THE UNIVERSITY OF GEORGIA
COOPERATIVE EXTENSION

College of Agricultural and Environmental Sciences
College of Family and Consumer Sciences

SOIL TEST HANDBOOK FOR GEORGIA

Georgia Cooperative Extension

College of Agricultural & Environmental Sciences

The University of Georgia

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INTRODUCTION

The soil testing program at the University of Georgia is a joint program of the Cooperative Extension and the Agricultural Experiment Station. The Cooperative Extension has the primary responsibility of operating the Soil, Plant, and Water Laboratory, providing recommendations, educational materials and supplies. Soil test calibration and soil fertility research are jointly administered by the Cooperative Extension and the Agricultural Experiment Station, under the Dean and Director, College of Agricultural and Environmental Sciences.

The Soil Testing and Plant Analysis Laboratory was established in 1970 to better serve the analytical needs of farmers and homeowners. The laboratory was equipped with the most modern analytical equipment to provide rapid and accurate analyses. Since 1970, soil sample volume has increased from 43,000 samples per year to more than 100,000 the majority of years. As a result of the increased sample volume and expanded services, laboratory space was increased by an additional 4,000 square feet in 1988-1989. In response to the rapid increase in sample volume and the need for quick turnaround time, the analytical equipment is continually updated and data acquisition and computations for making soil test interpretations and recommendations have been computerized. In addition, personal computers in all county Extension offices allow for electronic transfer of soil test data and recommendations back to county offices the same day samples are processed at the laboratory. As a result of these innovations it is possible to process a large daily volume of samples and yet maintain a laboratory turnaround time of approximately two days. In 1996, the laboratory was renamed the UGA Soil, Plant, and Water Laboratory when it expanded its analytical services to water testing.

In 1997, a new soil test report form was developed for reporting soil test results and limestone and fertilizer recommendations. The new forms made it possible to report soil test results both numerically and graphically. Illustrating the data graphically with bar graphs made it easier for the user to see the magnitude of the soil test level for each element and soil pH. In addition, the new report form was compatible with the regression technique for making fertilizer recommendations for agronomic, commercial vegetable, fruit, and nut crops. The regression technique makes it possible for fertilizer recommendations to be a continuous function of small incremental changes in phosphorus and potassium soil tests.

In 2004, the graphic information on soil test reports was modified to address changes in the methodology for determining soil pH and the lime requirement of soils. In order to make the reports more user friendly for growers and homeowners, they were modified again in 2006. The report forms for agronomic and horticultural crops now include pH, which is the equivalent water pH, and the Lime Buffer Capacity Index. For agronomic crops with a target pH of 6.0, reports now include lime recommendations for a target pH of 6.0 and 6.5, allowing the user to make the decision on the rate to use based on economics, field variability, and other production variables. Homeowner reports also present soil test results in graphic and numerical form but in order to simplify the reports, soil test levels are ranked as either "sufficient" or "insufficient" and information pertaining to the Lime Buffer Capacity Index is omitted.

This handbook is designed to serve as a reference guide for the University of Georgia Cooperative Extension personnel and others regarding Georgia's lime and fertilizer recommendations and to provide basic information pertinent to the soil testing program. It is published in a loose-leaf notebook format. Therefore, when recommendations are updated, individual pages can be sent to each user, who can remove the outdated material and insert the new pages. This will preclude the need for frequent reprinting of the entire bulletin.

Although all recommendations are made by computer, from time to time county agents and other users of this handbook may have to explain why certain recommendations are made for certain crops and cropping systems. Therefore, it is recommended that all users become familiar with the handbook as it contains valuable background information that will be helpful in understanding the basic principles of soil testing and the procedures used for developing lime and fertilizer recommendations.

Based on new research data, some revisions were made in existing recommendations and recommendations for additional crops have been added. Several faculty members from the Crop and Soil Sciences and Horticulture Departments served as resource personnel and assisted in formulating the recommendations in this handbook. These individuals are recognized in each of the respective sections.

SOIL TESTING

C. Owen Plank, Extension Agronomist - Retired
David E. Kissel, Director, Agricultural and Environmental Services Laboratories

A soil test is a chemical method for estimating the relative nutrient supplying power of a soil. Several chemical extractants have been developed, based on the chemical and physical properties of soils within various regions of the country, to evaluate the fertility status of soils. The extractant used in Georgia is the Mehlich-1 (0.05 N HCl in 0.025 N H_2SO_4) and was designed for use on low cation exchange capacity soils of the Southeast.

Most Georgia soils are low in pH and/or one of the essential plant nutrients. Soils in the state are quite variable and their response to lime and fertilizer additions vary considerably. For example, at a medium test level the soil will not require the application of as much phosphorus or potassium as it will at a low test level. A soil test is the best way to assess how soils will respond to these additions and to determine the amount of lime and fertilizer needed for crop production. Although this is the primary objective of soil testing, information gained from soil testing can also be used to: (1) monitor the fertility status of a given field – this is accomplished by maintaining soil test results on fields over a period of time, and (2) to evaluate the fertility status of soils on a county, soil area, or state-wide basis by the use of soil test summaries.

One important aspect to remember is that a soil test only measures a portion of the total nutrient supply in the soil. The values obtained when a soil sample is analyzed are of little use as raw analytical data. In order to make use of the values in predicting nutrient needs of crops, the test must be calibrated against nutrient rate experiments in the field. The nutrient category ratings and recommendations contained in this handbook are the result of the compilation of data from numerous field experiments in Georgia and neighboring states over many years.

SOIL SAMPLING

Soil testing can be divided into four steps (1) sampling, (2) analysis, (3) interpretation, and (4) recommendations. One of the most important aspects of soil testing is that of obtaining a representative sample of the area in question. Unfortunately, however, this is the weakest step in most soil testing programs. Due to the heterogeneous nature of soils, there is tremendous variability in soils across fields, even in those that appear to be uniform. In most fields in Georgia this is confounded due to the presence of two or more soil types.

Variability in the nutrient levels of soils can occur within a relatively small area. It has been shown that there is as much variability between cores taken at 10-foot spacings as ones that are spaced 100 feet apart, provided there is no substantial change in the soil type or soil characteristics. Intensive soil sampling is one of the most efficient ways to evaluate variability within a field. Depending upon the conditions, this could mean that several composite samples consisting of 10 to 20 individual cores be taken from a field.

Usually a composite soil sample weighs about 2 pounds. If the sample is taken from a 10-acre field to a depth of 6-7 inches, it would represent about 20,000,000 pounds of surface soil. Yet from the 2 pounds of soil that is sent to the laboratory for analysis, only 25 grams (less than 1 ounce) of soil is used for analysis. Therefore, it is very important that the sampling instructions be followed carefully because the analytical results and recommendations can be no better than the sample submitted to the laboratory.

Sampling Tools

There are a number of devices that can be used to collect the soil sample. The soil sampling tube is one of the more common tools and should be available in every county agent's office. When sampling small areas or when only a few samples need to be taken, a spade or trowel is a sufficient device for collecting individual soil cores or slices. When sampling to depths of 8 to 20 inches, it is necessary to use a soil auger. However, all of these sampling tools must be properly used if the collected samples are to be representative of the area under test.

Size of Area to Sample

Traditional Methods

The size of the area from which a sample is taken may vary from less than one acre (for example, lawns, gardens, etc.) to 15 acres. For most field conditions the size may range from 5 to not more than 15 acres. Variations in soil types, slope, drainage, or past management may require that smaller areas be sampled, resulting in three or more composite samples per field.

Precision Agriculture Methods

Precision farming uses the modern tools of Global Positioning Systems (GPS), Geographic Information Systems (GIS), and remote sensing to delineate subsections of fields that can be sampled separately. The division of field areas that can be sampled separately is typically based on soil type, field topography, or crop growth or yield maps from the previous season. Although areas of poor crop growth may be due to factors other than plant nutrition, sampling these areas separately helps to determine if lack of fertility may be reducing crop yield.

Areas Not To Sample

Due to past management and cultural practices, certain areas are brought into fields and should not be sampled. These are:

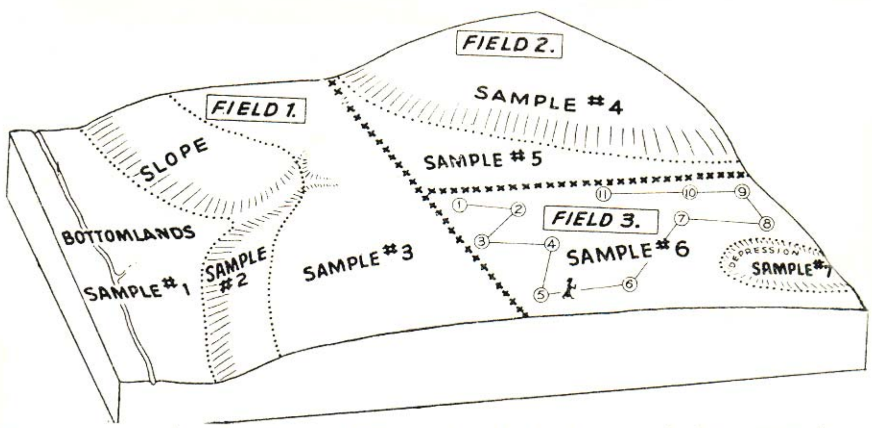
- Old fertilizer bands;
- Field borders, especially close to a gravel road;
- Dead furrows or back furrows;
- Terraces, old fence rows, or roads;
- Animal excretion spots;
- Where there have been straw stacks, manure piles, brush piles, or lime piles;
- Trouble spots, such as eroded areas. In some cases these areas may be sampled separately;
- Near trees;
- Old building sites.

Number of Cores

A composite soil sample is made up of a number of individual cores taken at random over a given area. The purpose of this is to minimize the variability that exists. This variation may have been caused by previous lime and fertilizer applications or slight soil variations.

If an insufficient number of cores are pulled for a composite sample, the sample results can be biased either too high or too low. It is recommended that a minimum of 10 to 20 cores be taken for a composite sample. Previous sampling studies have shown that the number of cores required per composite sample varies with the size of the area being sampled. For example, 20 cores were required for a 20-acre field, 15 cores for a 10-acre field, and 10 cores for a 5-acre field.

The cores should be taken at random over a section of the field or plot, and should be representative of the entire area. When all of the cores have been collected they should be thoroughly mixed together. After mixing, a sufficient amount of sample is placed in the soil sample bag to fill the bag up to the "fill line."



Areas cropped or fertilized differently should be sampled separately.

When to Sample

Soil test levels will change during the year, depending on the temperature and moisture of the soil. It's important, therefore, that samples be taken at the same time each year so results from year to year can be compared. Generally, nutrient levels will be lower during summer and fall as compared to winter and spring.

The best time to sample is one to six months prior to planting. The earlier the better if lime is needed, because lime requires several months to fully react and neutralize soil acidity. Fertilizer should be applied closer to the time the crop needs it, as recommended in the soil test report.

For most situations soils need to be tested every 2 to 3 years. However, test the soil when there is a suspected nutrient deficiency, once per crop rotation, or once every other year if the soil is fertilized and cropped intensively. **Annual sampling is recommended** (1) on areas where high-value cash crops such as tobacco and vegetables are grown, (2) on areas testing high in P and K where no phosphate or potash is recommended and none is applied, and (3) on areas where the annual nitrogen application rate exceeds 150 pounds of N per acre.

Soil samples should also be taken following crops where large amounts of nutrients are removed in the harvested portion of the plant, particularly silage crops, hybrid bermuda hay, and when peanut vines are used for hay.

Keep previous soil test results from individual fields (or advise growers to keep records) and refer to them when adjusting lime and fertilizer recommendations. Large changes in pH or nutrient levels may signal that a sampling or analytical error has been made and, if not taken into account, could lead to an improper recommendation.

Contamination

In order to prevent contamination of the sample, clean sampling tools and collection containers should be used. Do not use galvanized or brass buckets and tools. Such devices will contaminate the samples with copper and zinc. It is best to use plastic buckets and steel sampling devices.

Specific Sampling Procedures

Plowed Field Soils

Samples should be taken to the plow depth. The lime recommendations found in Tables A, B, C, and D are based on an 8-inch depth. Make adjustments in the lime recommendations to compensate for plow depth if other than 8 inches. The table "Lime Requirement Adjustments for Plow Depth" lists the adjustments for several plow depths.

Similarly, when plowing to greater depths, fertilizer rates may need to be increased to compensate for the greater volume of soil to which the fertilizer is being applied. This does not ordinarily pose a serious problem because sampling to depths of 8 to 12 inches usually results in lower soil test readings and high fertilizer recommendations.

In situations where the grower wants to build soil test levels to a higher level, failure to compensate for plow depth may result in a slower rate of buildup. Fertilizer recommendations are based on a 6-inch depth; consequently, if the effective plow depth or zone of mixing is 8 inches, the fertilizer rate should be increased 30%. If the plow depth is 10 inches, the fertilizer rate should be increased 60%. Therefore, if the fertilizer recommendation is 60 pounds per acre, the recommendations for 8 and 10-inch plow depths would be 80 and 100 pounds per acre, respectively.

Pasture and No-Till Fields

Pastures and no-till fields should be sampled to a depth of 4 inches. This represents the depth of active nutrient uptake, and the zone where residual fertilizer nutrients accumulate.

Orchards

Numerous sampling studies have shown that with most orchard crops the greatest root activity occurs at a depth of 8 to 12 inches. When sampling orchards, this depth should be included in the sample. For peach and apple orchards, a sampling depth of 12 to 14 inches is recommended. For pecans, a depth of 6 to 8 inches is recommended.

Gardens

The recommended sampling depth for gardens is 6 inches. This is the normal spading depth of most garden soils.

Lawns and Turf

Take soil samples to a depth of 4 inches. This is the actual soil depth and should not include roots or other accumulated organic material on the surface. When collecting soil plugs, remove the organic residue that may be present on the surface; this eliminates the contamination of the soil sample with dried plant material, which can influence the analysis. In order to take an inconspicuous sample, use small-diameter soil sampling tools. A sampling device for golf greens and tees can be made from an old golf club shaft.

Subsoil Sampling

Take a subsoil sample every four to five years. This is especially important in problem areas. A subsoil sample should be to a depth six inches below plow depth or normal surface sampling depth.

SOIL TESTING SERVICES AVAILABLE AT THE SOIL, PLANT, AND WATER LABORATORY

Leticia Sonon, Program Coordinator, Soil, Plant, and Water Laboratory
David E. Kissel, Director, Agricultural and Environmental Services Laboratories

1. **ROUTINE TEST:**
   Soil pH, Lime Requirement, Extractable Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Manganese (Mn), and Zinc (Zn) by the Mehlich I extract.

2. **MICRONUTRIENT & OTHER EXTRACTABLE ELEMENT TESTS:**
   Iron (Fe), Copper (Cu), Cadmium (Cd), Lead (Pb), Sodium (Na), and Nickel (Ni) by the Mehlich I extract.

3. **OTHER TESTS:**
   a. Hot-water Extractable Boron (B)
   b. CAST (Calcium Soil Test – Peanut Pegging Zone)
   c. Nitrate Nitrogen (Available NO_3-N)
   d. Ammonium Nitrogen (Available NH_4-N)
   e. Nitrite Nitrogen (NO_2-N)
   f. Soluble Salts (Electrical Conductivity, EC)
   g. Organic Matter (OM)
   h. Mechanical Analysis (sand, silt, clay) + Soil Type

4. **TOTAL ELEMENTAL ANALYSIS:**
   Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sulfur (S), Manganese (Mn), Iron (Fe), Aluminum (Al), Boron (B), Copper (Cu), Zinc (Zn), Sodium (Na), Lead (Pb), Nickel (Ni), Chromium (Cr), Cadmium (Cd), Molybdenum (Mo), Arsenic (As), Selenium (Se), Mercury (Hg)

5. **TOTAL CARBON (TC), TOTAL NITROGEN (TN), TOTAL SULFUR (TS)**

6. **GYPSUM SUBSOIL TEST**

7. **COMMERCIAL GREENHOUSE OR NURSERY SOIL:**
   pH, soluble salts (EC), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Nitrate-N (NO_3-N), Ammonium-N (NH_4-N), Boron (B), Copper (Cu), Manganese (Mn), Zinc (Zn)

8. **CATION EXCHANGE CAPACITY (CEC) AND PERCENT BASE SATURATION (%BS)**

A fee is charged for these analyses. Refer to the fee schedule provided by the laboratory to determine the charges for these analyses. Monthly billing is available for most analyses run by the laboratory. The monthly invoice contains a list of all samples received from the extension office, including client names, lab numbers, tests requested, and price per sample.

For non-online submission, a check to cover the cost for the tests should accompany the soil sample and be made payable to the Cooperative Extension office or to the Soil, Plant, and Water Laboratory. Unless prior payment arrangements have been made, no tests will be performed for samples received without payment for tests requested.

Provide all the information asked for on the soil sample bag, including the desired tests. Information given on the following page gives suggestions for selecting the proper soil analysis and/or analyses.

DETERMINING THE APPROPRIATE SOIL TEST

Not all the soil tests are equally applicable to every soil and cropping situation. The following suggestions will help you determine the appropriate soil test:

Soil Test	Purposes
ROUTINE TEST: pH, L.R., P, K, Ca, Mg, Mn, and Zn	All soils and crops. This test should be selected to evaluate the overall fertility status of a soil and for making fertilizer and lime recommendations.
OTHER TESTS:	
Hot-water Extractable Boron (B)	Primarily for sandy or eroded soils, low in organic matter for the crops, alfalfa, cotton, peanuts, and root crops.
Organic Matter (O.M.)	For all soils and crops. Knowing the O.M. content is of primary interest for special situations where soil tilth and water-holding capacity are important.
Soluble Salts (S.S.)	Of interest where large quantities of fertilizers have been applied particularly for potted plants, greenhouse beds, lawns and other turf crops, or ornamental plantings or beds. Not generally applicable to field soils.
Nitrate Content (NO_3)	Of particular interest for greenhouse soils, potted plants, and beds. Not generally applicable to field soils. As the NO_3-N level of soil increases, the rate of application of fertilizer nitrogen should be reduced.
Commercial Greenhouse or Nursery Soil Test: pH, Soluble Salts, NH_4, NO_3, P, K, Ca, Mg, B, Cu, Mn, Zn	For mixes that include soil, sand, peat, pine bark, perlite, vermiculite, etc., used to produce greenhouse or potted vegetable, flower, or ornamental plants. Not recommended for soil.
Subsoil Gypsum Test	Applicable to soils on which acid-sensitive crops such as alfalfa and cotton are to be grown.

OTHER ANALYTICAL SERVICES AVAILABLE AT THE AGRICULTURAL AND ENVIRONMENTAL SERVICES LABORATORIES

Leticia S. Sonon, Program Coordinator, Soil, Plant, and Water Laboratory
David E. Kissel, Director, Agricultural and Environmental Services Laboratories

A fee is charged for the following analytical services. Please refer to the fee schedule provided by the laboratory for the various charges.

A. PLANT TISSUE ANALYSIS

1. **BASIC PLANT ANALYSIS:** N, P, K, Ca, Mg, S, Mn, Fe, Al, B, Cu, and Zn

2. **COTTON PETIOLE ANALYSIS:** NO_3, P, and K

3. **TOTAL ANALYSIS:** Carbon (C), N, S, Arsenic (As), Selenium (Se), Mercury (Hg)

B. FEED AND FORAGE ANALYSIS

1. **Hays and Silage:**
   (1) **NIR or Wet Chemistry –** Moisture, Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), Calculated Crude Fiber, Crude Protein, Lignin, Total Digestible Nutrients (TDN), IVTDMD Prediction
   (2) **Minerals** - P, Ca, Mg, K, NO_3, Arsenic (As), Selenium (Se)
   (3) **pH**
   (4) **Relative Forage Quality (RFQ)**

2. **Other Feeds –** Moisture, Crude Fiber, Protein, P, Ca, Mg, IVTDM, Prediction

3. **Other Analysis upon Request**
   (1) Crude Fat
   (2) Bound Protein
   (3) Ash
   (4) Pepsin Digestibility
   (5) Urease Activity
   (6) Calorimetry/Gross Energy (BTU)
   (7) Total Aflatoxin
   (8) Protein Solubility (soybean meal)
   (9) Cyanide (Prussic Acid)
   (10) Salt/Chloride
   (11) Chlorinated Hydrocarbon and Organophosphate Insecticide Screen on Feed and Feed Ingredients

C. WATER ANALYSIS

1. **Basic Water Test:** pH, P, K, Ca, Mg, Mn, Fe, Al, B, Cu, Zn, Na, Cd, Ni, Cr, Mo, pH, and calculated hardness

2. **Expanded Water Test:** pH, P, K, Ca, Mg, Mn, Fe, Al, B, Cu, Zn, Na, Cd, Ni, Cr, Mo, pH, and calculated hardness, Chloride (Cl), Fluoride (F), Nitrate (NO_3), Phosphate (PO_4), Sulfate (SO_4)

3. **Other Tests:** Ammonium (NH_4), Lead (Pb), Arsenic (As), Selenium (Se), Mercury (Hg), Thallium (Tl), Antimony (Sb), Soluble Salts (Electrical Conductivity), Alkalinity, Acidity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Solids (TS), Total Volatile Solids (TVS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Phenol, Cyanide, Color, Turbidity, Oil and Grease Non-Petroleum

4. **Water Microbiology:** Total Coliform, *E. coli*, Fecal Coliform, Heterotrophic Count, Enterococcus, Fecal Enterococcus

5. **Pesticide Analysis:** Chlorinated Hydrocarbons and Organic Phosphate Insecticides, Herbicides, Phenoxyherbicides, Termaticides

D. ANIMAL WASTE (POULTRY LITTER, MANURE, AND LAGOON)

1. Basic Analysis – N, P, K, Ca, Mg, Mn, Fe, Al, B, Cu, Zn, Na, S
2. Kjeldahl Nitrogen (TKN)
3. Nitrate (NO_3)
4. Ammonium (NH_4)
5. Moisture

E. BIOSOLIDS, SLUDGE, AND NON-ANIMAL WASTE

1. Total Minerals – P, K, Ca, Mg, Mn, S, Fe, Al, B, Cu, Zn, Na, Pb, Cd, Ni, Cr, Mo
2. Ammonium (NH_4) and Nitrate (NO_3)
3. Kjeldahl Nitrogen (TKN)
4. Moisture, pH
5. Arsenic (As), Selenium (Se), Mercury (Hg)
6. Total Solids, Total Volatile Solids
7. Total Carbon, Total Nitrogen, Total Sulfur
8. Fecal Coliform

SUPPLIES AVAILABLE FROM THE COOPERATIVE EXTENSION STOREKEEPER

Leticia S. Sonon, Program Coordinator, Soil, Plant, and Water Laboratory
David E. Kissel, Director, Agricultural and Environmental Services Laboratories

1. **Soil Sample Bags**

   Packaged in lots of 100 to 500. Bags are to be used to submit soil samples to the laboratory for analysis. Sample bags should be filled to the **Fill Line**.

