1.11 Reading and Interpreting Soil Test Reports

Introduction: Reading and Interpreting Soil Test Reports

UNIT OVERVIEW

Soil analyses can help form the basis of a sound soil fertility and plant nutrition program. In this unit, students will learn how to collect soil samples for laboratory analysis, and interpret and use soil analysis report data as a tool for soil quality assessment. Lectures and demonstrations will present the way that soil analysis results can be incorporated into an overall soil management plan. The unit emphasizes the role of soil analyses in developing efficient nutrient budgets and selecting soil amendments and fertilizers for certified organic production systems.

Note: Before introducing the material in this unit, Part 2 of this manual on applied soil science (Units 2.1–2.3) should be presented to students who do not have a background in basic soil physical properties, chemistry, and biology. In addition, Unit 1.1, Managing Soil Fertility, should be presented prior to this unit.

MODES OF INSTRUCTION

> LECTURES (3 LECTURES, 2 HOURS)

Lectures will cover the role of soil analysis in sustainable agriculture, the soil properties measured in a comprehensive soil analysis, and basic considerations in applications of soil amendments and fertilizers.

> DEMONSTRATION 1: TAKING A REPRESENTATIVE SOIL SAMPLE (1.5 HOURS)

Demonstration 1 illustrates the basic procedures involved in taking a representative soil sample for laboratory analysis.

> DEMONSTRATION 2: READING SOIL TEST REPORTS (1.5 HOURS)

In Demonstration 2, students will learn how to read and interpret soil analysis reports and select mineral and organic matter amendments and fertilizers.

> DEMONSTRATION 3: NITROGEN BUDGETING (1 HOUR)

Demonstration 3 offers an example of how a simple nitrogen budget can be calculated for an organic farm or garden.

> DEMONSTRATION 4: FIELD OBSERVATIONS (1.5 HOURS)

Demonstration 4 provides an outline to use in visiting a farm or garden operation for which a soil report has been prepared. This outline will direct students in how to observe the relationship between soil fertility management practices and plant nutrient levels (identified in the soil test) to plant growth and pest responses found in the field.

> HANDS-ON EXERCISE: READING A SOIL TEST AND SELECTING AMENDMENTS (2 HOURS)

Students will be assigned a sample soil analysis report to practice interpretation, conversion to user-friendly form, and formulation of basic fertility programs for short- and long-term goals. The hands-on exercise also includes the development of a simple nitrogen budget.

> ASSESSMENT QUESTIONS (0.5 HOUR)

Assessment questions reinforce key unit concepts and skills.

LEARNING OBJECTIVES

CONCEPTS

- The role of soil analysis in providing current assessments of soil fertility/quality for crop growth
- The necessity of soil analysis in the formulation of accurate amendment recommendations for soil fertility and plant nutrition programs
- The importance of soil fertility in yields, crop health, crop quality, and the resistance and resilience of crop plants to pests and pathogens
- Fertilization trends in modern agriculture and the correlation with pest and disease susceptibility
- Factors involved in nitrogen budgeting and soil organic matter management

SKILLS

- How to access regional soils information
- How to take a representative soil sample
- How to read and interpret soil analysis report data
- How to estimate nutrient needs of several crops
- How to develop amendment and fertilizer recommendations for certified organic production systems
- How to develop an estimated nitrogen budget for your crop(s)
- How to relate observed crop problems to fertility programs

Lecture 1 Outline: Using a Soil Test to Assess Soil Quality

for the instructor

A. Pre-Assessment Questions

1. Characterize the physical, chemical, and biological components of soil fertility.
2. Which soil and plant nutrients affect the physical, chemical, and biological aspects of soil fertility?
3. Which soil and plant nutrients influence crop productivity and the susceptibility of crops to pests and diseases?
4. What negative consequences may result from excess nitrate nitrogen in the soil and in crops?
5. Explain the difference between well-decomposed, stabilized compost and other sources of raw organic matter (e.g., cover crops, manure) in terms of its utility as a soil amendment or fertilizer
6. In order to sustain crop production, what quantity of nutrients must be applied each year?
7. What materials would you use to supply plant available forms of nitrogen, phosphorus, potassium, calcium, magnesium, and micronutrients to your crops in a certified organic farming system?
8. How might one assure that adequate quantities of plant available nitrogen (N) are made accessible to crops without excessive fertilization?

B. Critical Terms in Soil Fertility Management of Organic Systems

1. Amendment
2. Fertilizer

C. The Role of Soil Analysis in Sustainable Agriculture: Reducing Fertilizer Use and Improving Soil Quality and Human and Environmental Health

1. Soil fertility, plant health, and the resistance and resilience of crop plants to pests and pathogens
   a) The soil conditions created by an optimal balance of available plant nutrients
2. Review of soil nutrients as limiting factors in plant growth
   a) Leibig's Law of the Minimum
      i. Example: Barrel analogy
3. Fertilizer, fertilizer use, and soil testing trends in modern agriculture (see Unit 3.1, The Development of U.S.Agriculture)
   a) Leibig oversimplified: Subsequent reductionist interpretations of Leibig's Law
   b) Increased reliance on synthetic nitrogen fertilizer in the U.S. (see Gliessman 1998; U.S. Geological Survey 1998)
   c) An increased intensity of nitrogen fertilizer use (see Young 1999)
   d) The historically low, but increasing use of soil testing in developing amendment and fertilizer plans
4. Excess fertilizer use, pest and disease susceptibility
   a) Over 60 studies have shown that crops grown in soils with excess or deficient nutrients or poor soil physical properties yield less, are more susceptible to pests and pathogens and produce crops with poor post-harvest quality (see Young 1999)

5. Excess fertilizer use and fertilizer pollution (see Unit 3.3, Environmental Issues in Modern Agriculture)
    a) Nitrogen and phosphorus deposition in surface and sub surface water, leading to eutrophication
    b) Nitrate leaching and groundwater contamination
    c) Question: Is there greater efficiency or reduced nutrient runoff from "organic" farms?
6. Summary

D. Soil Testing as a Soil Fertility Management Tool

1. A soil test provides current quantitative information on the nutrient content and the nutrient supplying capacity of a soil
2. Soil analyses can provide an accurate determination of a soil's textural classification
3. A soil analysis provides quantitative data allowing for the comparison of a given soil's nutrient and chemical profile with established agronomic benchmarks of soil fertility
4. Soil analysis also helps to identify nutrients that exists at very low levels—"limiting nutrients"—that may result in acute plant nutrient deficiencies
5. Soil testing provides essential information that may be used in developing nutrient budgets
6. The use of soil tests for periodic monitoring of soil nutrient levels allows a grower to gauge nutrient depletion or accumulation
7. Specialized testing: E.g., toxics, pesticides, heavy metals, nutrient profiles of compost
8. Summary

E. Soil Testing and Recommendation Philosophies

1. Sufficient Levels of Available Nutrients (SLAN) approach
2. Cation Saturation Ratio (CSR) approach
3. Nutrient Build-Up and Maintenance approach
4. Most testing services have established optimal ratios for general soil fertility that are a combination of SLAN, CSR, and Nutrient Build-Up and Maintenance approaches. As different testing services use different extraction techniques, it is import to consult with your local testing service on the system they use in developing recommendations. Always request "best practices" benchmarks from the testing service in order to maintain the highest yield and soil quality.

Detailed Lecture 1 Outline: Using a Soil Test to Assess Soil Quality

for students

A. Pre-Assessment Questions

1. Characterize the physical, chemical, and biological components of soil fertility.
2. Which soil and plant nutrients affect the physical, chemical and biological aspects of soil fertility?
3. Which soil and plant nutrients influence crop productivity and the susceptibility of crops to pests and diseases?
4. What negative consequences may result from excess nitrate nitrogen in the soil and in crops?
5. Explain the difference between well-decomposed, stabilized compost and other sources of raw organic matter (e.g., cover crops, manure) in terms of its utility as a soil amendment or fertilizer.
6. In order to sustain crop production, what quantity of nutrients must be applied?
7. What materials would you use to supply plant available forms of nitrogen, phosphorous, potassium, calcium, magnesium, and micronutrients to your crops in a certified organic farming system?
8. How might one assure that adequate quantities of plant available nitrogen (N) are made accessible to crops without excessive fertilization?

