Soil Acidity and Liming - Part 2

Internet Inservice Training

- Soil acidity review
- Animal waste effects on soil pH
  - Swine
  - Poultry
- Problems associated with conservation tillage
  - pH and nutrient stratification
  - Lime management
- The effect of sampling time on pH
- The effect of flooded soils on pH
- Turf pH management
- Calcium and peanuts
- Lowering soil pH
  - General discussion
  - Turf

Soil Acidity and Liming - Part 2

(a multi-state internet training)

Dates: January 17 to 28, 2000

Participating States and Specialists Are:

Alabama:	**Dr. Charles Mitchell**	**- Soil Fertility Specialist**
Georgia:	**Dr. Owen Plank**	**- Extension Specialist**
	Dr. Glen Harris	**- Soils and Fertilizer Specialist**
North Carolina:	**Dr. Carl Crozier**	**- Soil Science Specialist**
	Dr. Ray Tucker	**- Soil Testing Specialist**
South Carolina:	**Dr. Jim Camberato**	**- Soil Fertility Specialist**
	Dr. Bob Lippert	**- Soil Fertility Specialist**
Virginia:	**Dr. Steve Donohue**	**- Soils and Plant Analysis Specialist**
	Dr. Mark Alley	**- Agronomist**

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Soil Acidity and Liming (Overview)

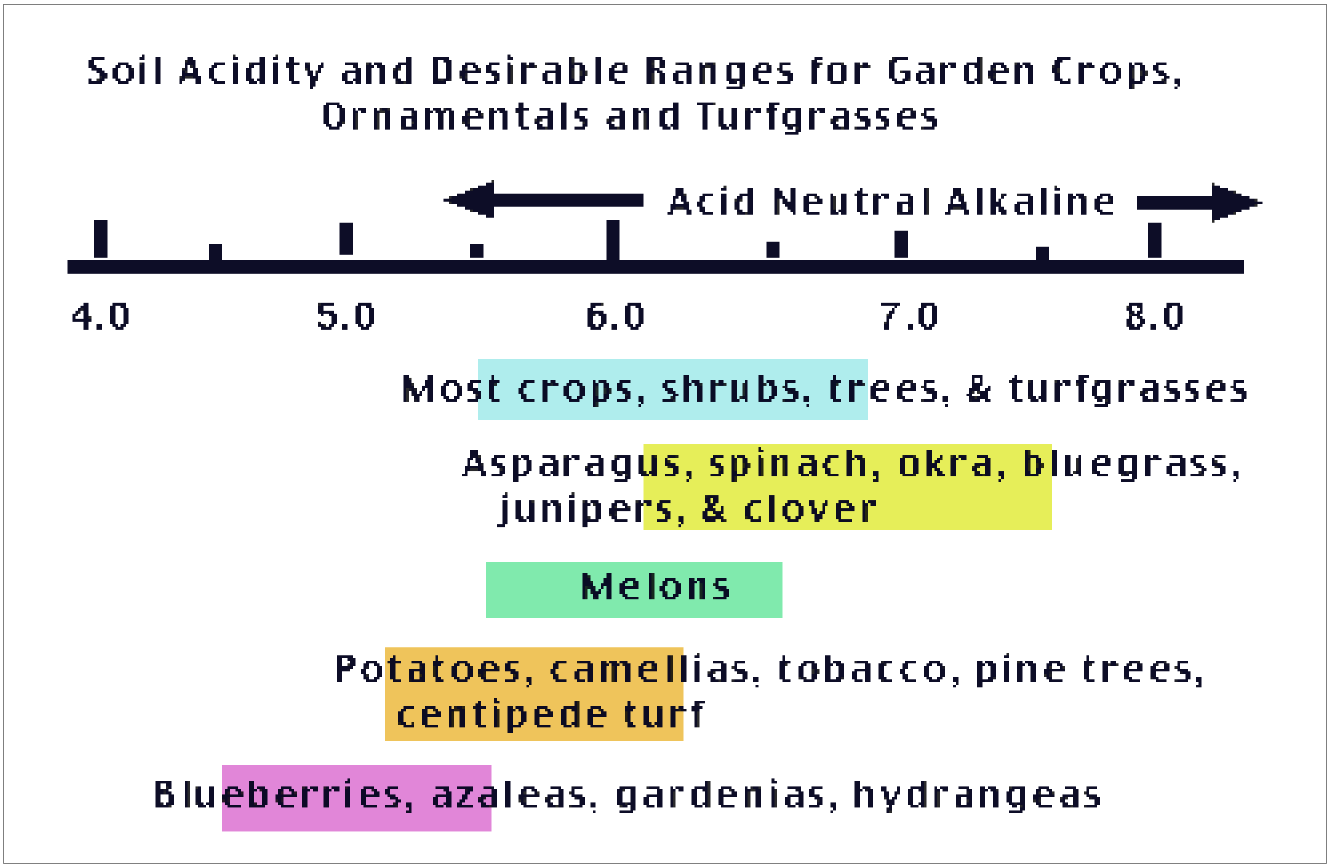
Measuring Acidity and Alkalinity

- **T**he term **pH** stands for the potential **(p)** of the hydrogen ion **(H^+)** in water. It is actually a way of reporting the concentration of H^+ in solution using an electrical "potential" to measure H^+. The pH of any solution is one of the easiest laboratory measurements to make using a pH meter and an electrode specifically designed to measure hydrogen (pH electrode). Color indicators and litmus paper are a quick alternative for less precise measurements. By mixing a quantity of soil with demineralized or distilled water (usually a 1:1 mixture), we can measure the pH of the water solution in equilibrium with the soil.

- **T**he pH measurement is based on a scale from 1 to 14 (pH is reported as the **negative logarithm of the hydrogen ion activity**). At a pH of 7.0, there is an equal balance of hydrogen (H^+) ions and hydoxyl (OH^-) ions, and the soil (actually the soil-water suspension) is said to be neutral. Because the pH measurement is logarithmic, each unit change in pH represents a ten-fold increase in the amount of acidity or basicity. That is, a soil solution with a pH of 6.0 has 10 times as much active H^+ as one with a pH of 7.0.

pH of solution	Hydrogen ion activity (g/liter)
9.0 (very alkaline)	10^{-9} (0.000000001)
8.0 (alkaline or basic)	10^{-8} (0.00000001)
7.0 (neutral, pure water)	**10^{-7}** (0.0000001)
6.0 (slightly acid)	10^{-6} (0.000001)
5.0 (very acid)	10^{-5} (0.00001)
4.0 (extremely acid)	10^{-4} (0.0001)

- **M**ost Southeastern soils have a pH ranging from 4 to 8. With the exception of some native vegetation (e.g. pine trees) and a few acid-loving plants such as azaleas, blueberries, gardenias, and centipede grass, most plants do best in a slightly acid soil with a pH between 6.0 and 7.0.



Acid Soil Infertility

- **W**hen the pH falls below 6.0, the availability of nutrients such as phosphorus, potassium, calcium, and magnesium decreases. The availability of the metallic micronutrients, however, like zinc, manganese, copper, and iron increases as the pH decreases.

- **P**lants don't need aluminum to grow. It's not an essential plant nutrient. Aluminum, however, is one of the prominent mineral components of silt and clay. Therefore, the earth's crust is naturally high in aluminum. Like zinc, manganese , copper and iron, the more acid the soil, the more aluminum will be dissolved into the soil solution. If the pH is allowed to drop much below 5.5, the availability of manganese and aluminum is increased to the point that they could become toxic to plants. **Aluminum toxicity to plants is the main concern we have with acid soils in our region.**

Problems in very acid soils	**Problems in alkaline soils**
*Aluminum toxicity to plant roots	*Iron deficiency
*Manganese toxicity to plants	*Manganese deficiency
*Calcium & magnesium deficiency	*Zinc deficiencies
*Molybdenum deficiency in legumes	*excess salts (in some soils)

*P tied up by Fe and Al	*P tied up by Ca and Mg
*poor bacterial growth	*bacterial diseases in potatoes
*reduced nitrogen transformations	

Some plants such as alfalfa, spinach, and lettuce require high levels of calcium and potassium and can tolerate high salt levels that may occur in near neutral to alkaline soils. White potatoes will do well in near neutral to slightly acid soils but are usually grown in more acid soils (pH less than 6.0) because of "scab", a bacterial disease. As already noted, bacteria don't thrive in very acid soils.

Factors Affecting Soil pH

Soils are not homogenous and the pH can vary considerably from one spot in the field to another. It also varies with depth. Soils in different geographic regions, as already mentioned, may have different pH's because of the five soil forming factors: (1) parent material, (2) climate, (3) living organisms, (4) topography, and (5) time.

Parent material. Soils of the Piedmont and Sandstone Plateau regions of Alabama are very acid because of the acid nature of the rocks (granites and sandstones, respectively) which formed these soils. Limestone valley soils were formed from basic rocks (limestones) but may be acid on the surface because of time and weathering. Some Black Belt Prairie soils may be alkaline because the Selma chalk (soft limestone) which formed the soils is alkaline.

Rainfall/leaching. Rainfall also affects soil pH. Water passing through the soil leaches basic cations such as calcium (Ca^{2+}), magnesium (Mg^{2+}), and potassium (K^+) into drainage water. These basic cations are replaced by acidic cations such as aluminum (Al^{3+}) and hydrogen (H^+). For this reason, soils formed under high rainfall conditions are more acid than those formed under arid conditions.