2. **Soil Sample Shipping Boxes**

   The size of the shipping boxes corresponds to the approximate number of soil sample bags that fit into the boxes.

   4x4x4 = 2-3 samples
   6x6x6 = 8-10 samples
   6x6x10 = 14-16 samples
   12x10x4 = 18 samples
   12x10x6 = 24 samples
   12x10x12 = 36 samples

3. **Water Bottles**

   Water bottles are available in various sizes for specific analyses. To order the appropriate bottle/and or bottles go to: http://aesl.ces.uga.edu and click Sample Containers, then Water Bottles.

   The above supplies should be ordered directly from the Storekeeper, Cooperative Extension Service, University of Georgia, Hoke Smith Annex, Room 107, Athens, GA 30602. Specify the number of packages (pkg.) desired for the bags and boxes. Order forms for these supplies can be obtained from the Storekeeper.

SUPPLIES AVAILABLE FROM THE SOIL, PLANT, AND WATER LABORATORY

4. **Soil Sample Submission Form**

   The soil sample submission form is available online. Go to http://aesl.ces.uga.edu/forms, and then click Soil Submission Form. The form can be printed in any quantity and is to be used by the County Office for recording the grower's name, sample number, crop codes, etc. This form must accompany soil samples submitted to the laboratory.

5. **Plant Analysis Kits**

   Available in any quantity for submitting plant and leaf tissue samples to the laboratory.

6. **Cotton Petiole Analysis Kits**

   Available on an annual basis in any number for submitting cotton petiole samples to the laboratory.

7. **Soil Sample Tubes**

   These stainless steel soil sampling tubes are ideal for taking soil samples. They are available for purchase directly from:

   Soil, Plant, and Water Laboratory
   2400 College Station Road
   Athens, GA 30602-9105

   The price for each tube is $45.00.

PROCEDURES FOR SUBMITTING SOIL SAMPLES TO THE UNIVERSITY OF GEORGIA SOIL, PLANT, AND WATER LABORATORY

Leticia Sonon, Program Coordinator, Soil, Plant, and Water Laboratory
David E. Kissel, Director, Agricultural and Environmental Services Laboratories

Laboratory Location and Turnaround Time:

The Soil, Plant, and Water Laboratory is located on the campus of the University of Georgia at 2400 College Station Road in Athens. It is equipped with the most modern instruments available for rapid and accurate soil sample analysis. Analysis time in the laboratory for a routine test averages approximately two days, depending on the time of year and current work load. Each county office can download analysis results and recommendations directly from the laboratory.

Procedure

Soil sample bags provided by the laboratory are to be used for submitting soil samples. Information asked for on the sample submission forms should be provided. This includes name and address of the sender, crop to be grown, sample identity or number, county code, and where applicable, a soil code. The county extension office is encouraged to submit routine samples online through the Data Transfer program.

Use of Soil Code

The soil code is to be used only in special situations to override the Coastal Plain and Piedmont ratings. There are locations, particularly along the fall line in central Georgia, where a county may have both Piedmont and Coastal Plain type soils. If a county is designated as being in the Coastal Plain and a Piedmont type sample is submitted, the rating will obviously be incorrect. A system has been developed by which the basic rating system can be overridden. When creating a soil submission in Data Transfer, you'll see "Piedmont" or "Coastal" in the **Soil type** column. If a Piedmont rating is needed in a Coastal Plain county (for example, Greenville soil), press the letter "P" in the Soil type column. Likewise, if a Coastal Plain rating is needed in a Piedmont county, press the letter "C." These items ensure proper identification for making lime and fertilizer recommendations by computer.

Plant Analysis

Plant tissue samples can be submitted to the Soil, Plant, and Water Laboratory for analysis and evaluation. Mailing kits that include sampling instructions, questionnaire, and a mailing envelope should be used to submit plant tissue samples to the laboratory. When a supply of kits is needed, a request should be sent to the laboratory. Order forms can be obtained online at http://aesl.ces.uga.edu/forms. Click **Order Form for Soil, Plant & Water Analysis Supplies**. Plant tissue samples are routinely analyzed for N, P, K, Ca, Mg, S, Mn, Fe, B, Cu, Zn, and Al.

Cotton Petiole Analysis

Cotton petiole samples are analyzed for the purpose of monitoring the nitrate nitrogen (NO_3-N), phosphorus (P), and potassium (K) levels in cotton so adjustments can be made in in-season fertilization practices. Cotton nitrate monitoring kits that include sampling instructions, field entry cards, information cards, and mailing envelopes should be used to submit petiole samples to the laboratory. The kit includes supplies for submitting samples on a weekly basis over a 10 week period. Requests for kits should be directed to the Soil, Plant, and Water Laboratory, 2400 College Station Road, Athens, Georgia 30602-9105.

Feed Analysis

Evaluation and ration recommendations for feeds are made by the Extension Animal and Dairy Science Departments. Sampling information can be obtained from the Extension Animal and Dairy Science Departments. Feed and forage testing application forms for beef cattle, dairy cattle, swine, sheep, horses, and goats must accompany each sample and can be obtained online from the Soil, Plant, and Water Laboratory at http://aesl.ces.uga.edu/forms. Click **Feed and Forage Testing Application Form For Beef Cattle and Dairy Cattle** and/or **Feed and Forage Testing Application Form For Swine, Sheep, Horses, and Goats**.

Water Analysis

The laboratory analyzes water samples used for different purposes such as drinking water, irrigation, and fishponds. Sample volumes required for submission vary depending upon the type of tests requested. Information on sample volumes and containers can be obtained online at http://aesl.ces.uga.edu/WaterBottles.doc. Refer to the fee schedule for the Agricultural and Environmental Services Laboratories for a detailed listing of analyses and their corresponding lab fees.

Sample bottles for mineral analyses are available from the Extension Storekeeper, Hoke Smith Annex. All drinking water samples should be collected from the kitchen faucet or from the faucet used most often for drinking. Drinking water samples for microbiology testing should be collected in pre-sterilized containers provided by the Feed and Environmental Waters Laboratory. Water samples for pesticide testing should be collected in amber bottles with Teflon-lined caps provided by the Pesticide and Hazardous Waste Laboratory. For detailed procedures on water sampling for a particular test, refer to the Agricultural and Environmental Services Laboratories fee schedule.

The laboratory provides interpretation of drinking water test results following the Environmental Protection Agency guidelines and makes recommendations regarding the potential need for water treatment.

Animal Waste

Poultry Litter: The nutrient content of litter in a poultry house can vary considerably depending on location within the house. It is not recommended to sample litter while still being used as a bedding layer in the poultry house. Wait until clean out to sample after mixing the litter by scraping it into a pile. The County Extension Office has sample submission forms and information on tests that are most often needed and can assist with shipping samples to the University of Georgia Agricultural and Environmental Services Laboratories. The basic manure test package at the UGA Agricultural and Environmental Services Laboratories includes a total analysis of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), sulfur (S), aluminum (Al), iron (Fe), boron (B), copper (Cu), manganese (Mn), and zinc (Zn).

Manure and Lagoon: Solid manure samples should represent the average moisture content of the manure. A one-quart sample is adequate for analysis. Samples should be taken from approximately eight different areas in the manure pile, placed in a clean plastic container, and thoroughly mixed. Approximately one quart of the mixed sample should be placed in a plastic bag, sealed, and shipped immediately to the laboratory. Samples stored for more than two days should be refrigerated. Lagoon samples should be collected using a clean plastic container. One pint of material should be taken from at least eight sites around the lagoon and then mixed in the larger clean plastic container. Lagoon samples submitted for basic manure testing at the UGA Agricultural and Environmental Services Laboratories will have additional analyses that include: total Kjeldahl nitrogen (TKN for permit), nitrate nitrogen (for permit), and ammonium nitrogen (not required for permit but used for nutrient management).

Biosolids, Sludge, and Non-animal Waste

Sludge and other biosolids, which are commonly used as soil amendments, are routinely analyzed for total N, P, K, Ca, Mg, S, Na, Fe, Al, B, Cu, and Zn. In addition, ammonium (NH_4) and nitrate (NO_3) are analyzed upon request.

Mechanical Analysis

A mechanical analysis is used to identify the textural classification of a soil. The percent sand, silt, and clay is determined at the laboratory using the hydrometer method.

SOIL ANALYSIS PROCEDURES USED AT THE UNIVERSITY OF GEORGIA SOIL, PLANT, AND WATER LABORATORY

Leticia Sonon, Program Coordinator, Soil, Plant, and Water Laboratory
David E. Kissel, Director, Agricultural and Environmental Services Laboratories

Sample Preparation:

Once soil samples are submitted to the laboratory, they are arranged in a tray or set box containing no more than 36 samples and assigned a laboratory number. The same laboratory number is then stamped on the soil submission form. The soils are dried in a large walk-in oven with a heating element and exhaust fan to remove moisture-laden air. The temperature of the oven does not exceed 110°F in order to approximate air drying conditions.

After drying, soil samples are crushed using a stainless steel grinder and sieved through a 2-mm screen (U.S. Screen Series #10).

For a routine test, two check samples and two redip samples are analyzed with each tray of 36 soil samples.

Soil pH, Lime Buffer Capacity, and Lime Requirement:

Soil pH and the Lime Buffer Capacity are determined using an automated LabFit AS-3000 pH Analyzer equipped with direct titration capabilities. Soil pH is determined using a 1:1 soil:0.01 M $CaCl_2$ suspension. The 0.01 M $CaCl_2$ readings are then converted to soil-water pH readings by adding a conversion factor of 0.6. The Lime Buffer Capacity is determined on samples with pH readings of less than 8.1 by direct titration using 0.023 M $Ca(OH)_2$. Lime recommendations are calculated using the target pH, measured pH, and the Lime Buffer Capacity only if the soil pH is less than the recommended pH for a given crop. For more detailed information on how the Soil, Plant, and Water Laboratory measures and reports pH and makes lime recommendations, go to: http://aesl.ces.uga.edu/publications/soilcirc.

Extractable Phosphorus, Potassium, Calcium, Magnesium, Manganese and Zinc

Extractable P, K, Ca, Mg, Mn, and Zn are determined using the Mehlich-1 extraction method. The amount of P, K, Ca, Mg, Mn, and Zn is determined simultaneously on an Inductively Coupled Plasma Spectrograph. The amount of element determined is expressed as pounds per acre of element on the basis of 2 million pounds of soil.

Cation Exchange Capacity (CEC) and Percent Base Saturation (BS)

The cation exchange capacity (CEC) of a soil is determined by adding the milliequivalents of bases (Ca, Mg, K, and Na) present in the Mehlich-1 extract and the milliequivalents of exchangeable hydrogen as determined by direct titration with 0.023M $Ca(OH)_2$, and expressed as milliequivalents per 100 grams of soil. The percent base saturation of a soil is calculated as the ratio of Ca, Mg, K, and Na to that of CEC.

Hot-Water Extractable Boron:

Soil samples are shaken in a water bath at 80ºC and filtered through Whatman #1 filter paper. Soluble boron is determined in the filtrate by an Inductively Coupled Plasma Spectrograph. The amount of the element extracted is expressed as pounds per acre.

Organic Matter Content:

The organic matter content is determined by the Loss On Ignition (LOI) method and is expressed as percent by weight.

Soluble Salts:

Soluble salts are analyzed using an Orion model 162A Conductance-Resistance meter to measure the conductance of a 1:2 soil:water extract. Results are reported as µS/cm.

Extractable Ammonium and Nitrate:

Samples are extracted with 0.1 N KCl and the extracts are analyzed for NH_4 and NO_3 colorimetrically. Ammonium is determined following the phenate method. Following cadmium reduction, nitrate is determined colorimetrically.

Total Elemental Analysis:

The samples are mixed with nitric acid and digested in a microwave. The digest is brought to volume with deionized water and the cations of interest are determined simultaneously on an Inductively Coupled Plasma Spectrograph.

Arsenic, Selenium, and Mercury:

Samples are digested in a microwave with nitric acid. Arsenic and selenium in the digest are determined simultaneously on an Inductively Coupled Plasma Spectrograph. Mercury is analyzed using cold-vapor atomic absorption spectrometry (CVAAS).

Total Carbon, Nitrogen, and Sulfur:

Samples are combusted in an oxygen atmosphere at 1350ºC, converting elemental carbon, sulfur, and nitrogen into CO_2, SO_2, and N_2. These gases are then passed through the IR (infrared) cells to determine the carbon and sulfur content and a TC (thermal conductivity) cell to determine N_2.

Greenhouse or Nursery Media Test:

Samples are analyzed following the saturated media extract (SME) method, modified to include diethylene triamine pentaacetic acid (DTPA) for extraction of micronutrients B, Cu, Fe, Zn, and Mn. From the extract, P, K, Ca, Mg, B, Cu, Fe, Zn, and Mn are determined simultaneously on an Inductively Coupled Plasma Spectrograph. Soluble nitrate is determined colorimetrically following cadmium reduction.

Mechanical Analysis:

The amount of sand, silt, and clay in a sample is determined by the Bouyoucos hydrometer method.

SOIL TEST INTERPRETATION & RECOMMENDATIONS

David E. Kissel, Director, Agricultural and Environmental Services Laboratories
C. Owen Plank, Extension Agronomist - Retired

The lime and fertilizer recommendation should be closely followed and only altered based on extenuating circumstances such as previous soil tests, yield goal, cropping sequence, a plant analysis result, or visual observations. Soils should be tested periodically, sampling about the same time of the year. Maintain records on soil test results and compare previous results with the most recent test results. Changes in pH and nutrient test levels should be countered with corresponding lime and fertilizer treatments to maintain the soil fertility level within the sufficiency range. For most soils and cropping situations, the soil pH should be between 5.5 and 6.5, the P and K levels within the high category, and the Ca and Mg levels adequate and medium, respectively.

Soil Acidity

The majority of soils in Georgia are slightly to strongly acid and need to be limed in order to attain good crop growth. Soils in Georgia are acidic in nature because of the parent materials from which they were developed and the high annual rainfall that leaches base-forming cations such as calcium and magnesium from the soil. This condition is accentuated by the use of acid-forming fertilizers, crop removal of calcium and magnesium, and other factors. Approximately 40 percent of the samples received at the UGA Soil, Plant, and Water Laboratory need lime.

Soil pH is considered by many scientists as being one of the most important indicators of soil fertility. Therefore, soil pH should be adjusted carefully. Soil pH affects soil fertility in the following ways:

- Plant nutrients such as iron, manganese, zinc, and others become less available if the pH is too high. Severe deficiencies of these nutrients result in poor plant growth.
- The elements aluminum and manganese can be toxic to some crops below pH 5.4. Other crops such as blueberry require acid soil, with a recommended pH between 4.0 and 5.0.
- Soil microorganisms are also affected by soil pH. Acid soils can slow the formation of nitrate in soils. Most plants prefer to have nitrate available in the soil for the best nutrition.

Although soil pH is a critical factor in determining response of crops to fertilizers, pH per se is not the factor that adversely affects plant growth. As the soil pH decreases, the amount of aluminum and manganese in the soil solution increases. Many plants are particularly sensitive to these two elements. Also, the amount of calcium and magnesium in the soil solution decreases as the soil pH decreases. At a low pH, there may not be sufficient calcium or magnesium in the soil solution to meet the crop requirement. Therefore, a deficiency of either or both elements can occur. Normally, magnesium deficiency is more likely than calcium to occur at low soil pH. When lime is applied, the amount of aluminum and manganese in the soil solution decreases and the amount of calcium and magnesium increases, thereby reducing the likelihood of a toxicity or deficiency, respectively.

Soil pH changes over time and the rate of change is dependent on the soil type, soil buffer capacity, fertilizer practices, and losses of calcium and magnesium by leaching, erosion, and crop removal. When a soil is intensively cropped, liming may be necessary every year.

The subsoil for most Georgia soils is acidic and is difficult to correct. Lime does not readily move down through a soil. Experiments have shown that downward movement of lime occurs only when the surface soil has been limed regularly over a long period of time or is near neutral (pH 7.0) or greater. Subsoil acidity can be detrimental to crops and can significantly affect crop growth by limiting root development into the subsoil. Root development in acid subsoils (pH <5.2) is limited because of the presence of toxic levels of aluminum (Al^{3+}) and manganese (Mn^{2+}). In order to minimize this problem, the surface soil should be kept at the proper pH by the addition of lime based on a soil test recommendation. If the surface soil pH is maintained at the proper level, development of extremely low subsoil pH and toxic levels of Al^{3+} and Mn^{2+} will be curtailed. In addition, the pH and supply of calcium and magnesium will remain fairly constant to an extended depth. This permits better root development and greater uptake of water and nutrients by plants. When a soil fertility problem exists, a subsoil analysis can be helpful in diagnosing the problem.

Lime Requirement (L.R.)

One of the major changes in the Georgia soil testing program is the methodology used in determining the lime requirement of soils. For several years the laboratory used the Adams-Evans buffer solution to determine acidity in soil samples. However, as a result of potential toxic chemicals in the buffer solution, alternative methodologies were sought. Through research at the University of Georgia, a new automated method that utilizes non-toxic chemicals was developed to determine a soil's Lime Buffer Capacity (LBC). The LBC (a fundamental property of the soil) is a measure of the amount of soil acidity that must be neutralized by pure calcium carbonate to raise the soil pH by one unit. The LBC is determined by titrating a sample with a dilute solution of calcium hydroxide (0.023 M $Ca(OH)_2$). The LBC, along with the target pH, the soil pH, and appropriate multipliers are used to calculate the lime recommendation.

The soil pH is a measure of the hydrogen ion activity in the soil solution (active acidity), whereas the exchangeable acidity on the soils exchange sites can be expressed as the LBC, the amount of pure calcium carbonate needed to neutralize the exchangeable acidity. The major sources of exchangeable acidity on soil exchange sites are primarily aluminum compounds that release acidity (H^+) or H^+ associated with soil organic matter.

The objective of liming a soil is to neutralize a portion of the acidity with limestone and replace the exchange sites previously occupied by aluminum compounds or H^+ with basic cations, for example, calcium (Ca^{2+}) and magnesium (Mg^{2+}). Therefore, as exchangeable acidity is neutralized and replaced by calcium and magnesium, the soil pH will increase. Since the concentration of hydrogen ions in the soil solution is in equilibrium with the acidity on the exchange sites, a change in the exchangeable acidity will affect the pH of a soil.

Two soils may have the same lime requirement but different pH values. Similarly, two soils may have the same pH but different lime requirements. These differences are primarily related to the amount of clay (texture of the soil) and organic matter present. Soils that are high in organic matter and clay content require more lime to raise the pH to a specific level than do sandy soils that are low in organic matter. For example, a sandy soil at pH 5.0 may require only 1 ton of limestone to raise the pH to 6.0, whereas a clay soil at the same pH may require 2 or more tons of limestone.

Crops have different soil pH requirements, therefore lime recommendations vary with the crop to be grown. Lime should be applied and mixed with the soil as soon after sampling as possible. It will begin to react with the soil immediately after application, but the full effect may not be evident for several months. The pH requirements on which lime recommendations for different crops are based are provided in the Crops and Lime Tables of the laboratories' Web site at http://aesl.ces.uga.edu/soil/crops.htm.

Determining the Soil Lime Requirement

How to Use the Lime Requirement Tables:

The lime requirement is determined by comparing the soil pH to the Lime Buffer Capacity. There are 4 tables given in this section that are to be used for this purpose. The tables are headed as follows:

A. Lime Requirement to raise pH of the surface 8 inches of soil to a pH of 7.0.

B. Lime Requirement to raise pH of the surface 8 inches of soil to a pH of 6.5.

C. Lime Requirement to raise pH of the surface 8 inches of soil to a pH of 6.0.

D. Lime Requirement to raise pH of the surface 8 inches of soil to a pH of 5.5.

Not all crops require the same soil pH adjustment. The specific soil pH instructions are given on the individual crop code sheets. Use these instructions to determine to what pH level the soil is to be adjusted.

Go to the lime table (A, B, C, or D) indicated for the particular crop. The soil pH is given in the rows on the left side of the table in tenths of pH units. The Lime Buffer Capacity is given in the columns across the top of the table in hundreds of pounds ranging from 100 to 1400. Find the row with the soil pH and then go across the row to the appropriate Lime Buffer Capacity column. The number given at the point of intersection is the pounds of lime needed to raise the soil pH to the specified soil pH.

