



Soil Testing Issues for the Southeastern U.S.

- Soil extractants used in the Southeast
- Using university fertilizer recommendations with private lab results
- Splitting soil samples between different labs to compare lab quality
- Cation exchange capacity and percent base saturation
- Subsoil nutrients

Soil Testing Issues for the Southeastern U.S.

(a multi-state internet training)

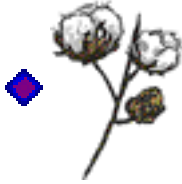
Dates: January 17 to 28, 2000

Participating States and Specialists Are:

Alabama:	<u>Dr. Charles Mitchell</u>	- Soil Fertility Specialist
Georgia:	<u>Dr. Owen Plank</u>	- Extension Specialist
	<u>Dr. Glen Harris</u>	- Soils and Fertilizer Specialist
North Carolina:	<u>Dr. Carl Crozier</u>	- Soil Science Specialist
	<u>Dr. Ray Tucker</u>	- Soil Testing Specialist
South Carolina:	<u>Dr. Jim Camberato</u>	- Soil Fertility Specialist
	<u>Dr. Bob Lippert</u>	- Soil Fertility Specialist
	<u>Dr. Kathy Moore</u>	- Extension Lab Director
Virginia:	<u>Dr. Steve Donohue</u>	- Soils and Plant Analysis Specialist
	<u>Dr. Mark Alley</u>	- Agronomist

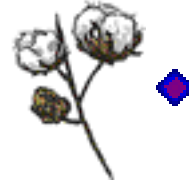


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Soil Extractants Used in the Southeast

● **G**rowers often have questions about the methods used in soil testing, from how an extractant works to the reasons for using a particular type of extractant. Understanding the reasons why a certain extractant is used can be very helpful in understanding the results of a soil test.



What is a soil extractant?

● **A** soil test requires an extractant to determine the amount of plant nutrients in the soil. A soil extractant is a solution made of water and a certain concentration of chemicals. The extractant is added to a fixed amount of soil and the two are shaken together for a prescribed length of time. This mixture is then poured through a filter paper. The soil is retained on the filter paper, and the extractant -- now containing the dissolved plant nutrients -- is caught in a vial.

● **T**he plant nutrients in the extractant are analyzed using the appropriate laboratory instruments to see how much was removed from the soil. The amount of the nutrients extracted will represent a fraction of the total nutrients available to the plants throughout the growing season.

● **C**alibration data from previous field experiments serve as a guide in rating the amount of extractable nutrients as low, medium, or high. These ratings are used to determine the amount and type of fertilizer, such as phosphorus (P_2O_5) and potash (K_2O), needed for optimum crop production. (**Note:** Soil testing for nitrogen is a special situation which is not included as a routine test in all the Southeastern states due to the mobile nature of nitrate-nitrogen.)



What is the Mehlich-1 extractant?

● **T**he **Mehlich-1** (use button above to view) extractant (implemented in 1953) was developed by Dr. Adolph Mehlich for the North Carolina Department of Agriculture Soil Testing Division. It is a versatile soil extractant that is used to determine the amounts of phosphorus, potassium, calcium, magnesium, zinc, manganese, and boron. Even though extractable copper is often reported, the Mehlich-1 extractant was not designed as a copper extractant. Because this extractant is made up of a dilute solution of hydrochloric and sulfuric acids, it is often referred to as the "double acid" extractant. It works well for acidic, low cation exchange capacity (CEC) soils, which includes almost all soils in the Southeast. The Mehlich-1 extractant is used by the state labs in Alabama, Florida, Tennessee, Virginia,

Georgia, and South Carolina, as well as many private labs.



What is the Mehlich-3 extractant?

● **I**n an attempt to make a universal extractant that could be used for any soil in the world, Dr. Mehlich developed the Mehlich-2 extractant which was used for about 2 years. The Mehlich-2 contained four different chemicals, but the chloride in the extractant caused laboratory instrument problems.

● **B**y changing the chemical composition of the Mehlich-2 extractant slightly to exclude the chloride component, Dr. Mehlich created the **Mehlich-3** (use button above to view) extractant. A chelating agent was added to this formula to increase the amount of micronutrients extracted, particularly copper. The Mehlich-3 extractant was adopted in 1984 and is being used throughout the world. In the Southeast, the Mehlich-3 extractant is used by the state labs in Kentucky and North Carolina and by some private labs.



