

UF/IFAS Extension Soil Testing Laboratory (ESTL) Analytical Procedures and Training Manual¹

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Acknowledgements

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Extension Soil Testing Laboratory: Mission and Purpose

The University of Florida (UF), Institute of Food and Agricultural Sciences (IFAS), Extension Soil Testing Laboratory (ESTL) was established to serve the people of Florida with their soil, plant, and water testing needs for ensuring economically and environmentally sustainable crop production. The ESTL clientele receive accurate agricultural test results, interpretations, and recommendations regarding appropriate rates, use of nutrients and nutrient management techniques developed for Florida.

Mission Statement

The mission of the UF/IFAS Extension Soil Testing Laboratory is

to serve the citizens of Florida, by providing appropriately selected soil, plant, and water testing, interpretation, and recommendations as an educational service through the Cooperative Extension Service to guide management decisions affecting lime and fertilizer use efficiency.

There are three main categories of soils with regard to soil test procedures applied in Florida. Most soils predominantly are acid-mineral soils, which are part of the typical coastal plain physiography of the Southeastern US with sandy textures and low cation exchange capacity (Mylavarapu et al. 2014). The other two categories are calcareous soils and organic or muck soils. In most of Miami-Dade and Monroe counties and in other localized areas of the state, calcareous soils can be found with up to 90% free calcium carbonate on the surface. The organic soils are found in the Everglades Agricultural Area spreading over 280,000 acres south and east of Lake Okeechobee, with up to 80% organic matter (Mylavarapu et al. 2014).

The ESTL provides chemical analyses of acid-mineral and calcareous soils, container media, plant tissue nutrients, irrigation and household water samples, animal manures and waste analyses for all Florida residents. Testing is restricted to samples originating from the state of Florida only. Muck or organic soil samples and should be sent to the IFAS soil testing laboratory at the Everglades Research and Education Center in Belle Glade directly. Chemical procedures used and/or the interpretations for organic soils of Florida are distinctly different from the acid-mineral and calcareous soils of the state.

Also, testing of materials such as drinking water, sewage sludges, hazardous chemical or biological tests of water or

soil, or limestone are NOT offered at these Labs and may be referred to other governmental or private laboratories.

Purpose of This Manual and Intended Audience

The procedures described in this manual reflect the current methodologies for agricultural testing offered by the UF/IFAS ESTL. *This Circular replaces all previous information that is contained in other IFAS publications.*

The ESTL services are offered as a part of the Nutrient Management Extension Program in fulfillment of the public service mandate of the land-grant university mission. Only tests that have been shown through research/experience to assist in crop-management decisions are offered by the ESTL to Florida residents. It is the intention of the Cooperative Extension Service to offer **only** analytical procedures whose results can be interpreted, and thus render assistance with management decisions involving water, plants, soils, and nutrients. The soil test methods and interpretations are effective only when validated through field calibration studies (Mitchell and Mylavarapu 2014). Where interpretations are NOT available, ESTL will strive to provide best assistance in locating an IFAS Specialist for interpretation and guidance. However, interpretation for newer landscape plants and varieties is **not** available.

A limited number of special tests and services for a fee may be extended to IFAS researchers, if needed, to assist them in making nutrient management decisions, particularly for accomplishing research objectives.

Description of Tests Offered Commercial Crop Production on Mineral Soils (Agronomic, Vegetable, Ornamental, and Fruit Crops)

The ESTL uses Mehlich-3 extraction procedure for extracting soil samples in preparation for further soil-fertility analyses. The Mehlich-3 extraction solution, (0.2M CH_3COOH , 0.25M NH_4NO_3 , 0.015M NH_4F , 0.013M HNO_3 , 0.001M EDTA), is intended for use in extracting phosphates, micronutrients and exchangeable cations effectively from soils generally with a wider pH range (4.0-7.4) (Zhang et al. 2014; Mylavarapu et al. 2014b; Pittman et al. 2005; Mylavarapu 2003). Also, Mehlich-3 procedure happens to be the only soil test extraction method that has been validated through inter-laboratory studies for extraction of plant available phosphorus and use as a reference method for testing soil materials for extractable P (Zhang et al.

2009). For calcareous soils of Florida, the recommended extractant is ammonium bicarbonate-DTPA (AB-DTPA method).

The ESTL offers a standard soil-fertility test for acid-mineral (non-calcareous, inorganic and mineral) soils of Florida. The standard test includes analyses for soil pH and macronutrients- phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) levels in the soil. The ESTL does NOT test for soil nitrogen (N) as there is no reliable soil test for predicting N availability to the plants. If a crop code is included on the analysis request form, a test for Buffer pH may be determined using Adams-Evans Buffer solution (pH 8.00), if the soil pH obtained is lower than the Target pH of the crop specified. The Target pH for a crop is that soil pH at which optimal crop performance and yield is achieved and is, therefore, specific to the crop. Buffer pH will not be determined if no crop is specified on the sample submission form or if the difference between the soil pH and the target pH is less than 0.2 pH units or if the soil pH exceeds the target pH. Subsequent to the Buffer pH determination, lime requirement is calculated using the amount of exchangeable (potential) acidity in the soil. The ESTL does not provide information concerning methods of lowering soil pH on a commercial scale due to hazards from accidental burning and/or other damage from application of acidification agents.

Results from the above soil tests are interpreted for crop response based on Table 1. The current interpretation values were determined from conversion models between Mehlich-1 and Mehlich-3 methods (Mylavarapu et al. 2014b and 2002). Field calibrations studies are on-going at the present time and as more data becomes available the interpretation charts will be fine-tuned appropriately. Typical interpretations and guidelines are developed from research studies and/or long-term field calibration studies on various crops and soils and experience in Florida and thus form the basis for lime, nutrient and management recommendations detailed on the soil test report sent to the clients.

The ESTL Soil Test Report will specify the recommended quantities of macronutrients (N, P, K, Ca and Mg) to be applied to the soil in order to increase the supply of these nutrients to the levels needed for optimum yield and/or quality for the crops requested. Quantities are reported in either pounds per acre, pounds per 100 linear bed feet, pounds per 1000 square feet, or pounds per 100 square feet, depending on the crop. The P and K recommendations are both reported as the oxide forms (P_2O_5 and K_2O) in order to comply with current fertilizer-label requirements.

Recommended quantities of N, Ca and Mg are reported as the elemental form. The report also will indicate the amount of lime needed, if any, to be added to the soil in order to raise the soil pH to that of the Target pH of the crop requested.

It should be noted that recommendations for N are **not based on soil testing**. The ESTL does NOT test for N in soil due to lack of a reliable soil test method through which N availability to meet plant needs can be predicted. The recommendations for N shown on the soil test report form are instead based on research studies that measured the response of the indicated crop to various levels of applied N fertilizers. The results of these studies are then used to determine the correct amount of N needed for optimum crop response. If part of soil N requirements will be met through nutrient release from organic sources such as crop residue or organic soil amendments, the N fertilizer recommendation should be lowered or adjusted appropriately by estimating the N availability from the amendment material.

Footnotes are an integral part of the recommendations and the test report. The footnotes included in the report elaborate on many aspects of fertilization and cultural management for the specified crop(s). It is strongly recommended that the producers consider the information contained in these footnotes when making management decisions for efficient fertilizer use.

The ESTL also offers a micronutrient test for Mehlich-3 extractable Cu, Mn, and Zn. The primary value of the micronutrient soil test is to determine if adequate levels of micronutrients already exist in the soil. A document detailing adequate/toxic levels of the soil micronutrients is included with the report for guidance. Micronutrient fertilizers should be used with discretion since it is possible to build up toxic levels of these elements in a soil. Use of the “shotgun” approach (i.e., addition of micronutrients as “insurance”) should be avoided. It should also be noted that pesticide formulations frequently contain one or more of these micronutrients. Therefore, if pesticides are applied, additional application of micronutrient fertilizer may often not be necessary.

