Plant Nutrient Element Management of Agricultural Soils in South Carolina

Based on Soil Test Results

Agronomic and Horticultural Crops
Home Gardens
Turfgrasses
Plant Elements
Soil Testing and Analysis
Nutrient Element Waste Management
South Carolina Land Resource Information

Clemson University

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I. 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 residing in South Carolina. The soil testing service provides lime and fertilizer recommendations essential for producers of agronomic and horticultural crops as well as those engaged in landscaping and home beautification services, managing tree farms, golf courses and commercial turf, and home gardeners. The soil test result and its accompanying recommendations provide both economic and environmentally sound information necessary to properly manage the fertility status of the tested cropland, turf or garden soil.

II. SOUTH CAROLINA LAND RESOURSE INFORMATION

1. Soil Groups/Soil Codes

There are more than 200 soil series in the state of South Carolina. For purposes of soil testing and fertility management, these soils have been divided into four groups (Groups 1 through 4). The physical characteristics to these soil series by Group are given in Table 1. In addition to these four groups, there are two additional classification groups:

- Group 5 for subsoil soil samples
- Group 6 for Carolina Bays and organic soil samples

These six soil groups are also referred to as ***Soil Codes***.

a. 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 occur on these soils the year after liming or when the soil is limed to a pH of 6.5 or higher.

b. Group 2/Code 2: Coarse-textured soils where the depth to the clay layer is 20 inches but not more than 40 inches. Underlying materials are sandy loams, sandy clay loams, and clay loams. Zinc deficiency on corn may occur 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.

c. Group 3/Code 3: Surface soil materials are mostly loamy sands, sandy loams and fine sandy loams to a depth of less than 20 inches, the depth to the clay layer. Subsoil materials are sandy clay loams, clay loams, silt loams and silty clay loams. Zinc deficiency on these soils may occur in corn if the soil is limed to a pH above 6.5. Manganese deficiency of soybeans could occur if the poorly drained soils in this group are limed to a soil pH greater than 6.2. A subsoil test for potassium, magnesium and sulfur is beneficial when making a fertilizer recommendation for these soils.

d. 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 the soil test recommendation for the crop to be grown. Good plant growth will be obtained when:

- soil pH is properly maintained
- adequate supplies of nitrogen (N), phosphorus (P) and potassium (K) exist in the soil
- favorable environmental conditions occur during the growing season

e. Group 5/Code 5: This soil code is reserved for all subsoil soil samples.

f. Group 6/Code 6: Designate soils from Carolina Bays and soils with organic matter contents greater than 10%. Good plant growth will occur if the pH of these soils is maintained between 5.0 and 5.5. Maintaining the pH within this range will also make correcting copper deficiency considerably easier. A "Target soil pH" of 5.5 is to be used for these soils.

2. Land Areas
Geographically, the five major group soils, Groups 1 through 4 and Group 6, are associated with five land resource areas. These five land areas are described below and shown in Figure 1.

a. Land Area 1. Blue Ridge mountain soils, designated as area "130" in Figure 1, occupy 2% of the state and are predominately those soils listed in Group 3 soil. There are a few soils from Group 4 in this area, but they all are best managed as Group 3 soils.

b. Land Area 2. Piedmont soils, designated as area "136" in Figure 1, occupy 35% of the state and are mostly Group 4 soils with small areas of Group 3 soils. For best results, all the soils in this region should be managed as Group 4 soils.

c. Land Area 3. Carolina Sandhill soils, areas designated "137" in Figure 1, occupy 11% of the state and are Group 1 and 2 soils. If limed based on a soil test recommendation, the only micronutrients that will be required are those recommended for specific crops. If the soil pH is high (>6.0 or 6.5 as defined by soil type), zinc deficiency can occur. Manganese deficiency should not occur unless the soil pH is above 6.2.

d. Land Area 4. Upper Coastal Plain soils, areas designated "133A" in Figure 1, occupy 14% of the state and are mostly Group 3 soils with some from Groups 1 and 2 soils throughout the region. With proper liming to maintain the desired soil pH, zinc and manganese deficiencies should not occur. Zinc deficiency may occur for corn in cool seasons if the soil pH is above 6.5. In those few regions of the area where the soils are poorly drained, manganese deficiency may occur for soybeans if the soil pH is above 6.2.

e. Land Area 5. Lower Coastal Plain, including the Atlantic Coast Flatwood and Tidewater soils, designated areas "153A" and "153B" in Figure 1, occupy 38% of the state and are mostly Group 1, 2, and 3 soils with some Group 4 and Group 6 soils in this land area. Managing the soil to prevent the occurrence of manganese deficiency is the major soil fertility requirement. The best approach is to soil test by soil area in order to identify the suspected fields, and then be prepared to take corrective steps if a manganese deficiency occurs. Manganese deficiency will most often occur on the poorly drained soils that are in Groups 2 and 3.

