Soil pH and Crop Response to Lime Source and Tillage

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Justification

- Ag lime recommendations are based on soil pH, buffer pH, and neutralizing index or effective calcium carbonate equivalent (ECCE) of the lime to be used (Laboski and Peters, 2012).
- Neutralizing index of a lime is a function of purity (calcium carbonate equivalent) and fineness (particle size) (Schulte et al., 2005).
- Pelletized lime is typically calcitic lime that has been finely ground and then pelletized.
  - Measuring the neutralizing index of pelletized lime is problematic.
    - Physical size of the pellet does not allow it to pass though the finer sieves; results in a low neutralizing index.
- Pelletized lime is often advertised as providing quicker, more consistent results than ag lime.
  - In some cases, the industry suggested application rate of pelletized lime is 20% of the application rate of ag lime with a neutralizing index of 91, which is the ECCE advertised for pelletized lime.
- The discrepancy in application rates between liming products (ie. university recommended rates for ag lime and industry recommended rates for pelletized limes) causes confusion amongst producers and agronomists.

Objective

To evaluate the effectiveness of pelletized lime to change soil pH compared to ag lime (70-79 neutralizing index) in no-till and chisel tillage systems.

Materials & Methods

- Four-year study at Arlington Ag Research Station on a Plano silt loam (fine-silty, mixed, superactive, mesic Typic Argiudolls).
- Field was under no-till management for at least 10 years prior to study.
- Experimental design was a split-split plot with four replications.
  - Tillage (no-till or chisel) was main plot.
  - Lime source (ag lime or pelletized lime) was sub plot.
    - Ag lime neutralizing index was 70-79.
    - Pelletized lime was calcitic.
  - Lime rate (0, 2.25, 5.61, and 11.23 Mg ha^{-1}) was sub sub plot.
- Plot size was 3.05 m wide and 12.2 m long.
- Lime broadcast in spring 2009 & tillage occurred immediately following lime application.
- Soybean was planted in 2009.
- Alfalfa was seeded in spring 2010 and grown through 2012.
  - Harvested twice in 2010 and three times in 2011 and 2012.
- Soil samples were collected in each plot.
  - From 0 to 5, 5 to 10, 10 to 15, 15 to 20, and 0 to 20 cm.
  - In spring 2009 prior to lime application, fall 2009, spring and fall 2010 and 2011, and spring 2012.
  - Soil pH was measured on a 1:1 soil:water slurry.
- Data was analyzed in JMP Pro 10 using a mixed model for a split-split-plot design where rep was the random effect.
  - All statistics were evaluated at the 0.10 probability level and Tukey was used for means separation.

Results & Discussion

Table 1. Initial soil pH in spring 2009 and the change in soil pH (Δ pH) in spring 2012 by soil depth increment for each lime source, lime rate, and tillage.