Tests to Choose From PRODUCER SOIL TEST

The list of crops with respective crop codes that can benefit from this test is provided on the Producer Soil Test Information Form (Mylavarapu et al. 2013a; Mylavarapu and Kerr 2013a). If a particular crop of interest is not on the list, the ESTL may be contacted to find an extension crop

Table 1. Current interpretation for Mehlich-3 soil test results for agronomic and vegetable crops (mg kg⁻¹)

| | Low | Medium | High |
|----|-----|--------|------|
| P | ≤25 | 26–45 | >45 |
| K | ≤35 | 36–60 | >60 |
| Mg | ≤20 | 21–40 | >40 |

specialist that can help interpret the test. The ESTL offers up to five soil testing options for producers of commercial agronomic, vegetable, fruit, and ornamental landscape crops. Soil samples for this test should be obtained from the 0- to 6-inch soil depth. It is important to denote the exact crop code to ensure appropriate nutrient recommendations. The test options include soil pH and lime requirement determination, standard soil fertility, micronutrients, organic matter and electrical conductivity (soluble salts). Soil pH and lime requirement test is included in the standard soil test and therefore a separate pH and lime requirement need not be requested. The measured soil pH is compared to the Target pH for the crop specified by the homeowner or gardener and a lime requirement, if any, is determined using the Adams-Evans Buffer pH Index. Both the soil pH and the recommended lime application rate for the specified crop are included in the soil test report. The nutrient recommendations and the accompanying footnotes should always be carefully understood and followed for optimum economic and environmental benefits.

LANDSCAPE AND VEGETABLE GARDEN TEST

The ESTL offers two soil testing options for the homeowner or home gardener (Mylavarapu et al. 2013b; Mylavarapu and Kerr 2013b). The first soil test option is for soil pH and lime requirement determination. No other nutrient analysis or fertilizer recommendation is provided under this option. The measured soil pH is compared to the Target pH for the crop specified by the homeowner or gardener and a lime requirement, if any, is determined using the Adams-Evans Buffer pH Index. Both the soil pH and the recommended lime application rate for the specified crop are included in the soil test report. General fertilizer recommendations for landscape, lawns, and vegetable gardens can then be found in a variety of UF/IFAS extension publications by visiting <http://edis.ifas.ufl.edu> or the local County UF/IFAS Extension Agency. It should be noted that general recommendations do not account for nutrients supplied to the plant from sources already within the soil. Instead, all nutrition is assumed to come only from the fertilizer added to the soil.

The second option includes tests for soil pH and lime requirement along with macronutrients (Mehlich-3 extractable P, K, Ca, and Mg). This information is then used to

calculate specific lime and fertilizer recommendations for the crop of interest and is included in the soil test report along with the appropriate footnotes. This allows the homeowner or gardener to develop their fertilization program according to the specific fertilizer needs of the crop they are growing. Recommendations are made for a variety of crops including landscaping plants, ornamentals, vegetable gardens, and lawn grasses (bahia, bermuda, centipede, St. Augustine, etc.) and are reported as either pounds of nutrient per 100 square feet or per 1000 square feet.

CONTAINER MEDIA TEST

The ESTL Container Media Test (Mylavarapu et al. 2013c; Mylavarapu and Kerr 2013c) is used to measure the levels of water-soluble nutrients in soilless media (e.g., mixtures of materials such as perlite, expanded plastics, vermiculite, peat, pine bark, wood shavings, compost, and sand). Analyses include pH, electrical conductivity, nitrate-N, P, K, Ca, and Mg, all of which are measured in a saturated water extract from the soilless media. This test is recommended as a diagnostic tool for fertilizer management in commercial container-plant production as a means of monitoring nutrients in the media throughout the growing season. The test report also provides the fact sheet (Mylavarapu, d'Angelo, and Wilkinson 2013b) that assists in the interpretation of the results. Test interpretations are meaningful *only* in commercial nursery situations. Unlike the other soil tests offered by the ESTL, container-media samples should NOT be dried prior to their delivery to the laboratory. Drying these types of media can adversely affect the results of the test by changing the amounts of nutrients extracted from the media.

WATER TEST

The ESTL offers testing of both household and other water supplies used for irrigation/micro-irrigation for mineral determinations only (Mylavarapu et al. 2013d; Mylavarapu and Kerr 2013d). All health-related and drinking water quality inquiries should be directed to the nearest county Health Department. Additionally, questions concerning municipal water supplies should be referred to the Department of Health and Rehabilitative Services as that agency is responsible for monitoring the quality of municipal water sources.

The ESTL Water Test Report includes values for pH, Ca, Mg, Fe, Mn, Na, Cl, hardness, total carbonates, and electrical conductivity. The irrigation water test includes all of the above, as well as a test for suspended solids. The report provides tables assisting with the interpretation of results.

In Florida, many irrigation-water sources originate from limestone aquifers, resulting in high-pH waters. Crops that are pH-sensitive, such as blueberries or pine seedlings, may benefit considerably by pretreating such water with acid to destroy carbonates and concurrently lower the pH. Results from the total carbonates test can be used to determine the amount of acid required to reduce this high-pH condition (Kidder and Hanlon 2012).

PINE NURSERY SOIL TEST

Soil samples from a pine nursery should be obtained from the 0- to 6-soil depth, and will be analyzed for soil pH, organic matter, and Mehlich-3 extractable P, K, Ca, and Mg (Mylavarapu et al. 2013e; Mylavarapu and Kerr 2013e).

COMMERCIAL SOD TEST

The test is designed to estimate the nutritional needs of Florida sod grown under commercial conditions. Analyses performed can include a Standard Soil Test (pH, P, K, Ca, and Mg), pH and Lime Requirement, and a Micronutrient Test (Cu, Mn, Zn) (Mylavarapu et al. 2013f; Mylavarapu and Kerr 2013f).

NUTRIENT TESTING FOR BAHIA PASTURES

The ESTL offers different options for Bahia Pastures depending on whether it is a new planting or an established pasture on the “Nutrient Testing Form for Bahia Pastures” (Mylavarapu 2014g; Mylavarapu and Kerr 2013g). For a new planting, a soil sample is submitted as for the Producer Soil Test. For established pastures, the test protocol requires that a soil and a plant tissue sample collected at the same time be submitted to the ESTL for determining crop P requirement and making a recommendation for P application using the interpretation chart below. Details on this protocol and more can be obtained from EDIS publication [SS163/SL129](#) entitled, “UF/IFAS Standardized Fertilization Recommendations for Agronomic Crops” (Mylavarapu 2013L). The nitrogen option is chosen based on usage. Refer to [SS163/SL129](#) for the nitrogen options. Testing for micronutrients, organic matter and electrical conductivity is also available.

PRODUCER CITRUS TEST

The Producer Citrus Test Form (Mylavarapu et al. 2013h; Mylavarapu and Kerr 2013h) must accompany soil samples submitted to the UF/IFAS Extension Soil Testing Laboratory. The test is designed to estimate the nutritional needs of Florida citrus grown under commercial conditions. Analyses performed can include a Standard Soil Test (pH, P, K, Ca, and Mg), pH and Lime Requirement, a Micronutrient Test (Cu, Mn, Zn), and Organic Matter. For trees over four years of age, a leaf tissue sample must be submitted in order to receive a recommendation for phosphorus. This protocol is detailed in publication [SS492/SL279](#), “Diagnostic Nutrient Testing for Commercial Citrus in Florida.”

PHOSPHOROUS INDEX TEST

To assess the risk of phosphorus leaving agricultural lands, a tool has been developed called the Phosphorus Index specific to Florida conditions. To have P loss assessment, soil samples should be collected from the specific field(s) and submitted with this form filled out completely to the UF/IFAS Extension Soil Testing Laboratory at the address above. The Phosphorus Index is estimated from the Mehlich-3 extractable P, Fe, and Al. The Standard Fertility Test is also available with the Phosphorus Index test (Mylavarapu et al. 2013i; Mylavarapu and Kerr 2013i).

PLANT TISSUE TEST

In addition to soil testing, the ESTL also offers a Plant Tissue Test (Mylavarapu et al. 2013j; Mylavarapu and Kerr 2013j). Test results from samples submitted by commercial growers are forwarded to a UF/IFAS Extension Specialist, where available, who evaluates the data and provides a report to the grower.

LIVESTOCK WASTE TEST

Laboratory analysis will include a test for nitrogen (N), ammonia nitrogen (NH₃-N), total phosphorus (P), and potassium (K) as well as percent moisture, percent solids, percent ash, and pH. Based on test results, nutrient recommendations for N, P, and K are provided for selected crops, and up to three different crops per sample can be selected from a given list (Mylavarapu et al. 2013k; Mylavarapu and Kerr 2013k).

