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## Soil Management and Soil Testing

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*Whenever we are studying an important crop plant such as cotton, it is natural to focus on the above ground portions of the plant, because that's where the bolls are. However, an equally important part of the plant is the root system, which is totally immersed in the soil. Soil provides all of the plant's mineral nutrition, water and mechanical support through the root system, and therefore, is a vital link to the plant's health and productivity. The soil is a focal point of any farming operation. Beginning each season, growers use various tillage operations to incorporate residues from previous crops and to prepare an adequate seedbed for the subsequent crop. As a result, most farmers are very familiar with their fields in terms of surface soils, where and how the textures change (i.e. clayey, sandy or rocky areas) and what is required to till them properly. Most of us working in the field also notice that despite the excellent soil maps and surveys, which provide general descriptions of soils, the most detailed mapping of the soils in that field will be performed by the (cotton) plants. For example, areas of a field with better soils will produce better plants, and vice versa. An excellent time to make note of this is during harvest. When you are riding a picker through the field you have an excellent vantage point from which to map the soils in the field, from strong to weak. In dryland areas this may be from a hilltop to a side-slope to the bottom of a swale in a field. Or in the irrigated west it may be from areas which were cut or filled in the process of land leveling, or from the presence of coarse soils which are remnants of old washes that passed through the area before cultivation.*

In this article we will discuss various aspects of soil evaluation including physical examination, soil sampling and analysis and soil test interpretation. We also will discuss how these approaches to soil evaluation can be incorporated into both short- and long-term management plans.

## Soil Evaluation

This time of the year it is wise to note patterns associated with your fields and map them out, particularly if there are definite production problems in certain parts of any field. One might ask, however, "What can I do about it even if I know where the problem spots are?" The first step would be to review plant conditions found in 1995 and previous years, then evaluate the extent to which problem areas exist, and are conditions getting better, worse or staying about the same. The second step would be to go out to these areas and compare what you might describe as a "problem area" versus a "good area." The next step (and commonly where someone's curiosity begins to wane) involves taking a shovel, soil probe or a soil auger into the field to excavate and evaluate the soil conditions throughout the rooting depth (usually considered as four feet for cotton, if unobstructed).

## Soil Evaluation - Physical Conditions

In a general sense, we can describe soil management practices and evaluations as being either physical or chemical. The main thing to look for in a field evaluation is the physical condition of the soil through the profile (vertical depth). Problem areas may show evidence of a clay layer, a hardpan (perhaps natural or a plowpan), abrupt changes in soil texture from one horizon to another, a gravel layer or even a water table. All of these factors can vary tremendously within a given field and can affect crop growth and productivity. Physical conditions in the soil, for the most part, are not easily altered (i.e. changing soil texture or horizon organization), but they can impact the way in which we manage these areas in terms of tillage, cultivation and/or irrigation practices. The presence of a hardpan or plowpan can be dealt with to some extent by the use of deep tillage (i.e. ripping). High water tables may require the use of some drainage techniques. The depth at which gravel, compaction or free water layers occur can indicate the general depth to which roots will grow. For example (as shown in Figure 1A), a coarse gravel or compacted layer detected about 18 inches below the surface, likely would indicate that the effective rooting zone would be limited to this depth as well. Instead of having a full soil profile of four feet available for rooting (water holding capacity and nutrient availability), as shown in Figure 1B, we only would be working with about 18 inches. The bottom line is "if you don't know what your soils look like below the surface, it may be worthwhile to find out." This could be useful in addressing some of the problems common to fields or parts of fields.

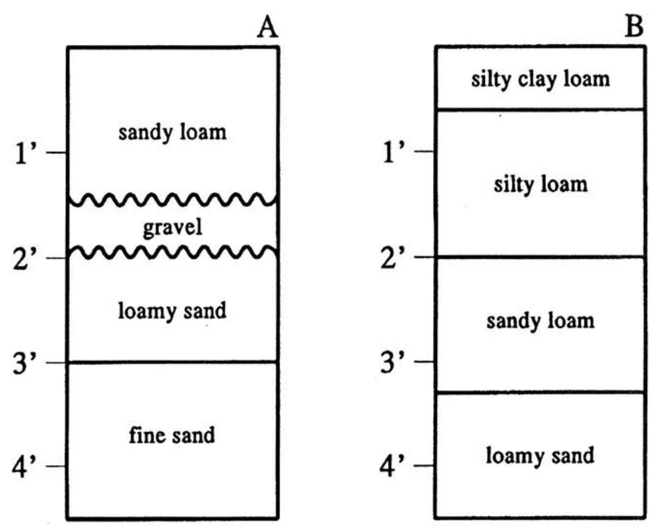


**Figure 1. (A)** A soil profile with a sandy loam surface underlain by a course gravel layer at approximately 18 inches, and **(B)** an open soil profile with a slight gradient in textures to a depth of four feet.

