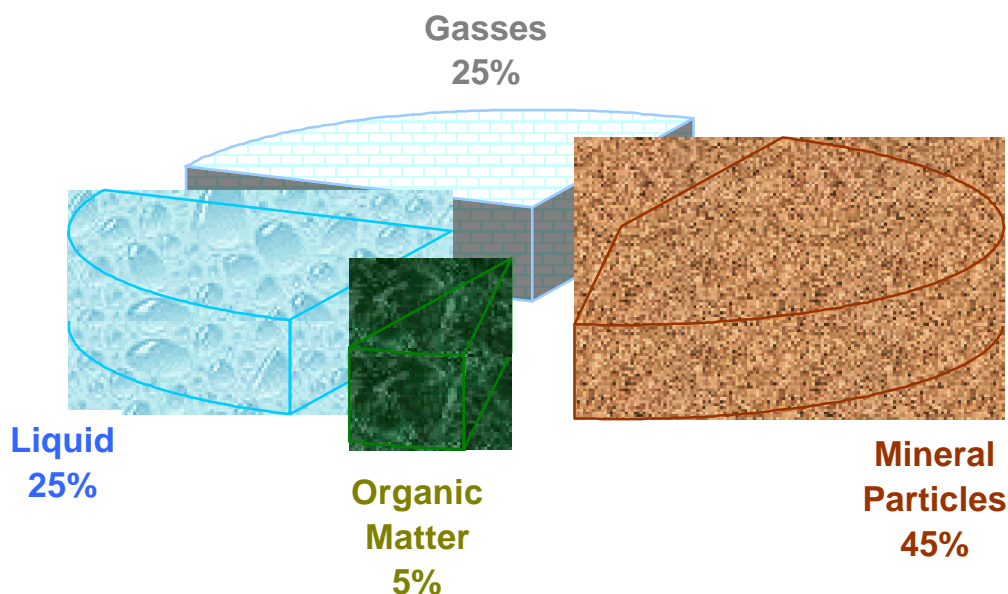


Soil

“To the uninitiated, gardening seems to be all about plants. Certainly each of the seemingly infinite variety of trees, shrubs, flowers, vegetables and grasses is fascinating. Artfully combining them to create landscapes and gardens is challenging and rewarding. However, to the initiated, gardening is really all about soil.” [*National Garden Bureau*, Liz Ball, author.]

Let's define soil: Typical soil consists of **mineral particles** (sand, silt and clay) that form the framework or matrix onto which **humus** and other **organic matter** are bound by moisture.

- This soil matrix constitutes **45 %** or more of the total soil volume.
- **Organic matter** consisting of incompletely decomposed compost, mulches, living and dead roots, micro and macro organisms, and finally **humus**, makes up about **5%** of this vital portion of the soil.
- Soil has porosity and the spaces between and amongst the soil particles are filled with either air or water. The **liquid** takes up about ½ of this area (**25%** of the total soil) and usually contains dissolved micronutrients including **humates** or **minerals**, and **trace elements**.
- The remaining **25%** is the aforesaid air space constantly undergoing atmospheric exchange. This may be in part the same air we breath, but is to a large extent consists of **gases** from root respiration, and the decaying and decomposition of organic matter, and to a lesser extent transpiration by macro organisms such as earthworms, nematodes, insects, and so forth.



The volume of water and air space bear a direct reciprocal relationship upon each other. Entrance of water into the soil excludes air. Likewise, as water is removed by plant use, drainage, or evaporation, pore space that was occupied by liquid becomes refilled with gases. This information helps to illustrate how much nutrient tie-up takes place and to what extent, as well as what percentage of available nutrients might actually be mobile.

Soil structure and texture: “**Texture**” describes the relative percentages of primary soil particles (sand, **silt**, and clay). **Sand**, silt (.02 mm), and clay are mineral particles defined by diameter and by chemical composition. “**Structure**” is very important since (along with **soil texture**) it affects the **porosity** of the soil. A dense structure will greatly reduce the amount of air and water than can move freely through the soil. Also, it will affect the plant's ability to propagate roots through the soil. Sandy soils often have poor structure; the coarse texture causes good drainage but poor retention of water. Clay soils with poor structure will have many small pores, but few large ones, and will thus drain poorly. Clay soils with good structure may have a balance of fine and large pores, and thus provide the moderate drainage/ retention required by many crops.