Table A. Lime Requirement to raise pH of the surface 8 inches of soil to a pH of 7.0

Soil pH	Lime Buffer Capacity [1]													
	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
	lbs Ag lime per acre 8" to raise pH to 7.0													
6.4	1000	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000
6.3	1000	1000	1500	2000	2500	3500	4000	4500	5000	5500	6000	6500	7000	7500
6.2	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6500	7000	7500	8000
6.1	1000	1500	2000	2500	3000	3500	4500	5000	5500	6000	6500	7500	8000	8500
6.0	1000	1500	2000	2500	3500	4000	4500	5500	6000	6500	7000	8000	8500	9000
5.9	1000	1500	2000	3000	3500	4000	5000	5500	6500	7000	7500	8500	9000	9500
5.8	1000	1500	2500	3000	3500	4500	5000	6000	6500	7500	8000	9000	9500	10000
5.7	1000	1500	2500	3000	4000	4500	5500	6000	7000	7500	8500	9500	10000	10000
5.6	1000	1500	2500	3500	4000	5000	5500	6500	7500	8000	9000	9500	10000	10000
5.5	1000	2000	2500	3500	4500	5000	6000	7000	7500	8500	9500	10000	10000	10000
5.4	1000	2000	3000	3500	4500	5500	6500	7000	8000	9000	10000	10000	10000	10000
5.3	1000	2000	3000	4000	4500	5500	6500	7500	8500	9500	10000	10000	10000	10000
5.2	1000	2000	3000	4000	5000	6000	7000	8000	9000	9500	10000	10000	10000	10000
5.1	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	10000	10000	10000	10000
5.0	1000	2000	3500	4500	5500	6500	7500	8500	9500	10000	10000	10000	10000	10000
4.9	1000	2500	3500	4500	5500	6500	7500	9000	10000	10000	10000	10000	10000	10000
4.8	1500	2500	3500	4500	5500	7000	8000	9000	10000	10000	10000	10000	10000	10000
4.7	1500	2500	3500	5000	6000	7000	8500	9500	10000	10000	10000	10000	10000	10000
4.6	1500	2500	3500	5000	6000	7500	8500	9500	10000	10000	10000	10000	10000	10000
4.5	1500	2500	4000	5000	6500	7500	9000	10000	10000	10000	10000	10000	10000	10000
4.4	1500	2500	4000	5500	6500	8000	9000	10000	10000	10000	10000	10000	10000	10000
4.3	1500	3000	4000	5500	6500	8000	9500	10000	10000	10000	10000	10000	10000	10000
4.2	1500	3000	4000	5500	7000	8500	9500	10000	10000	10000	10000	10000	10000	10000
4.1	1500	3000	4500	5500	7000	8500	10000	10000	10000	10000	10000	10000	10000	10000
4.0	1500	3000	4500	6000	7500	9000	10000	10000	10000	10000	10000	10000	10000	10000

[1] Pounds of pure calcium carbonate to raise soil pH one unit per 1,000,000 pounds of soil.

Table B. Lime Requirement to raise pH of the surface 8 inches of soil to a pH of 6.5

Soil pH	Lime Buffer Capacity [1]													
	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
	lbs Ag lime per acre 8" to raise pH to 6.5													
6.2	1000	1000	1000	1500	2000	2500	2500	3000	3500	3500	4000	4500	5000	5000
6.1	1000	1000	1500	1500	2000	2500	3000	3500	3500	4000	4500	5000	5500	5500
6.0	1000	1000	1500	2000	2500	3000	3000	3500	4000	4500	5000	5500	6000	6500
5.9	1000	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000
5.8	1000	1000	1500	2000	2500	3500	4000	4500	5000	5500	6000	6500	7000	7500
5.7	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6500	7000	7500	8000
5.6	1000	1500	2000	2500	3000	3500	4500	5000	5500	6000	6500	7500	8000	8500
5.5	1000	1500	2000	2500	3500	4000	4500	5500	6000	6500	7000	8000	8500	9000
5.4	1000	1500	2000	3000	3500	4000	5000	5500	6500	7000	7500	8500	9000	9500
5.3	1000	1500	2500	3000	3500	4500	5000	6000	6500	7500	8000	9000	9500	10000
5.2	1000	1500	2500	3000	4000	4500	5500	6000	7000	7500	8500	9500	10000	10000
5.1	1000	1500	2500	3500	4000	5000	5500	6500	7500	8000	9000	9500	10000	10000
5.0	1000	2000	2500	3500	4500	5000	6000	7000	7500	8500	9500	10000	10000	10000
4.9	1000	2000	3000	3500	4500	5500	6500	7000	8000	9000	10000	10000	10000	10000
4.8	1000	2000	3000	4000	4500	5500	6500	7500	8500	9500	10000	10000	10000	10000
4.7	1000	2000	3000	4000	5000	6000	7000	8000	9000	9500	10000	10000	10000	10000
4.6	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	10000	10000	10000	10000
4.5	1000	2000	3500	4500	5500	6500	7500	8500	9500	10000	10000	10000	10000	10000
4.4	1000	2500	3500	4500	5500	6500	7500	9000	10000	10000	10000	10000	10000	10000
4.3	1500	2500	3500	4500	5500	7000	8000	9000	10000	10000	10000	10000	10000	10000
4.2	1500	2500	3500	5000	6000	7000	8500	9500	10000	10000	10000	10000	10000	10000
4.1	1500	2500	3500	5000	6000	7500	8500	9500	10000	10000	10000	10000	10000	10000
4.0	1500	2500	4000	5000	6500	7500	9000	10000	10000	10000	10000	10000	10000	10000

[1] Pounds of pure calcium carbonate to raise soil pH one unit per 1,000,000 pounds of soil.

Table C. Lime Requirement to raise pH of the surface 8 inches of soil to a pH of 6.0

Soil pH	Lime Buffer Capacity [1]													
	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
	lbs Ag lime per acre 8" to raise pH to 6.0													
5.9	1000	1000	1000	1500	1500	2000	2000	2500	2500	3000	3000	3500	4000	4000
5.8	1000	1000	1000	1500	1500	2000	2500	2500	3000	3500	3500	4000	4500	4500
5.7	1000	1000	1000	1500	2000	2500	2500	3000	3500	3500	4000	4500	5000	5000
5.6	1000	1000	1500	1500	2000	2500	3000	3500	3500	4000	4500	5000	5500	5500
5.5	1000	1000	1500	2000	2500	3000	3000	3500	4000	4500	5000	5500	6000	6500
5.4	1000	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000
5.3	1000	1000	1500	2000	2500	3500	4000	4500	5000	5500	6000	6500	7000	7500
5.2	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6500	7000	7500	8000
5.1	1000	1500	2000	2500	3000	3500	4500	5000	5500	6000	6500	7500	8000	8500
5.0	1000	1500	2000	2500	3500	4000	4500	5500	6000	6500	7000	8000	8500	9000
4.9	1000	1500	2000	3000	3500	4000	5000	5500	6500	7000	7500	8500	9000	9500
4.8	1000	1500	2500	3000	3500	4500	5000	6000	6500	7500	8000	9000	9500	10000
4.7	1000	1500	2500	3000	4000	4500	5500	6000	7000	7500	8500	9500	10000	10000
4.6	1000	1500	2500	3500	4000	5000	5500	6500	7500	8000	9000	9500	10000	10000
4.5	1000	2000	2500	3500	4500	5000	6000	7000	7500	8500	9500	10000	10000	10000
4.4	1000	2000	3000	3500	4500	5500	6500	7000	8000	9000	10000	10000	10000	10000
4.3	1000	2000	3000	4000	4500	5500	6500	7500	8500	9500	10000	10000	10000	10000
4.2	1000	2000	3000	4000	5000	6000	7000	8000	9000	9500	10000	10000	10000	10000
4.1	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	10000	10000	10000	10000
4.0	1000	2000	3500	4500	5500	6500	7500	8500	9500	10000	10000	10000	10000	10000

[1] Pounds of pure calcium carbonate to raise soil pH one unit per 1,000,000 pounds of soil.

Table D. Lime Requirement to raise pH of the surface 8 inches of soil to a pH of 5.5														
Soil pH	Lime Buffer Capacity [1]													
	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
	lbs Ag lime per acre 8" to raise pH to 5.5													
4.9	1000	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000
4.8	1000	1000	1500	2000	2500	3500	4000	4500	5000	5500	6000	6500	7000	7500
4.7	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6500	7000	7500	8000
4.6	1000	1500	2000	2500	3000	3500	4500	5000	5500	6000	6500	7500	8000	8500
4.5	1000	1500	2000	2500	3500	4000	4500	5500	6000	6500	7000	8000	8500	9000
4.4	1000	1500	2000	3000	3500	4000	5000	5500	6500	7000	7500	8500	9000	9500
4.3	1000	1500	2500	3000	3500	4500	5000	6000	6500	7500	8000	9000	9500	10000
4.2	1000	1500	2500	3000	4000	4500	5500	6000	7000	7500	8500	9500	10000	10000
4.1	1000	1500	2500	3500	4000	5000	5500	6500	7500	8000	9000	9500	10000	10000
4.0	1000	2000	2500	3500	4500	5000	6000	7000	7500	8500	9500	10000	10000	10000

[1] Pounds of pure calcium carbonate to raise soil pH one unit per 1,000,000 pounds of soil.

Lime Requirement Adjustment for Depth and Area:

The lime requirement given in the Tables A, B, C, and D are for plow depths of 8 inches. For plow depths other than 8 inches, the lime requirement should be revised accordingly. The following table is provided for this purpose.

Lime Requirement Adjustment for Varying Plow Depths, lbs/A.							
Lime Requirements from Tables A, B, C, and D	**Depth of Plowing, inches**						
	2	4	6 2/3	8	10	12	14
0	None	None	None	None	None	None	None
1000	250	500	800	1000	1300	1500	1800
2000	500	1000	1700	2000	2500	3000	3500
3000	750	1500	2500	3000	3800	4500	5300
4000	1000	2000	3300	4000	5000	6000	7000
5000	1250	2500	4200	5000	6300	7500	8800
6000	1500	3000	5000	6000	7500	9000	10500
7000	1750	3500	5800	7000	8800	10500	12300
8000	2000	4000	6700	8000	10000	12000	14000
9000	2250	4500	7500	9000	11300	13500	15800
10000	2500	5000	8300	10000	12500	15000	17500

For those who work with specialty crops and lawns, the table below is given to assist in developing lime recommendations on a lbs/1000 sq. ft basis.

Lime Requirement Adjustment in Pounds Per 1000 sq. ft.			
Lime Requirement from Tables A, B, C, and D	**Lawns 4" Depth**	**Cultivated Soils 6 2/3" Depth**	**Cultivated Soils 8" Depth**
0	None	None	None
1000	11	19	23
2000	23	38	46
3000	34	58	69
4000	46	77	92
5000	57	96	115
6000	69	115	138
7000	80	134	161
8000	92	153	184
9000	103	173	207
10000	115	192	230

Lowering Soil pH

Most plants do best when the soil pH is maintained between 5.5 and 6.5. The exceptions are for organic soils where the soil pH is adequate from 5.0 to 5.5. Plants such as blueberries, azaleas, rhododendron, camellias, and Irish potatoes grow best at lower pH values. Therefore, on occasion it may be necessary to lower the soil pH by adding an acidifying agent such as elemental sulfur (S) or aluminum sulfate.

When adjusting soil pH by the addition of these materials, if the rates needed exceed 30 lbs. of S per 1000 square feet, it would be advisable to split the application. Apply one half of the recommended rate and after about 2 to 3 months, retest the soil. If the pH has not been sufficiently reduced, apply the remainder of the material. Sulfur applied intentionally to lower the soil pH may have only a temporary effect. Repeated sulfur applications may be needed to maintain a low soil pH. The table on the following page contains rates of sulfur to apply to reduce soil pH.

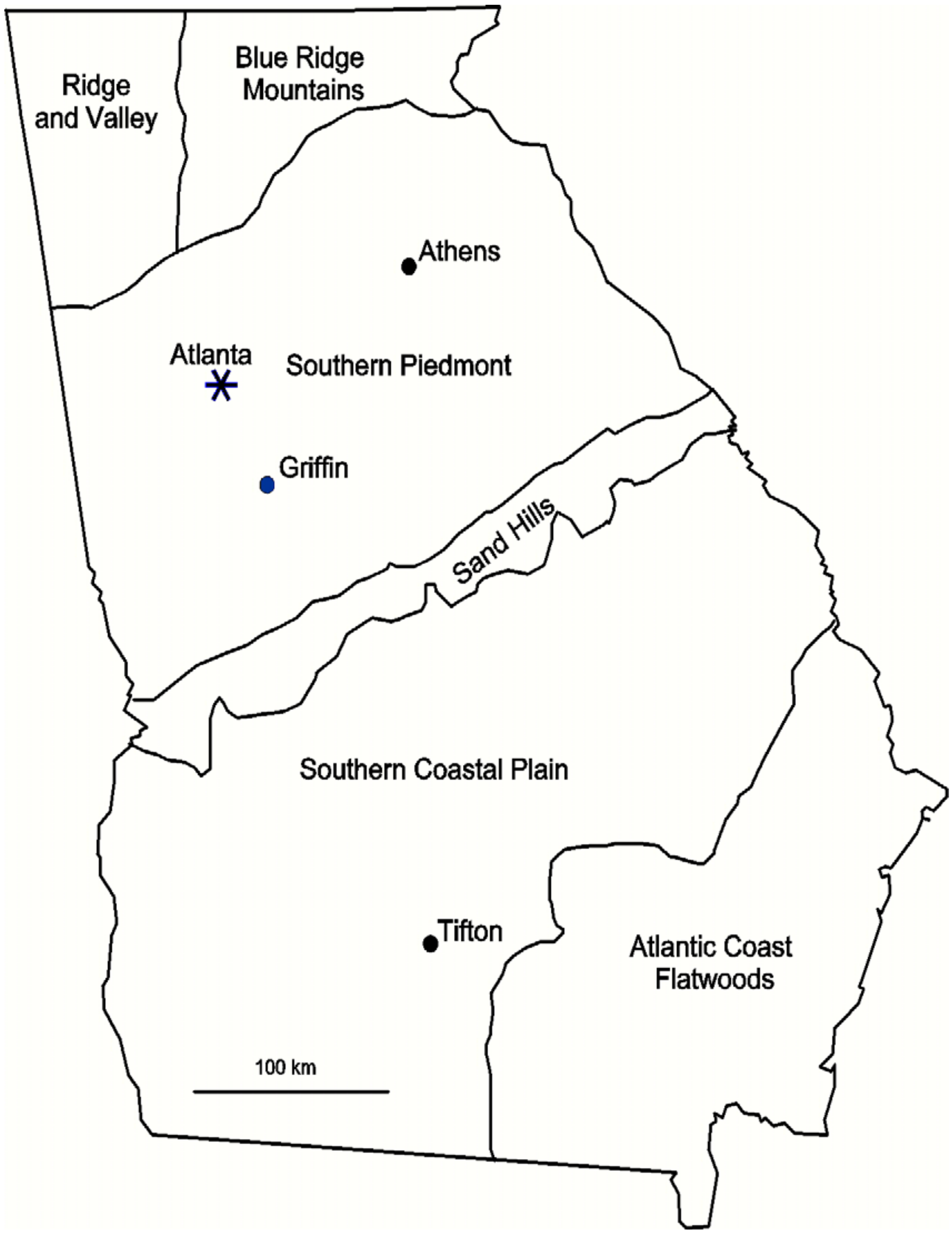
Reducing Soil pH with Sulfur or Aluminum Sulfate															
	Desired Soil pH														
Initial Soil pH	4.0			4.5			5.0			5.5			6.0		
	Textural Classification														
	Sandy	Loamy	Clayey	Sandy	Loamy	Clayey	Sandy	Loamy	Clayey	Sandy	Loamy	Clayey	Sandy	Loamy	Clayey
	Sulfur Required*, Lbs. Per 1000 sq. ft.**														
4.5	4	10	16												
5.0	8	20	32	4	10	16	0	0	0						
5.5	12	29	47	8	20	32	4	10	16	0	0	0			
6.0	15	38	61	12	29	47	8	20	32	4	10	16	0	0	0
6.5	19	48	77	15	38	61	12	29	47	8	20	32	4	10	16
7.0	23	57	92	19	48	77	15	38	61	12	29	47	8	20	32
7.5	27	67	107	23	57	92	19	48	77	15	38	61	12	29	47

* Aluminum sulfate = pounds of sulfur x 6. For lb/100 sq. ft. or oz/1 l/2 bu., move decimal one place to the left. For lb/A, multiply by 43.56.

** Example: Assuming the soil pH is 6.5 in a loamy soil and the pH should be reduced to 5.5, reading across from pH 6.5 to the "loamy" column under pH 5.5, 20 pounds of sulfur per 1000 square feet is required to reduce the soil pH to 5.5.

MAJOR LAND RESOURCE AREAS ON WHICH PHOSPHORUS, POTASSIUM, CALCIUM, AND MAGNESIUM FERTILITY RATINGS ARE BASED

The major land areas in Georgia are shown in the map below.



For practical purposes, soils are grouped into three major categories: (1) Coastal Plain, (2) Piedmont, Mountain and Limestone Valley, and (3) soils from landscapes, golf greens, greenhouses, and flower beds. These categories make for easier evaluation of fertility. Although the Piedmont, Mountain and Limestone Valley soils are considered as one group, a brief discussion of their characteristics is given separately below.

Coastal Plain Soils (Atlantic Flatwoods and Sand Hills Included):

Soils have sandy surfaces and cation exchange capacities (CEC) of 6 milliequivalents (meq.) per 100 g or less. Soils in their native state can be acid and infertile. Soils will vary in clay content, drainage characteristics, and color. Soils will vary in productivity, ease of handling, and adaptation to row crop production. Typical soil types are Norfolk, Lakeland, Lynchburg, and Tifton.

Piedmont Soils:

Soils are predominately upland, well-drained red soils with cation exchange capacities of 6 to 12 meq. per 100 g. Soils in their native state are acid and low in phosphorus but higher in potassium than the Coastal Plain Soils. Major soil series are Cecil, Madison, and Davison.

Mountain and Limestone Valley Soils:

Soils may have gray, sandy surface underlain with a heavy red sandy clay or clay texture soil. The alluvial terraces and river bottoms are gray to light brown in color with yellow to dark red sandy clay loam subsoil. Soils are acid and low in fertility. The major soil types are Porters, Hayesville, Talladega, Fannin, Congaree, Clarkesville, Fullerton, Dewey, and Decatur.

Soils from landscapes, golf greens, etc.:

These soils are frequently maintained differently than crop soils and are usually artificially constituted and maintained. Many are erratic in fertility and cannot be easily placed in one of the three categories given above.

DETERMINING RATING

In order to determine which rating to use in interpreting soil test results, counties are placed in either the Piedmont, Mountain, or Limestone Valley association or the Coastal Plain association as shown on the following pages. This method of rating works well for the vast majority of soil sample results processed through the computer.

Exceptions for Fall Line Counties

There are locations, particularly along the fall line in central Georgia, where a county may have both Piedmont and Coastal Plain type soils. If a county is designated as being in the Coastal Plain and a Piedmont type sample is submitted, the rating will obviously be incorrect. A system has been developed by which the basic rating system can be overridden. When creating a soil submission in Data Transfer, you'll see "Piedmont" or "Coastal" in the **Soil type** column. If a Piedmont rating is needed in a Coastal Plain county (for example, Greenville soil), press the letter "P" in the Soil type column. Likewise, if a Coastal Plain rating is needed in a Piedmont county, press the letter "C." These items ensure proper identification for making lime and fertilizer recommendations by computer.

COUNTIES WITH MAJOR SOIL ASSOCIATIONS IN THE COASTAL PLAIN:

County No.	County Name	County No.	County Name	County No.	County Name
001	Appling	099	Early	225	Peach
003	Atkinson	101	Echols	229	Pierce
		103	Effingham	235	Pulaski
005	Bacon	107	Emanuel		
007	Baker	109	Evans	239	Quitman
017	Ben Hill				
019	Berrien	125	Glascock	243	Randolph
021	Bibb	127	Glynn	245	Richmond
023	Bleckley	131	Grady		
025	Brantley			249	Schley
027	Brooks	153	Houston	251	Screven
029	Bryan			253	Seminole
031	Bulloch	155	Irwin	259	Stewart
033	Burke			261	Sumter
		161	Jeff Davis		
037	Calhoun	163	Jefferson	267	Tattnall
039	Camden	165	Jenkins	269	Taylor
043	Candler	167	Johnson	271	Telfair
049	Charlton			273	Terrell
051	Chatham	173	Lanier	275	Thomas
053	Chattahoochee	175	Laurens	277	Tift
061	Clay	177	Lee	279	Toombs
065	Clinch	179	Liberty	283	Treutlen
069	Coffee	183	Long	287	Turner
071	Colquitt	185	Lowndes	289	Twiggs
075	Cook				
079	Crawford	189	Macon	299	Ware
081	Crisp	193	Marion	303	Washington
		197	McIntosh	305	Wayne
087	Decatur	201	Miller	307	Webster
091	Dodge	205	Mitchell	309	Wheeler
093	Dooly	209	Montgomery	315	Wilcox
095	Dougherty	215	Muscogee	319	Wilkinson
				321	Worth

COUNTIES WITH MAJOR SOIL ASSOCIATIONS IN THE PIEDMONT, MOUNTAIN OR LIMESTONE VALLEY:

County No.	County Name	County No.	County Name	County No.	County Name
009	Baldwin	123	Gilmer	219	Oconee
011	Banks	129	Gordon	221	Oglethorpe
013	Barrow	133	Greene		
015	Bartow	135	Gwinnett	223	Paulding
035	Butts			227	Pickens
		137	Habersham	231	Pike
045	Carroll	139	Hall	233	Polk
047	Catoosa	141	Hancock	237	Putnam
055	Chattooga	143	Haralson		
057	Cherokee	145	Harris	241	Rabun
059	Clarke	147	Hart	247	Rockdale
063	Clayton	149	Heard		
067	Cobb	151	Henry	255	Spalding
073	Columbia			257	Stephens
077	Coweta	157	Jackson		
		159	Jasper	263	Talbot
083	Dade	169	Jones	265	Taliaferro
085	Dawson			281	Towns
089	DeKalb	171	Lamar	285	Troup
097	Douglas	181	Lincoln		
		187	Lumpkin	291	Union
105	Elbert			293	Upson
		191	Madison		
111	Fannin	195	McDuffie	295	Walker
113	Fayette	199	Meriwether	297	Walton
115	Floyd	207	Monroe	301	Warren
117	Forsyth	211	Morgan	311	White
119	Franklin	213	Murray	313	Whitfield
121	Fulton			317	Wilkes
		217	Newton		

NITROGEN RECOMMENDATIONS AND NITRATE-NITROGEN (NO_3-N) INTERPRETATION

Nitrogen is the nutrient needed in greatest quantities for most non-legume crops and is the nutrient that most frequently limits crop production. A satisfactory routine soil test has not been developed that will accurately predict the amount of available nitrogen in Georgia soils.

