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CORN

BEST MANAGEMENT PRACTICES

CHAPTER 25

Liming South Dakota Soils

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Figure 25.1 Landscape variability resulting in soil pH variability. (Courtesy of A. Bly)

Corn production can be limited by too low or too high soil pH values. The soil pH is a measure of the concentration of the H+ ion in the soil solution and it is reported on the logarithmic scale. It can range from 0 to 14 and a neutral solution has a pH value of 7. A pH change in one pH unit represents a 10-fold increase or decrease in acidity or alkalinity. Soil pH is highly variable and in many fields it can range from 6.0 in well-drained upper landscape positions to 8.0 in poorly drained lower landscape positions. Soil pH influences many soil properties, including nutrient availability and toxicities, plant growth, nutrient transformation, and herbicide effectiveness. The purpose of this chapter is to discuss liming requirements and the implications of soil pH on the soil chemical and biological properties.

Why Soil pH is Important

Soil pH influences crop productivity and it is a measure of soil acidity (pH<7) and alkalinity (pH>7). Soil pH requirements vary for different crops. For example, legumes typically require a higher soil pH than grasses or cereals. Herbicide effectiveness can also be influenced by soil pH. For example, Hitbold and Buchanan (1977) reported that atrazine persistence increases with pH, whereas imazaquin (Scepter), imazethapyr (Pursuit), and atrazine effectiveness are decreased with decreasing soil pH (Franzen et al., 2004; Franzen and Zollinger, 1997). Soil phosphorus is generally most available at pH values between 6.5 and 7.0. At low soil pH values (<6) the microbial process that converts ammonium (NH_4-N) to nitrate (NO_3-N) can be slowed.

Soils have varying abilities to moderate pH changes resulting from the addition of acids and bases. This ability to moderate pH is called buffering capacity. As a rule of thumb, soils with high clay and organic matter contents have higher buffering capacities than low organic matter, sandy soils.

One of the primary factors contributing to reductions in the soil pH (soil acidification) is the transformation of ammonium (NH_4) based fertilizers (urea, urea ammonium nitrate solution (28%),

Table 25.1 The impact of fertilizer source on the amount of calcium carbonate ($CaCO_3$) lime required to neutralize the acidity produced during the nitrification of the ammonia contained within the fertilizer. *(Modified from Curran and Lingenfelter, 2015)*				
Fertilizer source	**Chemical composition**	**% N**	**Lbs lime/ lb fertilizer**	**Lbs lime/ lb of N**
Anhydrous ammonia	NH_3	82	1.48	1.80
Urea	$CO(NH_2)_2$	46	0.84	1.83
Ammonium sulfate	$(NH_4)_2SO_4$	21	1.12	5.33

anhydrous ammonia) to nitrate (NO_3) (Tables 25.1, 25.2). This transformation process acidifies soil by producing hydrogen ions when the ammonium ion is nitrified to nitrate.

In South Dakota fields with low soil pH values, yields can be increased by applying lime (Fig. 25.2). Research conducted between 1999 and 2013 showed that corn yields were reduced 10% to 20% when the soil pH value was less than 5.8 (Fig. 25.2; Table 25.2), and that applying lime minimized these yield reductions. The amount of lime required is dependent on both the soil pH and soil buffering capacity. Low pH soils are most often observed in the eastern side of South Dakota (Table 25.3).

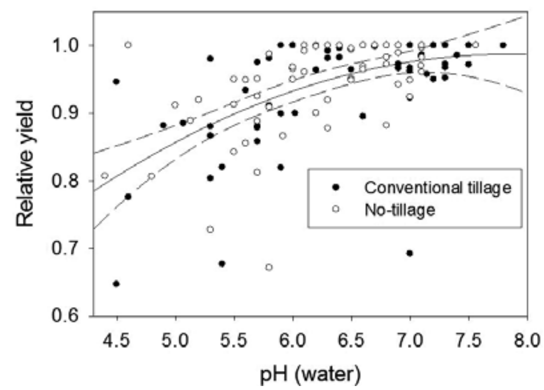

Figure 25.2 Relationship between pH and relative corn yields in South Dakota conventional-tillage and no-tillage plots. The dashed line represents the 95% confidence interval, and the research was conducted between 1999 and 2013.

South Dakota Lime Recommendation

South Dakota lime ($CaCO_3$) recommendations are based on the buffer pH (BpH) index method (Gerwing and Gelderman, 2005; Table 25.4). In this method, a soil extractant is used to measures the reserve alkalinity. Lime requirements may be different for different problems (Mallarino et al., 2013) and the rates should be adjusted based on the lime composition, purity, and fineness (Clay et al., 2011).

