MARYLAND COOPERATIVE EXTENSION
UNIVERSITY OF MARYLAND
COLLEGE PARK•EASTERN SHORE

Fact Sheet

Fact Sheet 782

Basics of Soil and Plant Fertility

Farmers need to develop an understanding of the basics of soil physiology and the factors that affect plant fertility. Not only is this knowledge essential for successful crop production, it is also important to livestock producers dependent on pastures as a primary part of their livestock feeding program. Pasture grass and legume species respond to the same basic soil and plant fertility principles as other farm crops.

I. What Is Soil?

Soil can be defined as a natural body, synthesized from a variable mixture of broken and weathered minerals, decaying organic matter, water, and air. Along with air, water, and nutrients, soil provides mechanical support to growing plants.

Soils consist of four major components—minerals, organic matter, water, and air. The volume of a typical silt loam soil in optimum condition for plant growth contains, approximately, the following: solids, composed of 45 percent minerals and 5 percent organic matter; water, 25 percent; and air, 25 percent. Soil pores, which are spaces, contain the water and air. In this typical silt loam soil, it is important to note, pores contain 50 percent of the volume.

II. Soil Texture

A very important physical property of soil is texture. The size of mineral particles, specifically, the relative proportion of various size groups in a given soil, create a soil's texture. This property helps determine the nutrient-supplying ability of soil solids and the supply of water and air that support plant life.

Soil texture is separated into three components based on particle size. These are *sand, silt,* and *clay.*

Silt and clay soils are finely textured and sustain slow water and air movement. They have a high water-holding capacity because they consist of a high percentage of pores. Silt and clay soils are referred to as heavy soils, with clay being the heavier of the two.

Clay separates are also the primary available plant nutrient-holding mechanisms in the soil. Shaped like plates, clay colloids or platelets act like micromagnets, capturing and holding plant nutrients. The nutrients remain in the clay until one of the following occurs: they are "kicked off" by an overload of another element, they are absorbed by a plant root, they are eaten by a soil macro- or microorganism, or they are adsorbed into the soil chemically.

Sandy to gravelly soils are referred to as lighter soils; water moves through them more rapidly and they have lower water-holding capacities than the heavier soils.

We use soil textural names to refer to and identify our soils. Sands are soils in which sand separates make up 70 percent or more of the soil by weight. Clay soils have at least 40 percent clay and may be referred to as sandy clay or silty clay.

Loamy soils possess the desirable qualities of sand and clay without exhibiting the undesirable characteristics of extreme looseness, low water-holding capacity, and slow water and air movement. Most agriculturally important soils are loams. Some loamy soils are simply called loams; however, in most cases, the quantity of sand, silt, or clay present modifies the name. Some examples are clay loam, sandy loam, silt loam, and silty clay loam.

III. Soil Compaction

Fine-textured soils are more easily compacted than lighter soils, especially when wet. Compaction reduces the size of the

pores that hold air and water. Compacted soils cause significantly reduced plant growth. Operating equipment on wet soils causes soil compaction, which can create problems in a field for an entire season or longer.

IV. Deep Versus Shallow Soils

The depth of that part of soil that supports plant growth is a significant factor to consider when evaluating a soil. Conditions that favor plant growth in this layer of soil,

which include good drainage, ample organic matter, and desirable soil texture, allow plant root development and penetration. *Shallow soils* have barriers to root penetration, such as compacted subsoil or rock or other material that restricts root development and limits plant growth. For example, hardwood trees planted in shallow soil will experience severely limited growth because of restricted root growth. *Deep soils* are not restrictive, allowing plants to extend their roots down into the soil to obtain nutrients and moisture in greater supply than shallow soils do. Deep root penetration also provides plants with a hedge against drought, as moisture is retained longer in deep soils and in soils with high levels of organic matter. The impact of soil depth on plants varies with plant species. Most shallow-rooted grasses and legumes are productive in shallow soils, while deep-rooted plants such as hardwood trees reach their full potential in deep, well-drained soils.

V. Field Slope

Land topography largely determines the amount of drainage, runoff, and erosion that takes place in a field. The steeper the land, the more management the land will require. The ease with which surface soils erode, along with the percentage of slope, helps determine a soil's potential productivity. Most of the soils in the Northeast region of the country are highly erodible.

VI. Soil Organic Fraction

A good, loamy soil is composed of about one-half pores (air and water) and one-half solid materials. Of this one-half of solid material, 90 percent is composed of minerals (bits of rock). The remaining 10 percent is the organic fraction. The influence of this small part of the soil on the soil's ability to support plant growth is significant.

The soil's organic fraction is dynamic and always undergoing change. The organic fraction consists of living organisms, plant and animal residues, and plant roots. The total weight of living organisms in the top 6 inches of an acre of soil can range from 5,000 to 20,000 pounds.

