INFLUENCE OF SOURCE AND PARTICLE SIZE ON AGRICULTURAL LIMESTONE EFFICIENCY AT INCREASING SOIL pH

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INTRODUCTION

Excessive soil acidity is known to have potential negative impacts on crop production. The chemical and physical characteristics of a liming material determine its capacity to neutralize soil acidity. The calcium carbonate ($CaCO_3$) equivalent (CCE) and estimates of particle size impact on the efficiency at increase soil pH are considered when assessing a material's liming value. The reaction of limestone particles within the soil depends largely on the soil pH and the material surface area in contact with the soil. Particle size then influences the speed of reaction, with finer materials allowing for more particles and surface area to react in a given volume of soil, and may also influence the maximum pH reached (Meyer and Volk, 1952; Motto and Melsted, 1960). A typical sample of aglime includes multiple particle sizes in varying proportions. Pelleted limestone is a particular liming product because finely ground aglime is granulated to facilitate the handling and application. It is generally assumed that the granules disintegrate effectively after application to most soil or after rainfall. An *effective* liming material has the potential to raise the soil pH to a desired level. An *efficient* liming material has the potential to raise the soil pH to a desired value with the smallest amount of material applied possible. Cost and availability must be taken into account when deciding to apply a liming material.

Both $CaCO_3$ and magnesium carbonate ($MaCO_3$) in aglime increase soils pH, as other materials do. The Soil Science Society of America defines dolomitic limestone as a natural liming material composed mainly of carbonates of Mg and Ca in approximately equal. In production agriculture and limestone trade there is no widely accepted definition, however, an aglime containing more than 70% $CaCO_3$ is usually referred to as calcitic and that containing 10% or more $MgCO_3$ concentration is considered dolomitic. While $MgCO_3$ has a higher acid neutralizing potential than $CaCO_3$ (mainly due to a lower molecular weight), the reaction rate of dolomitic limestone is known to be slower (Lindsay, 1979; Rippy et al, 2007). Recent field experiments in Iowa also showed that the time to reach a certain pH value was longer for dolomitic lime and that sometimes the maximum pH reached also was lower (Pagani and Mallarino, 2012).

The objective of this study was to evaluate the effect of particle size on efficiency of commercially available calcitic aglime, dolomitic aglime, and calcitic pelleted lime at increasing soil pH in various Iowa soils under controlled conditions.

SUMMARY OF PROCEDURES

Topsoil of three acidic Iowa soils with contrasting texture and organic matter content was collected for this study. The soil series were Fruitfield (sandy, mixed, mesic Entic Hapludolls), Nicollet (fine-loamy, mixed, superactive, mesic Aquic Hapludolls), and Otley (fine, smectitic, mesic Oxyaquic Argiudolls). The soils were air dried, sieved through a 2-mm sieve, mixed in a cement mixer, and kept in storage until the incubation experiment commenced. Soil pH, organic matter, and texture ranged from 5.2 to 6.0, 1.2 to 4.6%, and sand to clay-loam, respectively. The lime sources were pure finely-ground reagent grade $CaCO_3$, pelleted calcitic aglime, calcitic aglime, and dolomitic aglime. The two aglime sources were sieved to obtain material within five particle-size fractions. These fractions were material passing through mesh 4 but not mesh 8, passing through mesh 8 but not mesh 20, passing through mesh 20 but not mesh 60, passing through mesh 60 but not mesh 100, and passing through 100 mesh (Tyler mesh sieves). Different states of the northcentral region use different methods to measure aglime fineness and estimate its neutralizing power. For the determination of effective $CaCO_3$ equivalent (ECCE), the State of Iowa aglime quarry certification program requires measuring the proportion of the material that passes through mesh 4, mesh 8, and mesh 60 (IDALS, 2008). The materials were analyzed for total Ca and Mg concentration, CCE, and ECCE (Table 1).