In the past, lime has not been widely used in South Dakota, and available liming materials may include agricultural lime, pelleted agricultural lime, or municipal water-treatment lime (Kaiser et al., 2011; Mullins et al., 2009). South Dakota research showed that: 1) pelletized lime and municipal water-treatment lime have similar impacts on soil pH (Table 25.5); 2) there are differences between conventional and no-tillage systems (Table 25.5); and 3) the lime effectiveness was higher when tilled into the soil because lime is not mobile in the soil.

Table 25.2. Influence of N rate management on surface soil pH (0-6 inches) at the South Dakota Southeast Research Farm. The recommended N rates were based on the yield goal, rotation, and the amount of nitrate-N contained in the surface 2 feet. In this experiment, urea fertilizer was applied at rates of 0, 200, and 400 lbs N/acre from 1988 to 2006. (Author research results)		
Nitrogen treatment	**N Rate**	**pH (0-6 inch)**
	lbs/acre	-log[H+]
Check – no nitrogen	0	6.3
Spring – recommended N rate	110	6.0
Split – recommended N rate	110	5.7
Fall – recommended N rate	110	6.0
Spring 200	200	5.5
Spring 400	400	5.0

Table 25.3 The influence of South Dakota NASS region [northeast, NE; southeast, SE; north-central, NC; south-central SC; and western regions, WR (northwest, west, southwest)] on the pH value of soil samples submitted to the SDSU Soil Testing Laboratory.

South Dakota Region[B]	Average pH	pH range				
		<6.1	6.1-6.5	6.6-7.0	7.1-7.5	>7.5
	-log[H+]	-------------------- *% of samples* --------------------				
NE	6.61	**21**	27	27	17	8
SE	6.37	**32**	30	23	11	4
NC	6.49	**26**	30	25	14	5
SC	6.78	6	24	43	22	4
WR	6.98	8	25	20	19	29
Overall	6.54	**24**	28	26	15	7

[A] samples analyzed by the SDSU Soil Testing Laboratory
[B] NE=northeast, SE=southeast, NC=north-central, SC=south-central, WR=west river

Table 25.4 The amount of lime in South Dakota needed to raise the soil pH to 6.0. *(Gerwing and Gelderman, 2005)* Lime rates were based on the $CaCO_3$ equivalent of 90% and total effectiveness of 70%. One ton of pure $CaCO_3$ is equivalent to 1.6 tons of material.

Buffer Index	Lime required for 0-6 inch soil depth
Buffer pH	tons/acre
>6.5	0
6.2 – 6.5	2.0
5.9 – 6.2	2.5
5.6 – 5.9	3.0
<5.6	3.5

Table 25.5 The influence of the dry weight of different liming products and tillage on soil pH. Lime sludge was applied in 2005 and it was obtained from the Brookings Municipal Water Treatment Plant, while the Super Cal was obtained from Calcium Products Inc., located in Gilmore City, IA. Within a column, pH values with different letters are significantly different. The LSD is the least significant difference between treatment means, NS means not significantly different.

Lime		Conventional-tillage				No-till			
Source	Rate	0-2”	2-4”	4-6”	0-6”	0-2”	2-4”	4-6”	0-6”
	tons/a	----------------------------*pH* ---------------------------------------							
Check	0	5.3 b	5.5 b	5.6 b	5.4 b	5.2 b	5.4 b	5.5	5.3 b
Lime sludge annually applied 1998-2005	1	7.6 a	7.4 a	6.3 a	7.1 a	7.3 a	6.4 a	5.9	6.5 a
Super Cal annually applied 1998-2005	1	7.4 a	7.2 a	6.2 a	7.0 a	7.3 a	6.5 a	5.9	6.6 a
Super Cal applied in 1998 and 2002	4	7.5 a	7.5 a	6.3 a	7.1 a	7.4 a	6.5 a	6.4	6.8 a
LSD(.10)		0.3	0.4	0.5	0.4	0.2	0.4	NS	0.3

Summary

Field research suggests that corn yields can be increased by lime in soils with pH values <5.8 (Bly and Gelderman, 2015). Relatively low pH values are attributed to acidity produced during nitrification of applied N. Lime effectiveness is determined by $CaCO_3$ content and fineness of the material. Pelletized and water-treatment lime appear to be equally effective in changing soil pH. Soil pH changes from lime application was less effective at subsurface depths with no-till compared with conventional-tillage, however, grain yields were comparable. Corn grain yield improvement can be expected from lime applications if buffer pH is ≤6.4 and when the soil pH is ≤5.8. Examples for determining lime requirements are available in Clay et al. (2011) and US USDA-NRCS (1999).

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