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Nutrient Management for South Carolina

Based on Soil Test Results

Agronomic and Horticultural Crops, Home Gardens, Turf Grasses, Plant Nutrients, Soil Testing and Analysis, Nutrient Waste Management, and South Carolina Land Resource Information

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INTRODUCTION

The Clemson University Agricultural Service Laboratory is a part of the educational program of the Clemson University Cooperative Extension Service. The service is available to all citizens of South Carolina. The soil testing service will be helpful to producers of agronomic and horticultural crops and those interested in landscaping or home beautification, gardening, tree farming, and managing golf courses. Soil tests and nutrient recommendations are based on many years of research that have confirmed the reliability of soil test methods and verified nutrient recommendations. Soil testing and following the accompanying nutrient recommendations provides an environmentally sound basis for managing plant nutrients in soil.

Some of the soils in South Carolina will require lime, some will not require lime, and others have been over-limed. Most soils will need one or more of the fertilizer nutrients required for optimum crop growth. Some of the soils will require high rates of certain fertilizers, others will require medium rates, and a few will require a low rate or no fertilizer. The soil testing service will provide information on how much lime and what nutrients should be applied to improve the nutrient status of soils that have been depleted of their nutrient supplies (see page 10).

The three major steps in providing a good soil testing service are: (1) obtaining a representative sample of the area; (2) a reliable soil test; and (3) proper interpretation of the results. The most vulnerable step is that of obtaining a representative sample.

Soil Groups/Soil Codes

There are more than 200 soil series in South Carolina. For purposes of soil-testing and nutrient management, these soils are divided into four groups (Groups 1-4). A general guide to these common soil series according to the four groups is given in Table 1 on page 3. In addition to these four, two additional groups are defined: Group 5 for subsoil samples and Group 6 for Carolina Bays and organic soils. These six soil groups are also referred to as *soil codes* on the back of the "Soil Analysis Record Sheet."

Group 1/Code 1: Coarse-textured soils where the depth to the clay layer is greater than 40 inches. These soils are sands or loamy sands throughout with no obvious change in soil texture to a depth greater than 40 inches. Zinc deficiency on corn may be observed on these soils the year after liming or when the soil is limed to a pH of 6.5 or higher.

Group 2/Code 2: Coarse-textured soils where the depth to the clay layer is 20 to 40 inches. The surface materials are sands or loamy sands to a depth of 20 inches and not more than 40 inches. Underlying materials are sandy loams, sandy clay loams and clay loams. Zinc deficiency on corn may be a problem the year after liming or when the soil is limed to a pH above 6.5. Manganese deficiency on soybeans is likely to occur on the poorly drained soils in this group if limed to a pH greater than 6.2.

Group 3/Code 3: The depth to the clay layer is less than 20 inches. Surface soil materials are mostly loamy sands, sandy loams and fine sandy loams to a depth of less than 20 inches. Subsoil materials are sandy clay loams, clay loams, silt loams and silty clay loams. Zinc deficiency on these soils should not be a problem if the soils are not limed to a pH higher than 6.5. Manganese deficiency on soybeans could be a problem if the poorly drained soils in this group are limed to a pH greater than 6.2. A subsoil test for potassium, magnesium and sulfur would be helpful when making a fertilizer recommendation for these soils.

Group 4/Code 4: Surface soils are mostly sandy loams, fine sandy loams, silt loams and clay loams. Subsoils are clay, sandy clays, silty clays and heavy clay loams. Soils should be limed according to recommendations for the crop to be grown. Good plant growth can be obtained with proper soil pH; adequate nitrogen, phosphorus and potassium; and a favorable environment.

Group 5/Code 5: This soil code is reserved for any subsoil sample.

Group 6/Code 6: Soils from Carolina Bays and soils with greater than 10 percent soil organic matter. Use a Target pH of 5.5 for these soils. By keeping the pH of these soils between 5.0 and 5.5, good plant growth can be obtained and correcting copper deficiency, if it occurs, will be considerably easier than if the pH is greater than 5.5.

Land Areas

Geographically, the five major soil groups (Groups 1-4 and Group 6) are associated with five land resource areas as described below and shown in Figure 1 on page 4.

Land Area 1. The Blue Ridge mountain soils, designated as area "130" in Figure 1, occupy 2 percent of the state and are predominantly those soils listed in Soil Group 3. There are a few soils from Soil Group 4 in this area, but all can be successfully managed as Group 3 soils.

Land Area 2. The Piedmont soils, designated as area "136," occupy 35 percent of the state and are mostly Group 4 soils with small areas of Group 3 soils. No problems should occur if all the soils in this region are managed as Group 4 soils.

Land Area 3. The Carolina Sandhill soils, areas designated "137," occupy 11 percent of the state and are Group 1 and Group 2 soils. If the recommended liming program is used, the only micronutrients that will be required are those recommended for specific crops. If the soil pH is too high, zinc deficiency could be a problem. Manganese deficiency should not be a problem in this area unless the soil pH is above 7.0.

Land Area 4. The Upper Coastal Plains soils, areas designated "133A", make up 14 percent of the state and are mostly Group 3 soils with some of Groups 1 and 2 throughout the region. With proper liming to maintain the desired soil pH, zinc and manganese deficiency should not be a problem. Some zinc deficiency may occur on corn in cool seasons if the soil pH gets above the 6.5 level. There will also be a few regions in the area that are poorly drained and manganese deficiency may occur on soybeans if the pH is above 6.2.

Land Area 5. The Lower Coastal Plains, including the Atlantic Coast Flatwoods and the Tidewater soils, designated areas "153A" and "153B," occupy 38 percent of the state and are mostly Groups 1, 2 and 3 soils with some Group 4 and Group 6 soils. Managing the soil to prevent the occurrence of manganese deficiency in this area is the major soil fertility problem. The best approach is to manage the soil pH, use soil tests to identify the suspected fields, and be prepared to take corrective steps if the problem occurs. The problem most often occurs on the poorly drained soils in Groups 2 and 3.

Table 1. General Guide to Soil Series of S.C. for Nutrient Management.

Drainage and Profile Characteristics	Group 1		Group 2	Group 3	Group 4
	Sandy, Loamy Sands, or Sandy Loams Throughout	Subsoil texture 18-35% clay			Subsoil more than 35% clay
	More than 80 in. to subsoil	40-80 in. to subsoil	20-40 in. to subsoil	0-20 in. to subsoil	Usually less than 10 in. to subsoil
Excessively drained Sandy throughout Water table is more than 72 inches deep	Alpin Eustis Kershaw Lakeland Wando		Ailey (X) Blaney (X) Fuquay (P) Lucy (R) Wagram		
Well-drained Top 30 inches has no gray mottles Subsoil is bright colored	Alaga Foxworth Kenansville Louisburg (D) (Y) Toccoa (I) Wateree (D) (Y)	Blanton Eddings Troup	Bonneau Chisolm	Alamance (Z) Brevard (R) Congaree (I) Dothan (P) Durham Edneytown (D) Emporia Evard (D) Grover (D) Lockhart Noboco Norfolk Orangeburg Rion (D) Suffolk Vaucluse (X)	Appling Cataula (X) (R) Cecil (R) Davidson (R) Enon (D) (pH) Faceville (R) Georgeville (R) (Z) Hayesville (R) Herndon (Z) Hiwassee (R) Madison (D)(R) Marlboro Mecklenburg (D) (pH) Nason (D) Z) Pacolet (D) (R) Tatum (D) (R) (Z) Vance (D) Varina (P) Wilkes (D) (pH) (Y) Winnsboro (D) (pH)
Moderately well-drained Upper subsoil free of gray mottles	Centenary (S) Chipley Echaw (S) Seabrook		Bonneau Chisolm Uchee	Clarendon (P) Eunola Goldsboro Kirksey (D)(Z) Pelion Yauhannah	Craven Duplin Eulonia Helena Hornsville Iredell (D)(pH) Nemours Persanti
Somewhat poorly drained Gray mottles in top of subsoil	Cartecay (I) Kiawah (pH) Seewee (S) Witherbee (S)	Albany Murad	Coosaw (D) Ocilla	Chewacla (I) Lynchburg Yemassee	Dunbar Lenoir Okeetee (pH) Smithboro Tawcaw (I) Wahee
Poorly dained All of subsoil more than 60% gray with less than 7 inches of black surface	Leon (S) Osier	Plummer	Elloree (pH) Pelham Williman	Myatt Ogeechee Rains (O) Wadmalaw (pH) Wehadkee (I) Yonges (pH)	Argent (pH) Bethera (O) Bladen (O) Cantey (O) Chastain (I) Coxville (O) Grady (O) Leaf (O) Meggett (pH) McColl (O) (D) Rembert (D) (O) Worsham
Very poorly drained More than 7 inches of black surface over gray subsoil	Johnston Lynn Haven (S) Pickney Pocomoke (O) Rutledge (O)			Deloss Hobcaw Pantego (O) Paxville (O) Portsmouth (D)	Bayboro Brookman (pH) Byars (O) Cape Fear Santee (pH)