The incubation technique used had been developed for previous soil incubation studies in Iowa. The three lime sources and five fractions of the calcitic and dolomitic aglime were mixed with each soil at an equivalent rate of 4 ton CCE/acre. A no-limed control was also included. Therefore, there were 15 treatments for each of the three soils for a total of 39 soil-by-lime treatment combinations. Each soil-by-lime combination was incubated for periods of 1, 3, 5, 10, 15, 20, 25, and 30 weeks; and each treatment was replicated three times. The incubation was carried out in a temperature controlled, dark incubation chamber held constant at 25°C and soils were kept at approximately 70% of field capacity water content. After each incubation period was completed, the material from each cup was dried at 35-40°C in a forced-air oven, ground to pass through a 2-mm sieve, and analyzed in duplicate for pH in a 1:1 soil to water slurry. The efficiency of the different materials at increasing soil pH compared to pure $CaCO_3$ was calculated by dividing the net pH change for a material (pH_{final}-$pH_{initial}$) by the net pH change of pure $CaCO_3$ and multiplying by 100. Comparison of source, as well as mesh size comparison within a given source, soil pH, and limestone efficiency was conducted using the GLIMMIX procedure of SAS assuming fixed treatment effects.

HIGHLIGHTS OF RESULTS

Differences in rate and magnitude of pH increase over time varied by soil, incubation period, source, and aglime fineness fractions. However, the relative differences among the liming materials across the three soil series were minor compared with the effects of the source, fineness fraction, and incubation time. Therefore, averages across the three soils are shown in this brief article.

Figure 1 shows how the pure, finely ground $CaCO_3$ and the three "as-is" liming sources increased soil pH for all the incubation periods. The $CaCO_3$ increased pH the fastest and to a higher value than the other three sources did. The pelleted calcitic aglime showed the fastest increase in pH of the aglime sources, and for the longest incubation period nearly approached the maximum for $CaCO_3$. This figure also demonstrates that the calcitic aglime reacted faster than the dolomitic aglime for the shortest incubation periods, and maintained a larger magnitude of pH increase for the longer periods. It is important to note that all sources were statistically different for the longest incubation periods.

Figures 2 and 3 show the effect of different calcitic and dolomitic aglime fineness fractions on increasing soil pH for all incubation periods. As expected, pH increased faster and reached a higher maximum value for the finer materials (the larger mesh sizes). The 100+ mesh fraction showed the fastest increase in pH and the largest pH increase throughout all incubation periods. For the calcitic aglime fractions (Fig. 2) the 20-60, 60-100, and 100+ mesh fractions reached a pH of 6.5 by 5 weeks (6.5 is the optimum pH for corn and soybean for most Iowa soils), a high plateau was approached by the 25-week incubation period, and the two coarsest fractions (4-8 and 8-20 mesh) increased pH slower and did not increase it above 6.3 even for the longest incubation period. Approximately similar results were observed for the dolomitic aglime fractions (Fig. 3) but the efficiency at increasing pH was slightly lower than for the calcitic aglime and, most importantly, the differences between the fineness fractions was proportionally greater than for the calcitic aglime. Also, the two coarsest fractions began to approach a maximum pH not until the 20-week incubation period, a longer time than for the calcitic aglime.

Table 2 shows the limestone efficiency at increasing pH relative to pure $CaCO_3$ for all sources and aglime fineness fractions for a short incubation period (the average of the 3 and 5 week periods) and the average of the two longest incubation periods. These incubation periods would be comparable, although not exactly given the study incubation conditions, to the timeframes of lime application in spring before planting crops or in the fall. There were considerable differences in the efficiency values at each incubation period and the calcitic aglime fineness fractions had greater efficiency than the dolomitic aglime fractions. The efficiency of particle sizes of either aglime passing a mesh size 100 was significantly greater than those passing a mesh size 60 even for the longest incubation period in the study. Mesh 60 is the finest mesh usually required for aglime quarry certification in most states of the northcentral region. Another interesting result was that the efficiency of pelleted calcitic aglime was significantly greater than for either aglime, but was closer to the efficiency of material passing a mesh size 60 than mesh 100. Figure 4 compares more clearly the efficiency of calcitic and dolomitic aglime for the different fineness fractions. The efficiency of these two aglime types was statistically different for all fineness fractions, and the difference was approximately similar for all fractions.

