Soil Amendments and Fertilizers

Soil Amendments

A soil amendment refers to a material added to the soil to improve its physical, biological or chemical properties. There are many different types of soil amendments, each fulfilling a different goal. While some may add nutrients, others may improve soil structure. While some may act quickly others will act more slowly over a sustained time period. It is important to understand what different soil amendments do, how to apply them and their rate of action vs. duration. It is also important to note that any single amendment can, and often does have multiple reasons for its use.

In general, we break these amendments into four types based on their uses and form:

- mulches
- composts
- fertilizers
- soil conditioners (for pH in the case of lime or acidifier and compaction and water management in the case of composts).

Mulches are primarily used as either a weed suppressant or for climate control. Applied at the surface they act as a barrier to weed emergence but also aid in moderating soil temperatures and reducing water loss from the soil. There are a variety of mulches available from plastics and fabrics through rocks to organic materials such as wood chips or leaves. In most cases the mulch degrades (i.e. plastics) or decomposes (i.e. wood chips) and will need to be removed or replaced. As a side note, when the organic mulches decompose they will often provide multiple benefits to the soil while the plastics, if not removed, will become a pollutant.

Composts are decomposed organic matter that are added to soil as slowly releasing fertilizer, to help reduce compaction, to improve drainage or to increase water holding capacity. It can be added on top of the soil as a mulch or mixed into the top soil. There are a variety of composts available that are made from a diversity of organic materials. Due to this diversity of organic materials, not all composts are the same. As a result they are often used for different things. But all of them will in general provide nutrients to your plants, improve the structure of your soil, thus help with drainage and water storage, as well as provide a healthy environment for other soil organisms which will in turn create a healthy environment for your plants. It's also easily made at home.

Fertilizers are amendments that we add to give adequate nutrients for our plants. Often soils can't provide all the nutrients required for a healthy plant. This lack is particularly important with quick growing annual plants, but can also be found in perennial plants. We add fertilizer to make up for this lack. Fertilizers come in a variety of forms which we break up into two general forms and two general release rates. The forms are called inorganic and organic. **Inorganic** forms are produced artificially or are processed from minerals and rocks. **Organic** forms of fertilizer come from processed organic materials. It is important to note that the use of "organic" for fertilizers is not the same as "organically grown." Things that are grown organically may in fact have used rock and mineral sourced fertilizers. In this case inorganic and organic only refers to the source of the nutrient.

We also talk about fertilizers in relation to how *quickly* or *slowly* they release their nutrients to the plants. *Quick* release fertilizers generally release all of their nutrients immediately upon application. This can be good if your plants have significant nutrient needs, but with that *quick* release the plants won't be able to capture all of the nutrients. As a result, much of that fertilizer can escape into the groundwater and become pollution. Generally, *slow* release fertilizers slowly provide their nutrients over weeks or even months and into years once they have been added. These fertilizers are added to maintain general soil fertility throughout the growing season and into the next, but because of the *slow* release they may not provide enough nutrients when the plants are growing quickly. Careful timing and rates of application are critical to get the best outcomes without wasting your money or causing pollution problems.

Soil Conditioners are generally added to change some problem characteristic of the soil. In many cases this is about the pH of the soil, but they can also be added to deal with compaction or water management. For pH modification we will often add lime (or liming agents) to raise the pH or acidifiers (such as iron sulfate) to lower the pH. These amendments are usually added to bring the soil into neutral or slightly acid pH ranges as these are optimum for nutrient availability to the plants. But sometimes they can be used to bring the pH to a range that suites a particular plant. An example of this would be the addition of iron sulfate for blueberries requiring a low pH for growth and high berry yield. Another example of using soil conditioners would be organic matter additions to improve drainage in a clay soil or increase water holding capacity in a sandy soil.

Now that we have an idea about what soil amendments and fertilizers are. let's start by talking about organic matter.

Organic Matter

Soil organic matter is the fraction of the soil that consists of plant or animal tissue in various stages of breakdown (decomposition). We do find soils with very little to no organic matter and there are plenty of examples of entirely organic wetland soils, but in general most of our productive agricultural and garden soils have between 3 and 6% organic matter. So what is soil *organic matter*?

Soil organic matter is made up of different components that can be grouped into three general fractions (or parts):

1. Living organic matter - soil fauna, microbial biomass and plants.
2. Active soil organic matter, also referred to as detritus.
3. Stable soil organic matter, often referred to as humus.

The *living organic matter* includes the microorganisms responsible for decomposition (breakdown) as well as plants and animal living in the soil. The *active soil organic matter*, is deposited fauna/plant/microbial residues. This can be recently added organic matter or material that has been dead for some time but still is recognizable as organic material but hasn't yet been decomposed. S*table soil organic matter* is formed from decomposed plant and animal tissue. It is the final product of decomposition.

The *active soil organic matter* contribute to soil fertility because the breakdown of this material results in the release of plant nutrients such as nitrogen, phosphorus, potassium, etc.

The *stable soil organic matter*, while generally not a source of nutrients, when combined with soil minerals has a strong influence on soil fertility through their ability to hold nutrients and then make them available at a later date. The soil properties that control this are called cation exchange capacity (CEC) and base saturation (see Agronomy Fact Sheet #22 for more information, http://nmsp.cals.cornell.edu/guidelines/factsheets.html). *Stable soil organic matter* is a product of decomposition and will continue to decompose. But the rate of its decomposition is so slow and is renewed constantly by fresh decomposition, the amount of this type of organic matter becomes "stable" and hence the term *stable soil organic matter*. It is also this fraction that has a distinct dark color that gives soil the earthy browns that we associate with fertile and healthy soils.

These three fractions of soil organic matter each in their own way contributes to soil productivity.

Benefits of Stable Soil Organic Matter
There are numerous benefits to having a relatively high stable organic matter level in agricultural and garden soils. These benefits can be grouped into physical, chemical or biological outcomes:

Physical Benefits

- Enhances aggregate stability, improving water infiltration and soil aeration, reducing runoff.
- Improves water-holding capacity.
- Reduces the stickiness of clay soils making them easier to till.
- Reduces surface crusting, facilitating seedbed preparation.