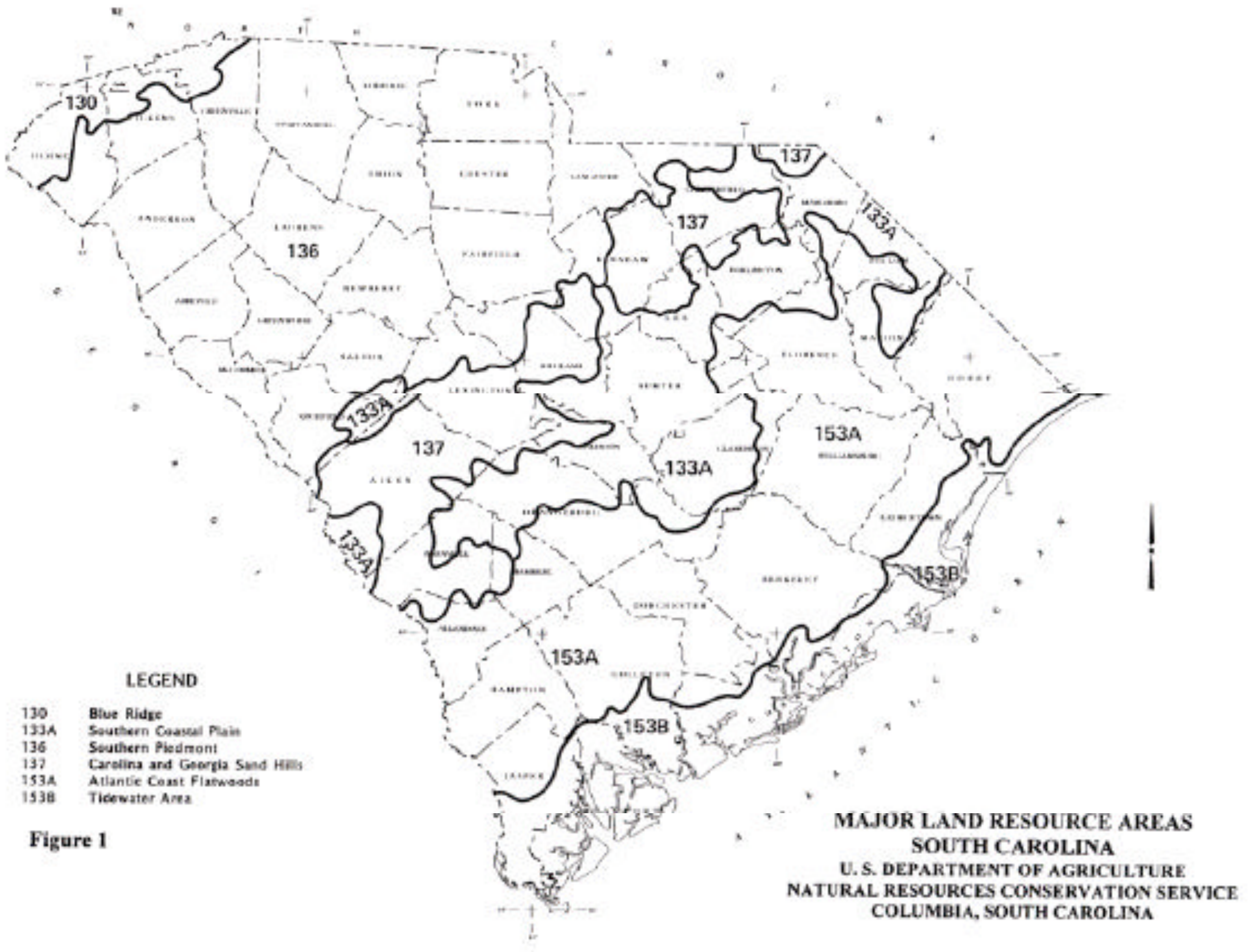

Figure 1

III. SOIL TESTING

1. Introduction

Most South Carolina cropland soils will require lime to correct soil acidity, and then maintain the soil at that pH level best for the crop(s) being grown. In addition, these same soils will require the application, as fertilizer, of one or more of the essential plant nutrient elements to sustain optimum crop growth. Some soils and/or crops may require high fertilizer application rates of these essential plant nutrient elements, others moderate or low, while some none at all.