Of the mineral particles found in a soil **clay** is probably the most important type. Despite their small size, clay particles have a very large surface area relative to their volume. This large surface is highly reactive and has the ability to attract and hold positively charged nutrient ions. These nutrients are available to plant roots for nutrition. **Clay particles** are also somewhat plastic (flexible) because of their lattice-like design. This feature allows clay particles to absorb water and other substances into their structure.” [UC DAVIS]

“**Soil structure**” further comprehends how the primary particles are arranged into aggregates or **peds**. Thus, a soil aggregate comprises many primary particles. **Peds** are the natural aggregates that can be clearly seen in the field. **Clods**, on the other hand, are aggregates that are broken into shape by artificial actions such as **tillage**. The surfaces of **peds** persist through cycles of wetting and drying in place. Commonly, the surface of the **ped** and its interior differ as to composition or organization, or both, because of **soil development**. Thus, earthy clods and fragments stand in contrast to **peds**, for which soil forming processes exert weak or no control on the boundaries.

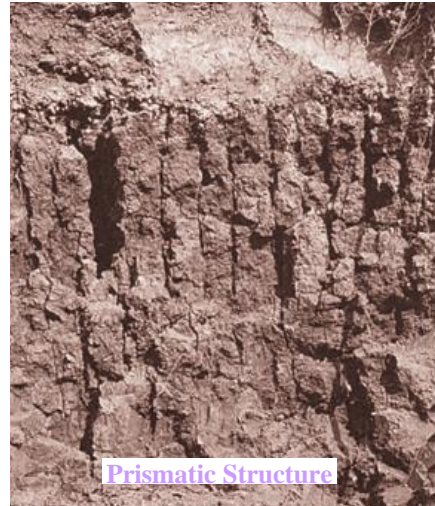
There are five major classes of structure seen in soils: **platy**, **prismatic**, **columnar**, **granular**, and **blocky**. http://en.wikipedia.org/wiki/Soil_structure There are also **structureless** conditions. Some soils have simple structure, each unit being an entity without component smaller units. Others have compound structure, in which large units are composed of smaller units separated by persistent planes of weakness.

Peds with a **platy structure** are made up of units that are flat and platelike. They are generally oriented horizontally. **Platy**



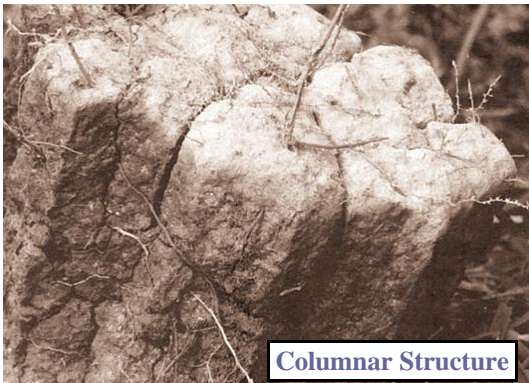
structure is usually found in subsurface soils that have been subject to compaction by animals or machinery or leaching. With little effort the horizontal layers can be pried with a pen knife. **Platy structure** tends to impede the downward movement of water and plant roots through the soil.

Individual units that are bounded by rounded to flat vertical faces reveal what is known as a **prismatic structure**. This variety of soil peds is comprised of units distinctly longer vertically, the faces typically appearing to be casts or molds of adjoining units. Vertices are angular or subrounded; although the tops of the prisms are somewhat indistinct and normally flat. **Prismatic structures** are characteristic of the **B horizon** subsoils. The vertical cracks result from wetting and drying and freezing and thawing along with the regular downward movement of water and roots.



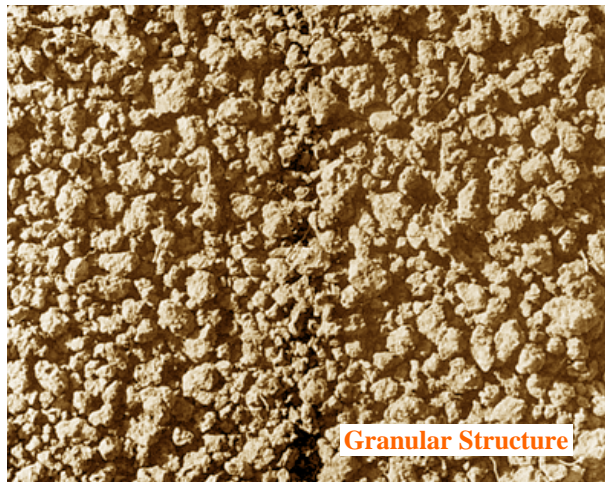
In **columnar structure**, the units are similar to

prisms, but in contrast the tops of columns are very distinct, and normally rounded. **Columnar structure** is common in the subsoil of sodium affected soils. Plant roots have difficulty penetrating these layers because columnar structure is very dense. Techniques such as deep plowing may help to restore fertility to some degree of to these soils.