There are several reasons for this. First, nitrate-nitrogen (NO_3-N) does not accumulate in Georgia soils because they are sandy and rainfall is high, resulting in leaching of nitrate-N. Secondly, nitrogen is stored in soils primarily in the soil organic matter. The rate at which nitrogen is released for use by crops is affected by organic matter content, temperature, moisture, length of growing season, and other factors that make it impractical to predict the amount of nitrogen that will be supplied for a growing crop. Thirdly, Georgia soils are low in organic matter content; therefore, the amount of nitrogen supplied from the organic fraction is often low. **Nitrogen recommendations for non-legume crops are based on nitrogen rate experiments conducted on soils in Georgia and on similar soils and cultural practices in neighboring states.**

The amounts of nitrogen used by growers may need to be adjusted based on past history of the field, previous experience, rainfall distribution, and plant analysis results. Nitrogen is not recommended for legume crops as they are able to fix their nitrogen from the air. With some crops, a lower rate of nitrogen will be recommended for crops that follow legume crops, because of the nitrogen contributed by legumes.

There are a few instances, for example, troubleshooting with field and greenhouse crops, when a nitrate-nitrogen test may be helpful. Therefore, a nitrate-nitrogen (NO_3-N) soil test is offered only upon request.

The value given on the soil test report is pounds of nitrate-nitrogen (NO_3-N) per acre. This form of nitrogen is considered to be available N and can be readily utilized by plants. This means that all or a sizeable portion of this nitrogen is available for plant growth, which can reduce the amount of N fertilizer needed to meet the crop requirement.

The amount of NO_3-N that contributes to the crop requirement will depend on the amount of time between sampling and plant use. The longer this time period the less will be available to the crop because NO_3-N can be leached from soils. In general, for field crops, when the NO_3-N test level is greater than 50 lbs. N/A, a corresponding reduction in applied N fertilizer should be made so that the combined soil test N plus the fertilizer N will not exceed the crop N requirement.

For greenhouse crops, small gardens, turf, ornamentals, or other special situations where excess NO_3-N can adversely affect growth, yield, and quality, a high NO_3-N test result may indicate no need to apply additional N fertilizer. For many of these cropping situations, a NO_3-N test value in excess of 100 lbs. N/A would indicate no need for additional N. However, there are exceptions as the 100-lb. N value is not a fixed one. Each case must be considered individually and, when assistance is needed, contact the Soil, Plant, and Water Laboratory at 706-542-5350 or soiltest@uga.edu.

SOIL TEST INTERPRETATION FOR PHOSPHORUS (P) AND POTASSIUM (K)

In their native state, the soils of Georgia are generally low in phosphorus. Through the continued use of commercial fertilizers and other soil amendments, approximately 45 percent of the samples analyzed at the Soil, Plant, and Water Laboratory are high or very high in phosphorus.

Phosphorus is unlike some of the other plant nutrients, in that it is less mobile and tends to remain near the soil's surface. The principal ways that phosphorus is removed from the soil is through water and wind erosion and crop removal.

Plants require much smaller quantities of phosphorus than either nitrogen or potassium. Generally most crop plants contain from 0.20 to 0.50 percent phosphorus as compared to 2.00 to 5.00 percent nitrogen and 1.50 to 5.00 percent potassium. Therefore, unless the entire plant is removed as hay or silage, the amount of phosphorus lost through crop removal is comparatively small.

Fertility programs should be designed to build the soil test phosphorus to a high level. Generally, at this level little or no response to applied phosphorus is expected. With some crops phosphorus is recommended at the high level, whereas with others none is recommended. When phosphorus is recommended at high test levels, it is primarily for maintenance purposes as a result of crop removal.

There are some conditions under which the crop will respond to phosphorus at high test levels. This usually occurs with crops planted in cool-moist soils, and is particularly noticeable in early planted corn. In cool springs, purple corn is common and is generally due to low phosphorus in the plant. It is not that soil phosphorus is less available but that root activity is decreased, resulting in reduced absorption of phosphorus by the plant. The use of starter fertilizers or banding a portion of the fertilizer to the side and below the seed is effective in alleviating this problem.

Recent soil test summaries show that a lower percentage of Georgia soils test high or very high in potassium. This may be due in part to the fact that plants have the capacity to take up more potassium than they need (luxury consumption) and potassium is subject to loss through leaching. The latter would be more of a problem on the sandy soils of south Georgia than on the generally heavier soils of north Georgia.

In cases where high rates of potassium are recommended for crops such as coastal bermudagrass, alfalfa, and vegetable crops, it is advantageous to split the potassium applications. This is particularly important on sandy soils and on soils where magnesium is approaching a low level. Large single applications of potassium on these soils may result in substantial losses of potassium due to leaching during years with above average rainfall. When the soil test magnesium level is low or approaching a low level, a high rate of potassium may induce magnesium deficiency.

The pounds per acre of phosphorus and potassium extracted from a soil are only index values, ***not*** the actual amount of phosphorus or potassium that is available to the plant. They are classified into low, medium, high, and very high categories based on the probability that the crop will respond to applied phosphorus or potassium fertilizer.

The interpretation of these categories is as follows:

A. **LOW:**

Soil is deficient and yield response to applied phosphorus or potassium fertilizer should occur 80% or more of the time.

B. **MEDIUM:**

Soil test level is sufficient to prevent a deficiency from occurring with expected yield response to applied phosphorus or potassium fertilizer about 50% of the time.

C. **HIGH:**

Soil test level is sufficient for most crops without the application of phosphorus or potassium fertilizer. Certain agronomic and horticultural crops may benefit from fertilization at this level. Expected response to applied fertilizer is generally less than 10% of the time.

D. **VERY HIGH:**

Soil test level may be approaching or at an excessive level. Generally no additional fertilizer is to be recommended or applied. Continued application can result in a nutrient imbalance and may impact water quality. Continued application of phosphorus fertilizer can induce zinc deficiency, whereas continued application of potassium fertilizer can induce magnesium deficiency.

Soil Test Phosphorus (P) and Potassium (K) Ratings

	Phosphorus Test Level lbs. P/A				Potassium Test Level lbs. K/A			
Soil Group	**Low**	**Medium**	**High**	**Very High**	**Low**	**Medium**	**High**	**Very High**
Crops: Agronomic crops (less legumes and cotton)**, Pecans, Sod Production, Wildlife/Forage Grasses and Grass Clover Mixture, Golf Fairways and Tees, Pine Trees, Field Nursery Stock, Christmas Trees, Wildlife/Brassicas and Chufa, and Lawns**								
Coastal Plain	0 - 30	31 - 60	61 - 100	100+	0 – 60	61 - 150	151 - 250	250+
Piedmont, Mountain & Valley	0 - 20	21 - 40	41 - 75	75+	0 - 100	101 - 200	201 - 350	350+
Crop: Peanuts								
Coastal Plain	0 - 15	16 - 30	31 - 60	60+	0 - 30	31 - 60	61 - 150	150+
Piedmont, Mountain & Valley	0 - 10	11 - 20	21 - 40	40+	0 - 50	51 - 100	101 - 200	200+
Crops: Legumes, Stone fruits and nuts, Cotton, Wildlife/Forage Legumes and Wildlife/Forage Chicory, and Vegetables								
Coastal Plain	0 - 30	31 - 60	61 - 100	100+	0 - 70	71 - 170	171 - 275	275+
Piedmont, Mountain & Valley	0 - 20	21 - 40	41 - 75	75+	0 - 120	121 - 250	251 - 400	400+
Crops: Golf greens, Ornamentals, and Flowers								
All Soils	0 - 50	51 - 100	101 - 200	200+	0 - 150	151 - 250	251 - 450	450+
Crops: Blueberries								
Coastal Plain	0 - 30	31 - 60	61 - 100	100+	0 - 70	71 - 120	121 - 275	275+
Piedmont, Mountain & Valley	0 - 20	21 - 40	41 - 75	75+	0 - 70	71 - 150	151 - 275	275+

SOIL TEST INTERPRETATION FOR CALCIUM (Ca)

When soil pH is maintained at or near the recommended level, the calcium level in soils will generally be satisfactory for most crops. The crops most sensitive to low calcium levels are peanuts, peppers, and tomatoes. A calcium deficiency may result in unfilled pods in peanuts and blossom end rot in peppers and tomatoes. If the soil pH is adequate and the calcium soil test level is low or if calcium deficiencies have been observed in the past, supplemental calcium should be supplied through the application of gypsum. Application rates of gypsum for peppers and tomatoes may range from 500 to 1,000 pounds per acre. Supplemental rates of calcium for peanuts vary with the type of peanut grown, and specific recommendations are included in the recommendations section for peanuts.

Soil Test Calcium (Ca) Ratings

Crops and Soil Groups	Soil Test Level, lbs. Ca/A			
	Low	Medium	High	Very High
Brassica and Solanaceous	0 - 800	801 - 1200	>1200	Never
Other crops: Coastal Plain	0 - 200	201 - 800	801 - 1400	>1400
Other crops: Piedmont, Mountain, & Valley	0 - 400	401 - 1200	1201 - 1800	>1800

SOIL TEST INTERPRETATION FOR MAGNESIUM (Mg)

Although there are some exceptions, magnesium deficiencies are most often associated with low soil pH. The magnesium requirements for most crops are usually supplied by following the lime recommendations.

When both soil pH and magnesium are low, dolomitic limestone is recommended. If the soil magnesium level is low and lime is not recommended, elemental magnesium is recommended at rates varying from 15 to 25 pounds per acre. Supplemental magnesium sources most often used are potassium magnesium sulfate, magnesium sulfate, and magnesium oxide.

In those areas where grass tetany can be a problem, the soil test magnesium level should be maintained within the medium range or higher. However, this will not always ensure that an adequate magnesium supply is being taken in by the animal. The uptake of magnesium by plants is dependent on the soil pH, level of soil magnesium, calcium, and potassium. In general, magnesium uptake by plants increases as the soil pH and soil test magnesium level increases. Since the potassium ion can depress the uptake of magnesium by plants, when the soil test magnesium level is approaching the low range, large single applications of potassium fertilizer should be avoided where possible. If a large application of potassium fertilizer needs to be applied, it would be advisable to split the applications. The soil test potassium level should not exceed the high category.

Soil Testing Rating for Magnesium (Mg) - Agronomic Crops (less Alfalfa, Canola, Small Grain Silage, and Tobacco Plant Bed)**, Turf** (less Industrial/Business Lawns and Sod Production)**, and Wildlife Plots**

Soil Group	Soil Test Level, lbs. Mg/A		
	Low	Medium	High
Coastal Plain	0 - 30	31 - 60	>60
Piedmont, Mountain, & Valley	0 - 60	61 - 120	>120

Soil Testing Rating for Magnesium (Mg) - All Other Crops

Soil Group	Soil Test Level, lbs. Mg/A		
	Low	Medium	High
Coastal Plain	0 - 60	61 - 120	>120
Piedmont, Mountain, & Valley	0 - 120	121 - 240	>240

SOIL TEST INTERPRETATION FOR BORON (B)

The amount of "total boron" in soils may range from less than 4 pounds per acre to more than 100 pounds per acre. However, less than 5 percent of the total boron is generally available to plants. Boron availability is influenced to a great extent by pH, calcium levels, nitrogen application rates, and moisture. The availability of boron is reduced at high pH and at high soil calcium levels, and liberal applications of nitrogen tend to reduce the availability of boron to some crops. Also, the availability of boron is reduced during dry weather.

Extraction with hot water is the most commonly used soil test method for determining the availability of boron. The amount of extractable boron considered to be adequate for crops grown in Georgia is 0.3 pounds per acre.

Due to the low level of boron generally extracted from soils, the chance for error is great; therefore, the best method for determining boron needs is by plant analysis.

Crops differ in the amount of boron they can tolerate. Sensitive crops are soybeans, peaches, and strawberries. Some of the tolerant crops are alfalfa, clovers, and root crops. Corn, cotton, tobacco, tomatoes, and small grains are intermediate. Boron is routinely recommended for alfalfa, cotton, peanuts, reseeding clover or where clover seed are to be harvested, and all commercial vegetable crops. **Do not exceed the rates recommended for the specific crops, as boron toxicity can occur from excessive applications.** When the soil test boron level exceeds 1.0 pound per acre, boron **should not** be applied, irrespective of the crop.

Soil Test Boron (B) Ratings

Crop	**Soil Test Level, lbs. B/A**	
	Low	**Adequate**
All Crops	0.0 - 0.2	0.3

SOIL TEST INTERPRETATION FOR MANGANESE (Mn)

Crops grown in Georgia that may require the addition of manganese are corn, cotton, soybeans, peanuts, and small grains. Manganese deficiency may occur on the Atlantic Coast Flatwoods and sandy Coastal Plain soils of south Georgia when the pH is 6.3 or higher and/or on soils testing low in manganese. Manganese deficiency does not generally occur when the soil pH is 6.0 or less. Band applications of nitrogen and phosphorus fertilizers can substantially increase the uptake of manganese by plants due to the increased solubility of manganese around the fertilizer band.

On soils with excessively high pH levels, soil application of manganese may not be the most effective method of correcting a manganese deficiency because the applied manganese will most likely be converted to unavailable forms in the soil. In such instances foliar applications are most effective. If severe manganese deficiencies have been observed in the past, growers should be advised to use foliar applications of manganese or to grow a less sensitive crop until the soil pH is reduced to the desired level.

When the soil pH is less than 5.6, no manganese should be applied irrespective of the soil test level. If the soil pH is greater than 5.6 and the soil manganese level is low, follow the manganese recommendation given for the crop.

Soil Test Manganese (Mn) Ratings

Soil Test Level, lbs. Mn/A	Recommend Manganese if the soil pH is greater than the following
0.0 - 1.1	5.7
1.2 - 2.3	5.8
2.4 - 3.5	5.9
3.6 - 4.8	6.0
4.9 - 6.0	6.1
6.1 - 7.2	6.2
7.3 - 8.4	6.3
8.5 - 9.6	6.4
9.7 - 10.8	6.5
10.9 - 12.0	6.6
12.1 - 13.3	6.7
13.4 - 14.5	6.8
14.6 - 15.7	6.9
15.8 - 16.9	7.0
17.0 - 18.1	7.1

SOIL TEST INTERPRETATION FOR ZINC (Zn)

Zinc deficiency is primarily a problem associated with corn and pecans on the very sandy soils of the Coastal Plain. Zinc deficiencies have also been observed in sorghum-sudan, small grains, and cotton. Soils high in phosphorus and with marginal zinc levels may result in visual symptoms being more pronounced during certain years.

Some corn hybrids tend to be more sensitive to zinc than others. The occurrence of symptoms may vary over a field with plants in adjoining rows and down the row, varying from normal in appearance to severe zinc deficiency symptoms.

The zinc soil test is of little value for soils of the Piedmont, Mountain and Limestone Valley. However, zinc deficiency can occur during cool, wet springs or when soils have been heavily limed and phosphated. But, the likelihood of zinc deficiency in these soils is considerably less than soils of the Coastal Plain. However, there are two exceptions: zinc is recommended for Cotton and Home Vegetable Garden crop codes in these soils if zinc tests 2 pounds per acre or less. ***If a zinc deficiency is suspected in North Georgia soils, a plant analysis should be used to confirm the deficiency***.

Soil Test Zinc (Zn) Ratings

Soil Group	**Soil Test Level, lbs. Zn/A**		
	Low	**Medium**	**Adequate**
Coastal Plain	<2	2 - 8	>8
Piedmont, Mountain, & Valley	Soil test not applicable to these soils		

For those crops considered to respond to an application of zinc (approximately 50 of the more than 200 crops in the soil test database), they will generally respond to Zn treatment if the soil is a Coastal Plain soil testing <2 lbs. Zn/A. However, soils testing 2-8 lbs. Zn/A will not always respond to Zn applications. If the soil test is 2-8 lbs. Zn/acre and a Zn deficiency is suspected, and the pH is 6.3 or higher, it is advisable to follow up with a plant analysis. Pecans are an exception. For pecans, zinc is considered low if <8 lbs/A for a Coastal Plain soil. Peanut is the only crop for which we provide a high soil test zinc rating. For peanut, the soil test is very high when soil test Zn is 10 lbs. Zn/A or higher. If zinc levels are raised too much above this level, plant toxicity may occur. When soil pH is maintained at the recommended level of pH 6, soil test Zn levels of 20 lbs/A are the critical level, above which there may be some toxicity to peanut with a possible reduction in yield.

SOIL TEST INTERPRETATION FOR SOLUBLE SALTS

If the soluble salt level is greater than 1.25 millisiemens (mS) for soils and 2.25 mS for peat-perlite mixtures, some action must be taken to remove these salts. Leaching is the most common method of salt removal. Several unique techniques can also be applied. To the leaching water add 1 lb. sucrose (table sugar) to 10 gallons of water and apply on 40 sq. ft. Gypsum (Calcium sulfate) may be applied, broadcasting on the surface at the rate of 2 to 10 lbs/100 sq. ft. prior to applying the leaching water. Considerable water may be needed to remove any sizeable quantities of salts. A general rule of thumb is that six inches of water will remove about half of the salt, 12" - 4/5, and 24" - 9/10.

The soluble salt content of a soil is given in millisiemens per centimeter (mS/cm) and is interpreted as follows:

Mineral Soil	
Soluble Salts, mS/cm	**Rating and Interpretation**
0 - 0.15*	Very low: plants may be starved.
0.15 - 0.50	Low: if soil lacks organic matter; satisfactory if soil is high in organic matter.
0.51 - 1.25	Medium: satisfactory range for established plants.
1.26 - 1.75	High: Okay for most established plants. Too high for seedlings or cuttings.
1.76 - 2.00	Very high: plants usually stunted or chlorotic.
>2.00	Excessively high: plants severely dwarfed, seedlings and rooted cuttings frequently killed.

**Ratings based on 1:2 soil to water ratio.*

Peat-Based Soilless Mixes	
Soluble Salts, mS/cm	**Rating and Interpretation**
0 - 0.74**	Low: indicates low to very low nutrient status.
0.75 - 1.49	Acceptable: satisfactory range for most plants, especially seedlings and salt sensitive plants.
1.50 - 2.24	Optimal: suitable for most plant growth; may be too high for seedlings.
2.25 - 3.49	High: suitable for established plants; may cause some reduction in growth of young potted plants when soluble salts are >3.00.
>3.49	Very high: reduced plant growth; values >4.00 will result in noticeable plant injury and growth reduction.

***Ratings based on saturated media extract.*

SOIL TEST INTERPRETATION FOR ORGANIC MATTER CONTENT

The organic matter content of a soil is expressed as percent by weight. Its level depends on many factors, such as soil type, past cropping history, drainage (moisture), temperature, etc.

There is no ideal soil organic matter content. Most Georgia surface soils will vary in organic matter content from 0.5 to 2.0%. Organic matter will tend to accumulate under cool, more poorly-drained soil conditions and be less under warm, well-drained conditions. Cultivated soils tend to be lower in organic matter than uncultivated soils. The organic matter content of a soil will remain fairly constant under natural conditions.

Knowledge of the organic matter content has only special uses, primarily associated with potted or bench grown plants and adjusting the application rates of some herbicides. The amount of organic matter will affect the water-holding capacity and the tilth of a soil. Organic matter also contributes to the cation exchange capacity of a soil which influences its buffer capacity. Therefore, the organic matter content and its interpretation will depend on the use of the soil.

LIME AND FERTILIZER RECOMMENDATIONS FOR SURFACE MINE SOILS

RULES OF SURFACE MINED LAND USE BOARD AND GEORGIA SURFACE MINING ACT OF 1968

1. **Requirements:**

   Under the Rules of Surface Mined Land Use Board, Chapter 645-5, page 24, a soil test result and lime and fertilizer recommendation must be submitted to the director prior to revegetation of mined areas. The mine operator is to collect the soil and submit the sample to the laboratory through the local county Extension office.

2. **Recommendations:**

   When called on to advise the local operator when complying to the Rules of Surface Mined Land Use Board, you should do the following:

   a. Only the routine soil test is required to check pH and level of phosphorus, potassium, calcium, magnesium, zinc, and manganese.

   b. On spoils covered by topsoil, the lime and fertilizer recommendation should conform to that given in this handbook for the crop specified. The establishment recommendations should be followed. The recommendation should include the tons of limestone needed and pounds of N, P_2O_5, and K_2O per acre required. The recommendation should include, when applicable, suggested grades, method, and time of application.

   c. For vegetative establishment on the spoil itself not covered by topsoil, the handbook recommendations are not applicable. The following general recommendations should be followed irrespective of the soil test results:

      1. Apply 1.0 ton/A limestone.
      2. Apply 1000 to 1500 lbs./A 6-12-12 or equivalent fertilizer, the higher rate on steep slopes or terraces.
      3. The following year, top dress grasses with 50 lbs. N/A and legumes with 500 to 700 lbs./A 0-14-14 or equivalent fertilizer.

   d. If the crop to be planted is not given in the handbook, you should consult with the Extension Specialist in the department related to that crop.

   e. The rules specify that recommendations may also be obtained from the Soil Conservation Service representative in the area. In the event that a mine operator does consult with SCS personnel, your cooperation and assistance, when called on, should be given as stated above. The SCS has land preparation, lime, fertilizer, and seeding recommendations that have proven successful in the establishment of vegetation on spoil banks. Your recommendations should conform to theirs, particularly with regard to lime and fertilizer recommendations. Those given in (c) above are in line with current SCS recommendations.

