It Takes More Than Calcium to Neutralize Soil Acidity

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Abstract

Proper pH management is the foundation to a good soil fertility program. Soil pH influences nutrient availability and root growth and function. Just because an agricultural product contains calcium does not mean that it will change soil pH. The effectiveness of three calcium products in raising soil pH was compared to an untreated check in acid soils. A field trial was conducted at 16 locations across Kentucky and a laboratory incubation study was conducted at the University of Kentucky Research and Education Center. The same application rates were used for the three products, whether in field trials or laboratory incubations. The rates were 46.8 L ha^{-1} for the liquid calcium and 4.5 Mg ha^{-1} for the pelletized and ag limes. The field studies exhibited higher soil pH at 3-month and 12-month sample dates with ag lime and pelletized lime treatments than with the check and liquid calcium treatments. The lab study exhibited higher soil pH values at each sample date (1, 3, 6 and 12 month) with ag lime and pelletized lime than with check and liquid calcium. The soil pH was not improved with the addition of liquid calcium (chloride) and results of this study are supported by the chemical foundations of soil acidity neutralization reactions - calcium chloride does not neutralize acidity and calcium carbonates do.

Introduction

Proper soil pH management is the foundation of a good soil fertility program. Soil pH indicates the amount of active acidity (protons, H^+) present in a soil and influences nutrient availability, plant root growth, the rate of many biological processes, and herbicide activity (Miller and Kissel, 2010). A single measure of water acidity does not indicate the amount of limestone or other neutralizing agent needed to adjust soil pH. The soil buffer pH, in conjunction with some measure of active acidity, is used to guide lime rates to adjust soil pH to the range needed for optimal crop growth (Sikora, 2006). Once the amount of acidity to be neutralized is determined there are a limited number of products that can be selected to ensure proper pH adjustment. The primary products used for pH management in agricultural field settings are forms of limestone, either calcitic or dolomitic. Some companies offer products and claim to neutralize acidity by adjusting the amount of base cations (Ca, Mg, K, or Na) present on the exchange complex, usually adding minute amounts of Ca in the form of calcium chloride ($CaCl_2$).

To neutralize acidity, the proton (H^+) must be consumed. The neutralization reaction for calcitic limestone is demonstrated in Equation 1.

Equation 1. $CaCO_3 + 2H^+ \rightarrow H_2CO_3 \rightarrow H_2O + CO_2 + Ca^{2+}$

The proton remains after the addition of $CaCl_2$, which has no neutralization ability (Equation 2).

Equation 2. $CaCl_2 + 2H^+ \rightarrow Ca^{2+} + 2H^+ + 2Cl^-$

Based on numerous questions and concerns from Kentucky producers, agribusiness personnel, and agricultural extension agents, we designed field and laboratory experiments to test the effectiveness of liquid calcium chloride, as compared to traditional liming materials utilized in forage production.

Methods

Field and laboratory incubation studies were established in the summer of 2021 and ended approximately one year later. The laboratory incubation study began 8 September 2021 and ended 29 August 2022. The multiple locations in the field study were established between 14 June and 30 July 2021. The "one year after dates" were approximately one year after initial treatments were established. Both studies utilized a randomized complete block design for the treatment arrangement (Figure 1). The same treatments were used for both studies: an untreated check, liquid calcium at 46.8 L ha^{-1} (5 gallon $acre^{-1}$), pelletized lime (RNV 83), and agricultural lime (RNV 79). Both pelletized and ag lime were applied at rates to give 4.5 Mg ha^{-1} (2 ton $acre^{-1}$) of 100 RNV lime. The field study was conducted at 16 locations across Kentucky, with assistance from University of Kentucky Cooperative Extension Agents and private producers, and on University of Kentucky Agricultural Experiment Station farms. The field study utilized a randomized small plot treatment arrangement with 2.32 m^2 plots and three replications. Soil samples for the field study were collected prior to treatment application, again approximately 3 months later, and again approximately one year later. Results for the field study are reported as the average soil pH across locations and as the change in soil pH due to the field sites having different initial soil pH levels. Forage data was collected approximately 3 months after treatment application and include: dry matter (DM) production, crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), and total digestible nutrients (TDN). The incubation study utilized a Crider silt loam (Typic Paleudalf) soil with an initial soil water pH of 5.2. Soils were placed in 120 mL specimen cups with small holes in the cap to allow gas exchange and treatment-sampling date combinations were replicated 4 times. Destructive sampling occurred at 1, 3, 6 and 12 months. Cups were maintained at 80% water filled pore space by weight until just before the 6-month sampling date. Shortly before the 6-month samples were to be taken the building was destroyed by an EF-4 tornado. Many samples were recovered but cup moisture wasn't maintained in the 12-month samples. Results for the incubation study are reported as actual pH. Data was analyzed using SAS version 9.4 (Cary, NC).

Figure 1. Generalized plot layout for the field study. Plastic 'whiskers' were used to mark location corners when flags had to be removed for general field management operations.

