The Basis of Soil Testing in Alabama

Agronomy and Soils Departmental Series No. 324A
Alabama Agricultural Experiment Station
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Auburn University, Auburn, Alabama
October 2012

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The Soil Testing Laboratory at Auburn University is a joint program of the Alabama Cooperative Extension System and the Alabama Agricultural Experiment Station. ACES has primary responsibility for education on soil testing and distribution of supplies while the AAES conducts soil test calibration research and operates the Soil Testing Laboratory.

For additional information contact the Soil Testing Laboratory at 334-844-3958 or visit the website at www.aces.edu/anr/soillab/

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This report can be found on the Web at http://repo.lib.auburn.edu/repo/handle/123456789/44101

NOTE: See companion publication AY-322B, "Nutrient Recommendation Tables for Alabama Crops," on the Web at http://repo.lib.auburn.edu/repo/handle/123456789/44102

The Basis of Soil Testing in Alabama

C.C. Mitchell and G. Huluka

Introduction

Most soils in Alabama must be fertilized for optimum production. Unfertilized soils are naturally low in plant nutrients because the parent materials from which they were formed were low in phosphorus (P), and many were low or medium in potassium (K). In addition, Alabama's relatively high temperatures and rainfall have caused dissolution, leaching, and runoff of nutrients from fields, especially where they have been cropped continuously and the surface has been allowed to erode. Likewise, the nitrogen (N) supplying capacity of soils is dependent on the organic matter content which is low in Alabama soils because of rapid decomposition under prevailing environmental conditions. Therefore, unless these major nutrients (N, P and K) have been built up in soils by past fertilization and management practices, soils will need additional nutrients for sustainable production.

Most Alabama soils have been in continuous production for more than 150 years. Some have been fertilized regularly throughout that period. The addition of nutrients to soils and crops where they are not needed and cannot be utilized is not only a wasted resource but could also degrade water and soil quality.

Nutrient needs were originally determined by hundreds of simple fertilizer experiments conducted on farms throughout the State. Prior to the establishment of the Auburn University Soil Testing Laboratory in 1953, general fertilizer recommendations were made by Auburn University for different soil types. These recommendations were based upon on-farm tests and more complex experiments conducted on Auburn University experiment fields and research stations throughout the State.

This system is no longer adequate because soils have been altered by recurring management. Properly managed soils have become more productive over the past 60 years as nutrient use has increased. Some nutrients may have been depleted while others have been built up in soils, depending on amounts supplied in fertilizers and amounts removed in harvested crops. General fertilizer recommendations based on soil type are no longer practical because past management practices now have more influence on soil fertility than does soil type. Soils separated only by a fence may differ in fertility more than the soils located in different regions of the State.

Soil tests have been developed to determine the fertility status of individual soils. This has required many years of field and laboratory research at many locations to correlate and calibrate test results with response to fertilizers in the greenhouse and field, respectively. Reliable soil tests based on such research are now the only practical basis for determining the nutrient needs of specific crops on the many soils in Alabama.

Plant Nutrients

At least 17 elements are known to be required for plant growth. These elements can be divided into four groups. Stars by the element below indicate suitability of soil tests for crop production in Alabama. Five stars indicate strong suitability of soil test as a means to determine the availability of a given nutrient for plant growth.

Macronutrients from carbon dioxide and water
1. Carbon (C)
2. Hydrogen (H)
3. Oxygen (O)

Primary nutrients from the soil
4. Nitrogen (N) ☆
5. Phosphorus (P) ☆☆☆☆☆
6. Potassium (K) ☆☆☆☆☆

Secondary nutrients from the soil
7. Calcium (Ca) ☆☆☆☆
8. Magnesium (Mg) ☆☆☆
9. Sulfur (S) ☆

Micronutrients from the soil
10. Boron (B) ☆☆
11. Zinc (Zn) ☆☆
12. Manganese (Mn) ☆☆
13. Copper (Cu) ☆
14. Molybdenum (Mo)
15. Iron (Fe)
16. Chloride (Cl)
17. Nickel (Ni)

Macronutrients

The elements C, O, and H are obtained by plants from air (CO_2 and O_2) and water (H_2O) in sufficient amounts to support maximum growth. These three constitute the bulk of plant

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weight. Carbon accounts for 40 to 50 percent of the dry weight of a plant.

Primary Nutrients

The elements N, P, and K constitute about 3 to 5 percent of the dry weight of most plants and may be deficient in Alabama crops. Accordingly, these are the nutrients in fertilizers most frequently and abundantly applied.

Nitrogen is the nutrient that most frequently limits crop production and is needed in greater quantities for most non-legume crops (Figure 1). Soil tests are not reliable for determining the nitrogen supplying capacity of individual soils in the Southeast. Nitrogen is mostly stored in soil organic matter. The rate of N release for crop use is affected by organic matter content, temperature, moisture, length of growing season, tillage, and other factors, which make it impractical to predict the amount that will be supplied by the soil for a growing crop. Futhermore, Alabama soils are low in organic matter and do not vary much in their capacity to supply nitrogen. Therefore, nitrogen recommendations are based primarily on the crop to be grown. Growers who have improved soil quality by building soil organic matter and organic farmers, can take advantage of N mineralization from soil organic matter.

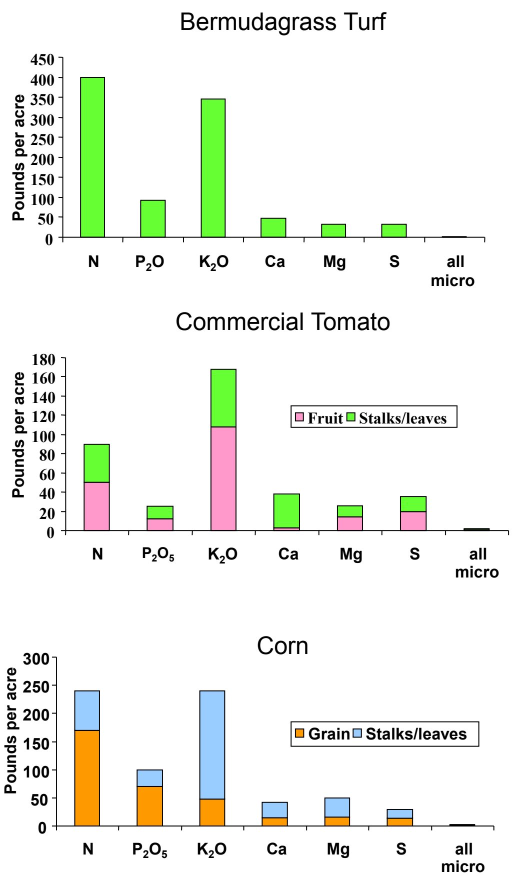

Figure1. Nutrient uptake by three different crops. Corn yields are 180 bu/A.

The most economical rates of application have been determined in numerous field experiments. The amounts recommended should be adjusted by growers based on experience with rates used previously. Nitrogen supply is the dominant fertility factor in determining rate and amount of growth of most crops. Legume crops get most of the N required for their growth from the air, which contains about 78 percent N.

Phosphorus content of most Alabama soils is naturally low. Historically, fertilizers used in Alabama always contained some P. Fortunately, P does not leach easily from soils but will be fixed and released slowly. Phosphorus may be lost from fields where the surface soil is allowed to erode. Also P in the plow layer may become diluted when plowing the land deeper than normal.

Crops require much smaller quantities of P than N or K. Usually plants contain less than 0.5 percent P. As a general rule, most crops will take up five times as much N as P. Therefore, under continuous fertilization, soil content of P has increased in many soils to high levels. About 50 percent of all samples received by the Soil Testing Laboratory in recent years have been high in P, and crops grown on those soils would not be expected to respond to P applications. Experiments at several locations have shown that where P has been built up to High or Very High levels, soils may be cropped for many years without reducing crop yields from a lack of P. Therefore, on soil test reports for field and forage crops, none is recommended at High levels, but growers should sample each year where none is applied to avoid any loss in yield should soil P drop back into the Medium range, where some response could be anticipated.

Potassium requirements of plants on some soils has increased as yields have been increased by higher N and P fertilization. Most of the sandy soils of Alabama are naturally low in K, while the clays and clay loams are less likely to be deficient. Response to K has been determined in numerous experiments throughout the State. Excessive use of K may cause Mg deficiency, especially on sandy soils. Recent residual studies have shown that K may accumulate in most soils where recommended rates are applied. When soil tests indicate that this accumulation has reached the High level, growers may cease applications until the soil level drops back into the Medium range.

Secondary Nutrients

The elements calcium (Ca), magnesium (Mg), and sulfur (S) are classified as secondary nutrient for plant nutrition. Some Alabama soils and crops should be supplied with these nutrients.

Calcium is supplied in both calcitic and dolomitic lime. Where soil pH is maintained in the range, 6.0 to 7.0, Ca deficiency is not likely to occur. Peanuts, tomatoes, peppers, and some melons are the only crops which have been found to suffer from lack of Ca in Alabama fields. This deficiency may result in unfilled pods (pops) in peanuts and blossom end rot in tomatoes and peppers. All samples are analyzed for Ca in the Soil Testing Laboratory. When the tests indicate that deficiencies may occur on these crops, gypsum may be recommended if lime is not needed. Calcium uptake is moisture dependent. Dry weather can induce Ca deficiencies in some crops, especially tomatoes.