CONCLUSIONS

Agricultural limestone source, the fineness to which it is ground, and the duration of its presence in the soil significantly affect its capacity to increase soil pH. Smaller aglime particles increase the pH at a faster rate and, for the duration of this study under controlled conditions, also reached higher maximum pH values. For the longest incubation periods of 25 to 30 weeks, the efficiency of aglime fractions passing a mesh size 100 and pelleted lime were within 86 to 97% of the efficiency of pure powdered $CaCO_3$. The results must be interpreted with caution for production agriculture because the materials cost and practical application issues should be considered when identifying the best liming material to reach soil pH management goals.

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TABLES AND FIGURES

Table 1. Laboratory analysis of the calcitic aglime, dolomitic aglime, and pelleted calcitic aglime sources.

Source	Pelleted	Calcitic	Dolomitic
	------------------	% -----------------	
Ca	45	42	22
Mg	0.2	0.2	15
Passing 4 mesh	100	100	99
Passing 8 mesh	100	99	88
Passing 60 mesh	97	37	48
$CaCO_3$ equivalent	94	95	100
Moisture	1.0	< 1	< 1
ECCE †	92.3	58.5	65.3

† ECCE, effective calcium carbonate equivalent (IDALS, 2008)

Table 2. Efficiency of liming materials at increasing soil pH relative to pure calcium carbonate for short and long incubation periods.

Source	Fineness (mesh)	Efficiency† Short	Efficiency† Long
		-------------- %	-------------
Calcitic aglime	-	57	59
	Pass 4, not 8	19	28
	Pass 8, not 20	25	39
	Pass 20, not 60	58	60
	Pass 60, not 100	69	80
	Pass 100	94	97
Dolomitic aglime	-	34	52
	Pass 4, not 8	4	10
	Pass 8, not 20	10	21
	Pass 20, not 60	25	43
	Pass 60, not 100	48	64
	Pass 100	63	86
Pelleted calcitic aglime	-	64	88

† Short, average for 3 and 5 weeks incubation periods; Long, average for the two longest periods (25 and 30 weeks).

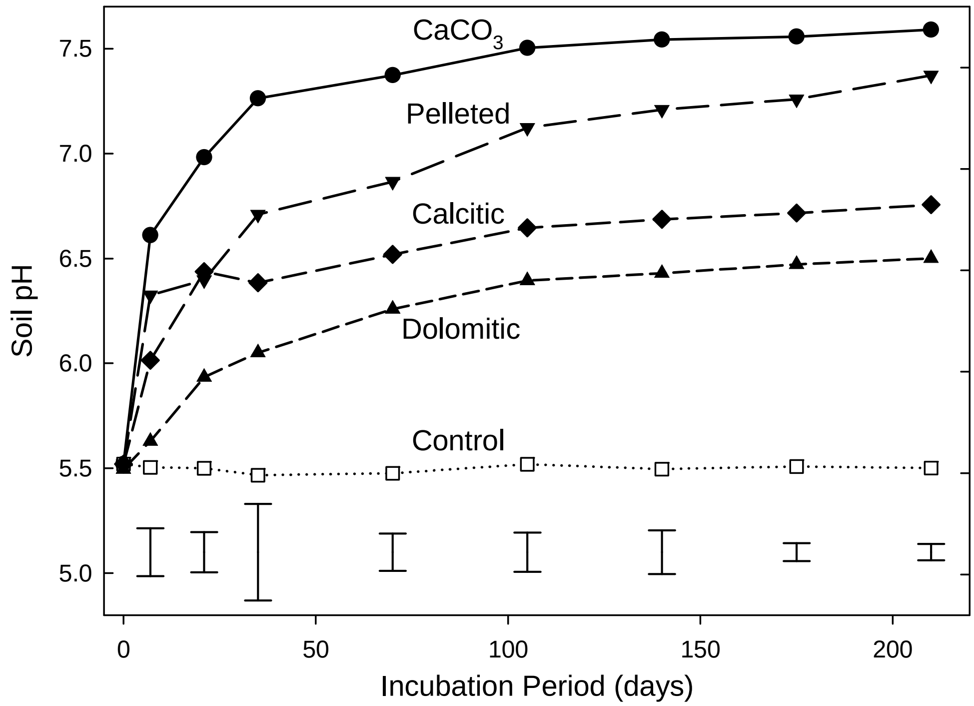

Figure 1. Soil pH over time for $CaCO_3$, calcitic aglime, dolomitic aglime, pelleted calcitic aglime, and an untreated control (averages across three soils). Vertical bars represent least significant differences (LSD) for each incubation period ($P \leq 0.05$).

