

MANAGING SOIL ACIDITY IN CONTINUOUS NO-TILL

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ABSTRACT

Recently, management of acidic soils in no-till cropping systems has become an important issue with increasing acreages of no-till and continued surface application of nitrogen fertilizer. Our objectives were to identify vertical movement of surface applied lime, determine the most effective type of lime in changing soil pH, and determine the correct application rate of lime for no-till soils. Two sites were selected for small-plot studies in south-central Kansas in 2000. Initial soil pH at these fields was less than 5.5. Seven treatments are being evaluated including four rates of Ag Lime (0, 1120, 1120 annually for four years, 2240, and 4480 kg ECC Ag lime ha⁻¹); (1120 and 1120 annually for four years kg ECC Pell-Lime ha⁻¹). Reaction of the lime with the soil was still being observed three years from the date of application. The addition of surface applied lime on acidic soils in no-till fields raised soil pH in the soil surface. However, since the initial lime applications the deepest observed change in soil pH was observed at a depth of 7.5-cm below the soil surface with the addition of 4480 kg ECC Ag lime ha⁻¹. KCl extractable Al was related to soil pH. Significant yields increases have not been observed for wheat (*Triticum aestivum* L.), soybeans (*Glycine max* Merrill), or grain sorghum (*Sorghum bicolor* (L.) Moench). Reducing recommended lime application rates for no-till soils in Kansas may be appropriate.

INTRODUCTION

During the past decade no-till crop acres have greatly increased in the North America. As a result, the amount of surface applied nitrogen has also increased in these systems. An increase in surface applied ammonium-forming fertilizers will slowly decrease soil pH. Past research has clearly indicated the incorporation of lime into the soil will neutralize soil acidity and in most cases increase productivity (Call and Throckmorton, 1918). However, little scientific information is available on management of acidic soils in no-tillage cropping systems.

Surface applied lime is generally believed to raise the pH primarily in the top 0 to 5-cm layer but may, under some conditions, change the pH throughout the upper 20-cm layer (McLean and Brown, 1984). Questions remain if neutralizing the surface 5-cm of soils is sufficient in some no-tillage systems where the top 15-cm is acidic. In Kentucky, Blevins et al. (1977) observed that surface application of lime is an efficient way to overcome soil acidity caused by N fertilization of no-tillage corn. However, many areas in the Midwest receive a significant less amount of precipitation than eastern States, reducing the downward movement of surface applied lime.

MATERIAL AND METHODS

Two no-tillage field sites (A and B) in Cowley County, Kansas were identified that had below optimal soil pH (pH < 6.0). Soil characteristics for each site are listed in Table 1. In

2000, seven treatments included four rates of Ag Lime (0, 1120, 1120 annually for four years, 2240, and 4480 kg ECC Ag lime ha⁻¹); one rate of Pell-Lime (1120 and 1120 annually for four years kg ECC Pell-Lime ha⁻¹). All treatments were one-time applications except the two treatments indicated above applied annually for four years. The 4480 kg ECC ha⁻¹ rate at site A corresponded to the lime recommendation rate used by the Kansas State University Soil Testing Laboratory to bring the soil pH up to 6.8. At site B, the 4480 kg ECC Ag lime ha⁻¹ rate was one-half of the full recommended rate to bring the soil to a target pH of 6.8. These lime recommendations were based on the SMP buffer and assumed a six-inch soil depth. Applications were first made in the spring of 2000, prior to planting. Treatments were replicated four times in a randomized complete block design. Soil samples from each plot were collected in the spring of 2001, 2002, and 2003 at one inch increments to a depth of six inches and analyzed for 1:1 soil pH. In 2003, KCl exchangeable Al and exchangeable acidity was determined on soil samples collected from site B (Sims, 1996). Grain yields were determined each year by hand harvesting 6-m length of row.