B. Critical Terms in Soil Fertility Management

1. Amendment: An organic matter or mineral material applied to the soil to improve or maintain the physical, chemical, and/or biological properties of the soil. (Contrast to fertilizer, below.)
2. Fertilizer: A readily available and concentrated source of plant nutrients used to supply limiting nutrients to growing plants in order to prevent short-term nutrient deficiencies

C. The Role of Soil Analysis in Sustainable Agriculture: Reducing Fertilizer Use and Improving Soil Quality and Human and Environmental Health

1. Soil fertility, plant health, and the resistance and resilience of crop plants to pests and pathogens
   a) Much like the importance of nutrition to the health of humans, an optimal balance of available plant nutrients will maintain desirable physical, chemical and biological properties of agricultural soils. Proper nutrition will also help prevent nutrient-related plant stress and crop losses through pests, diseases, and poor post-harvest quality.
2. Review of soil nutrients as potential limiting factors in plant growth
   a) Leibig's Law of the Minimum: "Plant production can be no greater than the level allowed by the growth factor present in the least amount to the optimum amount for that factor"
      i. Example: Barrel analogy with staves of varying lengths. The shortest stave (the limiting nutrient) will determine the total volume of water (yield) that can be held.
3. Fertilizer, fertilizer use, and soil testing trends in modern agriculture (see unit 3.1, The Development of U.S. Agriculture)

a) Leibig oversimplified: Subsequent reductionist interpretations of Leibig's Law have tended to focus research and development in soil fertility on defining sufficient levels of individual plant nutrients (see below) and the development of synthetic forms of nutrients in order to maximize crop yields while minimizing input costs. Such an approach to soil fertility management has led to the development and widespread use of synthetic N-P-K; however, overuse of these inputs often results in compromises in soil quality. This approach does not replace soil organic matter nor does it consider the optimal nutrient requirements needed to sustain the desirable physical, chemical, and biological properties of agricultural soils.

b) Increased reliance on synthetic N-P-K fertilizer in the U.S.: From 1940–1980 domestic synthetic nitrogen fertilizer use increased from 9 to 47 million tons/year (see Gliessman1998; U.S. Geological Survey 1998). Trends show steady increase in use of synthetic fertilizers (1983–1996) after steep decline in early 1980s (See www.ers.usda.gov/publications/sb969/sb969b.pdf)

c) An 18% increase in the concentration of nitrogen in fertilizer formulations from 1960–1995, resulting in increased intensity of nitrogen fertilizer use per acre (see Young 1999)

d) The use of soil testing in developing amendment and fertilizer plans: Many U.S. farmers have historically fertilized routinely using concentrated N-P-K fertilizers without determining the actual nutrient needs of the crops through soil analysis and nutrient budgeting. This has led in some instances to the overapplication of N-P-K fertilizers, while other limiting plant nutrients for soil chemical and physical properties have been overlooked.

4. Excess fertilizer use, pest and disease susceptibility

   a) Over 60 studies have indicated that crops grown in soils with excess or deficient nutrients or poor soil physical properties yield less, are more susceptible to pests and pathogens, and produce crops with poor post-harvest quality (see Young 1999)

5. Excess fertilizer use and fertilizer pollution (see Unit 3.3, Environmental Issues in Modern Agriculture)

   a) Nitrate enters streams and lakes mainly via leaching and subsurface flow; some organic N and ammonium are also deposited via runoff and erosion. Runoff and erosion are also major route for phosphorus. These nutrients may pollute surface waters, leading to eutrophication and the degradation of aquatic ecosystems

   b) Excess nitrate may also leach into groundwater, increasing the incidence of nitrate poisoning of infants and children. Subsurface flow down slopes is a major route for nitrate entering rivers and other waterways.

   c) Is there greater efficiency or reduced nutrient runoff from "organic" farms? Without proper nutrient budgeting and efficient amending, excessive organic matter-based fertilizer inputs into "organic" farms may also contribute to nutrient runoff resulting in similar environmental problems. It is therefore critical that both short- and long-term nutrient budgets be established in order to assure a balance of nutrient inputs (amendments, fertilizers) with outputs (harvest) and crop demand, and avoid excessive fertilization.

6. Summary: Soil nutrient deficiencies decrease soil quality and increase the risks of plant stress, poor yields, and susceptibility of crop plants to both pests and pathogens. Equally so, the overuse of synthetic or organic matter-based fertilizers may increase disease and pests incidences, reduce crop quality, and lead to environmental pollution and human health risks due to dietary exposure to nitrate. Without the replacement of soil organic matter, synthetic fertilizers pose the additional risks of soil degradation and eventual yield decreases. Soil analysis is therefore the foundation of a rational and efficient use of soil amendments and fertilizers that may help develop productive agricultural soil and at the same time avoid the problems associated with the overuse of fertilizers.

D. Soil Testing as a Soil Fertility Management Tool

1. A soil test provides current quantitative information on the nutrient content and the nutrient-supplying capacity of a soil (e.g., a quantitative measurement of the cation exchange capacity, or ppm N, P, K, Mg, etc.)
2. Soil analyses can provide an accurate determination of a soil's textural classification, which may help a grower anticipate how a soil will respond to cultivation as well as the soil's nutrient- and water-holding capacity
3. A soil analysis provides quantitative data allowing for the comparison of a given soil's nutrient and chemical profile with established benchmarks for each property. This helps to identify nutrient levels (or soil chemical properties such as pH) that are above or below optimal benchmarks. This may be remedied over the long term with annual soil amending.
4. Soil analysis also helps to identify nutrients that exist at very low (limiting nutrients) or very high (potentially toxic) levels that may result in acute plant nutrient deficiencies or toxicity. Once identified, these soil nutrient imbalances may be addressed through amending and/or a supplemental fertilizing program.
5. Soil testing provides essential information (e.g., estimated nitrogen release) that may be used in developing efficient nutrient budgets for your crops (see nitrogen budgeting, below)
6. Soil testing allows for periodic monitoring of soil chemical properties in order to maintain the soil nutrient levels (and chemical properties such as pH) within the established optimal ranges and may serve as an accurate indicator of nutrient depletion or accumulation
7. Specialized testing may be used for specific soil nutrients of concern, to test the nutrient content of composts, as well as to determine the presence of pesticides, heavy metals, or other potentially toxic compounds in a soil. See Resources section for testing services.
8. Summary: Soil analysis is the foundation of a rational and efficient use of soil amendments and fertilizers. When properly applied, these inputs—along with other sound agricultural practices—will help develop productive agricultural soil and avoid the environmental and pest management problems associated with nutrient deficiencies and the overuse of fertilizers.

E. Soil Testing and Recommendation Philosophies

1. Sufficient Levels of Available Nutrients (SLAN): The SLAN approach states that there are definable levels of individual nutrients in the soil below which crops will respond to fertilizers, and above which they likely will not respond through changes in measurable yield or reduction of deficiency symptoms. Building levels of soil nutrients above the point at which a yield increase is observed is considered inefficient.
2. Cation Saturation Ratio (CSR): The CSR approach states that there are optimal ratios of certain cation soil nutrients (e.g., calcium, magnesium, potassium, and sodium) that when present in agricultural soils lead to greater soil quality (physical, chemical, and biological properties), crop and animal health, an increased resistance to pests and pathogens (pre- and post harvest), and increased crop productivity.
3. Nutrient Build-Up and Maintenance: This approach calls for initial application(s) of given deficient nutrients in quantities that will raise the soil level of those nutrients to the point where crop yields are maximized. This is followed by annual amendment applications that will maintain a non-limiting soil nutrient level. It is often suggested that such build-up be done over a 2- to 4-year period. This approach emphasizes the major nutrients (nitrogen, phosphorus, and potassium) and does not focus equally on all 13 essential plant nutrients.
4. Most testing services have established optimal ratios for general soil fertility that are a combination of SLAN, CSR, and Nutrient Build-Up and Maintenance approaches. As different testing services use different extraction techniques, it is import to consult with your local testing service on the system they use in developing amendment recommendations. Always request "best practices" benchmarks for maintaining soil quality if different than above.

Note that different soils can require different nutrient extraction techniques, e.g., some are developed for soils with a given pH range and will give misleading results for soils outside of that range. Also, the presence of high levels of certain compounds in the soil may distort soil tests and require different extraction techniques.

The specific nutrient levels listed in this unit are based on the extraction techniques used at specific laboratories. Although over 90% of U.S. agricultural testing services use the same extraction techniques, some variation exists.

NOTE: It is **critical** that one confirms the specific "optimal" levels used in this unit with those used by your local testing service. The optimal levels presented in this unit are examples of those used by many A & L National Agricultural Laboratories.