## Soil Evaluation - Chemical Conditions

The other important aspect of soil evaluation is the chemical condition. Soils are very active chemically and can differ a great deal in terms of chemical conditions. The soil chemical environment is very important in that it determines the composition of the soil solution within which the roots live and function. This directly impacts plant nutrition. Physiologically, plant nutrition is clearly recognized as a fundamental aspect of a healthy, vigorous and productive cotton plant. Accordingly, soil testing has become an integral part of cotton production. In developing an assessment of soil chemical conditions or a soil fertility evaluation, it is worthwhile to review some basic aspects of making a soil fertility program functional and profitable.

As an example, soil pH conditions alone (the degree of acidity or basicity that is present) can have a strong impact on nutrient availability, root growth and overall plant health. In some portions of the Cotton Belt (particularly in the Southeast), acid subsoils can reduce or prevent root growth, which can limit the depth of the soil profile utilized by the plant. The end result is similar to the gravel layer described in Figure 1A. This condition may not be detected by augering through the soil and visually inspecting it, but it will be readily apparent if soil samples were collected at regular depth intervals and subject to a simple pH analysis.

## Soil Sampling - Collecting the Sample

Again, the only way to conduct this type of soil evaluation is to get out into the field with your soil probe, auger or a shovel and collect a good set of samples. Commonly, a recommended frequency for sampling a given field is once every three to four years, assuming no nutritional or production problems develop. This type of soil sampling frequency usually is considered a minimum for developing a soil fertility maintenance program.

Usually, it is recommended that a single soil sample be collected for any given field or management unit. However, a single soil sample should consist of at least 25 individual cores collected from representative areas of the field or management unit, which are then mixed together into a common "composite" soil sample. How much of this sample is sent to the soil testing lab will depend on the analyses to be performed and the specific lab. Usually about 20-30 ounces (volume) are required. Therefore, of the 25 or more soil cores collected from a field, management unit or problem area, only the amount needed to fill an appropriate soil sample container is actually collected and sent to the lab. Depth of sampling is usually at least six inches, but may extend to 12 inches or more, depending on the situation. Sampling technique (depth and placement) also may depend on whether the field is irrigated, bedded or flat, and also on what is needed from the analysis such as nitrate-nitrogen ($NO_3^-$-N), sulfate-sulfur ($SO_4^{2-}$-S), phosphate-phosphorus ($PO_4^{3-}$-P), sodium (Na) or total salt concentration, etc. Sample frequency, depth, amounts of soil needed and tests to run will depend on the nature and intent of the sampling process (whether routine management or diagnosis of problem areas in a field).

The identification of a field or management unit for soil sampling relates to the evaluation of field conditions at the end of the recent cotton production season. Individual fields are usually the largest unit recommended for an individual soil sample. However, if there are parts of a given field which are obviously unique and may require specific management, they should be sampled independently. For example, a relatively uniform field (Figure 2A), can be managed easily in a consistent manner, and therefore could be sampled by collecting at least 25 soil cores from representative areas (each core marked with an o). Figure 2B, on the other hand, could represent a field that has three distinct areas (A, B, and C), each of which should be sampled independently (25 soil cores from each of these areas). How one delineates between these areas in the field should depend first of all on plant growth and performance, which could relate to our end of season evaluations discussed earlier. The results you get back from the lab only will be as representative as the samples you collect.

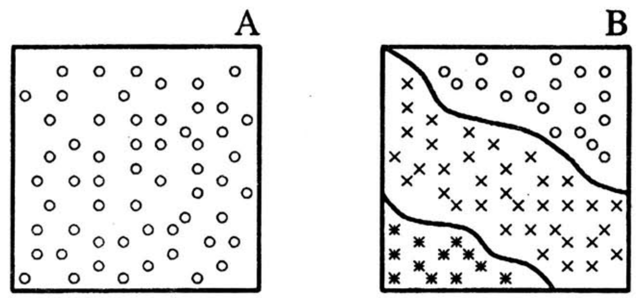


**Figure 2. (A)** Soil sampling pattern within a relatively uniform field, and **(B)** soil sampling pattern within three distinct zones of a field, each having unique characteristics warranting a separate sample (approximately 25-30 cores/sample).

