

INTRODUCTION

Soil testing helps us understand the soil environment in which our plants must survive. A complete understanding of the soil would include its physical, chemical, and biological properties. Physical properties relevant to plant production include soil texture, permeability, compaction, and water-holding capacity. Chemical properties include soil pH, salinity, and plant nutrients. Soil biology determines how efficiently nutrients are released from organic matter, how well organic matter is decomposed, and a host of other properties conducive to plant growth. Management practices affect all three of these categories.

Soil testing provides a “snapshot” of what conditions were like at the time of sampling, and this allows farmers and homeowners to plan their management practices for the coming growing season. Common questions like “How much manure should I add?” or “What fertilizer should I use this year?” or “Do I need to lower my soil pH?” can be answered with a soil test. It is most common to focus on the chemical and physical properties of soil, but the biological aspects are gaining more attention. Several tests have been developed to assess some of these properties. The USDA NRCS’s Soil Quality Assessment webpage (<http://soils.usda.gov/SQI/assessment/assessment.html>) offers some insight into measuring certain biological properties.

The focus of this publication is to provide guidance for people interested in knowing more about their New Mexico soil from a chemical and physical perspective.

OBTAINING A SAMPLE

A soil test is only as good as the sample from which it came. One core from the corner of a field, a fairway, or one’s front yard does not represent the whole field, golf course, or yard. Samples should be taken from areas that can be treated as distinct units (management zones).



Figure 1. Feeling the soil while sampling can give information about soil moisture and texture across the area being sampled.

The rough on a golf course differs from the green, and some areas cross soil type boundaries that vary greatly in their physical and chemical properties. It usually takes 12 to 15 subsamples taken to the same depth and combined into one sample in order to be confident in the soil test results from any given lab (Figure 1). The recommended number of subsamples ensures that the sample is representative of a “management zone.” This is an area that may be treated the same with regard to watering, fertilizer application, and yield potential.

The soil depth for sampling depends on tillage practices and the crop that is being grown. Areas that are not tilled, such as direct-seeded fields, orchards, vineyards, turfgrass, and perennial gardens, should be sampled to a depth of 6 to 8 inches. Any area that has been tilled, such as annual gardens, conventionally tilled production fields, or similar areas, should be sampled to a

¹Extension Agronomist, Department of Extension Plant Sciences, New Mexico State University.

depth of 12 inches. The second foot (12 to 24 inches), and deeper depths (>24 inches), of soil is often sampled to improve salinity and nitrogen management. When sampling for soil analysis, it is important to brush aside or remove the surface layer of leaves and other plant residues so that analytical results are more representative of stable soil organic matter. The tool of choice is a probe that allows easy soil retrieval without leaving behind a greatly disturbed area. Some soils are too hard to easily push in a probe, and a hammer is therefore necessary. Some probes are sold with “sliding-hammer” attachments that make sampling much easier. Spades are also a good tool, but you should limit how much soil you collect in the sampling container. For more information on proper sampling techniques, please refer to Guide A-114, *Test Your Soil* (http://aces.nmsu.edu/pubs/_a/a-114.pdf). You can also view a video on soil sampling at <http://www.youtube.com/watch?v=aQMZ-MsYBiQ>.

WHAT ANALYSES TO REQUEST

Key analyses that should be requested from any soil testing laboratory include

- pH,
- electrical conductivity (EC),
- sodium adsorption ratio (SAR),
- organic matter (OM) or soil organic matter (SOM),
- inorganic nitrogen (nitrate-N or ammonium-N),
- phosphorus (P),
- potassium (K),
- texture, and
- micronutrients such as iron (Fe), zinc (Zn), manganese (Mn), and copper (Cu).

These tests are not unique to New Mexico, but were used by the NMSU Soil, Water, and Agriculture Testing (SWAT) laboratory (closed in June 2012) on a routine basis.