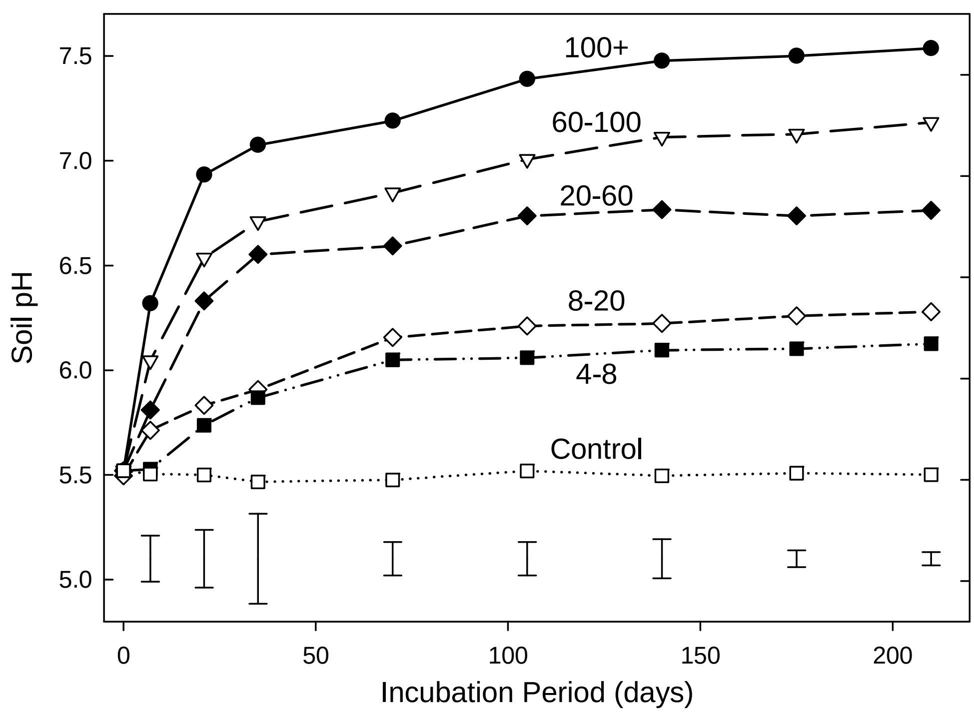

Figure 2. Soil pH over time for five fineness fractions of calcitic aglime and an untreated control (averages across three soils). Vertical bars represent least significant differences (LSD) for each incubation period ($P \leq 0.05$).