## Soil Testing

Soil tests and analyses are of course performed **after** a soil sample is collected, but it is probably a good idea to consult with some labs and select one **before** you actually collect the sample. You should discuss your situation with the managers of the soil testing lab to determine the sample collection process and to insure that you provide adequate materials for analysis. They also can help you determine what tests are needed. This will depend to some extent on your location, the problems you have encountered (plant symptoms experienced in the field) and past fertilization history.

The 13 essential mineral nutrients for cotton include the macronutrients: nitrogen (N), phosphorus (P) and potassium (K); the secondary nutrients: magnesium (Mg), calcium (Ca) and sulfur (S); and the micronutrients: boron (B), copper (Cu), chlorine (Cl), iron (Fe), molybdenum (Mo), manganese (Mn) and zinc (Zn). Some sources now may also include sodium (Na), cobalt (Co), vanadium (V) and silicon (Si) among the list of essential plant nutrients. Because a nutrient is considered "essential" you may not need to test for or fertilize with each and every one of these. This too will depend upon location, plant symptoms and fertilization history. A standard soil analysis will normally test for N, P, K and pH (level of soil acidity or basicity). In some cases it will also be necessary to include Zn, Fe and B.

In the western portions of the Cotton Belt it is always important to evaluate soil salinity by measuring the electrical conductivity of the soil extract ($EC_e$) and the Na levels. These levels are commonly expressed as an exchangeable sodium percentage (ESP) or the sodium adsorption ratio (SAR). Salinity levels can impact crop vigor and yield potential, particularly in the early stages of development. Sodium represents an aspect of the soil system that is evaluated chemically, but its primary impact is physical. High Na concentrations cause a dispersal of soil particles which in turn breaks down soil structure, reducing water penetration and infiltration, aeration and increasing crusting problems. Salinity and Na levels represent good examples of where it can be important to consider sample collection for a specific analysis. Instead of collecting a soil sample to a depth of 6 to 12 inches, it may be necessary to sample only the upper few inches of the soil surface when determining salt or Na levels. Relatively high concentrations of salt or Na in the upper few inches of the soil can have a severe impact on early seedling vigor (salt) or create soil crusting problems (Na).

## Interpretation of Soil Test Results

The purpose in analyzing a soil sample is not to determine the total amounts of the nutrient in question in the soil. In fact, the total amount of a nutrient seldom has much relationship to the amount available to a cotton crop. A key challenge in conducting a soil analysis is to use an extraction procedure that removes a portion of the nutrient from the soil that relates to the plant-available form and amount. For example, if one is analyzing a soil for P levels relative to cotton needs, a chemical extract is commonly used to measure a portion of the total soil P which is available to the cotton plant (phosphate-P, $PO_4$-P).

The soil tests and extracting procedures can vary a great deal across the Cotton Belt due to differences in soils, climates and production conditions. One also may find a variation among soil testing labs within a given state concerning soil testing methods due to differences in philosophy, experience and technique. The differences in soil testing methods, and the assertions and allegations that can go along with them, can be confusing and tiring to even the best and most patient experts. It is no wonder that farmers sometimes question the value of investing in a soil testing program. A fundamental key to look for in a lab is a satisfactory database relating the following factors: 1) **soil test results**, 2) **fertilization rates** and 3) **crop yields**. Unfortunately, some labs do not make a successful connection among these three points. Some labs analyze a lot of soils and make recommendations for fertilization, which are often followed diligently, but they are not able to follow through with connecting the resultant crop yields to the soil test levels or the fertilization rates. Collecting and developing a database inclusive of each of these factors for a large number of fields and seasons is referred to as soil test calibration and correlation. Such information is critical to the development of a reliable and successful soil test system. Essentially, this means it is important for a lab to be able to show that for a given soil test value and corresponding amount of fertilizer recommended (and applied), a corresponding yield can be produced. This represents a time consuming and expensive process, but it is absolutely critical to developing a truly functional soil test. It is not absolutely necessary for every lab to develop this type of a soil test calibration system, but it is important that labs use soil test procedures that have been calibrated and correlated sufficiently to crop yields. This is why different soil test procedures can be used in a given region with satisfactory results, providing that the soil tests in question were properly developed (calibrated and correlated) to crop response for that region. It is advisable to inquire into the background and support a given lab has for their soil tests and the fertilizer and soil management recommendations they offer from the soil test results.