Magnesium is determined in all soil samples. Some sandy soils in Alabama are deficient in Mg and these soils are usually low in pH. The most practical way to prevent Mg deficiency is by using dolomitic lime when soil tests indicate that Mg is Low. On soils where Mg is not found to be deficient, calcitic or dolomitic limestone is satisfactory.

Sulfur deficiency has increased as high analysis fertilizers made from ammonium phosphates have replaced fertilizers made from superphosphate, which contains about 12 percent S. Sulfur added to soils in rain has decreased in areas where effluent from industry has been reduced. Sandy soils of the Coastal Plain and Sandstone Plateaus are most likely to be deficient in S because this element may be leached from sandy surface soils. While soils may be tested for extractable sulfate-S (SO_4-S), the results have little practical value in predicting S deficiency. Sulfur tends to accumulate in clayey subsoils and plants may recover from deficiency when roots reach the subsoil. Current soil test reports recommend that all crops receive 10 pounds of S per acre per year, applied in fertilizer or in pesticide applications. Crops most likely to respond to S fertilization on sandy soils are wheat, corn, cotton, and vegetable crops. Perennials are not likely to respond to S applications.

Micronutrients

Although the eight micronutrients are as important in plant nutrition as the primary and secondary nutrients, they are needed in much smaller quantities, and most Alabama soils contain adequate amounts for most crops. The College of Agriculture's Department of Agronomy and Soils has conducted field, greenhouse, and laboratory research continuously since about 1930 on the response of crops to micronutrients. Field experiments with boron (B), zinc (Zn), manganese (Mn), copper (Cu), iron (Fe), and molybdenum (Mo) have been conducted with various crops on the substations, experiment fields, and on farmers' fields throughout the State. Whereas some crops may use between 20 and 200 pounds per acre of N, P, K, Ca, Mg and S, they use less than 1 pound per acre of all the micronutrients.

Most Alabama soils have an abundance of minerals containing micronutrients. In some cases, over application of micronutrients (e.g. Zn, Cu, B) could lead to toxicity. Metals such as Zn and Cu build up in the soil. These may also be found in certain pesticides and animal manures. Soil test for Zn and Cu may be more valuable for avoiding toxic buildup rather than for predicting deficiencies.

Research with field and forage crops has shown that most deficiencies of micronutrients are limited to boron and zinc for a few crops on certain soils. The most practical recommendation for these nutrients is to apply them to specific crops in all cases or on soils that may be deficient. Soil tests for micronutrients are not a basis for recommendations. On the other hand, extremely high soil test values are flagged as indicators of likely contamination. The following is a brief description of the Auburn Soil Testing Laboratory's recommendations for the micronutrient elements.

Boron is recommended for cotton, peanuts, clovers grown for seed, alfalfa, cauliflower, broccoli, root crops, apples, pears, and plums. Recommendations based on needs of specific crops are more practical than relying on a soil analysis. Boron is relatively mobile in the soil.

Zinc is recommended for corn on sandy soils where the pH is above 6.0 or for the first year after applying lime. It is also recommended for peaches, pecans, apples, and pears. These are the only crops that have responded to Zn on Alabama soils. Zinc deficiency in corn seedlings is likely to occur in cool, wet seasons. Corn plants usually recover when warm weather arrives but yield may be decreased by the early deficiency. Routine analysis for Zn is not necessary in most cases, but soil and plant analysis for Zn may be helpful in diagnosing suspected cases of deficiency or toxicity. Simultaneous applications of excessive amounts of both lime and phosphorus can induce Zn deficiency on almost any crop. Soil tests showing pH values above 7.0 along with Very High or Extremely High P indicate a probability that Zn deficiency may occur on some soils. Zinc toxicities could occur on sensitive crops such as peanuts where excessive Zn application have caused high soil Zn levels (>20 pounds per acre [10 mg/kg] extractable Zn) on sandy soils. Maintaining a soil pH above 6.0 may help to reduce Zn toxicity symptoms. Broiler litter, certain pesticides, and some industrial by-products used as soil amendments may contain high concentrations of Zn. High soil Zn levels may indicate the possibility of other metals accumulating in the soil.

Iron is a common deficiency for only a few crops (e.g. soybeans) on the high pH soils of the Black Belt and for some specialty plants (e.g. azaleas, centipedegrass, and blueberries) where lime or phosphorus is excessive. This deficiency cannot be corrected by application of Fe to the soil but can be corrected on ornamental and fruit crops by spraying with a dilute iron solution. Soil analysis for Fe is not reliable because Fe availability is highly pH dependent.

Molybdenum application to soybeans as a foliar or seed treatment at planting is recommended for all soils of North Alabama and for Black Belt soils. Deficiency of Mo on soybeans on acid soils can usually be prevented by liming. Because Mo is needed in such small quantities, soil testing may not be very helpful.

Manganese is high in almost all Alabama soils and is not recommended for any crop. Soybeans grown on sandy soils with poor internal drainage, high organic matter content, and a pH above 6.0 may show Mn deficiency. Symptoms of cyst nematode damage are very similar to those for Mn deficiency on soybeans. Soil test Mn concentrations must be used with soil pH and soil texture in order to properly interpret the values.

Copper and Chlorine have not been found to be deficient for any crop on Alabama soils. There is no need to supply these elements in fertilizers in Alabama. Excessive Cu may be applied to soil in broiler litter and certain Cu-containing pesticides.

Micronutrient Soil Testing

Interpretations for selected micronutrients on the routine soil test are provided in Table 1. Values are rated as Low, Medium, High, and Very High. Because most soils normally contain only a small concentration of these elements, establishing a reliable rating system is difficult. Most samples will fall into the High rating by design. Crops on soils rated Low should be monitored. Special comments are given for micronutrient fertilization on crops with a risk of micronutrient deficiencies in Alabama soils. A Very High rating indicates possible soil contamination and the potential for toxicities in some crops.

Table 1. Ratings Used for Mehlich-1 Extractable Micronutrients for all Soils and Crops*

Rating	Zinc	Copper	Manganese	Boron
	———	———	lb/A or pp2m	———
Low	0-0.8	<0.1	0-20	0-1.0
Medium	0.9-1.6	0.2-2.0	21-40	1.1-2.0
High	1.7-20	2.0-100	41-600	2.0-100
Very High	21+	101+	601+	101+

*This table is based upon observations and very limited soil test calibration research. Plant availability and potential toxicity of micronutrients are affected by many soil factors especially soil pH. Mehlich-1 is not very effective at removing these micronutrients in all soils.

THE SOIL TESTING PROCESS

Soil testing involves more than just a chemical analysis. For the results to be meaningful to a grower, the following four steps must receive careful attention.

Step 1: Taking a good sample

Recommendations based on a soil test can be no better than the soil sample from which they are made. Growers are urged to take great care to be sure that the sample submitted represents as accurately as possible the area from which it is taken. Generally a sample should be a composite of subsamples taken from 10 to 20 spots in the area (Figure 2). Samples from plowed fields should be taken to plow depth, usually 6 to 8 inches, while those from sod or areas not to be plowed should be taken to a depth of 2 to 3 inches (Figure 3).

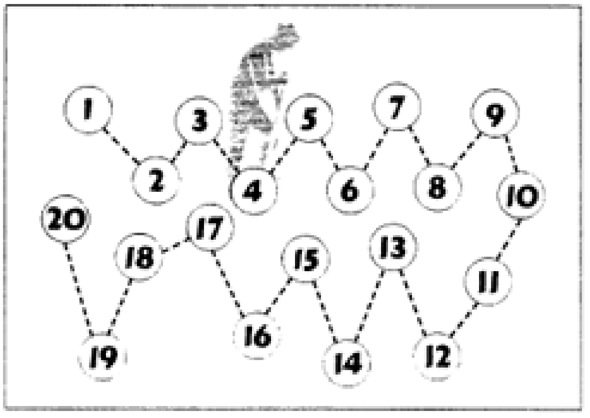

Figure 2. A good soil sample is composed of 10 to 20 random subsamples from the area to be tested.

