

SOIL pH AND CROP RESPONSE TO LIME SOURCE AND TILLAGE

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Overview

Maintaining the proper soil pH through liming agricultural soils is a hallmark of modern crop production. Benefits of liming include the optimization of nutrient availability and utilization, the reduction of available levels of Al and Mn, the enhancement of N₂ fixation in legumes, and improvement in the microbial-aided process of organic matter breakdown. The most common liming material by far in Wisconsin is crushed dolomitic limestone or aglime. Deposits of dolomitic limestone are common in the western, southern, and eastern portion of the state. Few, if any, deposits of limestone are found in the central and northern areas. Other lime sources include various by-product materials and calcitic lime, which is not indigenous to the state and therefore must be transported at significant expense. Lime should be applied according to recommendations that are based on a current soil test. The recommended rate is determined by soil pH desired for the most demanding crop in the rotation, the pH buffering potential of the soil, the soil pH, and the neutralizing index of the lime. The neutralizing index reflects both the purity of the lime relative to calcium carbonate and how finely it has been ground. Obviously purer and more finely ground materials, having more surface area, will react faster pound for pound compared to impure or coarser materials.

It is generally recommended that lime be thoroughly incorporated by tillage to optimize neutralization throughout the plowlayer. Even with good mixing it generally takes up to three years to reach the target pH, although the majority of the pH change is often noted in the first year. Cropping systems such as long-term no-till and managed pastures present a dilemma relative to soil pH management. Without tillage soil pH change in the plowlayer is dependent on the movement of the carbonate anion (CO₃⁻²) through the soil. Remember it is the anion that reacts with the H⁺ in the soil to form carbonic acid (H₂CO₃), which dissociates to CO₂ and H₂O. This movement is slow and has been estimated to occur at a rate of 0.5 to 1 inch/year.

Research on liming has been conducted in the UW Soil Science Department for decades, in large part due to the support of the industry through a tonnage fee on lime sales. A classic study conducted by UW Soil Science Professors J.R. Love and R.B. Corey, along with the UW Marshfield Soil Testing Lab Director C.C. Olsen examined the effect of particle size and rate on soil pH change. They applied dolomitic lime of various mesh sizes to an acidic Withee silt loam soil at rates ranging between none and 64 tons/acre. Figure 1 shows the soil pH change over three years for an application of six tons/a. These data demonstrate the importance of the fineness of grind on neutralizing soil pH. More data on this study are available in UWEX Pub. A3671 *Choosing Between Liming Materials*. A similar study was also conducted at the Arlington Agricultural research station in the late 1950s, which was re-sampled to depth by Professors E.E. Schulte and K.A. Kelling 24 years later (Figure 2). The results of their evaluation showed

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that the pH change migrated below the depth of tillage and that the change was rate dependent. This study confirms the speculation that the liming effect migrates about 1 inch/year.