Soils that are intensively managed should be tested every year whether lime or fertilizer had or had not been applied the previous year, since lime and fertilizer recommendations are made on a year-to-year basis.

The soil test result will determine how much lime and what plant nutrient elements need to be applied and at what rate to correct for soil nutrient element insufficiencies.

In order to use the Clemson University Soil Testing Service, the user must:

- acquire and complete the Soil Test Submission Form

- follow the sampling instructions to collect a soil sample representative of the area being tested
- submit sufficient quantity of soil in a designated container
- transport to the local County Extension Office or to the soil testing laboratory located on the Clemson University campus, Clemson, South Carolina
- pay the fee for the soil tests requested

2. Standard Soil Test

The **Standard Soil Test** includes the following:

- soil water pH (soil active acidity)
- buffer pH (used to estimate total exchangeable acidity)
- exchangeable potassium, calcium, magnesium, and sodium; and extractable phosphorus, boron, copper, manganese, and zinc
- cation exchange capacity (CEC) calculation
- acidity calculation
- % base saturation calculation

An extractable sulfate-sulfur determination for subsoils (Soil Group 5), and tests for soil organic matter, nitrate-nitrogen, and soluble salt contents are available upon request at an additional fee.

Prior to analysis in the laboratory, the received soil sample is air dried, and then the dried soil is crushed and placed on a 10-mesh sieve. That portion of the soil passing through the 10-mesh sieve is the portion assayed in the laboratory.

3. Laboratory Determinations

a. Soil water pH**:** measures the concentration of hydrogen (H^+) ions in the soil solution. Soil water pH, also referred to as just soil pH, is a measure of the amount of active acidity in the soil. Only a small portion of the exchangeable soil acidity is active. The soil pH is determined in a prepared 1:1 soil:water slurry [15 grams soil in 15 milliliters (mL) de-ionized water]. After stirring, then standing for 1 hour for equilibration, the soil pH is determined using a calibrated reference-glass electrode equipped pH meter

b. Buffer pH**:** measures total exchangeable or potential acidity in the soil [as hydrogen (H^+) and aluminum (Al^{3+}) ions]. The laboratory uses the Moore-Sikora buffer method for the exchangeable acidity determination. Fifteen milliliters of Moore-Sikora buffer solution at pH 8.0 are added to the soil-water slurry used for the soil pH determination. After mixing and equilibrating for 30 minutes, the buffer pH is determined using a calibrated reference-glass electrode equipped pH meter.

c. Exchangeable and Extractable Plant Nutrient Elements**:** 9 plant nutrient elements, exchangeable potassium, calcium, magnesium and sodium, and extractable phosphorus, boron, copper, manganese and zinc, are determined after being extracted from an aliquot of soil using the Mehlich No. 1 extraction reagent [also known as the "Dilute Double Acid" (0.05 N HCl in 0.025 N H_2SO_4)] procedure. Four milliliters (mL) of soil (approximately 5 grams) and 20 mL extraction reagent are shaken together for 5 minutes, and then the mixture filtered and the filtered extract collected. The concentrations of the 9 nutrient elements in the collected filtrate are determined by inductively coupled plasma (ICP) emission spectrophotometry.

The quantity of each nutrient element extracted from the soil is reported in 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 2 million pounds. The pounds per acre of the nutrient element extracted does not directly equate to that available for crop use, but is an "index value" that is correlated with a designated soil fertility status level and potential crop response to an application of that nutrient element. The index values are given in Section VIII. "Soil Test Rating System."