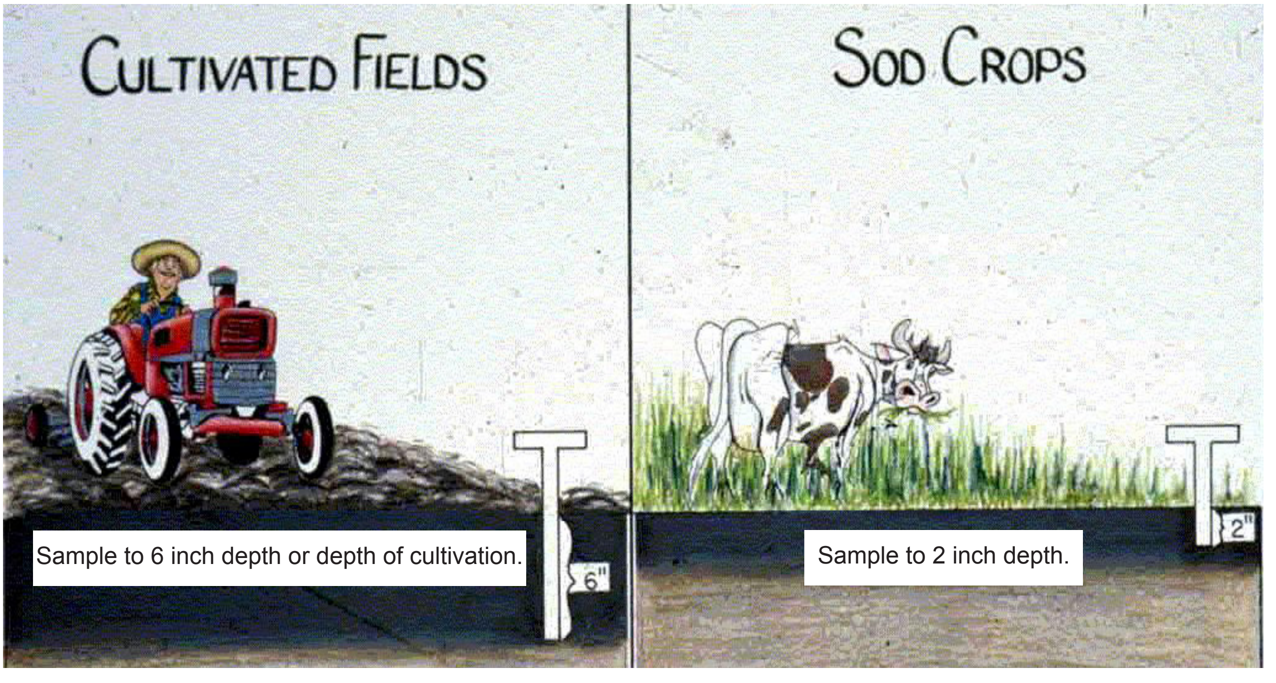

Figure 3. Taking a soil sample in cultivated fields (left) and sod crops (right).

Step 2: Analyzing a soil sample

This is the chemical extraction and testing procedure used by the soil testing laboratory. Values reported on a soil test represent extractable nutrients. These values are not total nutrients but they are related to plant-available nutrients in the soil. Research over many decades has identified certain chemical procedures that are correlated with nutrient availability and crop yield. No one extraction procedure works well under all soil and crop conditions.

The AU Soil Testing Laboratory uses the Mehlich-1 procedure for all soils except soils of the Black Belt region. For the Black Belts soils, the lab uses the Mississippi/Lancaster procedure. Neither procedure has been well correlated with extractable micronutrients although they are used for this purpose.

The Auburn University Soil Testing Laboratory uses procedures recommended and published by the Southern Extension and Research Activity on Soil Testing and Plant Analysis (SERA-6) and maintains quality control through participation in the North American Proficiency Testing program (NAPT). The procedure used is listed on the soil test report.

Some typical extractants used by soil testing laboratories in the United States are listed in Appendix 1.

Step 3: Interpreting the analysis

Results of the analysis must be related to plant growth or yield. Extensive soil test calibration research on the crops and soils of Alabama has been conducted and will continue. For each nutrient, crop, and soil, a good calibration must show that plant growth or yield increases as the level of an extractable nutrient increases up to a point where further increases in soil test levels fail to show significant or economical increases of plant growth or yield (Figure 4).

Step 4: Using the results

When growers receive a soil test report and appropriate recommendations, they must make certain practical decisions, which may result in a modification of the given recommendation. Some of these decisions may involve the following:

1. Using readily available fertilizers or ordering custom blended fertilizer.
2. Applying the same fertilizer grade to all fields or group of fields or ordering separate fertilizers for each field (or portion of a field) sampled.
3. Using premium fertilizers which contain secondary and micronutrients, or applying only those micronutrients specifically recommended for the crop.
4. Splitting fertilizer and/or lime applications.
5. Using starter fertilizers and foliar fertilizers to supplement recommendations.
6. Modifying nitrogen recommendations based upon comments on the report and past practices.
7. Applying fertilizers with other materials such as herbicides.
8. Modifying recommendations based upon current economic conditions.
9. Using organic materials, manures, and by-products to supply part of the nutrients recommended.

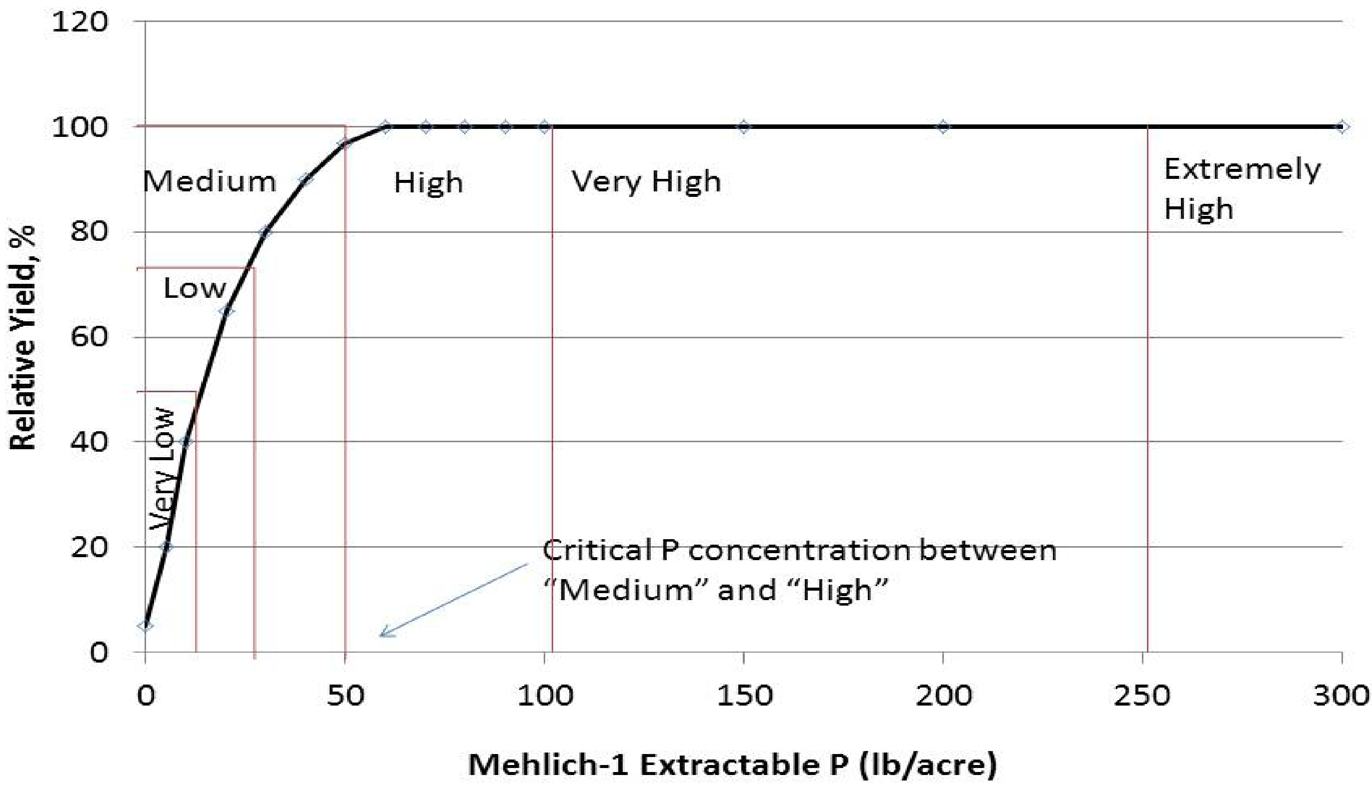

Figure 4. Example of soil test calibration for P on sandy and loamy Alabama soils for most crops.
The critical value is that point above which no additional fertilizer P is needed for 100 percent yield.

These and many other considerations affect how the soil test results are used and are decisions the grower or crop advisor must make.

INTERPRETATION OF THE SOIL TEST AND RECOMMENDATIONS

This section presents fertilizer recommendations made by the Auburn University Soil Testing Laboratory. The information is organized for the computer program that is used to make recommendations on samples analyzed by this laboratory. More than 100 crops/plants are placed into more than 56 Crop Code groups for the purpose of recommendations. Crops are listed in Appendix 2 with a summary of information used in classifying crops based on fertility requirements and in making recommendations for each crop. Tabular recommendations and comments for specific crops are presented in a separate Alabama Agricultural Experiment Station publication, AY-322B "Nutrient Recommendation Tables for Alabama Crop."