There are specific ways the soil must be processed in the lab to obtain accurate results. Soil pH, electrical conductivity, and sodium adsorption ratio are determined from a saturated paste extract. Organic matter is determined from a procedure known as the Walkley-Black method (as opposed to “combustion”). Inorganic nitrate-N can be determined by extracting the soil with a potassium chloride solution and testing for nitrate-N after cadmium reduction. Phosphorus is determined after extracting the soil with a solution of sodium bicarbonate (Olsen’s procedure) as long as the soil pH is above 7.2. A solution of ammonium acetate is used to extract potassium. Micronutrients are required by plants in small quantities and can be evaluated for plant availability by extracting with a DTPA solution. Other nutrients to consider include sulfate and boron. Please consult Circular 650, *Sulfur and New Mexico Agriculture*

(http://aces.nmsu.edu/pubs/_circulars/CR-650.pdf), for more information regarding the need for sulfate. Boron is often sold but seldom needed in New Mexico and should only be considered if plants exhibit deficiencies or tissue testing reveals low boron levels within the plant. Boron can be toxic to plants if applied at too great a concentration. The amount of soil lime present in the sample is also helpful when considering what plants to grow.

Saturated Paste Extract (Method S – 1.10 in Gavlak et al. [2005])

In this test method, soil samples are ground and passed through a 2-mm sieve, then just enough water is added to make a paste that glistens but does not flow from a cup. Soil texture greatly influences the amount of water that can be added to make it “saturated.” Soils with high amounts of clay often take 24 hours to fully absorb the added water. Once 24 hours have passed and the sample is saturated, the soil is placed under suction and the liquid is removed for further testing. This sample is known as the saturated paste extract and most closely resembles conditions after an irrigation. Soil pH, EC, and SAR (relative amount of calcium, magnesium, and sodium) are determined from the saturated paste extract.

Soil pH

Soil pH is a measure of the soil’s acidity or basicity (alkalinity). A substance is acidic if the pH is below 7.0 and alkaline if the pH is above 7.0. A neutral soil has a pH of 7.0. Technically, soil pH is the negative logarithm of the hydrogen ion activity ($-\log_{10}(\text{H}^+)$). Common household items that are acidic include vinegar, cola, and coffee, while antacids, detergents, and bleach are basic (alkaline). Ideally, soil pH should be near 6.5 in order to keep phosphorus in its most available form. Many micronutrients, such as iron and zinc, are also more available to the plant at a 6.5 soil pH. Other nutrients for plant growth are strongly affected by soil pH. Only nitrogen, potassium, and sulfur are unaffected by soil pH. Soil pH in New Mexico is normally between 6.5 and 8.4. Mountain soils, where more rain occurs, generally have a soil pH below 7.0. Many garden soils that have received too much organic matter may also have a lower soil pH, but not always. Soil pH should be determined from a saturated paste extract (pH_s).

It is also helpful to know the soil lime content in cases where gypsum is recommended as a reclamation tool. Elemental sulfur can be used in place of gypsum in situations where there is elevated sodium with lime (calcium carbonate) present in the soil.

Calcium Carbonate

For much of New Mexico, soil pH is controlled by the presence of lime (calcium carbonate). Lime acts as a buffer against changes in soil pH and can tie up phosphorus and iron, making them unavailable for plants. The percentage of calcium carbonate in soil can be determined at a soil testing lab. You can do a quick home test for the presence of lime using household vinegar. Simply pour a little vinegar on the soil. Lime is present if the soil fizzes when exposed to vinegar.

A soil with 5% lime in the top 6 inches has approximately 2,296 pounds of lime per 1,000 square feet. Soils with more than 3% lime are most likely to have a pH above 7.5. All of this lime must be neutralized before the soil pH can be lowered. Elemental sulfur is a common amendment used to lower soil pH. However, the presence of soil lime will prevent any change until the lime has been eliminated. It is often more economical to establish plants that are tolerant of alkaline soils and are not sensitive to soil lime. (Refer to the National Plants Database at <http://plants.usda.gov> for more information regarding plant tolerance to alkaline soils).

Electrical Conductivity (EC_e) (Method S – 1.20 in Gavlak et al. [2005])

Total soil salts are determined from the saturated paste extract to classify the soil as saline or nonsaline. Units are in mmhos/cm or dS/m. Electrical conductivity should be determined from a saturated paste extract (EC_e) for best correlation to plant performance. A saline soil has a conductivity greater than 4 mmhos/cm. Special management practices are necessary when soils test as saline. Salinity is more fully described in Circular 656, *An Introduction to Soil Salinity and Sodium Issues in New Mexico* (http://aces.nmsu.edu/pubs/_circulars/CR656.pdf). Instead of EC, many growers prefer to use parts per million total dissolved solids (ppm TDS) to indicate salinity. To calculate the ppm TDS, multiply EC by 640.