D – Clay content decreases with depth in the B horizon
I – Floodplain soils with indistinct horizons
O – May occur in Carolina bays
P – Plinthite in B horizons
pH – pH increases with depth indicating high base saturation

R – Red color in B horizon (subsoil)
S – Has a brittle stained subsoil layer
X – Firm, dense subsoil
Y – Hard bedrock at 40-80"
Z – High in silt

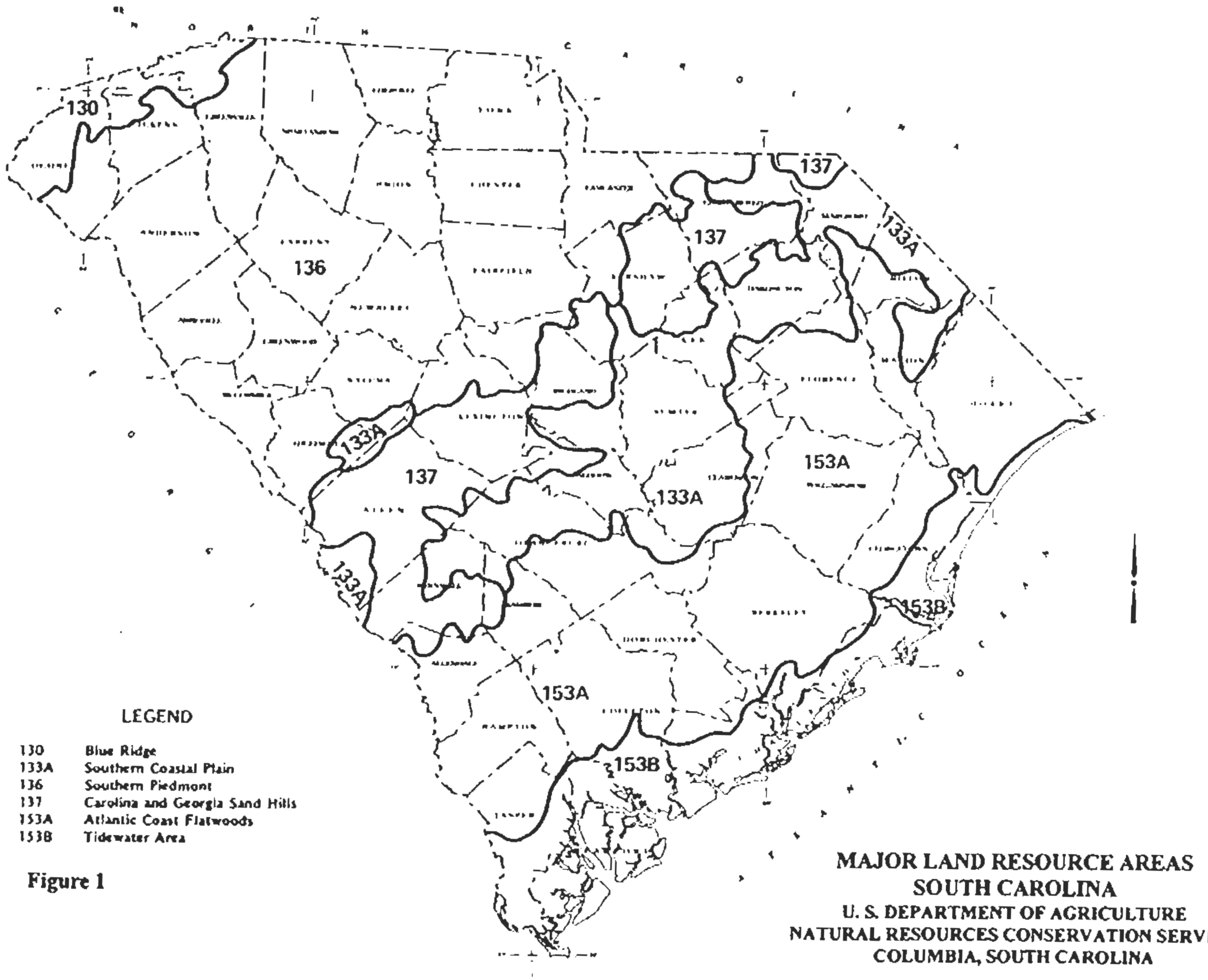
130
136
137
137
137
133A
133A
133A
133A
153A
153A
153B
153B
LEGEND
130 Blue Ridge
133A Southern Coastal Plain
136 Southern Piedmont
137 Carolina and Georgia Sand Hills
153A Atlantic Coast Flatwoods
153B Tidewater Area
MAJOR LAND RESOURCE AREAS
SOUTH CAROLINA
U. S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVI
COLUMBIA, SOUTH CAROLINA

Figure 1

Soil Sampling for Nutrient Management

Recommendations based on soil tests can be no better than the soil sample on which they are based. When taking soil samples, be sure that each sample is representative of the area to be managed. For example, if more than one soil type exists within a field and it is practical to manage the nutrient supplies separately, then separate composite samples should be collected for each soil type. Also, be careful not to contaminate samples with soil from other areas or with fertilizer. Soil should be collected from 10 to 20 spots in the field or area to be sampled using a soil probe or spade and mixed well before taking a composite sample for testing. A sample should represent no more than 20 acres but around the home and garden a sample may represent an area less than 100 square feet. Whether the area is a large field or a small garden plot, soil needs to be collected from several locations to obtain a composite sample representative of the entire area.

Soil should be taken from the surface 6 to 8 inches or to the plow depth on cultivated fields and garden plots that will be tilled. Pastures, hay fields and areas that will not be cultivated should be sampled to a depth of 2 to 3 inches. If Precision Farming Technology is used, a different and probably more intensive soil-sampling pattern may be appropriate. Low spots, eroded areas or other areas that may be managed differently should be sampled separately and, if practical, treated differently than the main area.

Soil samples should be obtained and tested every year whether or not any fertilizers are added, since fertilizer recommendations are made on a year-to-year basis. Lime recommendations generally will maintain the soil pH within the desired range for periods of three years or more.

Subsoil Sampling for Soil Groups 2 and 3 in the Coastal Plain

Research in South Carolina and adjacent states has shown that potassium, magnesium and sulfur accumulate in the subsoil (clay layer) of Coastal Plain soils. These nutrients may be present in sufficient amounts to supply most or all of the crop requirement for the nutrient involved. For example, even though the surface soil may be low or medium in potassium, there may be a potassium supply in the subsoil that plants can use with potential for savings in fertilizer.

Clemson's nutrient recommendations based on surface soil samples can be adjusted based on the nutrient level of the subsoil when the following conditions are met:

- A representative subsoil sample is analyzed for potassium, magnesium, and/or sulfur.
- Physical impediments to rooting into the subsoil, such as hardpans, are absent or disrupted by subsoiling or comparable deep tillage.
- Depth of the subsoil is no greater than 20 inches.
- Subsoil pH is no less than 5.0.
- The crop is capable of growing roots to the depth of the subsoil.

Therefore, in addition to surface samples taken as described above, we recommend that subsoil samples be taken and tested for sandy Coastal Plain soils, *when subsoiling is practiced.* These samples should be obtained from the top 3 to 4 inches of the more clayey layer and can also be obtained from the same auger-hole bored for a surface sample. However, these subsoil samples should be kept separate from surface samples and clearly labeled "**Soil Group 5**" on the outside of the sample box. Clemson's nutrient recommendations based on surface soil samples can be adjusted if potassium, magnesium or sulfur in the subsoil is sufficiently high. Actual details of these adjustments are described in a subsequent section (see Table 3, page 10).

We strongly recommended that subsoil sampling be made a part of regular soil sampling. Similarly, in-row subsoiling should be made a part of the cultural practice for row crops.