Chemical Benefits

- Increases the soil's ability to hold onto and supply over time essential nutrients such as calcium, magnesium and potassium.
- Improves the ability of a soil to resist pH change; this is also known as buffering capacity.
- Accelerates weathering of soil minerals over time, making the nutrients in the minerals available for plant uptake.

Biological Benefits

- Provides food for the living organisms in the soil.
- Enhances soil microbial biodiversity and activity which can help in the suppression of diseases and pests.
- Enhances pore space through the actions of soil microorganisms. This helps to increase infiltration and reduce runoff.

Organic Materials
Over time, the application and incorporation of organic materials can result in an increase in stable soil organic matter levels. Sources of organic materials include:

- Crop residues.
- Animal manure.
- Compost
- Cover crops (green manure)
- Perennial grasses and legumes.

The quickest increases are obtained with sources that are high in carbon such as compost or semi-solid manure.

Organic Matter Management

Practices that help to maintain or increase soil organic matter levels:

- Use of conservation tillage practices (for example zone tillage or no-till). Tillage exposes the organic matter to air and will result in the lowering of stable organic matter due to increased mineralization rates and erosion losses.
- Rotation of annual row crops with perennial grass or legume sods will reduce erosion and build up organic matter as a result of the decomposition of the root mass.
- Establishment of legume cover crops will enhance organic matter accumulation by providing the nitrogen (N) needed for decomposition of freshly added organic materials, especially those with a high C to N ratio (corn stover, cereal straw, heavily bedded manure, etc.).
- Avoiding soil compaction and maintaining proper pH.

Planting Cover Crops

Cover crops are another way to maintain or improve soil health. Some management goals of cover crops include:

- Suppressing weeds
- Protecting soil from rain or runoff
- Improving soil aggregate stability
- Reducing surface crusting
- Adding active organic matter to soil
- Breaking hardpan
- Fixing nitrogen
- Scavenging soil nitrogen
- Suppressing soil diseases and pests

Cornell has developed a Cover Crop Guide, designed to help growers use cover crops to reach various soil health goals. http://covercrops.cals.cornell.edu/index.php

Fertilizers

Plants take up the majority of their nutrients in dissolved (ionic) forms. To meet the needs of plants we often fertilize with nutrients delivered as soluble salts that when mixed with water dissolve much like common table salt into ions. When applied to a soil, these nutrient ions first mix with the soil water before very gradually moving with the water’s flow. As the nutrient ions dissolve and mix they slowly move away from where the fertilizer has been applied. This dilution and movement distributes the fertilizer through a much larger area that ideally include that roots of the plant you’re fertilizing.

If poorly applied, fertilizer can bypass the roots and not fertilize the plant, or build up as soluble salts in the soil and become toxic to plants. To avoid these problems of too little or too much it's important to read the fertilizer application instructions. Outside in the northeast too much is generally not a problem, but when fertilizer is applied at too high a rate or repeatedly without sufficient water to leach (wash) the fertilizer (salts) through the soil, the salts will build up and will kill plants. While this is rarely a problem in the garden or on a farm, soluble salt problems commonly occur with indoor or container plants that are insufficiently watered. The best way to prevent soluble salt injury is to leach the salts out of the pots. When applying water, allow some to drain through and then empty the drip plate. Some water should drain through each time you water the pot.

Another problem can be found with young or tender plant roots that are too close to where the fertilizer was applied. In these cases water is drawn from these roots, as well as from surrounding soil. This causes plant cells to begin to dehydrate and collapse, and the roots may burn to a point where they cannot recover. If soil moisture is limited, most of the water drawn towards the salt will come from plant roots, and the damage will be severe. The key to avoiding this problem is that when applying fertilizer during dry, hot weather you:

- do not over-apply nitrogen or potassium fertilizer
- make sure adequate moisture is present after applying fertilizers high in salts

The Nature of Fertilizer

As discussed earlier, there is much confusion over the terms inorganic, synthetic, organic, natural and special purpose when it refers to fertilizers. It is important to keep in mind that nutrients are available to plants in only one or two forms, regardless of the source. Put in another way, "a nitrate molecule is a nitrate molecule," whether from compost, manure or manufactured fertilizers.

Keep in mind that no matter what the source or form of the fertilizer, the percent nutrient concentration (or grade) should be displayed on the products label.

Inorganic Fertilizes

Some natural inorganic fertilizers exist in nature as insoluble parent/rock materials, for example: rock phosphate, sodium nitrate and potassium sulfate. Others are manufactured products made from non-living material and are referred to as synthetic or chemical fertilizers. Examples include ammonium sulfate (21-0-0), commonly used on acid-loving plants like blueberry and azalea; superphosphate (0-20-0), phosphate rock treated with sulfuric acid; granular fertilizers, such as 10-10-10 and 10-6-4; liquid fertilizers, such as Miracle-Gro.

Inorganic fertilizers are mineral salts with the nutrients in a soluble form which makes uptake by plants easy. But because they can be soluble they can leach easily in the soil. Generally, the nutrient analysis of inorganic fertilizers is high, this makes them concentrated. As a result, extra care should be taken when using them to avoid loss of nutrients from the rooting zone. Additionally, many inorganic fertilizers are “quick release” meaning that the nutrient ions are quickly available for plant uptake. Unfortunately, this “quick release” also means that any nutrients not taken up by plants won't remain in the rooting zone for long and will be lost from your farm or garden and could possibly create nutrient excess in other locations.

Organic Fertilizers

The term natural organic is applied to fertilizers derived solely from remains, or by-products, of a once-living organism. Various wastes and by-products of the plant and animal processing industries can be used as fertilizers. Cottonseed meal, blood meal, bone meal and horn meal, and manures are examples of natural organic fertilizers. When packaged as fertilizers, these products are generally less concentrated and less prone to leaching and loss from the root zone. Also organic fertilizers generally release their nutrients slowly. While this will prevent much of the loss of nutrients from the root zone associated with "quick release" fertilizers, care needs to be taken to provide enough nutrients for the growing plants.