Sample Submission

How to Submit Samples to the ESTL

A Sample Submission Form and full payment for the requested services should accompany the samples. Sample Submission Forms can be printed directly from the ESTL website (<http://soilslab.ifas.ufl.edu>) or can be picked up

Interpretation for P requirement of bahiagrass using Soil and Tissue Test

| Soil Test | Tissue Test | Recommendations |
|---------------|-----------------|------------------------------|
| P medium/high | No tissue test | 0 |
| P low/vlow | $P \geq 0.15\%$ | 0 |
| P low/vlow | $P < 0.15\%$ | 25 or 40 lbs P_2O_5 /acre* |

*Recommended amount of P_2O_5 depends upon nitrogen option chosen

from the local county UF/IFAS Extension office. Samples may be sent directly to the ESTL via the US Postal Service or express delivery companies. Instructions for collection of a representative sample, proper sample amount, mailing address and other vital information needed for proper sample processing are printed on the forms (described below). Mailing boxes for shipping samples to the ESTL are also available from the county Extension office. Samples may also be personally delivered directly to the laboratory in order to avoid shipping/ mailing delays.

Sample analysis generally requires an average of three working days from the time the sample is received at the ESTL. Results are e-mailed or mailed directly to the address provided on the submission form. Additionally, a copy of these results is sent to the county Extension office. All county Extension offices have the capacity to receive test results via electronic mail. Clients are encouraged to contact their county Extension office when seeking further assistance. Clients may also request to receive a copy of their results via fax.

Sample Submission

Relevant sample submission form(s) needs to be filled out completely and accompany all samples submitted for testing. The following forms correspond to the tests and testing options described above and can be downloaded and printed by the clients by from the following links. These and other information can also be accessed by visiting the ESTL website (<http://soilslab.ifas.ufl.edu>). The forms are also available from the nearest county Extension office.

Producer Soil Test Information Sheet (Fact Sheet SL-135). This form has been designed for use by commercial producers. The information sheet is self-explanatory and provides pertinent information for samples submitted to the ESTL.

Landscape and Vegetable Garden Soil Test Information Form (Fact Sheet SL-136). Both private and commercial clients fertilizing plants in the landscape, primarily home horticulture, should use this form.

Container Media Test Information Form (Fact Sheet SL-134). This form is designed for use by commercial growers using soilless media for container-plant production.

Water Test Information Sheet (Fact Sheet SL-133). This form should be used for analysis of irrigation water or household well water (not municipal or drinking water).

Pine Nursery Soil Test Information Sheet (Fact Sheet SL-132). Commercial operators of pine plantations and pine nurseries should use this form.

Commercial Sod Test Information Sheet (Fact sheet SL-393). All commercial sod production farms should use this form for soil testing.

Nutrient Testing Form for Bahia Pastures (Fact Sheet SL-395). This form is used to submit samples for Bahia pastures. For new plantings, send a soil sample using crop code 35. For established pastures, send the soil sample with a plant tissue sample using crop code 36 and test B1. A plant tissue test is necessary before we can give a recommendation for phosphorus fertilization. If plant tissue sample is not submitted then unfortunately phosphorus recommendation will NOT be made. In such cases where there is no plant tissue sample, please use Test 1.

Producer Citrus Test Form (Fact Sheet SL-396). This form is used to submit samples from commercial citrus groves. For trees less than four years of age, submit a soil sample using test C1 and the appropriate crop code. For trees older than 4 years of age, use test C2 and include a sample of the leaf tissue. Leaf tissue is required to get a phosphorus recommendation.

Phosphorus Index Test Form (Fact Sheet SL-394). This form is used to submit samples for the Phosphorus Capacity Index Test. Send the soil sample and select either the Standard Fertility Test and the Phosphorus Index Test or the Phosphorus Index Test by itself.

Plant Tissue Analysis Information Sheet (Fact Sheet SL-131). This form is used for submission of plant tissue samples. Plant tissue samples should be sent with the consent of an extension agent or state specialist. The agent

or specialist assumes the responsibility for interpretation of the plant tissue report. Interpretations are not provided with this report.

Livestock Waste Test Form ([Fact Sheet SL-397](#)). This form is used to submit, livestock waste, poultry litter and other composted samples for nutrient analysis. Choose the Standard Manure Test. There is an option for including micro-nutrients if desired.

Other supplies related to testing and sampling that can also be obtained at the county UF/IFAS Extension office include the following:

- soil sample bags
- a self-addressed cardboard mailer

Sample Preparation

Soil Samples

Soil samples should be prepared appropriately and made ready for shipping to the ESTL (Mylavarapu and Miller 2014). Firstly, all samples should be air-dried. Drying is best accomplished by spreading a thin layer of soil on clean wrapping paper or newspaper and placing it in a dry shaded area for at least 24 hours. Drying samples in direct sunlight or using a household oven is NOT recommended.

Container Media Samples

Container media samples should NOT be dried before shipment to the ESTL. Drying media samples will adversely affect the test results decreasing the usefulness of the test.

Plant Samples

The quality of the tissue samples submitted for analysis is of importance in ensuring proper processing and interpretation of the results. Tissue samples should not be contaminated with soil or sprays. If the tissue is dusty or contaminated, the sample should be gently washed with flowing distilled water and allowed to dry overnight prior to shipping. Do not sample diseased or damaged plant materials. Consult the local Extension agent to determine the proper plant part and the proper time to sample. Always place the tissue samples in paper bags only. Plastic bags are NOT recommended.

Water Samples

The container in which a water sample is sent to the ESTL can influence results greatly. For example, residual soap

from a plastic dish soap container will contaminate the water sample. The container should be clean to avoid contamination of the sample. The sample should be taken several minutes after the water source has been flowing from the spigot or irrigation pump. The container should be flushed thoroughly several times with the flowing water. The container should be filled completely with no airspace at the container top. Entrapped air in the container may affect well-water samples due to shifts in carbon dioxide, potentially affecting its pH.

Analytical Procedures for Soil

Soil Scooping Technique

Soil scooping technique is employed to draw an estimated weight of soil sample for testing from the soil sample submitted/prepared. The soil-scooping technique requires practice, despite its unsophisticated appearance. The technique depends upon uniform actions by the technician from sample to sample to produce consistent packing of soil into the scoop. To check scooping consistency, repeatedly scoop soil from one sample and check the weight of each scoop. If the procedure is being carried out properly, the weights should be uniform. The average weights for various scoop volumes are given in [Table 2](#). Scoop weights will vary from soil to soil depending on differences in soil texture.

Procedure

1. Dip the scoop into the center of the soil sample and fill the scoop with a twisting motion so that extra soil is mounded above the rim of the scoop. Do not press the scoop or force the soil against the side of the container (Jones 1992).
2. Strike the handle near the scoop two times with a plastic rod to settle soil particles.
3. Level the scoop with the plastic rod. Strike off all excess soil above the rim of the scoop in a single stroke so that the soil is not compacted into the scoop.

Soil pH (1:2 v/v)

This procedure uses a 20 cm³ soil scoop and 40 mL of pure water to obtain a 1:2 soil-to-water ratio. Sample pH may be affected by contaminated water, by microbial activity or by changes in solution chemistry if samples are allowed to sit longer than recommended prior to analysis. Other common errors associated with this method include improper scooping technique and improper electrode use. The pH meter should be calibrated on a daily basis using

Table 2. Applications for scoops used at the UF/IFAS Extension Soil Testing Laboratory

| Scoop Volume (cm ³) | Approx. soil weight (g) | Application |
|---------------------------------|-------------------------|-------------------------------------|
| 2.5 | 5 | Mehlich-3 extraction |
| 15 | 20 | Adams-Evans Buffer pH |
| 20 | 25 | Soil pH and electrical conductivity |

Note: Soil for the AB-DTPA extraction procedure is weighed and not scooped

commercially available buffer solutions. Fresh aliquots of buffer solution must be used each day.

Standard Solutions

Obtain commercially available standard buffer solutions of pH 4.00, 7.00, and 10.00.

Procedure

1. Standardize pH meter according to manufacturer's directions.
2. Scoop 20 cm³ of soil and pour into a 90 mL (3 oz) plastic cup.
3. Add 40 mL of pure water to each cup using an automatic pipette. Stir with a glass rod and let the sample stand for 30 min, but not more than 2 hours. Stir sample again just prior to analysis.
4. Continue stirring sample and measure soil pH.
5. Record pH to the nearest 0.1 pH unit (XX.X).

Adams-Evans Buffer pH

This procedure (Adams and Evans 1962) uses a 15 cm³ soil scoop and 30 mL of Adams-Evans Buffer solution for a soil to solution ratio of 1:2. Errors associated with this method include improper standardization of the Adams-Evans buffer solution, improper use of the electrode, and delays in analysis beyond the recommended equilibration period.

Reagents

Reagents used in this procedure are listed in [Table 3](#).