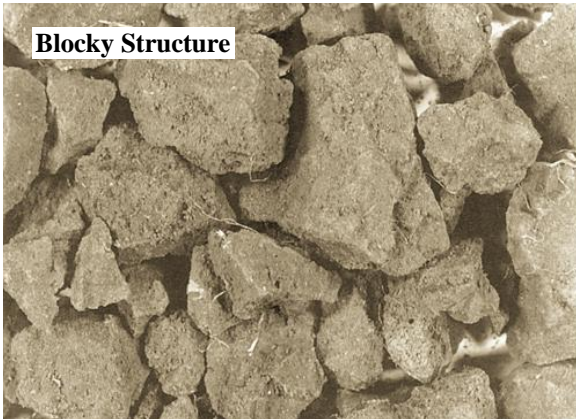


In **granular structure**, the structural units look like cookie crumbs. **Granular structure** is common in the surface soils of rich grasslands

and regularly amended garden soils high in organic matter. Mineral particles are both bridged and separated by organic matter, soil biota exudates, and breakdown products, making the soil much easier to work. Hand tools or tractor implement cultivation, macro organisms, and weathering help to mix the soil and decreases the size of the **peds**. One can readily observe that this structure allows for easy movement of air and water due to its good porosity. This kind of soil is a classic representation of the factors which combine to make for *good tilth*.



<http://soils.usda.gov/technical/manual/contents/chapter3g.html#60>



Peds with units having a block-like or polyhedral appearance are classified as a “**blocky structure**”. They are bounded by irregular surfaces that are casts of the faces of surrounding **peds**. The structure is described as “angular blocky” if the faces intersect at relatively sharp angles. Alternatively, “sub-angular blocky” may be the more apt description if the faces are a mixture of rounded and plane faces and the corners are mostly rounded. **Blocky structures** are common in subsoil but also occur in surface soils that are high in clay content. Swelling and shrinking of clay produces cracks leading to the strongest **blocky structure** formed as a result. The surfaces of dried-up ponds and sloughs show are an example of the characteristic cracking and peeling due to clays.

Some soils apparently lacking structure and are referred to as “**structureless**”. In **structureless layers** or **horizons**, after the soil has been gently disturbed, no units are observable in place. Tapping a spade containing a slice of soil against a hard surface or dropping a large fragment on the ground likewise will betray the soil’s lack of structural integrity. When structureless soils are ruptured many single grains along with noticeable soil fragments, result. Soil material of single grains lacks structure. In addition, it is loose.

There is no such thing as perfect soil. Every soil has problems in structure, texture, and/or chemistry that compromise its ability to nurture plants. The best way to confirm suspected soil problems is to submit a soil sample for laboratory analysis through the local agricultural cooperative extension office or professional lab. A lab’s computer printout profiles the soil content and structure, and can pinpoint deficiencies. Fortunately, the addition of organic matter, or humus, can mitigate against many of these problems. (*National Garden Bureau*, Liz Ball, author.)

Here are three typical soil problems that can be remedied:

1) Compaction

Air is essential to the micro-life that lives on its organic content and processes its nutrients to create fertility. Good soil is loose and crumbly because it has lots of air spaces. Plant roots are able to penetrate good soil deeply for extended drought resistance and stability. Typically, soil in a home landscape is compacted, so the air is compressed from it by the weight of foot traffic, home construction, mechanical yard care equipment, irrigation, and harsh weather. When planting, dig in compost, peat moss or the like into garden beds to improve aeration. To reduce accumulated compaction, spread a mulch or some organic material on bare soil in beds and under trees and shrubs year round.

2) Sandy soil (particle size diameter 1.5 mm - .075mm
<http://www.newton.dep.anl.gov/askasci/env99/env201.htm>)

Sandy soil's large particles accommodate wide air spaces between them. Therefore, it drains so fast that it often dries out too soon. Also, water-soluble nutrients leach out rapidly before the plants can use them. Both **clay** and **humus** incorporated into sandy soil act like sponges, absorbing and holding moisture and any nutrients dissolved in it.

3) Clay soil (particle size diameter =0.0015 mm)