3. **Source of Rules:**

Copies of the rules can be obtained from:

Georgia Surface Mined Land Use Board
P.O. Box 4845
Macon, Georgia, 31208

COMMERCIAL GREENHOUSE MEDIA TESTING

C. Owen Plank, Extension Agronomist - Retired
P. Thomas, Extension Specialist - Floriculture

Normal soil testing procedures used for mineral field soils are not suited for the analysis of modified or soilless media commonly used for greenhouse crops. Soilless media are typically composed of lightweight, natural, and processed material such as peat, bark, sand, perlite, vermiculite, compost, and similar materials. Most prepared root media have a limited nutrient reserve that can easily become deficient. Therefore, greenhouse operators are frequently faced with plant nutrition disorders and fertility management decisions that require testing of the media and/or plant analysis to aid in plant nutrient diagnosis. Greenhouse crops are high-value, often short-term crops that require quick diagnosis to correct nutritional disorders.

The saturated media extract (SME) and the modified (DTPA) SME procedures developed at Michigan State University have been adopted by the University of Georgia Soil, Plant, and Water Laboratory for use in testing peat and bark-based media samples. Routine analyses for media samples include: pH, soluble salts, ammonium-nitrogen (NH_4-N), nitrate-nitrogen (NO_3-N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg). Special analyses include tests for boron (B), copper (Cu), manganese (Mn), and zinc (Zn). The Commercial Greenhouse Test is for soilless media and modified soils only. Native (mineral) soils containing substantial quantities of peat, pine bark, sawdust, compost, etc. are also suitable for analysis by the **Greenhouse Test**. When mineral soils from field-flower production are to be tested, the **Routine Soil Test** plus tests for **Soluble Salts** and **Nitrates** is recommended.

Sampling, Submission, and Recommendation Procedures:

When sampling for greenhouse media testing it is important to obtain a representative sample. The following guidelines will aid in obtaining a representative sample:

1. Take samples at least 6 hours after watering.
2. If possible, take samples at least 5 days after a fertilizer application.
3. Prior to taking samples, scrape aside the top ¼ inch of media where the individual cores will be taken. (Note: It is not necessary to pick out slow release fertilizer granules such as Osmocote as the SME method has very little effect on increasing the solubilization of slow release fertilizers.)
4. **Bench Crops:** The cores should be taken from spots equally distributed throughout the bench, but not within 2 inches of the edge or ends of the bench. Take 10 to 15 full cores of media from the top to bottom of the bench to give a minimum pint sample. Place in a clean plastic container and mix thoroughly.
5. **Potted Plants:** Take core samples from top to bottom from 10 to 15 pots, place in a clean plastic container and mix thoroughly.
6. **Potting or Transplanting Media or Compost Pile:** Take small portions of media from 10 to 15 locations in the pile to give a minimum pint sample, place in a clean plastic container and mix thoroughly.

7. **Diagnostic Samples:** When diagnosing plant nutrition disorders, the media sample should be taken only from the problem areas, and a sufficient quantity of sample (10 to 15 cores) should be taken to give a minimum pint sample or to fill the soil sample bag about 3/4 full.
8. Spread the samples on newspaper in a warm room to air-dry overnight. Do not allow the sample to go to complete dryness as the sample should be slightly moist for shipment.
9. Put the sample in a soil test bag or into a quart Ziploc bag.
10. Complete the information on the soil sample bag and submission form.
11. Interpretations and recommendations will be made at the Soil, Plant, and Water Laboratory and/or by the Extension specialist. Results will go directly to the appropriate county Extension office. The Extension office sends the report of the analysis and recommendations to the grower or client.

Interpretations and Recommendations:

The ranges in nutrient levels shown in Table 1 **should be considered as guideline levels only,** because many factors affect plant nutritional needs. Factors to be considered in determining specific levels include: crop (nutritional requirements vary), stage of growth (seedlings and cuttings just planted require lower levels than established plants), season of year (nutrients are required in greater quantities when growth is rapid), fertilization and irrigation program (constant liquid feed vs. incorporated or controlled release fertilizers), growing medium (buffering capacity, water holding, and aeration characteristics), and other environmental factors (light, temperature, spacing, etc.).

Media test levels in the low range usually have insufficient nutrients to support adequate growth of most crops, regardless of the type of media. Bark mixes testing in the acceptable range usually have sufficient nutrients for normal growth. Top production will usually be obtained in peat-based mixes testing in the optimum range. Optimal growth using constant liquid feed programs can be obtained by maintaining the fertility parameters in the acceptable range. Maintaining higher nutrient levels for these three situations may result in soluble salt injury.

Soluble Salts:

Excessive soluble salt levels are one of the most common problems encountered by greenhouse operators. Soluble salts result from soluble ions such as nitrate, ammonium, potassium, calcium, magnesium, chloride and sulfate in the growth media or irrigation water. As previously noted, soluble salt levels (electrical conductivity) are reported in millisiemens per centimeter (mS/cm). Soluble salt levels of 3.50 to 4.99 mS/cm are slightly higher than desirable and loss of vigor may be noted in the upper end of the range on plants with low nutrient requirements. Levels above 5.00 mS/cm will usually result in reduced growth or quality, especially in young plants. Severe salt injury and crop failure are likely to occur at levels above 6.00 mS/cm. High soluble salts are more likely to cause injury in pine bark mixes compared to peat mixes, thus the acceptable range may be more desirable for bark mixes.

Soluble salt buildup can be minimized by applying enough water to cause some leaching. Soluble salt levels in the mid to upper portion of the high range can be reduced to an acceptable level by leaching the container or bed so that about 20% of the volume of the added water drains from the media and then repeating the procedure one or two hours later. When very high salt levels are encountered, repeating the procedure two or three days after the initial leaching may be required. Recheck the soluble salt level (electrical conductivity) to determine if the leaching has been effective in lowering the soluble salts to the optimum or acceptable range.

Table 1. General Guidelines for Interpreting Test Results for the Saturated Media Extract Method

Test	Low	Acceptable	Optimum	High	Very High
Soluble salts* mS/cm	0 - 0.74	0.75 – 1.99	2.00 – 3.49	3.50 – 4.99	5.00+
Nitrate-N ppm	0 – 39	40 - 99	100 - 199	200 - 299	300+
Phosphorus ppm	0 – 2	3 - 5	6 - 10	11 - 18	19+
Potassium ppm	0 – 59	60 - 149	150 - 249	250 - 349	350+
Calcium ppm	0 – 79	80 - 199	200+	--	--
Magnesium ppm	0 – 29	30 - 69	70+	--	--
Boron ppm	--	--	0.7 – 2.5	--	--
Copper ppm	--	--	0.5 – 1.5	--	--
Iron ppm	--	--	15 - 40	--	--
Manganese ppm	--	--	5 – 30	--	--
Zinc ppm	--	--	5 - 30	--	--
pH	<5.4	5.4 – 5.8	5.9 - 6.5	>6.5	--

**Saturated media extract method. These soluble salt levels are considerably higher than those obtained with the 1:2 soil and water procedure used by many growers. Millisiemen/centimeter (mS/cm) replaces millimho/centimeter (mmho/cm) as the method for expressing soluble salt (electrical conductivity) measurements. The value remains the same, only the unit changes. The relationship of commonly used expressions of soluble salt measurements are =mmho/cm = mS/cm = decisiemen/meter (dS/m).*

pH

pH is one of the most important chemical parameters of greenhouse growth media. It influences the availability and plant uptake of essential nutrients, root growth, and volatilization of certain elements. The pH of the growth media can change over the course of the production period. Therefore, when planning the lime program it is important to know the initial pH, the pH requirements of the specific crop, the effect of fertilizers and other amendments on pH, and the species effect on substrate pH. For most greenhouse and nursery plants, the desired pH for peat, and peat/pine bark mixes is 5.4 to 6.5. For plants such as azaleas and blueberries that prefer acid soils, the pH should be adjusted to 5.0 to 5.5 and 4.0 to 5.2, respectively.

Suggested guidelines for increasing the soil pH one unit (for example, pH 5.3 to 6.3) with finely ground limestone or lowering the pH one unit (for example, pH 7.5 to 6.5) with ferrous sulfate, aluminum sulfate and elemental sulfur are given in the following tables.

Table 2. Approximate amounts of finely ground limestone required to increase the media pH one unit.

	Type Media		
Rate/Unit	70% Peat/30%Sand	70% Peat/30% Bark	100% Peat
Lbs/cubic yard	4	5.5	6
Lbs/100 sq. ft.	8.5	11	12
Ounces/bushel	3.5	4	4.5

Table 3. Approximate amounts of ferrous sulfate ($FeSO_4 \bullet 7H_2O$) and aluminum sulfate ($Al_2(SO_4)_3 \bullet 16H_2O$) required to lower the soil pH one unit.

	Type Media		
Rate/Unit	70% Peat/30%Sand	70% Peat/30% Bark	100% Peat
Lbs/cubic yard	2	2.5	3
Lbs/100 sq. ft.	4	5.5	6
Ounces/bushel	1.5	2	2.5

Table 4. Approximate amounts of elemental sulfur required to lower the soil pH one unit

	Type Media		
Rate/Unit	70% Peat/30%Sand	70% Peat/30% Bark	100% Peat
Lbs/cubic yard	1.4	1.75	2
Lbs/100 sq. ft.	2.5	3.5	4
Ounces/bushel	1	1.2	1.5

When adding lime to greenhouse growth media it is best to under-lime initially than to over-lime because it is more difficult to lower pH than it is to increase it. However, when post-plant pH adjustments need to be made in pots, benches, or flats one of the following options can be used.

1. If the pH is ***low***, mix 1 pound of hydrated lime ($Ca(OH)_2$) with 3 to 5 gallons of warm water in a plastic bucket. Allow the mixture to settle then pour off only the clear solution (the supernatant) into another plastic bucket. Apply the clear solution with a fertilizer injector set at 1:100 or 1:128. *Hydrated lime is corrosive.* Avoid getting the solution on the foliage. If contact is made, wash off the foliage immediately after application. *Do not apply ammonium containing fertilizers immediately before or after application of this lime water solution. When ammonium containing fertilizers*

come in contact with lime it reacts and releases ammonia, which may burn plant foliage.

2. If the pH is ***high,*** dissolve 1 to 2.5 pounds of iron (ferrous) sulfate ($FeSO_4 \cdot 7H_2O$) in 100 gallons of water and apply to the root medium.

Fertilization Guidelines

In order to obtain good growth, nutrients need to be present in the media not only in the proper amounts but also in proper balance. Increasing the concentration of one element relative to the others will change their relative availability. Plant growth is better with balanced nutrient levels even at low fertility as compared to higher unbalanced levels. Also, plants have better tolerance to high soluble salt when the nutrients are balanced. Nutrient balance can be calculated as a percent of the total soluble salts. However, the concentration of soluble salts and nutrients must be converted to the same units (ppm). The concentrations of nutrients in the saturated paste extract are reported in ppm. Soluble salt levels (electrical conductivity) are generally reported as mS/cm or dS/m and can be converted to parts per million (ppm) by multiplying by 700. Thus for a sample with a nitrate – N concentration of 120 ppm and soluble salt concentration of 2 mS/cm the percent nitrate – N can be calculated as a percent of the total soluble salts in the following manner.

$$\begin{aligned}
\%\ Nitrate - N &= \frac{Nitrate - N\ \ Conc.,\ ppm}{Soluble\ Salt\ Conc.,\ mS/cm\ x\ 700}\ x\ 100 \\
&= \frac{120\ ppm}{2\ mS/cm\ x\ 700}\ x\ 100 \\
&= \frac{120\ ppm}{1400\ ppm}\ x\ 100 \\
&= 8.57\,\%
\end{aligned}$$

The nutrient balance given in the following table has been found to give the best plant growth.

Table 5. Desirable nutrient balance in saturation extracts

Nutrient	% of Total Soluble Salts
Nitrate – N	8 – 10
Ammonium – N	<3
Potassium	11 – 13
Calcium	14 – 16
Magnesium	4 – 6

The nutritional requirements of greenhouse crops can be met in a number of different ways. Two commonly used practices are the addition of limestone and dry fertilizer materials to the media preplant and injection of soluble fertilizer materials into the media post plant. Some guidelines for the various nutrients are given in the following sections.

Nitrate-Nitrogen (NO_3–N) – Optimum NO_3-N levels vary with plant age, type and growing conditions. Guidelines for desirable NO_3-N concentrations and nitrogen fertilizer materials to use to attain these levels are given in Tables 6 and 7.

A fairly constant level of nitrogen can be maintained by injecting additional nitrogen into the irrigation system. However, when injecting fertilizer into the irrigation water, be sure to water adequately to cause some leaching and prevent excess nitrate and soluble salt buildup.

Table 6. Desirable NO_3–N concentrations in greenhouse growth media saturation extracts.

Crop	NO_3–N, ppm
Seedlings	40 – 70
Young pot and foliage plants	50 – 90
Potted and bedding plants – growing on	80 – 160
Roses, mums, snapdragons in ground or raised beds	120 – 200
Tomatoes in ground beds	125 – 225
Azaleas	40 - 100

Table 7. Nitrogen fertilizer needed to increase the NO_3–N level in the saturation extract 10 ppm.

Nitrogen Carriers	N Content, %	Amount required to increase NO_3 – N 10 ppm		
		oz/bu	oz/cu yd	oz/100 sq ft
Potassium nitrate	13	0.12	2.3	4.6
Calcium nitrate	15	0.10	2.0	4.0
Ammonium nitrate	34	0.045	0.9	1.8
Urea	45	0.035	0.7	1.4

Phosphorus (P) – An adequate supply of P is necessary for good root development and rapid growth in plants as well as good flower quality in floral plants. The desired P concentrations in the saturation media extract and the amount of phosphorus fertilizers to use are given in the following tables.

Table 8. Desirable P concentrations in greenhouse growth media saturation extracts.

Crop	P, ppm
Seedlings	5 – 9
Potted and bedding plants	6 – 10
Roses, mums, snapdragons in ground or raised beds	10 – 15
Tomatoes in ground beds	10 – 15
Azaleas	3 – 5

Table 9. Phosphorus fertilizer needed to increase the P level in the saturation extract 2 ppm.

Phosphorus Carriers	P_2O_5 Content , %	Amount required to increase P 2 ppm		
		oz/bu	lb/cu yd	lb/100 sq ft
Normal superphosphate	20	0.76	0.90	1.8
Conc. superphosphate	46	0.33	0.40	0.8
Bone meal	25	0.60	0.75	1.5

Potassium (K) – Potassium is the nutrient most often limiting greenhouse production. This is due to the growth habits of many greenhouse plants and the fact that they have a K requirement equal to or greater than nitrogen. Therefore, it is important to establish a near optimum level of K in the growth media before planting to ensure a consistent supply of K throughout the growth period. The desired K concentrations in the saturation media extract and the amount of potassium fertilizers to use are given in the following two tables. The use of muriate of potash (KCl) to raise the potassium level in the media should be avoided because of its high salt index.

Table 10. Desirable K concentrations in greenhouse growth media saturation extracts.

Crop	K, ppm*
Seedlings	100 – 175
Bedding plants	150 – 225
Potted plants	175 – 250
Roses, mums, snapdragons in ground or raised beds	200 – 275
Tomatoes in ground beds	200 – 300
Azaleas	60 – 100

For pine bark-based mixes, reduce the desirable K concentrations by 50%

Table 11. Potassium fertilizer needed to increase the potassium level of the saturation extract 25 ppm.

Potassium Carriers	K_2O Content , %	Amount required to increase K 25 ppm		
		oz/bu	oz/cu yd	lb/100 sq ft
Potassium nitrate	44	0.19	3.75	0.46
Potassium sulfate	50	0.16	3.25	0.40
20 – 20 – 20	20	0.41	8.25	1.00

Calcium (Ca) – If not properly amended with lime, the calcium levels in soilless greenhouse media, especially those that are peat-based, may be low. Therefore, it is essential to have the media tested prior to planting. For most plants the Ca levels in the media should be maintained within the acceptable or optimum range. In cases where the pH of the media is acceptable but the Ca level is low, materials such as calcium nitrate and calcium sulfate (gypsum) can be used to increase the Ca levels in the media. Other sources can also be used and are listed in the following table.

Table 12. Calcium carriers and rates to use to increase the calcium level in the saturation extract 25 ppm.

Calcium Carriers	Ca Content , %	Amount required to increase Ca 25 ppm		
		oz/bu	oz/cu yd	lb/100 sq ft
Calcium sulfate	23	0.29	5.8	0.73
Calcium nitrate	19	0.35	7.0	0.88
Normal superphosphate	20	0.33	6.7	0.84
Conc. superphosphate	13	0.51	10.2	1.28

Magnesium (Mg) – The magnesium level of greenhouse media can be low, especially those in which the pH has been adjusted using calcitic limestone. Prior to planting it is essential to know the magnesium level of the media. If the pH is adequate and magnesium is low, apply magnesium sulfate at the rate of 4 to 8 ounces per cubic yard or per 100 gallons for drenching. Do not inject magnesium sulfate into the watering system with any other materials that contain calcium or phosphorus. This can result in the formation of precipitates and plugging of the injectors

Micronutrients (Boron (B), Copper (Cu), Iron (Fe), Manganese (Mn), Molybdenum (Mo), and Zinc (Zn)) – Although required in very small amounts, it is essential to supply greenhouse media with these essential elements. Many artificial mixes, especially peat-based ones, may be deficient unless adequate amounts of these nutrients are supplied. There are formulated greenhouse micronutrient mixes on the market or growers can formulate their own mix provided they have the proper equipment for weighing the small amount of materials.

Table 13. General micronutrient formulation to mix into stock growth media.

Compound	Quantity to use per cubic yard
Iron chelate (6% Fe)	1.0 oz
Manganese sulfate	1.0 oz
Copper sulfate	0.3 oz
Zinc sulfate	0.2 oz
Sodium borate (Borax)	0.1 oz
Sodium molybdate	0.03 oz

With the exception of molybdenum (Mo), the availability of micronutrients decreases as the pH of the media increases. Therefore, for greenhouse crops it is important to maintain the pH within the recommended ranges. While some plants can tolerate a pH of 6.8, most do best when the pH does not exceed 6.5. Iron (Fe) and manganese (Mn) are the two most likely micronutrients to become deficient at pH values above 6.5. Boron (B), copper (Cu) and zinc (Zn) deficiencies do not occur as frequently.

Before adding any micronutrient to correct a suspected micronutrient deficiency, check the media pH to make sure it is in the recommended range and take plant samples for plant analysis. If the pH is not within the recommended range, take appropriate steps to correct it. If the pH is too high, apply one of the materials listed in Tables 3 and 4 to lower the pH. With the exception of molybdenum, lowering the pH will increase the availability of other micronutrients. A plant analysis will aid in identifying a deficiency or toxicity. Also, a plant analysis will help to identify nutrients that may be low but not low enough to cause visual symptoms. Depending upon the stage of growth, low or deficient levels of micronutrient can be corrected by using one of the approaches listed in Tables 14 and 15.

Table 14. Sources, rates, and final concentration of micronutrients for a single corrective application of one or more micronutrients applied to the soil.

Micronutrient Source	Weight of source/100 gal Ounces	Grams	Final nutrient conc., ppm
Iron sulfate – 20% Fe	4.0	113.4	62.0
Iron chelate (EDTA) – 12% Fe	4.0	113.4	36.4
Manganese sulfate – 28% Mn	0.5	14.2	10.0
Zinc sulfate – 36% Zn	0.5	14.2	13.9
Copper sulfate – 25% Cu	0.5	14.2	9.3
Borax – 11% B	0.75	21.3	6.25
Solubor – 20% B	0.43	12.2	6.25
Sodium molybdate – 38% Mo	2.7	77	77
Ammonium molybdate – 54% Mo	1.9	54	77

Table 15. Sources, rates, and final concentration of micronutrients for single foliar sprays for correcting micronutrient deficiencies.*

Micronutrient Source	Weight of source/100 gal Ounces	Grams	Final nutrient conc., ppm
Iron sulfate – 20% Fe	4.0	113.4	62
Manganese sulfate – 28% Mn	2.0	56.7	40
Zinc sulfate – 36% Zn	2.0	56.7	40
Tribasic Copper sulfate – 53% Cu	4.0	113.4	159
Sodium molybdate – 38% Mo	2.0	56.7	57
Ammonium molybdate – 54% Mo	2.0	56.7	81

**Do not apply combinations without first testing on a small number of plants. Use the same spreader-sticker product rate with the above foliar sprays as used with insecticide and fungicide sprays*.

REFERENCES

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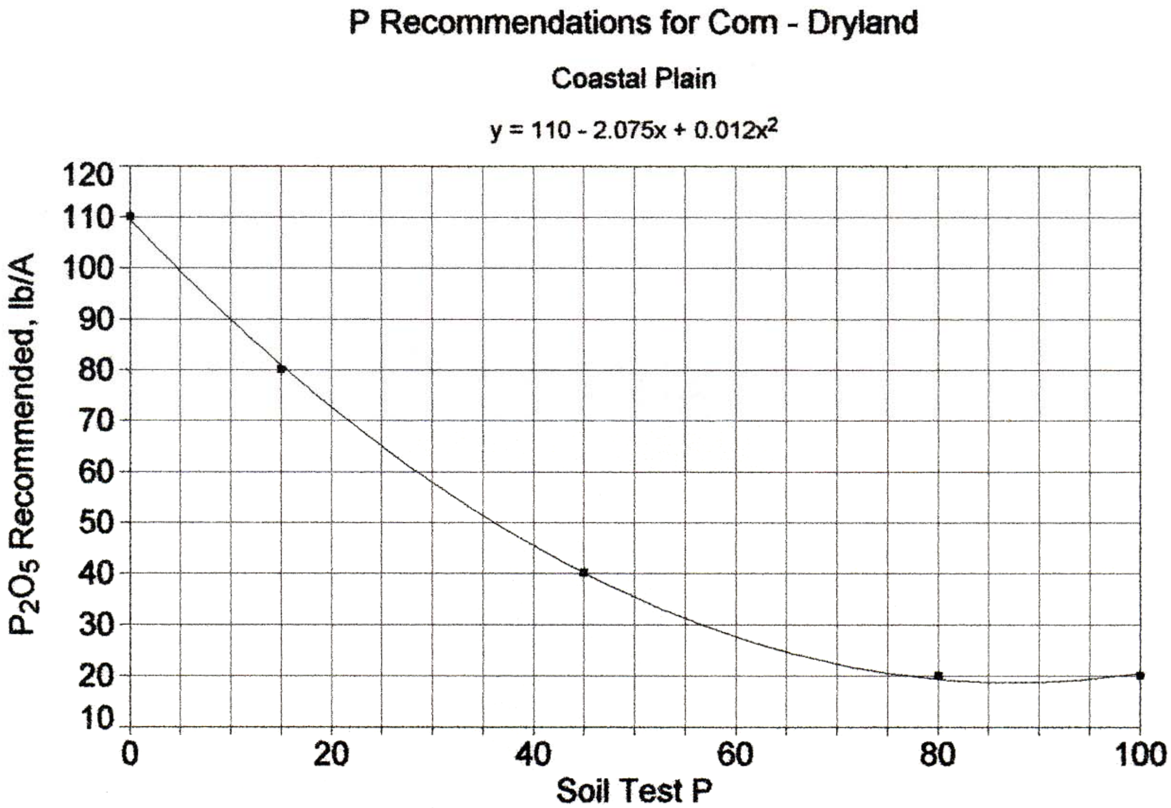
REPORTING SOIL TEST RESULTS AND FERTILIZER RECOMMENDATIONS

David E. Kissel, Director, Agricultural and Environmental Services Laboratories
C. Owen Plank, Extension Agronomist - Retired

In 1976, the Soil, Plant, and Water Laboratory began utilizing the computer for reporting soil test results and fertilizer recommendations. Since that time several major changes have been made in the report forms. Copies of the current report forms are presented on the following pages.