## Developing a Soil Management Plan

Protecting our soil resources is an important responsibility. Our soils serve as the basic foundation upon which the entire cotton production system is developed. As we push every acre of land for higher yields, we take a little bit more out of that land. As national and global populations continue to increase, the demands placed on agricultural lands will increase as well. Future generations will need a fully functional soil resource if they are to successfully supply society's need for food and fiber. It is up to us to pass on such a soil resource, hopefully in better condition than we found it. Our understanding and capabilities have improved a great deal in recent decades, our expectations have increased, and so have our incentives for sound land stewardship.

The development of a soil management plan can have both short- and long-term implications. In the short-term, the incentive is to be sure to provide both the best physical and chemical soil conditions possible for next year's cotton crop. Reviewing field conditions from this past year can help identify potential problem fields or parts of fields needing attention in the off-season. In the off-season, make good use of a soil auger to check soil profile conditions. Check for the presence or absence of any compacted or restrictive layers and review the general organization of soil textures throughout the crop rooting depth (about four feet). Tillage operations and their timing can be very important in improving or maintaining soil tilth and physical conditions. Tillage operations should be avoided whenever soils are too wet, particularly in finer textured soils. Tillage under these conditions can lead to compaction and loss of soil structure, which is severely damaging to soil physical conditions.

Preparing fields to provide soil fertility levels sufficient to meet high yield and quality demands is the primary incentive for developing a soil and fertilizer management plan each season. In the long-term sense, we don't want to deplete a soil's potential due to neglect and a gradual decline in the soil fertility level. The key objective agronomically, economically and environmentally is to provide adequate but not excessive levels of any plant nutrient. The most reasonable and effective way to get this done is to avoid the guesswork and embark on a soil testing program. As mentioned previously, soils should probably be sampled at least once every few years, more often if specific problems are noticed. Use a good lab, with a well-developed soil testing, interpretation and recommendation program. Most labs can provide advice and recommendations for many combinations of soil types and cropping systems, one year at a time and for a long-term approach.

Certain regions in the Cotton Belt have specific needs to be addressed in soil management. For example, in irrigated areas of the Western cotton states, soil salinity and Na problems are important to consider. Both can affect crop water use, irrigation efficiencies, crop vigor and management. These also represent factors that may not pose a problem one year, but due to subtle yet increasing amounts of salt and/or Na, they may limit the productivity of a cotton crop in a gradual yet devastating fashion. It is also important to consider the quality of the irrigation water applied to the soil and the crop. Irrigation water not only is the lifeblood of the crop in these regions, but it can also be the source of both salt and sodium which can accumulate over time, if not recognized and managed properly. The best approach is to monitor the system on a regular basis with both soil and water samples and to be capable of responding appropriately.

In some parts of the country, a new approach to soil fertility management is being implemented as a part of precision agriculture with site-specific soil management. This involves a detailed soil sampling scheme in which samples are collected in a systematic fashion in relation to specific field coordinates. Field maps are then developed from the soil test results. The variability encountered in any given field is then accounted for and fertilizers are applied with equipment capable of adjusting rates in the field for specific spots. Instead of treating an entire field in a uniform fashion to address the average case, the soil needs are addressed in a site-specific fashion. This technology provides the opportunity to improve fertilization and soil management efficiency, accomplishing agronomic, economic and environmental objectives simultaneously in the field. Some labs and fertilizer application facilities currently have this technology and it soon may become commonplace across the Cotton Belt.

## Wrap Up

The future holds many opportunities and challenges for those of us involved in cotton production. To realize our potential, we need to take care of the soil resources which we, and our cotton plants, depend. We can have the finest varieties in the world, make use of all the best plant-oriented technologies that are available. However, it won't do us any good if our plants do not have a proper nutritional or soil foundation on which to grow. If we take our soils for granted, use them and abuse them, it will catch up with us when we least expect it. Off-season is a good time to take a look at your soil management program, get out the soil probes and spend a little time working with your lab to develop the program that is best for your farm and fields. The benefits will show up in your crop next year and in your grandchildren's crops on the same fields in the years to come.

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