Lecture 2: Properties Measured in a Soil Analysis

for the instructor

A. Review of the Soil Properties Measured in a Comprehensive Soil Analysis
(see appendix 1, Sample [Blank] Soil Analysis Report)

1. Percent (%) Organic Matter
   a) Defined
   b) Desirable range for percent organic matter for one's climate
2. Estimated Nitrogen Release (ENR)
   a) ENR defined
   b) The accuracy of ENR figures, an estimate of the ENR of one year
   c) How to use ENR figures (discussed in Demonstration 3, Nitrogen Budgeting)
      i. ENR and annual crops: Use 60% of the ENR figure in nitrogen budgeting
      ii. ENR and perennial crops: Use 80% of the ENR figure in nitrogen budgeting
3. Extractable phosphorus (P): Two types of tests are commonly used to illustrate the phosphorus availability at different pH levels. Soil phosphorus availability is highly dependent on soil pH (see phosphorus section in Unit 2.2, Soil Chemistry and Fertility).
   a) Available phosphorus (P1) Weak Bray method for soils with pH below 6.2
      i. Optimal levels of more readily available phosphorus (P1): 30–40 ppm
   b) Olsen sodium bicarbonate extraction for soil with pH above 7.5
      i. Optimal levels of phosphorus: 55–65 ppm at pH of 6.2; 12–15 ppm at pH of 7.0
4. Extractable potassium/Potash (K)
   a) Optimal levels of available K
      i. The optimal level of K in a given soil is 2–5% of the cation saturation (may be higher in sandy soils)
      ii. Total amount (in ppm) to achieve this based on the CEC of the soil (discussed in greater detail in Demonstration 2, Reading and Interpreting a Soil Analysis Report)
      iii. Optimal levels for course-textured (sandy) soils range from 150–175 ppm; for heavy-textured (clay) soils, 175–250 ppm
5. Extractable magnesium (Mg)
   a) Optimal levels of available Mg
      i. The total amount (in ppm) to achieve this is based on the CEC of the soil (discussed in greater detail in Demonstration 2)
      ii. Optimal range of Mg: 100–250 ppm. Soils with Mg levels over 25% of cation saturation often exhibit drainage problems and require attention.
      iii. The optimal level of Mg in a given soil is 10–20% of the cation saturation (10% on clay soils, 20% on sandy soils)
6. Extractable calcium (Ca)
   a) Optimal levels of available Ca
      i. The optimal level of Ca in a given soil is 65–75% of the cation saturation
      ii. The total amount (in ppm) to achieve this based on the CEC of the soil (discussed in greater detail in Demonstration 2)

7. Sodium (Na) (not a necessary plant nutrient)
   a) Optimal levels of available Na
      i. The optimal level of Na in a given soil is 0–5% of the cation saturation
      ii. Sodium levels exceeding 5% of cation saturation may result in adverse physical and or chemical conditions. The total amount (in ppm) to achieve this based on the CEC of the soil (discussed in greater detail in Demonstration 2)
8. pH defined
   a) Example: A pH of 7.0 is neutral (e.g., pure water). Low pH is acid (e.g., lemon juice or vinegar pH ~4.0). A high pH is referred to as basic or alkaline (e.g., lye pH ~9.0).
   b) Optimal pH range: ~6.0–7.0 for a mineral soil; 5.5–6.0 for an organic soil
9. Buffer index: An index based on the soil pH that is used to estimate the amount of agricultural lime needed to raise a soil with a pH of 6.5 or less to several higher pH levels (6.0 and 6.5)
10. Hydrogen (H) ion concentration
11. Cation Exchange Capacity (CEC)
12. Percent cation saturation
    a) % Potassium (K): 2–5% (may be slightly higher in sandy soils)
    b) % Magnesium (Mg): 10–20% (10% in clay soils, 20% in sandy soils)
    c) % Calcium (Ca): 65–75%
    d) % Hydrogen (H): 0–20%
    e) % Sodium (Na): 0–5%
13. Nitrate nitrogen (NO_3^-)
14. Sulfate (SO_4^-), Sulfur (S)
    a) Optimal levels of available S: 25–35 ppm
15. Micronutrients/trace elements
    a) Zinc (Zn)
       i. Optimal levels of available Zn: 1.1–3.0 ppm (DTPA extraction)
    b) Manganese (Mn)
       i. Optimal levels of available Mn: 9–12 ppm (DTPA extraction)
    c) Iron (Fe)
       i. Optimal levels of available Fe: 11–16 ppm (DTPA extraction)
    d) Copper (Cu)
       i. Optimal levels of available Cu: 0.9–1.2 ppm (DTPA extraction)
    e) Boron (B)
       i. Optimal levels of available B: 0.6–1.2 ppm (hot water extraction)
    f) Plant tissue analysis is the most reliable way to monitor for adequate levels of micronutrients. See *A & L Agronomy Handbook* in Resources section.
16. Excess lime defined
17. Soluble salts defined
    a) Optimal levels of available soluble salts: Less than 2.0 mmhos/cm
18. Chloride (Cl)
19. Soil texture

B. Reading and Interpreting a Soil Analysis Report (Demonstration 2); Developing a Nitrogen Budget (Demonstration 3)

Following Lecture 2, students should be introduced to reading and interpreting a soil analysis report (refer to Demonstration 2) and be shown how to develop a simple nitrogen budget (Demonstration 3).

Detailed Lecture 2 Outline: Properties Measured in a Soil Analysis

for students

A. Review of the Soil Properties Measured in a Comprehensive Soil Analysis
(see appendix 1, Sample [Blank] Soil Analysis Report)

1. Percent (%) Organic Matter
   a) Defined: The measurement of the percent organic matter content of a soil. Includes raw and soil organic matter. Not a measure of the quality of organic matter.
   b) Desirable range for percent organic matter: As climate influences the ability of organic matter to accumulate, no benchmarks for soil organic matter (SOM) can be broadly applied. A 3–5% organic matter content in cool temperate climates is desireable.
2. Estimated Nitrogen Release (ENR)
   a) ENR defined: The amount of plant available nitrogen in lbs/acre estimated to be released through the mineralization of the currently existing soil organic matter during a single growing season
   b) The accuracy of ENR figures: The amount of nitrogen liberated from the decomposition of organic matter is dependent upon soil biological activity. This activity is influenced by soil and environmental conditions such as climatic conditions; soil pH; the chemical composition of the organic matter; soil aeration; and soil moisture, among others. Therefore, the ENR figure listed in the soil analysis report is strictly an estimate.
   c) How to use ENR figures: ENR data are one set of figures (added to the nitrogen contributions of compost and cover crops) that are used in calculating a nitrogen budget for your crop(s). (See nitrogen budgeting exercise, appendix 3 and appendix 4)
      i. ENR and annual crops: Use 60% of the ENR figure listed on the soil test for annual crop production
      ii. ENR and perennial crops: Use 80% of the ENR figure listed on the soil test for perennial crop production
3. Extractable phosphorus (P): Two types of tests are commonly used to illustrate the phosphorus availability at different pH levels
   a) Available phosphorus (P1) Weak Bray method for soils with pH below 6.2
      i. Optimal levels of more readily available phosphorus (P1): 30–40 ppm
   b) Olsen sodium bicarbonate extraction for soil with pH above 7.5
      i. Optimal levels of phosphorus: 55–65 ppm at pH of 6.2
4. Extractable potassium/potash (K): The amount of exchangeable K in ppm found in a given soil sample
   a) Optimal levels of available K
      i. The optimal level of K in a given soil is 2–5% of the cation saturation.
      ii. Total amount (in ppm) to achieve this is based on the CEC of the soil (see Demonstration 2 for greater detail)
      iii. Optimal levels for course-textured soils range from 150–175 ppm; for heavy-textured soils, 175–250 ppm
5. Extractable magnesium (Mg): The amount of exchangeable Mg in ppm found in a given soil sample
   a) Optimal levels of available Mg
      i. The total amount (in ppm) to achieve this is based on the CEC of the soil (see Demonstration 2 for greater detail)

ii. Optimal range of Mg: 100–250 ppm. Soils with Mg levels over 23% of cation saturation often exhibit drainage problems and require attention.
iii. The optimal level of Mg in a given soil is 10–20% of the cation saturation