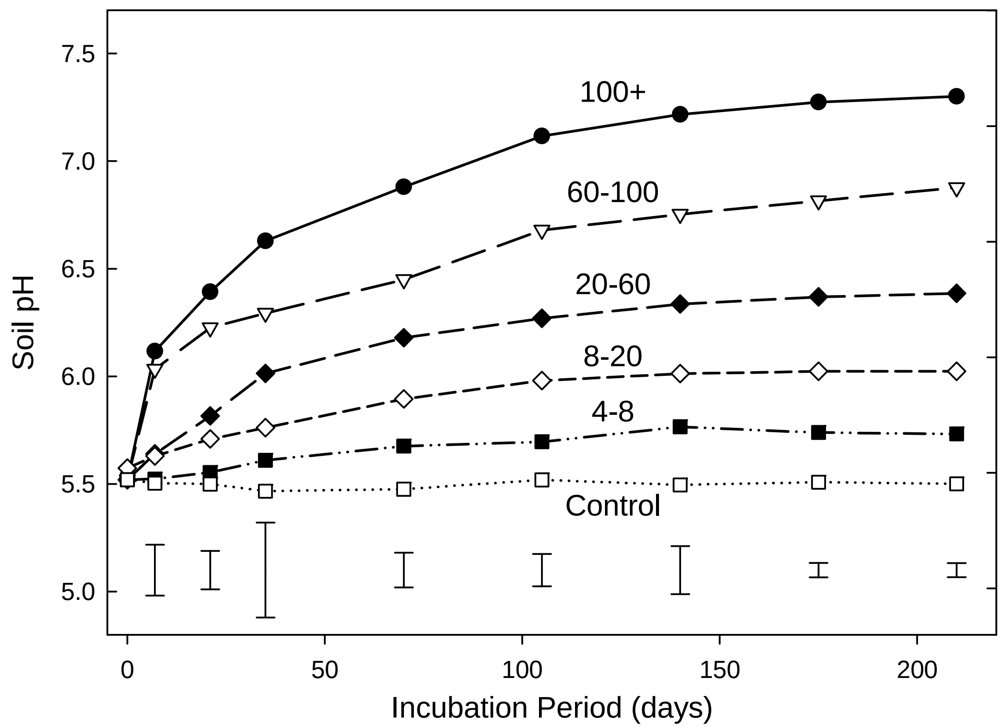

Figure 3. Soil pH over time for five fineness fractions of dolomitic aglime and an untreated control (averages across three soils). Vertical bars represent least significant differences (LSD) for each incubation period ($P \leq 0.05$).

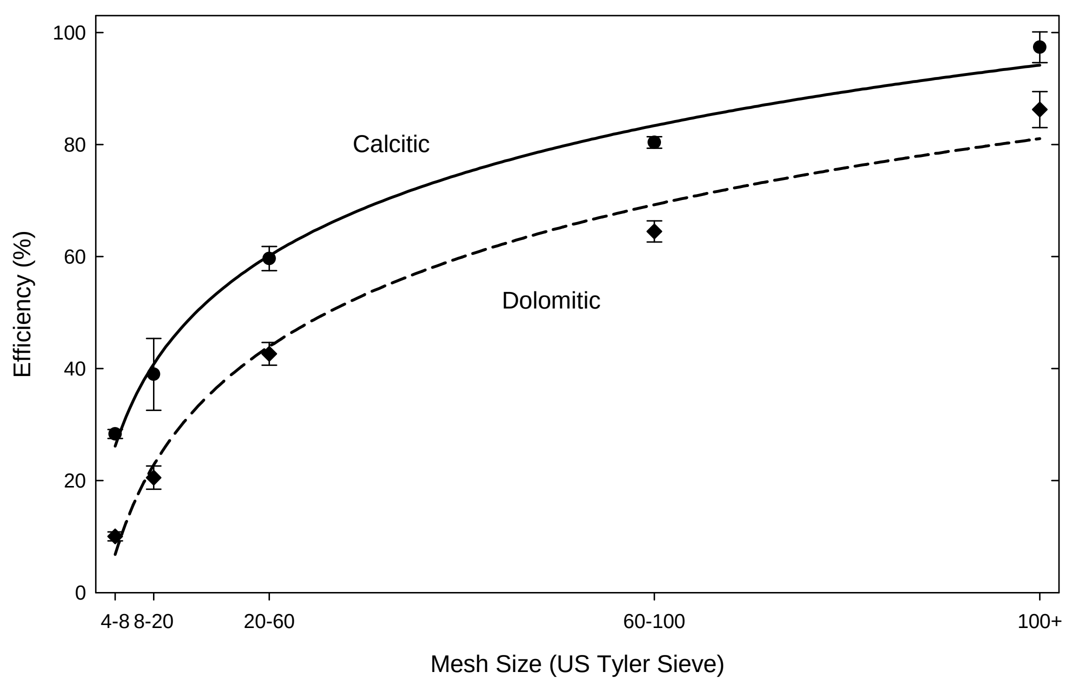

Figure 4. Efficiency of different fineness fractions of calcitic and dolomitic aglime at increasing soil pH. Averages for the two longest incubation periods (25 and 30 weeks) and across three soils. Vertical bars represent least significant differences (LSD) for each fineness fraction ($P \leq 0.05$).

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