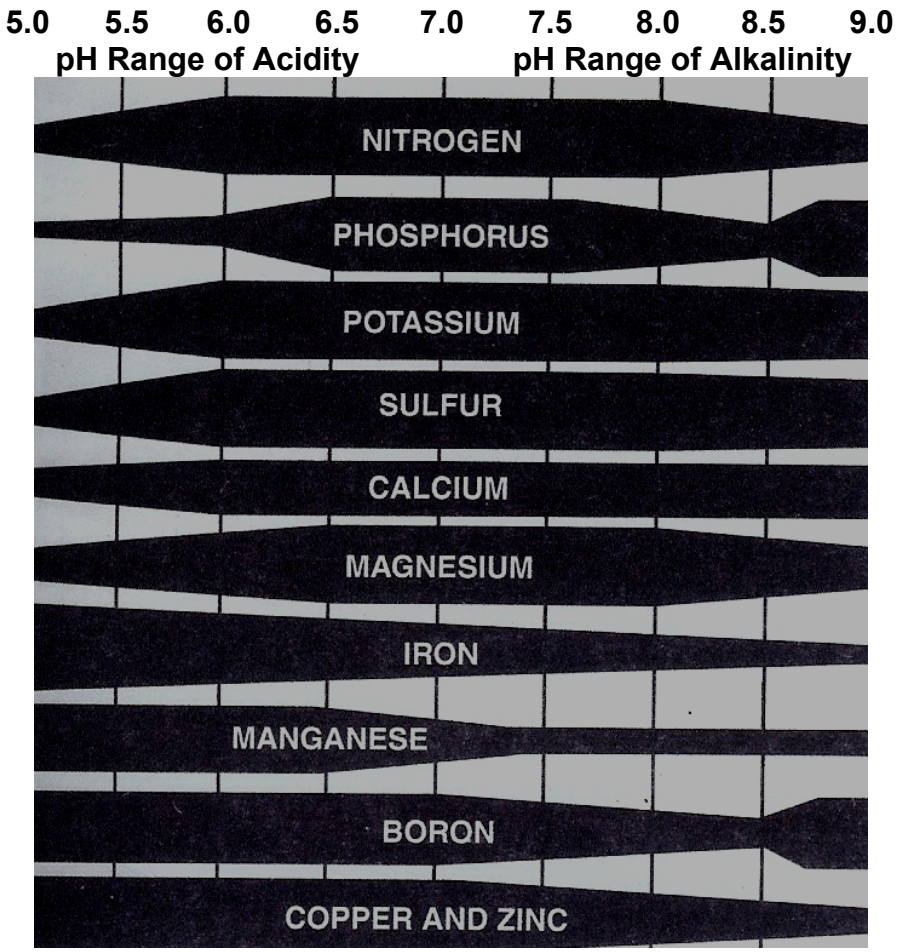
V. SOIL pH MANAGEMENT

1. Introduction

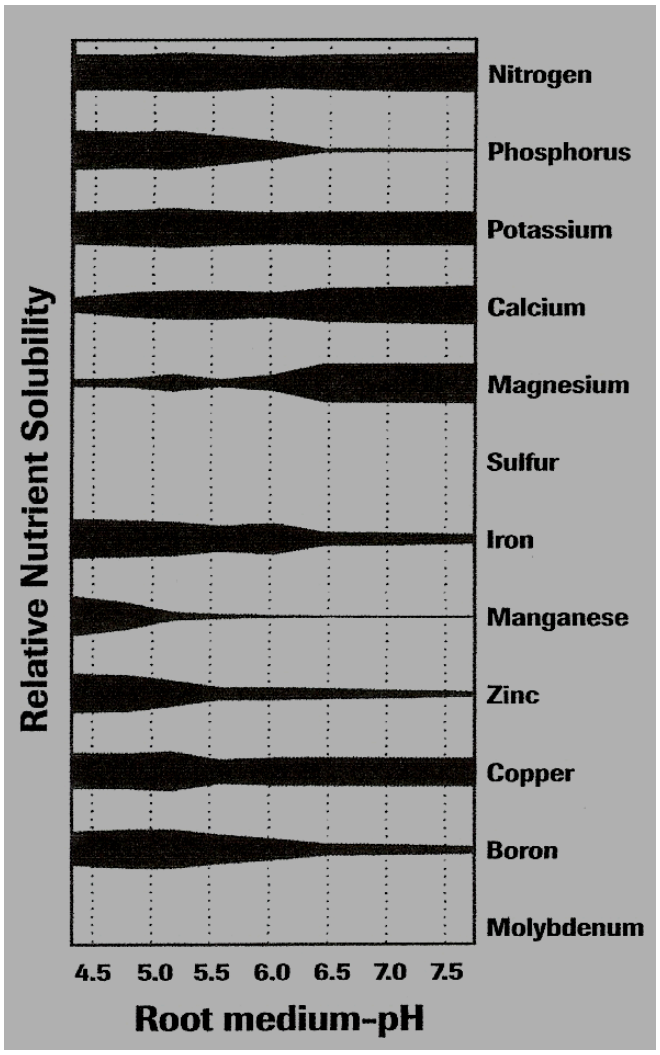
Probably the least understand aspect of soil fertility management is that associated with maintaining the soil pH within the appropriate range. In general, the soil pH for mineral soils considered best for optimum crop production for most crops is between 5.8 and 6.5. For organic and high (>5%) organic content soils, the optimum soil pH is between 5.0 and 5.5. However, there are some crops that grow best on slightly acid soils (pH 5.5-6.0), and a few grow best in near neutral to slightly alkaline soil conditions.