Sodium Adsorption Ratio (SAR) (Method S – 1.60 in Gavlak et al. [2005])

The liquid from the saturation extract is also used to determine the calcium, magnesium, and sodium in the soil to assess water infiltration hazards due to too much sodium. Gypsum recommendations are made using this parameter. For more discussion about SAR, see Circular 656, *An Introduction to Soil Salinity and Sodium Issues in New Mexico* (http://aces.nmsu.edu/pubs/_circulars/CR656.pdf).

Soil Organic Matter (SOM) (Method S – 9.10 in Gavlak et al. [2005])

The Walkley-Black procedure is suggested as a good measure of organic matter for New Mexico soils. Soil organic matter is more than the presence of compost and roots in the soil. Thirty pounds of plant-available nitro-

gen are credited to the soil for every 1% organic matter in the top foot of soil as determined by the Walkley-Black procedure. Knowledge of the soil organic matter content helps understand possible causes for salinity, improved water-holding capacity, and improved nutrient reserves. Organic matter benefits soil and crops by

- Helping strengthen soil aggregates, which improves soil tilth and structure.
- Improving aeration and water infiltration.
- Increasing water-holding capacity (0.08 to 0.19 inches per 1% SOM).
- Providing a significant number of nutrient exchange sites.
- Buffering against rapid changes in soil pH.
- Forming stable organic compounds that can increase micronutrient availability.
- Providing a source of plant nutrients (0.7 pounds N per 1,000 square feet per year per 1% SOM per foot of soil).
- Providing a food source and ecosystem for soil microorganisms as well as earthworms and other beneficial organisms.

Nutrient Analyses

Three primary nutrients should be evaluated on a routine basis: inorganic-N, phosphorus, and potassium. Four micronutrients analyses that are routinely requested are iron, zinc, copper, and manganese. The nutrients are interpreted according to the likelihood that plants would respond to additional fertilizer. A soil that is ranked low means there is not enough of that nutrient for the plant to grow correctly and that the plant would benefit from an application of that nutrient. If the nutrient is ranked high there is little chance the plant would respond to additions of that nutrient (i.e., it would be a waste of money to add more).

Inorganic Nitrogen (N) (Method S – 3.10 in Gavlak et al. [2005])

Inorganic-N is the sum of nitrate-N and ammonium-N in the soil. Nitrate-N is usually more prevalent and may be the only form tested by some labs. Several methods exist, but a common procedure uses potassium chloride (KCl) to extract the inorganic-N from the soil. The amount of fertilizer nitrogen needed is based on the amount of nitrogen in the soil and the amount of nitrogen required to adequately promote growth and performance of a given crop. Fast-growing plants generally require more nitrogen than slow-growing plants. Nitrogen fertilizer applications may be eliminated (at first) if the soil test is rated high for inorganic-N. Fertilizer should be applied when temperature and moisture conditions favor active growth; they should not be applied during times of stress. Heavy rains or excessive irrigation will lower

the nitrate-N content of the soil via leaching. Samples taken before a leaching event will overestimate the soil inorganic-N and subsequently underestimate the amount of nitrate-N that would be needed for a potential crop.

Phosphorus (P) (Method S – 4.10 in Gavlak et al. [2005])

Western soils are typically alkaline and should have plant-available phosphorus determined using a sodium bicarbonate solution (Olsen's procedure). This extract has been shown to correlate very well with plant-available phosphorus in high-pH (alkaline) soils. New Mexico soils that are low in organic matter usually are also low in plant-available phosphorus. Soil chemistry in New Mexico favors the creation of apatite (a calcium phosphate mineral) that is not available for plants to use. As a result, plant-available phosphorus is usually quite low in alkaline soils and should be supplemented for growing plants. Phosphorus fertilizers can be applied at 1/5th the nitrogen rate when making routine applications.

Potassium (K) (Method S – 5.10 in Gavlak et al. [2005])

The accepted method for determining plant-available potassium is extracting the soil with an ammonium acetate solution. Before NMSU's SWAT laboratory closed they used water-extractable potassium, which is a fraction of the extractable potassium for most soils. However, the value of one method over another is related to understanding of plant response to reported values. Low potassium, as well as other nutrient levels that are reported low, will generally mean a good chance for plant response to added fertilizer.