RESULTS AND DISCUSSION

Soil characteristics of small sites A and B are listed in Table 1. Significant treatment effects were observed at Site A in all three years but only in the surface 2.5-cm (Table 2). In 2001, surface soil pH increased by an average of 0.4 at site A with the addition of lime. Increases for 2002 and 2003 were 0.8 and 0.7, respectively, when averages of the lime treatments were compared to the control (Table 2). In both 2002 and 2003, at site B a significant treatment difference was detected in the surface 2.5-cm (Table 3). The application of lime increased soil pH by an average of 0.6 in 2002 and 1.2 in 2003. Below the surface, soil pH was significantly increased in the 2.5 to 5.0-cm depth by an average of 0.4 with the addition of lime at site B in 2003 (Table 3). Soil pH continues to increase at both sites indicating that neutralization of soil acidity is still occurring three years after initial lime application. The neutralizing capability and movement of the lime may have been limited by the lack of precipitation during 2001 (Figure 1).

Table 1. Selected soil characteristics for small plot locations.

Site	Depth	pH [†]	P [‡]	Ca [§]	K	CEC [¶]	Al [#]	O.M.	Sand	Silt	Clay
	- cm -		----	mg kg ⁻¹ ----		meq 100g ⁻¹		-----	g kg ⁻¹ -----		
A											
	0-7.5	5.5	83	1696	149	11.3	0.2	2.0	300	460	240
	7.5-15	5.6	52	1053	131	7.0	0.2	1.8	240	520	240
B											
	0-7.5	4.8	66	1064	179	8.4	1.4	2.1	260	520	220
	7.5-15	4.8	33	998	157	8.1	1.6	1.7	240	520	240

[†] 1:1 soil pH

[‡] Mehlich 3 Phosphorus

[§] Cations were extracted with 1 M NH₄OAc

[¶] Cation exchange capacity was determined using cation summation method.

[#] KCl extractable Al

Table 2. Measured pH values at three depths as affected by surface applied lime at site A.

Year	Treatments							
	Control	Ag Lime (kg ECC ha ⁻¹)				Pell Lime (kg ECC ha ⁻¹)		Pr>F
		1120 [†]	1120 [‡]	2240	4480	1120 [§]	1120 [¶]	
0 - 2.5-cm depth								
2001	5.5	5.6	5.8	6.0	6.1	5.7	5.7	0.03
2002	5.3	6.0	6.0	6.2	6.3	6.2	6.3	<0.01
2003	5.7	6.2	6.4	6.2	6.7	6.4	6.6	0.01
2.5 – 5.0-cm depth								
2001	5.4	5.5	5.5	5.5	5.5	5.4	5.4	0.43
2002	5.5	5.7	5.6	5.5	5.9	5.6	5.8	0.36
2003	5.5	5.6	5.6	5.7	5.8	5.6	5.9	0.23
5.0 – 7.5-cm depth								
2001	5.6	5.6	5.7	5.7	5.6	5.5	5.6	0.99
2002	5.6	5.7	5.6	5.8	5.8	5.6	5.8	0.46
2003	5.5	5.6	5.5	5.5	5.7	5.6	5.7	0.77
7.5 – 10.0-cm depth								
2001	5.4	5.6	5.5	5.6	5.5	5.5	5.5	0.51
2002	5.7	5.8	5.6	5.7	5.8	5.6	5.8	0.76
2003	5.5	5.4	5.5	5.6	5.6	5.5	5.7	0.87
10.0 – 12.5-cm depth								
2001	5.7	5.6	5.7	5.7	5.6	5.6	5.6	0.97
2002	5.8	5.8	5.7	5.8	5.9	5.6	5.9	0.73
2003	5.6	5.4	5.5	5.6	5.7	5.6	5.7	0.92
12.5 – 15.0-cm depth								
2001	5.6	5.7	5.6	5.7	5.7	5.7	5.6	0.96
2002	5.9	6.0	5.7	5.9	6.1	5.8	6.0	0.79
2003	5.6	5.8	5.5	5.8	5.9	5.7	5.8	0.75

[†] One-time Ag lime application of 1120 kg effective calcium carbonate ha⁻¹.

[‡] Four annual Ag lime applications of 1120 kg effective calcium carbonate ha⁻¹.

[§] One-time Pell lime application of 1120 kg effective calcium carbonate ha⁻¹.

[¶] Four annual Pell lime applications of 1120 kg effective calcium carbonate ha⁻¹.

Table 3. Measured pH values at three depths as affected by surface applied lime at site B.