***d. Test for Sulfur*:** sulfate-sulfur is extracted from the soil using a 0.5 *N* ammonium acetate in 0.25 *N* acetic acid extraction reagent. The sulfur concentration in the obtained filtrate is determined by ICP emission spectrophotometry. The reported soil sulfur concentration is as that described for the other nutrient elements (see above). Sulfur is considered sufficient if the sulfur concentration is 20 pounds or more per acre in the surface soil and 40 pounds or more in the subsoil (Soil Group 5). Concentrations of sulfur less than these levels are considered "insufficient," and a sulfur-containing fertilizer recommendation is made for sulfur-sensitive crops.

e. Organic Matter Content: organic content is determined by loss-on-ignition. An aliquot of soil is dried at 105°C for 2 hours, its weight determined, and then the soil sample is placed in a muffle furnace set at 360°C. After 3 hours, the soil is cooled and then weighed. The difference in soil sample weight between that at 105°C and 360°C determines organic matter content.

f. Nitrate-nitrogen (NO_3-N): a soil aliquot is extracted with 0.04 M ammonium sulfate [$(NH_4)_2SO_4$] and the nitrate concentration in the filtered extract is determined by automated flow injection cadmium-reduction spectrometry.

g. Soluble Salts: an aliquot of soil is stirred in a measured volume of water then shaken intermittently for 1 hour. The soil-water slurry is filter-screened and the conductivity of the filtrate determined using a conductivity meter. The conductivity measured is recorded as millimhos per centimeter (mmhos/cm).

4. Calculated Determinations

a. ***Cation Exchange Capacity (CEC):*** clay and organic matter colloids in the soil are negatively charged particles that attract and bind positively charged cations, aluminum (Al^{3+}), calcium (Ca^{2+}), hydrogen (H^+), magnesium (Mg^{2+}), potassium (K^+), and sodium (Na^+). The quantity of cations retained by the soil is referred to as the soil's "Cation Exchange Capacity (CEC)." The CEC is calculated from the sum of the determined exchangeable acidity and K^+, Ca^{2+}, Mg^{2+}, and Na^+ cation concentrations. The CEC is reported in milliequivalents per 100 grams (meq/100g) of soil.

The higher the CEC of a soil, the greater its storage capacity for the cations, H^+, Al^{3+}, Ca^{2+}, Mg^{2+}, K^+, and Na^+ and the greater its ability to resist a change of pH, its buffer capacity. Low CEC soils require more frequent liming, and normally the potassium level in the soil cannot be increased to a soil test rating higher than "Medium." The soil's CEC is not a useful index or measure of soil productivity. However, low CEC (<5 meq/100g) soils require greater management skill than soils with a higher CEC (>5 meq/100g) and are subject to greater leaching losses.

b. Base Saturation and Acidity: cations held on the soil's exchange sites are divided into acid-forming (H^+ and Al^{3+}) and base-forming (K^+, Ca^{2+}, Mg^{2+}, and Na^+). Base Saturation is that proportion of the CEC consisting of the basic cations and is expressed as a percent of the CEC. For example, the percent base saturation of a soil containing 3 meq/100g of exchangeable potassium, calcium, magnesium, and sodium (sum of all four) and having a CEC of 6 meq/100g would be 50%. The proportion of the CEC consisting of the acid-forming cations, H^+ and Al^{3+}, is called acid saturation. In this example, the acid saturation percentage would also be 50% since the sum of the acid and base saturation percentage must equal 100%.

c. Lime Requirement: The lime requirement recommendation is that amount of agricultural grade limestone or another liming material needed to raise the soil pH to the "Target pH" through soil application. Under South Carolina conditions and for most mineral soils, the Target soil pH will be either 6.0 or 6.5, depending on the specific soil type and crop to be grown.

Both the soil and buffer pH determinations are needed to calculate the lime requirement and both determinations are given on the Soil Analysis Report form. The lower the buffer and soil pHs, the greater will be the lime requirement. Two different soils may have the same soil pH, but different lime requirements. Also, two soils may have the same lime requirement, but different soil pHs. These differences are related to the soil's CEC (due to clay and organic matter colloid contents). Since most crops grow best when the soil is slightly acidic, the given lime requirement recommendation is adequate to neutralize only a portion of the total exchangeable acidity, depending on what the Target pH is for the crop to be or being grown. At soil pH 6.0, typical of most mineral soils in South Carolina, about 40% of the soil CEC is saturated with acidic (H^+ and Al^{3+}) and 60% saturated with basic (Ca^{2+}, Mg^{2+}, K^+, Na^+) cations. At soil pH 6.5, these same soil types are about 25% acid saturated and 75% base saturated.