The following information is contained in tables in this publication:

- **Crop code** and a list of the crops included in each crops code (Appendix 2).
- **N rate**. Each crop is assigned a standard, annual N rate based upon research conducted throughout Alabama. However, comments given with each crop may modify this rate based upon potential yield, soil, time of application, cropping system, etc. (Appendix 2).
- **P requirement level**. There are only two levels. Level 1 is for those crops with a low P requirement such as peanuts, blueberries, centipedegrass, and pine trees. All other crops fall in level 2 (Table 2).
- **K requirement level.** Crops are divided into three classes based on their K requirements. These classes are (1) peanuts, blueberries, centipedegrass, and pine trees (low K requirement), (2) soybeans and corn and other grasses (medium K requirement); and (3) cotton, forage legumes, gardens, lawns, shrubs, and other special crops (high K requirement). They are presented in Table 2 along with the extractable P and K used to rate the different soil groups from Very Low to Extremely High.
- **Mg Ratings and Mg Codes.** Magnesium is rated either High or Low based on the soil group and extractable Mg (Table 3). There are three Mg recommendation codes for different crops (Table 4).
- **Ca ratings.** Extractable Ca is calibrated only for peanuts and tomatoes, peppers, fruits, and nuts (Table 3). All other crops are not expected to respond to direct Ca applications if the soil is properly limed but receive a rating based upon that of tomatoes, peppers, fruits, and nuts.
- **Lime recommendation code number.** Crops vary in the amount of acidity they can tolerate. They are divided into six classes based on the pH ranges in which they produce best. The classes in Table 5 provide the basis for ground limestone recommendations for each crop.

Soil-Test Ratings

Results of chemical tests are used to rate the fertility level of soils for each nutrient element tested. The ratings range from Very Low to Extremely High. They are influenced by both the nutrient requirements of the crop to be grown and the soil group (Table 2). The ratings for P and K are based on the relative yield that may be expected without adding the nutrient and when all other elements are in adequate supply.

Very Low (VL)
Soil will yield less than 50 percent of its potential. Large applications for soil building purposes are usually recommended. Some of the fertilizer should be placed in the drill for row crops.

Low (L)
Soil will yield 50 to 75 percent of its potential. Some fertilizer should be placed in the drill for row crops.

Medium (M)
Soil will yield 75 to 100 percent of its potential. Continued annual applications should be made in this range.

High (H)
Nutrient is adequate/optimum/sufficient for the crop, and none is recommended for field and forage crops. Where this recommendation is followed, the soil should be resampled each year.

Very High (VH)
The nutrient is at least twice the amount considered adequate. Application of this nutrient is wasteful.

Extremely High (EH)
The nutrient is at least five times the amount considered High. The level is excessive and further additions may be detrimental to the crop and may contribute to pollution of ground and surface waters.

Soil test values for P, K, Ca, Mg, and micronutrients on which soil-test ratings are based for the different crops and soil groups are presented in Tables 1 to 5.

Cation Exchange Capacity (CEC)

Cation exchange capacity (CEC) is the sum total of exchangable cations that a soil can absorb. Cations include Ca^{2+}, Mg^{2+}, K^+, H^+, Al^{3+}, NH_4^+, and Na^+. Cation exchange capacity is affected by soil pH, organic matter content and the amount and type of clay in the soil.

The Soil Testing Laboratory at Auburn University calculates CEC by summation of Mehlich-1 extractable K, Mg, and Ca plus calculated exchange acidity using the modified Adams-Evans buffer (Huluka, 2005). The extractable bases are calculated using the following equations:

Extractable Ca^{2+} (cmolc/kg) = Mehlich-1 Ca (lb/A)/400.8
Extractable Mg^{2+} (cmolc/kg) = Mehlich-1 Mg (lb/A)/243
Extractable K^+ (cmolc/kg) = Mehlich-1 K (lb/A)/782

Table 2. Soil Test P and K Ratings Based on Soil Group, Crop, and Extractable P and K

Phosphorus					Potassium						
P requirement and Rating		Soil-test P			K requirement and Rating			Soil-test K			
P Level 2 Other crops	P Level 1 Peanut, pines, centipede, blueberry	Soil group 1,2	Soil group 3	Soil group 4*	K Level 3 Cotton, legumes, veggies	K Level 2 Corn, grass-es, soybean	K Level 1 Peanut, pines, centipede, blueberry	Soil group 1	Soil group 2	Soil group 3	Soil group 4*
Rating		lb/A			Rating			lb/A			
V low	V low	0	0	0-3	V low	V low	V low	0-20	0-30	0-40	0-50
V low	V low	1-2	1	4-6	V low	Low	Low	21-22	31-33	41-44	51-56
V low	V low	3-4	2	7-9	V low	Low	Low	23-24	34-36	45-48	57-62
V low	Low	5-7	3	10-12	V low	Low	Low	25-26	37-39	49-52	63-68
V low	Low	8-10	4-5	13-15	V low	Low	Low	27-28	40-42	53-57	69-74
V low	Medium	11-12	6-7	16-18	V low	Low	Medium	29-30	43-45	58-60	75-80
Low	Medium	13-19	8-11	19-27	Low	Low	Medium	31-40	46-60	61-80	81-120
Low	High	20-25	12-15	28-36	Low	Medium	High	41-60	61-90	81-120	121-160
Medium	High	26-34	16-21	37-48	Medium	Medium	High	61-80	91-120	121-160	161-190
Medium	High	35-43	22-26	49-60	Medium	High	High	81-100	121-150	161-200	191-220
Medium	High	44-50	27-30	61-72	Medium	High	V high	101-120	151-180	201-240	221-240
High	V high	51-65	31-40	73-94	High	High	V high	121-160	181-240	241-320	241-320
High	V high	66-100	41-60	95-144	High	V high	V high	161-240	241-360	321-480	321-480
V high	V high	101-135	61-81	145-195	V high	V high	V high	241-320	361-480	481-640	481-640
V high	V high	136-250	82-150	196-360	V high	E high	E high	321-480	481-720	641-960	641-960
E high	E high	251+	151+	361+*	E high	E high	E high	481+	721+	961+	961+

K Level 1 = peanut, centipedegrass, blueberries, and pine trees with a low K requirement.
K Level 2 = corn, most grasses, and soybeans with a moderate K requirement.
K Level 3 = cotton, legumes, vegetables, and ornamentals with a high K requirement.
*Group 4 soils are from Black Belt and are extracted with the Mississippi/Lancaster Procedure. All others are extracted with Mehlich-1.

Soil acidity (exchangeable H^+) is determined from the Modified Adams-Evans buffer pH:

Soil H^+ (cmolc/kg) = 8 x (8-buffer pH).

The cmolc/kg of Ca, Mg, and K and the exchangeable H are summed up to determine the ECEC. This is also called CEC by summation and is reported only on the spreadsheet report as ECEC.

Buffer CEC is estimated from the following equation using the buffer pH:

Buffer CEC = Soil H+ / H-saturation,
where H-saturation is expressed as a fraction of CEC.
Hence, CEC=[8(8-buffer pH)]/H-saturation

Buffer CEC is not reported. Under normal circumstances, the summation and the buffer CEC should be close to the same and can be used as a quality control tool (Hue and Evans, 1983). Any discrepancy should be justified by a soil with high soluble salts, free calcium carbonate (e.g., calcareous Black Belt soils [Soil Group 4]), and/or free ground limestone or too much active acidity. Both CEC values are generated for internal lab use and flag descrepancy for quality control.

Soil Groups

The summation ECEC results are used to separate soils into four groups for the purpose of interpreting extractable P, K, Ca, and Mg. These groups are reported on all soil test reports.

Soil Group 1

Sandy soils with an ECEC less than 4.6 cmolc kg^{-1} of soil. Examples of soil series in this group are Dothan, Orangeburg, Alaga, Ruston, and Troup.

Soil Group 2

Loamy and clayey soils with an ECEC of 4.6 to 9.0 cmolc kg^{-1} of soil. Examples of soil series in this group are Madison, Lucedale, Allen, Hartsells, Cecil, Pacolet, and Savannah.

Soil Group 3

Clayey soils from areas other than the Black Belt with an ECEC more than 9 cmolc kg^{-1} of soil. Colbert, Decatur, Dewey, Talbott, Boswell, and Iredell are examples of soil series from this group.

Soil Group 4

Calcareous clayey soils of the Black Belt. These soils are extracted using the Mississippi/Lancaster extractant instead of the Mehlich-1. Examples of soil series in this group are Houston, Sumter, Oktibbeha, Leeper, and Vaiden.

The group in which a soil is classified may affect the fertility ratings, and, therefore, the P, K, Ca, and Mg recommendations (Tables 2 and 3). Growers sometimes do not understand why samples from individual fields change groups between samplings. When a soil is near the borderline between groups, (e.g. 4.6 cmolc kg^{-1}) it may fall into one soil group one year and the other group the following year. Liming and/or fertilizing the soil may also cause it to be shifted from Group 1 to Group 2 or from Group 2 to Group 3 because of the increase in extractable cations.

Extractable Nutrients

Soil test results are reported as "pounds per acre" which is the same as parts per 2 million (pp2m). An acre furrow slice of soil has an area of 43,560 ft^2, a depth of about 6 inches, and weighs about 2 million pounds. We know that a dry sandy soil in an acre weighs a lot more than 2 million pounds while a dry, clayey soil weights less than 2 million pounds. Technically, "pounds per acre" is NOT an appropriate way to report concentration of nutrients because an acre is a surface measurement and soil testing is a measurement based on a quantity of soil (weight or volume). A scientifically appropriate way of reporting extractable nutrients is milligrams per kilogram (mg/kg or mg kg^{-1}) of soil. This value is the same as "parts per million" (ppm) because there are 10^6 or 1 million milligrams in one kilogram. However, over the years, soil testing laboratories have traditionally used this 2-million-pound per acre furrow slice to report soil test values. To convert from "pounds per acre" to ppm, simply multiply value by 0.5 (or divide by 2).