Solutions

The Adams-Evans Buffer solution is prepared as follows:

1. Weigh 180 g of the p-Nitrophenol into a 6 L Erlenmeyer flask containing about 4 L of pure water. Add 135 g of the Boric Acid and dissolve. Use low heat to dissolve, if necessary.

2. Dissolve 95 g of the Potassium Hydroxide in approximately 200 mL of pure water contained in a 500 mL beaker.

3. Using a 20 L carboy calibrated at 18 L volume, add 6 L of pure water. Weigh 666 g of the Potassium Chloride and transfer to the carboy.

4. Combine all solutions by quantitatively transferring the p-Nitrophenol/Boric Acid solution, followed by the Potassium Hydroxide solution, to the carboy containing the Potassium Chloride solution. Bring to 18 L final volume with pure water. Adjust the solution pH to 8.00 ± 0.02 with small amounts of Potassium Hydroxide (for raising pH) or Hydrochloric Acid (for lowering pH), as needed. Let stand overnight and check pH.

Alternately, a commercially prepared Adams-Evans buffer solution can be purchased and prepared as per the manufacturer's instructions.

Procedure

1. Standardize the pH meter according to the manufacturer's directions.
2. Measure the pH of the Adams-Evans Buffer Solution to insure that the solution reads 8.00 ± 0.02.
3. Scoop a 15 cm³ volume of soil into a 50 mL beaker.
4. Add 30 mL of the buffer solution using an automatic pipette.
5. Stir for 4 min on a mechanical stirrer. Timing of this test is critical. The reaction starts when the buffer solution is added to the sample.
6. Immediately after stirring, measure the solution pH. Excessive delays will result in low bias in the buffer-pH readings.
7. Record pH to the nearest 0.01 pH unit (XX.XX).

Table 3. List of reagents used in Adams-Evans Buffer pH procedure

| Name | Formula | F.W.* |
|---------------------|--|--------|
| p-Nitrophenol | NO ₂ C ₆ H ₄ OH | 139.11 |
| Boric Acid | H ₃ BO ₃ | 61.8 |
| Potassium Hydroxide | KOH | 56.1 |
| Potassium Chloride | KCl | 74.6 |

* Formula weight in grams

Mehlich-1 Extractable P, K, Ca, Mg, Cu, Mn, and Zn

This procedure uses a 2.5-cm³ scoop (approximately 3 g of mineral soil) and 25 mL of Mehlich-3 extraction solution to provide a soil to solution ratio of 1:10. Once the extraction is complete, the sample is filtered through Whatman 42 filter paper or its equivalent. The filtered solution should be analyzed as soon as possible following the extraction procedure. If refrigeration is not available, the sample must be analyzed the same day as it is extracted. With refrigeration, samples should be analyzed within five days. Common errors associated with this method include mistakes in sample shake time, delayed filtration, and reagent, filter paper or cup contamination.

Reagents

A list of reagents is found in [Table 4](#).

Solutions

Mehlich-3 Extracting Solution

Prepare a Stock Solution of 3.75M NH₄F – 0.25M EDTA by dissolving 138.9 g of Ammonium Fluoride and 73.05 g EDTA in 1 L of DI water.

To prepare the Working Extractant, pour approximately 15 L of DI water into a 20 L plastic carboy. Add 400 g of Ammonium Nitrate and stir to dissolve. Add 80 mL of the Stock Solution prepared above and mix. Add 230 mL of Acetic Acid and 16.4 mL of concentrated Nitric Acid, bring to a final volume of 20 L with DI water and mix well. The pH of this solution should fall between 2.4 and 2.6.

Table 4. List of reagents used in Mehlich-3 Extractable P, K, Ca, Mg, Cu, Mn, and Zn procedure

| Name | Formula | F.W./Conc.* |
|---------------------------|---|-------------|
| Acetic Acid | CH ₃ COOH | 99.7% |
| Ammonium Nitrate | NH ₄ NO ₃ | 80.05 |
| Ammonium Fluoride | NH ₄ F | 37.04 |
| Nitric Acid, concentrated | HNO ₃ | 15.8M |
| EDTA (chelate) | C ₁₀ H ₁₆ N ₂ O ₈ | 292.25 |

* Formula weights in grams or concentration in molarity or percent

Procedure

- Scoop 2.5 cm³ of mineral soil and transfer into a 50 mL extracting bottle.
- Dispense 25 mL of Mehlich-3 extracting solution into each extracting bottle using an automatic pipette.
- Shake each sample for 5 min on a reciprocating shaker and then filter through filter paper (11 cm Whatman No. 42 or equivalent) into a plastic cup.
- Transfer the filtrate to an appropriate vial for analysis. If samples are not to be analyzed immediately, they should be capped or otherwise covered. Sample solutions are stable for 5 days, if refrigerated.
- The filtrate may be analyzed for nutrients using either ICP (Inductively Coupled Plasma Spectrometer, EPA Method 200.7) or AAS (Atomic Absorption/flame emission Spectrophotometer, EPA Method 200.0) in combination with colorimetric analysis for phosphorus determination (EPA Method 365.2).
- Instrument readings are recorded in mg L⁻¹ solution concentration. Final results are reported in mg kg⁻¹ -dry weight (ppm) calculated as follows:

$$\frac{\text{mg}}{\text{L}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{\text{mL sol'n}}{\text{g soil}} \times \frac{1000 \text{ g}}{1 \text{ kg}} = \frac{\text{mg}}{\text{kg}}$$

Soil Organic Matter

A. WALKLEY-BLACK METHOD

The Walkley Black (WB) method used for determining Soil Organic Matter (SOM) involves a known volume of acidic dichromate solution reacting with an aliquot of soil in order to oxidize the SOM (Allison, 1965, Mylavarapu, 2014). The oxidation step is then followed by titration of the excess dichromate solution with ferrous sulfate. The SOM is calculated using the difference between the total volume of dichromate added and the volume titrated after reaction. Problems associated with this procedure include excessive organic matter in the soil (the limit for this procedure is approximately 6%) and difficult end point determination (dark-colored soil solution). The use of a lighted stir plate can be of assistance in the end-point determination. The WB procedure also results in production of chromate, which is categorized as a hazardous chemical. Studies are currently ongoing to develop an alternative method to WB to avoid production any hazardous waste.

Reagents

Reagents used in this procedure are listed in [Table 5](#).

Solutions

0.16M Potassium dichromate

Dissolve 98.08 g of oven-dry/desiccated Potassium dichromate in approximately 1500 mL of pure water and dilute to 2 L. After preparation of this solution, transfer to a clean glass bottle for use with a repipetter. Do not mix old Potassium dichromate solution with the new solution.

1.0M Ferrous Sulfate

Dissolve 556.04 g of Ferrous Sulfate in approximately 1500 mL of pure water. Carefully add 30 mL of concentrated Sulfuric Acid, mix, cool, and dilute to 2 L. After preparation, this solution may be transferred to a clean 8 L plastic carboy. Do not mix old Ferrous Sulfate solution with the new solution. The tubing, stopcock, and attachments to the burette should be rinsed three times with new Ferrous Sulfate solution before titrating any blanks or samples. Prepare a new solution every 30 days.

Procedure

1. Weigh 1.0 g of mineral soil into a 250-mL wide mouth graduated Erlenmeyer flask.

2. Titrate two blank samples (no soil) before proceeding with any unknown samples in order to standardize the Ferrous Sulfate solution. If the difference between the two blanks is not within 0.2 mL of Ferrous Sulfate solution, clean the burette and associated tubing. Reanalyze two more blanks to determine if the problem has been eliminated.
3. Pipet 10.0 mL of the Potassium dichromate solution into each flask containing unknown soil and mix by carefully rotating the flask to wet all of the soil.
4. Under a fume hood, carefully add 20 mL of concentrated Sulfuric Acid to each flask and mix gently.
5. Allow flasks to stand for 5 min under the fume hood.
6. Add pure water to each flask such that the final volume is approximately 125 -mL. Mix by swirling gently.
7. Add 5 or 6 drops of Phenanthroline complex and immediately titrate with the Ferrous Sulfate solution. As the titration proceeds, the solution will take on a green color that will change abruptly to reddish-brown when the endpoint of the titration is reached.
8. Record each volumetric reading to the nearest X.X mL.
9. The % OM is calculated as follows:

$$(1 - S / B) \times 10 \times 0.68 = \text{organic matter (\% of sample)}$$

where:

S = Volume of Ferrous Sulfate solution required to titrate the sample, in mL.