Part of the soil organic fraction is soil organic matter, which consists of plant and animal residues in various stages of decay. Organic matter in adequate levels benefits soil in the following ways:

1. It improves physical condition
2. It increases water infiltration
3. It improves soil tilth
4. It decreases erosion losses
5. It supplies plant nutrients
6. It retains available plant nutrients

VII. Essential Plant Nutrients

There are 16 identified elements that are essential to plant growth. Three of these elements are obtained mostly from air and water: they are carbon (C), hydrogen (H), and oxygen (O). The other 13 essential elements come from soil solids and are the elements we tend to focus on in plant fertility management.

The 13 essential plant nutrients are divided into three categories based on the amount of the element required for plant growth. The nutrients and their categories are:

1. Primary Nutrients

- a) Nitrogen (N)
- b) Phosphorus (P)
- c) Potassium (K)

2. Secondary Nutrients

a) Calcium (Ca)
b) Magnesium (Mg)
c) Sulfur (S)

3. Micronutrients

a) Iron (Fe)
b) Magnesium (Mg)
c) Boron (B)
d) Molybdenum (Mo)
e) Copper (Cu)
f) Zinc (Zn)
g) Chlorine (Cl)

Plants require primary nutrients in high amounts, secondary nutrients in lesser amounts, and micronutrients in only small amounts. Whether a nutrient is primary, secondary, or a micronutrient, it is essential to plant growth. A deficiency in any one of the essential nutrients will restrict plant growth.

A typical expression of the primary nutrients appears on bags of commercial fertilizer. A fertilizer product has three numbers to identify the type, or percentage, of fertilizer contained in the bag. Some examples are 10-6-4, 5-10-5, and 20-20-20. These numbers refer to the percentage of N, P, and K in the fertilizer.

Fertilizer numbers also reflect the ratio of these elements to each other. For example, 10-6-4 is a 2:1:1 ratio fertilizer, 5-10-5 is a 1:2:1 ratio fertilizer, and 20-20-20 is a 1:1:1 ratio fertilizer. The ratio of elemental nutrients in fertilizer is important for maintaining or correcting the balance of P and K in the soil. A fertilizer with a higher ratio of P or K can be applied to soil deficient in one of those elements without adding to an element that has no deficiency.

Fertilizers of comparable ratio can be substituted for one another if you compensate for the difference in material concentration during application. Differences in price or availability of a recommended fertilizer may require the use of an alternative. Using a substitute fertilizer with a comparable ratio will be consistent with the soil test recommendation.

Example: A soil test recommends applying 5-10-5 at a rate of 1,000 lbs per acre. However, 12-24-12 is available at a better price. What is the difference in the application rate using 12-24-12?

1,000 lbs x .05 = 50 lbs *(recommendation based on lbs per acre of nitrogen)*
50 lbs/.12 = 416.67 lbs per acre *(lbs of 12-24-12 per acre that substitute for 5-10-5)*
416.67 x .24 = 100 lbs *(lbs of phosphorus per acre applied at this rate of 12-24-12)*

Most farm fertilizer dealers can custom mix the fertilizer ratio recommended by a soil test. However, several commonly available commercial fertilizers can be used individually or in combination to meet the soil test recommendation.

Common Fertilizers

- Urea 46-0-0
- Ammonium nitrate 34-0-0
- UAN (urea ammonium nitrate) 30-0-0
- Ammonium sulfate 21-0-0
- DAP (diammonium phosphate) 18-46-0
- MAP (monoammonium phosphate) 11-52-0
- Triple superphosphate 0-46-0
- Muriate of potash 0-0-60

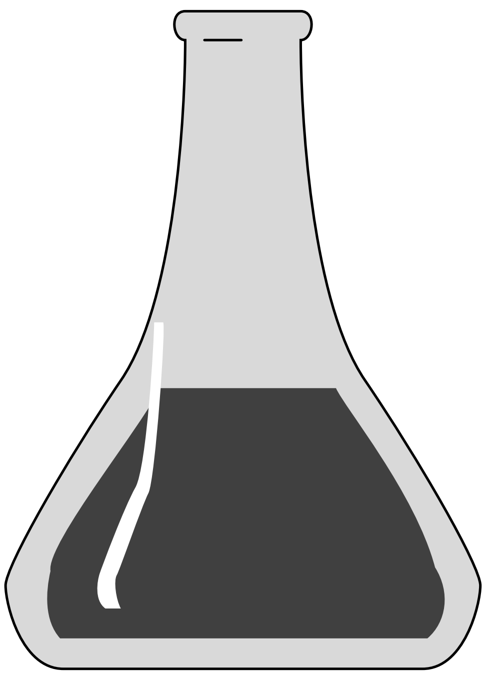
One way of comparing commercial fertilizers is to calculate the quantity of actual nutrients each contains, using this formula:

percent nutrients x 2,000 lbs = lbs actual nutrients per ton.

Example: Ammonium sulfate 21-0-0-24(S) (Note: In addition to the nitrogen, phosphorus, and potassium in ammonium sulfate, there is 24% sulfur.)

.21 x 2,000 lbs = 420 lbs nitrogen/ton
.24 x 2,000 lbs = 480 lbs sulfur/ton
Total nutrients = 900 lbs/ton

Use the cost per pound of actual nutrients as a method of comparing the real cost of commercial fertilizers. Determine cost per pound of nutrients by, first, calculating the amount of actual nutrients per ton of fertilizer (using the formula above), then dividing the fertilizer cost per ton by the pounds of actual nutrients.