Recommendations are appropriately made in "pounds per acre" because fertilizers are spread on the surface of a soil. An area measurement (acre) is quite appropriate for recom-

Table 3. Soil Test Mg and Ca Ratings Based on Crop and Extractable Mg and Ca

Magnesium (all crops)*			Calcium (all soils)			
Rating	Soil group 1	Other soil groups	Rating	Peanuts	Tomatoes, peppers, fruits,nuts	All others
	lb/A or pp2m			lb/A or pp2m		
Low	0-25	0-50	Low	0-175	0-300	0-300
			Medium	176-300	301-500	301-500
High	26+	51+	High	301+	501+	501+

* Soil-test Mg

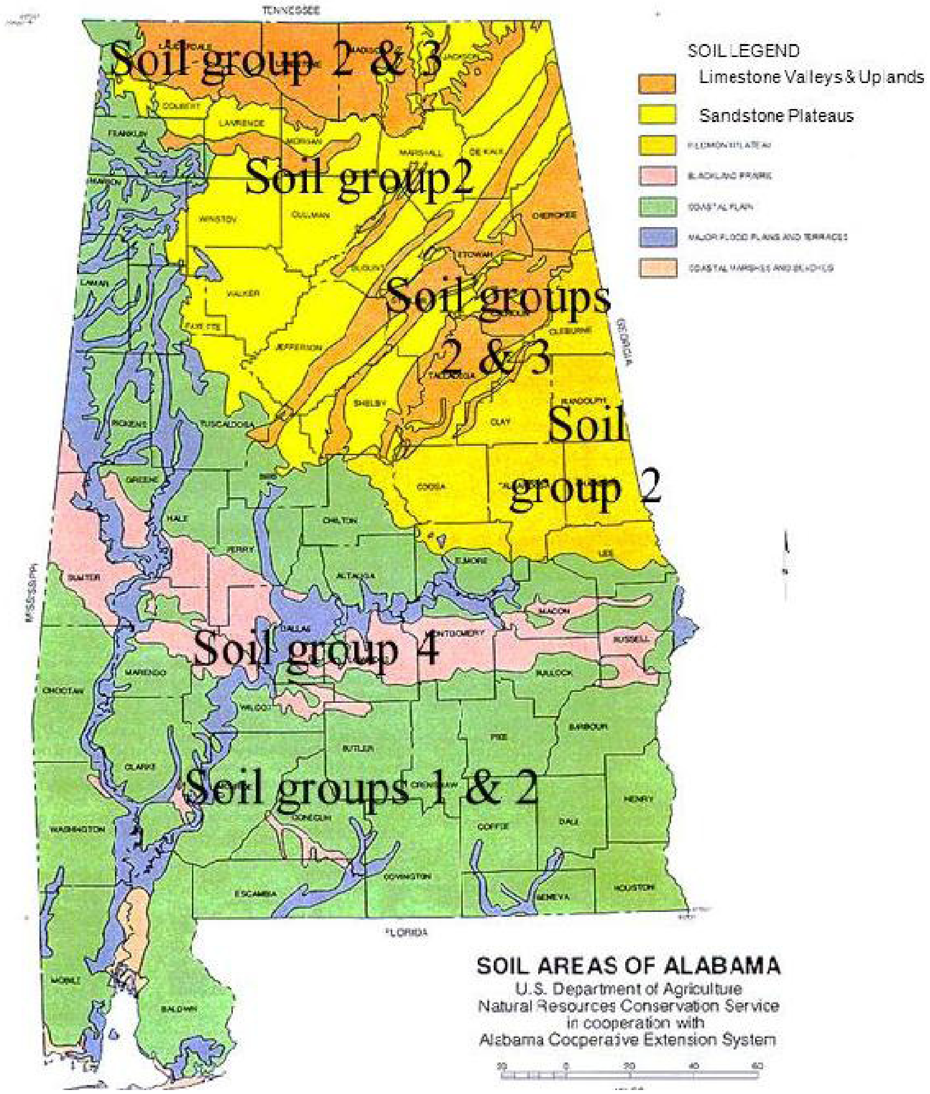

Figure 6. Major Alabama soil areas and the soil groups likely to be found in each area.

Table 4. Magnesium Recommendation Codes	
Code 1	If magnesium is low and lime is recommended, both soil acidity and low magnesium can be corrected by applying dolomitic lime at the recommended rate. If magnesium is low and lime is not recommended, no magnesium is required. (These crops have not been shown to respond to magnesium.)
Code 2	If magnesium is low and lime is recommended, both soil acidity and low magnesium can be corrected by applying dolomitic lime at the recommended rate. If magnesium is low and lime is not recommended, low magnesium may be corrected by applying 25 pounds per acre of Mg as magnesium sulfate, magnesium oxide, or sulfate of potash-magnesium, or if the pH is 6.5 or below, by applying 1,000 pounds per acre of dolomitic limestone (cotton, vegetable crops, and orchards).
Code 3	If magnesium is low and lime is recommended, both soil acidity and low magnesium can be corrected by applying dolomitic lime at the recommended rate. If lime is not recommended and Mg is low, low magnesium may be corrected by applying 25 pounds per acre of Mg as magnesium sulfate, magnesium oxide, or sulfate of potash-magnesium. Potatoes, blueberries, pines, and tobacco have a high Mg requirement but are sensitive to high pH.

mendations. Home ground sample recommendations (gardens, orchards, shrubs, turfgrass, etc.) are given in pounds per 1,000 square feet (e.g. 50 ft. x 20 ft. area). Recommended nutrients should be applied annually until soil is resampled.

Ground Limestone Recommendations and Buffer pH

Practically all Alabama soils, except for the calcareous soils of the Black Belt, are slightly or strongly acid and may need to be limed for most crops. This acid condition results from the low level of limestone in the original soils, the high rate of leaching from rainfall, the use of acid-forming fertilizers, and crop removal. About one-half of the samples received in the Auburn University Soil Testing Laboratory need lime. This ratio has not changed much in recent years. Growers should use soil-test recommendations to maintain soil pH between 5.8 and 6.5 for most crops (Table 5). Soil testing is the only practical basis for determining when and how much lime should be applied. Soil pH is a critical factor in determining response of crops to fertilizers and maintaining a favorable soil environment for profitable production. Soils should be sampled every 2 or 3 years to ensure that production is not limited by soil acidity.

Ground limestone or “lime” recommendations are based on two separate tests made in the Auburn University Soil Testing Laboratory on each sample. These are (1) the determination of soil pH in water, pHw, which indicates the active acidity in the soil, and (2) the buffer pH, pHB, which is related to potential acidity or the acidity associated with soil clay and organic matter. The pHB is used to calculate the amount of lime required to raise the pHw to a desired value known as the target pH. The amount of lime required varies among soils at the same pHw because of differences in the kind and amount of clay in the soil, soil organic matter, and target pH. Soils that are high in organic matter and clay content require more lime to raise the pH to a specific range 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 ground limestone to raise the pH to 6.5, while a clay soil at the same pH may require 4 tons of ground limestone.

Ground limestone is recommended to correct the pH of the top 8 inches of soil. Growers who plow deeper than 8 inches should increase the rates accordingly. Limestone should be thoroughly mixed with the soil because the primary reason for applying lime is to adjust the soil pHw rather than to supply plant nutrients such as Ca and Mg. Lime should be applied and mixed with the soil as early as practical. Ground limestone will begin to react with the soil immediately after application but the full effect may not be evident for several months. Fineness and purity of ground limestone are important in determining the rate of reaction. Lime recommendations are based on the minimum quality ground agricultural limestone as defined by the Alabama Department of Agriculture and Industries:

- 90 percent $CaCO_3$ equivalent
- 90 percent passes a 10-mesh sieve
- 50 percent passes a 60-mesh sieve

Lime that meets these minimum criteria will have a $CaCO_3$ equivalent (CCE) of 63 percent. Lower rates could be used for higher quality ground limestone. The pH requirements on which lime recommendations for different crops are based are presented in Table 5.

Lowering Soil pH

Most plants grow best where the soil is slightly acid in the range of pH 6.0 to 7.0. However, a few plants such as azaleas, gardenias, and blueberries grow best at lower pH values. In rare cases, it may be desirable to lower the pH by adding an acidifying agent such as elemental sulfur or aluminum sulfate (Table 6). This can be done successfully on soils that do not contain large amounts of free lime. Calcareous Black Belt soils cannot be practically acidified because much of the soil contains lime ($CaCO_3$). In other cases, the pH can be lowered simply by using acid-forming fertilizers. Ammonium sulfate and sulfur-coated urea are two of the best choices for acidifying soils.