B = Average Volume of Ferrous Sulfate solution required to titrate the two blanks, in mL.

10 = conversion factor for units.

0.68 = a factor derived from the conversion of % organic carbon to % organic matter (1.724), the fraction of Organic Carbon oxidized to CO₂ (0.76) and the milliequivalent weight of carbon (0.003 g).

B. LOSS-ON-IGNITION METHOD

The Loss-on-Ignition (LOI) organic matter determination is used for analyzing soil samples in which the organic matter content is greater than 6%. This procedure involves exposing the soil sample to high temperatures in an oxygen atmosphere in order to convert any organic carbon

Table 5. List of reagents used in the Walkley-Black Method

| Name | Formula | F.W./Conc.* |
|---|----------------------|-------------|
| Potassium dichromate | $K_2Cr_2O_7$ | 294.19 |
| Ferrous Sulfate | $FeSO_4 \cdot 7H_2O$ | 278.02 |
| Sulfuric Acid | H_2SO_4 | 18M |
| 1, 10-Phenanthroline Ferrous Sulfate complex | | |
| * Formula weights in grams or concentration in molarity | | |

compounds to carbon dioxide, which is then lost to the atmosphere. The difference between the soil dry weight and the weight of the sample after ignition is then used to calculate the amount of organic matter in the sample. This procedure has been reported to be consistent with even lower SOM levels (<6%) such as sandy soils in Florida. Studies are on-going to determine the suitability and for possible replacement method for WB procedure.

Procedure

1. Label and accurately weigh (to 4 decimal places) an oven dried 50 mL Pyrex beaker.
2. Add approximately 10-12 g of soil to the beaker.
3. Place sample in the oven at a constant temperature of 105°C and allow sample to dry for a minimum of 2 hrs.
4. Remove sample from the oven at the end of two hours and place immediately into a desiccator to cool. Allow sample to cool to room temperature (approximately 30 minutes) and then accurately weigh sample and beaker
5. After weighing, place sample into a muffle furnace and heat at 450°C for a minimum of 6 hours. Do not exceed this temperature as $CaCO_3$ may be converted to CO_2 and cause erroneous results.
6. At the end of the heating period, allow samples to cool slightly and then transfer immediately to a desiccator. Allow samples to cool to room temperature in the desiccator.
7. After samples reach room temperature, remove from the desiccator and accurately weigh sample and beaker.
8. The % OM is calculated as follows:

$$\% \text{ OM} = \frac{(\text{Oven Weight} - \text{Furnace Weight})}{\text{Sample Dry Weight}} \times 100$$

Where:

Oven Weight = weight of beaker + sample after drying at 105°C

Furnace Weight = weight of beaker plus sample after ignition in muffle furnace at 350°C

Sample Dry Weight = weight of sample plus beaker after drying at 105°C minus weight of beaker

Electrical Conductivity (1:2 Soil:Water)

The ESTL offers a test for soil Electrical Conductivity (EC) by which a value for the “Soluble Salts” in the soil content can be estimated. In this test, 20 cm³ of a mineral soil are mixed with 40 mL of pure water resulting in a soil to water ratio of 1:2. The resultant suspension is allowed to equilibrate for 4 hours in order to allow slowly-soluble constituents to approach solution equilibrium. The suspension is then filtered and the electrical conductivity is immediately determined. Sources of error include improper instrument calibration and incorrect equilibration times.

Standards

A solution of 0.005M KCl has an electrical conductivity of 720 deciSiemens per meter (dS/m) at 25°C. Alternately, a commercially available NIST traceable reference solution of the appropriate concentration and conductivity may be used.

Procedure

1. Weigh 20 g of soil and transfer to a plastic 90-mL (3-oz.) cup.
2. Add 40 mL of pure water to each cup. Stir and allow the suspension to stand for 4 hours.
3. At the end of 4 hours, stir the suspension to create slurry. Immediately filter through an 11 cm filter paper (Whatman No. 42 or equivalent). Collect the filtrate in a 90 mL (3 oz.) plastic cup.

4. Using the reference standard, calibrate the Electrical Conductivity Meter according to manufacturer's directions. Measure the EC of the solution and report results to two significant figures in dS/m.

While the ESTL reports all electrical conductivity measurements in dS/m, many clients are accustomed to values given in ppm "soluble salts." The calculation to convert EC to soluble salts is given below along with the formula for conversion of EC to salt index. There are many inaccurate assumptions included in these conversions and clients are encouraged to adapt to the more precise and widely-accepted terminology of EC in dS/m.

$$\text{EC in dS/cm} \times 700 = \text{soluble salts in ppm}$$

$$\text{Salt index} = \text{EC (as direct 2:1 reading)} \times 8$$

Analytical Procedures for Container Media

Water-Extractable P, K, Ca, Mg, NO₃-N, pH, and Electrical Conductivity

The entire sample (or that portion of the sample that nearly fills a 600 mL plastic beaker) is used for this diagnostic test (Mylavarapu and Bartos 1999c). De-ionized distilled water is added to the sample to the point of saturation. The sample is then filtered under vacuum and the filtrate is analyzed. Under- or over-estimating the point of sample saturation will introduce some error. If possible, the analysis of the filtrate should be completed on the same day that the extract is prepared. If unable to complete the analysis on the same day, the sample may be refrigerated but analysis must be completed within 48 hours or the sample must be re-extracted.

Extraction Procedure

1. Place the entire sample (or a representative sample aliquot) into a 600 mL plastic beaker and conservatively add pure water to the point of complete saturation. At this point, the surface of the mix should glisten, but no water should puddle on the surface. Mix well with a spatula, and let stand for 2 hours.
2. Place a 9 cm Whatman No.1 filter paper into a large Buchner funnel. Wet the filter paper with approximately 2 mL of pure water and transfer the saturated media onto the filter.

3. Place the funnel under a vacuum and leave until sufficient solution is extracted from media to complete the necessary tests. Transfer the filtrate to an appropriate container for analysis.

pH

Standardize the pH meter according to manufacturer's directions and then determine the pH of an aliquot of the filtrate. Results are reported to one decimal place.

EC

Standardize the EC meter according to manufacturer's directions and then determine the electrical conductivity of an aliquot of the filtrate. Report results to two significant figures in dS/m.

NO₃-N

The ESTL uses semi-automated colorimetric analysis (EPA Method 353.2) to determine NO₃-N in the media extract. The instrument (OI Analytical Alpkem Flow IV or equivalent) is set up and calibrated as per manufacturer's directions. Instrument results are reported to one decimal place as mg L⁻¹ NO₃-N.

Water-Extractable P, K, Ca, Mg

1. The filtrate may be analyzed for all other nutrients using either ICP or AAS in combination with colorimetric analysis for phosphorus determination.
2. Results for P, K, Ca, and Mg are reported in mg L⁻¹ (ppm).

Analytical Procedures for Calcareous Soils

Ammonium Bicarbonate-DTPA (AB-DTPA) Extractable P

The AB-DTPA extractant works well on soils with high and neutral pH (Soltanpour 1990). Previous studies in Florida have shown that this procedure can be interpreted only for P test results. Therefore, results for other nutrients are included in the report. It is not suitable for determination of Ca or Mg. This extraction procedure is used only on soils that have a pH of 7.4 and above (Hanlon et al. 1989).

Solutions

AB-DTPA Extracting Solution

Prepare this solution under a fume hood to avoid possible contact with vapors. Add approximately 700 mL of pure water into a 1-L volumetric flask. Add 0.5 mL (10 drops) of concentrated Ammonium Hydroxide. Dissolve 1.97 g of DTPA in this solution. This dissolution may take several hours. After the DTPA has been dissolved, add 79.06 g of Ammonium Bicarbonate, mix, and dilute to 1 L. Adjust to pH 7.6 using concentrated Hydrochloric Acid (for lowering pH) or Ammonium Hydroxide (for raising pH). Prepare this solution daily, as it is pH unstable.

Reagents

Reagents used in this procedure are listed in [Table 6](#).

Analytical Procedures for Water

The following procedure lists the various subsections that deal with water analyses (SRIEG 1983). To preclude errors introduced by microbial activity, water samples should be analyzed as soon as possible after sampling. Sample containers should be filled completely with no headspace above the sample surface and should only be opened immediately prior to analysis, since exposure to air can cause changes in the chemical equilibrium of the sample.

pH

Standardize the pH meter according to manufacturer's directions and then determine the pH of an aliquot of the sample. Results are reported to one decimal place.