Commercial fertilizers, animal manures, and composts are good sources of most of the essential nutrients; however, you may need to apply some of the micronutrients as a supplement. Obtain calcium and magnesium by applying a liming agent.

Avoid overapplying any plant nutrient. Excessive levels of any one of the essential nutrients can throw soil fertility out of balance and result in reduced plant growth. Excessive levels of some elements can even be toxic to plants, especially in the case of many of the micronutrients. Excessive levels of N and P in the soil are detrimental to water quality.

Base the application of fertilizer on the fertility needs of the crop and the results of a reliable soil test. Always calibrate fertilizer spreading equipment to insure accurate application. A nutrient management plan can be developed for each field on the farm. This plan will prescribe the exact amount of fertilizer needed to achieve crop yield goals and helps to prevent the application of excess nutrients, which can have a negative impact on water quality and the environment. The plan is based on soil test results, field history, and the addition of any organic materials such as manure. Most farmers in Maryland are required to have nutrient management plans for their farmland. Cooperative Extension can assist you in learning more about developing a nutrient management plan.

VIII. Soil pH

Soil pH is a measure of the relative alkalinity or acidity of soil. Soil pH test results are based on a pH scale in which 7.0 is neutral, above 7.0 is alkaline, and below 7.0 is acidic. Soil tests that measure pH are commercially available.

Soil pH directly affects how available essential nutrients are to plants. It is important to know the optimum pH for the plants you grow. Soil pH also affects the adaptability of plants to a given soil. For example, azaleas and blueberries prefer an acidic soil and suffer when the pH nears neutral. Most agricultural plants prefer a slightly acidic pH of 6.4. However, there are exceptions; be familiar with the pH and nutritional needs of all the crops you grow.

Liming materials to raise soil pH are commercially available; these include limestone and industrial by-products. Either of these materials will effectively do the job. Be sure to note the percentage of oxides in these materials; it will vary between 40 and 50 percent. Soil test recommendations for raising soil pH are based on pounds of oxides per acre. Oxides are that part of the liming material that affects soil pH. You can find percentage of oxides on the product label.

Some soil test recommendations will directly prescribe the required pounds of oxides per acre, while others will prescribe tons of limestone per acre. If the recommendation is expressed in tons of limestone, the assumption is that the liming material is 50 percent oxides. The amount of material applied per acre will have to be adjusted if it is not 50 percent oxides.

For example, a soil test indicates a soil pH of 6.2 and recommends an application of 1,500 pounds of oxides. After shopping around, you determine that the two best choices are aglime (50 percent oxides) and industrial stackdust (41 percent oxides). Two questions arise: (1) What are the application rates for each material, and (2) what is the cost per acre for each material?

Example: Soil test indicates a pH of 6.2
Recommendation: 1,500 lbs/acre of oxides
Choices: aglime, 50% oxides, and stackdust, 41% oxides

Aglime
1 lb/.50 = 2 lbs *(material needed for 1 lb oxides)*
2 x 1,500 = 3,000 lbs *(material needed for recommendation per acre)*
3,000 x (cost/lb) = cost/acre of aglime

Stackdust
1 lb/.41 = 2.44 lbs *(material needed for 1 lb oxides)*
2.44 x 1,500 = 3,660 lbs *(material needed for recommendation per acre)*
3,660 x (cost/lb) = cost/acre of stackdust

Industrial by-product liming materials are typically found in the oxide form as calcium oxide (CaO). This type of product, which is very soluble, is immediately available to raise the pH of the soil. Commercial aglime products are typically calcium carbonate ($CaCO_3$), which will vary in mesh size (fineness). The mesh size of the product affects how rapidly the product raises soil pH. A typical aglime will be 80 percent material at 90–100 mesh and 20 percent at 20 mesh. Aglime material at 90-100 mesh is soluble and will raise soil pH as rapidly as CaO. Aglime material at 20 mesh can take 6 months or longer to become soluble enough to affect soil pH; this slow-release of oxides can help maintain soil pH.

When you apply liming materials, it is important to remember that recommendations are based on applying enough oxides to raise the plow layer (the top 9 inches of soil) to the desired pH level. Liming applications that are surface applied on a pasture, for example, are limited to 1,500 pounds per acre of oxides per year. Applications above this can lead to crop injury.

Soils with a pH above 7.0 can restrict plant growth. There are some commercially available sulfur-based materials that will effectively lower the soil pH; however, most soils in the Northeast region of the country are naturally below pH 7.0. Ammonium sulfate is a commercial fertilizer that contains 25 percent sulfur. This product is commonly used as a soil sulfur source that will slightly lower soil pH; severe pH reductions, however, will require another choice. Check with your county office of Maryland Cooperative Extension if you have questions about your soil pH.

Conclusion

Always base the addition of any liming or acidifying materials on the results of a reliable soil test. Overapplication of either material can lead to crop injury. Soil tests are available through an Extension office and most farm fertilizer dealers.

References

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