What is the Bray P-1 extractant?

● **T**he **Bray P-1 extractant** (use button to view) was developed before the Mehlich-1 extractant and was widely used by the Southeastern states. Even though it works well on acid soils, it is only useful for extracting phosphorus. Therefore, an additional extractant must be used for determining other plant nutrients such as potassium, calcium, and magnesium. As the demand for soil testing increased and laboratory instrumentation improved, it became desirable to have an extractant that could be used for a wide range of plant nutrients, including micronutrients. Many Southeastern states switched to the Mehlich-1 since it could be used as a single extractant for many important plant nutrients rather than phosphorus alone.

● **T**he only time the Bray P-1 is used on Southeastern soils is when the soil samples are analyzed by a private laboratory which also services farms from the Midwest, where the Bray P-1 soil extractant is still commonly used. Since Southeastern Land Grant Universities have no current information for interpreting soil phosphorus levels using the Bray P-1 extractant, this extractant is not recommended.



Why do some states use the Mehlich-1 extractant and other states use the Mehlich-3 extractant?

● Although the Mehlich-1 extractant works very well as a soil extractant, some states in the Southeast have switched to the Mehlich-3 extractant. Mehlich-3 is a better predictor of nutrient levels in soils above pH 6.5 where free calcium carbonates may be present. Soils with a pH value greater than 7.0 are relatively limited in the Southeast, occurring only with over-liming, long-term use of hen manure, or frequent irrigation with high bicarbonate water common to the coastal region.



How does the Mehlich-3 extractant compare to the Mehlich-1 extractant?

● The Mehlich-1 and Mehlich-3 will extract about equal amounts of most plant nutrients, but rates vary when it comes to phosphorus. The amount of phosphorus extracted by the Mehlich-3 will be approximately 1.5 times to twice the amount extracted by Mehlich-1. This ratio should not be used to derive Mehlich-1 based recommendations with Mehlich-3 extractant results or vice versa. These are only rough comparisons and do not apply to all soil types.



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Using Your State University's Fertilizer Recommendations with Other Lab Results

- **Y**our State University Laboratory isn't the only place to have a soil sample tested. Farmers, fertilizer dealers, and consultants may choose to send samples to a private soil-test lab or another state lab for analysis. However, they shouldn't make the mistake of trying to use your state lab's fertilizer recommendations with the other lab's results.
- **I**n testing a sample, labs use a substance called an extractant to help identify available plant nutrients in the soil. After the extractant removes plant nutrients from a soil sample, laboratory equipment can determine how much of each nutrient is present. A lab can then recommend a course of action for improving the soil with fertilizers.
- **T**here are several different extractants used in the United States. Each was developed for specific soil conditions and they all extract different amounts of each nutrient. In our region, the most commonly used extractants are Mehlich-1 and Mehlich-3. In addition, some labs may also use a Bray P-1 extractant for phosphorus. Results from any extractant can be used to make good fertilizer recommendations, but the information from a test using one extractant can't be applied to recommendations which were calibrated for another extractant. For example, the Clemson Lab soil-test recommendations for phosphorus, potassium, calcium, magnesium, zinc, and manganese are calibrated for extractions done with Mehlich 1. A sample sent to the state lab in North Carolina will be extracted with Mehlich 3 and the results will be reported as an index instead of pounds per acre or parts per million as is commonly done by other labs. Since two different extractant solutions are used, fertilizer recommendations from Clemson's lab would not apply to the results received from the North Carolina lab. Comparing the test results from these labs would be like comparing apples to oranges.
- **E**ven if labs use the same extractant, they may use different scales to rate the pounds per acre of extractable nutrients. Results are usually shown as high, medium, or low, but the meaning of those labels can differ from one lab to another. The amount of a nutrient one lab considers high might be labeled medium by another lab. The medium rating would call for adding more of that particular nutrient to the soil than a high soil-test rating would recommend.
- **I**t is possible, however, to apply your state lab's fertilizer recommendations to another lab's analytical report as long as both labs use the same soil extractant. Consult the information in your state's nutrient management guidelines to convert the pounds per acre extractable value for each nutrient into a rating of high, medium, or low. Once this interpretation has been made, your state's recommendations can be used with another lab's soil-test results.