For agronomic, fruit, nut, ornamental, and commercial vegetable crops, soil test results for P, K, Ca, Mg, Mn and Zn are reported in the space provided on the computer printouts in lbs./A on an elemental basis. When requests for special analyses such as B, NO_3-N, and organic matter are made, the results are printed out in statement form immediately below the **Recommendations Section**. Boron will be rated as either low or adequate for all crops. No rating is given for special analyses such as NO_3-N, soluble salts, or organic matter. If a micronutrient recommendation is available for a given crop, a rating (for example, low, sufficient, high) will be given in the results section and a recommendation in the recommendation section.

The regression technique is used for making computer generated phosphorus and potassium recommendations for most agronomic, fruit, nut, and commercial vegetable crops. The laboratory adopted the regression technique because using a fixed rate of phosphorus or potassium at a given soil test category (low, medium, high) may in some cases result in substantial differences in fertilizer recommendations although small differences may exist in soil test levels. This is particularly evident when soils are borderline of being classified as "low or medium" and "medium or high." If two soil samples had extractable phosphorus levels of 28 lbs/A (low) and 32 lbs/A (medium), using the category approach the phosphorus recommendation for a crop such as corn would be 80 and 40 lbs. P_2O_5/A, respectively. However, using the regression approach, the amount of phosphorus recommended is a continuous function of small incremental changes in the soil test phosphorus level (See example on following page). For the two samples cited above, based upon regression, the phosphorus recommendation would be 60 and 50 lbs. P_2O_5/A, respectively.



Regression curve used for making computerized phosphorus fertilizer recommendations for corn.

In order to establish the regression equations, the recommendations given in the handbook are set in the middle of each category. Since the recommendations change with incremental changes in the soil test level, this results in a range in the amount of P_2O_5 or K_2O that will be recommended in a particular category. For example, if 80 lbs. of P_2O_5/A is recommended in the handbook at a low test level, computer generated recommendations may vary $\pm$ 10 lbs/A depending on whether or not the soil test level is increasing or decreasing from the midpoint of the category.

Recommendations for lawns, golf greens and tees, landscape ornamentals, flowers, and home gardens are reported in a slightly different manner. ***Limestone recommendations are given on the report form in lbs. per 1000 square feet and have been corrected for sampling depths***. The fertilizer recommendations are not based on regression and are reported in the recommendation section in the appropriate units specific for the intended plants.

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Soil, Plant, and Water Laboratory
2400 College Station Road
Athens, Georgia 30602-9150
Web site: http://aesl.ces.uga.edu

Soil Test Report

(CEC/CEA Signature)

Sample ID

Client Information	*Lab Information*	*County Information*
Doe, John 123 Main Street Anywhere, GA 31071 Sample: 112 Crop: Corn (for Grain) Irrigated	Lab #9919960 Completed: 12/14/2006 Printed: 07/23/2007	**Wilcox County** Co Ag Bldg 667 Second Ave Rochelle, GA 31079 phone: 229-365-2323 e-mail: uge2315@uga.edu

Results

Mehlich I Extractant | UGA Lime Buffer Capacity Method*

	Phosphorus (P)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Zinc (Zn)	Manganese (Mn)	pH *	Lime Buffer Capacity (LBC)	
Soil Test Index	36 lbs/Acre	115 lbs/Acre	362 lbs/Acre	57 lbs/Acre	3 lbs/Acre	14 lbs/Acre	5.3	181	**Soil Test Index**

Recommendations

Limestone Target pH: 6.0 (Recommended)	Limestone Target pH: 6.5	Nitrogen (N)	Phosphate (P_2O_5)	Potash (K_2O)	Sulfur (S)	Boron (B)	Manganese (Mn)	Zinc (Zn)
0.5 tons/Acre	0.75 tons/Acre	180 lbs/Acre	100 lbs/Acre	90 lbs/Acre	10 lbs/Acre	--	--	--

A target pH of 6.0 is recommended for most Agronomic crops. However, a lime recommendation for pH 6.5 is also provided on this soil test report. Liming to pH 6.5 helps reduce low pH areas in highly variable fields.

*For information on how the Soil, Plant, and Water Laboratory measures and reports pH and makes lime recommendations, see http://aesl.ces.uga.edu/publications/soilcirc.

See Corn (for Grain) Irrigated Fact Sheet

Corn (for Grain) Irrigated Fact Sheet for Doe, John

The recommendations given are for an expected corn grain yield of 150 bushels per acre. For expected yields in excess of 150 bushels per acre, increase the nitrogen (N) rate 12 pounds per acre, the phosphate (P_2O_5) rate 6 pounds per acre, and the potash (K_2O) rate 10 pounds per acre for every 10-bushel increment over 150 bushels per acre.

Reduce the nitrogen rate by 20 to 40 pounds per acre following peanuts and soybeans, and by 80 to 100 pounds per acre following alfalfa or a legume winter cover crop that is allowed to bloom.

Split the nitrogen applications, applying one-fourth to one-third of the nitrogen prior to or at planting and the remainder as a sidedress application when the corn is 18 to 24 inches high; or apply the remainder of the nitrogen through the irrigation system in 3 to 4 equal applications at 7 to 10 day intervals, beginning at the 6 leaf stage.

For new ground testing low in phosphorus (P), double the recommended rate of phosphate.

For early planted corn, apply a starter fertilizer at a rate to supply 10 to 20 pounds nitrogen per acre and 30 to 60 pounds phosphate per acre.

The applied fertilizer should contain sufficient sulfur (S) to supply 10 pounds sulfur per acre. Since sulfur is highly leachable, especially on deep sands, application of sulfur with post plant nitrogen applications may improve efficiency.

Use plant analysis to monitor the nutrient status of the plants. If any are found to be low they can be applied to the crop as a sidedress, foliar application or through the irrigation system. Contact your local county agent for additional information.

NOTE: The amount of nitrogen (N), phosphate (P_2O_5), and potash (K_2O) actually applied may deviate 10 pounds per acre from that recommended without appreciably affecting yields.

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Soil, Plant, and Water Laboratory
2400 College Station Road
Athens, Georgia 30602-9150
Web site: http://aesl.ces.uga.edu

Soil Test Report

(CEC/CEA Signature)

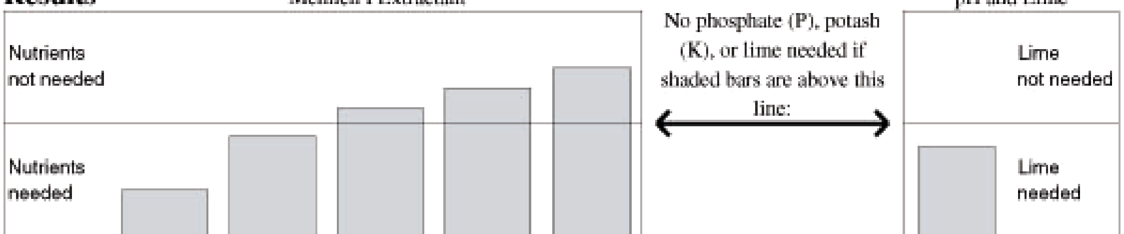
Sample ID

Client Information	*Lab Information*	*County Information*
Doe, John 123 Main Street Anywhere, GA 30052 Sample: 1 Crop: Hybrid Bermuda Lawn	Lab #999986 Completed: 07/11/2007 Printed: 07/23/2007	**Walton County** P O Box 151 Monroe, GA 30655 phone: 770-267-1324 e-mail: uge1297@uga.edu

Results

Mehlich I Extractant

pH and Lime



	Phosphorus (P)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Zinc (Zn)
Soil Test Index	17 lbs/Acre	180 lbs/Acre	742 lbs/Acre	117 lbs/Acre	8 lbs/Acre

pH	
5.4	**Soil Test Index**

Recommendations

Limestone: 25 pounds per 1000 square feet

Recommended pH: 5.5 to 6.0

For establishment, incorporate 25 pounds of 5-10-15 per 1000 square feet into the top 4 to 6 inches of soil prior to seeding, sprigging, or sodding. Then apply 3 pounds of 34-0-0 or 2 pounds of 46-0-0 per 1000 square feet monthly during the growing season through August. To improve winter hardiness, apply 6 pounds of 16-4-8 or 8 pounds of 12-4-8 per 1000 square feet in September. Follow this fertilizer program for the first year only, then use the maintenance fertilizer program for the next 2 to 3 years. Retest 2 to 3 years after establishment.

For maintenance, apply 10 pounds of 10-10-10 per 1000 square feet when spring growth begins and again in September. In May, June, and July apply 3 pounds of 34-0-0 or 2 pounds of 46-0-0 per 1000 square feet.

Clippings do not contribute to thatch under proper management and thus, do not need to be removed. If they are removed, increase the fertilizer application rate by 30%.

CAUTION: Water lawn thoroughly immediately after applying fertilizer. Do not apply fertilizer when grass is wet.

COMPARATIVE SOIL TEST RESULTS

C. Owen Plank, Extension Agronomist - Retired

Occasionally a Georgia farmer or grower will send a soil sample to a fertilizer company or commercial laboratory for analysis or will split a soil sample, sending a portion to one of these laboratories and another to the University of Georgia Soil, Plant, and Water Laboratory. Upon receiving the soil test results, the farmer may come to you for help in interpreting the results.

It should be remembered that there are numerous methods for analyzing soils. Extracting reagents, soil:solution ratios, and shaking time can have a significant effect on the amount of an element extracted and measured. Therefore, a comparison cannot be made unless the methods of analysis are known.

The UGA Soil, Plant, and Water Laboratory uses the Mehlich-1 extractant (0.05 *N* HCl in 0.025 *N* H_2SO_4) with a 1:4 soil to solution ratio, shaking 5 minutes at 200 oscillations per minute for P, K, Ca, Mg Mn and Zn. The state laboratories in South Carolina, Virginia, Florida, Tennessee, and Alabama use essentially the same methods as Georgia. Several private and commercial laboratories use the same procedure for soils submitted from these southern states.

Most of the soil testing laboratories in the Midwest use Mehlich-3 extracting solution P, K, Ca, and Mg, and chelate extractants for Mn and Zn. This extracting solution will extract a different amount of P, K, Ca, Mg, Mn and Zn than the Mehlich-1 extractant. Therefore, soil test results conducted on the same soil sample but using different test procedures will not be comparable to those obtained at the UGA Soil, Plant, and Water Laboratory. ***One cannot take a soil test result using a different extractant and use the interpretations in this handbook.***

Not only may a test result be different due to the extraction method used in the laboratory, but the method of expressing the results will vary from lab to lab. Some express results in pounds per acre (lbs/A), parts per million (ppm), milliequivalents per 100 grams (meq./100 g), or as an index or sufficiency value on a scale of 0 to 100 or to some other level greater than 100. All soil test results for extractable nutrients from the UGA Soil, Plant, and Water Laboratory are reported as lbs/A.

If a farmer brings you a soil test result from a laboratory other than the UGA Soil, Plant, and Water Laboratory, you cannot use this handbook to make a lime and fertilizer recommendation unless the soil test method used to test the soil is the same as the UGA Soil, Plant, and Water Laboratory. Since the UGA Soil, Plant, and Water Laboratory soil tests have been calibrated with crop response under Georgia soil and climatic conditions, farmers should be cautioned if they rely on soil testing services outside the state. If you need help interpreting a soil test result from another laboratory, you should contact the UGA Soil, Plant, and Water Laboratory for assistance.

SUGGESTED FERTILIZER SOURCES FOR N, P, K, Ca, Mg, S AND MICRONUTRIENTS

C. Owen Plank, Extension Agronomist - Retired

In general, most of the recommendations in this handbook are given in pounds of N, P_2O_5, and K_2O with no additional suggestions regarding grades of fertilizers. The application of specific amounts of the major elements may not always be possible. Therefore, when writing a fertilizer recommendation or adjusting the computerized fertilizer recommendations, it may be advisable to suggest a particular grade or grades that would come reasonably close to meeting the soil test recommendation. Depending upon whether the soil test level is at the upper or lower end of a soil test category, the amount of fertilizer applied may deviate by 10-20 lbs. per acre from that recommended in this handbook without appreciably affecting yields. Since the selection of a particular grade cannot be set on a state-wide basis, the decision regarding a suggested grade is left to each county agent who is more familiar with the grades available in a particular geographic region.

A fertilizer recommendation should not be made in such a way as to favor a particular source or grade of fertilizer. The ultimate decision regarding the use of any particular grade should be left to the farmer and his fertilizer dealer. A recommendation should offer the farmer several means of supplying the nutrients needed so the farmer can choose the method best suited to his own situation.

Nitrogen Sources:

There are numerous nitrogen carriers that can be used as fertilizers, although about four substances make up most of the commonly used materials.

Nitrogen Sources

Inorganic:	**Formula**	**Form**	**Percent N**
Ammonium nitrate	NH_4NO_3	Solid	34
Ammonium sulfate	$(NH_4)_2SO_4$	Solid	21
Ammonium thiosulfate	$(NH_4)_2S_2O_3$	Liquid	12
Anhydrous ammonia	NH_3	Gas[1]	82
Aqua ammonia	NH_4OH	Liquid	20-25
Calcium cyanamide	$CaCN_2$	Solid	21
Calcium nitrate	$Ca(NO_3)_2$	Solid	16
Nitrogen solutions	(varies)	Liquid	19-32
Sodium nitrate	$NaNO_3$	Solid	16
Potassium nitrate	KNO_3	Solid	13
Synthetic Organic:			
Urea	$CO(NH_2)_2$	Solid	45-46
Sulfur Coated Urea (SCU)	$CO(NH_2)_2$-S	Solid	40
Urea - Formaldehyde	$CO(NH_2)_2$-CH_2O	Solid	38

Natural Organic:			**Lb. N/ton**
Cotton seed meal	----	Solid	12-13
Milorganite	----	Solid	12
Animal manure	----	Solid	10-28
Sewage sludge	----	Solid	10-20
Chicken litter	----	Solid	25-73

Phosphorus Sources:

There are a number of phosphorus sources that vary widely in solubility. The percent P_2O_5 listed on the fertilizer bag is that which is citrate soluble. With some materials, all of the citrate soluble phosphorus may also be completely water soluble. There have been many arguments regarding the value of water solubility. In general, one can summarize research findings and practical experience in this way:

> For soils low in available soil test phosphorus (P), banding highly water soluble phosphorus fertilizers will generally give better results than the use of phosphorus fertilizers of lower water solubility. If the fertilizer is broadcast and mixed intermittently with the soil, the highly water soluble phosphorus fertilizers may not perform as well as those of less water solubility. When the soil test phosphorus level is medium to high, the source of phosphorus and its water solubility is of little significance, except in the case of rock phosphate, basic slag, or bone meal, which have a slow release rate.

Phosphorus Sources	Formula	N %	Available* P_2O_5 %	Available P_2O_5 that is water soluble %
Ordinary superphosphate	$Ca(H_2PO_4)_2$	0	16-22	90
Concentrated superphosphate	$Ca(H_2PO_4)_2$	0	44-52	95-98
Monoammonium phosphate	$NH_4H_2PO_4$	11 12	48 61	100
Diammonium phosphate	$(NH_4)_2HPO_4$	16 18 21	48 46 53	100
Ammonium Polyphosphate	$(NH_4)_3HP_2O_7 \cdot H_2O$	10 11	34 37	100 100
Phosphoric Acid	H_3PO_4	0	55	100
Superphosphoric acid, polyphosphate (pyrophosphate)	H_3PO_4 and $H_4P_2O_7$	0	76-85	100
Rock phosphate Fluoro – and chloroapatites	$3Ca_3(PO_4)_2 \cdot CaF_2$	0	3-26	0
Basic slag	$5CaO \cdot P_2O_5 \cdot SiO_2$	0	2-16	--
Bone meal	----	0	22-28	--

**Neutral 1.0 N ammonium citrate procedure.*

Potassium Sources:

All of the potassium sources are water soluble. The selection of potassium materials depends primarily on the crop. Muriate of potash (0 - 0 - 60) is the most commonly used potassium source. The other salts of potassium have specific uses. For example, potassium sulfate (K_2SO_4) is used primarily for tobacco, potassium nitrate (KNO_3) for greenhouse and garden crops, and potassium thiosulfate for foliar application and drip irrigation.

Potassium Carriers	**Formula**	**Percent K_2O**
Muriate of potash	KCl	60-63
Potassium sulfate	K_2SO_4	50-52
		22-23
Potassium magnesium sulfate	$K_2SO_4 \bullet MgSO_4$	22
Potassium nitrate	KNO_3	44
Potassium thiosulfate	$K_2S_2O_3$	25
Potassium hydroxide	KOH	83

Calcium Sources

Deficiencies of calcium leading to yield reductions are rather rare in agricultural soils. Generally, soils that have been limed to the proper pH will contain adequate amounts of calcium for good growth and for good crop quality. Calcium shortages are more likely to occur in sandy soils and in crops such as tomatoes, peppers, fruits, and peanuts. Therefore, supplemental applications of calcium are occasionally necessary. Some of the more common sources of calcium are shown below.

Carrier	**Formula**	**Percent Ca**
Lime Material		
Blast furnace slag	$CaSiO_3$	29
Calcitic limestone	$CaCO_3$	32
Dolomitic limestone	$CaMg(CO_3)_2$	22
Hydrated lime	$Ca(OH)_2$	46
Burnt lime	CaO	60
Fertilizers		
Calcium nitrate	$Ca(NO_3)_2$	19
Superphosphate, normal	$Ca(H_2PO_4)_2 + CaSO_4 \cdot 2H_2O$	20
Superphosphate, triple	$Ca(H_2PO_4)_2$	14
Soil Amendment		
Gypsum	$CaSO_4 \bullet 2H_2O$	23
Gypsum (by-product)		17*
Gypsum (impure)		15*

**Ca content varies*

<u>Magnesium Sources</u>:

Magnesium deficiency is best controlled by applying dolomitic limestone. In cases where the soil pH is adequate and magnesium is needed, a number of sources of magnesium can be included in the applied fertilizer. In general, the more soluble magnesium carriers are most effective for immediate availability and response.

Magnesium Sources	**Formula**	**Water Solubility**	**Percent Mg**
Dolomitic Limestone	$CaCO_3 \cdot MgCO_3$	Insoluble	6-12
Kiesertie (Magnesium sulfate)	$MgSO_4 \cdot H_2O$	Slightly	18
Epsom Salt (Magnesium sulfate)	$MgSO_4 \cdot 7H_2O$	Completely	10
Sul-Po-Mag or K-Mag (Potassium magnesium sulfate)	$K_2SO_4 \cdot MgSO_4$	Soluble	11
Pro/Mesium	$3MgO \cdot SiO_2 \cdot 2H_2O$	Insoluble	22
Magnesium oxides	MgO	Slightly	50-55

Sulfur Sources:

Sulfur deficiencies have become more prevalent in recent years, particularly in the very sandy soils in south Georgia. Corn, cotton, small grains, and commercial vegetables are the principal crops most often affected. If the fertilizer materials being used do not contain sulfur, the probable occurrence of this deficiency is greatly enhanced. Normally the deficiency develops early but, as the plant roots move into the lower soil horizons, the deficiency tends to disappear. It is advisable, particularly for corn, cotton, and commercial vegetables, to include a sulfur-bearing material in the fertilizer treatment. Since sulfur leaches readily on sandy Coastal Plain soils, sulfur applied to small grains should be applied in combination with the top dress nitrogen.

A number of fertilizer materials are available that contain sulfur.

Sulfur Sources	**Formula**	**Percent Sulfur**
Sulfur (S)	S	90-100
Ammonium sulfate	$(NH_4)_2SO_4$	24
Gypsum (calcium sulfate)	$CaSO_4 \bullet 2H_2O$	19
Epsom Salt (magnesium sulfate)	$MgSO_4 \bullet 7H_2O$	13
Potassium sulfate	K_2SO_4	18
Potassium thiosulfate	$K_2S_2O_3$	17
Potassium magnesium sulfate	$K_2SO_4 \bullet MgSO_4$	23
Superphosphate	$CaSO_4$ + calcium phosphates	12
Ammonium thiosulfate	$(NH_4)_2S_2O_3$	26
Sulfur Coated Urea	$CO(NH_2)_2$ -S	10
Nitrogen-S Solution	$CO(NH_2)_2 \bullet NH_4NO_3 \bullet (NH_4)_2SO_4$	2-5

Micronutrient Sources:

Micronutrient deficiencies normally occur in specific situations. For example, zinc deficiency has been observed in corn and cotton grown on sandy soils of south Georgia and on soils where the soil has been limed to pH 6.5-7.0. Therefore, a micronutrient application should only be recommended based on known occurrences, soil test results, and/or plant analysis diagnosis. Indiscriminate use of micronutrients should be avoided.