Fertilizers. Both chemical and organic fertilizers may eventually make the soil more acid. Hydrogen is added in the form of ammonia-based fertilizers (NH_4^+) , urea-based fertilizers [$CO(NH_2)_2$], and as proteins (amino acids) in organic fertilizers. Transformations of these sources of N into nitrate (NO_3^-) releases H^+ to create soil acidity. Therefore, fertilization with fertilizers containing ammonium or even adding large quantities of organic matter to a soil will ultimately increase the soil acidity and lower the pH.

$$\mathbf{NH_4^+ + 2O_2} \longrightarrow \text{bacteria} \longrightarrow \mathbf{NO_3^- + H_2O}$$

- **P**lant uptake. Plants take up basic cations such as K^+, Ca^{++}, and Mg^{++}. When these are removed from the soil, they are replaced with H^+ in order to maintain electrical neutrality.

Raising Soil pH (Liming Acid Soils)

- **S**oils are limed to reduce the harmful effects of low pH (aluminum or manganese toxicity) and to add calcium and magnesium to the soil. The amount of lime needed to achieve a certain pH depends on (1) the pH of the soil and (2) the buffering capacity of the soil. The buffering capacity is related to the cation exchange capacity (CEC). The higher the CEC, the more exchangeable acidity (hydrogen and aluminum) is held by the soil colloids. As with CEC, buffering capacity increases with the amounts of clay and organic matter in the soil. Soils with a high buffering capacity require larger amounts of lime to increase the pH than soils with a lower buffering capacity. Most soil testing laboratories use a special buffered solution to measure the exchangeable acidity. This is the form of soil acidity that must be neutralized for a change in soil pH. By calibrating pH changes in the buffered solution with known amounts of acid, the amount of lime required to bring the soil to a particular pH can be determined.

- **L**ime reduces soil acidity (increases pH) by changing some of the hydrogen ions into water and carbon dioxide (CO_2). A Ca^{++} ion from the lime replaces two H^+ ions on the cation exchange complex. The carbonate (CO_3^-) reacts with water to form bicarbonate (HCO_3^-). These react with H^+ to form H_2O and CO_2. The pH increases because the H^+ concentration has been reduced.

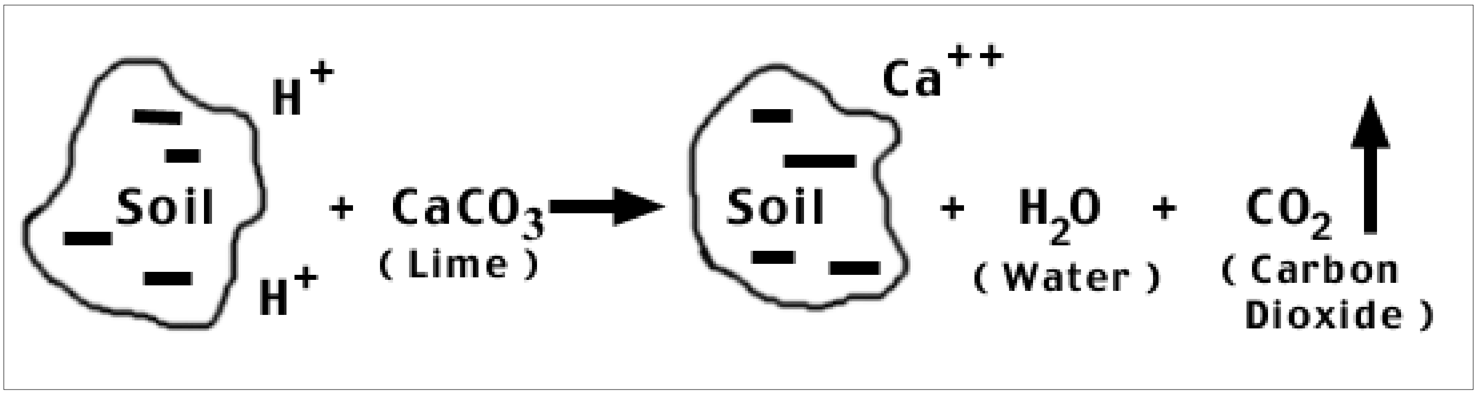
$$\text{Soil Colloid}\begin{matrix} H^+ \\ \\ H^+ \end{matrix} + CaCO_3 \longrightarrow \text{Soil Colloid-}Ca^{++} + H_2O + CO_2 \uparrow$$

- **R**emember, the reverse of the above process can also occur. An acid soil can become more acid as basic cations such as Ca^{2+}, Mg^{2+}, and K^+ are removed, usually by crop uptake or leaching, and replaced by H^+.

Liming Materials

- **T**he most common liming materials are calcitic or dolomitic agricultural limestone. These are natural products made by finely grinding natural limestone. Since natural limestone is relatively insoluble in water, agricultural limestone must be very finely ground so it can be thoroughly mixed with the soil and allowed to react with the soil's acidity. Calcitic limestone is mostly calcium carbonate ($CaCO_3$). Dolomitic limestone, according to most state laws, must have at least 6 percent magnesium, and is made from rocks containing a mixture of calcium and magnesium carbonates. Either will neutralize soil acidity. Dolomitic limestone also provides magnesium. Other liming materials which are less frequently used are listed in Table 2.

- **B**ecause high quality, finely ground limestone is very dusty and difficult to spread, some companies market a "prilled" or "granular" limestone for home use. A small amount of clay or a polymer is added to the ground limestone so small prills are formed instead of dust. This makes it easier to spread by hand or with a garden fertilizer spreader. Once applied, soil moisture will cause the "prills" or "granules" to dissociate and disperse the limestone particles. The limestone can then react with exchangeable acidity in the following manner.



Application and Placement of Lime

- **T**<u>ime of year.</u> Lime may be applied at any time during the year. For the farmer or gardener, winter or early spring just prior to soil preparation is usually most convenient. Don't apply caustic liming materials such as burned lime, hydrated lime, or wood ashes to actively growing plants. Ground limestone will not harm plants.

- **L**<u>ime placement.</u> The most important consideration is lime placement. Ground agricultural limestone is relatively insoluble in water so maximum contact with the soil is necessary to neutralize the soil acidity. Lime will not move into the soil like water-soluble fertilizers. Thoroughly mix the recommended amount of lime with the top 6 to 8 inches of soil. As soon as moisture is present, the lime will begin to react. Coarse lime particles react more slowly than very fine particles. Therefore, using very finely ground limestone and thoroughly mixing it are necessary to achieve the desired soil pH change within a few months. If the soil will be turned with a bottom plow, turn it first and then apply the lime and mix.

Some common soil liming materials.

Material	**Relative Neutralizing value** ----------- % ------------	**Comment**
pure $CaCO_3$	100	not generally available
Calcitic agricultural lime, (calcium carbonate, $CaCO_3$ +impurities)	90 - 100	easily available
Dolomitic agricultural lime, $CaCO_3$ + $MgCO_3$	95 - 108	easily available; provides Mg
Ground oyster shells	85 - 95	
Selma chalk/marl, $CaCO_3$ + clay	50 - 85	contains clay; keep dry
Burned lime, CaO	150 - 175	very caustic; don't use
Hydrated lime or builders' lime, $Ca(OH)_2$	120 - 135	caustic; use with caution; no Mg
Basic slag	50 - 70	contains some P & micronutrients; byproduct
Wood stove or fireplace ashes	40 - 70	provides some plant nutrients
Boiler wood ash	30 - 60	provides some plant nutrients
By-products	Variable	use as specified by manufacturer
Gypsum and/or ground drywall, $CaSO_4$	0	NOT A LIMING MATERIAL