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Splitting Soil Samples to Compare Lab Quality

● Occasionally, a farmer may want to compare the soil-test results from two separate labs. The farmer collects a soil sample from a few spots in the field, mixes the samples together in a bucket, and sends a portion of the soil to two different labs. When samples are split between labs in this manner, there are several reasons why the soil-test results are likely to be quite different.



It's difficult to mix soil samples to make them completely uniform.

● Every year, several labs from the Southeastern and Mid-Atlantic States participate in a regional soil-test exchange involving approximately seven state-supported labs and five privately owned labs. Before the samples are distributed to these labs for analysis, the bulk sample is first completely air-dried to ensure thorough mixing. Then it's run through a grinder that breaks up the clods and sieves out any rocks or organic debris. Finally, the sample is mixed in a large container for several minutes.

● When the individual samples are removed, care is taken to keep the larger soil particles in the container from settling. A number of samples are then removed and analyzed by one lab to ensure that the mixing was thorough.

● Professional technicians take these steps to make the sample as uniform as possible. This detailed procedure is a far cry from taking two samples of soil simply mixed in a bucket. Mixing soil that is either moist or too dry is difficult, and studies show that samples split in this manner will be significantly different even when measured by the same lab.



Soil-test labs use different extractants.

● After the exchange samples are analyzed by the various laboratories, the results are grouped by the type of soil extractant used for a proper comparison. Due to differences in lab techniques, even the results from samples tested by laboratories that use the same extractant solution will usually vary by a few pounds per acre. Differing test results are normal -- and expected. The following table illustrates that matching tests rarely produce the same results.

Soil phosphorus (in pounds per acre) reported by six regional state labs using the Mehlich 1 extractant for the 1997 sample exchange.

Sample No.	Lab A	Lab B	Lab C	Lab D	Lab E	Lab F	Average
1	35	21	38	32	32	24	30
2	32	16	45	32	35	22	30
3	58	45	51	59	56	34	51



Soil-test labs use different extractable nutrient rating systems.

● **T**he rating system used to indicate whether an extracted level of a nutrient is high, medium, or low will differ from one lab to another. Even when two labs extract the same amount of a nutrient using the same extractant, one lab may call that amount medium, while another lab indicates that the level is high. This is called "soil test calibration" and should be based on extensive and dependable research with similar soils and crops.



Soil-test labs make different recommendations.

● **T**he fertilizer recommendations may also vary for each lab. The recommendations are ideally based on Experiment Station information specific to a particular region's climate and soils. If they don't have data from their own Experiment Station for a particular crop, some labs will use data from adjacent states. Then too, some private labs use data from universities.

● **I**t's easy to see how a farmer can get different results from a soil sample sent to two separate labs. The results may differ because the sample wasn't mixed properly. Perhaps the labs used different extractants, different rating systems, or follow different guide-lines to make their recommendations. With only two sets of results for comparison, it's extremely difficult to know which is best to follow. Many farmers will choose the lab result that shows what they'd like to see, even though it may not be the most appropriate for their situation.

● It's best to stick with one laboratory and develop a long-term relationship with their services. If you have any questions about a sample, the lab should be willing to re-test it.



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Cation Exchange Capacity and Percent Base Saturation

- Among all the information that appears on soil test reports, the **cation exchange capacity (CEC)** and **percent base saturation** are the least understood.



Cation Exchange Capacity

- Any element with a positive charge is called a cation and, for agricultural purposes, it refers to the basic cations, calcium (Ca^{+2}), magnesium (Mg^{+2}), potassium (K^{+1}) and sodium (Na^{+1}) and the acidic cations, hydrogen (H^{+1}) and aluminum (Al^{+3}). The CEC refers to the total amount of these positively charged elements that a soil can hold. The cations are held on "exchange sites" where one cation can be exchanged for the same type or a different cation. The CEC is expressed in milliequivalents per 100 grams (meq/100g) of soil. The larger this number, the more cations the soil can hold. A clay soil will have a larger CEC than a sandy soil. In the Southeast, where we have highly weathered soils, the dominant clay type is kaolinite, which has very little capacity to hold cations compared to other clays. A typical CEC for a soil in the coastal plains region is about 2.0 meq/100g of soil, and the typical CEC for a soil in the piedmont is about 5.0 meq/100g of soil. The CEC gives an indication of the soil's potential to hold plant nutrients. Increasing the organic matter content of any soil will help to increase the CEC since it also holds cations like the clays. Organic matter has a high CEC, but there is typically small amounts of organic matter in our soils.