Human-made organic materials used for fertilization are termed synthetic organics. Examples are urea (a water-soluble nitrogen under controlled conditions); ureaform (made by reacting urea and formaldehyde) and IBDU (made by reacting urea and isobutyraldehyde).
When using organic fertilizers there are a number of things that you should consider:

- Organic fertilizers may not release enough of their principal nutrients at a time to give the plant what it needs for best growth.
- Organic fertilizers are beneficial for improving the soil's physical structure, and increasing bacterial and fungal activity, (particularly by the mycorrhizal fungi that help make phosphorus more available to plants.)
- Because organic fertilizers depend on soil organisms to break them down to release nutrients, they are only effective when the soil is moist and warm (activity begins when soil temperatures reach 50°). Microbial activity is also influenced by soil pH and soil aeration.
- Even though fresh manures have the highest amount of nutrients they also contain high soluble salt levels which can burn tender plant roots or plants. Also, heat and acetic acid from improperly composted manure can cause plant damage. It is always best to use aged (preferably a year old) compost for gardening purposes. Aged compost should also contain fewer viable weed seeds. (Typical rates of manure applications vary from a moderate 200 pounds (5 bu. per 1000 sq. ft. to as much as 1 ton per 1000 sq. ft. (50 bu.).
- There are no state or federal standards regulating the use of terms like organic, natural, or natural organic, when applied to fertilizers. But they are listed on the OMRI (Organic Materials Review Institute) Brand Name Products list.
- Some organic materials, particularly composted manures and sludges, are sold as soil conditioners and do not have a nutrient guarantee although small amounts of nutrients are present.
- Sewage sludge (or bio-solids as they are now called), is a recycled product of municipal sewage treatment plants. Three forms may be available; heat-dried activated and composted. Activated sludge has a higher concentration· of nutrients (approximately 6-2-0) then composted sludge (1-2-0). Although these materials can be used on turf and landscape plants they are not recommended for use on edible crops.
- As sewage sludge/bio-solids are a recycled product of municipal sewage treatment plants, they often contain contaminates that are not degraded or decomposed in the composting process. These products may include heavy metals (e.g. lead), pharmaceuticals (e.g. hormones, medicines, etc.), hydrocarbons (e.g. oils) or other industrial and commercial waste products. For more information about sewage sludge/bio-solids and land application see Case for "Caution Revisited: Health and

Environmental Impacts of Application of Sewage Sludges to Agricultural Land" at https://ecommons.cornell.edu/handle/1813/47580.

Special Purpose Fertilizers

When you are shopping for fertilizers, you will find them packaged for certain uses or types of plants, such as Rhododendron and Azalea Food, Holly Tone or Rose Food. Rhododendron, azalea, and holly are acid-loving plants and the ingredients used in these fertilizers lower the acidity of the soil. As a result these fertilizers are especially beneficial for acid loving plants where the soil is not acidic enough. It is not expected that these "acidic" fertilizers can permanently change an alkaline soil to an acid one and there are limitations on how much or how long a fertilizer can alter the soil pH. Soils tend to revert back to their original pH if amendments are not regularly applied. We will talk more about this when we discuss soil pH and liming.

As a result be sure to know the soil pH and pH range your plant prefers. For example blueberries will never thrive in an alkaline soil and the ongoing effort to maintain an acid soil for your blueberries may not be worth the time and money in the long run.

Other fertilizers packaged for specific plants, such as roses, often do not have a valid research basis for being called "special." Perform a soil test before purchasing any expensive special-purpose fertilizer. It is not possible to make a blanket statement that one fertilizer is best for every area of the state. While it is true that different plants have different nutrients needs, often soils may already be able to provide for those needs. What is unknown is the reserve of nutrients already in the soil and this changes with every soil type, location and management history.

Fertilizer Forms

Granular Fertilizers
These fertilizers are conventional, traditional, or synthetic chemicals. They are manufactured and packaged into bags (5 lb., 10 lb., 25 lb. 50 lb. or more). They can be organic or inorganic in composition, and are applied by broadcasting them over the soil and incorporating them into the soil to prepare for planting.

Water Soluble Fertilizers
These fertilizers (often termed "quick release") are sold as liquids or powders in small packages. The fertilizer is dissolved in a bucket or watering can, filled with water and applied as a solution. Brands like 'Miracle Gro' or 'Rapid Gro' are familiar to most shoppers, although there are other brands on the market. They must be applied much more frequently than any other form of fertilizer (frequently every 1-14 days during the growing season for fast growing annual plants), as they can quickly move through the soil and are lost from the root zone. If it rains immediately after applying water-soluble fertilizer, the rainwater can leach the fertilizer altogether from the root zone, sometimes requiring that it be reapplied after the rain.

Slow-Release Fertilizers
These fertilizers are generally sold in pellet or powder forms and applied in very small amounts on the top of the soil or incorporated into the top layer of soil. Plants take up fertilizers continuously, so it is beneficial to provide them with a balance of nutrients

throughout their life. Perhaps the most efficient way to achieve this is to apply a slow-release fertilizer. Slow-release fertilizers contain one or more essential nutrients, which are released or made available to the plant over an extended period of time (e.g., 3 mo, 6 mo., or 9 mo.) These fertilizers often have layers or coatings which degrade due to temperature, moisture and microbial activity. As the coating breaks down nutrients are released into the soil.

Use caution when applying slow-release fertilizers around trees and shrubs, as they may keep the plant growing late in the summer. Late season growth may not harden off completely, and result in excessive winter damage.

WIN and WSN
The initials WIN and WSN on fertilizer labels stand for "water insoluble nitrogen"· and "water soluble nitrogen" respectively.