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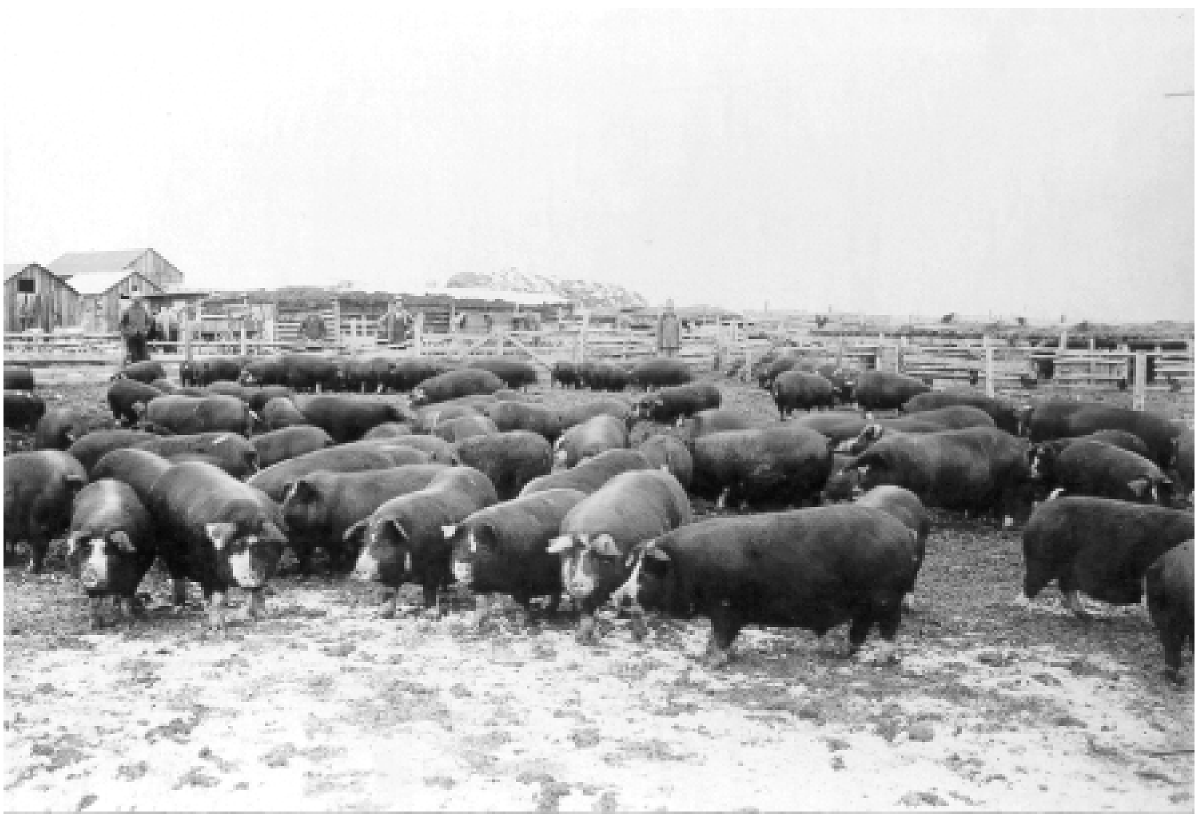
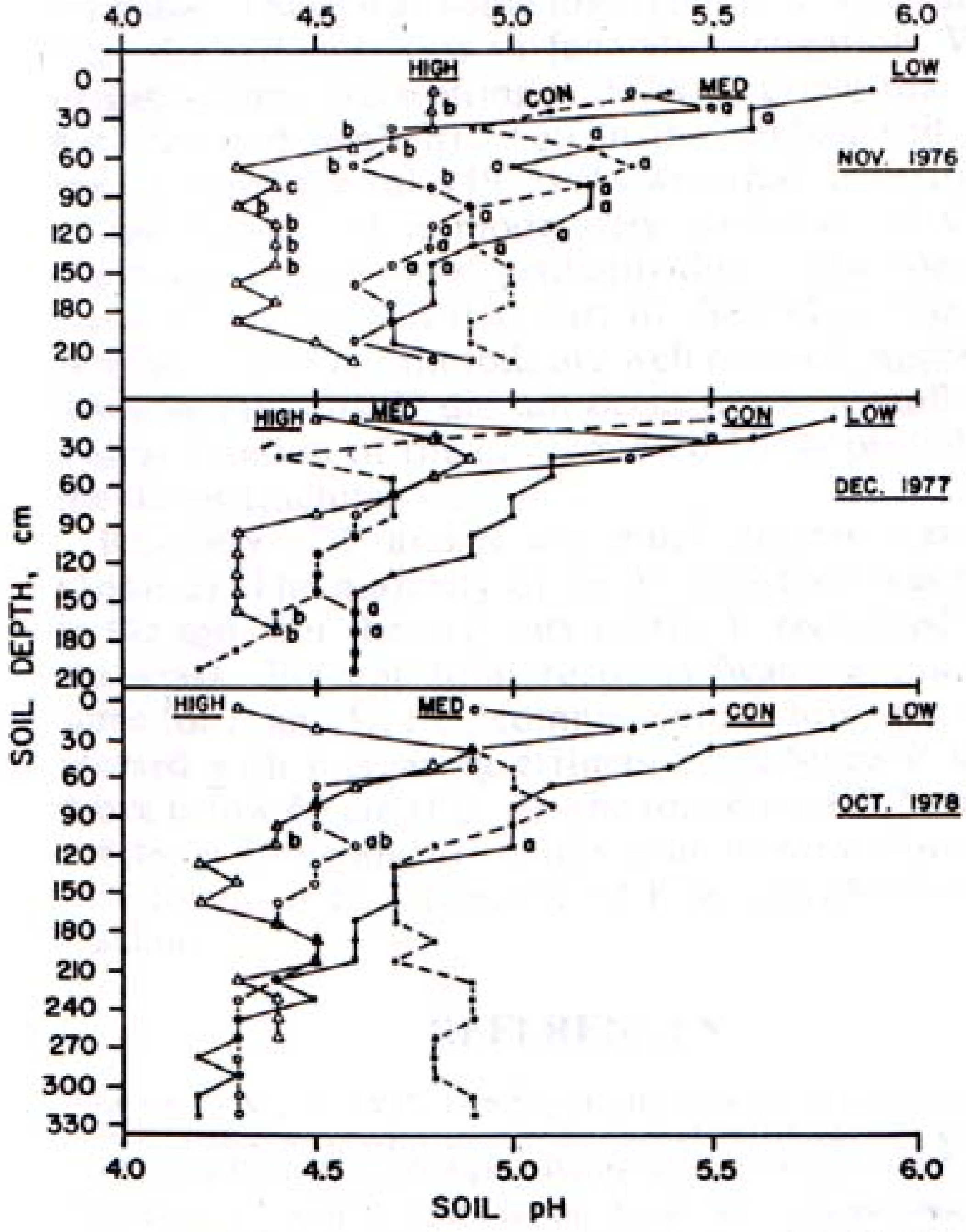
Return to Soil Acidity & Liming - Part II

Effects of Swine Effluent on the Soil pH Value

- The general effect of swine effuent application on soil pH is a decrease in pH with increasing application rates. In 1977 and 1978, large differences were found between treatments but large variations among replicates of the same treatment resulted in a few significant differences. The decline in pH with increasing application rate is consistent with the loss of Ca^{2+} and Mg^{2+} from the surface layer due to effluent additions of Na^{+}, K^{+} and NH_4^{+}. The pH decline and the loss of Ca^{2+} and Mg^{2+} stress the need for periodic additions of dolomitic limestone.



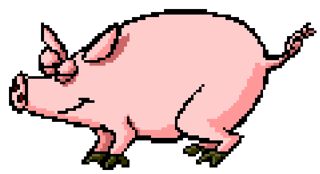


Effect of lagoon effluent irrigation rates on soil pH.

- "Swine Lagoon Effluent Applied to 'Coastal Bermudagrass: II. Effects on Soil"
  King, Westerman, Cummings, Overcash and Burns
  J. Environ Qual., Vol. 14, no. 1, 1985



Return to Soil Acidity & Liming - Part II



Liming Value of Poultry Manures

- The type of poultry manure determines its effects on soil pH because poultry feed contains varying amounts of calcium carbonate. All poultry rations contain some ground limestone. Broiler and turkey feed may contain less than 1% ground limestone whereas layer and breeder rations may contain 7 to 10% ground limestone. Most of this ground limestone will be passed through the bird and ends up in the manure or litter. In broiler litter (manure plus bedding), the manure and the limestone may be concentrated in the bedding as several flocks are produced on the same bedding, and it dries out.

- A survey of Alabama fescue pastures showed that fields that had received repeated applications of poultry broiler litter over many years had an average surface soil pH of 6.3 (±0.1) compared to fields receiving only commercial fertilizers. These latter fields had a surface pH of 5.8(±0.1) (Kingery et al., 1993). Hue (1992) also showed that chicken manure was very effective in raising soil pH. He theorized that much of this pH increase was due to reactions of organic anions. Poultry litter can detoxify Al by increasing soil pH, complexing soluble Al with organic acids, and complexing soluble Al as it reacts with phosphorus in the litter/manure. (Typically hen manures have calcium carbonate contents of 15 to 18% (300 to 360 lb calcium carbonate per ton).

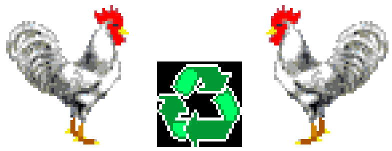
- Soil pH may increase substantially with applications of hen manure because the amount of liming material added to the soil exceeds the amount of acidity released by the conversion of nitrogen. Over application of hen manure/litter could result in too high a soil pH on very sandy Coastal Plain soils. This could result in micronutrient deficiencies (e.g. Mn) on some Coastal Flatwoods soils. Soil pH's greater than 7.0 in the upper one foot of soil and nearly 7.0 in the one to two foot sampling depth, were found in a number of Piedmont fields receiving repeated applications of hen manure and no commercial limestone applications. Although no crop production problems associated with these unusually high soil pH's have been documented in these clay soils, pH values this high would likely cause problems in sandy Coastal Plain soils. The liming value of layer manure should be considered when layer manure is used as a crop nutrient source. This value is not trivial as one ton of lime per acre every three years currently costs about $30 per acre or $10 per acre per year.

- **P**repared by Jim Camberato and Charles Mitchell

- **R**eferences

- Hue, N.V. 1992. Correcting soil acidity of a highly weathered ultisol with chicken manure and sewage sludge. Commun. Soil Sci. Plant Anal. 23:241-264.

- Kingery, W.L., C.W. Wood, D.P. Delaney, J.C. Williams, G.L.Mullins, and E. van Santen. 1993. Implications of long-term land application of poultry litter on tall fescue pastures. J. Prod. Agric. 6:315-395.



Return to Soil Acidity & Liming - Part II

Nutrient and pH Stratification With Conventional and No-Till Management

Our work addressed the following management questions for North Carolina conditions (Piedmont, Coastal Plain, Tidewater regions):

1) What are reasonable and/or commonly recommended soil sampling depths?
2) Does soil sampling depth affect soil test results?
3) How sensitive are lime and fertilizer application rate recommendations to sampling depth?

Interest in these then leads to the following more basic questions:

4) Does tillage or no-till management change how lime and fertilizer are distributed in the soil profile?
5) Do soil pH and nutrient concentration differ predictably among soil layers?
6) With no-till management, does the surface soil layer become more acidic? Less acidic? Why?