CEC (meq/100g)	ACIDITY	% BASE SATURATION				
		Ca	Mg	K	Na	TOTAL
5.0	1.0	50	20	5	5	80



Percent Base Saturation

- Percent base saturation tells what percent of the exchange sites are occupied by the basic cations. If calcium has a base saturation value of 50% and magnesium has a base saturation value of 20% as shown above, then calcium occupies half of the total exchange sites (CEC) and magnesium occupies one-fifth of the total exchange sites (CEC). In this example, where the soil has a CEC of 5 meq/100g, 2.5 meq/100g of the CEC is occupied by calcium and 1 meq/100g of the CEC is occupied by magnesium. If all the exchangeable bases (Ca, Mg, K and Na) total 100%, then there is no exchangeable acidity.



Acidity

● **T**he acidity on the soil test report is the amount of the total CEC occupied by the acidic cations (H^{+1} and Al^{+3}). The acidity, like the CEC, is expressed as meq/100g of soil. If the CEC is 5 meq/100g of soil and the acidity is 1 meq/100g of soil (see sample soil test report data in Table 1), then one-fifth of the exchange sites in the soil are occupied by acidic hydrogen and aluminum ions. The remaining 4 meq/100g of soil (or 80% of the CEC) is occupied by the basic cations. The more acidic a soil is and the lower the soil pH value, the closer the acidity number will be to the CEC number.



Sodium

● **S**odium is sometimes included among the bases to indicate whether sodium levels are getting too high. This happens in situations where industrial by-products are applied to the soil or where soils along the coastal region are irrigated with water high in sodium. The acceptable base saturation limit for sodium is 15%. This is also called the Exchangeable Sodium Percent (ESP). Sodium levels higher than 15% on the exchange site could result in soil dispersion, poor water infiltration, and possible sodium toxicity to plants.



How to Use This Information

● **S**o, why bother with the CEC, acidity, and base saturation? Some consultants and farmers prefer to use the base saturation of the plant nutrients instead of the extractable amounts as a guide for maintaining optimum fertility. For Southeastern soils with kaolinitic clays, a base saturation of 45 to 65 percent will be satisfactory for good plant growth. **Table 2** gives the approximate base saturation for kaolinitic soils of a given soil pH:

Table 2. Approximate base saturation for kaolinitic soils.	
Soil pH	% Base Saturation
3.9	0
4.5	0
5.3	25
6.2	50
7.1	75
7.5	90
8.0	100

● **I**n the Southeast, if fertilizer and lime is applied to raise the base saturation of a kaolinitic soil to 85 percent as commonly done in the Midwest, the resulting pH would be between 7.1 and 7.5. Soil pH values in that range would result in major problems with zinc and manganese deficiency. That is why the Southeastern states' fertilizer recommendations are determined by the amount of each nutrient extracted from the soil (usually expressed in pounds per acre) instead of using the percent base saturation as a guide. A favorable base saturation will be obtained if the soil pH is maintained between 5.8 and 6.5.



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Subsoil Nutrients

● **W**hen you buy a product and receive a rebate coupon for your next purchase, it's like throwing money away to discard the coupon if you know you'll buy the product again. The same is true when it comes to the rebate of extra plant nutrients often available in subsoil clay for crops grown on Coastal Plain soils.



POTASSIUM AND MAGNESIUM

● **O**ppositely charged particles are attracted to each other the same way that positive and negative poles of magnets are attracted. Even though potassium and magnesium are positively charged ions and held by negatively charged sites on clay and organic matter, they may still leach down through the soil with time. This is especially true for Coastal Plain soils, which have small amounts of clay and organic matter in the sandy surface depth. The potential for these nutrients to move through the surface depth is also indicated by the low cation exchange capacity (CEC) values on the soil test reports. The CEC is a quantitative measure of the soil's capacity to retain positively charged nutrients (cations) such as potassium, calcium, and magnesium.