Soil Testing

The standard soil test includes determination of:

- Soil pH (soil active acidity)
- Buffer pH (used to estimate total exchangeable acidity)
- Plant-available phosphorus, potassium, calcium, magnesium, zinc, manganese, copper, and boron
- Cation exchange capacity (CEC)
- Acidity
- % base saturation

In addition, a test for extractable sulfur is available for subsoil samples. Upon request, and for an additional fee, soil samples can also be tested for organic matter, nitrate-nitrogen and soluble salts.

Soil pH is a measure of the concentration of hydrogen ions in the soil solution. Soil pH, also referred to as water pH, measures the amount of active acidity in the soil. Only a small portion of the exchangeable acidity in soil is active. The soil pH is determined with a glass electrode and pH meter on a 1:1 soil water suspension (20-grams soil to 20-milliters of de-ionized water). A 16-ml scoop is used to estimate 20 grams of soil.

Buffer pH is used to measure the total exchangeable or potential acidity in the soil (hydrogen and aluminum ions). Clemson's laboratory uses the Adams-Evans buffer method for measuring exchangeable acidity. Twenty milliliters of Adams-Evans buffer solution, pH 8.0, are added to the soil-water mixture used to determine soil pH. After mixing and equilibrating for one hour, the buffer pH is measured with a glass electrode and pH meter.

Exchangeable and Plant-Available Nutrients: Phosphorus, potassium, calcium, magnesium, zinc, manganese, copper and boron are extracted with 0.05 N HCl + 0.025 N H_2SO_4, known as Mehlich No. 1 extractant or the "Dilute Double Acid" method. Four ml of soil (approximately 5 grams of soil) are mixed with 20 milliliters of extractant, shaken for 5 minutes and then filtered. The nutrient concentrations in the extract are determined by inductively coupled plasma (ICP) spectrometry.

The quantity of each nutrient extracted, which is related to plant availability, is reported in units of pounds per acre. This unit of measure is based on the assumption that the surface 6-inch layer of soil over an area of one acre weighs approximately 2 million pounds. The amount of the nutrient extracted does not exactly equal availability, but it is used as an index or guide for comparing the relative amount of extractable nutrients in different samples. The values are meaningful because they have been correlated with crop responses in the field. Table 2 (opposite) interprets the levels of extractable phosphorus, potassium, calcium and magnesium based on research in South Carolina and neighboring states.

The test for sulfur measures the amount of sulfate-sulfur present. Sulfate is extracted with a solution of 0.5 *N* ammonium acetate in 0.25 *N* acetic acid. The sulfur content of the extract is determined by ICP. Sulfur is considered sufficient (S) if the sulfate concentration is 20 pounds or more per acre in surface samples and 40 pounds or more for subsoil samples (Soil Group 5). Concentrations less than these values are considered Insufficient (I).

Cation Exchange Capacity (CEC): Clay particles and soil organic matter have negatively charged exchange sites on their surfaces that attract and bind positively charged ions (cations) such as aluminum, calcium, hydrogen, potassium and magnesium. The amount or quantity of cations that can be retained by the soil is referred to as the Cation Exchange Capacity (CEC). CEC is calculated from the exchangeable acidity, as described above, and the sum of the base-forming cations, described below. We report CEC in units of millequivalents per 100 grams of soil (meq/100g). What is the significance of CEC? The higher the CEC of a soil, the larger its storage capacity for cations such as calcium, magnesium and potassium. However, CEC is not a useful index or measure of soil productivity. The best way to measure the nutrient status of a soil and manage nutrient supplies is by using soil testing and following nutrient recommendations such as provided in this circular.

Base Saturation and Acidity: Cations held by exchange sites can be divided into acid-forming (hydrogen and aluminum) and base-forming cations (mainly calcium, magnesium, potassium and sodium). Base Saturation is the proportion of the CEC consisting of basic cations and is usually expressed as a percent of the CEC. For example, the base saturation of a soil containing 3 meq/100g of exchangeable calcium, magnesium, potassium and sodium (sum of all four) and having a CEC of 6 meq/100g would be 50 percent. The proportion of the CEC consisting of acid-forming cations, hydrogen and aluminum, is called acid saturation. In this example, the acid saturation would be also be 50 percent since the sum of the acid and base saturation must equal 100 percent.

Lime Requirement: Both the soil pH and the buffer pH are given on the soil test report form. The lower the buffer pH and the soil pH, the higher the lime requirement. Both pH values are needed to estimate the lime requirement and it is important to realize that two soils may have the same soil pH, but different lime requirements. Also, two soils may have the same lime requirements, but different soil pHs. Since most crops respond best when soils are slightly acidic, lime recommendations are adequate to neutralize only a portion of the exchangeable acidity, depending on the desired soil pH. At pH 6.0, soils typical of this region are about 40 percent saturated with acidic ions and 60 percent saturated with basic cations (calcium, magnesium, potassium and sodium). At pH 6.5, these soils are about 25 percent acid saturated and 75 percent base saturated. The lime recommendation is the amount of lime required to raise the pH of the soil to the desired level (Target pH), which is **6.0 or 6.5** for most crops.

Soil Test Ratings

Tables 2 and 2A give soil test ratings and corresponding ranges in extractable phosphorus, potassium, calcium and magnesium upon which Clemson University fertilizer recommendations are based. Note that phosphorus and magnesium ratings depend upon the soil group and that soil test phosphorus and potassium ratings for peanuts (Table 2A) are different from other crops

Table 2. Range in Extractable P, K, Ca, and Mg Represented by the Soil Test Ratings of the Clemson University Agricultural Service Laboratory.

SOIL-TEST RATING	-(all crops except peanuts)--- P		K	------------(all crops)------------ Ca	Mg	
	Soil Groups 1,2,3 & 6	Soil Groups 4 & 5	All Soil Groups	All Soil Groups	Soil Groups 1,2,3, & 5	Soil Groups 4 & 6
	lb/acre	lb/acre	lb/acre	lb/acre	lb/acre	lb/acre
VL	0-10	0-6	0-24	0-200	0-10	0-20
L	11-20	7-12	25-48	201-300	11-20	21-32
L+	21-30	13-20	49-70	301-400	21-32	33-46
M-	31-40	21-26	71-98	401-530	33-40	47-66
M	41-50	27-32	99-128	531-670	41-50	67-86
M+	51-60	33-40	129-156	671-800	51-60	87-100
H-	61-80	41-54	157-182	801-1200		
H	81-100	55-68	183-208	1201-1600	61+	101+
H+	101-120	69-80	209-235	1601-2000		
VH	121-240	81-240	236+	2001+		

Table 2 applies to all conditions except phosphorus and potassium for peanuts.

Table 2A. Soil Test Ratings and Corresponding Ranges in Extractable P and K for Peanuts. Applicable for all soils on which peanuts are grown.

Soil-Test Rating	P lb/acre	K lb/acre
VL	0-4	0-20
L	5-10	21-28
M	11-19	29-40
H	20-50	41-100
VH	>50	>100

Interpreting Soil Test Rating for Phosphorus, Potassium, Calcium and Magnesium

Very Low. Soil is deficient and application of the nutrient in question can be expected to produce a significant yield increase provided adequate soil moisture is available and other environmental conditions are favorable. High rates of the plant nutrient are needed if soil reserves are to be built up. Part of the fertilizer, especially phosphorus, should be banded beside the row for row crops planted in the spring when the soil temperature is low.

Low. Application of the nutrient can be expected to increase yield.

Medium. The supply of nutrient in the soil is adequate for many agronomic crops, but a yield response can be expected about 50 percent of the time. On Soil Groups 1 and 2, it may not be economical to build potassium, calcium, and/or magnesium levels higher than this level.

High. The supply of nutrient in the soil is adequate for most agronomic crops. No fertilizer is recommended for most crops and no yield response is expected. Certain agronomic crops and horticultural crops may benefit from fertilization at this level.

Very High. Supply of the nutrient is adequate for all agronomic crops and certain horticultural crops, and fertilizer is not recommended for those crops.

Excessively High. Supply of nutrients is excessively high and is more than adequate for all crops. The continued application of the nutrient could be detrimental to plant growth and may impact water quality.

Explanation of Recommendations

Clemson University's soil test report includes nutrient and lime recommendations based on expectation that a plant response is likely to occur, as explained in the previous section. Recommendations provided with the Clemson University soil test report depend on the soil test results, the crop or plant to be grown, and yield response experiments conducted in South Carolina and adjacent states. These experiments have been conducted over many growing seasons and weather conditions on soils typical of South Carolina and the Southeast.