Soil pH affects the availability of the major and micronutrient elements as well as other non-essential elements that can adversely affect plants. Their availabilities (or solubilities in the soil) are shown in the following figures for mineral and organic soils:

Nutrient Availabilities in Mineral Soils



Nutrient Availabilities in Organic Soils



Therefore, the main objective for water pH adjustment is to reduce the availability (solubility) of those elements than can adversely affect the nutrition and growth of the plant, while optimizing the availability (solubility) of those elements that are essential to the plant.

2. The "Target pH"

Crop species vary in their response to soil pH, and therefore different "Target pHs" have been established for crops grown on South Carolina mineral soils as shown in the following table.

Crop	**Target pH**
Alfalfa and tomatoes	6.5

Clovers, vegetables, fruit, and nuts	6.5
Christmas trees, pines, Irish potatoes, sweet potatoes, and centipede and carpet grass	6.0
Azaleas, rhododendron, and camellias	6.0
All home owner crops except centipede, carpet grass, azaleas, rhododendron, camellias, and blueberries	6.2
Tobacco	6.0
Blueberries, palms and pine trees	No Lime
All crops except those listed above	6.0 or 6.5

Note that the "Target pH" given above is for mineral soils, while the desired pH range for Carolina Bays or soils with more than 10% organic matter (Soil Code 6) is 5.5.

It is important to understand that the desired "Target pH" is determined by both crop species and soil characteristics. When to make a soil pH adjustment is discussed in the next section.

3. Soil pH

When the soil pH is found to be less than that required for the crop to be grown or currently growing, an adjustment is recommended to bring the soil pH to the "Target pH."

VI. Acid Soil pH Adjustment by Liming

The reasons for liming an acid soil are to:

- raise the soil pH to the "Target" level optimum for the crop
- reduce the availability (solubility) of toxic elements
- optimize the availability (solubility) of elements essential to the plant
- supply elements (mainly Ca and Mg) that are components in the liming material

When to increase the soil pH by crop is as follows:

Crop	**Lime if pH is less than**
Alfalfa and tomatoes	6.0
Clovers, vegetables, fruit, and nuts	6.0
Christmas trees, pines, Irish potatoes, sweet potatoes, and centipede and carpet grass	5.5
Azaleas, rhododendron, and camellias	5.5
All home owner crops except centipede, carpetgrass, azaleas, rhododendron, camellias, and blueberries	6.0
Tobacco	5.8
Blueberries, palms and pine trees	No Lime
All crops except those listed above	6.0

Note: the minimum lime recommended for alfalfa is 1 ton per acre and all other agronomic crops is 0.5 ton per acre.

The impact for liming a soil in order to raise its soil pH is determined by:

- quantity and quality of the liming material applied, whether agricultural limestone or waste product liming materials
- method of incorporation
- time of application.

The quantity of soil-applied agricultural limestone required is calculated by-laboratory determined soil and buffer pHs. The quality of the agricultural limestone is measured by both its physical characteristics and elemental content. The percent range in particle size fractions in the applied agricultural limestone will influence its reactivity when applied to a soil. The higher the percentage of finer particles, the faster its reactivity. The higher the percentage of courser particles, the longer the lime effect will exist. Structure, whether crystalline or amorphous, will also influence solubility, amorphous limestone being more soluble than crystalline forms. The composition of an agricultural limestone as to the ratio of calcium to magnesium carbonate and the content of impurities will influence reactivity. In general, the solubility of agricultural limestone increases with an increase in concentration in both magnesium carbonate and impurities. In addition, there are other less commonly used liming materials, such as hydrated lime which is calcium hydroxide, burned or quick lime which is calcium oxide, and slag, a by-product from the production of iron, steel, or other similar substances.