Why the Interest in Soil Sampling Depth?

Many analytical laboratories now recommend shallower soil sampling depths for fields with no-till management than with conventional tillage since nutrients and plant roots are generally more concentrated near the surface. Surface soil properties, such as bulk density, organic matter, pH, extractable nutrients, and plant root distribution change with the adoption of no-till methods. Nevertheless, the impacts on soil test results and fertilizer recommendations are not well understood. Soil pH stratification patterns are less consistent than those reported for nutrients and roots with no-till management. Soil surface acidification can occur, presumably due to near-surface nitrification of ammoniacal N fertilizers and decomposition of crop residues. In contrast, the soil surface can become less acidic than the underlying soil, presumably due to surface liming. Thus, variation in soil profile pH patterns is probably related to liming practices. Recommendations made by soil testing laboratories need to be applicable on a regional basis across a wide range of soils, climates, and management situations. The objective of our study was to determine the effect of soil sampling depth on soil test results for a broad range of soils on commercial and large-scale research fields managed with conventional tillage and no-till for varying lengths of time. This study differs from many others in that it investigates replicate fields from a broad spectrum of soils and crop management practices, rather than focusing on uniformly managed research plots. Thus, it better represents the nature of samples likely to be submitted to a soil test laboratory.

Our Methods

- **F**ields from several geologic regions and with different tillage histories were selected from across North Carolina. All fields were to be planted with corn in 1996. There were 45 commercial fields and 14 research plots representing a great deal of soil diversity: 22 soil series. Tillage histories in this study were conventional tillage (CT), no-till for less than 3 years (NT<3), no-till for 3 to 6 years (NT 3-6), and no-till for more than 6 years (NT>6). Conventional tillage refers to a variety of tillage intensities, including disking, chisel plowing, and subsoiling, but in most cases does not involve moldboard plowing. Fields were sampled between January and April 1996, prior to lime and fertilizer applications. From each field, samples were collected from 0-8 inches deep, 0-4 inches and 4-8 inches, and from 0-2 inches. A composite sample from each depth was submitted for analysis following procedures of the Agronomic Division, North Carolina Department of Agriculture (Mehlich-3 extractant, results converted to index units). Data were analyzed separately for each tillage history category. For statistical testing, we used Wilcoxon's signed ranks test to determine if soil test results for a given parameter differed significantly among depth intervals for each tillage category. We used this rather than an analysis of variance since soil test values varied so widely among fields. We grouped data across regions to obtain a minimum sample size for statistical testing. No statistical comparison of fertility status across tillage categories was possible with our sampling design since field selections within each region were based on the tillage history and next crop (corn), without regard for soil type or crop management decisions.

Our Answers to the Questions Posed

1) What are reasonable and/or commonly recommended soil sampling depths?

- **F**or a routine soil sample, NCDA currently recommends sampling field crops to the plow layer depth, usually 6-8 inches. Samples should be collected to a depth of 4 inches for established pasture, turf, and minimum/no-tillage systems. For problem diagnosis, a separate subsoil sample (8-16 inches) is also requested. [Tucker et al., Soil Testing Services, Agronomic Division, N.C. Dept. of Agriculture, 1995].

- **A** national publication reports that a survey of several states suggests a sampling depth of 2-4 inches for conservation tillage fields. [James and Wells, p. 37 in Soil Sample Collection and Handling; Chapter 3 in Soil Testing and Plant Analysis, 3rd Edition, R.L. Westerman (ed.). 1990.]

2) Does soil sampling depth affect soil test results?

Table 1. Differences between soil test results of shallow (0-4") and deeper (0-8") soil depth layers. Values shown are the differences: means of 0-4" samples minus means of 0-8" samples. A "+" indicates higher values in the shallower surface layer sample.

Assay	**CT**	**NT < 3**	**NT 3-6**	**NT > 6**
pH	NS	+0.1*	NS	NS
P-Index	NS	+ 20 ***	+ 27 **	+ 28 **
K-Index	NS	+ 24 ***	+ 14 ***	+ 15 **
Mg%	NS	NS	NS	+ 1 *
Zn-Index	NS	+ 27 **	+ 58 **	+ 63 **
Cu-Index	NS	NS	NS	+ 22 *
S-Index	NS	- 8 *	- 2 *	NS
Statistical significance: p < *0.05, ** p < 0.01, and *** p < 0.001.				

No significant differences in soil test results were detected in the conventionally tilled fields unless the comparison was made with an even shallower sampling depth (0-2 inches, data not shown). In all no-till duration categories, soil test P, K, and Zn concentrations were higher with the shallow sampling depth. In the long-term no-till category (NT > 6), soil test Mg and Cu indexes were also higher with the shallow sampling depth. Our results are consistent with previous reports describing higher nutrient concentrations in the surface soil with no-till management.

3) How sensitive are lime and fertilizer application rate recommendations to sampling depth?

Table 2. Differences between lime and fertilizer application rate recommendations based on shallow (0-4") and deeper (0-8") soil depth layers. Values shown are the differences: means of 0-4" samples minus means of 0-8" samples. A "-" indicates lower rates recommended based on the shallower surface layer sample.

Material	**CT**	**NT < 3**	**NT 3-6**	**NT > 6**
Lime (T/A)	NS	NS	NS	NS
P_2O_3 (lb/A)	NS	NS	- 12 *	NS
K_2O (lb/A	NS	- 5 *	- 12 **	- 6 *

Statistical significance: $p<0.05$, ** $p < 0.01$, and *** $p < 0.001$.

Since P and K concentrations are above sufficiency levels in many North Carolina fields, many sites received no fertilizer recommendation regardless of sampling depth. If P or K concentrations were below the sufficiency level, higher nutrient concentrations near the surface led to reduced fertilizer rate recommendations when based on the shallower sampling depth. Since the overall pH effects were relatively small, the only significant relationship between sampling depth and lime recommendation noted was for the NT<3 sites when comparing 0-2 inch and 0-8 inch samples (data not shown). On average, less lime was recommended if rates were based on the shallower sampling depth.

4) <u>Does tillage or no-till management change how lime and fertilizer are distributed in the soil profile?</u>

Table 3. Differences between soil test results of surface (0-4") and underlying (4-8") soil depth layers. Values shown are the differences: means of 0-4" samples minus means of 4-8" samples. A "**+**" indicates higher values in the shallower surface layer sample.

Assay	**CT**	**NT < 3**	**NT 3-6**	**NT > 6**
pH	NS	+ 0.2**	+ 0.3**	NS
Acidity	NS	NS	- 0.2*	NS
P-Index	+ 30**	+ 31**	+ 52**	+ 44**
K-Index	+ 29**	+ 30***	+ 23**	+ 31***
Ca%	NS	+ 4^{+}	+ 5*;	NS
Mg%	NS	NS	+ 2*	+ 2*
Mn-Index	NS	+ 23***	+ 33*	NS
Zn-Index	+ 36**	+ 47**	+ 125**	+ 117***
Cu-Index	NS	+ 15*	+ 31*	+ 42**
S-Index	NS	-7^{+}	-7*	NS
Statistical significance: NS (not significant), + ($p < 0.1$),* ($p < 0.05$), ** ($p < 0.01$), and *** ($p < 0.001$).				

- **C**omparison of the surface (0-4 inch) and underlying (4-8 inch) soil depths indicate that some degree of chemical stratification occurred for all tillage categories. Note that P, K, and Zn concentrations were greater (positive difference) for all tillage categories. Nutrient and pH stratification probably occurs in conventionally tilled fields since moldboard plows and rotary tillers are not used frequently, and since fertilizer banding is relatively common in North Carolina. Stratification in no-till fields is likely to be enhanced due to the surface application of materials and the lack of soil mixing.

- **S**tratification of pH, Ca, Mn, Cu, and S was also noted for fields with NT < 3 years. For NT 3-6, in addition to the previously mentioned parameters, Mg concentrations were also significantly greater in the surface layer. The CT and NT > 6 fields did not exhibit consistent variation with respect to stratification of pH, Ca, Mn, or S. Thus, either these nutrients were uniformly distributed in these soils or variation was inconsistent across the tillage category.

- **E**xcept for S, elements were more concentrated near the surface if stratification was detected. The S assay measures extractable sulfate (SO_4^{-2}), a highly leachable anion. Thus, S concentrations tend to be greater in lower soil layers. Although the P assay also measures extractable anions, phosphates are less mobile in soils due to complexation and precipitation reactions.

- **D**ata from the 0-2 inch sampling depths (data not shown) followed soil pH, P, Ca, and Mg stratification trends detected with the other sampling increments. For example, mean P concentrations were even greater in the 0-2 inch increment than in the 0-4 inch increment.

5) <u>Do soil pH and nutrient concentration differ predictably among soil layers?</u>

- **W**e use our statistical tests to evaluate how predictable these differences are. In general, we observed some stratification even in conventionally tilled fields. This is probably because soil mixing is not complete, especially when disks and chisel plows rather than moldboard plows are used. With the adoption of no-till methods, stratification becomes even more pronounced. Interestingly, stratification in pH, Ca, Mn, and S were more likely for fields in the early stages of no-till than in longer-term no-till.