Year	Treatments							
	Control	Ag Lime (kg ECC ha ⁻¹)				Pell Lime (kg ECC ha ⁻¹)		Pr>F
		1120 [†]	1120 [‡]	2240	4480	1120 [§]	1120 [¶]	
0 - 2.5-cm depth								
2001	5.4	5.3	5.7	5.5	5.6	5.4	5.2	0.65
2002	5.0	5.6	5.4	5.5	5.6	5.7	5.8	0.07
2003	4.9	5.5	6.1	5.9	6.6	5.6	6.5	<0.01
2.5 – 5.0-cm depth								
2001	4.8	4.8	4.8	4.6	4.6	4.7	4.5	0.01
2002	4.7	4.9	4.9	4.9	4.9	4.9	4.8	0.55
2003	4.7	4.7	5.1	4.9	5.4	4.8	5.4	0.01
5.0 – 7.5-cm depth								
2001	4.6	4.8	4.5	4.7	4.8	4.7	4.7	0.89
2002	4.9	4.7	4.7	4.8	4.9	4.8	4.8	0.55
2003	4.7	4.7	4.7	4.7	5.0	4.6	4.9	0.14
7.5 – 10.0-cm depth								
2001	4.7	4.7	4.7	4.5	4.5	4.7	4.5	0.06
2002	4.8	4.8	4.9	4.6	4.8	4.7	4.6	0.44
2003	4.7	4.9	4.7	4.7	4.9	4.6	4.8	0.46
10.0 – 12.5-cm depth								
2001	4.7	4.8	4.7	4.8	4.9	4.8	4.9	0.52
2002	4.9	4.7	4.8	4.9	5.0	4.9	4.9	0.56
2003	4.8	5.0	4.7	4.8	4.9	4.7	4.8	0.46
12.5 – 15.0-cm depth								
2001	4.9	4.9	5.0	4.9	4.8	4.9	4.8	0.60
2002	5.0	4.9	5.1	5.0	4.9	5.0	4.8	0.26
2003	4.8	5.1	4.9	5.0	5.0	4.9	4.9	0.59

[†] One-time Ag lime application of 1120 kg effective calcium carbonate ha⁻¹.

[‡] Four annual Ag lime applications of 1120 kg effective calcium carbonate ha⁻¹.

[§] One-time Pell lime application of 1120 kg effective calcium carbonate ha⁻¹.

[¶] Four annual Pell lime applications of 1120 kg effective calcium carbonate ha⁻¹.