- WSN dissolves readily and is usually in very simple forms of nitrogen (usually ammonium or nitrate). Nitrogen in organic forms in fertilizer or organic matter must be broken down by microbial activity into an ammonium or nitrate form before it can be used by plants.
- WIN is referred to as a slow-release nitrogen source, delivering nitrogen at different rates according to slow release source. Slow-release N may also exist as coated soluble N sources, often referred to as controlled-release N (CRN)
- Slow-release N may also exist as coated soluble N sources, often referred to as controlled-release N (CRN).

Fertilizer Analysis and Grade
Fertilizer analysis provides information on how much of a nutrient is in a formulation. It is based on a percentage of the weight. All fertilizers are labeled with three numbers that indicate the guaranteed analysis, or the fertilizer grade. These three numbers give the percentage of nitrogen (N), phosphate (P_2O_5), and potash (K_20).

State regulations require that actual analysis values must be within certain limits of the labeled grade. To simplify matters, these numbers are often said to represent nitrogen, phosphorus, and potassium, or N-P-K. But we should remember that it is not N-P-K, but N-P_2O_5-K_20. If we have a 100-pound bag of fertilizer labeled 5-10-10, there are 5 pounds of N, 10 pounds of P_2O_5, and 10 pounds of' K_20, To calculate the actual amount of P in this fertilizer take the percentage of P_2O_5, multiplied by 0.44 equals. Only 44% of P_2O_5 is phosphate. This means that is are 2.2 lbs. of P in the 100 lb. bag of this fertilizer. To determine potassium take the percentage of K_20, multiplied by 0.83 and we would determine at there is 8.3 lbs. of potassium in the bag of fertilizer.

Fortunately, we don't usually have to do this calculation as most nutrient recommendations we get for our plants and soil take this conversion into account and provide the recommendation based on N-P_2O_5-K_20 even if the bag is labeled N-P-K.

Interestingly, when you add up the percentages of N-P-K in the fertilizer the nutrient amounts do not add up to 100 percent. There are several possible reasons for this. First, often the nutrients are in a compound or material that contains other elements. Much of K used in fertilizers is in the form of potassium chloride. Secondly, a fertilizer may also contain materials other than N, P, K. These additives they may contain clay or organic based fillers or conditioners to ensure good physical properties and light weight absorbents to give slow release of nutrients. In addition, they also can make it easier to spread and apply the fertilizer to the soil. In some cases, limestone is added as filler to neutralize the acidifying effects of some N sources.

The information contained on a fertilizer label has been standardized, and the consumer is protected by state laws requiring manufacturers to guarantee the claimed nutrients. If you are unable to purchase the fertilizer percentages you wish, you can often combine two or more fertilizers with a different N-P-K analysis to meet your plants' and soil's needs. When you do this, you will have to adjust the amount of fertilizer applied per unit area to compensate for difference in analysis.

Complete Fertilizers
Complete fertilizers contain each of three major plant nutrients: nitrogen, phosphorus, and potassium. Grades such as 10-10-10, 16-8-8 and 5-10-10 represent complete fertilizers. Grades such as 0-25-25 and 20-0-10 represent incomplete fertilizers (one or more of the major nutrients is missing from the fertilizer), and 5-0-0, 0-20-0 or 0-0-60 are considered single nutrient fertilizers.

Fertilizer Ratio
Fertilizer ratio refers to the relative amounts of N, P2O5, and K20 in a fertilizer. Your soil test results may indicate a need for nutrients in a particular proportion. Select a fertilizer as close to the recommended ratio as possible.

Grade	**Ratio**
10-10-10	1:1:1
5-10-5	1:2:1
12-24-12	1:2:1
12-4-8	3:1:2
0-25-25	0:1:1

Sample fertilizer label adapted from Penn State Extension Master Gardener Manual.

Brand Name **30-3-12 (grade)** Guaranteed Analysis Total Nitrogen (N)… 30% 2.2% Ammoniacal nitrogen 7.4 % Water-insoluble nitrogen (WIN) 10.8% Urea nitrogen 9.6% Other water-soluble nitrogen (WSN) Available Phosphate (P_2O_5)… 3% Soluble Potash (K_2O)… 12% Manufacturer Name Address Net Weight (lbs)

How and when you apply fertilizer is just as important as how much fertilizer you add. We generally associate this with application and there are a number of methods you could consider.

Application Methods

Broadcasting

Broadcasting is used over large garden areas or when time or labor is limited. It is spreading a recommended rate of fertilizer over the surface of the growing area. It is often combined with a rototiller, spade or watering to incorporate it into the soil.

Banding

This method is used primarily in the vegetable garden. It is applying narrow bands or strips of fertilizer in furrows several inches to the side and sometimes below the seeds or transplants. The best technique is to stretch a string where the seed row will be. With a corner of a hoe, dig a 3-inches deep furrow, 3-inches to one side of and parallel with the string. Spread the fertilizer in the furrow and cover with soil. Repeat on the other side of the string. Seeds are sown under the sting after the fertilizer is applied.

For widely spaced plants, such as tomatoes, place fertilizer in bands 6-inches long for each plant or in a circle around the plant. Place the bands 4-inches from the plant base. If fertilizer is used in the hole itself, place the fertilizer at the bottom of the hole, work it into the soil, and place a layer of soil about 2-inches deep over the fertilized soil before putting the plant in the hole.

Side Dressing

This is also used primarily in a vegetable garden, but could be adapted for other annual plants. Dry granular fertilizer is scattered on both sides of a row 6-8 inches from plants after plants are up and growing. Work it into the soil and water thoroughly. Timing of side dress applications is important and depends on the specific plant The best time to side dress for beans - when in bloom, carrots - when 4" tall, cucumbers - when vines spread, potatoes - when 8" tall and tomatoes at fruit set.