6. Extractable calcium (Ca): The amount of exchangeable calcium in ppm found in a given soil sample
   a) Optimal levels of available Ca
      i. The optimal level of Ca in a given soil is 65–75% of the cation saturation
      ii. The total amount (in ppm) to achieve this is based on the CEC of the soil (see Demonstration 2 for greater detail)
7. Sodium (Na): The amount of exchangeable sodium in ppm found in a given soil sample
   a) Optimal levels of available Na
      i. The optimal level of Na in a given soil is 0–5% of the cation saturation. Sodium levels exceeding 5% of cation saturation may result in adverse physical and/or chemical conditions. The total amount (in ppm) to achieve this is based on the CEC of the soil (see Demonstration 2 for greater detail).
8. pH: The measurement of the acidity or alkalinity of a given soil (determined by the concentration of hydrogen ions)
   a) Example: A pH of 7.0 is neutral (e.g., pure water). Low pH is acid (e.g., lemon juice or vinegar pH ~4.0). A high pH is referred to as basic or alkaline (e.g., lye pH ~9.0).
   b) Optimal pH range: 6.3–6.8 for a mineral soil; 5.5–6.0 for an organic soil (see Unit 2.2, Soil Chemistry and Fertility)
9. Buffer index: An index based on the soil pH that is used to estimate the amount of agricultural lime needed to raise a soil with a pH of 6.5 or less to several higher pH levels (6.0 and 6.5)
10. Hydrogen: A measurement of the hydrogen ion concentration in meq/100g of soil in a given soil sample. As the hydrogen ion concentration increases, soil acidity will correspondingly increase, represented by a decrease in pH.
11. Cation Exchange Capacity: A measurement of the soil's ability to hold and exchange cation nutrients (e.g., Ca, Mg, Na, K, hydrogen) with growing plants. The sum of the exchangeable cations. The CEC of a soil is influenced by the amount and types of clays and organic matter in the soils; soils with higher clay and organic matter content usually have higher CECs, and are therefore the most fertile (see Unit 2.2, Soil Chemistry and Fertility).
12. Percent (%) saturation: The relative percentages of the major cation nutrients found occupying cation exchange sites in a given soil. (Balances recommended by most agronomists are given below. Totals of these percentages should add up to 100.)
   a) % Potassium (K): 2–5%
   b) % Magnesium (Mg): 10–15%
   c) % Calcium (Ca): 65–75%
   d) % Hydrogen (H): 0–20%
   e) % Sodium (Na): 0–5%
13. Nitrate nitrogen (NO_3^-): The amount of water-soluble nitrogen (nitrate) in ppm found in a given soil sample. Not a reliable test in organic farming systems for determining the need for nitrogen inputs.
14. Sulfate (SO_4^-) sulfur (S): The total amount of sulfur in ppm found in a given soil sample
   a) Optimal levels of available S: 25–35 ppm
15. Micronutrients/trace elements
   a) Zinc (Zn): The extractable amount of zinc (in ppm) found in a given soil sample
      i. Optimal levels of available Zn: 1.1–3.0 ppm (DTPA extraction)
   b) Manganese (Mn): The extractable amount of Mn (in ppm) found in a given soil sample
      i. Optimal levels of available Mn: 9–12 ppm (DTPA extraction)

c) Iron (Fe): The extractable amount of Fe (in ppm) found in a given soil sample
   i. Optimal levels of available Fe: 11–16 ppm (DTPA extraction)
d) Copper (Cu): The extractable amount of Cu (in ppm) found in a given soil sample
   i. Optimal levels of available Cu: 0.9–1.2 ppm (DTPA extraction)
e) Boron (B): The extractable amount of B (in ppm) found in a given soil sample
   i. Optimal levels of available B: 0.6–1.2 ppm (hot water extraction)
f) Plant tissue testing is the most accurate way to gauge adequate micronutrient levels. See *A & L Agronomy Handbook* in Resources section.

16. Excess lime: A visual observation and rating of carbonates in a soil sample. High levels of free lime present may interfere with nutrient availability.
17. Soluble salts: Total measurement of soluble salts by electrical conductivity. High levels indicate higher risk of plant toxicity due to salt accumulation from fertilizers, poor irrigation water, or chemical contamination.
    a) Optimal levels of available soluble salts: Less than 2.0 mmhos/cm
18. Chloride
19. Soil texture: The relative proportions (percentage) of sand, silt, and clay particles measured in the soil anslysis

Lecture 3 Outline: Applying Soil Amendments and Fertilizers

for the instructor

A. Applying Soil Amendments and Fertilizers
(see www.groworganic.com for more information on materials, and equipment for amending and fertilizing)

1. Soil amendments
   a) Timing of amending
   b) Quantities to apply in a given year
      i. Example: Agricultural lime and micronutrients
   c) Depth of incorporation of soil amendments
   d) Tools and techniques used for incorporating soil amendments

B. Supplemental Fertilizing

a) Timing of fertilizing
b) Quantities to apply in a given year
c) Application of supplemental fertilizers
   i. Foliar application
   ii. Soil-based application
d) Tools used for incorporating fertilizers
   i. Spray rigs or backpack sprayers
   ii. Fertigation
   iii. Others

C. Hands-On Exercise: Reading and Interpreting Soil Analysis Reports, Nutrient Budgeting, and Selecting Mineral and Organic Matter
Demonstration 4: Field Observations

Following Lecture 3, students should practice reading and interpreting soil analysis reports, nutrient budgeting, and selecting soil amendments (refer to the Hands-On Exercise). Students should also visit a working farm or garden operation for which a soil test has been done (refer to Demonstration 4, Field Observations for a discussion of soil fertility and nutrient management practices on a working farm).

Detailed Lecture 3 Outline: Applying Soil Amendments and Fertilizers

for students

A. Applying Soil Amendments and Fertilizers
(see www.groworganic.com for more information, materials and equipment for amending and fertilizing)

1. Soil Amendments
   a) Timing of amending: Early fall is a preferred time for soil amending with mineral amendments as it allows for several months of winter to elapse during which mineral amendments break down, making the nutrients more available in the spring
   b) Quantities to apply in a given year: Total quantities of amendments to be applied will depend on the levels of soil nutrients reported in a soil analysis report and determined necessary through nutrient budgeting. If soil tests indicate the need for large quantities of amendments, growers should follow the manufacturers' and agronomists' recommendations for application rates, as the potential toxicity of different soil amendments to the soil and crops is highly variable.
      i. Example: Agricultural gypsum with a low potential toxicity may be applied when indicated by a soil test to the soil at an annual rate of 2+ tons/acre, whereas most micro-/trace elements have a high potential toxicity and should be applied sparingly, often at 0.5–2 gallons/acre
   c) Depth of incorporation of soil amendments: Soil amendments should be evenly incorporated into the depth of tillage, or banded down rows in the case of accute nutrient deficiencies
   d) Tools and techniques used for incorporating soil amendments: Soil amendments may best be incorporated with cover crops seed in the fall using similar equipment

B. Supplemental Fertilizing

a) Timing of fertilizing: The timing of supplemental fertilizing is determined by need based on plant tissue testing and/or growth response observations
b) Quantities to apply in a given year: The concentration of nutrients varies in various supplemental fertilizers; follow the manufacturer's and agronomists' recommendations for application rates
c) Application of supplemental fertilizers
   i. Foliar application: Foliar fertilizers are sprayed directly on the growing plants and are absorbed through the stomata. Foliar fertilizers should be applied during cool parts of the day (when the greatest number of stomata are most open) and to the underside of the leaves (where the greatest concentration of stomata are located).
   ii. Soil-based application: Supplemental fertilizers may be injected into the irrigation system (requires filtration) or applied directly to the soil surface around the root systems of the crops. If applied directly to the soil surface it is generally recommended to apply the fertilizer prior to irrigation.
d) Tools used for incorporating fertilizers
   i. Spray rigs or backpack sprayers may be used on a field and garden scale to apply mist and liquid fertilizers
   ii. Fertigation (injecting fertilizer through irrigation equipment): See equipment suppliers for specialized equipment and formulations
   iii. Others

Demonstration 1:
Taking a Soil Sample for Laboratory Analysis

for the instructor

OVERVIEW

Collecting a representative sample of a given soil is critical to receiving accurate soil analysis information. In this demonstration, the instructor should discuss the sampling considerations given in the Demonstration Outline, and demonstrate the tools and techniques used to take soil samples and prepare a suitable sub-sample for laboratory analysis.

RESOURCES AND REFERENCES

- *Agronomy Handbook: Soil and Plant Analysis*. A & L Western Agricultural Laboratories, Inc. 1311 Woodland Ave., #1. Modesto, California 95351. (209) 529-4736
- Magdoff, Fred and Harold Van Es. *Building Soils for Better Crops, Second Edition*. Handbook Series Book 4, Sustainable Agriculture Network. Ch. 19: Getting The Most Out of Soil Tests. Available from www.sare.org.