The plant nutrients needed in largest amounts are nitrogen, phosphorus and potassium. In many cases, these are the only plant nutrients that need to be applied on a regular basis. Our recommendations are adequate to provide for optimal yields under most soil and crop management conditions. Experience has documented that yield increases are not observed when the recommended rates are exceeded or when application is made when soil test rating is High or above. When the recommended amounts of nutrients are applied, and if appropriate weed and other pest management practices are followed, rainfall and soil moisture conditions almost always limit yield.

Nitrogen is recommended each year for all crops except legumes. Most of the plant-available nitrogen in soil is in the form of nitrate, which readily leaches from soil. Unless a special request is made, a soil test for nitrogen is not included with the regular soil test because most soils in this region have little carryover of plant-available nitrogen and are low in soil organic matter content. Therefore, soils in this region cannot supply enough nitrogen to provide for optimal yields without nitrogen fertilization. If there is reason to believe that a substantial amount of plant-available nitrogen remains in the soil from the previous application, that needs to be confirmed by having a 3-foot soil core analyzed for nitrate-nitrogen.

Generally, the yield of most non-leguminous crops is more sensitive to nitrogen than any other nutrient except water. For several crops, comments provided with our nitrogen recommendations describe when nitrogen rates should be adjusted, up or down, depending on past experience, soil conditions and crop management. For example, our normal recommendation for nitrogen on unirrigated corn is 120 pounds per acre, but when it is grown on very sandy soils having a yield potential of 80 bushels per acre or less, we recommend decreasing the rate to 80 pounds per acre. In contrast, when it is grown in river bottoms and other locations where yields of 130 bushels per acre or more are commonly obtained, we suggest increasing the rate to 150 pounds per acre. We provide similar guidance for adjusting the nitrogen rate for Coastal bermudagrass, bahiagrass, cotton, small grain used for grazing and for several of the horticultural crops. This guidance is provided in the comments that accompany the recommendation.

Will the nitrogen rates we recommend provide for your yield goal? Agronomists find that fertilization rates of 1.0 to 1.25 pounds of nitrogen per bushel of corn and 1.25 to 1.4 pounds per bushel of wheat typically will support reasonable yield goals. Considering two important crops, corn and wheat, and based on these estimates for yield responses, the ranges of recommended nitrogen rates and yield potentials are:

Crop	N Rate, lb/acre		Yield Potential, bu/acre	
	Low	High	Low	High
Wheat	80	100	57-64	71-80
Corn, unirrigated	100	150	80-100	120-150
Corn irrigated	180	220	144-180	176-220

If yields above or below these ranges are expected, the nitrogen rate should be adjusted up or down, accordingly.

Phosphorus and **potassium** are recommended for all crops when soil test levels are Medium, Low or Very Low, and for a few crops even when soil test levels are High.

Calcium and **magnesium** are usually supplied when lime is applied to raise the soil pH. When lime is not needed but soil test levels of either of these nutrients are low, they can be supplied by addition of gypsum for calcium and Epsom salt or sulfate of potash magnesia (SUL-PO-MAG) for magnesium.

Sulfur is routinely recommended only for soils that do not have a clay layer within 20 inches of the surface (Soil Groups 1 and 2). Other soils may not need sulfur application dependent on factors described in the section describing subsoil sampling.

Manganese: except for poorly drained Coastal Plain soils with pH above 6.1 and other coarse textured Coastal Plain soils that have a pH greater than 6.4, most soils can supply adequate amounts of manganese. Manganese deficiencies are most common when the pH of well-drained soils rises above 6.7. Crops prone to manganese deficiency when soil pH is too high are soybeans, peanuts, oats, wheat, and cotton.

Zinc is routinely recommended only for corn grown on deep sandy soils (Soil Groups 1 and 2, soils that do not have a clay layer within 20 inches of the surface). When zinc deficiency on pecan, peaches or apples is confirmed, the most effective treatment to correct the problem is a foliar application of a zinc chelate.

Boron is routinely recommended only for the following crops: alfalfa, apples, broccoli, cabbage, cauliflower, clover (when reseeding or if to be harvested for seed), cotton, peanuts and root crops. Other crops normally obtain enough boron from the natural soil.

Copper is reported for diagnostic purposes but is not normally recommended. Copper deficiency is likely to be a problem only with soils especially high in organic matter, and coarse textured soils that have been overlimed.

Modification of Nutrient Recommendations for Coastal Plain Soils Based on Subsoil Sample Analysis

Potassium, sulfur and magnesium are leached from the surface of sandy Coastal Plain soils and accumulate in the more clayey subsoil. These nutrients are available to crops if and when roots reach and penetrate this layer where clay has accumulated. Subsoiling is a very important management practice on Coastal Plain soils because it allows roots to proliferate into the clay layer and extract water and nutrients.

Generally, if the clay layer is within 20 inches of the surface, the subsoil can be an important source of potassium, sulphur and magnesium if the subsoil pH is not too acidic (soil pH should be 5.0 or more) and subsoiling is practiced. When subsoiling penetrates the clay layer, plant roots are able to use nutrients and water in the clayey subsoil provided it's not too acidic. Therefore, subsoil samples should routinely be taken from Coastal Plain soils ***if subsoiling is practiced and its pH is 5.0 or more***. The sample should be taken to a depth of 3 to 4 inches below the top of the more clayey layer (or top of the subsoil). A subsoil sample can be obtained from the same auger-hole from which a surface sample is obtained. All the general guidelines taken for routine sampling should be followed for subsoil sampling.

Potassium fertilizer recommendations based on available potassium in the surface soil should be reduced if available potassium in the subsoil is Medium or Higher. See Table 3 for recommended adjustments. The soil test report for Group 5 samples includes these adjustments.

Table 3. Adjustments to Nutrient Recommendations Based on Subsoil Sample Analysis.

Subsoil Nutrient Level	Recommended Adjustment
Potassium (K)	
Low	Based on the soil-test results, no adjustment is recommended in fertilizer rates based on the topsoil sample.
Medium	Subsoil contains medium level of K. The recommended rated of K_2O should be reduced by one-fourth. In-row subsoiling needs to be a part of routine cultural practices for row crops.
High	Subsoil contains a high level of K. The recommended rate of K_2O should be reduced by one-half. In-row subsoiling needs to be a part of routine cultural practices for row crops.
Very High	Subsoil contains a very high level of K. The recommended rate of K_2O should be reduced by three-fourths. In-row subsoiling needs to be a part of routine cultural practices for row crops.
Magnesium (Mg)	
Medium to Very High	Subsoil contains adequate magnesium; disregard any recommendation for magnesium based on topsoil sample. However, in-row subsoiling may need to be a part of the cultural practices for row crops.
Sulfur (S)	
Sufficient	Test for sulfur indicates there is sufficient sulfur in the subsoil for good plant growth. Disregard any other recommendation for sulfur on this area. However, in-row subsoiling should be a part of the cultural practices for row crops.

Essential Plant Nutrients

Nitrogen (N)

A realistic measure of nitrogen in the soil can not be obtained from analysis of surface soil samples submitted for routine soil testing. Small amounts of nitrogen, perhaps 10 to 20 pounds per acre per year, will be released from decomposing organic matter in the soil during the warm season. In addition, some of the nitrogen remaining from the previous fertilizer application (residual nitrogen) may remain in the root zone and become available during the following growing season. Poor growing conditions in the previous year and low rainfall through the cool season can result in significant nitrogen remaining in the soil profile. Residual nitrogen in the profile can be estimated by obtaining soil samples taken to a depth of up to 36 inches and testing for nitrate-nitrogen.

The amount of nitrogen soils in this region can supply for plant growth due to the decomposition of soil organic matter is small compared to the amount needed for optimal crop production. Unless significant residual nitrate remains in the soil from the previous crop, nitrogen recommendations for non-legume crops are based on nitrogen rate experiments and plant responses conducted on soils in South Carolina and on similar soils and in neighboring states. These nitrogen recommendations are suggested as being the most profitable provided good management is practiced. Growers should increase or decrease the nitrogen rate if a local situation has shown the change to be desirable. Too much nitrogen applied too close to harvest will cause excessive vegetative growth and delay harvest.