Foliar Feeding
Foliar nutrition supplements soil nutrition at a critical time for the plant. This method is used if:

(1) insufficient fertilizer was applied before planting
(2) you want a quick growth response
(3) when micronutrients (e.g., iron or zinc) are unavailable from the soil
(4) soil is too cold for plants to extract or use nutrients from the soil

Foliar-applied nutrients are water soluble and absorbed and used by plants quite rapidly. Absorption begins within minutes after application and, for most nutrients, is completed within 1 to 2 days. It should be noted that this is not a substitute for good soil fertility management, but rather a corrective practice to deal with a severe nutrient deficiency. For example at transplanting time, a foliar application of a balanced fertilizer can sometimes help establish young plants in cold soils. Be sure to use label recommended dilutions as high concentrations will often damage the plant.

Applying Fertilizers
The amount of fertilizer you need to apply depends upon the analysis of the fertilizer, the area to be covered, the nutrient needs of the plants and the nature of the soil. It is extremely important to accurately calculate the area to be fertilized. No additional benefit will come from adding more nutrients to the soil than are needed by the plant. Further the excess fertilizer can have negative environmental consequences in your garden as well as nearby water bodies, not to mention wasted money. Avoid these potential environmental pollution problems by taking the time to determine the area and apply fertilizer at the recommended rate only.

To help you understand fertilizer calculations here are two exercises to illustrate how you would go about figuring out how much fertilizer you would need.

Granular Fertilizer Calculations:

Nutrients needed/Fertilizer analysis (%) = amount of fertilizer to apply

In the below calculations notice the fertilizer analysis of 21% is written as 0.21, this saves one step. (21%: 21/100= 0.21)
Question 1: How much ammonium sulfate, with an analysis of 21-0-0, would you need to apply at the rate of 1 lb of N per 1000 sq ft. to a lawn that is 3000 sq ft in area?

Step 1: Note the recommended amount of nutrient to apply (1 lb of nitrogen for each 1000 sq ft), then note the analysis of the nitrogen source (in this case 21%)

1lb/0.21 = 4.76 lbs of ammonium sulfate will be needed for each 1000 sq ft.

Step 2: Note how much area is to be treated (here the lawn is 3000 sq ft)

So we'll need to apply 14.28 lbs of ammonium sulfate (3 X 4.76) to fertilize the total lawn area to deliver nitrogen at the 1lb rate.

Question 2: Would you need more or less product to do the job if you used urea (46-0-0)?
1 lb/0.46= 2.17 lbs (or about 2.2lbs) for each 1000 sq. ft so 6.6 lbs for the whole 3000 sq. ft lawn area. (Urea is a more concentrated nitrogen source).

Liquid Fertilizer Calculations:

With liquid fertilizers, the amount of fertilizer in a package is expressed on a volume basis, while the analysis is expressed on a percentage basis. To begin any calculation, you must first determine the weight of a given volume of fertilizer and then calculate the weight of N, P, and K in that volume of fertilizer.

Question: How much 20-40-10 liquid fertilizer would you apply to obtain a fertilization rate of 2 lbs of N per 1000 sq ft when you have a 2000 sq ft area?
Given that: 1 gal of 20-40-10 liquid fertilizer weights 11.5 lbs, calculate the amount of nitrogen contained in each gallon.

11.5 lbs (weight of gallon) x 0.20 (the nitrogen analysis)= 2.3 lbs of nitrogen in each gallon of 20-40-10

Using the formula:

2lbs N is the recommended rate/ 2.3 lbs (nitrogen content/gallon) = 0.87 gallons of 20-40-10 is needed per 1000 sq feet

Your area is 2000 sq ft in size so 0.87 gallons x 2= 1.7 gallons are needed to do the entire area.

Soil Conditioners as mentioned earlier are added to change some problematic characteristic of the soil. This is usually about the pH, compaction or water management.

Changing pH

Soil pH is an important consideration for plant growth success. As discussed earlier, pH impacts the availability of nutrients but also can have direct harmful effects on plants. Soil pH is a measure the hydrogen ions (H^+) concentration in the soil (both on the soil surfaces and in the soil water). These two pools maintain an equilibrium of H^+ concentration where the majority of the ions are located on the soil surfaces, but the total amount of H^+ is based on the soil's texture, amount of organic matter, nutrient concentrations and soil water.

So where do the hydrogen ions come from? It turns out that water (H_2O) naturally will break up (or dissociate) into two very chemically active parts. It is only a small amount of water molecules that will do this (1 in 10,000,000,000,000) but with so many water molecules it happens all the time. The first part of the dissociated water is H^+ ion and the second is OH^- ion (hydroxide). As these two parts are reactive they will often rebind with each other or with other ions or compounds. When the two ions are equal the pH of the soil is 7 (or neutral). But if one ion (either H^+ or OH^-) begin to bind more than the other the pH will change. When there is more H^+ than OH^- the pH drops (or acidifies). When there is more OH^- than H^+ the pH rise (or becomes more alkaline). It is the absolute concentration of H^+ to that determines the pH.

Because we can't directly measure the H^+ on the soil surfaces, we measure the pH of the soil water and based on the H^+ balance between the soil water and soil surfaces we have a good estimate of a soil's total pH. If we want to raise the pH (liming) we need to neutralize the H^+ and if we want to lower the pH (acidifying) we need to add additional H^+. We will generally get a quick pH response, but in time as the H^+ in the soil water comes into balance with the H^+ on the soil surfaces the pH will return towards the original pH. As a result changing the pH can be a slow process because as you change the concentration of H^+ in the soil solution the concentration will also change on the soil surfaces. The amount of loss or gain of H^+ on the soil surfaces will be based on both the type and size of soil particles as well as the amount of organic matter in the soil. It should be noted that finer textured and/or organic rich soils can be very resistant to pH change and, as a result, modifying them over long periods from their native pH will require consistent and long lasting additions of pH modifying soil conditioners (whether to lime or acidify the soil).

Liming (raising the pH)
The chemistry behind using liming agents to neutralize acid and raise the pH of a soil can be complex, but the principle is fairly simple. The liming agent will separate in solution and some component of it will combine with the reactive acidic hydrogen ions (H^+) to remove (or neutralize) the acidifying effect of the H^+. There are number of different liming agents from simple limestone rock to industrial produced calcium hydroxide. These products also vary in cost and strength. Here are some general ideas to consider when trying to raise your soil's pH.