PREPARATION AND MATERIALS

- Stainless steel or chrome soil auger or stainless steel trowel
- Plastic buckets
- Sample bags from laboratory
- County soil survey maps
- Laboratory forms for submitting sample and request for analysis
- Notebook, pen, and folder for documenting
- Student prepatory reading: A & L Reference Guide—"Soil Sampling"

PREPARATION TIME

1.5 hours

DEMONSTRATION TIME

1.5 hours

DEMONSTRATION OUTLINE

A. Sampling Procedures

1. Sample area
   a) First discuss the use of County soil maps to help delineate regional variations in soil textural classifications
   b) Different soil types (texture and color), distinct crop growth response areas, or soil treatment areas are sampled separately
   c) Each sample should be from a plot no larger than 40 acres
   d) Avoid: Corners of fields, poorly drained areas, and 50 feet from structures and roads
   e) Problem areas: Sample "problem" areas (e.g., poor drainage, poor plant growth responses) and "good" areas for comparison; include surface and subsoil sample for problem areas
   f) Varying terrain: Sample bottom land and hills separately
2. Time of year to sample
   a) Samples may be taken at any time (though fall is often recommended)
   b) Be consistent from year to year with sampling time and testing service
   c) Combining soil samples and plant tissue samples with plant growth observations
   d) Frequency
      i. Initial stages of soil development and intensive cropping systems: 1x/year
      ii. Once chemical benchmarks have been reached: 1x/2-3 years
3. Demonstrate tools used in sampling
   a) Stainless steel soil auger, steel trowel, or spade/shovel
   b) Plastic buckets
   c) Sample bags from lab
4. Demonstrate sampling depth (should be consistent from year to year)
   a) Initial sampling
      i. Remove plant residues from surface (do not include this or other distinguishable forms of organic matter in sample)
      ii. Sample distinct soil horizons separately (e.g., A and B horizons), if within the depth tillage, noting depth to each horizon
   b) Subsequent sampling
      i. Remove plant residues from surface (do not include in sample)
      ii. Sample to 12 inches or depth of tillage unless problem soil (see below)
      iii. Include entire soil profile from auger core or soil slice
   c) "Problem" soils
      i. Include separate surface and sub-soil sample (inquire with testing service)
   d) Orchard systems
      i. Pre-plant depth: Sample to depth of tillage
      ii. In established no-till orchards: Sample to 6 inches in depth
5. Demonstrate sample size
   a) 2 cups of soil sub-sampled from well-mixed composite of 10–20 random samples, including for textural classification
   b) 2 cups each for nematodes, pesticide residues, or other specialized sampling
6. Demonstrate sample preparation
   a) Mix cores or slices together
   b) Fill sample bag provided with sub-sample (no need for further processing)

7. Completing lab forms and personal documenting
    a) Location of sample/field
    b) Date
    c) Previously grown crops and/or crops to be grown
    d) Sample depth
    e) Specific type of analysis to request
        i. Initial soil analysis
        ii. Problem soils/trouble shooting
    f) Plant growth responses
8. Specialized sampling (separate test for each)
    a) Pesticides (inquire with testing service)
    b) Nematodes (inquire with testing service)
    c) Problem soils (inquire with testing service)
    d) Compost analysis (inquire with testing service regarding organic amendment sampling)

Demonstration 1: Taking A Representative Soil Sample For Laboratory Analysis

step-by-step instructions for students

INTRODUCTION

The key to receiving accurate soil analyses information is to properly collect and submit a representative sub-sample of a given soil. Follow the steps outlined in these instructions when taking a soil sample for laboratory analysis.

PREPARATION AND MATERIALS

- Stainless steel or chrome plated soil auger or stainless steel trowel
- Plastic buckets
- Sample bags from soil testing laboratory
- County soil survey maps

RESOURCES AND REFERENCES

- For a review of plant analysis techniques see: *Agronomy Handbook: Soil and Plant Analysis.* Chapter II. A & L Western Agricultural Laboratories, Inc. 1311 Woodland Ave., No. 1. Modesto, California 95351. (209) 529-4736
- Illustrated soil sampling techniques: www.back-to-basics.net/efu/pdfs/sampling.pdf
- Magdoff, Fred, and Harold Van Es. *Building Soils for Better Crops, Second Edition*. Chapter19, Getting the Most Out of Soil Tests

STUDENT OUTLINE

A. Sampling Procedures

1. Sample area
   a) County soil maps may help delineate regional variations in soil textural classifications and land uses for that soil type
   b) Different soil types, including texture, color, distinct crop growth response areas and/or soil treatment areas should be sampled separately
   c) Sample from areas of 40 acres or less
   d) Avoid: Corners of fields, poorly drained areas and 50 feet from structures and roads
   e) Problem areas: Sample "problem" areas (e.g., poor drainage or poor plant growth responses) and "good" areas for comparison; include surface and subsoil sample
   f) Varying terrain: Sample bottom land and hills separately

2. Time of year to sample
   a) Samples may be taken at any time (though fall is often recommended)
   b) Be consistent from year to year with sampling time, locations, and testing service
3. Frequency of sampling
   a) Initial stages of soil development and intensive cropping systems:1x/year
   b) Once chemical benchmarks have been reached: 1x/2–3 years
4. Tools to use when taking soil samples
   a) Stainless steel soil auger, stainless steel trowel or stainless spade/shovel
   b) 5-gallon plastic buckets (to hold 15–30 cups of soil total)
   c) Sample bags from testing agency
5. Sampling depth (should be consistent from year to year)
   a) Initial sampling
      i. Remove plant residues from surface (do not include in sample)
      ii. Sample distinct soil horizons separately (e.g. , A and B horizons), if within the depth of tillage, noting depth to each horizon
   b) Subsequent sampling
      i. Remove plant residues from surface (do not include in sample)
      ii. Sample to 12 inches unless problem soil (see below)
      iii. Include entire soil profile from auger core or soil slice
   c) Problems soils
      i. Include separate surface and sub-soil sample (inquire with testing service)
   d) Orchard systems
      i. Pre-plant depth: Sample to depth of tillage
      ii. In established no-till orchards: Sample to 6 inches in depth
6. Sample size
   a) 2 cups of soil sub-sampled from well-mixed composite of 10–20 random samples, including for textural classification
   b) 2 cups each for nematodes, pesticide residues, or other specialized sampling
7. Sample preparation
   a) Mix cores or slices together from 10–20 random samples
   b) Fill sample bag provided with 1.5 cups of soil sub-sampled from well mixed composite
   c) No need for further processing
   d) For problem soils, submit soil sample with a plant tissue sample and description of plant growth observations when trouble shooting poor crop growth responses (see sample depth, above)
8. Completing lab forms and personal documenting
   a) Location of sample/field
   b) Date
   c) Crop previously grown and/or those to be grown
   d) Sample depth
   e) Specific type of analysis requested (inquire with testing service)
   f) Observations of plant growth responses, if problems
9. Specialized sampling
   a) Pesticides (inquire with testing service for specific sampling procedures and sample volumes)
   b) Nematodes (inquire with testing service)
   c) Problem soils (inquire with testing service)
   d) Compost analysis (inquire with testing service about organic matter amendment sampling)

Demonstration 2: Interpreting a Soil Test Report

for the instructor

OVERVIEW

This demonstration introduces students to reading and interpreting sample soil analysis reports. Based on these reports, students will learn to select the appropriate types and amounts of soil amendments and fertilizers for use in certified organic production systems. Such interpretation skills will provide students with the ability to develop both amendment recommendations for long-term soil fertility management plans and address acute soil and plant nutrient deficiencies through proper supplemental fertilization.

Following the outline below, demonstrate and discuss each step in the interpretation process, beginning with a description of the Nutrient Budgeting Worksheets (appendix 2) used to track calculations. Using the appendices listed below, demonstrate and discuss the following: Reviewing the accuracy of sampling information; use of the analysis report to describe the general characteristics of the sampled soil; how to transfer data to the nutrient budgeting worksheets and convert figures from ppm tested to lbs/acre of soil nutrients; the contrasting of soil nutrient levels with defined optimal levels to define limiting and/or excess soil nutrients; selecting the type and quantities of soil amendments to address limited or imbalanced soil nutrients or soil chemical properties.

The instructor should explain amendment options, including the advantages and disadvantages of each option and their relative environmental and financial costs. An example of a nitrogen budget should be calculated using the nitrogen budgeting worksheets, factoring ENR from compost, cover crops, and existing soil organic matter (see Demonstration 3, Nitrogen Budgeting). This pair of demonstrations should be followed by the Hands-On Exercise in which students are asked to read and interpret a sample soil analysis report, select amendments and fertilizers, and develop a simple nitrogen budget for a hypothetical farm or garden operation.