Micronutrients (Method S – 6.10 in Gavlak et al. [2005])

Iron (Fe): Iron is extracted with DTPA (a chelate) by most soil testing labs in the West. Iron deficiencies can occur with sensitive plants grown in alkaline or calcareous soil. If the soil pH is above 7.5, less iron is available to the plant because the chemistry of the soil favors the creation of a mineral form of iron that is not available for plant use. Even though a soil may test high in available iron, iron-sensitive crops may still exhibit deficiency symptoms. Chelates often are used to keep iron fertilizers in a more available form, but care should be taken to pick EDDHA or DTPA as the chelate of choice in New Mexico instead of EDTA. EDDHA is most stable across all soil pH ranges, while DTPA should not be used in soil with a pH above 7.6. These two classes of chelates will generally improve iron nutrition in plants.

Zinc (Zn): Zinc, like iron, is extracted with DTPA by most labs in the West. Zinc can be an economic problem for many crops like corn, sorghum, and pecans. Zinc is most unavailable in soils with pH greater than 7.5. Extremely high levels of phosphorus can cause zinc deficiencies by competing for adsorption sites on the soil. Soil test results are classified as low, medium, or high.

Copper (Cu): Copper deficiencies have not been verified in New Mexico soils. Factors that contribute to copper deficiency are high organic matter, sandy textural class, and very high pH. Copper toxicities, on the other hand, have been an issue in some New Mexico fields that have been treated with copper-containing amendments.

Manganese (Mn): Manganese deficiencies have begun to show up in pecans and some other crops in New Mexico. Deficiency symptoms can occur under the same conditions that promote iron and zinc deficiencies.

Boron (B) (Method S – 7.10 in Gavlak et al. [2005]):

Boron is another micronutrient that is needed by plants but is usually sufficient in soils in low rainfall areas. Plant tissue testing can indicate whether or not there is sufficient boron available to the plant. Some plants such as pistachios can exhibit boron deficiency. Soil levels are assessed using a hot water extract of the soil. Treating plants or soil with boron should be approached with caution because of the potential for boron toxicity if over-applied.

Sulfate (SO₄-S) (Method S – 11.10 in Gavlak et al. [2005]):

Sandy soils are prone to sulfur deficiencies. However, addition of organic matter, sulfate-containing fertilizers, and irrigation water often supplies enough for crop needs. For more information on sulfur in New Mexico, see Circular 650, *Sulfur and New Mexico Agriculture* (http://aces.nmsu.edu/pubs/_circulars/CR-650.pdf).

Soil Texture (Method S – 14.10 in Gavlak et al. [2005], or Thien [1979])

Soils are composed of mineral particles with an infinite number of sizes and shapes. Individual mineral particles are divided into three major categories based on their size: sand, silt, or clay. Many of soil's important physical and chemical properties are associated with the surface of these particles. Soil texture is most often estimated by the "feel" method, but sieves or hydrometer readings can be requested, usually at a much higher price. Soil texture gives a preliminary indication about the soil's water-holding capacity.

LABORATORIES

Soils are complex biological, chemical, and physical systems. Diligence in interpreting soil test results can save hundreds of dollars every year. The only way to know what a soil is truly like is to start with a soil sample. Several commercial labs are given in Table 1 with a listing of test packages or names that would be useful for interpretation of New Mexico soils. Be aware that procedures should be similar to those suggested in this document. Individual labs vary in services offered, prices, and the time they require for analyses. The list of laboratories in Table 1 is not all-inclusive, and the list of services may change over time. To select a lab, consider convenience, services offered, and quality. Consider using laboratories that participate in the North American Proficiency Testing Program (Table 1). This program assists soil, plant, and water testing laboratories in their performance through inter-laboratory sample exchanges and a statistical evaluation of the analytical data.

QUALITY ASSURANCE

Soils are heterogeneous, and replicates of the same sample will never have the exact same analytical result from one laboratory to another. The North American Proficiency Testing Program guidelines have been developed for the agricultural laboratory industry by representatives from groups familiar with and involved in standardizing methods and developing nutrient recommendations for soil and plant analysis methods within the U.S. and Canada. It is operated as an activity of the Soil Science Society of America and overseen by an oversight committee comprising representatives of the aforementioned groups. These include regional soil and plant analysis workgroups, scientific organizations, state/provincial departments of agriculture, and private and public plant analysis labs.