EC

Standardize the EC meter according to manufacturer's directions and then determine the electrical conductivity of an aliquot of the sample. Report results to two significant figures in dS m^{-1} .

Metals

Ca, Mg, Fe, Mn, and Na may be analyzed by either ICP (EPA Method 200.7) or AAS (EPA Method 200.0).

Cl

The ESTL uses semi-automated colorimetric analysis (EPA Method 325.2) to determine chloride in waters. The instrument (SEAL Analytical AQ2+) is set up and calibrated as per manufacturer's directions. Instrument results are reported to one decimal place as mg L^{-1} of Cl concentration.

Carbonate Equivalent

A 50-mL aliquot of water sample is titrated against a standardized hydrochloric acid solution to a pH of 4.0. The volume of acid required is then used to calculate the carbonate and bicarbonate equivalence of the sample. While very low levels of bicarbonates may be present in solution below pH 7.0, these levels are assumed to pose no problems agriculturally. The volume of acid required to titrate the sample to the desired pH is assumed to be entirely due to the neutralization of carbonates and bicarbonates. The most common error associated with this method is degradation of the THAM buffer solution. The THAM titrant should be replaced at least once every week. Only newly-opened water samples should be analyzed since changes in carbonate and bicarbonate levels can occur upon exposure to the air.

Reagents

Reagents used in this procedure are listed in [Table 7](#).

THAM 0.020M Titrant

Place approximately 1.0 g of THAM into a glass beaker and cover the beaker with a watch glass. Dry at 75°C for 15 to 20 min and cool to room temperature in a desiccator. Accurately weigh 0.4846 g THAM and transfer it to a 200 mL volumetric flask. Dissolve the THAM by swirling and bring

Table 6. List of reagents used in ammonium bicarbonate-DTPA (AB-DTPA) extractable P

| Name | Formula | F.W./Conc.* |
|----------------------------------|---|-------------|
| Ammonium Hydroxide, concentrated | NH_4OH | 14.8M |
| DPTA (Baker Cat. E 376-.07) | $\text{C}_{14}\text{H}_{23}\text{N}_3\text{O}_{10}$ | 393.35 |
| Ammonium Bicarbonate | NH_4HCO_3 | 79.06 |
| Hydrochloric Acid, concentrated | HCl | 12.1M |
| Nitric Acid, concentrated | HNO_3 | 15.8M |

* Formula weights in grams or concentration in molarity

Table 7. Reagents used in water analysis procedure

| Name | Formula | F.W/Conc.* |
|-------------------|--|------------|
| THAM | C ₄ H ₁₁ NO ₃ | 121.14 |
| Hydrochloric Acid | HCl | 12.1 M |

* Formula weight in grams or concentration in molarity

to volume with pure water. Keep this solution refrigerated until needed.

Standardized Hydrochloric Acid

Using a pipette, measure 5.0 mL of concentrated Hydrochloric Acid and quantitatively transfer it to a 10 L carboy calibrated at 7 L. Bring the container to a 7 L volume with pure water. This solution should be standardized before use. Acid Standardization: Pipette 25.0 mL of the Hydrochloric Acid prepared above into a 100 mL beaker or Erlenmeyer flask. Titrate to pH 7.00 with the 0.020M THAM titrant solution. Repeat this procedure to obtain two readings. The difference between the two readings should be no more than 0.3 mL. Use the average of the two readings to calculate the molarity of the Hydrochloric Acid (HCl) according to the following equation:

$$(M \text{ HCl}) = [0.020 \text{ M THAM} \times (\text{mL of THAM})] / (\text{mL of HCl})$$

where:

M HCl is the calculated Molarity (equivalent to normality for Hydrochloric Acid)

0.020 M THAM is the Molarity of 0.4846 g of THAM

mL of THAM is the quantity of THAM needed to reach a final pH of 7.0

mL of HCl is the original volume of Hydrochloric Acid used in the titration process

Record the calculated molarity to the nearest 0.001 and label the carboy accordingly. If properly prepared and standardized, the molarity of the acid should be within the range of 0.005 to 0.015 M. This solution should be restandardized every month.

Procedure

1. Calibrate the pH meter according to manufacturer's instructions.
2. Pipette 50.0 mL of the water sample into a 100 mL beaker.

3. Read the pH of the sample.
4. If the pH is greater than 7.0, proceed with the titration of the sample.
5. Titrate to pH = 4.00 +/- 0.05 with the standardized Hydrochloric Acid solution. The sample should be stirred during the titration process.
6. Record the volume of Hydrochloric Acid solution used to titrate the sample, to the nearest 0.1 mL. The concentration of total carbonate and bicarbonate, in mg L⁻¹ in the sample is calculated as follows:

$$(M \text{ HCl}) \times (\text{mL of HCl}) \times 1000/50.0 \text{ mL} = \text{mg L}^{-1}$$

where:

M HCl = molarity of the Hydrochloric Acid titrant

mL of HCl = amount required to titrate the sample

1000 = conversion factor for units

50.0 mL = volume of unknown (water sample)

Analytical Procedures for Plants

Digestion Procedure for the Determination of Ca, Mg, P, K, Na, Mn, Cu, Fe, Zn, and B in Plant Tissue

This digestion procedure has been developed with a sufficiently large dilution factor to allow accurate determination of macronutrients and secondary nutrients that are often in relatively high concentrations within the plant. This procedure may not be suitable for certain micronutrient or heavy metal analyses because of the selected dilution factor. If the expected micronutrient concentration in the plant is less than 5 mg kg⁻¹, the element may be diluted below the detection limit of the method. Selection of muffle furnace temperature and its control directly affect the analytical results of this process. The use of borosilicate glassware can be a source of B and Si contamination.

Reagents

Reagents used in this procedure are listed in [Table 8](#).

Solutions

6.0M Hydrochloric Acid

Add approximately 4 L of pure water into a plastic carboy calibrated at 8 L. Under a fume hood, slowly bring to 8 L volume with concentrated Hydrochloric Acid, and mix using a magnetic stir bar with stirrer. Alternately, any repipette container to which equal volumes of pure water and concentrated Hydrochloric Acid have been added is sufficient.

Procedure

1. Weigh 1.00 g of oven-dry, ground plant tissue into a 50 mL porcelain crucible and place in a muffle furnace.
 - Duplicate every 20th sample to measure the precision of the test.
 - Digest at least one external or internal plant tissue standard sample with each digestion.
2. Place samples in muffle furnace. Ensure temperature controls are set to 500°C and turn the furnace on.
3. Once the internal temperature of the oven reaches 500°C, allow samples to ash for a minimum of 5 hours (ashing time should never exceed 16 hours). Shut oven off and allow oven to cool.
4. Once the furnace temperature is below 200°C, carefully open the furnace door to expedite the cooling process. **CAUTION:** The internal temperature of the muffle furnace should be below 200°C before opening the furnace door so that the samples are not ignited or disturbed by the rapid influx of air.
5. Once samples reach room temperature, remove them from the oven and moisten the ash by adding approximately 5 drops of pure water using an eyedropper followed by the addition of 5 mL of 6 M Hydrochloric Acid. Let this suspension stand for at least 30 minutes before proceeding.

6. With the aid of a funnel, quantitatively transfer the solution containing the ash to a 50 mL volumetric flask. Rinse beaker with pure water and transfer the rinsate to the flask also. Repeat the rinse steps a second time and then bring to volume with pure water. Mix thoroughly.
7. Transfer an aliquot of the sample to an appropriate container for analysis. If filtration is required, use a (Whatman No. 42 or equivalent) filter paper.
8. The sample solution may be analyzed using either ICP or AAS in combination with colorimetric analysis for P determination.
9. Sample results are reported in mg kg⁻¹ plant dry weight for B, Cu, Fe, Mn and Zn and in % plant dry weight for P, K, Ca and Mg.

Total Kjeldahl Nitrogen (TKN) in Plant Tissue

The TKN method is used to analyze for nitrogen in organic materials. Most organically-bound nitrogen (such as that found amines, proteins, etc.) as well as any nitrogen in the form of ammonium ion can be determined using this method. In general, nitrates, nitrites, and some cyclic nitrogenous compounds resistant to digestion are not determined using this method. The Kjeldahl digestion process produces a highly acidic solution and is therefore not recommended for nitrate analysis, as it will cause damage to the instrument.

Reagents

Reagents used in this procedure are listed in [Table 9](#).