PREPARATION AND MATERIALS

- Sample lab analyses report reproduced on overhead transparency (OHT)

The following appendices on (OHT):

- Appendix 1, Blank Sample Test
- Appendix 2, Nutrient Budgeting Worksheets
- Appendix 5, Supplemental Fertilizers Worksheet
- Appendix 6, Optimum Nutrient Levels of Major Cations Based on CEC
- Appendix 7, Nutrient Profiles of Common Fertilizers and Amendments
- Appendix 8, Fertilizer Solutions Chart
- Agricultural supply catalogues for National Organic Program-approved amendments and fertilizers: Peaceful Valley Farm Supply, www.groworganic.com/
- Overhead projector
- Pen for writing on OHT

PREPARATION TIME

1 hour

DEMONSTRATION TIME

1.5 hours

DEMONSTRATION OUTLINE

A. Goals of the Session

- To teach students how to read and interpret sample soil analysis reports and how to calculate the proper amounts of mineral and organic matter soil amendments needed to make the necessary soil adjustments using the Nutrient Budgeting Worksheets
- To teach students how to determine the need for supplemental fertilizers
- To teach students how to develop an estimated Nitrogen Budget for crops

B. The Role of Nutrient Budgeting Worksheets

Nutrient Budgeting Worksheets are a format for tracking calculations to determine the type and quantities of soil amendments and fertilizers, if any, to use in adjusting the chemical properties of a given soil. Will also demonstrate if you are adding more nutrients than are removed in the crop harvests. Any excess will either accumulate in the soil (soil tests over number of years should show this) or be lost to the environment.

C. Using a sample soil test report and the Nutrient Budgeting Worksheets (Appendix 2), demonstrate reviewing the accuracy of sampling report information

1. Name
2. Field identification name/number
3. Date sampled
4. Crop
5. Soil depth from which sample was taken

D. Demonstrate transcribing the following data from the soil report to the Nutrient Budgeting Worksheets to help isolate the general agronomic characteristics of the soil

1. Soil textural classification
2. Soil pH
3. Organic matter
4. Excess carbonates/lime
5. CEC
6. Buffer pH
7. Soluble salts
8. Describe and discuss the general agronomic characteristics of the soil based on the lab report

E. Demonstrate transcribing all of the nutrient levels tested in ppm from the lab report to the "ppm tested" (Row A) of the Nutrient Budgeting Worksheets

1. Soil cations
   a) Calcium (Ca):
   b) Magnesium (Mg):
   c) Potassium/Potash (K):
   d) Sodium (Na):
   e) Hydrogen (H) ion concentration:
2. Macronutrients
   a) Available phosphorus (P1) Weak Bray method:
   b) Olsen method phosphorus (P2) extraction:
   c) Nitrate nitrogen (NO_3^-):
   d) Sulfate (SO_4^-) Sulfur (S):

3. Micronutrients/trace elements:
   a) Zinc (Zn)
   b) Manganese (Mn)
   c) Iron (Fe)
   d) Copper (Cu)
   e) Boron (B)

F. Demonstrate transcribing all of the qualitative descriptors (High, Med, Low, etc.) of the nutrient levels into Row G of Nutrient Budgeting Worksheets

G. Demonstrate transcribing the "Percent Cation Saturation" ratios from the soil test to the %CSR (Row H) of the Nutrient Budgeting Worksheets

1. % Potassium (K)
2. % Magnesium (Mg)
3. % Calcium (Ca)
4. % Hydrogen (H)
5. % Sodium (Na)

H. Demonstrate converting all the nutrient levels tested in ppm to lbs/ac (listed in E, above)

1. Demonstrate multiplying nutrient levels tested in ppm (Row A) by conversion factors (Row C) and placing the sum in Row E
2. Explain the conversion factors used in converting ppm to lbs/acre

I. Demonstrate determining the ppm optimal range (Row B) for the major cation (Ca, Mg, K) nutrients using the CSR (Row H), the CEC of the tested soil, and Appendix 6

1. Ca
2. Mg
3. K

J. Demonstrate determining lbs/ac optimal range for major cations

1. Multiply Row B by Row C = Row D

K. Demonstrate calculating lbs/ac of actual nutrient required for all nutrients

1. Demonstrate subtracting "lbs/acre tested" (Row E) from "lbs/ac optimal range" (Row D) = "lbs/acre of actual nutrient required" (Row D - Row E = Row F)

L. Demonstrate selecting appropriate mineral amendments to supply needed nutrients

1. Review Row G of Nutrient Budgeting Worksheets for "Very High" nutrient levels in order to avoid selecting amendments that would add nutrients that already exist at a very high level
2. Select soil amendment using appendix 8, the Fertilizer Solutions Chart and/or agricultural supply catalogues (see Resources section)

M. Demonstrate determining the nutrient content (by percentage) of amendments using appendix 7 and/or agricultural supply catalogues (see Resources section)

1. Transcribe nutrient percentages into Row K, "Nutrient content by %," of the Nutrient Budgeting Worksheets (convert % to decimal, e.g., 39% = 0.39)

N. Demonstrate calculating lbs/acre of the amendment required to increase the nutrient level to the optimal range

1. Divide the "lbs/acre of nutrient required" (Row F) by the "Nutrient content by percentage/%"(Row K) of the soil amendment to be used = "lbs/acre of amendment required" (Row L). (Row F/Row K = Row L).

O. Demonstrate calculating tons/acre or lbs/100 square ft of amendment needed

1. Divide "lb/acre amendment required" (Row L) by 2000 lbs (1 ton) = tons/acre of amendment needed
2. To calculate lbs/100 square ft amendment required: Divide the lbs/ac-ft amendment required (L) by 440. Enter this value into Row M. (L/440 = M).

P. Demonstrate calculating costs of amendments

1. Multiply tonnage or lbs of amendment needed (Row L) by price/ton or lb (see agricultural supply catalogues in Resources section)

Q. Demonstrate identifying nutrient deficiencies to address through supplemental fertilizing

1. Review soil report for "Low" and "Very Low" nutrient levels
2. Transfer this information to appendix 5, Supplemental Fertilizers Worksheet

R. Demonstrate selecting fertilizers to alleviate stress and prevent acute nutrient deficiencies (see appendices 5 and 8)

S. Discuss timeline and application rates for applying amendments and fertilizers identified as necessary based on interpretation process

1. Current season
   a) Timing
   b) Application rates
2. Subsequent years
   a) Timing
   b) Application rates
3. Discuss frequency of subsequent soil sampling

T. Discuss and demonstrate writing a summary of findings and specific amendment recommendations

1. Qualitative description of the agronomic characteristics of the soil
2. Defined nutrient excesses, imbalances, and/or deficiencies
3. Amendments selected to address excesses, imbalances and/or deficiencies
4. Associated costs
5. Timeline for implementation and application rates to be used
6. Defined acute nutrient deficiencies
7. Supplemental fertilization to address acute nutrient deficiencies
8. Timeline for implementation and application rates to be used
9. Nitrogen requirements of crop(s)
10. Estimated nitrogen contributions of soil organic matter (ENR), compost and cover crops
11. Timeline, application rates of compost, cover crop species and seeding rated used to meet N needs

Follow up this demonstration with Demonstration 3, Nitrogen Budgeting.

Demonstration 2: Interpreting Soil Test Reports

step-by-step instructions for students

These instructions will help you read and interpret soil analysis reports and select soil amendments and fertilizers. This information will help you interpret soil analysis lab results, develop amendment recommendations for long-term soil fertility management plans, and address acute soil and plant nutrient deficiencies through proper supplemental fertilization. This sheet, along with Appendix 2: Nutrient Budgeting Worksheets, will help you with the following: review the accuracy of sampling information on your soil test; describe the relevant agronomic characteristics of your soil; assist you in the necessary conversions from parts/per million (ppm) nutrients tested to lbs/acre of soil nutrients; contrast soil nutrient levels with defined optimal benchmarks in order to define limiting and/or excess soil nutrients; and select the type and quantities of soil amendments and/or fertilizers that may be used to address limited or imbalanced soil nutrient levels. This form and the associated appendices will also help you develop a nitrogen budget for your crop(s) through calculating the nitrogen contributions from compost, cover crops and existing S.O.M. and contrasting this with estimates of nitrogen removal through cropping.