Finally, keep a record of your lab results. If you need help interpreting the results, please consult with your New Mexico State University Cooperative Extension Service county office.

FOR FURTHER ASSISTANCE

Clientele are encouraged to contact their county Extension agent with specific questions, or Dr. Robert Flynn, who has assisted with soil test interpretations in New Mexico, at rflynn@nmsu.edu or 575-748-1228.

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Robert Flynn is an Associate Professor of Agronomy and Soils and an Extension Agronomist at New Mexico State University. He earned his Ph.D. at Auburn University. His research and Extension efforts aim to improve grower options that lead to sustainable production through improved soil quality, water use efficiency, and crop performance.

Table 1. Laboratories to Consider for Evaluating New Mexico Soils for Plant Production*

Lab Contact	National Quality Assurance Program	Homeowner Test Suggestion†	Farmer Test Suggestion
USUAL 9400 Old Main Hill Logan, UT 84322 435-797-2217 http://www.usual.usu.edu/forms/soilform.pdf	PAP‡ / Soil, Plant, Water, and Environmental Soil Program	Complete	Complete
Ward Laboratories 4007 Cherry Ave. Kearney, NE 68848-0788 800-887-7645 http://www.wardlab.com/FeeSchedule/SoilAnalysis.aspx	Soil, Plant, and Water Program	S4, Salinity/Sodium Evaluation (SAR), Walkley-Black OM, Olsen (bicarbonate) P	S4, Salinity/Sodium Evaluation (SAR), Walkley-Black OM, Olsen (bicarbonate) P
Western Laboratories P.O. Box 1020 211 HWY 95 Parma, ID 83660 1-208-722-6564 http://www.westernlaboratories.com/	PAP / Soil, Plant, and Water Program	Test 70 Garden Test	Test 1 (Ag) Complete Soil Test
Servi-Tech Laboratories-Amarillo 6921 S. Bell Ave. Amarillo, TX 79109 806-677-0093 http://www.servitechlabs.com/Services/Soil/tabid/63/Default.aspx	Soil, Plant, and Water Program	Lawn & Garden Soil Analysis, Golf Course and Athletic Turf Analysis, and Soil Salinity Appraisal	Soil Salinity Appraisal, Row Crop Test
Dellavalle Laboratory, Inc. 1910 W. McKinley Ave. Suite #110 Fresno, CA 93728 800-228-9896 http://www.dellavallelab.com/	PAP / Soil, Plant, and Water Program	FA2 Sodium & Salinity Assay, Gypsum Requirement	FA2 Sodium & Salinity Assay, Gypsum Requirement
Colorado State Univ. Soil, Water & Plant Testing Lab Campus Delivery 1120 NESB Room A319 Fort Collins, CO 80523-1120 970-491-5061 http://www.soiltestinglab.colostate.edu/	PAP, Soil program 4x/yr	Routine and SAR	Routine and SAR
Inter AG Services Laboratory 2515 E. University Dr. Phoenix, AZ 85034 602-273-7248 http://www.iaslabs.com/Tests/Soil-Test.aspx	Soil and Plant Program	Complete with Crop-Specific Recommendations; Water-Soluble Ca, Mg, K, and Na; Olsen (bicarbonate) P	Complete with Crop-Specific Recommendations; Water-Soluble Ca, Mg, K, and Na; Olsen (bicarbonate) P
Analytical Sciences Laboratory University of Idaho Holm Research Center 2222 W. Sixth St. Moscow, ID 83844-2203 208-885-7900 http://www.agls.uidaho.edu/asl/	PAP / Soil and Plant Program	SNMP or SEFT; SOML; SELC; SGRQ; SNMS; SCCE	SNMP or SEFT; SOML; SELC; SGRQ; SNMS; SCCE

* Most of the laboratories listed also test for irrigation water quality and perform plant tissue analysis.

† Refers to what is found on the lab's list of tests offered to clients.

‡ Performance Assessment Program. A voluntary program offered as a service of the Soil Science Society of America (SSSA), operated as a part of the North American Proficiency Testing Program (NAPT) and administered by the NAPT Oversight Committee. The NAPT Program (a program of the SSSA; <http://www.soils.org>) assists soil, plant, and water testing laboratories in their performance through inter-laboratory sample exchanges and a statistical evaluation of the analytical data.

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