6) <u>With no-till management, does the surface soil layer become more acidic? Less acidic? Why?</u>

- **A**lthough surface soil pH was consistently higher than pH in underlying layers in the short-term no-till sites, the magnitude of these differences was often very small (0.2-0.3 pH units). Stratification was inconsistent in the long-term no-till plots (NT > 6). Thorough liming prior to the onset of no-till management has been promoted in North Carolina, and may have countered surface acidification in these soils (G. Naderman, unpublished). The less consistent soil pH profile in older no-till fields may be due to the variation in liming history among fields. In our study, some long-term (NT > 6) fields had received lime within as recently as 1 year, while others had not received any lime for 10 years prior to our sampling. Earlier detection and correction of surface acidification is one reason for shallower sampling in no-till. For these North Carolina fields with higher surface soil pH, shallower soil sampling could actually delay lime application since it fails to detect subsoil acidity.

Conclusions

Some chemical stratification occurred for all tillage categories, this became more pronounced with the adoption of no-till management. Soil sampling is a valuable tool for 1) specific lime and fertilizer recommendations, and 2) monitoring long-term soil changes. In consideration of specific lime and fertilizer recommendations: switching from a 0-8 inch to a 0-4 inch sampling depth in no-till situations yields higher soil P, K, Zn, and Cu levels, and thus reduces recommended fertilizer rates. In consideration of monitoring long-term soil changes: sampling no-till fields requires even more attention to depth than for conventionally tilled fields.

By: C.R. Crozier*, G.C. Naderman, M.R. Tucker, and R.E. Sugg

Published in: Communications in Soil Science and Plant Analysis 30:65-74, 1999.

Return to Soil Acidity & Liming - Part II

Effectiveness of Surface Liming

- In 1985 a study was initiated at Penn State to look at the effects of surface application of lime on a very acid, long-term no-till soil. Since 1977 this field had been in no-till corn production with no limestone applied. The initial pH of "plow layer" was 5.1 and the surface 2 inch pH was 4.5. The limestone recommendation, based on the SMP buffer pH and a target pH of 6.5, was 6000 lb calcium carbonate equivalent (CCE) per acre. The study included four limestone rates (0, 3000, 6000, 9000 lb CCE/A) and liming programs ranging from applying lime every year to once every five years. Each year the soil was sampled in the spring in 2 inch increments to a depth of 6 inches. No-till corn was grown from 1985 to 1991, no-till soybeans were grown in 1992 and 1993, oats was grown in 1994 and wheat in 1995 and corn in 1996, 1997 and 1998.

- Soil pH results from soil samples taken in the spring of each year from 1985 through 1994 for selected liming programs are given in Figures 1 and 2. The soil pH results for the 6000 lb/A, every third year liming program are shown in Figure 1. This treatment was chosen for illustration because this would be the recommended limestone rate based on a plow depth soil sample and this frequency of liming is fairly common in many areas. The pH results in Figure 2 are from the every year, 3000 lb/A liming program. The every year program is of interest because there has been speculation that more frequent smaller applications of limestone may be necessary in no-till. Several observations can be made based on these results. First, it is clear that the recommended limestone application changed the soil pH in the surface 2 inches within the first year after application. Soil pH measurements taken within the first year indicated that most of the pH change in the surface layer occurred within the first two months after spring liming. This rapid increase at the surface was expected since this was a high quality finely ground limestone with 90% passing a 100 mesh sieve. Although the 0 to 2 inch layer was not subdivided for routine pH determination, spot checks of pH in this layer indicated that most of the pH change was in the surface 1/2 inch. However, there was little change in the soil pH below the surface 2 inches until about the fourth year of the study following subsequent limestone applications. Even after 9 years the soil pH in the 2 to 6 inch layers has not yet reached the target pH of 6.5 that was achieved rather quickly in the surface layer. There is little apparent difference between the standard, every third year liming program, and the more frequent every year liming program.

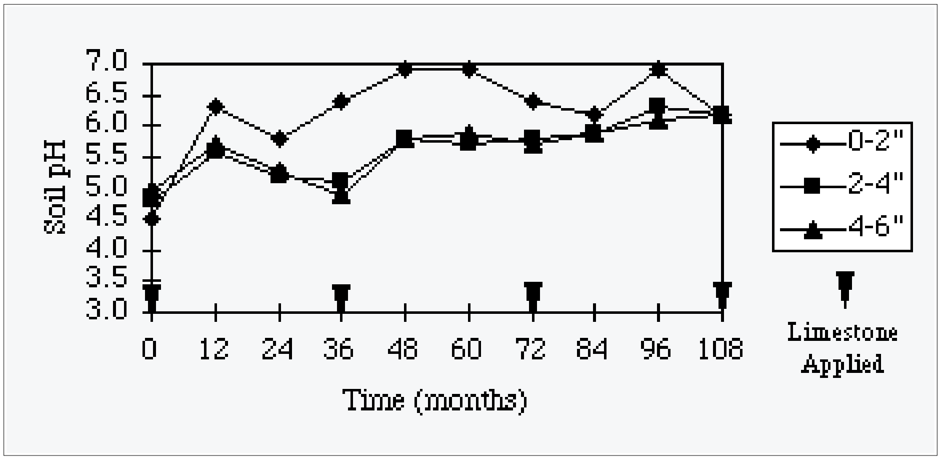


Figure 1. Soil pH vs time for a no-till soil limed at 6000 lb/A every third year

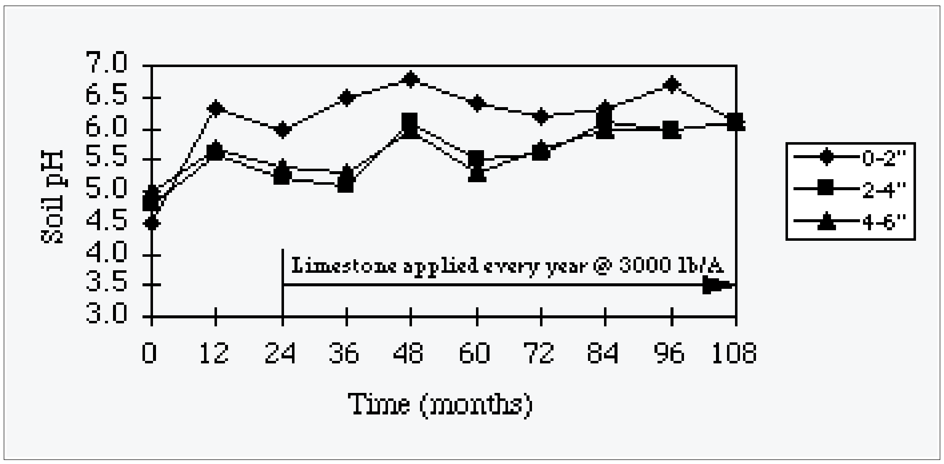


Figure 2. Soil pH vs time for a no-till soil limed at 6000 lb/A initially and then every year since 1987 at 3000 lb/A.

These pH effects from the liming treatments resulted in slight but generally insignificant increases in corn yield. The greatest yield response was in the wheat crop in 1995. Some negative responses were observed in the years when soybeans were the plots. However, it was speculated that this was due to compaction from the liming operation especially in the more frequent liming programs. A triazine weed control treatment was included in the early years of this study. This work showed that the initial liming which only affected the pH at the soil surface did improve the efficacy of the triazine herbicides. Similar to the effect observed with the triazine activity, there were significant effects on plant tissue concentrations immediately after liming even though the pH effect from the lime was limited to the soil surface. These plant nutrient effects were a significant increase in calcium and a decrease in manganese. From this work it was concluded that surface application of limestone will rapidly change the soil pH at the surface of the soil. It was also observed that even this shallow pH improvement could affect herbicide activity and nutrient availability. A second major conclusion is that a very long time is required to have much effect on the soil pH below the surface 2 inches in no-till crop production. Finally, there seems to be little justification for more frequent liming in no-till systems.

Thus, the current recommendation is that where possible on a very acid soil, limestone should be incorporated to adjust the soil pH to the desired level in the entire plow layer before no-till crop production in initiated. Other work has shown that if the soil pH is in the desired range to begin with, it can be maintained by surface applications of limestone in no-till systems. Thus, if a regular liming program is followed and soil pH is not allowed to drop to very low levels further incorporation of limestone should not be necessary. Where incorporation is not possible there are beneficial effects of surface application of limestone to acid no-till soils even though the immediate effect will only be near the soil surface. Also, with surface liming the standard every three year or so liming program based on a regular soil testing program should be adequate.

Prepared by:
Douglas B. Beegle, Professor of Agronomy
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Return to Soil Acidity & Liming - Part II

Soil Acidity and Liming - Part 2

Internet Inservice Training

The following is adapted from an Arkansas Experiment Station Bulletin 777, September, 1972

Variations in Soil Test Results as Affected by Seasonal Sampling

- It has been apparent to those working in soil testing laboratories in Arkansas and other states that seasonal variations occur in soil test data. This has been observed in results from experimental plots that were sampled three or more times during the year. It has also been measured in soils sampled a number of times during the year to determine the rate of lime reaction by changes in soil pH values. In these studies, the samples taken in the fall from unlimed plots showed the lowest pH values.

- Seasonal variations in soil test values have been reported in the literature. Some of the factors influencing variations in soil pH are the presence of soluble salts and carbon dioxide.

- The purpose of this study was to determine the nature and magnitude of variations in soil test values for some of the prominent soil types used for row crops in Eastern Arkansas. It was felt that knowledge of the variations could be used to adjust limestone recommendations.