PREPARATION AND MATERIALS

- Lab analyses report

The following appendices on overhead transparencies (OHT):

- Appendix 2, Nutrient Budgeting Worksheets
- Appendix 4, Nitrogen Budgeting Worksheet Exercise
- Appendix 5, Supplemental Fertilizer Worksheet
- Appendix 6, Optimal Nutrient Levels of Major Cations Based on CEC
- Appendix 7, Nutrient Content of Common Fertilizers and Amendments
- Appendix 8, Fertilizer Solutions Chart
- Appendix 9, Approximate Pounds/Acre of Nutrients Removed by Common Crops
- Calculator
- Pencil
- Agricultural supply catalogues for National Organic Program-approved amendments and fertilizers

REFERENCE

- *Agronomy Handbook: Soil and Plant Analysis.* A & L Western Agricultural Laboratories, Inc. 1311 Woodland Ave., #1. Modesto, California 95351. (209) 529-4736

A. Collect and organize the materials listed above

B. Review and confirm the accuracy of sampling information using the Soil Test Report and Appendix 2, Nutrient Budgeting Worksheets)

1. Name
2. Field identification name/number
3. Date sampled
4. Crop
5. Soil depth sampled
6. Soil textural classification

C. Transcribe the general agronomic characteristics of the soil from the lab report to the nutrient budgeting worksheets

1. Soil textural classification
2. Soil pH
3. Organic matter
4. Excess carbonates/lime
5. CEC
6. Buffer pH
7. Soluble salts

D. Transcribe tested nutrient levels and ratios from the lab report to the nutrient budgeting worksheets

1. Transcribe the nutrient levels tested in ppm from the lab report to Row A of the Nutrient Budgeting Worksheets
2. Transcribe the Percent Cation Saturation Ratios (%CSR) from the lab report to Row H of Nutrient Budgeting Worksheets

E. Convert the nutrient levels tested to lbs/ac

1. Convert all nutrients tested from ppm to lbs/ac by multiplying ppm tested (Row A) by the conversion factor in Row C. Write the answer for each in Row E. (A x C = E).
2. Define the optimal range in ppm for Ca, Mg, K required to achieve optimal Cation Satuation Ratios using the cation exchange capacity (CEC) of the tested soil and appendix 6). Write the optimal range for each nutrient in Row B. Optimal ranges for all other nutrients have been included in the Nutrient Budgeting Worksheets.
3. Now convert the ppm optimal range for Ca, Mg, and K to the optimal range in lbs/ac for each nutrient by multiplying ppm optimal range (B) by the conversion factor in Row C. Write the answer for each in Row D. (B x C = D)

F. Calculate lbs/ac of actual nutrient required

1. Calculate lbs/ac of actual nutrient required by subtracting lb/ac-ft optimal range (Row D) from lb/ac tested (Row E). Write the answer for each in Row F. (D - E = F).

G. Characterize each of the soil nutrient levels with a qualitative description

1. Contrast the nutrient levels tested in lbs/ac (Row E) with the lbs/ac optimal range (Row D)
2. Document a qualitative description (Row G) for each of the nutrient levels using the following: Very Low (VL) = well below the optimal range; Low (L) = just outside or the low end of the optimal range; Medium (M) = close to average of the optimal range; High (H) = just above or the high end of the optimal range; Very High (VH) = well above the optimal range. Confirm with soil test descriptions.

H. Select appropriate mineral amendments to supply needed nutrients

1. Select amendment using the Fertilizer Solutions Chart (appendix 8). Avoid selecting any amendment that contains a nutrient known to already exists at "High" or "Very High" levels in the soil.
2. Determine the nutrient content (by percentage) of amendments using appendix 8 or agricultural supply catalogues. Enter this value into Row K.

I. Calculate lbs/ac amendment required

1. Calculate lbs/ac amendment required by dividing lbs/ac of nutrient required (Row F) by the percentage of actual nutrient contained in the amendment (Row K). Enter this value into column L. (F/K = L).

J. Calculate tons/acre (or lbs/100 square ft) of amendment required

1. To calculate tons/acre of amendment required: Divide lbs/ac amendment required (Row L) by 2000 lbs. Enter this value into column M. (L/2000 = M).
2. To calculate lbs/100 square ft amendment required: Divide the lbs/ac amendment required (Row L) by 440. Enter this value into Row M. (L/440 = M).

K. Calculate the cost of amendments/acre and total cost of amending all acreage for each amendment

1. Enter the price/unit volume of each selected amendment selected in Row N. See agricultural supply catalogues in Resources section.
2. Define total surface area (acres or square feet) in needed amendment. Enter this value into Row O.
3. Multiply tons/ac (or lbs/sq-ft) of amendment needed (Row M) by the price/unit volume of amendment (Row N). This is the cost of amendment per acre. Multiply this figure by the total acreage or total square footage in need of amending (Row O) . This is the total cost of amendment for all acreage. Enter this value into Row P. (M x N x O = P)

L. Calculate total costs of all amendments over all acreage

1. Add all the total costs of each amendment in Row P. This is the total cost of all amendments over all acreage. Enter this value into the far right side of the bottom row total cost of Row P.

M. Nitrogen budgeting: Meeting the nitrogen requirements of crops (see appendix 4)

1. Determine amount of nitrogen removed in lbs N/acre
   a) Line 1: Using appendix 9, Approximate Pounds/Acre Of Nutrients Removed By Common Crops, determine the amount of nitrogen removed in lbs N/acre for a specific crop or crops. Enter this value into line 1.
2. Calculate the estimated nitrogen contributions from the following sources:
   a) Soil organic matter (SOM) – Line 2: Multiply the total Estimated Nitrogen Release (ENR) figure from your soil report x 60% (for annual cropping systems) or x 80% (for perennial/ no- or low-till systems). Enter this value into line 2. This is an estimate of the lbs N/acre mineralized from SOM in one year's time.
   b) Compost – Line 3: First enter the application rate of compost in tons/acre. Next enter the percent nitrogen content of your compost (use average or test results). Multiply total wet weight of compost by 0.35 and subtract this figure from total application rate (tons/acre). This gives you dry weight. Multiply total pounds of dry weight compost applied by the percent nitrogen of the compost. This is the total pounds of actual nitrogen applied/acre. Next, multiply the average amount of nitrogen made available in the first year (~50%) by the total pounds of actual N applied. This is the estimated nitrogen released in the first 3–6 months of the growing season from well-decomposed compost. Enter this value in line 3.

c) Nitrogen fixing cover crops – Line 4: Using the UC Davis Covrer Crop Data Base: www.sarep.ucdavis.edu/cgi-bin/ccrop.EXE/show_crop_5, or the calculations from Unit 1.6, Selecting and Using Cover Crops, enter the estimated pounds of nitrogen/acre fixed by a legume cover crop into the blank space in line 4

This is the estimated nitrogen contribution of a legume cover crop when directly incorporated into the soil at the optimal stage of development (~75% of full bloom). Next multiply the average amount of nitrogen made available in the first year (~50%) by the total pounds of actual N fixed. This is the estimated nitrogen released in the first 3–6 months of the growing season from a nitrogen fixing cover crop. Enter this figure into line 4.

3. Calculate the total available nitrogen from all of the above sources
   a) Line 5 – Add up lines 2-4. Enter this figure into line 5. This is the total available nitrogen from all sources.
4. Determine the need for supplemental nitrogen
   a) Line 6 – Subtract line 5 from line 1. Enter this figure into line 6. *If this figure is a negative number it is estimated that the crops should not need any additional sources of nitrogen. If this figure is a positive number, then one should increase the application rate of compost, adjust the species or seeding rate of cover crops, and/or select the proper supplemental fertilizer (below) to supply the needed nitrogen. If number is large and negative or remains negative from year to year, it may indicate N loss to environment.

N. Identify potential acute nutrient deficiencies

1. Review soil report for "Very Low" and "Low" nutrient levels (Row G). Enter all nutrients found to exist in the soil at "Very Low" and "Low" into the first column of the Supplemental Fertilizers Worksheet (appendix 5) under "Potential Limiting Nutrients".

O. Select a supplemental fertilizer to prevent acute nutrient deficiencies

1. Select a proper supplemental fertilizer(s) using appendix 8, the Fertilizer Solutions Chart. Using an agricultural supply catalogue, record all relevant information for the use of the needed supplemental fertilizer in the subsequent columns. Calculate total volume of supplemental fertilizers needed and their associated costs.

