THE UNIVERSITY OF ARIZONA
Cooperative Extension

Soil Management and Soil Testing for Irrigated Cotton Production

Introduction

Whenever we are studying an important crop plant such as cotton, it is a natural tendency 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 hidden from view and totally immersed in the soil. The soil provides all of the mineral nutrition, water, and mechanical support to the plant through the root system, and therefore, is a vital link to the health and productivity of any cotton plant. The soil is a focal point of any farming operation. At the beginning of 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 available to us, which provide general descriptions of soils we encounter in a given field, 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 will also discuss how these approaches to soil evaluation can be incorporated into both short- and long-term management plans.

Soil Evaluation

Therefore, this time of the year it is good to make note of patterns associated with your fields and to even make an effort to map them out, particularly if there are definite production problems associated with certain parts of any field. One might ask, however, "so what are you going to do about it even if you know where the problem spots are?" The first step would be to review plant conditions found in 1995 and previous years, and the evaluate the extent to which problem areas exist, and if they are getting better, worse, or staying about the same. The second step would be to actually go out into the areas in question, 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 one would be looking for in a field evaluation would be the physical condition of the

2/2001 AZ1216

THE UNIVERSITY OF ARIZONA
COLLEGE OF AGRICULTURE AND LIFE SCIENCES
TUCSON, ARIZONA 85721

Jeffrey C. Silvertooth
Cotton Extension Agronomist

This information has been reviewed by university faculty.

ag.arizona.edu/pubs/crops/az1216.pdf

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 to us the general depth to which roots will grow. For example, as shown if Figure 1A, if a coarse gravel or compacted layer were detected about 18 inches below the surface, this would be a good indication that our effective rooting zone would be limited to this depth as well. So 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 would only be working with about 18 inches. The bottom line in this respect is "if you don't know what your soils look like below the surface, it may be worthwhile to go find out". This could be useful in addressing some of the problems common to fields or parts of fields.

Soil Evaluation - Chemical Conditions

The other aspect of soil evaluation that is important is that of the chemical condition. Soils are very active chemically and they can differ a great deal in terms of chemical conditions present. The soil chemical environment is very important in that it determines the composition of the soil solution within which the roots live and function, which 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 modern agriculture and certainly for cotton production. In developing an assessment of soil chemical conditions or a soil fertility evaluation, it is probably worthwhile to review some basic aspects of making a soil fertility program functional and profitable. This would be true if we were dealing only with problem areas or entire fields.

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 and have a similar end result as the gravel layer described in Figure 1A. This condition may not be detected by augering through the soil and visually inspecting it, but it would be readily apparent if soil samples were collected at regular depth intervals and subjected to a simple pH analyis.

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 favorite 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 is usually considered as a minimum for developing a soil fertility maintenance program.

Usually, it is recommended that a single soil sample should 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 to send into the soil testing lab will depend on the analyses to be performed and the specific lab, but usually about 20-30 ounces (volume) are required. Therefore, of the 25 or more soil cores which are collected from a field, management unit or problem area, only the amount needed to fill an appropriate soil sample container is actually collected from the composite sample and sent into 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) may also depend on whether the field is irrigated, bedded or flat, and also on what is needed from the analysis such as nitrate-nitrogen (NO3—N), sulfate-sulfur (SO42—S), phosphate-phosphorus (PO43—P), sodium (Na) or total salt concentration, etc.. In reference to sample frequency, depth, amounts of soil needed, and tests to run; this will all depend to some extent on the nature and intent of the sampling process as to whether it involves 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 that is 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 easily managed 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 will only be as representative as the sample you collect.

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 consultants or managers of the soil testing lab you chose to use regarding the sample collection process to insure that you provide adequate materials to the lab for analysis. They can also help you determine what you want the samples to be analyzed or tested for. 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 as being essential for cotton growth and development, does not necessarily mean that you will need to test for or fertilize with each and every one of these. This too will depend upon location, plant symptoms, and fertilization history. The nutrients to test for in a standard soil analysis will normally include 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 will always be important to evaluate soil salinity by measuring the electrical conductivity of the soil extract (ECe) and the Na levels, 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 it's primary impact is physical in that high Na concentrations cause a dispersal of soil particles which in turn results in a breakdown in 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 six 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 subjecting a soil sample to analysis for a given nutrient is not to determine the total amounts of the nutrient in question in the soil. In fact, the total amount of a given nutrient in a soil seldom has much relationship to what amount is 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 that measures a portion of the total soil P which is available to the cotton plant (phosphate-P, PO4-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 may also find a considerable amount of 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 of experts. It is no wonder that farmers can sometimes become disillusioned with the value in investing in a soil testing program. The fundamental key to look for in the abilities of any lab to analyze your soils and to make reliable recommendations for fertilizing a cotton crop is that of having 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 a lot of 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, and 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. Therefore, it would be advisable for one 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. Generally, the farther away a lab is, the less likely they are to use locally applicable soil test procedures and interpretations that are appropriate.