- To make soils less acid, apply a material that contains some form of lime.
- Ground limestone is most frequently used and is economical though can be slow to act.
- The neutralizing value of the specific liming material determines the amount needed to make the pH change. This value is often provided with soil fertility tests but does require an idea of what type of plants you wish to grow.
- Dolomitic limestone also contains magnesium and is recommended when soil with a low pH is also low in Mg.
- The finer the grind of the liming agent, the more rapidly it becomes effective.
- Different textured soils will require a different amount of lime to adjust the pH. More clay means more lime will be needed.
- Soils low in organic matter content (lower CEC) require much less lime than soils high in organic matter to make the same pH change.
- Lime must be in contact with the soil. It should be incorporated into the soil.
- Since lime does not move much in the soil, applying lime before planting is always better. If you apply lime to an established bed, limit the application at any one time (e.g. 50 pounds of lime per 1000 square feet for turfgrass). If needed, it might be worthwhile to make a lime solution and apply near the roots of established trees, shrubs and herbaceous perennials.

Acidifying (Lowering the pH)
The reverse of the liming process can also occur. A soil can become more acidic as plant nutrient ions such as Ca^{+2}, Mg^{+2} and K^{+} are removed from the soil solution by plant uptake. If these ions are not replaced by mineral weathering, organic matter decomposition or fertilizer the concentration of H^{+} will increase. These basic ions can also be lost by leaching again increasing the H+ concentration. As the H+ concentration steadily increases, the soil pH will lower and become more acidic. This often will take time and can often be offset by good fertility management.

If pH is too high, a sulfur source can be added to the soil to reduce alkalinity. Do not use large amounts of aluminum sulfate to lower the soil pH. At low soil pH's aluminum is quite soluble and can be toxic to plants. One good source to use is elemental sulfur or other acidifying agents, such as iron sulfate. Iron sulfate will require larger amounts than elemental sulfur (as much as 3 to 4 times more) to achieve the same effect as elemental sulfur but can have other fertility benefits.

Blueberries and many ornamental plants require slightly to strongly acid soil to thrive. These species develop iron chlorosis when grown in alkaline soils. Iron chlorosis is often confused with nitrogen deficiency because the symptoms (a definite yellowing of leaves) are similar. Iron chlorosis can be corrected by reducing the soil pH. Applying chelated iron formulations to the soil or spraying foliage with solutions of iron chelate or iron (ferrous) sulfate is a temporary solution.

The term chelate (pronounced key-late) comes from the Greek word for claw. Chelates are chemical claws that help hold metal ions, such as iron, in solution, so that the plant can absorb them. Different chemicals can act as chelates from relatively simple natural chelates like citrate to more complex manufactured chemicals. When a chelate metal is added to the soil, the nutrient held by the chelate will remain available to the plant.

Most nutrients do not require the addition of chelate to aid absorption. Only a few of the metals, such as iron, benefit from added chelates. The type of chelate used will depend on the nutrient needed and the soil pH.

pH testing demonstration: https://www.youtube.com/watch?v=eSnbo0J_99Y

Troubleshooting Specific Soil Problems

Improving Compacted Soil

As discussed earlier, soil structures are the aggregates that are formed when individual soil particles, sometimes with organic matter, clump together as the soil develop. From a garden and farm perspective, soil structures are extremely important as they greatly contribute to water behavior (infiltration, drainage and storage), aeration in soils, as well as a plant's rooting ability. While soil structure can be found throughout the soil, the granular (small crumb-like) structures near the soil surface play the most dramatic role in the life of plants. These granular structures, formed by activities of soil organisms are a mixture of mineral particles, root hairs, fungal masses and decomposed organic matter. Further, as they are near the surface, these are the structures that are the most easily destroyed as the simple pressure of driving equipment or even walking on the soil can crush and break them apart. As the pressure is applied, macropores in the soil are squeezed and compressed into micropores with a dramatic loss of soil volume and a dramatic loss of pore space. While some soils are naturally dense, this pressure creates compacted soils that have very little space for water and air to move. In fact, it takes very little pressure – about 4 pounds per square inch (psi) or approximately the pressure under a typical person's footprint – to cause this compaction. Interestingly the pressure of compaction creates its own plate-like type of structures that lay flat, near or at the surface. These structures, as well as the density of compaction, have a number of problematic impacts on the soil:

- granular structural units are broken down
- large flat plate-like structures are created
- increased soil density
- reduction of pore space
- limited aeration
- limited access to oxygen by plants
- less water infiltration
- limited water movement
- impeded soil drainage
- reduced water movement to and from the roots
- extremes of wet and dry soils
- impaired root growth and biological activity
- increased tillage difficultly

Once soil is compacted, it is not impossible to fix, but it turns out that prevention is a lot easier than correction. So, let's start by considering some best management practices. Compaction is much more severe and easier to create on wet and flooded soils as compared to moist or dry soils.

Soil moisture is probably the most important factor to consider when trying to prevent compaction. The wetter the soil, the easier it is to compact. Don't walk or drive on saturated soils and never till wet soils. Wait for the soil to drain if you need to get to the soil. If you really need to go into your garden or field when it's wet, stay between rows. If you need to access the plants on a regular basis when the soil is wet consider making dedicated paths – and stay on them! This won't prevent compaction, but it will limit the amount and locate it to small non-planted areas of your garden or field. You might also consider boards or mulch as walkways at this will distribute the weight and reduce pressure on the soil. The take home message is stay off wet soils.

To remediate compacted soil there are three commonly used practices. It is important to note that these three practices are often used in combination to increase the rate of remediation, but even when used effectively and in combination they won't immediately remedy compacted soils:

- Reduce or remove traffic and tillage

- Limited tillage when the soil is dry
- Addition of organic matter

Reduce or remove traffic and tillage: As compaction is due to pressure, reducing or removing traffic prevents addition damage to your soil and allows you to correct the problem. **Without removal or reduction of traffic, compaction can't be eliminated.** If you have to walk or drive on the soil even when it's wet, consider creating dedicated paths. Continued tilling or cultivation also destroys the healthy granular soil structure.