P. Write a summary of your findings and specific amendment recommendations

1. Qualitative description of the agronomic characteristics of the soil
2. Defined nutrient excesses, imbalances, and/or deficiencies
3. Amendments selected to address excesses, imbalances, and/or deficiencies
4. Associated costs
5. Timeline for implementation and application rates of amendments to be used
6. Defined acute nutrient deficiencies
7. Supplemental fertilization to address acute nutrient deficiencies
8. Timeline for implementation and application rates of fertilizers to be used
9. Nitrogen requirements of crop(s)
10. Estimated nitrogen contributions of soil organic matter (ENR), compost, and cover crops
11. Time line, application rates, and cover crop species to be used to meet N needs in future
12. Frequency and date of subsequent soil sampling

* Note: Seasonal environmental conditions may create growing conditions (e.g., cool and wet soils) that may depress mineralization and N availablity, thereby creating a demand for supplemental fertilizer despite the presence of adequate quantities of N in the soil.

Demonstration 3: Nitrogen Budgeting

for the instructor

OVERVIEW

This demonstration offers an example of how a simple nitrogen budget can be calculated for an organic farm or garden. Using the nitrogen budgeting worksheets and the Demonstration Outline below, discuss and demonstrate the process of calculating an estimated nitrogen budget for a farm, factoring estimated nitrogen release (ENR) from compost, cover crops, and existing soil organic matter. For this exercise, appendix 3 (Nitrogen Budgeting Exercise) includes an example of the steps involved in calculating a basic nitrogen budget. Following this demonstration, students should be given the Hands-On Exercise.

PREPARATION AND MATERIALS

- Appendix 3, Example of a Nitrogen Budget
- Appendix 9, Approximate Pounds/Acre of Nutrients Removed by Common Crops
- Sample soil test report
- Overhead projector
- Pen for writing on overhead transparency film

PREPARATION TIME

0.5 hour

DEMONSTRATION TIME

1 hour

DEMONSTRATION OUTLINE

A. Discuss rationale and goals of nitrogen budgeting

1. Meeting but not exceeding crop nitrogen requirements of crops

B. Discuss factors to consider in N-budgeting for organic farming and gardening systems

1. Crop removal estimates and nutrient contributions of inputs (cover crops, compost, and ENR from SOM)

C. Demonstrate how to use the crop removal estimates in appendix 9 to provide an approximation of the amount of plant nutrients that are removed from the soil in a year by a specific crop or crops

1. This figure is placed on Line 1 of the Nitrogen Budgeting Worksheet Exercise (appendix 4)

D. Discuss nitrogen contributions from three major sources in organic farming systems: ENR from SOM, compost, and cover crops

1. Demonstrate how to transcribe the estimated nitrogen release (ENR) figures from the soil test to the Nitrogen Budgeting Worksheet for calculating the nitrogen contribution of ENR (see Line 2 of the Nitrogen Budgeting Worksheet)
   a) Discuss the use of estimated nitrogen release in an annual and perennial cropping system
   b) Demonstrate calculations
2. Demonstrate how to factor in the nitrogen contribution of compost using Line 3 of the Nitrogen Budgeting Worksheet
   a) Discuss application rate
   b) Discuss nitrogen content derived from analysis, and that nitrogen content is based on dry weight
   c) Discuss wet weight of compost and how to calculate dry weight
   d) Demonstrate multiplying dry weight by %N
   e) Discuss and demonstrate %N available
3. Demonstrate how to determine the nitrogen contribution of nitrogen-fixing cover crops (see www.sarep.ucdavis.edu/ and Unit 1.6, Selecting and Using Cover Crops, for more information). These data should be included in Line 4 of the Nitrogen Budgeting Worksheet
   a) Demonstrate calculations
4. Discuss factoring in the nitrogen concentration in irrigation water.
5. Discuss the accuracy of this type of nitrogen budgeting (see F, below)

E. Demonstrate how to calculate the balance of nitrogen inputs and outputs

1. Demonstrate totaling the nitrogen inputs by adding Lines 2–4 of the Nitrogen Budgeting Worksheet. This figure should be placed on Line 5 of the Nitrogen Budgeting Worksheet.
2. Demonstrate how the nitrogen contributions of all inputs should be subtracted from the crop removal estimates to determine the need for additional nitrogen inputs (e.g., increased application of compost, increased seeding rate of nitrogen-fixing cover crops, or supplemental fertilizing). This figure should be placed on Line 6 of the Nitrogen Budgeting Worksheet.

F. The challenges of accurate nitrogen budgeting in organic farming systems: Factors influencing the release of nitrogen from organic matter

1. 99% of the N in most soil is tied up in soil organic matter (SOM), the release of which is dependent on soil conditions such as temperature, aeration, and moisture, which are in turn dependent on weather/air temperature, tillage, rainfall, and irrigation practices
2. The quality and quantity of existing soil organic matter and organic matter inputs. The C:N ratio, the presence of lignins and tannins, soil biological activity, and the placement of organic matter amendments in the soil profile all influence the mineralization rate of organic matter. The accuracy of the mineralization rates listed in the Nitrogen Budgeting Worksheet must be understood in this light and represent only a rough estimate.
3. Discuss long-term budgeting and nutrient management. The use of this nitrogen budgeting exercise, combined with annual soil analysis report data, can give a grower an indication of either the accumulation or depletion of soil nutrients. With such information, the grower may make adjustments to the system in order to balance nutrient inputs with outputs, thereby both assuring nutrient availability and avoiding the problems associated with excess soil nutrients.

Demonstration 4: Field Visit to A Working Agricultural Operation — Relating Crop Growth Observations to Fertility Programs

for the instructor

OVERVIEW

Visit a local garden or farm for which a soil analysis report has been prepared and reviewed by the class. Request from the grower an overview of the current soil fertility and pest and disease management plans and practices used in the operation. The overview should include the following components: soil textural classification; hydrology of fields; history of cultivation; history of soil testing and amending; the use of cover crops, compost, and crop rotation; the use of supplemental fertilization; primary tillage practices used; any persistent pest, disease, plant growth response and/or crop quality concerns occurring in the production of the crop(s).

Following the presentation, tour the fields/gardens looking for any nutrient deficiency symptoms that may be correlated with known physical or chemical properties of the soil (refer to soil analysis), and that may be associated with specific cultural practices. With the permission of the grower, samples of crop vegetation can also be taken for later comparison with photographs of crops with known nutrient deficiencies.

PREPARATION AND MATERIALS

- Sample lab analyses report
- Crop deficiency and toxicity reference charts (see below)

RESOURCES AND REFERENCES

- *Agronomy Handbook: Soil and Plant Analysis.* A & L Western Agricultural Laboratories, Inc. 1311 Woodland Ave., #1. Modesto, California 95351. (209) 529-4736. (For crop deficiency symptoms see pp. 87-92.)
- Unit 2.2 of this manual, Introduction to Soil Chemistry and Fertility. (For crop deficiency symptoms see Detailed Lecture Outline; for web sites containing photographs of specific crops with specific nutrient deficiencies see Resources section.)

DEMONSTRATION OUTLINE

A. Soil Fertility and Pest and Disease Management Plans and Practices: Grower Overview

1. Soil textural classification
2. Soil quality/soil tilth
3. Hydrology of fields
4. History of cultivation
5. History of soil testing, amending, and plant growth responses
6. The use of cover crops: Timing, application rate, and type
7. The use of composts: Timing, application rate, and type
8. The use crop rotation: Timing and type
9. How they budget for nitrogen
10. The use of plant tissue testing: Timing and type
11. The use of supplemental fertilization: Timing, application rate, and type
12. Primary tillage practices used
13. Irrigation practices
14. Any persistent and economically significant problems
    a) Pests
    b) Diseases
    c) Plant growth responses
    d) Crop quality concerns

B. Field Observations

1. Deficiencies: Are there major or micro-nutrient deficiencies evident from the soil analysis? Are they also evident in the field?
2. Excesses: Are there major or micronutrient imbalances evident from the soil analysis (including those that cause poor soil physical conditions or toxicity such as...)? Are they also evident in the field?
3. Soil physical condition: How is the tilth of the soil? Is it cloddy or cracked, does it take tillage to achieve loose soil? Is there a compacted plow or disc pan 6 to 12 inches below the surface? Is the soil well aggregated?
4. Organic matter: Is there evidence of raw OM, an active humus layer, healthy bioactivity?
5. Crop health: Do the plants look healthy and deep green? Do they appear to be overfertilized with nitrogen?
6. Pests and disease: Is there evidence of pests, diseases, or damage from either? Does it appear that the plants are resilient to the damage, or do the crops appear stressed?
7. Water relations: Does the soil appear to have standing water, does it drain well, or have poor water retention? Does the soil stick to shoes when you walk through it? Are farm operations ever performed when it is wet?