Digestion Procedure for Plant Samples

1. Weigh 0.200 +/- 0.005 g of plant tissue onto a nitrogen-free weighing paper. Carefully fold the paper containing the sample and place into a TKN digestion tube (25 mm × 300 mm 100 mL Volumetric tube).
 - Duplicate every 20th sample to measure the precision of the test.
 - Digest at least one external or internal plant tissue standard sample with each digestion.

Table 8. Reagents used in digestion procedure

| Name | Formula | Conc.* |
|-----------------------------|---------|--------|
| Hydrochloric Acid | HCl | 12.1 |
| * Concentration in molarity | | |

Table 9. Reagents used in TKN procedure

| Name | Formula | F.W./Conc.* |
|--|--------------------------------|-------------|
| Kjeldahl mixture No. 2 (10 g K ₂ SO ₄ + 0.30 g CuSO ₄) | | |
| Sulfuric Acid | H ₂ SO ₄ | 18M |

* Formula weight in grams or concentration in molarity or percent

- Scoop approximately 2.0 g of Kjeldahl digestion mixture (this mixture may be obtained from Alfie-Packers, Omaha, NE 68127) and transfer to the bottom of the digestion tube with the aid of a long stem funnel.
- Carefully add 5 mL of concentrated Sulfuric Acid to each tube.
- Start the digestion by placing samples in a block digester. Set temperature to 250°C. When block reaches 250°C; let samples digest for 1 hour. Increase temperature to 380°C and continue digesting for 2.5 hours
- After digestion is complete, allow block to cool to 80°C. When tubes are cool enough to handle, remove from the digestion block and place into a wire rack to cool to room temperature.
- Using a wash bottle, add 5 to 10 mL of pure water washing the sides of each tube. Mix using a Vortex mixer.
- Bring to 100 mL volume with pure water, cap with rubber stopper and mix well.
- Filter using Whatman No. 2 or equivalent) filter paper. Transfer an aliquot of the sample to an appropriate container for analysis.
- The ESTL uses semi-automated colorimetric analysis (EPA Method 351.2) to determine nitrogen in TKN digestates. The instrument (Alpkem Flow Solution IV or Astoria Pacific Analyzer 2) is set up and calibrated as per manufacturer's directions. Instrument calibration standards and quality control samples should be digested in the same manner as the samples. Instrument results are reported to one decimal in mg L⁻¹. Final results are reported as %N-plant dry weight and are converted from mg L⁻¹ using the following equation:

$$\text{Observed value in mg L}^{-1} \times (100 \text{ mL}/0.2 \text{ g})/10,000 = \% \text{ TKN}$$

Analytical Procedures for Livestock Waste

Determination of P and K in Livestock Waste

Phosphorus and potassium are determined in livestock waste samples using the procedure in Chapter 5, Section 5.4 on page 35 of Peters 2014. Calcium, magnesium, and the micronutrients copper, manganese, and zinc can also be determined using this digestion. The digested samples are analyzed using Inductively Coupled Plasma Spectrometry (EPA 200.7).

pH

The determination of pH in livestock waste is done using the procedure in Chapter 7 of Peters 2014.

Ammonia

Manure samples are prepared for ammonia analysis using the procedure in Chapter 4, Section 4.3 of Peters 2014. Liquid manure and KCl extracts of the solid manure samples are analyzed using EPA method 350.1

Total Kjeldahl Nitrogen (TKN) in Livestock Waste

Livestock Waste samples for Total Kjeldahl Nitrogen are digested using the procedure in Chapter 3, Section 3.2.6 of Peters 2014, Micro Kjeldahl Analysis, using a block digester for digestion of the livestock waste. The colorimetric determination is performed using EPA method 351.2.

Percent Moisture, Percent Solids

The determination of Percent Solids and Percent Moisture is performed using the procedure in Chapter 2 of Peters 2014.

Percent Ash

For the Percent Ash determination, the dry sample from the Percent Solids determination is heated at 500°C for four hours in a muffle furnace. The sample is cooled in a desiccator for four hours or until the sample is at room temperature and weighed.

Procedure

1. Take sample from Percent Solids determination and place in a muffle furnace.
2. Set muffle furnace temperature to 500°C and turn on the furnace. Once the temperature reaches 500°C, allow the samples to ash for four hours. Shut off furnace and allow the furnace to cool.
3. When the temperature is below 200C, open the furnace and transfer samples to a desiccator. Allow samples to cool to room temperature.
4. When the samples are at room temperature, accurately weigh them on an analytical balance.
5. The Percent Ash is determined using the following equation:

$$\% \text{ Ash} = \frac{[(\text{weight ashed sample} + \text{container}) - (\text{weight empty container})]}{[(\text{weight undried sample} + \text{container}) - (\text{weight empty container})]} \times 100$$

Quality Control

Operations within an analytical laboratory must address quality control in order to maintain both accuracy and precision. This dedication to quality control must begin with detailed procedures and address all steps in which inaccuracies can be introduced. Efforts to control inaccuracies are directed at three levels: quantitative chemical techniques, instrument monitoring, and managerial process inspection. The ESTL's Quality Control Plan addresses each of these areas assuring that the laboratory produces high quality and reliable data. Details concerning the ESTL's Quality control procedures can be obtained by contacting the laboratory director or the manager. This lab participates in the North American Proficiency Testing (NAPT) Program (a program of the [Soil Science Society of America](#)) which assists soil, plant and water testing laboratories in their performance through inter-laboratory sample exchanges and a statistical evaluation of the analytical data.

Laboratory Safety

The University of Florida has in place a Chemical Hygiene Plan that has been developed by the Division of Environmental Health and Safety (EH&S) to assist UF departments in the recognition, evaluation and control of hazards associated with laboratory chemical operations and is intended to meet the requirements of the OSHA Laboratory Standard, 29CFR1910.1450.

The primary focus of this core Chemical Hygiene Plan (CHP) is to provide guidance to the laboratory staff to safely use chemicals in the laboratory. All lab personnel are required to attend annual Hazardous Waste Management training sessions. In addition there is an annual Laboratory Safety survey conducted by EH&S staff.

The following is a general list of safety requirements that should be followed by any person handling laboratory chemicals or working in a chemical laboratory:

1. Always wear an acid/base resistant laboratory coat.
2. Always wear goggles/eyeglasses as minimum eye protection.
3. Always wear appropriate gloves when handling chemicals.
4. Never work alone in a chemical laboratory.
5. Never eat or drink in the laboratory area.
6. Do not store food in chemical refrigerators.
7. If working with an unfamiliar chemical, always read the label and check the MSDS before proceeding.
8. Always transport concentrated acids/bases or other dangerous chemicals in a rubberized safety bucket.
9. Know where the nearest fire extinguisher and eye wash station are located.
10. Know the location of the nearest phone and how to reach 911 or the local emergency number.
11. Do not pipette chemicals by mouth.
12. Wear appropriate laboratory clothing including closed-toe shoes and long pants. Tie back long hair.

References

- Adams, F., and C.E. Evans. 1962. A rapid method for measuring lime requirement of red-yellow podzolic soils. *Soil Sci. Soc. Am. Proc.* 26: 355–357.
- Allison, L. E. 1965. Organic carbon. In C.A. Black, D.D. Evans, L.E. Ensminger, J.L. White, and F.E. Clark (ed). *Methods of Soil Analysis, Part 2.* pp. 1367–1378.