Some micronutrients, particularly boron, can be highly toxic to plants when applied in excess. When applying boron to crops, care should be taken to make sure that the proper amount of boron is used, because the difference between the amount of boron required to correct a deficiency and that which will result in a toxicity is small.

A micronutrient improperly used for one crop may carry over and adversely affect a sensitive crop that is planted at a later date. A build-up of one micronutrient may induce a deficiency of another. It is known that high zinc concentrations can interfere with the function of iron in the plant, resulting in an iron deficiency. Although many plants have a wide tolerance for some of the micronutrients, animals do not. Therefore, indiscriminate use of any one of the micronutrients in the production of an animal feed can affect animal health.

When a micronutrient deficiency has been properly determined, there are usually several ways of supplying the needed nutrients. The specific rates of application on an elemental basis are given in the recommendations. Normally the source given is that preferred. However, there are other sources that may be equally effective.

There are two factors that should be considered when recommending a particular micronutrient source. The recommendations given in this handbook are in lbs. of the elemental form such as Zn; therefore, sufficient material needs to be applied to supply the recommended elemental rate. Usually the water soluble materials are more effective than the less soluble ones. However, there are exceptions. For example, zinc oxide (ZnO), a highly insoluble substance, has proven to be as effective as zinc sulfate ($ZnSO_4$), a completely water soluble material, when applied to acidic soils but not when applied to neutral or alkaline soils.

Micronutrient Sources	**Formula**	**Micronutrient Content**
Boron:		
Fertilizer borate - 48	$Na_2B_4O_7 \cdot 10H_2O$	14-15% B
Fertilizer borate - (Granular)	$Na_2B_4O_7 \cdot 10H_2O$	14% B
Foliarel	$Na_2B_8O_{13} \cdot 4H_2O$	21% B
Solubor	$Na_2B_4O_7 \cdot 4H_2O + Na_2B_{10}O_{16} \cdot 10H_2O$	20.5% B
Borax	$Na_2B_4O_7 \cdot 10H_2O$	11% B

Micronutrient Sources	Formula	Micronutrient Content
Copper:		
Copper sulfate (monohydrate)	$CuSO_4 \cdot H_2O$	35% Cu
Copper sulfate (pentahydrate)	$CuSO_4 \cdot 5H_2O$	25% Cu
Cupric oxide	CuO	75% Cu
Cuprous oxide	Cu_2O	89% Cu
Cupric ammonium phosphate	$Cu(NH_4)PO_4 \cdot H_2O$	32% Cu
Basic copper sulfates	$CuSO_4 \cdot 3Cu(OH)_2$ (general formula)	13-53% Cu
Cupric chloride	$CuCl_2$	17% Cu
Copper chelates	$Na_2CuEDTA$	13% Cu
	NaCuHEDTA	9% Cu
Copper polyflavonoid	Organically bound Cu	5-7% Cu
Iron:		
Ferrous ammonium phosphate	$Fe(NH_4)PO_4 \cdot H_2O$	29% Fe
Ferrous ammonium sulfate	$(NH_4)_2SO_4 \cdot FeSO_4 \cdot 6H_2O$	14% Fe
Ferrous sulfate	$FeSO_4 \cdot 7H_2O$	19-21% Fe
Ferric sulfate	$Fe_2(SO_4)_3 \cdot 4H_2O$	23% Fe
Iron chelates	NaFeEDTA	5-14% Fe
	NaFeHEDTA	5-9% Fe
	NaFeEDDHA	6% Fe
	NaFeDTPA	10% Fe
Iron polyflavonoids	Organically bound Fe	9-10% Fe
Manganese:		
Manganese sulfate	$MnSO_4 \cdot 4H_2O$	26-28% Mn
Manganese oxide	MnO	41-68% Mn
Manganese chelate	Mn-EDTA	5-12% Mn
Molybdenum:		
Ammonium molybdate	$(NH_4)_6Mo_7O_{24} \cdot 2H_2O$	54% Mo
Sodium molybdate	$Na_2MoO_4 \cdot 2H_2O$	39-41% Mo
Molybdenum trioxide	MoO_3	66% Mo
Zinc:		
Zinc sulfate	$ZnSO_4 \cdot H_2O$	35% Zn
Zinc oxide	ZnO	78-80% Zn
Zinc Chelates	$Na_2ZnEDTA$	14% Zn
	NaZnNTA	13% Zn
	NaZnHEDTA	9% Zn
Zinc polyflavonoids	Organically bound Zn	10% Zn

SOLUBILITY OF FERTILIZER MATERIALS

There are several instances when it may become necessary to apply fertilizer materials in solution. Solubility of materials is an important factor in preparing foliar sprays or starter fertilizer solutions. Some chemicals have low solubilities and hot water may be needed to get them dissolved.

Material	**Solubility in Cold Water (lb/100 gal)**
Primary Nutrients	
Ammonium nitrate	984
Ammonium sulfate	592
Calcium cyanamide	Decomposes
Calcium nitrate	851
Diammonium phosphate	358
Monoammonium phosphate	192
Potassium nitrate	108
Sodium nitrate	608
Superphosphate, ordinary	17
Superphosphate, triple	33
Urea	651
Secondary and Micronutrients	
Ammonium molybdate	Decomposes
Borax	8
Calcium chloride	500
Copper oxide	Insoluble
Copper sulfate	183
Ferrous sulfate	242
Foliarel	123 @ 68^{o}F
Magnesium sulfate	592
Manganese sulfate	876
Sodium chloride	300
Sodium molybdate	467
Solubor	79 @ 68^{o}F
Zinc sulfate	625

Source: O. A. Lorenz & D. N. Maynard. 1988. Knott's Handbook for Vegetable Growers. (3rd edition.) John Wiley & Sons, Inc., New York.

THE NUTRIENT VALUE AND USE OF POULTRY LITTER AS FERTILIZER

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When properly managed, poultry litter (manure mixed with wood shavings or similar bedding material) can be a valuable source of plant nutrients for Georgia crops. This includes row crops, forage crops, and some fruit and nut crops. The fertilizer value of poultry litter depends on a number of factors including moisture, temperature, feed rations, number of batches before clean-out, storage, and handling. In general, broiler litter is equivalent to 3-3-2 fertilizer (N%-P_2O_5-K_2O). Based on this average, one ton of broiler litter contains 60 lb/A of N, 60 lb/A of P_2O_5 and 40 lb/A of K_2O. Due to variability in N-P-K content, it is recommended that litter be analyzed for nutrients by a reputable laboratory before application rates are determined. Table 1 gives the average nutrient composition of various types of poultry litter from analyses conducted at the University of Georgia Agricultural and Environmental Services Laboratory.

Table 1. Average nutrient composition of various types of poultry litter on an as-received basis.

Constituent	Broiler Litter*	Broiler Stockpiled	Broiler Cake	Breeder Manure
	---------------------- lbs/ton --------------------			
Nitrogen	62	55	47	31
P_2O_5	55	57	59	40
K_2O	47	47	46	35
Calcium	43	36	54	120
Magnesium	9	81	10	11
Sulfur	15	91	12	8
Manganese	0.65	0.66	0.70	0.64
Copper	0.57	0.63	0.52	0.24
Zinc	0.52	0.54	0.55	0.57

*Based on annual cleanout

Because poultry litter also contains significant levels of other essential plant nutrients (except maybe boron), it is considered a complete fertilizer and is comparable to a commercial fertilizer such as 10-10-10 with micronutrients. The nutrients in poultry litter are not as concentrated as a commercial fertilizer, which makes it bulky and harder to transport and spread. Another major difference is many of the essential nutrients are in an organic form. About 90% of nitrogen is in the organic form. This means only 10 to 15% of the nitrogen is immediately available for crops to use. The organic nitrogen is slowly released over time through biological processes that are influenced by soil moisture and temperature. Consequently, the exact timing of the nitrogen release from poultry litter cannot be accurately predicted. As a rule of thumb, only 60% of the nitrogen in poultry litter is considered to be available to the first crop after application, if the litter is incorporated into soil within 48 hours after application. When poultry litter is left on the surface for longer than 48 hours after application, only 50% of the nitrogen is available for the crop.

A common mistake when considering the availability of nitrogen from poultry litter is to assume that the nitrogen that is not available to the first crop after application (40 to 50%) will be available to the second crop. The nitrogen cycle is complex, and there are many different ways nitrogen can be lost or "tied up" in the environment. This results in very little nitrogen being carried over to the second crop.

Other essential plant nutrients found in litter such as P and K are considered 80 to 100% available to first crop after litter application. Notice this range for availability is higher than nitrogen. Secondary and micronutrients (elements such as calcium, sulfur, manganese and zinc) are also considered to be 80 to 100% available.

Poultry litter contains a relatively high phosphorus content. Most plants need a ratio of approximately 4-1-2 in N-P-K. Since poultry litter contains N-P-K in the ratio of 3-3-2, if poultry litter is applied at rates to meet the nitrogen needs of the crop, then excess P is applied. Over time this can lead to a buildup of soil test P. High soil test P levels and surface applied poultry litter can cause elevated P in runoff from fields either as dissolved P in the water or as P attached to eroded soil particles. The P that exits a field and reaches a water body such as a lake, stream, or pond can cause excess algae growth and, in extreme cases, fish kills. This process of adding excess nutrients to a water body and causing a water quality issue is called eutrophication.

The best way to avoid the detrimental environmental impacts of excess P buildup from poultry litter application is to use nutrient management planning. For some agricultural operations, nutrient management plans are required for poultry litter use. Information on regulations and developing nutrient management plans can be found at: http://www.agp2.org/aware/.

Another way to avoid excess P buildup in the soil is to apply poultry litter to meet the P needs of the crop. In this case, poultry litter provides P and only a portion of the crop nitrogen need. The remainder of nitrogen and other nutrients that litter does not provide can be supplied using commercial inorganic fertilizers. This is basically using poultry litter in a "P-based" vs. an "N-based" strategy. For most crops grown in Georgia, a 2 ton/A application of poultry litter is a good base rate. This should be applied either preplant in the case of row crops or prior to "green up" in the case of forage crops. The 2 tons/A rate usually provides most if not all of the P and K needed by the crop and good portion of N to get the crop started. The need for additional P, K, and other nutrients will depend on the initial soil test levels.

Buildup of other constituents such as zinc, copper, and arsenic may be a long-term concern for using poultry litter as fertilizer. For example, peanuts are particularly sensitive to zinc if the soil pH is below 6.0. There are no indications of these constituents creating problems if poultry litter is used at recommended rates.

FERTILIZER CALCULATIONS

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When assisting growers with computerized lime and fertilizer recommendations, occasionally one will have to make additional calculations to convert the recommendations to the individual's needs. For example, a recommendation for 150 bushel/acre non-irrigated corn is 180-60-80 lbs of N, P_2O_5, and K_2O, respectively. The grower is going to plant early and wants to use 10-34-0 as a starter fertilizer to supply 20 lbs N/A. The 10-34-0 has a density of 11.4 lbs per gal. How many gallons of 10-34-0 will he have to apply per acre?

Solution:

$$\frac{20\,lbs\,N}{A}\,x\,\frac{100\,lbs\,of\;10-34-0}{10\,lbs\,N}\,x\,\frac{1\,gal}{11.4\,lbs}=17.5\,gal\;10-34-0/A$$

To complete his fertilization program he needs to apply 160 lbs. N/A (180 – 20 = 160) and 80 lbs. K_2O/A. All the recommended P_2O_5 was supplied in the starter fertilizer. How much 34-0-0 and 0-0-60 would have to be purchased to supply the 160 lbs N/A and 80 lbs. of K_2O/A?

Solution:

$$\frac{160\,lbs\,N}{A}\,x\,\frac{100\,lbs\,of\;34-0-0}{34\,lbs\,N}=471\,lbs.\;34-0-0/A$$

For the 80 lbs. K_2O/A follow the same procedure:

$$\frac{80\,lbs\,K_2O}{A}\,x\,\frac{100\,lbs\,of\;0-0-60}{60\,lbs\,K_2O}=133\,lbs.\,0-0-60/A$$

Development of fertilizer recommendations and conveying the information to homeowners in a format that is easily understood is a very comprehensive process. In order to assist homeowners with fertilization programs, the University of Georgia Soil, Plant, and Water Laboratory fertilizer recommendations are given in pounds (lbs.) of a fertilizer grade (for example, 12-4-8) to apply to a specified area. Lawn and turf recommendations are given in pounds per 1000 sq. ft., ornamental and flower recommendations in pounds per 100 sq. ft., and home garden in both pounds per 1000 sq. ft. and lbs. per 100 linear ft. This alleviates the homeowner from having to make countless calculations. However, occasions will arise where one fertilizer grade will have to be substituted for another or perhaps one will have to calculate the amount of fertilizer needed to supply a specified amount of nutrient per given area (for example, the amount of urea needed to supply 1 lb. of N per 1000 sq. ft. for a 23,000 sq. ft. area).

Fertilizers are sold in many grades. Complete fertilizers, such as 10-10-10 or 16-4-8, contain all three primary nutrients. Single nutrient fertilizers contain only one, but they generally are a high analysis, and economical source of that nutrient (for example, Urea [46-0-0], Muriate of Potash [0-0-60]). Numbers on the fertilizer bag indicate the minimum percentages of nutrients by weight. These percentages are guaranteed by law to protect the consumer. For example, a 100 lb. bag of a 16-4-8 fertilizer contains 16 lbs. of nitrogen (N), 4 lbs. of phosphate (P_2O_5) and

8 lbs. of potash (K_2O). Most lawn and garden fertilizers are complete fertilizers. They are convenient to use, but sometimes it may be difficult to find one that exactly matches the fertilizer recommendation given on a soil test report. When called upon to assist homeowners in selecting an alternate fertilizer grade, select one with a similar ratio of N-P_2O_5-K_2O to that recommended. For example, 10-10-10, 16-4-8, and 12-4-8 analysis fertilizers have ratios of 1-1-1, 4-1-2, and 3-1-2, respectively. The ratios are calculated by dividing the numbers in the fertilizer grade by the lowest divisible number. For the three grades (10-10-10, 16-4-8, and 12-4-8), the lowest divisible numbers are 10 and 4, respectively. The ratios are calculated as follows:

$$\frac{10-10-10}{10} = 1-1-1$$

$$\frac{12-4-8}{4} = 3-1-2$$

$$\frac{16-4-8}{4} = 4-1-2$$

Suppose a recommendation was for 10 lbs of 12-4-8 per 1000 square feet. The garden center had no 12-4-8 available, but an 8-8-8, 27-3-3, 25-5-11, and 16-4-8 were available. Which would be the best grade to substitute for the 12-4-8? Calculating the ratios as illustrated above, the fertilizers offered by the garden center have ratios of 1-1-1, 9-1-1, 5-1-2, and 4-1-2, respectively. The 12-4-8 has a ratio of 3-1-2, thus the 16-4-8 with a ratio of 4-1-2 would be the closest fit to the recommendation and the 25-5-11 with a ratio of 5-1-2 would be the second best fit. Since the recommended rate of 10 lbs of 12-4-8 would supply 1.2 lbs N per 1000 square feet, the amount of 16-4-8 can be calculated as follows:

$$1000\ ft^2\ x\ \frac{1.2\ lbs\ N}{1000\ ft^2}\ x\ \frac{100\ lbs\ 16-4-8}{16\ lbsN} = 7.5\ lbs\ 16-4-8$$

It is most important to accurately match the N requirement when selecting the grade and calculating the fertilizer rate and then compromise somewhat if necessary for phosphate (P_2O_5) and potash (K_2O). For most lawns and gardens the greatest compromise can be made with phosphate as many soils used for these purposes test HIGH or VERY HIGH in phosphorus.

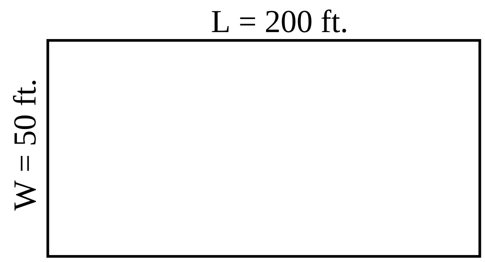
The following example illustrates the various steps involved in calculating fertilizer rates:

A soil test report for a bermudagrass lawn recommends the application of 10 lbs. of 10-10-10 per 1000 square ft. when spring growth begins and 8 lbs. of 12-4-8 or 6 lbs. of 16-4-8 per 1000 square ft in June, July, August, and September.

To determine how much fertilizer is required for a given area:

Step 1: If the dimensions of the area are not known, measure the area to be fertilized in feet (for example, 200 ft. long x 50 ft. wide) and then calculate the number of square feet in the rectangular area.

Example:



$$
\begin{aligned}
Area &= l \; x \; w \\
&= 50 \; ft \; x \; 200 \; ft \\
&= 10{,}000 \; ft^2
\end{aligned}
$$

Step 2: Calculate the amount of fertilizer that would be needed for the area based on the soil test recommendation. The following equation can be used to calculate the needs.

$$
\begin{aligned}
lbs \; of \; fertilizer \; needed &= 10{,}000 \; ft^2 \; x \; \frac{10 \, lbs \, 10-10-10}{1{,}000 \; ft^2} \\
&= 100 \, lbs \; 10-10-10
\end{aligned}
$$

So for the spring application a total of **100 lbs of 10-10-10** would need to be purchased.

Step 3: Calculate the amount of fertilizer that would need to be purchased for the 4 summer applications. The same equation can be used.

$$
\begin{aligned}
lbs \; fertilizer \; needed &= 10{,}000 \; ft^2 \; x \; \frac{8 \, lbs \, 12-4-8}{1{,}000 \; ft^2} \\
&= 80 \, lbs \, of \; 12-4-8 \\
&= 80 \, lbs \; x \; 4 \, applications \\
&= 320 \, lbs \, 12-4-8
\end{aligned}
$$

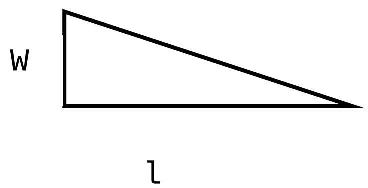
For the summer applications, a total of **320 lbs of 12 - 4 - 8** would be required for the 4 applications.

Note: Sometimes a soil test report may only recommend that nitrogen be applied. Suppose the recommendation was to apply 34-0-0 at a rate equivalent to 1 lb of N per 1000 ft^2. How much 34-0-0 would be required for the area?

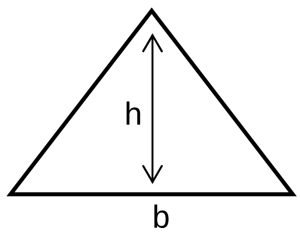
$$
10{,}000 \; ft^2 \; x \; \frac{1 \, lb \, N}{1{,}000 \; ft^2} \; x \; \frac{100 \, lb \, 34-0-0}{34 \, lb \, N} = 29 \, lbs \, 34-0-0
$$

Also, areas to be fertilized are often encountered that are not always square or rectangular in shape. Several approaches can be used to calculate the area. One approach is to mark the area off in as large a rectangle or square as possible. Then mark the remaining area off in smaller squares, or triangles or right triangles

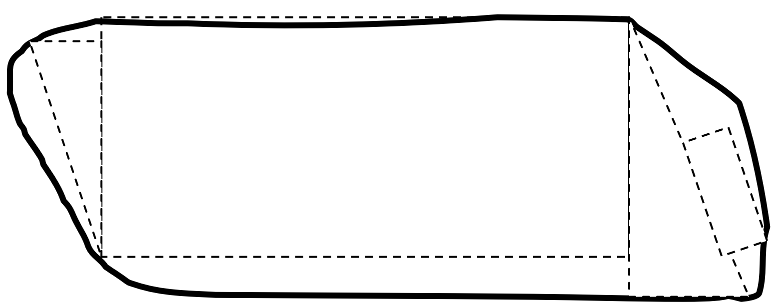
(See sketch below). Calculate the areas for each marked off area and ***sum*** the values. The formula given above for the area of a rectangle can also be used for a square. The area of a right triangle and triangle can be calculated using the following formulas:



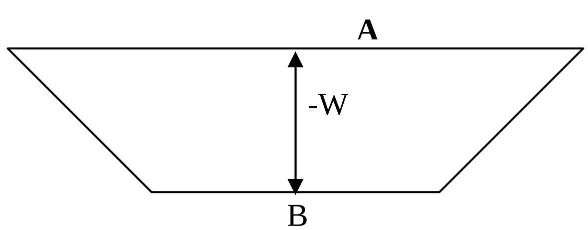
$$Area = \frac{Length\ x\ Width}{2}$$



$$Area = \frac{Base\ x\ Height}{2}$$



To calculate the area of a trapezoid (only two sides parallel), use the following formula:



$$Area = \frac{(A + B)\, x\, W}{2}$$

USEFUL CONVERSION FACTORS AND SHORTCUTS IN CALCULATION

1. **Liquid Conversion Factors**:

   (a) 1 level teaspoon equals 1/6 fluid oz.

   (b) 1 level tablespoon equals 3 teaspoons equals 1/2 fluid oz. equals 1/16 cup.

   (c) 1 fluid ounce (oz.) equals 2 tablespoons equals 6 teaspoons.

   (d) 1 cup equals 8 fluid ozs. equals 1/2 pint equals 16 tablespoons equals 48 teaspoons.

   (e) 1 pint equals 2 cups equals 16 fluid ozs. equals 32 tablespoons.

   (f) 1 quart equals 2 pints equals 4 cups equals 32 fluid ozs. equals 64 tablespoons.

   (g) 1 gallon equals 4 quarts equals 8 pints equals 16 cups equals 128 ozs.

2. **Weight Conversion Factors**:

   (a) 1 ounce (oz.) equals 28.35 grams.

   (b) 1 pound (lb.) equals 16 ozs. equals 453.6 grams.

   (c) 1 ton equals 2000 lbs.

3. **Volume and Area Conversion Factors:**

   (a) 1 cubic foot equals 1/27 cubic yard equals 8/10 bushels equals 7.5 gallons.