Nitrogen is not recommended for legume crops since they benefit from atmospheric nitrogen fixed by soil micro-organisms associated with the roots of legumes. Thus air is the source of nitrogen for legumes. A lower rate of nitrogen is recommended for crops that follow legume crops because a nitrogen credit of 25 pounds per acre is given to the following crops and their nitrogen recommendation should be reduced when following a legume crop. Seeds of all leguminous crop should be inoculated before sowing unless legumes have been grown on the field within the past two to four years. Inoculation ensures optimum nodule formation and growth and therefore effective nitrogen fixation. Specific Rhizobium strains may be required for effective nitrogen fixation by some crops such as cowpea and Southern peas. If nitrogen fertilizer is applied to legumes, biological nitrogen fixation is likely to be reduced.

Organic nitrogen, such as that contained in biosolids and manure, cannot be utilized by plants until it has been converted to an ammonium form. This conversion process, termed mineralization, is carried out by naturally occurring soil microorganisms and occurs as plant residues and other organic substances are decomposed. The process occurs more rapidly during the warm season than during the cool season. Once nitrogen is in an ammonium form, it is converted to nitrate by soil microorganisms in one to three weeks, during the warm season.

Nitrogen fertilizer should be applied at planting, or as close as practical to the time when crops need it. Split applications of nitrogen are a way to achieve this. For example, we recommend that only 20 to 30 pounds of the total nitrogen recommendation for small grain be applied at fall planting. The balance should be top-dressed in February. Likewise, 30 pounds per acre of the nitrogen for corn should be applied at planting and the balance side-dressed when the plants are 18 to 30 inches high. This practice conserves resources, saves money by maximizing fertilizer use efficiency and protects water resources.

Phosphorus (P)

The amount of phosphorus extracted by our soil test procedure (Mehlich No. 1 extraction) has been correlated with crop responses to varying rates of phosphorus fertilization and has been found to provide a reliable basis for phosphorus fertilizer recommendations. The recommended phosphorus rate is based on the soil test, the soil group and the crop. Use a fertilizer program designed to maintain the soil test level at a high rating, but not higher, and follow good conservation practices. The phosphorus in fertilizer usually remains in the surface soil. Most of the phosphorus in soil is unavailable to plants because it is tightly bound to soil particles or precipitated as aluminum, iron and calcium compounds having extremely low solubility in the soil solution. Although some phosphorus may move downward when soil available phosphorus reaches very high levels in coarse-textured soils, leaching of phosphorus is usually not a problem. Significant amounts of phosphorus are not lost by leaching, but on Soil Groups 1, 2 and 3 there may be some downward movement as a result of tillage. Normally, the subsoil will test low in phosphorus even though the surface may be high in available phosphorus. While leaching is not a problem with phosphorus, surface losses can be significant. Erosion of soil and phosphorus that is attached to soil particles can contribute to excessive levels of phosphorus in surface waters. Phosphorus enrichment of surface waters can stimulate growth of aquatic plants such as algae.

Soils that have been fertilized for several years using only, or primarily, poultry litter, dairy wastes and other animal manure tend to build up very high levels of available phosphorus. In most cases, application rates are based on the nitrogen content of the organic material. Most animal manure contains similar concentrations of nitrogen and phosphorus yet most crops take up five to 10 times more nitrogen than phosphorus. Thus phosphorus will build up in the soil under such nutrient management practices.

Although soil acidity and soil moisture and temperature are sometimes associated with phosphorus availability, the effect of soil temperature on corn seedling response to phosphorus is the one most likely to be observed. In cool springs, purple coloration of corn leaves may be seen. This effect is not due to phosphorus being in an unavailable form but most likely due to slow root growth and a lower rate of absorption of phosphorus by plant roots in the cold soil.

There are three situations when banding of phosphorus is desirable:

- For transplants when phosphorus is recommended.
- When planting in cold soil in late winter or early spring and the soil test for phosphorus is low or very low.
- When the soil test for phosphorus is very low.

In the event that the soil test for phosphorus is high or above and none is applied, soil sampling should be done the following year. Additional phosphorus may not be needed for soybeans or peanuts if the recommended amount of phosphorus has been applied to the preceding crop.

Potassium (K)

Recommendations for potassium, as for phosphorus, are based on the likelihood of obtaining a response to potassium fertilizer. Potassium is subject to luxury consumption, that is, the plant will take up much more than is needed if more potassium is added than is recommended. Also, potassium is subject to leaching loss, especially in soils of the Coastal Plains. When potassium is applied immediately prior to planting, leaching of potassium should not be enough to reduce yield with normal rainfall. However, in years when rainfall is high, leaching of potassium may affect yield on Soil Groups 1 and 2 but not for other soil groups.

Because of luxury consumption, considerable potassium is removed when the entire plant is harvested, and subsequent crops will require more potassium. The recommended rate should be taken from the table for the specific crop and soil group. Luxury consumption and leaching loss make it undesirable to try to build the potassium level above medium. When the soil potassium level is high, potassium not removed by the crop will tend to leach to the clay layer. If a subsoil test is run on Soil Group 2 (having a clay layer within 20 inches of the surface) or Soil Group 3 and the test is high, the recommended rate based on the surface soil sample may be reduced. When the level of magnesium in the soil is low, a high rate of potassium may induce magnesium deficiency. In the event that the soil test for potassium is high or above and none is applied, soil sampling should be done the following year.

Calcium (Ca)

Soil testing measures the amount of available or exchangeable calcium in soil. The calcium requirement for most crops is satisfied if the lime recommendation is followed. Using either calcitic or dolomitic limestone and a good liming program will normally maintain a favorable calcium level. When calcium tests low, a small amount of lime (500 to 1,000 pounds per acre) may be used to correct the deficiency if the soil pH is not too high, and thus the possibility of inducing micronutrient deficiency does not exist. If soil pH is near the desired level, use another source of calcium, such as gypsum. The crops most sensitive to low calcium levels are tomatoes, pimentos, peanuts, fruit and nuts.

Magnesium (Mg)

Magnesium requirements are usually supplied most economically by using dolomitic limestone. Soil acidity, low magnesium and low calcium can be corrected with dolomitic limestone at the recommended rate. When magnesium deficiency occurs, it is often due to low soil pH. When lime is required and the soil test for magnesium is medium or less, use dolomitic limestone. When lime is required and the soil test for magnesium is medium plus or above, any source of lime may be used. The use of dolomitic limestone every time the soil is limed will not result in magnesium toxicity or cause a cation imbalance situation in the soils in South Carolina. When the soil tests low in magnesium and lime is not required, apply 10 to 15 pounds per acre of magnesium as magnesium sulfate or sulfate of potash-magnesia. If the subsoil contains adequate magnesium, a magnesium recommendation based on a surface soil sample test should be disregarded. A subsoil test should be done to assess the magnesium requirement accurately.

Vegetable crops like beets, broccoli, cabbage, carrots, cauliflower, collards, eggplant, onions, pepper, pole beans, spinach or greens are very susceptible to magnesium deficiency when magnesium or pH levels are low.

Sulfur (S)

The increased use of ammonium phosphate and concentrated superphosphate (triple superphosphate) rather than superphosphate in fertilizers has resulted in an increase in the occurrence of sulfur deficiency. Organic matter is a source of sulfur, but most soils in the Coastal Plain of South Carolina contain too little organic matter for this to be an adequate source. Precipitation contributes 8 to 11 pounds per acre of sulfur per year in South Carolina. This sulfur is injected into the atmosphere from natural and artificial sources.

Sulfur deposited from the atmosphere is retained on clay surfaces and is adequate to satisfy crop requirements in the Piedmont. For this reason a need for sulfur is not expected for the soils in Group 4. However, in the Coastal Plain sulfur will leach from the surface soil, but it is retained in the clay layer. A subsoil testing program should be used for soils in Soil Group 2 if the clay layer is within 20 inches of the surface and for Soil Group 3. The test will indicate if the level of sulfur in the subsoil is Sufficient (S) or Insufficient (I). If the test is (I) Insufficient, the fertilizer used should supply 10 pounds of sulfur per acre. When depending on subsoil sulfur, it must be possible for plant roots to grow into the subsoil. In-row subsoiling or chisel plowing may be necessary on some soils if plant roots are to reach this source of sulfur.

During periods of low temperature and/or when excessive rainfall occurs in the spring, sulfur deficiencies may be observed on plants, especially corn growing in sandy soils. The plants will usually recover when roots reach the subsoil zone where sulfur has accumulated, but side-dressing with a nitrogen-sulfur solution may be desirable.