Selecting a lower "Target pH", smaller amounts of lime will be needed to neutralize soil acidity. Sometimes it is preferable to lime less frequently by using a large amount of courser lime.

When a permanent pasture, hayfield, or an orchard is being established, this is an opportune time to incorporate lime into the soil profile. After establishment, the lime required to maintain the appropriate pH is then surface applied. Since most liming materials are of low solubility, soil acidity below the surface cannot be easily or effectively neutralized. Also, economic factors may influence the scheduling of lime applications. The potential for exceeding the "Target pH" on coarse-textured Coastal Plain soils is also another consideration. Thus, there are soil, crop and economic considerations that affect the selection of the "Target pH."

It is generally held that periodic applications, once every 2 or 3 years of agricultural limestone, may be sufficient to sustain most soils within the optimum soil pH range. Under intense crop management, it may be necessary to lime a cropland soil yearly to counter acidification from both natural causes and the application of acid-forming fertilizer. Sandy soils with low CECs (<5.0 meq/100g) will require more frequent liming than clay and/or high organic matter content soils that have higher CECs.

1. Liming Rate Determination

The amounts of lime needed to raise the soil pH to 5.5, 6.0, 6.2, or 6.5 for a range of soil pH and buffer pH values are given on the following tables, respectively. The amounts of lime indicated are based on a soil mixing depth of 8 inches. For ornamentals and turf grass where no tilling will be performed, apply half of the recommended lime requirement, and in 6 months, the remaining half.

Lime recommendations are given to the nearest 100 pounds per acre of agricultural limestone in order to avoid the potential for over-liming poorly buffered soils in the Coastal

Plain. Exceeding the actual lime requirement by several hundred pounds may raise the pH of such soils to that greater than 7.5, inducing the potential for zinc, manganese, and iron micronutrient deficiencies.

Since it may be impractical to apply less than 0.5 ton per acre of a liming material, it may be acceptable, in some cases, to round up to the nearest 0.5 ton. In other cases it may be preferable to wait until the lime recommendation is close to 0.5 ton per acre. Cost of application, the difference between soil pH and the "Target pH," and the potential to induce a micronutrient deficiency in the crop to be grown, are factors to be considered. If a variable rate application method is used, application of small amounts of lime can be practical.

The quantity of limestone required to raise the soil pH of the surface 8 inches to 5.5 based on the Adams-Evans method.

Buffer pH	Soil pH										
	5.4	5.3	5.2	5.1	5.0	4.9	4.8	4.7	4.6	4.5	4.4
	pounds/acre agricultural limestone										
7.95	0	100	100	200	200	200	300	300	300	400	400
7.90	100	200	300	300	400	500	600	600	700	800	900
7.85	100	300	400	500	600	700	800	900	1000	1200	1300
7.80	200	400	500	700	800	1000	1100	1200	1400	1500	1800
7.75	200	400	700	800	1000	1200	1400	1500	1700	1900	2200
7.70	300	500	800	1000	1200	1400	1700	1900	2100	2300	2700
7.65	300	600	900	1200	1400	1700	1900	2200	2400	2700	3100
7.60	400	700	1000	1400	1600	1900	2200	2500	2800	3100	3600
7.55	400	800	1200	1500	1800	2200	2500	2800	3100	3500	4000
7.50	500	900	1300	1700	2100	2400	2800	3100	3400	3800	4500
7.45	500	1000	1400	1900	2300	2600	3000	3400	3800	4200	4900
7.40	600	1100	1600	2000	2500	2900	3300	3700	4100	4600	5400
7.35	600	1200	1700	2200	2700	3100	3600	4000	4500	5000	5800
7.30	600	1300	1800	2400	2900	3400	3900	4300	4800	5400	6300
7.25	700	1300	2000	2500	3100	3600	4100	4600	5200	5800	6700
7.20	700	1400	2100	2700	3300	3900	4400	5000	5500	6100	7100
7.15	800	1500	2200	2900	3500	4100	4700	5300	5900	6500	7600
7.10	800	1600	2300	3000	3700	4300	5000	5600	6200	6900	8000
7.05	900	1700	2500	3200	3900	4600	5200	5900	6600	7300	8500
7.00	900	1800	2600	3400	4100	4800	5500	6200	6900	7700	8900

The quantity of limestone required to raise the soil pH of the surface 8 inches to 6.0 based on the Adams-Evans method.