Methods:

- Eighteen soil series from Eastern Arkansas were used for the study. They included the following texture classes: silt loam, sandy loam, clay and clay loam. Most of the soils were in cotton or soybeans during the two summer sampling season. At each site, permanent reference points were established so samples could be taken from the same location. Sampling was started in June 1965 and was repeated approximately every two weeks through November. From December 1965 through April 1966, samples were collected monthly, weather permitting. From May until December 1996, or until the rows were destroyed after the 1966 crop, samples were taken approximately every two weeks. The soil pH was determined by using a standard laboratory method which uses de-ionized water. The soil pH was also determined by using salt solutions containing either 1.0N KCl or 0.01M $CaCl_2$ to see if this would suppress the seasonal variations.

Results:

Table 1. **Average and range for water pH values for 18 soil sites.**

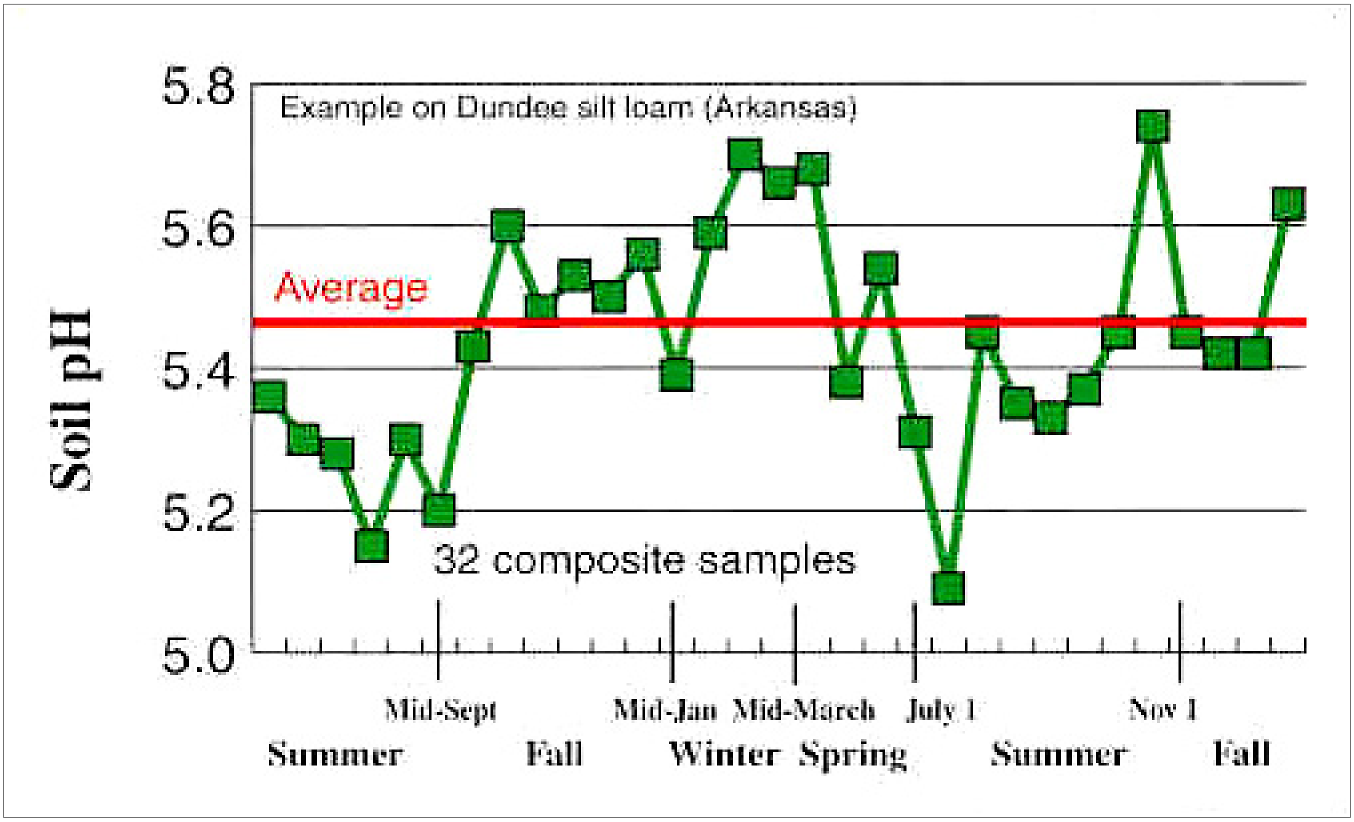
Soils	Average	Range
Silt loam loess		
Calloway	5.60	5.40 - 5.90
Henry	5.30	5.04 - 5.48
Crowley	4.90	4.56 - 5.08
Calloway	4.81	4.54 - 5.02
Crowley	7.71	7.26 - 7.94
Sandy loam alluvium		
Robinsonville	6.55	6.00 - 6.90
Beulah	6.93	6.40 - 7.20
Rilla	6.59	6.12 - 6.98
Bosket I	5.68	5.40 - 5.96
Bosket II	5.72	5.48 - 5.90
Silt loam alluvium		
Commerce	6.08	5.70 - 6.34
Rilla	6.70	6.42 - 6.96
Dundee	5.44	5.06 - 5.70
Forestdale	5.39	5.16 - 5.58
Clay and clay loam alluvium		
Sharkey	6.52	6.10 - 6.80
Earle	5.61	5.44 - 5.74
Alligator	5.60	5.40 - 5.96
Perry	5.86	5.52 - 6.36

Table 2 gives the distribution of soil pH values. The shift of plus and minus pH values by season is apparent for all soils. There are less plus values in the spring and summer samplings and relatively more in the fall and winter. Minus readings are more apparent in the spring and summer months with almost none in the fall months.

Table 2. Distribution of Water pH by Season.

		Summer			Fall			Winter	
		1965			**1965**			**1966**	
	+	Ave.	-	+	Ave.	-	+	Ave.	-
All Soils	9	87	35	23	81	4	11	33	8
		Spring			**Summer**			**Fall**	
		1966			**1966**			**1966**	
All Soils	+	Ave.	-	+	Ave.	-	+	Ave.	-
	2	43	19	6	72	19	20	50	1

\+ = greater than the average plus 1 standard deviation
Ave. = overall average plus or minus 1 standard deviation
- = less than the average minus 1 standard deviation



- **D**iscussion:

  There was no consistency for pH variation by season within the soil texture classes. The only generalized statement that can be derived from study is the overall trend towards lower pH values in the spring and summer and higher pH values in the fall.

  The soil pH values which were determined by using salt solutions containing either 1.0N KCl or 0.01M $CaCl_2$ showed similar patterns of variation as the standard pH method.

  By: Joseph Keogh and Richard Maples

Return to Soil Acidity & Liming - Part II

How does flooded soil conditions affect the soil pH?

- Soils which have been saturated with water for a prolonged period of time may show an increased soil test pH value. The main reason for the change is the denitrification of soil nitrate to nitrogen gas which occurs under anaerobic conditons. For each atom of nitrate nitrogen which is converted to nitrogen gas, 6 atoms of acidic hydrogen are neutralized by forming water molecules as part of the bio-chemical reaction. The amount of pH change is dependent on the amount of residual nitrates in the soil and may increase as much as several tenths of a pH unit. Since this change in soil pH is due to a non-reversible bio-chemical reaction, we suggest that farmers follow the soil test lime recommendations from samples collected from these flooded soils and make no adjustments to the recommended lime application rate.

Return to Soil Acidity & Liming - Part II

Turf pH Management

Causes of Low Soil pH with Turf

- Low soil pH occurs naturally throughout the Southeast. Many soils that have not been cultivated have pH's in the low 4's. The exceptions are some Coastal soils high in calcium carbonate from sea shells or irrigated with high bicarbonate irrigation water. Sediments dredged from ponds, ditches, and wetlands may have near neutral pH (around 7) when removed, but low pH develops if the sediments remain aerated. Oxidation of sulfur compounds in the sediments can result in soil pH in the low 3's. Over-application of elemental sulfur will also have a similar affect on soil pH.

- Although oxidation of reduced sulfur compounds can result in precipitous and rapid declines in soil pH, declining pH in most soils is typically a more gradual process. The primary cause of declining soil pH is the application of ammonium containing or forming fertilizers, such as ammonium sulfate, ammonium nitrate, ammonium phosphate, and urea. When ammonium is converted to nitrate by soil bacteria, acidity is released. Nitrogen sources differ in the amount of acidity they generate. Ammonium sulfate is two to three times more acid than the other commonly used ammonium nitrogen sources. Calcium, potassium, and sodium nitrate do not create any acidity, but actually increase soil pH.

- There are several factors that are detrimental to turf growth at low soil pH. Toxic levels of aluminum, hydrogen, and manganese may occur in the soil water. Aluminum and hydrogen damage grass roots directly, whereas manganese is toxic to the leaves and stem of the grass. At low pH, phosphorus availability is reduced and calcium and magnesium levels are typically inadequate. Deficiencies of these nutrients may occur. Microbial activity is also reduced at low soil pH resulting in thatch accumulation and slowed release of nitrogen from organic sources. Dependent on the soil type and grass species some or all of these factors may decrease turf growth.

- Grasses vary in their tolerance to acid soils. Bermudagrass, centipedegrass, and seashore paspalum are moderate to highly tolerant to acid soils. Tall fescue, zoysiagrass, and bentgrass are intermediate in tolerance and ryegrass, bluegrass, and St. Augustinegrass have low tolerance. Generally, soil pH should be maintained between 5.5 and 6.5 with values below 5.8 appropriate only for the more tolerant grasses.

Liming turf soils to correct low pH

- Maintaining soil pH at favorable levels is a simple but continual process. Soil sample annually and apply lime based on the recommendation. Dolomitic lime is generally preferred because it will provide sufficient magnesium as well as calcium. Both are usually low when soil pH is low. Calcitic lime can be used when soil test shows magnesium to be adequate, but is not necessary because detrimental effects due to extra magnesium are unlikely. Dolomitic lime is the least expensive source of magnesium if soil pH needs to be increased.