Depth	Lime rate	Ag lime, chisel		Ag lime, no-till		Pell lime, chisel		Pell lime, no-till	
		Spring 2009	Spring 2012	Spring 2009	Spring 2012	Spring 2009	Spring 2012	Spring 2009	Spring 2012
cm	Mg ha^{-1}	soil pH	Δ pH	soil pH	Δ pH	soil pH	Δ pH	soil pH	Δ pH
0 – 5	0	5.8	-0.15	5.5	0.00	5.7	-0.05	5.7	-0.25
	2.25	6.0	-0.10	5.6	0.23	5.7	0.25	5.9	0.25
	5.61	5.7	0.83	5.8	0.43	5.7	0.68	5.7	0.73
	11.23	5.7	1.03	5.5	0.68	5.5	1.18	5.8	0.95
5 – 10	0	5.9	-0.15	5.6	0.15	5.9	-0.10	5.8	-0.03
	2.25	6.0	-0.10	5.8	0.05	5.8	0.23	5.7	0.15
	5.61	5.7	0.98	5.8	-0.03	5.8	0.55	6.0	-0.08
	11.23	5.8	0.90	5.6	0.30	5.8	1.03	5.9	0.30
10 – 15	0	6.3	-0.28	6.0	0.10	6.2	-0.23	6.1	0.00
	2.25	6.3	-0.18	6.1	0.05	6.2	-0.08	6.2	0.03
	5.61	6.1	0.45	6.2	-0.05	6.2	0.18	6.1	0.15
	11.23	6.1	0.58	6.0	0.25	6.1	0.48	6.2	0.08
15 – 20	0	6.3	0.00	6.3	0.08	6.3	0.08	6.3	0.05
	2.25	6.3	-0.10	6.3	-0.03	6.4	-0.03	6.3	0.08
	5.61	6.2	0.33	6.3	-0.13	6.3	0.10	6.5	-0.10
	11.23	6.2	0.30	6.3	0.08	6.4	0.18	6.3	0.08
0 – 20	0	6.1	-0.10	5.9	-0.03	6.0	-0.08	6.0	-0.08
	2.25	6.1	0.33	6.0	0.18	6.0	0.05	6.0	0.33
	5.61	6.0	0.45	6.0	0.05	6.0	0.23	6.0	0.68
	11.23	6.0	0.68	5.9	0.15	6.0	0.70	5.9	0.95

Figure 1. Increase in soil pH in the 0- to 5-cm depth over time as a function of lime source and lime rate for chisel and no-till.

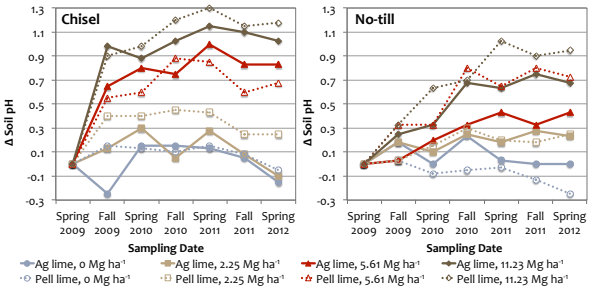

Table 2. Effect of tillage, lime source, and lime rate on cumulative alfalfa yield in 2010 to 2012.

Tillage	Source	Rate	2010	2011	2012			2010	2011	2012
			Mg DM ha^{-1}					Mg DM ha^{-1}		
Chisel	Ag lime	0	6.29	9.75	6.92	Source of variation				
		2.25	6.85	9.88	6.76	Tillage (T)		<0.01	0.87	0.24
		5.61	6.98	10.53	6.62	Source (S)		0.15	0.64	0.14
		11.23	6.96	10.91	6.78	T x S		0.13	0.02	0.10
	Pell lime	0	6.71	10.62	8.82	Rate (R)		0.02	0.14	<0.01
		2.25	6.69	12.01	9.95	T x R		0.73	0.18	0.75
		5.61	6.67	11.18	10.51	S x R		0.63	0.82	<0.02
		11.23	7.10	12.17	10.49	T x S x R		0.43	0.39	0.46
						CV, %		9.00	9.00	8.00
No-till	Ag lime	0	4.65	11.20	9.41	Means				
		2.25	5.25	11.32	9.95	Tillage	Chisel	6.78 b†	10.89	8.35
		5.61	5.12	11.52	9.21		No-Till	4.49 a	10.82	9.50
		11.23	5.07	10.98	9.81	Source	Ag lime	5.88	10.76	8.17
	Pell lime	0	3.50	9.95	8.13		Pell lime	5.39	10.94	9.68
		2.25	3.82	10.04	8.94	Rate	0	5.28 b	10.37	8.31 c
		5.61	4.42	11.18	10.37		2.25	5.66 a	10.80	8.89 b
		11.23	4.20	10.35	10.28		5.61	5.79 a	11.09	9.18 ab
							11.23	5.84 a	11.09	9.34 a

† Within a main effect, means with the same letter are not significantly ($p \leq 0.10$) different.