Buffer pH	Soil pH								
	5.9	5.7	5.5	5.3	5.1	4.9	4.7	4.5	4.4

pounds/acre agricultural limestone

7.95	100	100	200	300	300	400	400	500	500
7.90	100	300	400	600	700	800	900	1000	1100
7.85	200	400	700	900	1000	1200	1300	1500	1600
7.80	200	600	900	1100	1400	1600	1800	2000	2200
7.75	300	700	1100	1400	1700	2000	2200	2500	2700
7.70	300	900	1300	1700	2000	2400	2700	3000	3300
7.65	400	1000	1500	2000	2400	2800	3100	3500	3800
7.60	400	1100	1700	2300	2700	3100	3500	4000	4300
7.55	500	1300	2000	2600	3100	3500	4000	4500	4900
7.50	500	1400	2200	2800	3400	3900	4400	5000	5400
7.45	600	1600	2400	3100	3800	4300	4900	5500	6000
7.40	600	1700	2600	3400	4100	4700	5300	6000	6500
7.35	700	1900	2800	3700	4400	5100	5800	6500	7100
7.30	700	2000	3100	4000	4800	5500	6200	7000	7600
7.25	800	2100	3300	4300	5100	5900	6700	7500	8100
7.20	800	2300	3500	4500	5500	6300	7100	8000	8700
7.15	900	2400	3700	4800	5800	6700	7500	8500	9200
7.10	900	2600	3900	5100	6100	7100	8000	9000	9800
7.05	1000	2700	4100	5400	6500	7500	8400	9400	10000
7.00	1000	2800	4400	5700	6800	7900	8900	9900	10000

The quantity of limestone required to raise the soil pH of the surface 8 inches to 6.2 based on the Adams-Evans method.

Buffer pH	Soil pH									
	6.1	5.9	5.7	5.5	5.3	5.1	4.9	4.7	4.5	4.4
	pounds/acre agricultural limestone									
7.95	100	200	200	300	400	400	400	500	500	600
7.90	100	300	500	600	700	800	900	1000	1100	1200
7.85	200	500	700	900	1100	1200	1300	1500	1600	1700
7.80	200	600	900	1200	1400	1600	1800	2000	2100	2300
7.75	300	800	1100	1500	1800	2000	2200	2400	2700	2900
7.70	300	900	1400	1800	2100	2400	2700	2900	3200	3500
7.65	400	1100	1600	2100	2500	2800	3100	3400	3800	4000
7.60	400	1200	1800	2400	2800	3200	3600	3900	4300	4600
7.55	500	1400	2100	2700	3200	3600	4000	4400	4800	5200
7.50	600	1500	2300	2900	3500	4000	4500	4900	5400	5800
7.45	600	1700	2500	3200	3900	4400	4900	5400	5900	6300
7.40	700	1800	2800	3500	4200	4800	5400	5900	6400	6900
7.35	700	2000	3000	3800	4600	5200	5800	6400	7000	7500
7.30	800	2100	3200	4100	4900	5600	6200	6900	7500	8100
7.25	800	2300	3400	4400	5300	6000	6700	7300	8000	8600
7.20	900	2400	3700	4700	5600	6400	7100	7800	8600	9200
7.15	1000	2600	3900	5000	6000	6800	7600	8300	9100	9800
7.10	1000	2700	4100	5300	6300	7200	8000	8800	9700	10000
7.05	1100	2900	4400	5600	6700	7600	8500	9300	10000	10000
7.00	1100	3000	4600	5900	7000	8000	9000	9800	10000	10000

The quantity of limestone required to raise the soil pH of the surface 8 inches to 6.5 based on the Adams-Evans method.