- Surface-applied lime is slow to react and the affects move downward into the soil profile slowly. To hasten the reaction and movement of the lime, incorporation into the soil by application after core aerification is recommended. When devastatingly low pH's are encountered incorporation is required in order to increase the pH of a significant volume of the root zone. The smaller the particle size of the lime the faster it will react. The faster reaction rate of a ground limestone, rather than a pelletized lime, is particularly important when very low pH's are encountered.

- ***Adapted from the article, 'Tales from the Annals of Disease', by Bruce Martin and Jim Camberato, which first appeared in the September-October 1999 issue of Carolinas Green.***

Return to Soil Acidity & Liming - Part II

Use of Lime as a Calcium Source with Peanuts

- Liming has a long history of improving peanut yields in the soils of the Coastal Plain. In 1948, it was reported that dolomitic lime top dressed at seedling emergence was as effective as gypsum applied at bloom in two of three cases. In 1982, some researchers reported two examples from sandy soils where limed plots yielded higher than gypsum-treated plots under leaching conditions. Lime can improve soil conditions for peanut growth through reducing Al, Mn, and Zn toxicity, or through increases in soil Ca and Mg levels.

- The limited solubility of lime led some to believe that it could not supply available Ca to the fruiting zone as effectively as gypsum. This was reinforced by studies showing limited responses to lime. Lime application in the seed furrow at planting or applications in the fall prior to moldboard plowing were ineffective in supplying sufficient Ca to virginia type peanuts not only because of their greater Ca requirement, but also because of spatial unavailability. Timing of applications is also important. Applications at bloom are not effective, since the lime has insufficient time to react with the soil before the critical uptake period. In many cases, results from virginia market types were erroneously extended to smaller seeded cultivars.

- Numerous studies conclusively show that lime can provide adequate Ca for maximum yield of runner-type peanuts when applied and incorporated into the pegging zone after moldboard plowing prior to planting. Where recommended to correct low pH, lime incorporated in the surface after moldboard plowing can also supply Ca (at a lower cost) and eliminate a trip across the field before bloom. Lime applied in the spring is less subject to leaching than gypsum, and the possibility of missing a needed gypsum application because of wet fields or scheduling problems is averted. Lime is not the most appropriate supplemental Ca source in all cases. Applying lime on freshly plowed soil is difficult, increases maintenance costs for spreader trucks, and can lead to undesirable compaction. High flotation equipment is better suited to this task, but very few of these expensive units are available. Many dealers have tractor-pulled spreaders available for farmer use, but timing can become a problem for growers with large acreage. They must turn the land, lime, and apply herbicides before incorporation.

Overliming can become a serious problem in some areas. If poorly drained sands of the Atlantic Coast (Aquults) are overlimed Mn deficiences are frequently observed. Greatly reduced pod yield has been found at pH 6.8 in comparison to pH 6.0 due to Mn deficiency. For this reason, excessive use of limestone as a Ca source should be avoided. In Georgia, North Carolina, South Carolina, and Virginia, growers are advised to keep pH below 6.3 in susceptible soils. When soil pH is adequate, Georgia recommends a pod zone (0-3 in.) soil sample at 10-14 days after planting. If soil test Ca is <500 lb/acre (250 ppm) gypsum application is recommened at first bloom for runner-type peanuts. Gypsum is always recommended for virginia-type peanuts and any peanuts to be used for seed.

From Hodges, S. C., G. J. Gascho, and G, Kidder (1993) Calcium and Magnesium, Chap. 6 in Southern Cooperative Series Bulletin No. 380 "Research-based Soil Testing Interpretation and Fertilizer Recommendations for Peanuts on Coastal Plain Soils". C.C. Mitchell, Editor.

Return to Soil Acidity & Liming - Part II

Lowering Soil pH

Some plants need a low pH.

Elemental Sulfur

Most plants grow best where the soil is slightly acid in the range of pH 5.8 to 7.0. A few plants, however, such as azaleas, gardenias, and blueberries grow best at lower pH levels. Others such as centipede turf, camellias, and potatoes grow well in a wide range of pH conditions, but seem to thrive best in more acid soils. Centipede turf is prone to iron chlorosis (iron deficiency) when soil pH is too high (above 6) and soil phosphorus is excessive due to over-fertilization.

Why is the pH so high?

Sometimes gardeners inadvertently over lime their soil. They may not have tested the soil but lime just because "Granddaddy always did and he had a beautiful garden." Others rationalize that "Sure I limed according to soil test, but I also used basic slag." Others say, "Wood ashes make a great mulch." There may be a few whose neighbor works for company XYZ. Company XYZ has a huge pile of free lime from the mill so "I just had a few dumptruck loads piled in the garden." Any of these situations could create a very high soil pH - so high that some plants have a difficult time surviving.

If soil pH is above 7.0 anywhere in the Southeast, one needs to find out why. Of course, some soils from the Black Belt prairie region of central Alabama are naturally calcareous and alkaline. They are formed from the soft limestone known as Selma chalk. Some soils could be as much as 50% lime and have a pH value as high as 8.3. There's not much one can do about this. Just grow plants tolerant of calcareous soils - not azaleas, camellias, gardenias, and blueberries. Soils that have an artificially high pH, however, may also have a high salt content. Some waste products such as wood ashes (not agricultural lime) applied to the soil could be high in salts (salts of sodium, potassium, etc.). High salts probably caused the initial damaging effects to the plants. With time, rainfall will leach the salts out of the rooting zone. A high pH (up to about pH 8.0) would probably create severe micronutrient deficiencies (iron, zinc, and manganese) and result in a general yellowing and poor growth. High salts will kill plants.

Use fertilizer to lower soil pH.

In most cases, the pH can be lowered simply by using fertilizers containing ammonium-N (**Table 1**). Ammonium sulfate and sulfur-coated urea are two of the best choices for acidifying soils. Most specialty fertilizers for "acid-loving" plants contain ammonium sulfate or sulfur-coated urea. These are popular sources of nitrogen for azaleas and blueberries.

$$2NH_4^+ + 3O_2 \xrightarrow{\text{bacteria}} 2NO_2^- + 2H_2O + 4H^+$$

ammonium + oxygen → nitrite + water + acid

If you are desperate, try sulfur or aluminum sulfate.

In rare cases, it may be desirable to lower the pH by adding an acidifying agent such as elemental sulfur (flowers of sulfur) or aluminum sulfate. This can be done successfully on soils that do not contain large amounts of free lime. Amounts of sulfur needed to lower the pH of a silt loam soil to a 6-inch depth are given in **Table 2**. Sandy soils would require less and clayey soils would require more. Elemental sulfur is converted to sulfuric acid by soil bacteria. Therefore, in order for sulfur to work the following must be satisfied:

- Sulfur must be mixed with the soil to provide contact.
- The soil must be moist.
- The soil must be aerated (bacteria need oxygen).
- The soil must be warm for rapid bacterial growth.
- Time is required for the reaction to go to completion.