Table 5. Lime Recommendation Codes

Code	Lime if below	Lime to	Crops
	pH		
0	Lime recommended only under special condiitions		Blueberries, azaleas
1	5.8	6.5	All except those listed below
2	6.0	6.5	Corn, cotton, most clovers, gardens, vegetable crops, and most fruits and nuts
3	6.5	7.0	Alfalfa
4	5.0	5.5	Irish potatoes, tobacco, Christmas trees
5	5.6	6.0	Centipedegrass

Table 6. Pounds of Elemental Sulfur* Per 100 ft^2 Needed to Lower Soil pH of a Silt Loam Soil

Present pH	Desired pH				
	6.5	6.0	5.5	5.0	4.5
	lb/100 ft^2				
8.0	3.0	4.0	5.5	7.0	8.0
7.5	2.0	3.5	4.5	6.0	7.0
7.0	1.0	2.0	3.5	5.0	6.0
6.5	–	1.0	2.5	4.0	4.5
6.0	–	–	1.0	2.5	3.5

* If aluminum sulfate is used, multiply by 6.

Soil Organic Matter

Soil organic matter (SOM) affects the CEC, nitrogen supplying capacity, water holding capacity, water infiltration, soil tilth (crumbliness) and other soil quality factors. There can never be too much soil organic matter in Alabama soils. Increasing or stabilizing SOM should be an objective of any soil improvement program. The organic matter content of most cultivated Alabama soils is low (less than 1 percent) and does not vary widely among soils. Soil organic matter is not reported on routine soil tests at the present time because of the cost of analysis but we do offer a quantitative determination of SOM on special request. Those desiring organic matter analyses should request it on the Special Soil Analysis information sheet submitted with soil samples.

Fertilizer Recommendation

Fertilizers are recommended in pounds per acre of N, P_2O_5, and K_2O. Comments specific to the recommendation are printed on the report. These comments can be found under specific crops in a separate AAES publication, AY-322B "Nutrient Recommendation Tables for Alabama Crops." Recommendations for P and K are based on regression equations for crops and soil groups (Appendix 2). Recommended fertilizer rates will be in 10-pound increments with a minimum recommendation of 30 pounds per acre of P_2O_5 or K_2O.

Specific fertilizer grades (e.g. 13-13-13, 8-24-24, 15-0-15, etc.) are not recommended because of the availability of so many fertilizer materials and grades that could be used. Most fertilizer dealers will custom blend specific grades to meet the needs of the customer when ordering large amounts of fertilizer.

For home gardens and specialty crops, the choice of grades is more limited. In these cases, specific grades are mentioned in comments. The use of a grade such as 13-13-13 as an example, does not indicate that purchasers should insist on this specific grade, but that any equivalent ratio may be substituted. If 10-10-10 is used instead of 13-13-13, the amount used should be increased by 1.3 and the result will be the same. If concentrated superphosphate, which contains 46 percent P_2O_5 is used instead of superphosphate, which contains 20 percent P_2O_5, the amount used should be reduced by about 43 percent. The same is true for nitrogen sources and other materials.

Organic Fertilization

Some growers are interested only in organic fertilization practices because they are certified or seeking certification through the USDA National Organic Program (NOP) or because of personal preference. This preference does not change the soil testing process or nutrient recommendations. It does change Step 4 in the soil testing process, "Using the results." Recommendations for organic fertilization are specifically given in comments for only two crop codes, Crop Code 59 for Vegetable Garden (organic fertilization) and Crop Code 97 for Blackberries (commercial). Estimated nutrient values in some popular organic fertilizer materials are listed in Table 7.

Table Versus Formulas

Fertilizer recommendations are given by formulas in Appendix 2 or in both table format and formulas in AAES publication AY-322B, "Nutrient Recommendation Tables for Alabama Crops." The formulas with each recommendation may allow for smaller incremental increases or decreases in fertilizer rates as compared to those rates presented in tables. To use the formulas, follow this procedure:

1. Determine the soil group on your report;
2. Look up the appropriate equation in Table 1;
3. Substitute pounds per acre of soil test P or K for "x" and then solve the equation. The results will be in pounds per acre of P_2O_5 or K_2O that is recommended. Round up to the nearest 10 pounds per acre.

Example calculation:

1. Crop = corn, 120 bushels per acre (see crop code 13)
2. 25 pounds per acre soil test K from report
3. Soil Group 1 from report
4. Equation: 80 - 0.99x
5. 80 - 0.99(25) = 55 pounds K_2O per acre
6. Round off to nearest 10 pounds; thus, the recommendation will be 60 pounds K_2O per acre .

The formula will allow for lower fertilizer rates when soil test levels are approaching a higher fertility rating.

Yield Potential (Yield Goal) and Crop Varieties

Over fertilizing based upon arbitrary yield goals has been shown to result in economic losses to the grower and water quality problems in some parts of the United States. Auburn University's soil test calibrations and recommendation are based on maximum yield potential from actual experiments conducted on experiment stations and farms throughout Alabama under both irrigated (where possible) and non-irrigated conditions. Phosphorous and potassium rates are rarely related to yield potential but may be adjusted based upon anticipated crop removal (e.g. forage crops). Nitrogen rates for grain crops (e.g. corn or wheat) may need to be adjusted up or down based upon yield potential. Conditions for adjustments are usually given in comments. However, sources of fertilizer and timing of application may have as much impact on crop yields as the total annual rate used.

New and improved crop varieties may have a higher yield potential than older varieties but rarely have higher P and K rates been justified for these newer varieties. Higher N rates for grain crops and N and K for higher yielding forages may be justified because of the yield potential and crop removal. These are usually covered in the comments on the soil test report and different crops codes such as that for corn.

Table 7. Estimated Total Fertilizer Value of Some Popular, Organic Materials or Materials Used in Organic Fertilization

Material	Approximate % N-P_2O_5-K_2O value (fertilizer grade)*	Other considerations
High N materials		
Blood meal	13 - 2 - 1	
Cottonseed meal	6 – 3 - 1	
Feather meal	11 – 1 - 1	
Fish meal (dried)	10 – 6 - 1	
Fish emulsion	6 – 1 - 1	
Legume hay/alfalfa meal	3 – 1 - 2	
Grass hay	1.5 - 0.5 - 2.0	
Nitrate of soda (mined)	16 – 0 - 0	
High P materials		
Bone meal	0 -10 - 0	
Rock phosphate (ground)	0 - 2 to 30 - 0	Mined product
Manures		
Most manures have a N: P_2O_5 ratio close to 1:1 and can results in a buildup of soil P if used as a source of N		
Cattle (fresh, dry)	1.5 - 1.5 - 1.2	
Cattle (composted)	0.5 – 0.5 - 0.5	
Horse (fresh)	0.5 – 0.2 - 0.3	
Poultry broiler (fresh)	3 – 3 - 2	
Poultry broiler (composted)	2 – 2 - 1	
Hen, caged layers (moist)	1.5 – 1.3 – 0.5	
Hen litter	1.8 – 2.8 – 1.4	
Sheep	0.6 – 0.3 – 0.2	
Swine (fresh)	0.6 – 0.4 – 0.1	
High K materials		
Greensand	0 - 0.5 - 6	Very slowly available
Sul-po-mag (potassium magnesium sulfate)	0 – 0 - 21	Mined product
Potassium sulfate (mined)	0-0-52	Mined product
Seaweed (dried)	0.7 – 0.8 – 5.0	
Other Materials		
Sawdust	0.2 – 0 – 0.2	High C:N ratio; slow to break down
Biosolids/sewage sludge	5 – 6 – 0.5	Not approved for organic use
Wheat/oat straw	0 - 0 - 1	High C:N ratio; slow to break down
Wood ashes	0 – 2 - 6	Highly alkaline; use as liming material; 70 percent $CaCO_3$ equivalent
Yard waste (composted)	1 – 2 - 1	

*Values shown here are highly variable based upon the source of the material.

APPENDIX 1. Typical Soil Extractants Used by Soil Testing Laboratories in the United States

Typical Soil Extractants Used by Soil Testing Laboratories in the United States*

Extractant	Other names	Soil suitability	Best for testing	Not suitable for
Mehlich 1*	Dilute double acid	Acid, weakly buffered soils	P, K, Ca, Mg	Alkaline soils
Mehlich 3		Acid to neutral soils	P, K, Ca, Mg, Zn, Mn	Alkaline soils
Olsen	Sodium bicarbonate	Alkaline and calcareous soils	P	micronutrients
Mississippi*	Lancaster	Acid to alkaline	P, K, Ca, Mg	micronutrients
Bray P1 or Bray P2	Weak Bray or Strong Bray	Highly buffered, acid	P	Other nutrients
Morgan		acidic	P, K, Ca, Mg	micronutrients
Ammonium acetate buffered at pH 4.5 or 7.0	NH_4OAc	all	Cations (K, Ca, Mg, Na)	P and micro-nutrients
Hot water		all	B	Other nutrients
0.01 N HNO_3	Dilute nitric acid	all	Zn, Mn, Cu, Fe	Other nutrients; alkaline soils
1.0 M KCl		all	Nitrate-N, Ammonium-N	Other nutrients
0.01 M $Ca(H_2PO_4)_2.2H_2O$		all	Sulfate-S	Other nutrients