It may be possible to get good crop yield on Soil Groups 1 and 2 for a few years without adding sulfur. However, we recommend sulfur fertilization of these soils since their organic matter content is low, sulfur will readily leach from these coarse-textured soils, and the depth to clay is greater than 20 inches. Until a practical soil test procedure for predicting sulfur deficiency in Soil Groups 1 and 2 is developed, we recommend application of 10 pounds of sulfur annually in the fertilizer or pesticide applications for all crops grown in Soil Groups 1 and 2.

For Soil Group 5 (subsoil samples), the amount of sulfur is considered Insufficient (I) if the value is 40 pounds per acre. For Soil Groups 1, 2, 3, 4 or 6, the amount of sulfur is considered Insufficient (I) if the value is 20 pounds per acre or less.

Boron (B)

A soil test for boron is included as a part of the standard soil test. When extractable boron is 0.1 pound per acre or more, there is adequate boron in the soil. However, application of small amounts of boron are routinely recommended for several crops as described below. A plant analysis is the best method for determining when boron is actually needed. Boron in the soil is in organic and inorganic forms. There may be 20 to 200 lb/acre in the surface layer of soil, but only a small amount is available. Boron is made available as soil organic matter is mineralized and as boron-containing minerals slowly dissolve. Boron is often contained in soil amendments including manure, superphosphate and lime.

Calcium, potassium and nitrogen can affect boron nutrition. The calcium-boron relationship is the most important. Soils high in calcium will require more boron. Lower rates of boron will be required for soils low in calcium, and chances of boron toxicity are greater. Crops differ in tolerance to high levels of boron in soils. Sensitive crops are peaches, strawberries and soybeans. A few of the more tolerant crops are cotton, sunflowers and alfalfa. Corn, tobacco, tomatoes and small grains are somewhere in between. Boron is recommended routinely for cotton, peanuts, reseeding clover or where clover seeds are to be harvested, alfalfa, apples, root crops, cabbage, broccoli, and cauliflower. Ranges of boron application rates for some crops when deficiency symptoms are observed are given in Table 4. Boron toxicity is definitely possible, and care should be taken not to exceed the recommended rates. The amount of boron required is dependent upon the crop, soil conditions, the source of boron and the method of application. For any given crop, higher rates of boron may be applied to clayey soils, soils with a high pH or high calcium level, and soils with a high organic matter content. Broadcast applications may be higher than either banded or foliar application.

Table 4. Rates of Boron Suggested for Correcting Boron Deficiency of Various Crops.
(The amounts given are pounds of elemental boron per acre. The actual amount of material applied will depend on the boron concentration in the source).

Crop	Amount lb/acre
Alfalfa	2.0-4.0
Apples	0.3-1.4
Cabbage	1.0-4.5
Carrots	1.0-1.7
Clovers	0.6-2.3
Corn	0.6-1.0
Cotton	0.6-1.0
Grapes	0.6-1.0
Peanuts	0.3-0.5
Peas	0.9-1.2
Potatoes	0.6-1.0
Strawberries	0.6-1.0
Sweet potatoes	0.6-1.7
Tobacco	0.3-0.6
Tomatoes	0.6-1.7

Zinc (Zn)

Soil and plant analysis can be used to help determine whether a zinc problem exists. The standard soil test includes zinc analysis. If there is a problem, it may be either a toxicity or deficiency. A toxicity might result from several years of use of a fungicide containing zinc such as in old peach orchards. The use of high rates of sludge, slag, or poultry litter containing high concentration of zinc can cause zinc toxicity. The effect of zinc toxicity may be reduced or eliminated by using lime to raise the soil pH above what would normally be considered adequate.

When soils are tested for zinc, they are rated "S" (Sufficient) or "I" (Insufficient). If the test indicates less than 1.6 pounds of zinc per acre, it is regarded as Insufficient (I), and zinc is recommended for certain crops. The rate to use would be 3 to 5 lb of Zn/acre.

Zinc deficiency may be observed on early planted corn during a cool, wet season and when polyphosphate is banded. The plants usually recover when soils dry out and warm up. Zinc is routinely recommended for corn on sandy soils (Groups 1 and 2) when the soil pH is above 6.5. Also, zinc application is suggested for pecans, peaches and apples, unless a plant analysis indicates it is not required. To correct a zinc deficiency for peaches, plums or nectarines, apply a foliar spray of chelated zinc according to the label or apply 3 ounces of zinc sulfate per 100 gallons of spray, three times at three-week intervals. If a fungicide containing zinc is used, additional zinc will not be required.

Manganese (Mn)

If manganese deficiency is suspected, both plant tissue and soil samples should be submitted for analysis to confirm that manganese deficiency is the problem. Manganese deficiency should be corrected by soil or foliar application. For soybeans, 15 to 75 pounds of manganese sulfate (26 to 28 percent manganese) or its equivalent per acre may be applied for optimum yield when the soil pH is around 6.4. However in soils with a high pH, correcting manganese deficiencies by soil application is difficult as the applied manganese will most likely be converted to an unavailable form in the soil. In the case of soybeans, the best way to correct the deficiency is to apply 1 pound manganese per acre as $MnSO_4$ as a foliar spray twice during the season. Then, rotate to corn, which should lower the soil pH sufficiently to correct the problem.

Soil factors that contribute to manganese deficiency are: (1) water-logged conditions during a portion of the year, and (2) poorly drained soils with low manganese supply and high pH. Manganese deficiency most likely occurs on soybeans, peanuts, oats, wheat and cotton on Soil Groups 1, 2 and 3 in area 5 and on a few poorly drained fields in area 4 when the soil pH is too high.

When the soil is tested for manganese, it will be rated "S" Sufficient or "I" Insufficient. The soil test level considered to be sufficient depends on the soil pH as shown below:

Sufficiency Level	Soil pH
0.0-0.9	5.1
1.0-1.9	5.2
2.0-2.9	5.3
3.0-3.3	5.4
3.4-3.9	5.5
4.0-4.9	5.6
5.0-5.9	5.7
6.0-6.9	5.8
7.0-7.9	5.9
8.0-8.9	6.0
9.0-9.9	6.1
10.0-10.3	6.2
10.4-10.9	6.3
11.0-11.9	6.4
12.0-12.9	6.5
13.0-13.9	6.6
14.0-14.9	6.7
15.0-15.9	6.8
16.0-16.9	6.9
>17.0	7.0

Any soil test value less than 6 pounds per acre, regardless of the pH value, is rated "I" (Insufficient) and any value 6 pounds per acre or greater, regardless of the pH value, will be rated "S" (Sufficient).

Iron (Fe)

Iron deficiency in plants in most cases is not due to the lack of iron in the soil. Rather, it is caused by soil conditions such as high soil pH; low soil oxygen levels caused by water logging or prolonged periods of excessive soil moisture; excessive temperature; and excessive phosphorus, copper, manganese and zinc. For these reasons, and the lack of a useful correlation between extractable iron and plant responses, soil samples are not tested for iron.

Crops in South Carolina that may exhibit iron deficiencies are pecans (when over fertilized with zinc), centipede-grass, blueberries and certain ornamentals, such as azaleas and camellias. Foliar application of iron is the most effective way to correct iron deficiency. A 1-percent solution of ferrous sulfate (add a little sulfuric acid to keep it in solution) should correct iron deficiency when sprayed on deficient plants. A 2-percent solution using chelated iron would be equally as effective.

Copper (Cu)

Copper is included as a part of the standard soil test. Copper deficiency *may* be a problem on high organic soils and very sandy soils that have been over-limed and thus have a high pH. Copper will be leached from the very sandy soils low in organic matter, but it is retained in available forms by clayey soils. Copper deficiencies on organic soils may require application of 20 to 50 pounds per acre of copper sulfate or foliar application of 1 to 2 pounds per acre of copper sulfate. Copper deficiency has not been a major problem in South Carolina and recommendations for copper should be based on analysis of plant tissue. There is a very narrow range between deficiency and toxicity of copper.

Molybdenum (Mo)

Soil samples are not tested for molybdenum. The soil normally contains 1 to 6 pounds per acre of molybdenum. Soil pH is the major soil factor affecting the availability of molybdenum to plants. Generally, if the pH is 6.0 or higher, a deficiency will not occur. Therefore, molybdenum application is not normally recommended. If the soil pH is below 6.0 and molybdenum deficiency is suspected, the recommended application rate for most legume crops is 2 to 8 ounces per acre applied as a seed treatment or foliar spray. Molybdenum is not recommended for non-legume crops.