Developing a Soil Management Plan

Protecting our soil resources is an important responsibility of those involved in crop production and land management. 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 squeeze a little bit more and more out of it. As national and global populations continue to increase, the demands being placed on the agricultural lands, including cotton fields and their soils in the U.S., 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 crop of cotton plants. Reviewing field conditions from this past year can help identify potential problem fields or parts of fields in need of attention in the off-season. Making good use of a soil auger to check soil profile conditions concerning the presence of absence of any compacted or restrictive layers, and the general organization of soil textures throughout the crop rooting depth (about four feet) can be done in the off-season. 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, that 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 addressing a soil and fertilizer management plan each season. In a long-term sense, we don't want to deplete a soil's basic productive 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 was mentioned before, soils should probably be sampled at least once every few years, unless specific problems are noticed. A good lab, with a well-developed soil testing, interpretation, and recommendation program should be employed once the samples are collected. Most labs can provide advise and recommendations for many combinations of soil types and cropping systems, one year at a time and for a long-term approach as well.

Certain areas or regions in the cottonbelt 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 address. Both of which can effect 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 become limiting to the productivity of a cotton crop in a gradual yet devastating fashion. It is also important to consider the quality of the irrigation water that is being applied to the soil and the crop. The 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 with both soil and water samples on a regular basis 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 and 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. So 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 upon 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 may soon become commonplace across the cottonbelt.

The future holds many potential opportunities and challenges for those of us involved in cotton production. To realize our potentials, we need to take care of our soil resources upon which we and our cotton plants depend. We can have the finest varieties in the world, make use of all the plant-oriented technologies that are available, but it won't do us any good if our plants do not have a proper nutritional or soil foundation to grow upon. We can take our soils for granted, use them and abuse them, but that can catch up with us when we least expect it. It is a good time in the off-season 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 your farm and fields. The benefits can be found with your crop this next year and in your grandchildren's crops on the same fields in the years to come.

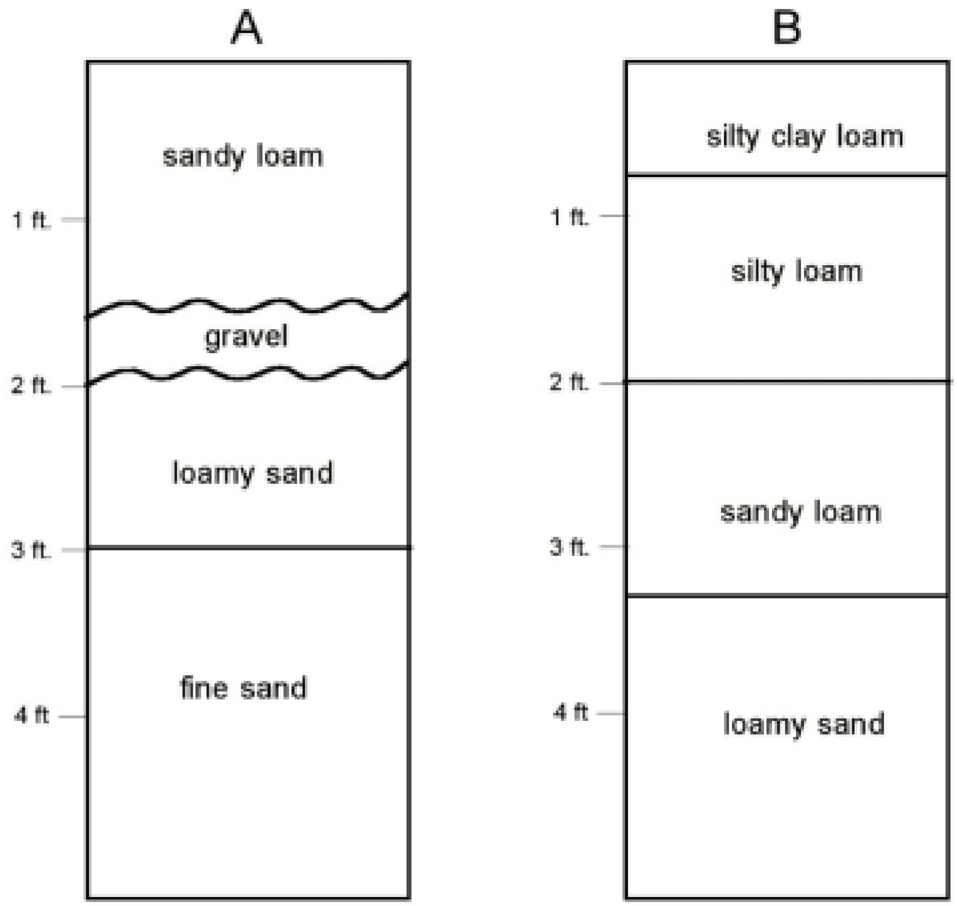

Figure 1. (A) A soil profile with a sandy loam surface underlain by a course gravel layer at approximately 18 inches, and (B) an open soil profile with a slight gradient in textures to a depth of four feet.

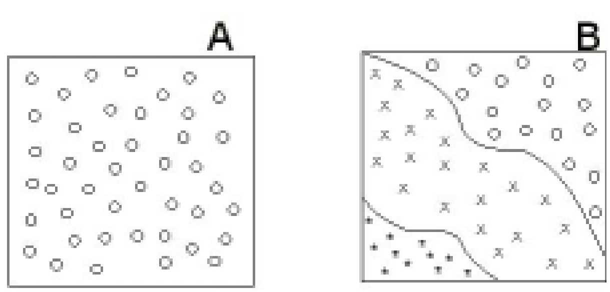

Figure 2. (A) Soil sampling pattern within a relatively uniform field, and (B) soil sampling pattern within three distinct zones of a field, each having unique characteristics warranting a separate sample (approximately 25-30 cores/sample).