* Extractants used by the AU Soil Testing Laboratory

APPENDIX 2. INFORMATION USED TO GENERATE RECOMMENDATIONS FOR ALABAMA CROP GROUPS

Crop code	Crop group name	Soil group[1]	P equation[2] P_2O_5 (lb/A) =	K equation[2] K_2O (lb/A) =	N rate[3]	P level[4]	K level[5]	Lime code[6]	Mg code[7]
	PASTURES, HAY CROPS, AND FIELD CROPS								
1	Summer grass pasture	1	80-1.57x	80-0.99x	60	2	2	1	1
		2	80-1.57x	80-0.66x					
		3	80-2.58x	80-0.49x					
		4	80-1.11x	80-0.42x					
2	Bermuda or bahiagrass hay	1	100-1.96x	300-3.70x	100	2	2	1	1
		2	100-1.96x	300-2.48x					
		3	100-3.23x	300-1.88x					
		4	100-1.37x	300-1.58x					
3	Perennial winter grass pasture	1	100-1.96x	100-1.23x	60	2	2	1	1
		2	100-1.96x	100-0.83x					
		3	100-3.23x	100-0.63x					
		4	100-1.38x	100-0.52x					
4	Temp. summer grass pasture, Johnsongrass	1	120-2.35x	120-1.48x	60	2	2	1	1
		2	120-2.4x	120-0.99x					
		3	120-3.9x	120-0.75x					
		4	120-1.66x	120-0.63x					
5	Annual legume w/small grain	1	120-2.35x	120-1.5x	60	2	3	1	1
		2	120-2.35x	120-0.99x					
		3	120-3.87x	120-0.75x					
		4	120-1.64x	120-0.63x					
6	Perennial clovers and legumes	1	180-3.53x	180-1.49x	0	2	3	2	1
		2	180-3.53x	180-0.99x					
		3	180-5.81x	180-0.75x					
		4	180-2.47x	180-0.75x					
7	Summer grass w/perennial legume	1	180-3.53x	180-1.49x	0	2	3	2	1
		2	180-3.53x	180-0.99x					
		3	180-5.81x	180-0.75x					
		4	180-2.47x	180-0.75x					
8	Cool-season grass w/perennial legume	1	180-3.53x	180-4.29x	0	2	2	2	1
		2	180-3.53x	180-2.90x					
		3	180-5.81x	180-2.20x					
		4	180-2.47x	180-1.48x					
9	Summer grass pasture w/annual legume	1	100-1.96x	100-1.23x	0	2	2	1	1
		2	100-1.96x	100-0.83x					
		3	100-3.23x	100-0.63x					
		4	100-1.37x	100-0.52x					
10	Cotton	1	120-2.35x	120-0.99x	90	2	3	2	2
		2	120-2.35x	120-0.67x					
		3	120-3.87x	120-0.50x					
		4	120-1.64x	120-0.48x					

Information Used to Generate Recommenations for Alabama Crop Groups (cont.)

Crop code	Crop group name	Soil group[1]	P equation[2] P_2O_5 (lb/A) =	K equation[2] K_2O (lb/A) =	N rate[3]	P level[4]	K level[5]	Lime code[6]	Mg code[7]
	PASTURES, HAY CROPS, AND FIELD CROPS (CONT.)								
11	Native grasses (switchgrass, indiangrass, bluestem)	1	80-1.57X	80-0.99x	30	2	2	5	1
		2	80-1.57X	80-0.67x					
		3	80-2.58X	80-0.50x					
		4	80-1.10X	80-0.42x					
13	Corn (120-150 bu/A), non-irrigated	1	80-1.57x	80-0.99x	120	2	2	2	1
		2	80-1.57x	80-0.67x					
		3	80-2.58x	80-0.50x					
		4	80-1.10x	80-0.42x					
16	Corn (150-240+ bu/A) irrigated or corn or sorghum silage	1	120-2.35x	120-1.48x	200	2	2	2	1
		2	120-2.35x	120-0.99x					
		3	120-4.00x	120-0.75x					
		4	120-1.64x	120-0.63x					
17	Peanut	1	120-6.00x	120-2.86x	0	1	1	1	1
		2	120-6.00x	120-1.94x					
		3	120-10.00x	120-1.46x					
		4	120-4.29x	120-0.98x					
19	Annual legumes	1	100-2x	100-1.23x	0	2	2	1	1
		2	100-2x	100-0.83x					
		3	100-3.33x	100-0.62x					
		4	100-1.39x	100-0.52x					
20	Southern peas, cowpeas	1	100-1.96x	100-1.23x	30	2	2	1	1
		2	100-1.96x	100-0.83x					
		3	100-3.23x	100-0.62x					
		4	100-1.37x	100-0.52x					
21	Sorghum, sugarcane, sunflower	1	80-1.57x	80-0.99x	80	2	2	1	1
		2	80-1.57x	80-0.67x					
		3	80-2.58x	80-0.50x					
		4	80-1.10x	80-0.42x					
22	Alfalfa	1	200-3.92x	480-5.93x	0	2	3	3	1
		2	200-3.92x	480-3.97x					
		3	200-6.45x	480-2.98x					
		4	200-2.74x	480-2.51x					
23	Sericea lespedeza	1	120-2.35x	120-1.48x	0	2	2	1	1
		2	120-2.35x	120-0.99x					
		3	120-3.87x	120-0.75x					
		4	120-1.64x	120-0.63x					

Information Used to Generate Recommenations for Alabama Crop Groups (cont.)

Crop code	Crop group name	Soil group[1]	P equation[2] P_2O_5 (lb/A) =	K equation[2] K_2O (lb/A) =	N rate[3]	P level[4]	K level[5]	Lime code[6]	Mg code[7]
	PASTURES, HAY CROPS, AND FIELD CROPS (CONT.)								
24	Soybean	1	120-2.35x	120-1.48x	0	2	2	1	1
		2	120-2.35x	120-0.99x					
		3	120-3.87x	120-0.75x					
		4	120-1.64x	120-0.63x					
25	Small grain followed by soybean	1	160-3.14x	160-1.98x	100	2	2	1	1
		2	160-3.14x	160-1.32x					
		3	160-5.16x	160-0.99x					
		4	160-2.19x	160-0.84x					
26	Tobacco, flue cured	1	200-3.92x	200-2.47x	60	2	3	4	2
		2	200-3.92x	200-1.65x					
		3	200-6.45x	200-1.24x					
		4	200-2.74x	200-1.24x					
27	Small grain or temp. winter grass pasture	1	120-2.35x	120-1.48x	100	2	2	1	1
		2	120-2.35x	120-0.99x					
		3	120-3.87x	120-0.75x					
		4	120-1.64x	120-0.63x					
	TURFGRASS LAWNS, GOLF COURSES, AND ROADSIDE								
40	Bermuda, zoysia, St. Augustine lawn	1	80-1.57x	80-0.67x	80	2	2	1	1
		2	80-1.57x	80-0.45x					
		3	80-2.58x	80-0.34x					
		4	80-1.10x	80-0.34x					
42	Centipede lawn	1	40-2.00x	40-0.95x	40	1	1	5	1
		2	40-2.00x	40-0.65x					
		3	40-3.33x	40-0.49x					
		4	40-1.43x	40-0.33x					
43	Ryegrass, fescue, bluegrass lawn	1	80-1.57x	80-0.67x	80	2	2	1	1
		2	80-1.57x	80-0.45x					
		3	80-2.58x	80-0.34x					
		4	80-1.10x	80-0.34x					
44	Golf green, tee, commercial sod	1	200-3.92x	200-1.66x	400	2	2	1	1
		2	200-3.92x	200-1.11x					
		3	200-6.45x	200-0.83x					
		4	200-2.74x	200-0.83x					
45	Golf fairway	1	80-1.57x	80-0.66x	120	2	2	1	1
		2	80-1.57x	80-0.45x					
		3	80-2.58x	80-0.33x					
		4	80-1.10x	80-0.33x					

Information Used to Generate Recommenations for Alabama Crop Groups (cont.)

Crop code	Crop group name	Soil group[1]	P equation[2] P_2O_5 (lb/A) =	K equation[2] K_2O (lb/A) =	N rate[3]	P level[4]	K level[5]	Lime code[6]	Mg code[7]
	TURFGRASS LAWNS, GOLF COURSES, AND ROADSIDE (CONT.)								
46	Athlelic field	1	80-1.57x	80-0.66x	200	2	2	1	1
		2	80-1.57x	80-0.45x					
		3	80-2.58x	80-0.33x					
		4	80-1.10x	80-0.33x					
47	Roadside turf establishment	1	160-3.14x	160-1.32x	120	2	2	1	1
		2	160-3.14x	160-0.88x					
		3	160-5.16x	160-0.66x					
		4	160-2.19x	160-0.66x					
48	Roadside turf maintenance	1	80-1.57x	80-0.66x	80	2	2	1	1
		2	80-1.57x	80-0.45x					
		3	80-2.58x	80-0.33x					
		4	80-1.110x	80-0.33x					
	VEGETABLE GARDENS AND COMMERCIAL VEGETABLES								
59	Vegetable garden, organic fertiliza-tion	1	180-3.53x	180-1.49x	120	2	3	2	2
		2	180-3.53x	180-0.99x					
		3	180-5.81x	180-0.75x					
		4	180-2.47x	180-0.75x					
60	Vegetable garden, conventional fertilization	1	180-3.53x	180-1.49x	120	2	3	2	2
		2	180-3.53x	180-0.99x					
		3	180-5.81x	180-0.75x					
		4	180-2.47x	180-0.75x					
61	Commercial vegetable crops	1	180-3.53x	180-1.49x	120	2	3	2	2
		2	180-3.53x	180-0.99x					
		3	180-5.81x	180-0.75x					
		4	180-2.47x	180-0.75x					
62	Tomatoes	1	180-3.53x	180-1.49x	120	2	3	2	2
		2	180-3.53x	180-0.99x					
		3	180-5.81x	180-0.75x					
		4	180-2.47x	180-0.75x					
63	Sweet potatoes	1	160-3.14x	200-1.65x	80	2	3	1	2
		2	160-3.14x	200-1.11x					
		3	160-5.16x	200-0.83x					
		4	160-2.19x	200-0.83x					
64	Irish potatoes	1	200-3.92x	200-1.67x	120	2	3	4	3
		2	200-3.92x	200-1.11x					
		3	200-6.45x	200-0.83x					
		4	200-2.74x	200-0.83x					
65	Melons, cucumberss, beans, squash, okra	1	120-2.4x	120-0.99x	80	2	3	1	2
		2	120-2.4x	120-0.66x					
		3	120-4x	120-0.50x					
		4	120-1.67x	120-0.50x					

Information Used to Generate Recommenations for Alabama Crop Groups (cont.)