Chlorine (Cl)

Although chlorine is an essential element, soil samples are not tested for chlorine because it is so abundant in nature. Chlorine excesses are more common than deficiencies. Plants can also absorb chlorine from the air through their leaves. For tobacco, the use of sulfate or nitrate sources of potassium is recommended rather than potassium chloride (muriate of potash), because of the adverse effects of chlorine on tobacco quality. Also, for blueberries, acid-forming fertilizers that do not contain chlorides are preferred.

Lowering Soil pH

Soil pH is lowered as a result of natural processes and by the use of ammonium forms of nitrogen. Acid is produced when ammonium forms of nitrogen are naturally converted to nitrate-nitrogen. Intensive cropping using large amounts of ammonium forms of nitrogen will accelerate soil acidification. Occasionally, it will be desirable to lower the soil pH for a lawn with centipede grass or in preparing plant beds for blueberries, azaleas, camellias, rhododendron, and so-called "acid-loving plants." Two or more soil samples should be taken from the area for a firm estimate of the soil pH and the amount of chemical to add. The amount of aluminum sulfate or elemental sulfur required to lower the pH to different levels is given in Table 5.

Table 5. 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 sulfur.**)

	Desired pH				
Present 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

Lime Recommendations

The main reasons for applying lime are to supply calcium or magnesium and to raise the pH to a level that optimizes the availability of phosphorus and several trace elements. Applying lime when it isn't needed or over-liming may raise the soil pH too high and induce deficiencies for micronutrients such as manganese and zinc. Crops such as soybean and corn grown on coarse-textured soils in the Coastal Plains are especially prone to this problem. Therefore, to use lime when it isn't needed may be as detrimental as not using lime when it is required. Soil testing is the only practical way to determine when to lime and at what rate. Lime requirement of a soil is based on the soil pH and the amount of exchangeable acidity. A buffer solution is used to determine exchangeable acidity.

Soil pH and the buffer pH are needed to determine the amount of lime needed to raise the soil pH to a "Target pH" (the maximum soil pH considered safe) for the crop to be grown. The soil pH values considered desirable for crops produced in South Carolina are given in Table 6, page 18. Note that the Target pH for alfalfa and short stake tomatoes in the Piedmont is 6.5. Formerly, the Target pH was 7.0. Also, for other crops not specifically cited in Table 6, including most field crops such as soybeans, corn and small grain, the Target pH is either 6.0 or 6.5. Most of these crops will grow equally well at either pH.

Table 6. Desired pH for Different Crops.

Crop	Lime if pH is Less Than	Target pH
Alfalfa and short stake tomatoes in the Piedmont	6.0	6.5
Clovers, vegetables, fruit, and nuts	6.0	6.5
Christmas trees, pines, tobacco, Irish potatoes, sweet potatoes, and centipede and carpetgrass	5.5	6.0
Azaleas, rhododendron, and camellias	5.0	6.0
All crops except those listed above	5.8	6.0 or 6.5

Note: The pH for Carolina Bays or soils with more than 10 percent organic matter should be maintained between 5.0 and 5.5.

Using a lower Target pH will result in more frequent applications of small amounts of lime, which is generally a more effective management strategy for neutralizing soil acidity. However, sometimes it is preferable to lime less frequently but use large amounts of lime. For example, when a permanent pasture or hayfield is being established, that is an opportune time to incorporate lime into the soil profile. After establishment lime applications, by necessity, must be surface applied. Since lime has very low solubility, soil acidity much below the surface cannot be easily or effectively neutralized. Also, short versus long-term lease agreements may affect the economics of scheduling lime applications. The potential for exceeding the Target pH on coarse-textured Coastal Plain soils is still another consideration. Thus there are many soil, crop and economic considerations that affect the selection of a Target pH. When in doubt about Target pH, ask your Extension agent, Certified Crop Adviser or crop consultant for advice.

The amounts of lime needed to raise the soil pH to 5.5, 6.0, 6.5 or 7.0 for a range of soil pH and buffer pH values are given on the following pages in Tables 7, 8, 9 and 10, respectively. The amounts of lime indicated are based on a soil mixing depth of 8 inches. The requirements are given in 100-pound increments. Lime recommendations are now reported to the nearest 100 pounds per acre of agricultural limestone, that is, we no longer round up to the nearest 0.5 ton because of the potential for over-liming poorly buffered soils in the Coastal Plain. For example, exceeding the actual lime requirement by several hundred pounds may raise the pH of such soils to more than 7.5, inducing micronutrient deficiencies.

In most instances it may be impractical to apply less than 0.5 to 1 ton per acre. The farmer and/or crop adviser must decide when to apply lime if the recommendation is for only a few hundred pounds per acre. In some cases it may be acceptable 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, difference between soil pH and target pH, and potential to induce a micronutrient deficiency in the crop to be grown are factors to be considered. If variable rate application is used, application of small amounts of lime may be practical.

The pH for Carolina Bays or soils with more than 10 percent organic matter should be maintained between 5.0 and 5.5.

Table 7. 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 Value										
	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

This table is only applicable to results from Clemson University Soil Testing Laboratory.

Example: A soil pH of 4.8 and a buffer pH of 7.65 will require 1,900 pounds of lime per acre.

Table 8. 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 Value								
	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

This table is only applicable to results from Clemson University Soil Testing Laboratory.

Table 9. 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 Value										
	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

This table is only applicable to results from Clemson University Soil Testing Laboratory.

Table 10. The quantity of limestone required to raise the soil pH of the surface 8 inches to 7.0 based on the Adams-Evans method.

Buffer pH	Soil pH Value												
	6.9	6.7	6.5	6.3	6.1	5.9	5.7	5.5	5.3	5.1	4.9	4.7	4.5
	pounds/acre agricultural limestone												
7.95	100	200	300	400	500	500	500	600	600	600	600	700	700
7.90	200	500	700	800	900	1000	1100	1100	1200	1200	1300	1300	1400
7.85	300	700	1000	1200	1400	1500	1600	1700	1800	1900	1900	2000	2000
7.80	400	900	1300	1600	1800	2000	2200	2300	2400	2500	2600	2600	2700
7.75	500	1200	1700	2000	2300	2500	2700	2800	3000	3100	3200	3300	3400
7.70	600	1400	2000	2400	2800	3000	3200	3400	3600	3700	3800	4000	4100
7.65	700	1700	2300	2800	3200	3500	3800	4000	4200	4300	4500	4600	4800
7.60	800	1900	2700	3200	3700	4000	4300	4600	4800	4900	5100	5300	5400
7.55	900	2100	3000	3600	4100	4500	4900	5100	5400	5600	5700	5900	6100
7.50	1000	2400	3300	4000	4600	5000	5400	5700	5900	6200	6400	6600	6800
7.45	1100	2600	3700	4500	5100	5500	5900	6300	6500	6800	7000	7200	7500
7.40	1200	2800	4000	4900	5500	6000	6500	6800	7100	7400	7700	7900	8200
7.35	1300	3100	4300	5300	6000	6500	7000	7400	7700	8000	8300	8600	8800
7.30	1300	3300	4700	5700	6400	7000	7500	8000	8300	8600	8900	9200	9500
7.25	1400	3500	5000	6100	6900	7500	8100	8500	8900	9300	9600	9900	10000
7.20	1500	3800	5300	6500	7400	8000	8600	9100	9500	9900	10000	10000	10000
7.15	1600	4000	5700	6900	7800	8600	9200	9700	10000	10000	10000	10000	10000
7.10	1700	4300	6000	7300	8300	9100	9700	10000	10000	10000	10000	10000	10000
7.05	1800	4500	6300	7700	8700	9600	10200	10000	10000	10000	10000	10000	10000
7.00	1900	4700	6700	8100	9200	10000	10000	10000	10000	10000	10000	10000	10000

This table is only applicable to results from Clemson University Soil Testing Laboratory.

Manure Utilization as a Crop Nutrient Source

Manure should be managed based on its content of plant-available nutrients. Nutrient content of manure varies depending on several factors including the source, moisture content, the amount of bedding or other material that is mixed with the manure, and whether the manure has been composted. A composite sample should be analyzed for its nutrient content to determine the amount of plant-available nutrients, which is needed to determine the appropriate application rate. As with other nutrient sources, including inorganic commercial fertilizers, the application rate should be based on soil test results and accompanying nutrient recommendations.