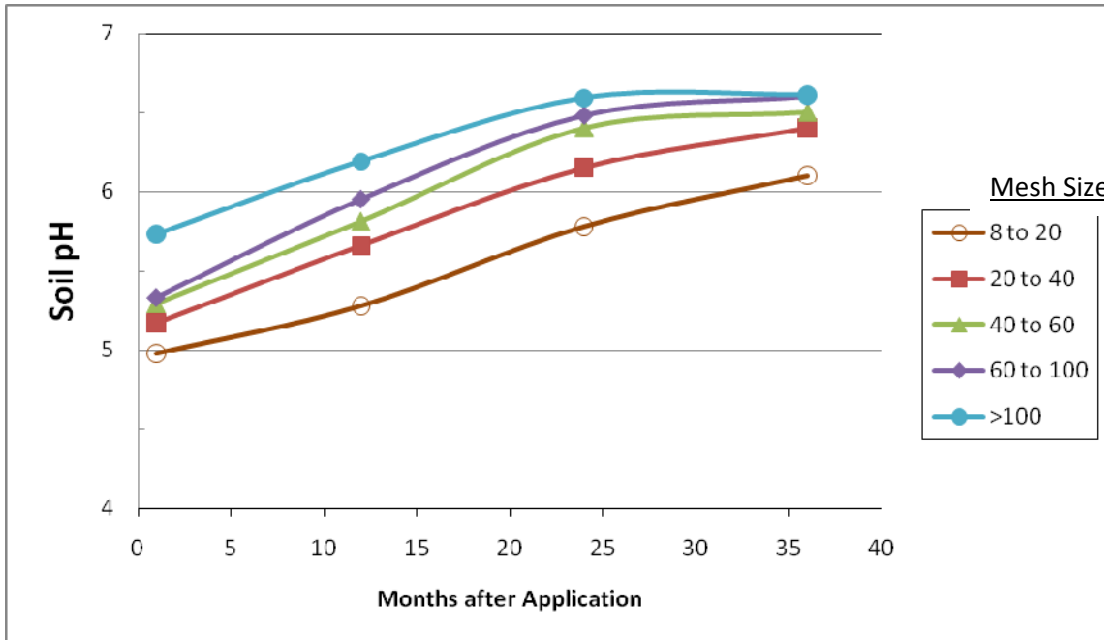


Figure 1. Effect of lime of various mesh sizes applied at six ton/acre on the change in soil pH of a Withee silt loam (after Love et al., 1960).

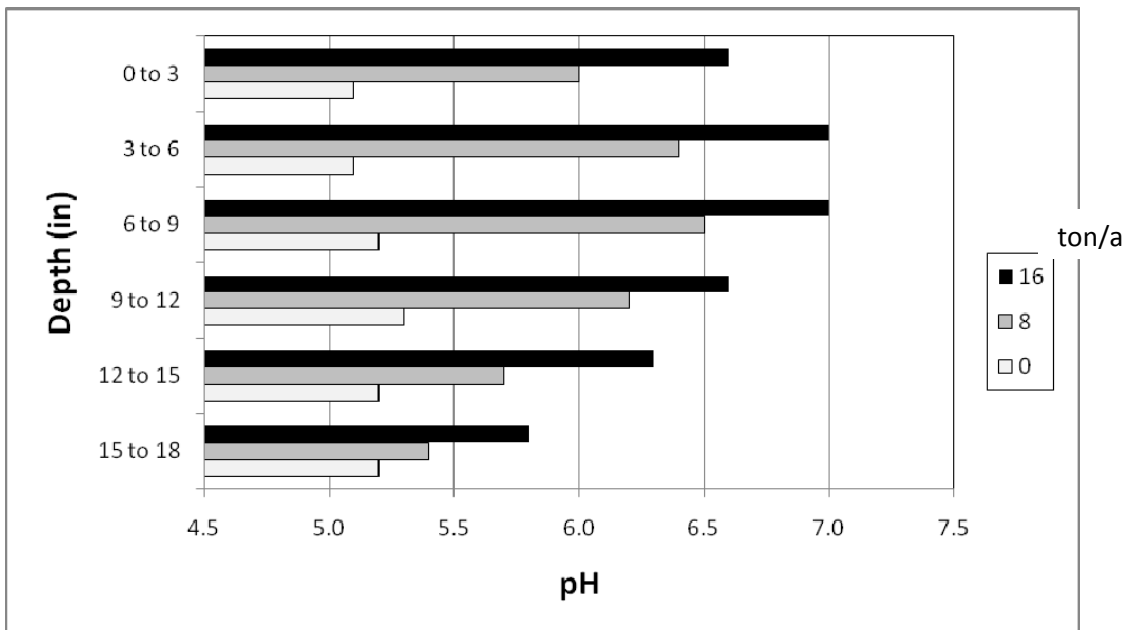


Figure 2. Effect of 20–40 mesh lime rate on the change in soil pH with depth on a Plano silt loam after 24 years (after Peters et al., 1996. UWEX Pub. A3671).

The current recommendation for soil sampling long-term no-till fields is to include a 0- to 2-inch sample, along with the plowlayer sample. The 0- to 2-inch sample is only analyzed for soil test components that provide a lime recommendation. Presumably producers would consider the application of lime that would be appropriate for neutralizing acidity in the shallow surface zone. Communication with our lab staff suggests that very few fields are sampled in this way. Recent incremental sampling studies by Wolkowski (unpublished data) demonstrated that acidification is typically confined to the surface two inches in long-term no-till. Table 1 shows the pH levels in a field where various tillage practices had been in place for 20 years at the Arlington Agricultural Research Station. Lime was never applied in this time period and N fertilizer was broadcast to corn each season at the recommended rate. Clearly the mixing of the soil by tillage increased acidification at a greater depth, which followed the pattern of intensity from moldboard to chisel to no-till. Therefore a strategy to apply lime to address the surface acidification of such a soil may be appropriate for many long-time no-till fields.

Table 1. Soil pH as affected by 20 years of continuous tillage management, Arlington, Wis.

Depth (inch)	Moldboard	Chisel	No-till
0 - 2	5.7	5.6	5.6
2 - 4	5.9	5.6	6.5
4 - 6	6.0	5.8	6.6
6 - 8	6.0	6.3	6.6

Wolkowski, unpublished data.

