 (10.6)	0.5a	23b	3,096b	9b	2b	1.0b
16 (21.2)	0.5a	26a	4,143a	9b	1b	1.5a
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Variance	1.18	56.70	1,480,729	54.56	15.10	0.28
C.V.	39.4	33	32.8	54.5	157.3	44.5

*Applied as tons of lime/ac. Parentheses values are tons of SBWL lime/ac.
**Different letters indicate statistical differences at the 0.05 level.

Results

Sugarbeet waste lime treatments increased the soil pH of the 0-3 and 0-6 in depths. Lime applications of 4, 8, and 16 tons/ac increased the 3-6 in soil depth (Table 1).

The regression analysis procedure produced statistically significant polynomial regressions from all, except the 6.3 and 7.1 buffer pH soil environments (Table 2).

Sugarbeet waste lime treatments impacted salinity, P, Ca, Mn, Al, and calcium-carbonate-equivalent (Table 3). However, SBWL treatments did not impact soil organic matter (p-value 0.955), nitrate (p-value 0.703), potassium (p-value 0.983), magnesium (p-value 0.799), zinc (p-value 0.888), sodium (p-value 0.698), and cation exchange capacity (p-value 0.995). The 4, 8, and 16 tons lime/ac treatments increased soil salinity (Table 3).

Table 1. Beet lime impacts on soil pH at various depths.

Lime	0-3in	3-6in	0-6in
tons/ac*	pH		
0	5.4e	6.0d	5.7e
2 (2.6)	6.0d	6.0d	5.9d
4 (5.3)	6.4c	6.2c	6.3c
8 (10.6)	6.7b	6.4b	6.7b
16 (21.2)	7.0a	6.7a	6.9a
P-value	<0.001	<0.001	<0.001
Variance	0.609	0.461	0.528
C.V.	4.28	6.50	5.30

*Applied as tons of lime/ac. Parentheses values are tons of SBWL/ac.

Conclusions & Implications

- Surface applied SBWL could improve crop yields from by increasing the soil pH and by reducing Al and Mn.
- The regression equations (Table 2) based on the initial buffer pH[11] can be used to guide producers on lime recommendations. Soil buffer pH values of 6.1 or less and 7.2 or greater were not collected in this study.
- All pH buffer tests were greater than 6.3 and indicates that the reserve acidity pool is relatively small[11]. Liming these soils to desirable pH levels (i.e. pH 6) could be required once a decade or more. Saskatchewan research suggests that similarly cropped, fertilized, and limed soils acidify in 18 years[3].
- Olsen P soil tests increased from SBWL applications (Table 3). Sugarbeet waste lime in an acid soil environment might serve as P fertilizer.
- Soil salinity increased from SBWL (Table 3). However all treatments were less than 0.5 mmhos/cm and likely would not negatively impact North Dakota crop yields[5].
- Calcium increased from SBWL applications (Table 3). Manganese and soil extractable Al levels decreased from SBWL treatments. Lime increased the soil pH and likely rendered Mn and Al insoluble[8].
- Two and 0 tons of lime/ac treatments both had 0.6% calcium-carbonate equivalence (Table 3). This suggests that the 2 tons of lime/ac reacted with the soil in one growing season.

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