If manure is used as the sole source of plant nutrients, soil phosphorus levels will gradually increase and after several years are likely to reach very high levels. In such situations soil enriched with phosphate can be moved by drainage waters into surface waters causing water quality problems. Very high levels of soil test phosphorus can be avoided by basing manure applications on phosphorus rather than nitrogen before the soil phosphorus levels reach the Very High level. As a result of concerns about water quality, among other things, operators of confined animal facilities are required to develop comprehensive nutrient management plans. These plans along with monitoring requirements, ceiling concentrations and soil loading with respect to copper and zinc are described in Regulation 61-43, *Standards for the Permitting of Agricultural Animal Facilities*, dated June 26, 1998, applies to swine and other animal facilities.

Land Application of Nonagricultural Wastes as Crop Nutrient Sources

Regulations

Many wastes—including agricultural, industrial and municipal—are suitable for application to crop land so that their nutrient contents can be recycled naturally. In addition, land application of nonhazardous wastes has many environmental advantages compared to land filling and other disposal methods that fail to capture useful resources present in these wastes. Manure and other agricultural wastes have been land applied since agriculture began. However, land application of nonagricultural wastes is relatively new, and special regulations that ensure public and environmental health and safety have been developed.

Sewage sludge, also called "wastewater biosolids," and many industrial sludges and wastes contain nitrogen and other plant nutrients that can be used by crops, including lawns and gardens. The South Carolina Department of Health and Environmental Control (DHEC) regulates land application of sewage sludges and nonhazardous solid wastes in South Carolina. DHEC's guidelines for sludge are presented in *Beneficial Use of Wastewater Biosolids* dated February 1996. The state regulations covering land application of solid wastes were covered by regulation R. 61-107.15, *Solid Waste Management: Land Application of Solid Waste.*

The regulations and guidelines for land application of wastes are designed to protect human health and the environment while allowing for beneficial recovery of plant nutrients. The regulatory requirements and guidelines are described in the publications mentioned above. In this publication we address only the nutrient management aspects of land application of wastes that are declared by DHEC to be nonhazardous and therefore appropriate for land application. In many cases, waste management plans stipulate waste application rates based on the agronomic considerations described in this publication.

Nutrient Management

From the standpoint of nutrient management practices, wastes should be managed with the same considerations as for fertilizer, lime and other nutrient sources with regards to nitrogen rate, time of application and maintenance of soil pH. Wastes should be applied so as not to exceed the agronomic rate.

NUTRIENT MANAGEMENT PRACTICES FOR AGRONOMIC CROPS

Crop Code No. 050

Alfalfa

Soil Groups 3 or 4				Desired pH 6.0-6.5
Phosphorus	Potassium			
	Low	Medium	High	Very High
		Pounds of N-P_2O_5-K_2O per Acre		
Very Low	0-240-300	0-240-200	0-240-100	0-240-0
Low	0-200-300	0-200-200	0-200-100	0-200-0
Medium	0-100-300	0-100-200	0-100-100	0-100-0
High	0- 0-300	0- 0-200	0- 0-100	0- 0-0
Very High	0- 0-300	0- 0-200	0- 0-100	0- 0-0

When alfalfa is being established, lime and phosphorus should be applied and worked into the soil prior to planting. Maintenance fertilizer applications and lime, if needed, should be applied in the spring. If the pH is below 6.5, the recommended rate of lime should be at least 1 ton per acre. It may be possible to extend the life of an alfalfa stand by applying recommended potassium in two equal applications, one-half in the spring and one-half after the third harvest. Seed should be inoculated. Three pounds of actual boron per acre should be applied annually.

Crop Code No. 007

Annual Legumes (Arrowleaf, Yuchi, Crimson, etc.)

Soil Groups 1, 2, 3 or 4			Desired pH 6.0-6.5	
Phosphorus	Potassium			
	Low	Medium	High	Very High
		Pounds of N-P_2O_5-K_2O per Acre		
Very Low	0-120-100	0-120-40	0-120-0	0-120-0
Low	0- 80-100	0- 80-40	0- 80-0	0- 80-0
Medium	0- 50-100	0- 50-40	0- 50-0	0- 50-0
High	0- 0- 100	0- 0-40	0- 0-0	0- 0-0
Very High	0- 0- 100	0- 0-40	0- 0-0	0- 0-0

Apply $1^1/_2$ pounds per acre of actual boron for reseeding or clover seed harvest. Seed should be inoculated.

Crop Code No. 005

Annual Legumes (Arrowleaf, Yuchi, Crimson, etc.) on Summer Grass Pasture (Bahia, Dallis or Bermudagrass)

Soil Groups 1, 2, 3 or 4			Desired pH 6.0-6.5	
Phosphorus	Potassium			
	Low	Medium	High	Very High
		Pounds of N-P_2O_5-K_2O per Acre		
Very Low	0-120-80	0-120-40	0-120-0	0- 120-0
Low	0- 80-80	0- 80-40	0- 80-0	0- 80-0
Medium	0- 40-80	0- 40-40	0- 40-0	0- 40-0
High	0- 0-80	0- 0-40	0- 0-0	0- 0- 0
Very High	0- 0-80	0- 0-40	0- 0-0	0- 0- 0

Apply $1^1/_2$ pounds per acre of actual boron for reseeding or clover seed harvest. Seed should be inoculated.

Crop Code No. 031 or 032

Cool-Season Perennial Grass Pasture (Fescue [031] or Orchardgrass [032])

Soil Groups 3 or 4 — Desired pH 5.8-6.5

Phosphorus	Potassium			
	Low	Medium	High	Very High
	Pounds of N-P_2O_5-K_2O per Acre			
Very Low	100-100-80	100-100-40	100-100-0	100-100-0
Low	100- 80-80	100- 80-40	100- 80-0	100- 80-0
Medium	100- 40-80	100- 40-40	100- 40-0	100- 40-0
High	100- 0-80	100- 0-40	100- 0-0	100- 0-0
Very High	100- 0-80	100- 0-40	100- 0-0	100- 0-0

The profitable nitrogen rate for fescue or orchardgrass pastures may range from 60 to 160 pounds per acre depending on stocking rate and forage needs. Apply one-half or not more than 80 pounds of nitrogen in late August and the balance in February. If stocking rate is reduced, adjust nitrogen rate accordingly. Apply all the phosphorus and potassium in the fall.

Crop Code No. 001

Cotton

Soil Groups 1, 2, 3 or 4 — Desired pH 5.8-6.5

Phosphorus	Potassium			
	Low	Medium	High	Very High
	Pounds of N-P_2O_5-K_2O per Acre			
Very Low	70-140-100	70-140-60	70-140-0	70-140-0
Low	70-100-100	70-100-60	70-100-0	70-100-0
Medium	70- 60-100	70- 60-60	70- 60-0	70- 60-0
High	70- 0- 100	70- 0- 60	70- 0- 0	70- 0- 0
Very High	70- 0- 100	70- 0- 60	70- 0- 0	70- 0- 0

The nitrogen rate should be decreased by 20 to 30 pounds per acre on land where excessive growth has caused problems with late maturity or boll rot. In contrast, where vegetative growth has been inadequate, increase the nitrogen rate by 20 to 30 pounds per acre. When cotton follows soybeans or other legume in rotation, reduce nitrogen rate by 20 to 30 pounds per acre. Apply one-fourth to one-third of the nitrogen at planting and the balance as a sidedressing. Sidedressing should be applied by June 15. If it is necessary to apply after July 1, it would be desirable to use a nitrate source applied at low rates (10 to 15 pounds of nitrogen per acre).

Fertilizer should supply 10 pounds per acre of sulfur and 0.4 pound per acre of boron. As an alternative, boron may be supplied in the insecticide in one or more applications so long as the total amount applied does not exceed 1.0 pound per acre of boron. Apply 5 to 15 pounds per acre of manganese when the soil pH is greater than 6.2 and manganese deficiency has been observed in the field in previous years. This manganese deficiency problem usually occurs on the following soil series: Coosaw, Ocilla, Pelham, Williman, Chewacla, Lynchburg, Yemassee, Myatt, Ogeechee, Rains, Wadmalah, Wehadkee or Yonges. If manganese deficiency symptoms occur and are confirmed by plant analysis, manganese may be applied as a foliar spray either alone or mixed with a pesticide. In such cases, make one or two applications of 1 or 2 pounds per acre of actual manganese. Contact your county agent for additional information. Apply 10 to 15 pounds per acre of magnesium with fertilizer if no lime is recommended and magnesium according to soil test is less than 50 pounds per acre.