Crop code	Crop group name	Soil group[1]	P equation[2] P_2O_5 (lb/A) =	K equation[2] K_2O (lb/A) =	N rate[3]	P level[4]	K level[5]	Lime code[6]	Mg code[7]
	VEGETABLE GARDENS AND COMMERCIAL VEGETABLES (CONT.)								
66	Sweet corn	1	120-2.35x	120-0.99x	150	2	3	2	2
		2	120-2.35x	120-0.67x					
		3	120-3.87x	120-0.50x					
		4	120-1.64x	120-0.50x					
67	Pepper	1	180-3.53x	180-1.49x	100	2	3	2	2
		2	180-3.53x	180-0.99x					
		3	180-5.81x	180-0.75x					
		4	180-2.47x	180-0.75x					
68	Canola	1	120-2.35x	120-1.48x	160	2	2	1	2
		2	120-2.35x	120-0.99x					
		3	120-3.87x	120-0.75x					
		4	120-1.64x	120-0.63x					
	SHRUBS AND ORNAMENTALS								
80	Shrubs and perennial flowers	1	120-2.35x	120-0.99x	120	2	3	1	2
		2	120-2.35x	120-0.67x					
		3	120-3.87x	120-0.50x					
		4	120-1.64x	120-0.50x					
81	Azaleas, gardenias, rhododendrons	1	120-2.35x	120-0.99x	120	2	3	0	2
		2	120-2.35x	120-0.67x					
		3	120-3.87x	120-0.50x					
		4	120-1.64x	120-0.50x					
82	Roses, mums, annual flowers	1	120-2.35x	120-0.99x	120	2	3	1	2
		2	120-2.35x	120-0.67x					
		3	120-3.87x	120-0.50x					
		4	120-1.67x	120-0.50x					
	FRUITS, ORCHARD CROPS, AND TREES								
85	Christmas trees	1	80-1.57x	80-0.66x	*	2	1	4	3
		2	80-1.57x	80-0.44x					
		3	80-2.64x	80-0.33x					
		4	80-1.10x	80-0.33x					
89	Strawberries	1	180-3.53x	180-1.49x	120	2	3	1	2
		2	180-3.53x	180-0.99x					
		3	180-5.81x	180-0.75x					
		4	180-2.47x	180-0.75x					
90	Peaches	1	60-1.18x	90-1.12x	*	2	2	2	2
		2	60-1.18x	90-0.75x					
		3	60-1.94x	90-0.56x					
		4	60-0.82x	90-0.47x					
91	Muscadine grapes	1	60-1.18x	90-1.12x	*	2	2	2	2
		2	60-1.18x	90-0.75x					
		3	60-1.94x	90-0.56x					
		4	60-0.82x	90-0.47x					

Information Used to Generate Recommenations for Alabama Crop Groups (cont.)

Crop code	Crop group name	Soil group[1]	P equation[2] P_2O_5 (lb/A) =	K equation[2] K_2O (lb/A) =	N rate[3]	P level[4]	K level[5]	Lime code[6]	Mg code[7]
			FRUITS, ORCHARD CROPS, AND TREES (CONT.)						
92	Apples, pears	1	60-1.18x	90-1.12x	*	2	2	2	2
		2	60-1.18x	90-0.75x					
		3	60-1.94x	90-0.56x					
		4	60-0.82x	90-0.47x					
93	Plums	1	60-1.18x	90-1.12x	*	2	2	2	2
		2	60-1.18x	90-0.75x					
		3	60-1.94x	90-0.56x					
		4	60-0.82x	90-0.47x					
94	Pecans	1	60-1.18x	90-1.12x	*	2	2	2	2
		2	60-1.18x	90-0.75x					
		3	60-1.94x	90-0.56x					
		4	60-0.82x	90-0.47x					
95	Home orchards	1	50-0.98x	50-0.62x	*	2	2	2	2
		2	50-0.98x	50-0.42x					
		3	50-1.61x	50-0.31x					
		4	50-0.68x	50-0.26x					
96	Commercial blueberries	1	50-2.50x	50-1.19x	*	1	1	0	3
		2	50-2.50x	50-0.81x					
		3	50-4.17x	50-0.62x					
		4	50-1.79x	50-0.41x					
97	Commercial blackberries	1	60-1.18x	90-0.75x	100	2	3	1	3
		2	60-1.18x	90-0.50x					
		3	60-1.94x	90-0.38x					
		4	60-0.82x	90-0.38x					
100	Pine plantations	1	150-7.50x	*	na	1	1	4	1
		2	150-7.50x	*					
		3	150-12.50x	*					
		4	150-5.36x	*					
			WILDLIFE PLOTS						
101	Wildlife food plots, cool-season grasses, legumes	1	120-2.35x	120 -1.48x	60	2	2	1	1
		2	120 – 2.35x	120 -0.99x					
		3	120 –3.87x	120 -0.75x					
		4	120 -1.64x	120-0.63x					

[1] See explanation of soil groups on page 10.
[2] P equations and K equations are used to generate P_2O_5 and K_2O recommendations from extractable P and K values (x variable) entered as extractable P or K in pounds per acre or pp2m.
[3] N rate is the standard, annual N rate printed on the soil test report.
[4] P level is given in Table 2.
[5] K level is given in Table 2.
[6] Lime codes are given in Table 5.
[7] Mg codes are given in Table 4.

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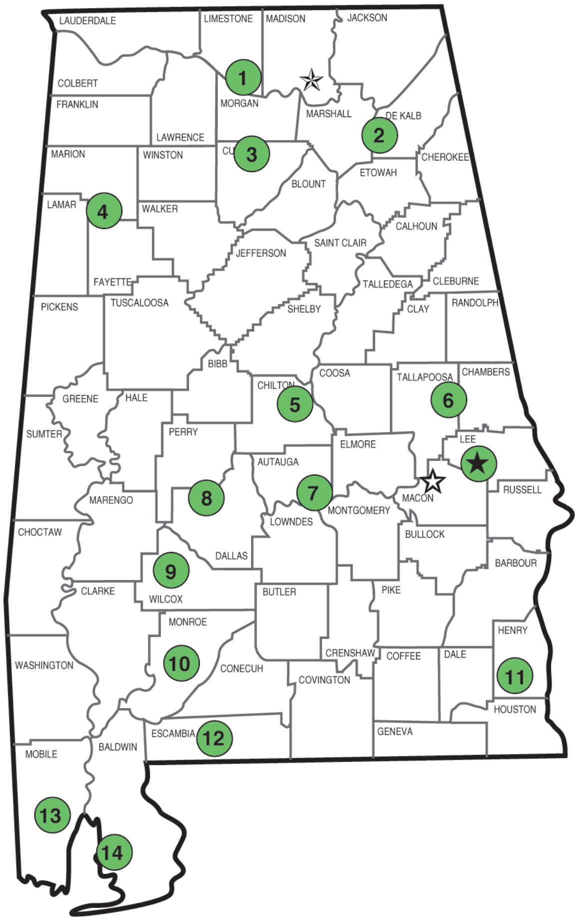

Research Unit Identification

★ Main Agricultural Experiment Station, Auburn.
☆ Alabama A&M University.
☆ E. V. Smith Research Center, Shorter.

1. Tennessee Valley Research and Extension Center, Belle Mina.
2. Sand Mountain Research and Extension Center, Crossville.
3. North Alabama Horticulture Research Center, Cullman.
4. Upper Coastal Plain Agricultural Research Center, Winfield.
5. Chilton Research and Extension Center, Clanton.
6. Piedmont Research Unit, Camp Hill.
7. Prattville Agricultural Research Unit, Prattville.
8. Black Belt Research and Extension Center, Marion Junction.
9. AU Natural Resources Education Center, Camden (inactive).
10. Monroeville Agricultural Research Unit, Monroeville.
11. Wiregrass Research and Extension Center, Headland.
12. Brewton Agricultural Research Unit, Brewton.
13. Ornamental Horticulture Research Center, Spring Hill.
14. Gulf Coast Research and Extension Center, Fairhope.