Buffer pH	Soil pH 6.4	6.2	6.0	5.8	5.6	5.4	5.2	5.0	4.8	4.6	4.4
	pounds/acre agricultural limestone										
7.95	100	200	300	300	400	400	500	500	500	600	600
7.90	100	300	500	600	800	900	900	1000	1100	1100	1300
7.85	200	500	800	1000	1100	1300	1400	1500	1600	1700	1900
7.80	300	700	1000	1300	1500	1700	1900	2000	2200	2300	2500
7.75	300	900	1300	1600	1900	2100	2300	2500	2700	2900	3100
7.70	400	1000	1500	1900	2300	2600	2800	3000	3200	3400	3800
7.65	500	1200	1800	2300	2700	3000	3300	3500	3800	4000	4400
7.60	500	1400	2000	2600	3000	3400	3700	4000	4300	4600	5000
7.55	600	1500	2300	2900	3400	3800	4200	4600	4900	5200	5600
7.50	700	1700	2600	3200	3800	4300	4700	5100	5400	5700	6300
7.45	700	1900	2800	3600	4200	4700	5200	5600	5900	6300	6900
7.40	800	2100	3100	3900	4600	5100	5600	6100	6500	6900	7500
7.35	900	2200	3300	4200	4900	5600	6100	6600	7000	7500	8100
7.30	900	2400	3600	4500	5300	6000	6600	7100	7600	8000	8800
7.25	1000	2600	3800	4800	5700	6400	7000	7600	8100	8600	9400
7.20	1000	2800	4100	5200	6100	6800	7500	8100	8600	9200	10000
7.15	1100	2900	4300	5500	6400	7300	8000	8600	9200	9800	10000
7.10	1200	3100	4600	5800	6800	7700	8400	9100	9700	10000	10000
7.05	1200	3300	4900	6100	7200	8100	8900	9600	10000	10000	10000
7.00	1300	3400	5100	6500	7600	8500	9400	10000	10000	10000	10000

a. Mixing Depth: as stated above, liming recommendations are given for a mixing depth of 8 inches. If that mixing depth is either less or greater than 8 inches, following the given lime requirement would result in either "over liming" or "under liming" the soil, respectively. If the mixing depth is not 8 inches, an adjustment in the lime requirement recommendation must be made as follows.

Lime Requirement for Varying Plow Depths, lbs/A

Depth of Plowing, inches						
2	**4**	**6.66**	**8**	**10**	**12**	**14**
250	500	800	1000	1300	1500	1800
500	1000	1600	2000	2600	3000	3600
750	1500	2400	3000	3900	4500	5400
1000	2000	3200	4000	5200	6000	7200
1250	2500	4000	5000	6500	7500	9000
1500	3000	4800	6000	7800	9000	10800
1750	3500	5600	7000	9100	10500	12600
2000	4000	6400	8000	10400	12000	14400
2250	4500	7200	9000	11700	13500	16200
2500	5000	8000	10000	13000	15000	18000

b. Rate of Reaction: applied lime will react with the soil at a rate determined by the fineness of the applied liming material, its chemical composition, and the physical and chemical properties of the soil. Liming a very acid soil may initially cause what has been termed "lime shock" as the chemical properties of the soil adjust to the changing pH. In order to allow sufficient time for applied lime to react, its application should be made 4 to 6 months prior to planting a crop. There is also danger that a portion of nitrogen applied as either fertilizer or other nitrogen source may be lost due to volatilization if applied shortly after lime has been applied.

2. Liming Materials

A variety of agricultural liming materials, including both calcitic and dolomitic limestone, are readily available in South Carolina. Agricultural liming materials are defined by South Carolina law (Title 46 – Agriculture, Chapter 26, Agricultural Liming Materials, SECTION 46-26-10 Definitions) as follows:

1) "Agricultural liming materials" mean a product whose calcium and magnesium content are capable of neutralizing soil acidity.

2) "Limestone" means a material consisting essentially of calcium carbonate or of calcium carbonate with magnesium carbonate capable of neutralizing soil acidity.

3) "Dolomitic limestone" means those materials of which sixteen percent or more of the neutralizing value expressed as calcium carbonate is derived from magnesium carbonate.

The two most commonly used liming materials in South Carolina are calcitic and dolomitic limestone. Other less commonly used liming materials are burned or hydrated lime as well as slags, considered safe for the crop to be grown. These liming materials including their "Neutralizing Value" are:

Materal	**Name**	**Neutralizing Value**
CaO	Calcium oxide or burned quick live	179
$Ca(OH)_2$	Calcium hydroxide, slake lime, Hydrated lime or builders lime	135
$CaMg(CO_3)$	Dolomitic lime	68 – 109
$CaCO_3$	Calcitic lime	86 – 100
CaO + impurities*	Basic slag (depending on source)	25 – 70

*may contain magnesium, manganese, iron, and phosphorus

Another common means of comparing liming materials is by their Calcium Carbonate Equivalents (CCEs*):

Liming Materials	**% CCE**
Calcium carbonate, pure	100
Calcitic limestone	85 – 100

Dolomitic limestone	95 – 108
Marl (Selma Chalk)	50 – 90
Calcium hydroxide (slaked lime)	120 – 135
Calcium oxide (burnt or quick lime)	150 – 175
Calcium silicate	86
Basic slag	50 – 70
Ground oyster shells	90 – 100
Cement Kiln dusts	40 – 100
Wood ashes	40 – 50
Power plant ashes	25 - 50

*The Calcium Carbonate Equivalent (CCE) is a means of comparing liming materials based on their equivalence to pure calcium carbonate which has a CCE of 100 as shown above.