   (b) 1 bushel equals 1-1/4 cubic feet.

   (c) 1 cubic yard equals 27 cubic feet equals 22 bushels equals 54 square feet (to a 6-inch depth).

   (d) 100 square feet (to a 6-inch depth) equals 50 cubic feet equals 40 bushels or almost 2 cubic yards.

   (e) 1 square foot equals 144 square inches.

   (f) 1 acre equals 43,560 square feet.

CONVERSION FACTORS FOR ENGLISH AND METRIC UNITS*

To convert column 1 into column 2, multiply by	Column 1 (Metric Units)	Column 2 (English units)	To convert column 2 into column 1, multiply by
	Length		
0.621	kilometer, km	mile, mi	1.609
1.094	meter, m	yard, yd	0.914
0.394	centimeter, cm	inch, in	2.54
	Area		
0.386	kilometer^{2,} km^2	mile^2, mi^2	2.590
247.1	kilometer^2, km^2	acre, acre	0.00405
2.471	hectare, ha	acre, acre	0.405
	Volume		
0.00973	meter^3, m^3	acre-inch	102.8
3.532	hectoliter, hl	cubic foot, ft^3	0.2832
2.838	hectoliter, hl	bushel, bu	0.352
0.0284	liter	bushel, bu	35.24
1.057	liter	quart, qt	0.946
	Mass		
1.102	ton (metric)	ton (English)	0.9072
2.205	quintal, q	hundredweight,cwt (short)	0.454
2.205	kilogram, kg	pound, lb	0.454
0.035	gram, g	ounce (avdp), oz	28.35
	Yield or Rate		
0.446	ton (metric)/hectare	ton (English)/acre	2.240
0.892	kg/ha	lb/acre	1.12
0.892	quintal/hectare	hundredweight/ acre	1.12
1.15	hectoliter/ha, hl/ha	bu/acre	0.87
	Temperature		
(9/5 ^{o}C) + 32	Celsius	Fahrenheit	5/9 (^{o}F-32)
	-17.8^{o}C	O^{o}F	
	O^{o}C	32^{o}F	
	20^{o}C	68^{o}F	
	100^{o}C	212^{o}F	

* Adapted from Soil Sci. Soc. Amer. Proc. 41 (6) vi. 1977.

OTHER USEFUL CONVERSION FACTORS (Chapman and Pratt, 1961)

To convert	Multiply	By	To obtain
Volume units	Cubic centimeters	6.102×10^{-2}	Cubic inches
	Cubic centimeters	1×10^{-6}	Cubic meters
	Cubic centimeters	3.53×10^{-5}	Cubic feet
	Cubic centimeters	2.642×10^{-4}	Gallons
	Cubic centimeters	10^{-3}	Liters
	Cubic centimeters	1.057×10^{-3}	Quarts (Liquid)
	Cubic feet	2.832×10^{4}	Cubic centimeters
	Cubic feet	1728	Cubic inches
	Cubic feet	0.03704	Cubic yards
	Cubic feet	7.48052	Gallons
	Cubic feet	28.32	Liters
	Cubic feet	0.23743	Barrels (U.S.)
	Cubic inches	16.39	Cubic centimeters
	Cubic inches	5.787×10^{-4}	Cubic feet
	Cubic inches	4.329×10^{-3}	Gallons
	Cubic inches	1.639×10^{-2}	Liters
	Cubic meters	35.31	Cubic feet
	Cubic meters	1.308	Cubic yards
	Cubic meters	264.2	Gallons
	Cubic yards	27	Cubic feet
	Cubic yards	0.7646	Cubic meters
	Cubic yards	202.0	Gallons
	Gallons (U.S.)	231.0	Cubic inches
	Gallons (U.S.)	3785	Cubic centimeters
	Gallons (U.S.)	0.1337	Cubic feet
	Gallons (U.S.)	3.785	Liters
	Gallons (U.S.)	0.83267	Imperial gallons
	Liters	0.03531	Cubic feet
	Liters	61.02	Cubic inches
	Liters	0.2642	Gallons

OTHER USEFUL CONVERSION FACTORS

To convert	Multiply	By	To obtain
Volume units	Acre-inches	3630	Cubic feet
	Acre-inches	27,167	Gallons
	Acre-inches	0.0833	Acre-feet
	Acre-feet	43,560	Cubic feet
	Acre-feet	326,000	Gallons
	Acre-feet	12	Acre-inches
	Bushel	1.2444	Cubic feet
	Bushel	32	Quarts (dry)
	Bushel	35.238	Liters
Area units	Acre	43,560	Square feet
	Acre	0.0015625	Square miles
	Acre	4840	Square yards
	Acre	0.40468	Hectare
	Acre	4046.8	Square meters
	Acre	160	Square rods
	Hectare	2.471	Acres (U.S.)
	Hectare	10,000	Square meters
	Square feet (U.S.)	144	Square inches
	Square feet (U.S.)	929.034	Square centimeters
	Square inches (U.S.)	645.16	Square millimeters
	Square inches (U.S.)	6.4516	Square centimeters
	Square mile	640	Acres
	Square mile	258.99	Hectares
	Square yard	9	Square feet
	Square yard	0.83613	Square meter

OTHER USEFUL CONVERSION FACTORS

To convert	Multiply	By	To obtain
Weight units	Tons (long)	1.12	Tons (short)
	Tons (long)	2240	Pounds
	Tons (long)	1016.047	Kilograms
	Tons (short)	2000	Pounds
	Tons (short)	907.1848	Kilograms
	Tons (short)	0.90718	Tons (metric)
	Tons (metric)	2205	Pounds
	Tons (metric)	1000	Kilograms
	Cubic feet water	62.43	Pounds water
	Acre-feet water	2.72×10^6	Pounds water
	Acre-feet soil	4.0×10^6	Pounds soil (approx.)
	Cubic feet soil	68 to 112	Pounds soil
	Gallons water	8.3453	Pounds water
	Grains (Troy)	0.0648	Grams
	Grams	l5.43	Grains
	Grams	10^3	Milligrams
	Grams	0.03527	Ounces
	Grams	2205×10^{-3}	Pounds
	Kilograms	2.205	Pounds
	Ounces	16	Drams
	Ounces	0.0625	Pounds
	Ounces	28.3495	Grams

OTHER USEFUL CONVERSION FACTORS

To convert	Multiply	By	To obtain
Weight units	Ounces (Troy)	480	Grains
	Ounces (Troy)	31.10348	Grams
	Pounds	16	Ounces
	Pounds	7000	Grains
	Pounds	0.0005	Tons (short)
	Pounds	453.5924	Grams
	Pounds	14.5833	Ounces (Troy)
	Pounds water	0.01602	Cubic feet water
	Pounds water	27.68	Cubic inches
	Pounds water	0.1198	Gallons
	Parts per million (ppm)	0.0001	Percent (%)
	Parts per million (ppm)	0.002	Pounds per ton
Rate of flow units	Cubic feet/second	448.8	Gallons/minute
	Cubic feet/second	0.646	Million gallons/day
	Cubic feet/second	23.8	Acre-inches/24 hours
	Cubic feet/second	1.984	Acre-feet/24 hours
	Gallons/minute	0.0023	Cubic feet/second
	Gallons/minute	0.00144	Million gallons/day
	Gallons/minute	0.053	Acre-inches/24 hours
	Acre-inches in 24 hours	18.86	Gallons per minute
	Acre-inches in 24 hours	0.042	Cubic feet/second
	Millions gallons/day	1.547	Cubic feet/second
	Millions gallons/day	694.4	Gallons/minute
	Millions gallons/day	36.81	Acre-inches in 24 hrs

OTHER USEFUL CONVERSION FACTORS

To convert	Multiply	By	To obtain
Chemical-gravimetric factors	Ca	2.4973	$CaCO_3$
	Ca	4.2959	$CaSO_4.2H_2O$
	Ca	1.40	CaO
	Ca	1.85	$Ca(OH)_2$
	$CaCO_3$	0.4004	Ca
	$CaSO_4.2H_2O$	0.23277	Ca
	$CaCO_3$	0.84	$MgCO_3$
	CaO	0.715	Ca
	$CaSO_4.2H_2O$	0.5579	SO_4
	Cu	3.9296	$CuSO_4.5H_2O$
	CuO	0.79884	Cu
	CuO	3.1391	$CuSO_4.5H_2O$
	$CuSO_4.5H_2O$	0.25448	Cu
	Fe	1.4297	Fe_2O_3
	Fe_2O_3	0.69944	Fe
	$FeSO_4.7H_2$	0.20088	Fe
	$FeSO_4.7H_2O$	0.28720	Fe_2O_3
	Mg	1.67	MgO
	Mg	2.42	$Mg(OH)_2$
	Mg	3.47	$MgCO_3$
	Mg	1.67	Ca
	Mg	4.17	$CaCO_3$
	MgO	0.6032	Mg
	MgO	2.50	$CaCO_3$
	$MgCO_3$	0.288	Mg
	$MgCO_3$	1.19	$CaCO_3$
	$MgSO_4.7H_2O$	0.0987	Mg
	$MnSO_4$	0.36383	Mn
	MnO	0.77446	Mn

OTHER USEFUL CONVERSION FACTORS

To convert	Multiply	By	To obtain
Chemical-gravimetric factors	N	1.2159	NH_3
	N	1.2884	NH_4
	N	4.7168	$(NH_4)_2SO_4$
	N	3.2844	NO_2
	N	4.4266	NO_3
	$NaNO_3$	0.16480	N
	NH_3	0.82245	N
	NH_3	3.6407	NO_3
	NH_4	0.77617	N
	NH_4	3.4373	NO_3
	$(NH_4)_2SO_4$	0.21201	N
	NO_3	0.22591	N
	NO_3	0.27467	NH_3
	NO_3	0.2909	NH_4
	NO_2	0.30447	N
	P	2.2914	P_2O_5
	P	3.0661	PO_4
	PO_4	0.32613	P
	PO_4	0.7473	$P2O_5$
	P_2O_5	0.43642	P
	$P2O_5$	1.3381	PO_4
	$Ca_3(PO_4)_2$	0.45762	P_2O_5
	$Ca_3(PO_4)_2$	0.1997	P
	$Ca(H_2PO_4)_2.H_2O$	0.2457	P
	$CaHPO_4.H_2O$	0.3599	P
	KH_2PO_4	0.2276	P
	K	1.2046	K_2O
	KCl	0.52443	K
	K_2O	0.83015	K
	K_2SO_4	0.44874	K
	S	5.3695	$CaSO_4.2H_2O$
	S	2.995	SO_4
	S	3.0566	H_2SO_4
	H_2SO_4	0.3271	S

OTHER USEFUL CONVERSION FACTORS

To convert	Multiply	By	To obtain
Chemical-gravimetric factors	$CaSO_4.2H_2O$	0.1862	S
	$CaSO_4.2H_2O$	0.5566	SO_4
	SO_4	1.7812	$CaSO_4.2H_2O$
	SO_4	0.3217	S
	Zn	1.2447	ZnO
	Zn	4.3982	$ZnSO_4.7H_2O$
	ZnO	0.8033	Zn
	$ZnSO_47H_2O$	0.22736	Zn

Reference: Chapman, H. D. and P. F. Pratt. 1961. Methods of analysis for soils, plants, and waters. University of California, Division of Agricultural Sciences, Riverside, CA.

Fertilizer Recommendations by Crops, Categorized

(Crop codes in parentheses)

I Field Crops

1. (**701**) Canola Spring Type
2. (**702**) Canola Winter Type
3. (**001**) Corn (for Grain) Dryland
4. (**002**) Corn (for Grain) Irrigated
5. (**003**) Corn Silage
6. (**500**) Cotton - 750 lbs yield goal
7. (**501**) Cotton - 1000 lbs yield goal
8. (**502**) Cotton - 1250 lbs yield goal
9. (**503**) Cotton - 1500 lbs yield goal
10. (**006**) Grain Sorghum
11. (**010**) Peanuts
12. (**013**) Small Grain - Barley
13. (**012**) Small Grain - Oats
14. (**014**) Small Grain - Rye for Seed Production or Cover Crop
15. (**011**) Small Grain - Wheat
16. (**711**) Small Grain Silage
17. (**004**) Sorghum Silage
18. (**017**) Soybeans
19. (**008**) Sugar Cane
20. (**009**) Sunflower
21. (**007**) Sweet Sorghum
22. (**019**) Tobacco (Average Pebble Soil)
23. (**018**) Tobacco (Low Moisture and Sandy Soils)
24. (**020**) Tobacco Plant Bed
25. (**015**) Wheat - Grain Sorghum Rotation
26. (**016**) Wheat - Soybean Rotation

II Pastures, Hay Crops

1. (**025**) Alfalfa-Establishment
2. (**026**) Alfalfa-Maintenance
3. (**028**) Amclo Clover
4. (**032**) Annual Lespedeza
5. (**046**) Bahia Grass Pasture
6. (**042**) Brown Top Millet
7. (**035**) Coastal Bermuda Pasture
8. (**037**) Coastal Bermuda-Hay
9. (**045**) Common Bermuda Pasture
10. (**030**) Crimson Clover
11. (**047**) Dallis Grass Pasture
12. (**740**) Fescue Hay
13. (**040**) Fescue Pasture
14. (**039**) Fescue-Clover Associations
15. (**742**) Forage Chicory
16. (**036**) Hybrid Bermudas - Pasture
17. (**038**) Hybrid Bermudas-Hay
18. (**043**) Hybrid Millets
19. (**033**) Lupine

II Pastures, Hay Crops *(cont.)*

20. (**029**) Mechee Clover
21. (**041**) Orchard Grass Pasture
22. (**051**) Perennial Peanuts
23. (**048**) Sericea
24. (**044**) Sorghum Sudan Hybrids
25. (**031**) Subterranean Clover
26. (**049**) Summer Perennials Overseeded in Fall
27. (**050**) Temporary Winter Grazing
28. (**034**) Vetch
29. (**741**) White Clover
30. (**027**) Yuchi Clover

III Pine Trees, Field Nursery Stock, and Christmas Trees

1. (**078**) Christmas Trees - Cedar
2. (**077**) Christmas Trees - Pine and Leyland Cypress
3. (**075**) Field Nursery - Broadleaf Evergreen (production)
4. (**074**) Field Nursery - Deciduous Trees & Shrubs (production)
5. (**071**) Field Nursery - Deciduous Trees (pre-plant)
6. (**073**) Field Nursery - Evergreens (pre-plant)
7. (**076**) Field Nursery - Narrow Leaf Evergreen (production)
8. (**072**) Field Nursery - Shrubs (pre-plant)
9. (**069**) Pine Plantation - Establishment
10. (**070**) Pine Plantation - Maintenance
11. (**068**) Pine Seedling Nursery

IV Fruits and Pecans

1. (**115**) Apples (bearing)
2. (**117**) Apples (non-bearing)
3. (**131**) Blackberries (commercial)
4. (**126**) Blueberries–Rabbiteye (commercial)
5. (**134**) Blueberries–Southern Highbush in Pinebark Beds
6. (**133**) Blueberries–Southern Highbush in Soil or Amended Soil
7. (**129**) Figs (commercial)
8. (**127**) Grapes (bunch, hybrid)
9. (**128**) Grapes (muscadine)
10. (**119**) Nectarines (bearing)
11. (**122**) Nectarines (non-bearing)
12. (**120**) Peaches (bearing)
13. (**123**) Peaches (non-bearing)
14. (**116**) Pears (bearing)

IV Fruits and Pecans *(cont.)*

15. (**118**) Pears (non-bearing)
16. (**125**) Pecans
17. (**121**) Plums (bearing)
18. (**124**) Plums (non-bearing)
19. (**132**) Raspberries (commercial)
20. (**130**) Strawberries-Plasticulture

V Vegetables

1. (**140**) Asparagus
2. (**165**) Basil (and other herbs not listed)
3. (**144**) Beets
4. (**146**) Broccoli, fresh market
5. (**147**) Cabbage, fresh market
6. (**160**) Cantaloupes
7. (**145**) Carrots
8. (**148**) Cauliflower, fresh market
9. (**185**) Chives
10. (**184**) Cilantro
11. (**149**) Collards, fresh market
12. (**159**) Cucumbers
13. (**164**) Eggplant
14. (**183**) Endive
15. (**173**) English Peas
16. (**180**) Greenhouse Tomatoes
17. (**177**) Irish Potatoes
18. (**150**) Kale, fresh market
19. (**154**) Lettuce, fresh market
20. (**142**) Lima Beans
21. (**151**) Mustard, fresh market
22. (**170**) Okra
23. (**171**) Onions (green bunching)
24. (**172**) Onions (mature and dry)
25. (**169**) Onions (plantbed)
26. (**166**) Parsley
27. (**175**) Pepper (Bell and Pimento)
28. (**176**) Pepper Transplants
29. (**143**) Pole Beans
30. (**162**) Pumpkin
31. (**167**) Radishes
32. (**168**) Rhubarb
33. (**141**) Snap Beans
34. (**174**) Southern Peas
35. (**152**) Spinach, fresh market
36. (**161**) Squash
37. (**181**) Staked Tomatoes
38. (**158**) Sweet Corn
39. (**178**) Sweet Potatoes
40. (**182**) Tomato Transplants
41. (**153**) Turnips, fresh market

V Vegetables *(cont.)*

42. (**163**) Watermelon

VI Sod Production

1. (**769**) Sod Production Centipede
2. (**768**) Sod Production Hybrid Bermudas
3. (**771**) Sod Production St. Augustine
4. (**772**) Sod Production Tall Fescue
5. (**770**) Sod Production Zoysia

VII Ornamentals and Flowers (nursery field production)

1. (**887**) Annual Flowers (commercial)
2. (**880**) Azaleas (commercial)
3. (**882**) Camellias (commercial)
4. (**883**) General Ornamental Shrubs (commercial)
5. (**884**) Ground Cover (commercial)
6. (**885**) Ornamental Trees (commercial)
7. (**888**) Perennial Flowers (commercial)
8. (**881**) Rhododendrons (commercial)
9. (**890**) Roses (commercial)
10. (**886**) Shade Trees (commercial)
11. (**891**) Spring Flowering Bulbs (commercial)
12. (**889**) Summer Bulbs (commercial)

VIII Home Lawns

1. (**CLE**) Centipede Lawn - Establishment
2. (**CLM**) Centipede Lawn - Maintenance
3. (**052**) Common Bermuda Lawn
4. (**059**) Cool Season Grass Mixtures
5. (**053**) Hybrid Bermuda Lawn
6. (**057**) Kentucky Bluegrass
7. (**060**) Ryegrass for Overseeding Lawns
8. (**SSP**) Seashore Paspalum
9. (**055**) St. Augustine Lawn
10. (**058**) Tall Fescue Lawn
11. (**056**) Zoysia Lawn

IX Golf Courses

1. (**061**) Bentgrass Golf Greens
2. (**062**) Bermuda Golf Greens (Overseeded)
3. (**063**) Golf Fairways
4. (**064**) Golf Tees

X Industrial/Business Lawns

1. (**790**) Industrial/Business Lawns - Bermuda
2. (**BCE**) Industrial/Business Lawns - Centipede Establishment
3. (**BCM**) Industrial/Business Lawns - Centipede Maintenance

X Industrial/Business Lawns *(cont.)*

4. (**792**) Industrial/Business Lawns - St. Augustine
5. (**794**) Industrial/Business Lawns - Tall Fescue
6. (**793**) Industrial/Business Lawns - Zoysia

XI Other Turf

1. (**065**) Athletic Field
2. (**066**) Roadside Turf - Establishment
3. (**067**) Roadside Turf - Maintenance

XII Home Landscape Plants

1. (**087**) Annual Flowers
2. (**080**) Azaleas
3. (**082**) Camellias
4. (**083**) General Ornamental Shrubs
5. (**092**) Goldenseal
6. (**084**) Ground Cover
7. (**085**) Ornamental Trees
8. (**088**) Perennial Flowers
9. (**081**) Rhododendrons
10. (**090**) Roses
11. (**086**) Shade Trees
12. (**091**) Spring Flowering Bulbs
13. (**089**) Summer Bulbs

XIII Home Garden

1. (**095**) Apples - Home Garden
2. (**096**) Blackberries - Home Garden
3. (**098**) Blueberries–Home Garden
4. (**099**) Bunch Grapes - Home Garden
5. (**100**) Citrus - Home Garden
6. (**101**) Figs - Home Garden
7. (**114**) Herbs (homeowner)
8. (**112**) Home Vegetable Garden
9. (**102**) Kiwifruit - Home Garden
10. (**103**) Muscadine - Home Garden
11. (**104**) Nectarines - Home Garden
12. (**105**) Peaches - Home Garden
13. (**107**) Pears - Home Garden
14. (**109**) Pecans (bearing) - Home Garden
15. (**108**) Pecans (young trees) - Home Garden
16. (**106**) Plums - Home Garden
17. (**097**) Raspberries - Home Garden
18. (**110**) Strawberries - Home Garden

XIV Wildlife Plots

1. (**W10**) Dove Fields - Brown Top Millet, Proso, Sesame, and Buckwheat
2. (**W12**) Dove Fields - Corn or Grain Sorghum
3. (**W11**) Dove Fields - Peredovic Sunflower

XIV Wildlife Plots *(cont.)*

4. (**W09**) Fall Deer - Alfalfa
5. (**W08**) Fall Deer - Forage Chicory
6. (**W05**) Fall Deer Mix - Brassicas
7. (**W04**) Fall Deer Mix - Cool season annual grasses
8. (**W06**) Fall Deer Mix - Cool Season Grasses with Clover
9. (**W07**) Fall Deer Mix - Legumes
10. (**W02**) Summer Deer Mix (Grass only)
11. (**W01**) Summer Deer Mix (Legume only)
12. (**W03**) Summer Deer Mix (Legumes and Grass)
13. (**191**) Wildlife Plots - Chufa
14. (**190**) Wildlife Plots - Temporary Winter Grazing

Fertilizer Recommendations by Crops, Alphabetized

(Crop codes in parentheses)

The crop sheets are available at:

http://aesl.ces.uga.edu/publications/soil/CropSheets.pdf

Learning for Life

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