Limited tillage when the soil is dry: An initial tillage or breaking of the soil by shovel when the soil is dry will break up the plate-like structures that have developed during compaction. Do not do this when the soils is wet as it will just add to the problem of compaction. This is generally just a one-time event and is often combined with the addition of organic matter to encourage the formation of the healthy granular soil structure found at the soil surface.

Addition of organic matter: as discussed earlier, organic matter greatly improves infiltration, drainage and water storage as well as aeration in soil. It is these same four characteristics that compaction destroys. The real issue is how we add organic matter to get these benefits. The simple solution is to just add organic matter to the surface and let the soil organisms mix it into the mineral soil. It doesn't have to be that much, perhaps a few inches on the surface. Good sources include peat moss, used potting soil, composted animal manures, leaves or leaf mold, sawdust, compost and straw.

To speed up the process we recommend mixing the organic matter into the soil so that the soil organisms will more easily decompose the organic matter and create the desired granular soil structures. Conditions such as adequate moisture, aeration, temperature and nutrient availability that encourage biological activity, will in turn encourage increased rates of decomposition and granular soil structure creation and a loosening of the soil.

Ideally all three practices will be used in combination, as this will greatly increase the rate of remediation, yet as noted earlier, it will still take some time to repair the damage. But even if you can't use all three practices, simply removing the traffic will gradually improve the problem.

Soil Contaminants and Best Practices for Healthy Gardens (CWMI factsheet)

How do plants get contaminated?

There are three main ways that heavy metals such as lead could contaminate garden crops. This information is important to help select the best crops for particular situations.

(1) Deposition from the air: This used to be a major source of lead contamination in urban areas until leaded gasoline was phased out completely in the 1980s. Some lead deposition still occurs due to wind-blown dust from contaminated soils and streets. Other airborne contaminants can also end up on plants. This is a particular problem for leafy crops, which have a high surface area in contact with airborne particles.

(2) Uptake into plant roots: In most situations, unless soil is acidic (low pH) or very low in organic matter, not much lead is transferred from contaminated soils to garden crops through plant roots. However, roots are likely to have a higher concentration of lead than leaves and stems, and fruits or seeds are likely to be lowest in lead of all plant parts. Cadmium and some other heavy metals of concern are more readily taken up from contaminated soils into roots and plant tops.

(3) Direct contamination by garden soil: Root and tuber crops are more likely to be contaminated than other types of crops because they are in direct contact with soil. Leafy vegetables (lettuce, spinach, collard greens) are also easily contaminated by soil splash and dust. Washing leafy crops can remove up to 80% of lead contamination, and much of the lead can be removed from vegetables such as carrots and potatoes by peeling. However, in situations where lead contamination is moderate to severe, growing these types of crops directly in the contaminated soil is probably not the best choice.

Luckily, there are several natural barriers that limit heavy metal transfer into crops.

- Soil-Root Barrier: Some toxic metals (such as lead) have low solubility in most soils, and do not readily enter the plant through roots.
- Root-Shoot Barrier: Most toxic metals bind relatively strongly in roots, and movement to other plant parts is limited.
- Shoot-Fruit Barrier: Most toxic metals are largely excluded from entering the reproductive parts (fruits, seeds) of the crop, remaining instead in the vegetative parts.

Best Practices for Healthy Gardens

- Incorporate or top dress the garden area with clean materials such as uncontaminated soil, compost, manure, or peat moss.
- Adjust soil pH to near neutral. Most metals are more bioavailable in more acid soils and can harm plants or animals when pH is too low.
- Mulch walkways and other areas to reduce dust and soil splashing back onto crops, or maintain healthy grass or other ground cover.
- Don't grow edible produce directly adjacent to buildings, where lead levels are likely highest.
- Build raised beds with clean soil to grow food crops in more contaminated areas. A layer of landscape fabric will prevent plant roots from entering the contaminated soil below the bed.
- For raised beds and other garden projects, don't use certain types of treated lumber that may have chemicals that will further contaminate the soil. In the past, some commercially-available treated lumber contained copper, chromium, and arsenic.
- In more contaminated areas, first consider whether the practices outlined here can sufficiently reduce the amount of contaminants in contact with crops. This can be verified by testing the soil or plant tissue.
- If it is not possible to protect crops from contamination, consider growing crops that are less likely to be contaminated (see list below).
- Because of the many benefits of eating fresh fruits and vegetables, growing ornamental plants instead of food crops should only be considered as a last resort.

Which Garden Crops Are Suitable to Grow in Contaminated Soils?

Some garden crops can take advantage of these natural barriers. However, the physical contamination of crops by soil dust, splash or aerial deposition can often bypass the natural barriers of protection. Practices to reduce the physical contamination of garden food crops and to reduce human exposure therefore become important.

In addition to what is known about contamination pathways, the results of past research also provide some information about the potential for heavy metal transfer into garden crops. All of this information allows for recommendations for garden crops that are most and least suitable for growing directly in contaminated soils. These resources will be updated and expanded in the future as new information and research findings become available.

Most Suitable:

- Vegetables, fruits and seeds: tomatoes, eggplant, peppers, okra (seed pods only), squash (summer and winter), corn, cucumber, melons, peas and beans (shelled or cleaned thoroughly), onions (bulb only)
- Tree fruits: apples, pears
- Berries: blueberries, strawberries, raspberries, blackberries (if cleaned thoroughly)

Least Suitable:

- Green leafy vegetables: lettuce, spinach, swiss chard, beet leaves, cabbage, kale, collards
- Other vegetables: broccoli, cauliflower
- Root crops: carrots, potatoes, turnips

Controlling Erosion

Soil erosion is a major concern during construction when large areas of soil may be exposed to rain and wind. Dust is a nuisance as well as a health issue. Sediment can have significant offsite impacts, such as filling gutters and storm drains, and degrading stream water quality. Erosion control can be accomplished by implementing one or more best management practices designed to reduce erosion and to retain eroded sediment on site.