● **T**he following table illustrates the effect of time and rainfall on the movement of surface-applied potassium in a Coastal Plain soil (Marlboro loamy sand). The soil has 7 percent clay in the surface depth and 40 percent clay starting at the 1-foot depth.

Weeks after application	Accumulative rainfall (inches)	Potassium accumulation (fallowed soil)
5	1.3	Most of the potassium is near the surface
17	10.3	Potassium accumulation at 3 inches (135 lbs/acre) and at 12 inches (115 lbs/acre)
46	42.0	Most of the potassium accumulation is at 12 inches
76	69.4	Only 10 lbs/acre potassium left near the surface. The rest is at 12-inch depth

Boswell, F.C. and O.E. Anderson. 1968. "Potassium movement in fallowed soils," Agron. J. 60:688-691.

● **T**he following data shows the soil-test results for phosphorus, potassium, magnesium, and sulfur in a field which has several soil types and had been managed under conventional tillage for at least 10 years prior to sampling.

Soil type	Depth to clay (inches)	Soil pH	Phosphorus	Potassium	Magnesium	Sulfur
			(lbs/acre & rating*)			
Norfolk --plow layer --subsoil	8	6.5 5.9	71 H- 0 VL	106 M 263 VH	151 H 333 H	6 I 112 S
Goldsboro --plow layer --subsoil	12	6.4 4.6	63 H- 2 VL	116 M 128 M	215 H 136 H	9 I 97 S
Dunbar --plow layer --subsoil	15	6.5 4.5	66 H- 0 VL	75 M- 99 M	199 H 135 H	9 I 124 S
Noboco --plow layer --subsoil	14	6.6 5.1	37 M- 0 VL	115 M 215 H+	184 H 249 H	8 I 112 S
* H = high, VH = very high, M = medium, VL = very low, I = insufficient, S = sufficient						
Samples collected Sept. 8, 1995, at the Coastal Plain Soil, Water and Plant Research Center by Bob Lippert, Extension Soil Fertility Specialist, Clemson University and John Sadler, Soil Scientist, USDA-Agricultural Research Service.						

● **T**he crop rotations included corn, wheat, sorghum, and soybeans. Each year's fertilizer applications were based on Clemson University's recommendations. Notice how the phosphorus accumulates in the plow layer but the potassium, magnesium, and sulfur accumulate in the subsoil clay.

● **F**or the plants to utilize subsoil nutrients efficiently, subsoiling may be necessary to ensure that a hardpan will not deter access of the roots to the subsoil. The subsoil clay should also be no greater than 15 to 20 inches from the soil surface and have a pH value higher than 5.0.



SUBSOIL SAMPLING AND TESTING

● **S**ome states have developed a subsoil sampling and testing program so farmers can adjust for these nutrients with their fertilizer applications. The following are the guidelines developed by Clemson University for subsoil Potassium, Magnesium and Sulfur.

● **T**o sample the subsoil, take samples from the top 4 inches of the clay layer at several locations in the field. Both plow layer and subsoil samples can be taken from the same core locations. Mix the clay cores in a clean container and send the sample to the Agricultural Service Laboratory. The fee is \$5.00 per sample. The lab report will give the pH; CEC; percent base saturation; amounts of phosphorus, potassium, calcium, magnesium, zinc, manganese, copper and boron; plus comments regarding fertilizer application reduction. A test for sulfur requires an additional \$5.00 fee.

● **I**f the test results show high or very high levels of potassium in the subsoil, the recommendation for potassium from the plow layer soil test can be reduced by as much as one-half. If a subsoil test indicates a high level of magnesium, then any recommendations for magnesium indicated by the plow layer soil test can be ignored.



SULFUR

● **J**ust as magnet poles with the same charge repel each other, the negatively charged sulfate ion will be repelled by the negatively charged clay and organic matter exchange sites in the soil. Subsequently, the sulfur will easily move down through the sandy soil layer with rainfall and accumulate in the subsoil clay. A plow layer test for sulfur, therefore, will give misleading results. The test for sulfur in plow depth samples will likely show insufficient levels in sulfur even though there is a sufficient amount in the subsoil clay (see previous table). The subsoil test is the best analysis to determine if sulfur is needed. The sample collected for the subsoil potassium and magnesium test can also be used for the subsoil sulfur test. If the subsoil contains 40 pounds per acre or more sulfur, then there will be sufficient sulfur for that year's crop.



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