$$2S + 3O_2 + 2H_2O \xrightarrow{\text{bacteria}} 2H_2SO_4$$

sulfur + oxygen + water → sulfuric acid

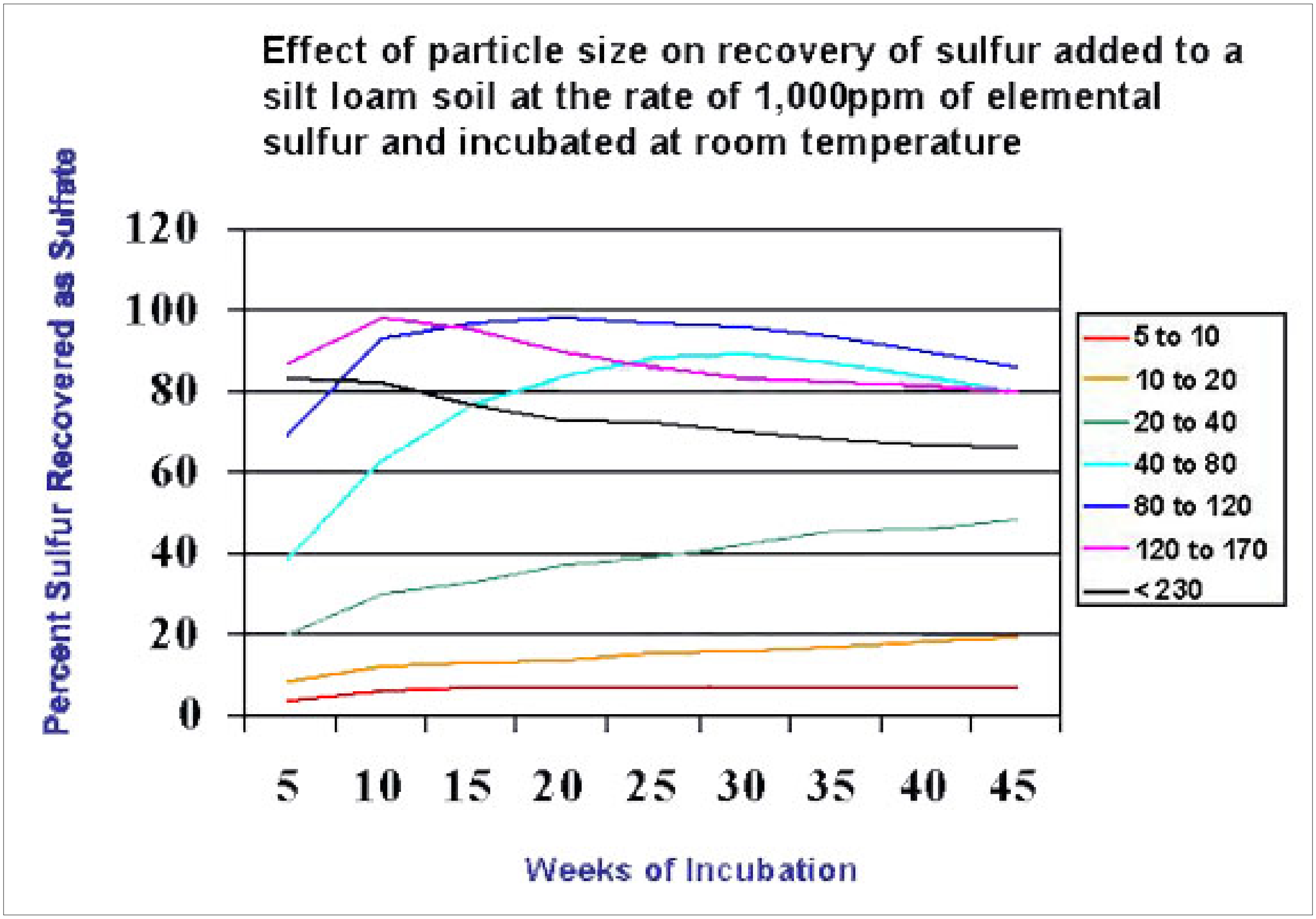


Table 1. **Acidifying effect of some common fertilizers and soil amendments.**

Material	Pure $CaCO_3$ needed to neutralize acidity in 100 pounds of material
	------ pounds ------
ammonium nitrate	60
ammonium sulfate	110
32% liquid nitrogen	55
urea	81
sulfur-coated urea	118
diammonium phosphate	70
flowers of sulfur (elemental S)	312
aluminum sulfate	45

Alumimum sulfate may be better for the home gardener to use because he/she is less likely to over-apply the material. Six times as much aluminum sulfate is needed as elemental sulfur. Aluminum sulfate should also be mixed with the soil, but the reaction is a chemical one rather than a biological reaction.

$$\underset{\text{aluminum sulfate}}{Al_2(SO_4)_3} + \underset{\text{water}}{6H_2O} \longrightarrow \underset{\text{gibbsite (solid)}}{2Al(OH)_3} + \underset{\text{sulfuric acid}}{H_2SO_4}$$

Table 2. **Pounds of elemental sulfur needed to lower soil pH of a silt loam soil to a depth of 6 inches*.**

Present pH	Desired soil pH 6.5	6.0	5.5	5.0	4.5
	- - - - - - - lb. S per 100 sq. ft. - - - - - - -				
8.0	3.0	4.0	5.5	7.0	8.0
7.5	4.0	3.5	4.5	6.0	7.0
7.0	1.0	2.0	3.5	5.0	6.0
6.5	---	1.0	2.5	4.0	4.5
6.0	---	---	1.0	2.5	3.5

***For sandy soils, reduce amount by 1/3; for clayey soils, increase amount by 1/2; if aluminum sulfate is used, multiply by 6.9.**

Sulfur is also an essential plant nutrient.

Do not confuse sulfur as a soil acidifying agent with sulfur as a plant nutrient. All soil test reports recommend 10 pounds of sulfur per acre as a plant nutrient. Most fertilizer sources of sulfur are in the sulfate form (SO_4^{-2}) which is readily available to plants, e.g., ammonium sulfate, calcium sulfate (gypsum), potassium sulfate, sul-po-mag, magnesium sulfate (epsom salts), etc. Sulfate sulfur is usually contained in mixed fertilizers. This form will not acidify soils. Elemental sulfur (a yellow powder), the form used for soil acidification, is not plant available until it is oxidized by soil bacteria to the sulfate form. This takes time - usually several weeks. Elemental sulfur is sometimes sold as "flowers of sulfur".

Summary

Before recommending that a gardener add a material to acidify the soil, make sure the pH is too high and find out why. Perhaps using an acid-forming nitrogen source such as ammonium sulfate or sulfur-coated urea will gradually correct the problem. If not, recommend aluminum sulfate as the first choice. He/she is less likely to over-apply this material. Recommend "flowers of sulfur" only for large scale growers, and caution them about over-applying sulfur. Don't confuse elemental sulfur as a soil acidifying agent with sulfur recommendations as a plant nutrient.

Prepared by: Charles C. Mitchell, Jr., Extension Agronomist-Soil Fertility & James F. Adams, Assistant Professor

Return to Soil Acidity & Liming - Part II

Lowering Soil pH with Elemental Sulfur on Turfgrass

In the Carolinas excessively high soil pH occurs in Coastal areas when high bicarbonate water is used for irrigation. With alkaline water, soil pH will increase over time and stabilize around pH 8.2, if calcium is the predominant cation in the soil. Calcium carbonate (lime) is formed in the soil at this pH. Soil pH can exceed pH 8.2 when sodium, rather than calcium, is the dominant cation. In these soils lowering pH is necessary to increase the availability of calcium and micronutrients, particularly iron and manganese. Elemental sulfur (S) is often chosen to lower soil pH, but it must be used carefully. Elemental S has a high potential to burn plant tissue and can lower soil pH too much (pH < 4.0 is possible) if used improperly or at too high an application rate.

Mode of Action

Sulfur is oxidized by soil bacteria, thereby forming sulfuric acid which is the substance that lowers soil pH. Each 10 pounds of elemental S generates enough acidity to neutralize 30 pounds of lime. Warm temperatures and good moisture and aeration are required for S oxidizing bacteria to function. Sulfur oxidation is minimal at soil temperatures less than 50ºF. Consequently S oxidation in the winter can be limited even in our mild climate. Sulfur that lies 'dormant' in the winter, however, will be oxidized when hot temperatures occur. Even at 75ºF the oxidation rate of S is about 15% of that at 85ºF, so peak rates of S oxidation don't occur until late spring. Applications are best made when temperatures are warm enough for the bacteria to oxidize the S (70 - 80ºF), but not hot enough to accentuate tissue burn.

Advantages of Incorporation Over Surface Application

Sulfuric acid produced on leaf and crown tissue can burn these tissues. Incorporation of S into the soil by application just after core aerification is a good method for reducing burn. In addition, incorporated S is preferred over surface application because acidification is accelerated and a greater volume of soil is treated.

1) Less chance for leaf and crown damage with incorporated applications. Sulfuric acid generated on leaves and in thatch can damage foliage and destroy crowns. Contact with the soil buffers the decrease in soil pH around the S particle so this damage is limited.

2) Faster reaction of incorporated S in comparison to surface applied S occurs because of higher soil moisture levels. Sulfur oxidation requires good moisture which is more prevalent in the soil than in the thatch or on the leaf surface. Plenty of irrigation water should be applied to wash the S from the turfgrass leaves after any method of application.

3) Incorporated applications acidify a larger portion of the root zone than surface applications. Elemental S is immobile in the soil so surface applications remain on the soil surface. Even after the S is oxidized the acidity produced is slow to move into the root zone. Consequently severe decreases in pH may occur in the thatch layer and immediate soil surface with little impact on the remainder of the root zone.

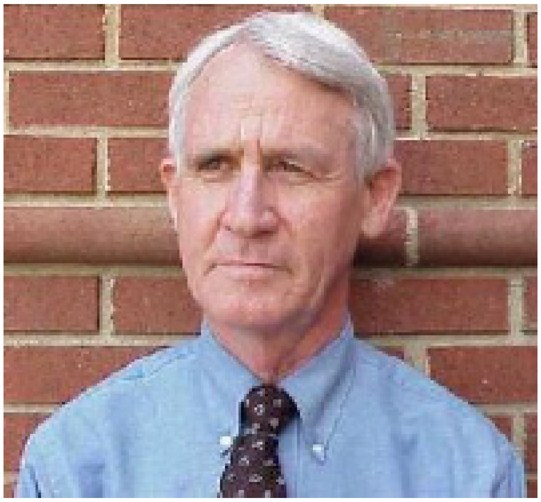
Sulfur Application Rates

- Sulfur application may be warranted on soils with pH in the high 7's or greater. Using S on soils of lower pH is usually not necessary and can be dangerous due to over-acidification. Calcium should be added to soils dominated by sodium at the same time soil pH is lowered with S.

- Sulfur rates should be low to avoid damage to the crowns of the turfgrass plant. Each application to bermudagrass at fairway or rough height should be less than 5 pounds per 1000 square feet, with lower rates being safer. Applications to greens should not exceed 0.5 pounds per 1000 square feet per application. It is wise to check the soil pH before re-application of S to avoid over-acidification, especially on sand-based greens that have little capacity to buffer changes in soil pH. Before taking a soil sample and considering re-application of S, ensure that temperatures and time were sufficient for the S to have been oxidized, > 75°F and 4 to 6 weeks. Commercial S sources range in purity from 50 to 99%, so remember to adjust the application rate based on the S content of the material.

Contributed by: Dr. Jim Camberato, Clemson University

Return to Soil Acidity & Liming - Part II



- Dr. Bob Lippert's F.A.Q. Regarding Soil Testing, Plant Analysis and Fertilizers
- Soil Acidity and Liming - Part I - Extension Internet Inservice Training
- Soil Acidity and Liming - Part II - Extension Internet Inservice Training
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