Arlington Lime Source, Rate, and Tillage Study

A study was established at the Arlington Agricultural Research Station in the spring of 2009 to evaluate the response of a field that had been in no-till for at least 20 years to the application of two sources of lime applied at four rates of application in a chisel and no-till system. The experiment was set up in a split-split plot treatment arrangement with tillage as the main plot, lime source (NI 70–79 dolomitic aglime or pelletized calcitic lime) as the subplot, and rate (0, 1, 2.5, and 5 ton/acre) as the sub-subplot. Treatments were pre-weighed for the 10 x 40 foot plot area and were applied by hand. Appropriate plots were then chisel plowed twice and then field cultivated to establish a seedbed. Pioneer Brand 92Y20 soybean was planted in 30-inch rows, which were harvested for grain the following fall. The site was seeded to alfalfa in the spring of 2010 (Dairyland HybriForce 2400) and was harvested twice during the seeding year.

Soil samples were collected each year by sampling single whole cores to a depth of 8 inches, as well as 2-inch incremental cores to a depth of 8 inches from all plots in the spring and fall. The spring 2009 samples were collected prior to lime treatment and tillage. Spring samples were analyzed for pH, organic matter, P and K, whereas the fall samples were analyzed for pH only.

Soil pH

The pre-treatment soil pH values for the two inch increments and the 0- to 8-inch depth are shown in Table 2. These samples were collected prior to tillage from every plot so pH change

could be more precisely monitored. This field had an average plowlayer pH of 6.0 and showed modest stratification, having a difference of about 0.5 pH unit in the plowlayer from the surface down into the soil. The soil pH changed from 5.7 to 6.3 from the surface down to eight in. Overall the variability of the samples was low and is consistent with the variability associated with the measurement of soil pH. Table 3 shows the main effect of tillage, lime rate, and lime source on the soil pH for the 0- to 2-inch and 0- to 8-inch depth for each of the 2009 and 2010 samplings. Tillage and lime rate both significantly affected soil pH in the surface two inches and the entire plowlayer; however, lime source had no effect on pH in either increment. Chisel tillage resulted in soil pH values that were higher than those in no-till in both the surface two inches and plowlayer because of better mixing in the soil. As expected, soil pH increased with increasing lime rate.

The relationship between tillage and lime source for soil pH for the study period when applied at 2.5 t/a is shown in Figure 3. This comparison was made to determine if the two lime sources performed differently in the two tillage systems. The Pr>F values for tillage x lime source interaction in the 0- to 2-inch depth for the 5-month sampling was 0.10, and 0.07 for the same depth at 17 months indicates a strong relationship between these factors. These data show that the aglime produced similar pH values in the 0- to 2-inch increment in chisel after 17 months, whereas the pell-lime produced a pH that was 0.4 units higher in the no-till treatment. This response may be caused by the fineness of the lime in the pellet and perhaps the somewhat higher solubility of the calcitic lime used to make this material. This relationship was not significant at the other depth increments. It should be recognized that past research has shown that lime may take up to three years to react to reach its target pH and therefore the final soil pH values may not differ.

Table 2. Pre-treatment soil pH values for the lime study site (avg. of 64 measurements).

Depth (inch)	Average	Standard deviation	Range
0 – 2	5.71	0.22	5.3 – 6.4
2 – 4	5.80	0.20	5.2 – 6.2
4 – 6	6.14	0.18	5.5 – 6.5
6 – 8	6.30	0.17	5.9 – 6.4
0 – 8	5.98	0.17	5.6 – 6.4

Crop Yield

There was no significant effect of lime source or rate on soybean yield in 2009 (Table 4). Chisel tillage significantly increased yield compared to no-till. The 0- to 2-inch and 0- to 8-inch soil pH values were less than the target pH of 6.3 for soybean. Thus, a response to liming would be expected, though none occurred. It is possible that the 0- to 8-inch pH of 6.0 or 6.1 was not low enough to result in poor N fixation and subsequent yield loss.

The effect of tillage, and lime source and rate on the yield of both cuttings of alfalfa in the 2010 seeding year is shown in Table 5. Yield was substantially higher in the chisel, compared to

no-till. The no-till treatment was infested with a high population of dandelion, which were very competitive with the new seeding. It was decided to maintain the stand to avoid further disturbing the soil by reseeding and the fact that a growth response in the no-till was

Table 4. Soybean yield response to liming and tillage, Arlington, Wis., 2009.