The list of these best management practices is longer than the scope of this chapter and your local CCE office or Extension Associate is a good source of information. From a garden perspective there are three common approaches that we take to control erosion:

- Water/Wind breaks
- Cropping practices
- Mulching/Capture practices

Water/Wind breaks are practices designed to prevent the rapid and/or continuing flow of wind or water over the soil. They primarily act to divert the flow before it reaches the soil. They come in a variety of forms and can be a simple planted hedgerow or as dramatic as a diversion ditch. What is important here is to determine the likely source(s) of wind or water energy that will create erosion and stop, reduce or divert its energy.
Cropping practices are methods of planting designed to stabilize soil and/or reduce the energy of the water/wind over the soil. While water/wind breaks are usually placed to prevent erosive energy from reaching the soil, cropping practices are often placed to both reduce the energy as well as make the soil more resistant to the erosive energy that reaches the soil. These practices make extensive use of above ground plant biomass to slow water/wind energy as well as below ground plant roots to anchor soil and improve infiltration. The improved infiltration acts to reduce the amount of water that will move across the soil and thus prevent erosion.
Mulching/Capture practices are very similar in use as cropping practices but they are placed primarily to armor the soil against the erosive energy or water/wind. They are generally very selectively used as the mulch itself can be eroded, but when anchored, filter fabrics, plastics

mulches, etc. can be very effective in encouraging water infiltration as well as catching sediment before it leaves your site. These practices are often used when soils need to be exposed for some period of time and sediment need to be prevented from moving off site.

One way of understanding how these three practices are used is to think about where they are placed relative to the erosive water/wind energy that is causing the problem.

- Water and wind breaks are generally placed *in front* of the soil that is to be protected.
- Cropping practices are generally placed *on* the soil that is to be protected. Though they can be placed *in front* of the soil to reduce the erosive energy across the soil that is to be protected.
- Mulching and capture practices are generally placed *on* soils that are to be protected or *behind* to capture sediment that is leaving the site.

As mentioned earlier there are many methods to deal with sediment control and often these methods are used at the same time. If used well, they are effective in diverting erosive energy, anchoring erodible soil, increasing water infiltration and/or operating as a sediment trap for soil.

While prevention is the best practice, it is not always an option. Consider using erosion control practices whenever erosion becomes a problem. Many can be easily installed, cost little and effectively keep your soil where you want it. If you have any questions, contact your local CCE office or an extension associate.

Improving Soil Drainage

Ponding or high water tables often can be problems for plant growth, basements or even pathways or driveways. The following practices can be used to alter soil drainage:

- **Amend soils with organic matter.** Organic matter improves drainage in fine-textured soils. Using organic matter to amend soils may improve drainage near the surface, but subsurface drainage may still be a problem if the subsurface layer impedes water movement. Consider adding sustainable rates of organic matter, especially in permanent planting areas; otherwise the effect is temporary and original conditions will return once the organic matter has decomposed.
- **Install subsurface tile drains.** A tile drain is a length of perforated plastic pipe that can be buried up to several feet beneath the soil surface. Depth of the pipe's placement is based on the needs of the project. Because excess soil water enters the pipe and is conducted to an open ditch or gutter outside of plant root zones, care is needed to maintain a gentle downwards slope away from where you wish to move the water. If the slope of the pipe isn't correctly placed, the water can flow towards where you wish to remove it. There are many potential and creative uses for subsurface tile drains in landscapes: in planting beds, behind retaining walls, in tree vaults. Many home improvement stores market tile drain materials and provide informational brochures on installation.
- **Install vertical drains in planting holes.** A vertical drain or "dry well" is a hole 4 to 6 inches in diameter and 3 to 5 feet deep placed in the bottom of a tree or shrub's planting hole. A soil bucket auger or posthole digger can be used to excavate the hole. Fill the

hole with coarse gravel to provide a drainage outlet for water that might otherwise pool in the bottom of a planting area.

- **Construct raised beds or planting boxes.** Raised beds or planting berms raise a part of the plant root system above the native, poorly drained soil. Beds 8 to 12 inches high are adequate for many garden plants, while hills or berms 2 to 3 feet high are better for woody plants.

Managing Soil Salinity (from *Sustainable Landscapes & Gardens*, Before You Plant, pg 9)

Salinity is a measure of the total amount of soluble salts in soil. As soluble salt levels rise it becomes increasingly difficult for plants to extract water from soil. This problem is called chemical drought, since affected plants show visual symptoms similar to those from water stress even when water is present. It is also why we can't water plants with salt water. Soil salinity levels can be assessed with a simple and inexpensive soil test.

High soil salinity can be created virtually anywhere as a result of poor soil drainage; use of irrigation water with high levels of salts; application of excessive amounts of fertilizer, manure or compost; or runoff from deicing salts used on sidewalks and roads.

Different plants vary widely in their salt tolerance. One method of addressing a soil salinity problem is to select and plant salt-tolerant vegetation in saline soils, coastal areas or areas prone to receiving salts from deicing activities. Curbing and raised planting areas serve to channel deicing salts away from soil around plants.

The only effective way to reduce soil salinity is for the soluble salts to be leached (washed) from the soil by clean (non-salty) water irrigation. The salt will mix with the water and will then be leached away if excess water is applied. The drainage will essential for reclaiming saline soils since water must move through the soil to leach salts below the plant root zone. Adequate drainage is necessary and if the soil is poorly drained because of compaction, a restrictive layer such as a plow pan, poor structure or fine texture, these problems must be addressed first. Also consider where that drained water will go. You don't want to move the problem, you want to solve it.

This activity was adapted from *Soils and Fertilizers*, Soils-MG/NYS 12.04, Jonathan Russell-Anelli and Joann Gruttadaurio.

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