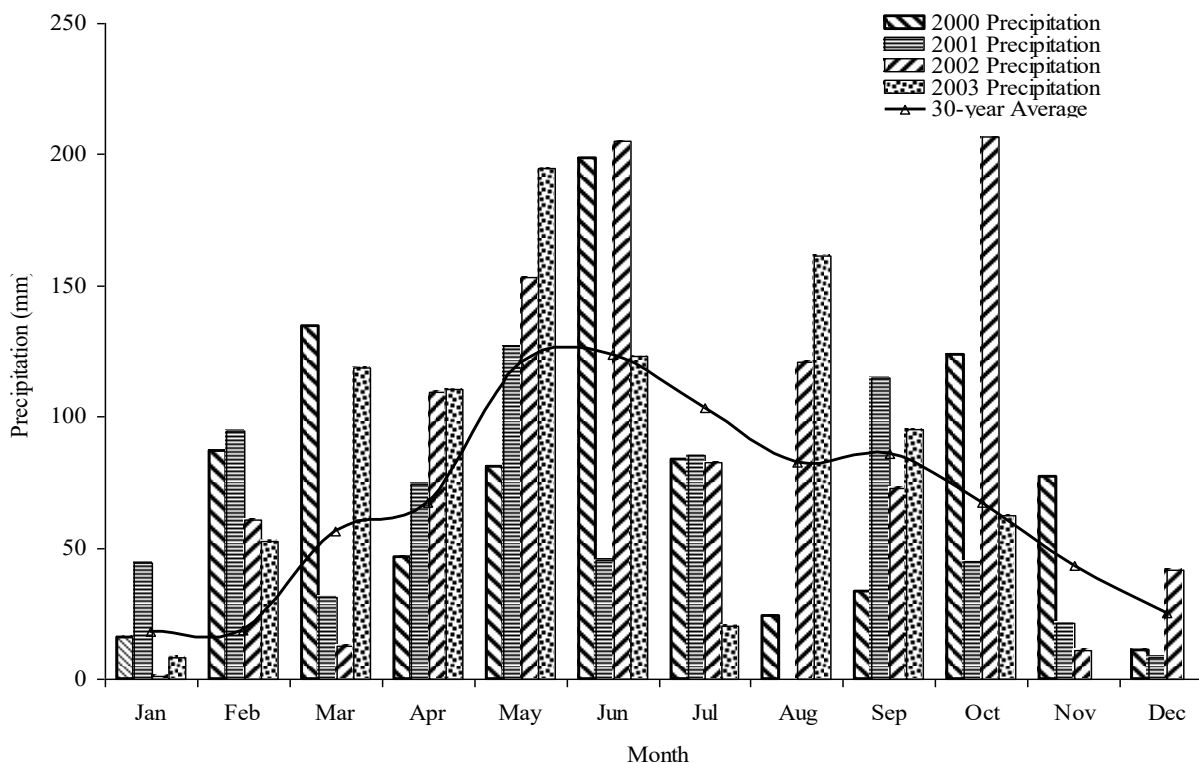


Figure 1. Precipitation amounts for Winfield, Kansas (Cowley County) (Weather Data Library, Kansas State University Manhattan, KS 66506).

Comparing individual treatments in 2003, all lime applications significantly increased soil pH in the surface 2.5-cm when compared to the control at both sites (Table 4). The most consistent treatment responses at both sites were from the 1120 kg ECC Pell Lime ha⁻¹ applied annually four times and the 4480 kg ECC Ag lime ha⁻¹.

Application of 1120 kg ECC Pell Lime ha⁻¹ (applied annually four times) increased soil pH in the surface 2.5-cm at site A by 0.9 and 1.6 at site B when compared to the control (Tables 2, 3 and 4). Soil pH was also significantly increased in the 2.5 to 5-cm depth at both sites with the addition of 1120 kg ECC Pell Lime ha⁻¹ (applied annually four times) (Table 4). Specifically, soil pH increased 0.4 at site A and 0.7 at site B with the addition of 1120 kg ECC Pell Lime ha⁻¹ (applied annually four times) when compared to the control (Tables 2 and 3). The 1120 kg ECC Pell Lime ha⁻¹ (applied annually four times) treatment has only been applied three times but the results of this treatment are similar to the one time application of 4480 kg ECC Ag lime ha⁻¹.

Addition of 1120 kg ECC Pell Lime ha⁻¹ (applied annually four times) treatment significantly increased soil pH when compared to the one time application of 1120 kg ECC Ag lime ha⁻¹ (Table 4). Specifically at site A pH increased 0.4 in the 0 to 2.5-cm depth and 0.3 in the 2.5 to 5-cm depth (Table 2). At site B, pH increases were 1.0 at the 0 to 2.5-cm depth and 0.7 for the 2.5 to 5-cm depth (Table 3). The addition of Pell lime appears to increase the neutralization of soil acidity deeper in the profile when compared to similar treatments of Ag lime.

Table 4. Selected contrasts for small-plot soil pH at individual sites in 2003.

Contrast	0 to 2.5-cm depth		2.5 to 5.0-cm depth		5.0 to 7.5- cm depth	
	Site	Site	Site	Site	Site	Site
	----- Prob > F -----					
1120 kg Ag lime vs 1120 kg Pell lime	0.05	0.01	0.09	0.01	0.38	0.11
1120 kg Ag lime vs 4480 kg Ag lime	0.03	0.01	0.34	0.01	0.76	0.03
1120 kg Pell lime (four) [†] vs 2240 kg Ag	0.08	0.01	0.15	0.01	0.19	0.21
2240 kg Ag lime vs 4480 kg Ag lime	0.05	0.01	0.50	0.01	0.46	0.07
Control vs 1120 kg Ag lime	0.09	0.01	0.35	0.60	0.65	0.90
Control vs 1120 kg Pell Lime	0.01	0.01	0.29	0.27	0.85	0.71
Control vs 1120 kg Ag lime (four)	0.01	0.01	0.44	0.01	0.96	0.97
Control vs 1120 kg Pell lime (four)	0.01	0.01	0.01	0.01	0.19	0.14
Control vs 2240 kg Ag lime	0.06	0.01	0.23	0.09	0.99	0.82
Control vs 4480 kg Ag lime	0.01	0.01	0.07	0.01	0.45	0.04

[†] Four applications of 1120 kg effective calcium carbonate ha⁻¹.