Results and Discussion

Soil pH values in the field trials behaved as would be expected according to Equations 1 and 2. The soil pH values were similar at the onset of the experiment, prior to any treatment being applied ($p = 0.854$). Treatments that received products containing carbonates (i.e., ag lime and pelletized lime) resulted in an increased ($p < 0.001$) soil pH and treatments that did not contain carbonates (check and liquid calcium) did not change soil pH ($p < 0.001$) (Table 1). Addition of limestone to agricultural fields does not usually cause an immediate reaction, and a noticeable pH change was not expected to occur immediately. In this instance, the rather low initial soil pH and the higher quality of the limestones used resulted in the 3-month pH increase. Normally, lime use raises soil pH over the course of one to four years (Ritchey and McGrath, 2022). A small increase in soil pH was observed at the 3-month sample collection time with ag and pelletized lime use, while soil pH a slightly decreased in the check and liquid calcium treatments. The difference is soil pH 1 year after application was much greater for ag and pelletized limes than for the other two treatments ($p < 0.001$). The shifts in soil pH with liquid calcium application were never different from those observed in the untreated check.

Table 1. Average soil pH values prior to treatment application and at 3 and 12 months following treatment application in the field trials, and average changes in soil pH during each time period.

	---------------------- Soil pH --------------------			--------Change in Soil pH-----	
Treatment	Initial	3-month	12-month	3-month	12-month
Pr > F	0.854	< 0.001	< 0.001	< 0.001	< 0.001
Check	5.8 a[1]	5.6 a	5.9 a	-0.10 a	0.11 a
Liquid Calcium	5.8 a	5.7 a	5.8 a	-0.02 a	0.08 a
Pelletized Lime	5.8 a	6.1 b	6.5 b	0.30 b	0.67 b
Ag Lime	5.8 a	6.2 b	6.5 b	0.43 b	0.77 b

[1]Mean values within a column followed by the same letter are not significantly different at the 90% level of confidence (P > 0.10).

The laboratory incubation exhibited results similar to those found in the field incubation study in that the products that were expected to raise soil pH (i.e., those containing carbonates) did neutralize soil acidity and soil pH increased within any given incubation period (Table 2). The results of the 6-month sampling were very promising and illustrate how ideal, controlled laboratory conditions improve the speed of neutralization compared to neutralization in the field under ambient soil conditions. In the laboratory study, soil moisture was maintained at 80% water filled pore space, temperature was always about 24 °C, and gas exchange between the soil in the cups and the atmosphere was facilitated. A one-unit change in soil pH would not be expected to occur in field settings due to less than ideal environmental conditions. After the tornado, soil cups were stored in an unheated garage and soil moisture content was not maintained at 80% pore filled volume. Soil dryness can influence soil pH in a negative way, as demonstrated by soil pH values at the 12-month sampling time (Table 2).

Table 2. Average soil pH values in the laboratory incubation trial 1 month, 3 months, 6 months, and 12 months after treatment application. Initial soil pH was 5.2.

	------------------------ Soil Laboratory Incubation Time ------------------------			
Treatment	1 month	3 months	6 months	12 months
Pr > F	< 0.001	< 0.001	< 0.001	< 0.001
Check	5.2 a[1]	5.1 b	5.0 a	5.1 a
Liquid Calcium	5.3 a	5.0 a	5.0 a	5.0 a
Pelletized Lime	5.9 b	6.3 d	6.5 b	6.3 b
Ag Lime	6.1 b	6.2 c	6.4 b	6.2 b

[1] Mean values within a column followed by the same letter are not significantly different at the 90% level of confidence (P > 0.10).

Although no positive results in terms of soil pH change were observed after liquid calcium application, the authors wanted to test the influence of the treatments on the yield and feed value of the different forages in this experiment. No significant results were observed with any of the yield components 3 months after treatments were applied (Table 3). Although soil pH is an important part of a good soil fertility program, significant improvement in these factors were not expected in the study time frame. The random variation of the results is indicative of variable stand densities within given hayfield or pasture situations. The small plot size was maintained to reduce soil pH variation within individual fields, but these results may have benefited from a larger plot size.

Table 3. Forage yield and feed nutritive results at from the field approximately 3 months after treatment application.

Treatment	DM[1] (kg ha^{-1})	CP[2] (%)	ADF[3] (%)	NDF[4] (%)	TDN[5] (%)
Pr > F[6]	0.620	0.865	0.793	0.693	0.575
Check	2,100	11.6	37.1	60.3	58.8
Liquid Calcium	2,206	11.5	36.7	60.8	59.2
Pelletized Lime	2,375	11.0	37.6	61.5	58.3
Ag Lime	2,053	11.1	37.4	60.2	58.5

[1] DM = forage dry matter
[2] CP = crude protein

[3] ADF = acid digestible fiber
[4] NDF = neutral digestible fiber
[5] TDN = total digestible nutrients
[6] No statistical differences observed at the 90% level of confidence ($P > 0.10$)

Conclusions

Results of the field trials indicate that proven practices to neutralize soil acidity still hold true. The results of the field trials support the results of the laboratory incubation study, which are in complete agreement with sound soil chemistry foundations. In short, to effectively neutralize soil acidity and increase soil pH the addition of products that contain carbonates, oxides, or hydroxides must be done – not products that just contain a calcium salt, whether chloride, nitrate or sulfate.

References

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