Lime rate (t/acre)	<u>Chisel</u>		<u>No-till</u>	
	70 -79	Pell-lime	70 -79	Pell-lime
	----- bu/acre -----			
0	37	42	38	30
1	40	41	38	30
2.5	40	41	38	31
5	36	41	35	32
Pr>F				
Tillage	0.02	Lime rate	0.82	
Lime source	0.60	T * LR	0.91	
T * LS	0.25	LS * LR	0.30	
		T * LS * LR	0.73	

visibly affected by lime rate. Lime source did not affect the yield of either cutting. Lime rate increased the yield of both cuttings. There were several interactions between treatments that were significant. One was that between tillage and lime rate, where relative yield response to increasing lime rate was generally greater in no-till than it was under chisel tillage. The interaction between lime source and rate was significant for the second cutting.

Table 5. Alfalfa yield response to liming and tillage, Arlington, Wis., 2010.

Lime rate (t/acre)	<u>First Cutting</u>				<u>Second Cutting</u>			
	<u>Chisel</u>		<u>No-till</u>		<u>Chisel</u>		<u>No-till</u>	
	70 -79	Pell-lime	70 -79	Pell-lime	70 -79	Pell-lime	70 -79	Pell-lime
	----- ton dry matter/acre -----							
0	1.30	1.36	0.79	0.52	1.23	1.33	1.06	0.85
1	1.35	1.41	0.90	0.56	1.42	1.27	1.20	0.97
2.5	1.37	1.33	0.91	0.67	1.41	1.38	1.15	1.09
5	1.46	1.37	0.92	0.67	1.35	1.47	1.13	0.99
Pr>F								
Tillage		<0.01				<0.01		
Lime source		0.26				0.34		
T * LS		0.27				0.28		
Lime rate		<0.01				<0.01		
T * LR		<0.01				<0.01		
LS * LR		0.37				<0.01		
T * LS * LR		<0.01				<0.01		

Summary

Soil pH management through liming is a basic practice for optimizing crop yield. Producers are faced with several liming practice concerns based on tillage and lime source. Soil pH stratifies over time in no-till or other low disturbance systems, becoming more acidic at the surface. Without tillage lime can not be uniformly mixed after application. A study was established in 2009 to examine the relationship between tillage, lime source, and lime rate on soil pH change and yield. Preliminary results from this research shows that pelletized lime was more effective than an aglime for adjusting the pH in a short time in no-till. This response did not appear to translate into an increased yield of either soybean or alfalfa. Also growers should compare the price of lime when making management decisions. It may be possible to purchase two to three times as much aglime compared to pelletized lime when comparing the value of each material on a pound for pound basis.

Table 3. Main effect of tillage, and lime source and rate on the soil pH in the 0- to 2-inch and 0- to 8-inch depths, Arlington, Wis., 2010.

Treatment	Pre-treatment (Spring 09)		Fall 2009		Spring 2010		Fall 2010		
	Depth (inch)	0-2	-8	0-2	0-8	0-2	0-8	0-2	0-8
Tillage	Chisel	5.7	6.0	6.2	6.3	6.3	6.2	6.3	6.3
	No-till	5.7	6.0	5.9	6.2	5.9	6.1	6.1	6.2
Source	Aglime	5.7	6.0	6.0	6.2	6.0	6.1	6.1	6.3
	Pell-lime	5.7	6.0	6.1	6.3	6.1	6.2	6.3	6.3
Rate (t/a)	0	5.7	6.0	5.8	6.1	5.7	6.0	5.8	6.0
	1	5.8	6.0	6.0	6.2	6.0	6.1	6.0	6.2
	2.5	5.7	6.0	6.1	6.3	6.2	6.2	6.4	6.4
	5	5.6	6.0	6.3	6.3	6.3	6.3	6.5	6.5
Pr>F									
Tillage		0.47	0.35	<0.01	0.03	<0.01	0.03	0.01	0.02
Lime source		0.83	0.99	0.43	0.54	0.37	0.18	0.05	0.73
T * LS		0.06	0.27	0.10	0.13	0.01	0.15	0.07	0.08
Lime rate		0.12	0.70	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
T * LR		0.26	0.84	<0.01	0.04	0.82	0.32	0.04	0.08
LS * LR		0.84	0.85	0.98	0.42	0.15	0.02	<0.01	0.13
T * LS * LR		0.07	0.63	0.03	0.31	0.33	0.79	0.50	0.79

Figure 3. Soil pH change by depth as affected by tillage and lime source at 0, 5, and 17 months after application, Arlington, Wis. (2.5 t/a).