[‡] Bold numbers are considered significant.

However, the greatest soil pH change was observed with the 4480 kg ECC Ag lime ha⁻¹, where soil pH increased 0.9 and 1.6 at sites A and B, respectively, when compared to the control in the surface 2.5-cm (Table 4). The addition of 4480 kg ECC Ag lime ha⁻¹ also increased soil pH in the 2.5 to 5-cm depth by 0.3 and 0.7 at sites A and B respectively (Table 2 and 3). At site A, soil pH was significantly increased in the 5 to 7.5-cm depth with the addition of 4480 kg ECC Ag lime ha⁻¹ (Table 3). This was the deepest observed pH change at either site.

Despite the lack of significant lime movement below the 2.5-cm depth there appears to be a general trend of increasing pH with increasing amounts of lime applied at site A (Table 2). Initial observations at site B indicate the bulk density of the soil is lower than the bulk density of the soil at site A. This would help explain the deeper movement of lime at site B when compared to site A. Amount of precipitation would also be a critical factor in downward movement of lime. However, both of these sites are in close proximity to each other so the amount of precipitation has been similar over the past three years.

A relationship between aluminum saturation percentage and soil pH for all the samples collected at site B in 2003 indicated that aluminum saturation percentage decreased exponentially with increasing pH (Figure 2). Prior research has indicated that above 15 percent yield reduction can be caused by aluminum in soil solution (Kamprath, 1970). Based on this relationship when soil pH was at or below 4.6, the aluminum saturation percentage was 15 percent. As expected, exchangeable acidity was also observed to decrease exponentially with increasing pH (Figure 3).

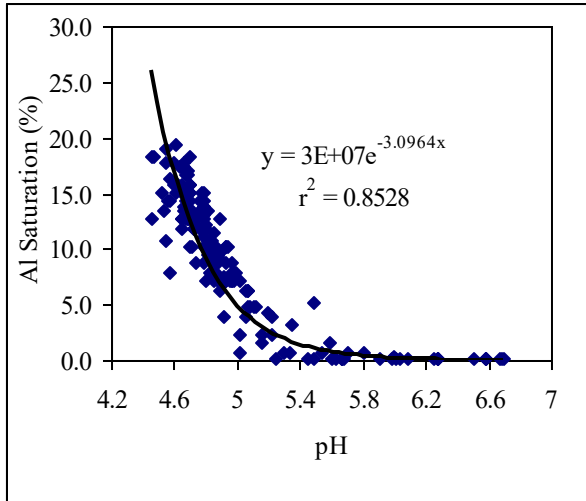


Figure 2. Aluminum saturation percentage as a function of 1:1 soil pH at Site B in 2003.

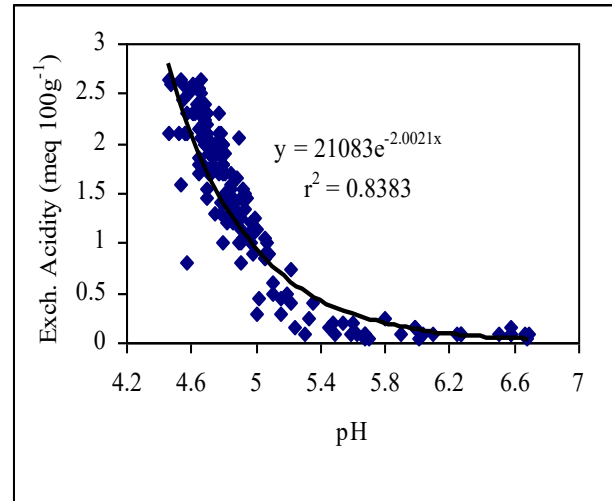


Figure 3. Exchangeable acidity as a function of 1:1 soil pH at Site B in 2003.