Following a given lime recommendation, the soil pH will generally be maintained within the desired range for one year for sandy soils, and up to 3 years for silt loam/clay soils, depending on applied cultural practices and crop removal amounts.

5. Surface Soil Sampling Procedures

Recommendations based on a soil test result are no better than the quality of the collected soil sample. The soil sample must be representative of the area to be limed and fertilized. For example, if more than one soil type exists within the field to be tested, and it is practical to manage each soil type area separately, collect a composite sample from each soil type.

a. Cropland Soil Sampling Procedure**:** collect a series of soil cores, using either a soil probe or spade, from each of 10 to 20 randomly selected spots in the field or area to be tested. Take the soil cores from the surface to a depth of 6 to 8 inches or to the plow depth on cultivated fields. Take soil cores from pastures, hay fields, and areas that are not being cultivated to a depth of 2 to 4 inches from the surface soil. Mix the collected soil cores well, forming the composite that is then placed into the soil bag for submission to the laboratory. A single composite sample should represent no more than 10 cropland acres. Low spots, eroded areas or other areas that are being managed differently should be sampled separately, and if practical, treated differently than the main area. If Precision Farming Technology procedures are being used, follow the sampling recommendations for the system being employed.

b. Home and Garden Soil Sampling Procedure**:** since a single composite soil sample may represent an area less than 100 square feet, whether the area is a large field or a small garden plot, take a sufficient number of soil cores from several locations in order to obtain a composite sample that is representative of the entire area. Using either a soil probe or spade, core from the surface to the depth that the garden plot will be tilled.

c. Lawn and Recreational Turf Soil Sampling Procedure**:** a composite soil sample to be representative of the entire area requires taking 10 to 12 soil cores from randomly selected locations. Core from the soil surface under the turf mat to a depth of 2 to 4 inches using either a soil probe or spade. Separate soil samples should be taken for each turf species.

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

Clemson University Agricultural Laboratory's fertilizer recommendations based on a surface soil test result can be adjusted based on the nutrient element (potassium, magnesium, and/or sulfate-sulfur test levels) status of the subsoil when the following conditions exist:

- physical impediments to rooting into the subsoil, such as plow- or hard-pan, are absent or have been disrupted by subsoiling or comparable deep tillage
- depth from the soil surface to the subsoil is no greater than 20 inches
- subsoil pH is not less than 5.5
- the roots of the crop plant are capable of reaching into the subsoil

From research conducted in South Carolina and adjacent states, K^+ and Mg^{2+} cations and the SO_4^{2-} anion, have been found to accumulate in the subsoil clay layer of Coastal Plain soils. These three plant nutrient elements (potassium, magnesium, and sulfur) may be present at sufficient available quantity to supply all or most of the crop requirement. For example, even though the surface soil may test "low" or "medium" in potassium, there may be sufficient potassium in the subsoil to satisfy the crop requirement without the need to apply this element as fertilizer to the surface soil. The same situation may exist for both magnesium and sulfate-sulfur, either eliminating the need to include either element in the fertilizer recommendation, or substantially reducing the recommended application if that rate was only based on the surface soil test result. However with time, failing to maintain the surface soil test level within the "sufficiency" range can result in a depletion of the subsoil level, thereby reducing crop yield.

For sandy Coastal Plain soils when subsoiling is practiced, subsoil samples should be taken from the top 3 to 4 inches of the more clayey layer, drawn from the same bored auger-hole used to collect the surface sample. Keep the subsoil sample separate from surface sample and clearly label the subsoil sample "Soil Group 5" on the outside of the soil sample bag and enter a "5" for the Soil Code on the sample submission form. Fertilizer potassium, magnesium and sulfur recommendations based on the surface soil test results will be adjusted based on the potassium, magnesium and sulfate-sulfur levels, respectively, found in the subsoil. Actual details of these adjustments are described in a subsequent section (XI. "Subsoil Fertility").

The surface soil sample must be submitted in a separate bag along with the subsoil sample. Subsoil sampling should be included as a regular soil testing procedure when in-row subsoiling is the routine cultural practice for growing row crops.