Soil pH

- In spring 2009 prior to lime application, soil pH increased with increasing soil depth (Table 1).
- Initial soil pH varied by up to 0.3 units between reps within a treatment, additionally pH varied with treatment before treatment application (Table 1).
  - Data were normalized by subtracting the initial soil pH in spring 2009 from the soil pH on each sampling date in each plot.
- In general, as the rate of lime applied increased, soil pH increased (Figure 1).
  - For either lime source, soil pH stopped increasing 18 to 24 mo after application; about 12 mo sooner than expected.
- Three years after application, no significant difference in the increase in soil pH between lime sources regardless of the rate of lime applied (Table 1).
  - Data suggest that pelletized lime does not react more quickly with soil than ag lime.
- There were some notable differences in the change in soil pH with lime application between tillage systems in Spring 2012 (Table 1).
  - 0- to 5-cm depth, no difference in the increase in soil pH between tillage systems for each rate of lime applied, regardless of source (Figure 1).
  - Chiseling resulted in a significantly larger increase in soil pH in the 5- to 10-, 10- to 15-, and 0- to 20-cm depths at 11.23 Mg ha^{-1} rate, and the 5- to 10- and 15- to 20-cm depths at the 5.61 Mg ha^{-1} rate; otherwise there was no difference.
  - Pelletized lime was more effective at increasing soil pH in the 0- to 20-cm depth compared to ag lime in the no-till system, but not in the chisel system.

Crop Response

- Soybean yield in 2009 was not affected by lime source or rate.
  - Inadequate time for lime to react with soil.
  - Chiseling resulted in significantly greater yield than no-till (2.70 vs 2.29 Mg ha^{-1}).
- Seeding year alfalfa yield was significantly greater in chisel (6.68 Mg DM ha^{-1}) compared to no-till (4.49 Mg DM ha^{-1}) (Table 2).
  - Any amount of lime significantly increased yield compared to no lime.
  - No effect of lime source.
- In 2011 and 2012, there was a significant tillage by lime source interaction.
  - In 2011 for chisel, pelletized lime had greater yield compared to ag lime (11.49 vs 9.70 Mg DM ha^{-1}).
  - In 2011, for no-till, pelletized lime had lower yield compared to ag lime (10.37 vs 11.25 Mg DM ha^{-1}).
  - Similar trends were observed in 2012.
  - Data suggest that incorporation of pelletized lime promoted breakdown of the pellet and the greater neutralizing index of the more finely ground lime reacted more quickly.
    - Soil pH data does not corroborate this observation and hypothesis.
- In 2012, as lime rate, averaged over tillage and source, increased cumulative alfalfa yield increased (Table 2).
- Alfalfa stand density was measured after the first cutting in 2011 and 2012.
  - In 2011, no effect of tillage, lime source, or lime rate.
  - In 2012, chisel plow had a significantly greater stand density than no-till (51.6 vs 42.0 plant m^{-2}) and ag lime had a significantly greater stand density than pelletized lime (50.6 vs 43.0 plant m^{-2}).

Conclusions

- *In a chisel plow system*, no clear advantage to using pelletized lime with regard to increasing soil pH.
  - Effectiveness of either lime source is related to application rate.
  - Chisel plowing provides adequate mixing of the lime with the soil.
- *In a no-till system*, there may be a slight advantage to using pelletized lime if a pH changed is desired through a 20-cm depth, though individual depth increments did not show this advantage. If smaller pH changes are desired then, pelletized lime applied at a 2.25 to 5.61 Mg ha^{-1} rate could be as effective as ag lime with a neutralizing index of 70-79 at 11.23 Mg ha^{-1}.
- In spring 2013, ag lime with a neutralizing index of 80-89 cost approximately $36 Mg^{-1} and pelletized lime cost approximately $213 Mg^{-1} .
- ***Regardless of tillage system, traditional ag lime is a more cost effective liming source.***

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