The magnesium carbonate content in dolomitic limestones is normally expressed as a percent of the calcium carbonate equivalent. For example, a dolomitic limestone that contains 11% magnesium has ~22% of its calcium carbonate equivalent derived from magnesium carbonate.

3. Minimum Screening and Calcium Carbonate Equivalent Standards for South Carolina
All agricultural liming materials marketed in South Carolina as agricultural lime are classified and labeled in terms of their fineness and calcium carbonate equivalent with no less than the following minimum fineness and minimum calcium carbonate equivalent standards.

A. Standards for Classification in Terms of Fineness

		Minimum Guaranteed to Pass (%)
Pulverized Mesh Screen	20	95
	100	73
	10	90
Standard Ground Mesh Screen	50	50
	100	25
	10	90
Coarse Ground Mesh Screen	50	40
	100	25

B. Standards for Classification in terms of Calcium Carbonate Equivalent of Agricultural Liming Materials

Material	**Calcium Carbonate Equivalent**
Burnt lime	not less than 140%
Hydrate lime	not less than 110%
Shells	not less than 85%
Limestone	not less than 85%

Limestone (75% neutralizing value)	not less than 75%
Industrial slag	**not less than 50%**

4. Adding Essential Plant Nutrient Elements
Depending on the type of liming material applied, most liming materials will add calcium and/or both calcium and magnesium to the soil, two essential plant nutrient elements. Some liming materials, particularly waste products and slags, may also contain one or more of other essential plant nutrient elements, such as iron, manganese, zinc, and copper.

5. Over Liming
Liming a soil when not needed can be as detrimental as not liming when required. Liming a soil when not needed, or applying more lime than needed (over liming), can raise the soil pH to that level which will induce deficiencies particularly for the micronutrients manganese and zinc. Crops, such as soybean and corn grown on coarse-textured soils in the Coastal Plains, are especially prone to deficiencies of these two micronutrients when the soil pH is greater than 6.5.

VII. Lowering the Soil pH

Soil acidification (lowering soil pH) occurs by:

- natural processes
- use of acid-forming fertilizers
- cropping (nutrient element removal)
- application of acidifying agents (i.e., elemental sulfur or aluminum sulfate)

Occasionally, it will be desirable to lower the soil pH for so-called "acid-loving plants," such as centipede lawn grass or in preparing plant beds for blueberries, azaleas, camellias, rhododendron, Two or more soil samples should be taken from the area for a firm determination of the soil pH.

The amount of aluminum sulfate ($AlSO_4 \cdot H_2O$) or elemental sulfur required to lower the pH to different levels is given as:

Amount of Aluminum Sulfate Required to Lower Soil pH of a Loamy Soil
(For sandy soils reduce the amount indicated by one-third and for clayey soils increase it by one-half. Multiply the values for aluminum sulfate by 0.15 to convert to elemental S.)

	Desired Soil pH				
Present Soil pH	**6.5**	**6.0**	**5.5**	**5.0**	**4.5**
	pounds of aluminum sulfate per 10 square feet				
8.0	1.8	2.4	3.3	4.2	4.8
7.5	1.2	2.1	2.7	3.6	4.2
7.0	0.6	1.2	2.1	3.0	3.6
6.5		0.6	1.5	2.4	2.7

6.0	0.6	1.5	2.1

Granular, superfine dust, or wettable sulfur may be used to decrease pH. Granular sulfur is best for home lawn situations due to the ease of application with cyclone fertilizer spreaders and the reduced possibility of foliar burn from the granules. Thoroughly water-in sulfur after application, taking care to wash off all above-ground plant parts. Do not apply more than 5 to 10 pounds sulfur per 1,000 square feet per application. Repeat applications of sulfur should not be made more often than once every 2 to 3 months and only when temperatures are cool (<75°F) and should be watered-in immediately after application (Southern Lawns, Bert McCarty, Editor, Clemson University, EC 707, 2003).