- Hanlon, E. A., G. J. Hochmuth, S. O'Hair, Y. Li, H. Bryan, M. Lamberts, T. Olczyk and J. Crane. 1999. Development of Calcareous Soil Testing and Recommendation System: Approved Version. Position Paper submitted to IFAS Research and Extension Administration and approved by the IFAS Fertilization Recommendation Oversight Committee, IFAS, University of Florida, Gainesville, FL 32611. pp18.
- Kidder, G., and E. A. Hanlon. 2012. *IFAS Cooperative Extension Service, University of Florida, Gainesville, FL 32611*. pp.6. <http://edis.ifas.ufl.edu/ss165>.
- Mitchell, C. C., and R. Mylavarapu. 2014. Soil Test Correlation and Calibration for Recommendations. *In Soil Test Methods from the Southeastern United States*. Southern Cooperative Series Bulletin No. 419. USDA-SERA-IEG-6. ISBN 1-58161-419-5. <http://www.clemson.edu/sera6/MethodsManualFinalSERA6.pdf>.
- Mylavarapu, R., C. C. Mitchell, and H. J. Savoy. 2014. Soils of the Southeastern US. *In Soil Test Methods from the Southeastern United States*. Southern Cooperative Series Bulletin No. 419. USDA-SERA-IEG-6. ISBN 1-58161-419-5. <http://www.clemson.edu/sera6/MethodsManual-FinalSERA6.pdf>.
- Mylavarapu, R., and R. Miller. 2014. Soil Preparation, Measurement, and Storage. *In Soil Test Methods from the Southeastern United States*. Southern Cooperative Series Bulletin No. 419. USDA-SERA-IEG-6. ISBN 1-58161-419-5. <http://www.clemson.edu/sera6/MethodsManual-FinalSERA6.pdf>.
- Mylavarapu, R. 2014. Walkley-Black Method. *In Soil Test Methods from the Southeastern United States*. Southern Cooperative Series Bulletin No. 419. USDA-SERA-IEG-6. ISBN 1-58161-419-5. <http://www.clemson.edu/sera6/MethodsManualFinalSERA6.pdf>.
- Hochmuth, G. J., R. Mylavarapu, and E. A. Hanlon. 2014. *Developing a Soil Test Extractant: The Correlation and Calibration Processes*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. SL409/SS622. pp4. <http://edis.ifas.ufl.edu/ss622>.
- Mylavarapu, R., T. A. Obreza, K. Morgan, G. Hochmuth, V. Nair, and A. Wright. 2014b. *Extraction of Soil Nutrients Using Mehlich-3 Reagent for Acid-Mineral Soils of Florida*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. SL407/SS620. pp7. <http://edis.ifas.ufl.edu/ss620>.
- Mylavarapu, R., W. d'Angelo, and N. Wilkinson. 2013a. *Producer Soil Test Form*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. SL135/SS186. pp2. <http://edis.ifas.ufl.edu/ss186>.
- Mylavarapu, R., W. d'Angelo, and N. Wilkinson. 2013b. *Landscape and Vegetable Garden Test Form*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. SL136/SS187. pp2. <http://edis.ifas.ufl.edu/ss187>.
- Mylavarapu, R., W. d'Angelo, and N. Wilkinson. 2013c. *Container Media Test Form*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. SL134/SS185. pp2. <http://edis.ifas.ufl.edu/ss185>.
- Mylavarapu, R., W. d'Angelo, and N. Wilkinson. 2013d. *Water Test Form*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. SL133/SS184. pp2. <http://edis.ifas.ufl.edu/ss184>.
- Mylavarapu, R., W. d'Angelo, and N. Wilkinson. 2013e. *Pine Nursery Soil Test Form*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. SL132/SS183. pp1. <http://edis.ifas.ufl.edu/ss183>.
- Mylavarapu, R., W. d'Angelo, and N. Wilkinson. 2013f. *Commercial Sod Test Form*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. SL393/SS595. pp1. <http://edis.ifas.ufl.edu/ss595>.
- Mylavarapu, R., W. d'Angelo, and N. Wilkinson. 2013g. *Nutrient Testing Form for Bahia Pastures*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. SL395/SS597. pp2. <http://edis.ifas.ufl.edu/ss597>.
- Mylavarapu, R., W. d'Angelo, and N. Wilkinson. 2013h. *Producer Citrus Test Form*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. SL396/SS598. pp2. <http://edis.ifas.ufl.edu/ss598>.
- Mylavarapu, R., W. d'Angelo, and N. Wilkinson. 2013i. *Phosphorus Index Test Form*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. SL394/SS596. pp2. <http://edis.ifas.ufl.edu/ss596>.
- Mylavarapu, R., W. d'Angelo, and N. Wilkinson. 2013j. *Plant Tissue Test Form*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. SL131/SS182. pp1. <http://edis.ifas.ufl.edu/ss182>.
- Mylavarapu, R., W. d'Angelo, and N. Wilkinson. 2013k. *Livestock Waste Testing Form*. Gainesville: University of

- Florida Institute of Food and Agricultural Sciences. SL397/SS599. pp2. <http://edis.ifas.ufl.edu/ss599>.
- Mylavarapu, R., D. Wright, and G. Kidder. 2013L. *UF/IFAS Standardized Fertilization Recommendations for Agronomic Crops*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. SL129/SS163. pp8. <http://edis.ifas.ufl.edu/ss163>.
- Mylavarapu, R., and C. Kerr. 2013a. *Hoja de Información: Análisis de Suelo para Productores*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. SL135-Span/SS604. pp2. <http://edis.ifas.ufl.edu/ss604>.
- Mylavarapu, R., and C. Kerr. 2013b. *Hoja de Información: Análisis de Suelo de Jardines y Huertos*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. SL136-Span/SS605. pp2. <http://edis.ifas.ufl.edu/ss605>.
- Mylavarapu, R., and C. Kerr. 2013c. *Análisis de Medios de Macetas*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. SL134-Span/SS603. pp2. <http://edis.ifas.ufl.edu/ss603>.
- Mylavarapu, R., and C. Kerr. 2013d. *Hoja de Información: Análisis de Agua*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. SL133-Span/SS602. pp2. <http://edis.ifas.ufl.edu/ss602>.
- Mylavarapu, R., and C. Kerr. 2013e. *Hoja de Información: Análisis de Suelo de Pinos*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. SL132-Span/SS601. pp1. <http://edis.ifas.ufl.edu/ss601>.
- Mylavarapu, R., and C. Kerr. 2013f. *Análisis de Suelo para Césped Comercial*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. SL393-Span/SS606. pp1. <http://edis.ifas.ufl.edu/ss606>.
- Mylavarapu, R., and C. Kerr. 2013g. *Análisis de Nutrientes para Pastos de Bahía*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. SL395-Span/SS608. pp2. <http://edis.ifas.ufl.edu/ss608>.
- Mylavarapu, R., and C. Kerr. 2013h. *Hoja de Información: Análisis para Productor de Cítricos*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. SL396-Span/SS609. pp2. <http://edis.ifas.ufl.edu/ss609>.
- Mylavarapu, R., and C. Kerr. 2013i. *Hoja de Información: Índice de Fósforo*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. SL394-Span/SS607. pp2. <http://edis.ifas.ufl.edu/ss607>.
- Mylavarapu, R., C. Kerr. 2013j. *Hoja de Información: Análisis de Tejido Vegetal*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. SL131-Span/SS600. pp1. <http://edis.ifas.ufl.edu/ss600>.
- Mylavarapu, R., C. Kerr. 2013k. *Hoja de Información: Análisis de Estiércol*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. SL397-Span/SS610. pp2. <http://edis.ifas.ufl.edu/ss610>.
- Mylavarapu, R., J. F. Sanchez, J. H. Nguyen, and J. M. Bartos. 2002. Evaluation of Mehlich-1 and Mehlich-3 Extraction Procedures for Plant Nutrients in Acid Mineral Soils of Florida. *Comm. Soil Sci. Plant Anal.* 33(5&6): 807–820.
- Pittman, J. J., H. Zhang, J. L. Schroder, and M. E. Payton. 2005. Differences of phosphorus extracts determined by colorimetric and spectroscopic methods. *Comm. Soil Sci. Plant Anal.* 46:1641–1659.
- Soltanpour, P. N. 1991. Determination of nutrient availability and elemental toxicity by AB-DTPA soil and ICPS. In B.A. Stewart (ed.) *Advances in Soil Science*. 16:165–190.
- Zhang, H., D. H. Hardy, R. Mylavarapu, and J. J. Wang. 2014. Mehlich-3. In *Soil Test Methods from the Southeastern United States*. Southern Cooperative Series Bulletin No. 419. USDA-SERA-IEG-6. ISBN 1-58161-419-5. <http://www.clemson.edu/sera6/MethodsManualFinalSERA6.pdf>.
- Zhang, H., S. Kaiuki, J. L. Schroder, M. E. Payton, and C. Focht. 2009. Interlaboratory validation of the Mehlich 3 method for extraction of plant-available phosphorus. *J AOAC Int.* 92: 91–102.
- Methods for the Determination of Metals in Environmental Samples, Supplement I; USEPA, National Exposure Risk Laboratory-Cincinnati (NERL-CI), EPA/600/R-94/111, May 1994.
- Peters, J. D., ed. *Recommended Methods of Manure Analysis*, Dept. Soil Sci., University of Wisconsin-Madison, WI. Accessed on Dec 1, 2014. <http://uwlabs.soils.wisc.edu/pubs/A3769.pdf>.
- US Environmental Protection Agency (USEPA). 1993. *Methods for the Determination of Inorganic Substances in Environmental Samples*, (NERL-CI), EPA/600/R-93/100. National Exposure Risk Laboratory, Cincinnati, OH.