Exchangeable aluminum of soil samples in the control treatment was significantly less in the surface 2.5-cm that in the 2.5 to 5-cm depth (Figure 4). This may be partially explained by the slightly higher pH in the surface 2.5-cm when compared to the pH of the 2.5 to 5-cm depth. However, increased organic matter in the surface 2.5-cm may be playing a role in aluminum availability. Increased organic matter content at the soil surface in no-till systems is often observed and may be a key factor in managing acid soils in no-till systems.

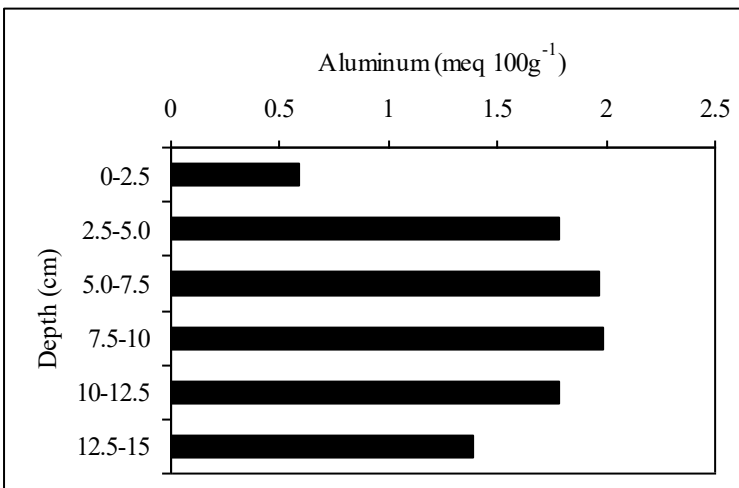


Figure 4. Exchangeable Aluminum as a function of soil depth for the control treatment at Site B in 2003.

Grain yield was calculated for 2000, 2001, 2002, and 2003 (Table 5). No significant differences in grain yields were detected. In 2001, yields were below normal due to lack of moisture during the growing season. The average yield at Site A was only 4 bu/a, while at Site B the average grain yield was 19 bu/a. Potential treatment effect at site B in 2002 may have been masked by banding of phosphorus at time of wheat planting.

Table 5. Grain yield from 2000-2003.

Site	Crop	Treatments							LSD (0.10)
		Ag Lime (kg ECC ha ⁻¹)					Pell Lime (kg ECC ha ⁻¹)		
		0	1120	1120 [†]	2240	4480	1120 [§]	1120 [¶]	
----- kg ha ⁻¹ -----									
2000									
A	Soybeans	1277	1613	1747	1478	1881	1344	1344	NS
B	Sorghum	8466	7727	9138	8600	8533	8332	8130	NS
2001									
A	Soybeans	255	258	305	289	207	329	309	NS
B	Soybeans	1291	1329	1301	1280	1299	1300	1279	NS
2002									
A	Wheat	2278	2313	2277	2305	2303	2229	2279	NS
B	Wheat	3209	3141	3234	3510	3273	3449	3296	NS
B [#]	Soybeans	3048	3287	3100	3385	3411	3339	3392	NS
2003									
A	Soybeans	586	541	592	502	586	598	601	NS
B	Grain Sorghum	5361	5531	5856	5408	5642	5201	5529	NS

[†] One-time Ag lime application of 1120 kg effective calcium carbonate ha⁻¹.

[‡] Four annual Ag lime applications of 1120 kg effective calcium carbonate ha⁻¹.

[§] One-time Pell lime application of 1120 kg effective calcium carbonate ha⁻¹.

[¶] Four annual Pell lime applications of 1120 kg effective calcium carbonate ha⁻¹.

[#] Double crop soybeans after wheat was harvested.

SUMMARY

Surface applied lime to acidic soils in no-till cropping systems will most likely reduce soil acidity in the surface 5-cm. However, lime movement below the surface 5-cm will depend on soil characteristics of a given field. Lime recommendations in no-till cropping systems should be based on an incorporation depth of no more than 7.5-cm. Soil chemical properties unique to no-till cropping systems may be influencing aluminum availability, thus may alter management of acid soils in these systems by reducing the amount of lime applied.

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