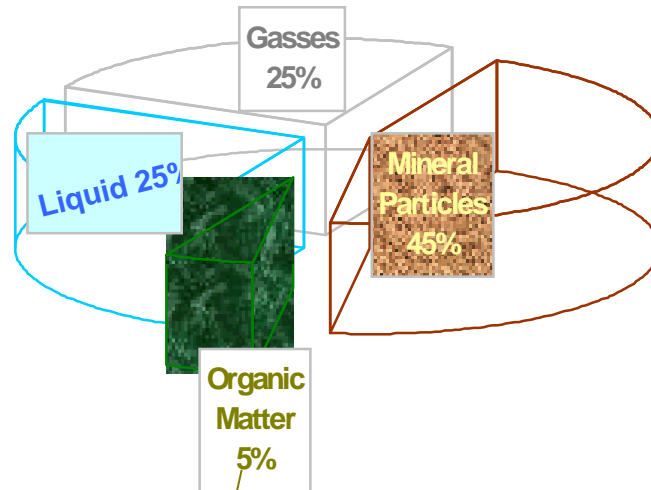
Clay soils are comprised of very small particles with correspondingly reduced air spaces between them. Thus, they suffer from diminished porosity and tend to stick together and cause water to fill up the air spaces. Since moisture does not drain well from pure clay soil, plant roots can rot. But, this is not all bad. Adding clay to sandy soils can retard drainage that is too rapid. Likewise, the addition sand and humus to clay soils discourages the small particles from sticking so tightly. These mixtures tend to aggregate into larger clumps creating larger spaces that not only then drain appropriately, but also retain air to improve soil texture.

Topsoil. Generally speaking, topsoil is the naturally-occurring, unconsolidated mineral and organic material at the surface of the earth that is capable of supporting plant growth and retaining air and water. It typically extends from the surface to about 5 inches below the depth at which properties produced by soil-forming processes can be detected [**Glossary of Forestry Terms**]. The soil-forming processes are an interaction amongst climate, living organisms, chemistry and other actions acting on soil parent material. This variable depth from one locale to the next perhaps can best be understood against the backdrop of a systematic index of soil horizons that soil scientists have devised. One TEASPOON of agricultural soil (1 gram dry) may have between: 100 million to 1 billion bacteria, many thousand protozoa (amoebas, ciliates and flagellates) several yards of fungal strands, and a couple dozen nematodes (that are likely feeding upon bacteria or fungi, but with a few of their society forming a predacious group that help themselves to other nematodes). One square foot of that same soil may also accommodate up to 100 arthropods (insects and others), as well as, up to 30 earthworms (annelids). <http://www.mosesorganic.org/broadcaster/13.5soilbio905.htm>

Soil horizons: The designations for soil horizons have changed over time and differ among countries. In the chart below, the current designations used by the **USDA** are listed in the left-hand column and other information is narrated to the right.

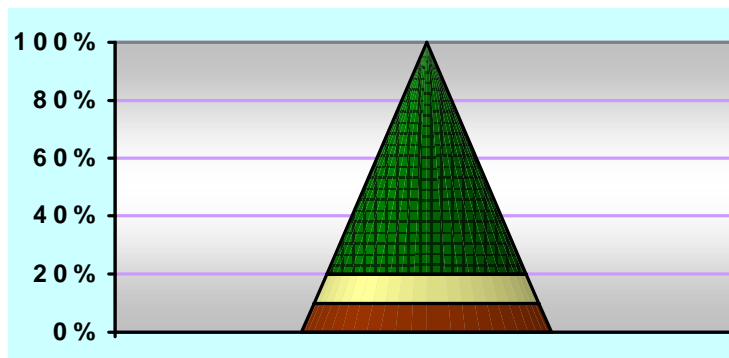
O	= organic horizon in general. Divided into O_i , O_e , and O_a .
O_i	= litter or recognizable sources of organic materials. Comparable to "L:" and "a _o ".
O_e	= intermediate decay with no longer recognizable sources. Comparable to "F" and "a _i ".
O_a	= amorphous, dark, well-matted organic layer. Comparable to "H" and "a _{ii} ".
A	= mineral soil near surface, contains lots of organic matter.
B	= somewhat weathered, mineral soil.
C	= unconsolidated mineral material (just) above bedrock.

Organic material is any matter derived from living organisms, animal or vegetable. It is detected by its carbon content. Dead organisms in a relatively short time break up into fragments. These fragments further disintegrate into smaller pieces that are known as detritus, and are included amongst worm castings (earthworm excrement that appear dark and granular like soil, and are rich in soil nutrients.), along with other soil components that are inorganic substances such as rocks, metals, glass, and synthetic particles. Generally speaking, **humus** makes up about 8/10 of the soil's **organic matter**. Living **root systems** account for approximately another 1/10 while **living organisms** of all descriptions comprise the remaining 1/10. Organic material, however, is the preferred basis for compost because of its superior nutritive value.



Compost may be made from anything from kitchen waste to sawdust and woodchips, lawn cuttings and leaves (incorrectly termed **humus** prior to complete decomposition), manures, fish guts and recycled pruning cuttings, or even under-ripe or overripe fruit.

ORGANIC MATERIAL



Good mulches are typically made from partially decomposed compost plus **peat**. With the addition of **chelated trace minerals**, and aerobically decomposing substances like bat guano, composts soon take on the connotation of **potting soils**.

At this juncture it is difficult to draw the line between the latter and true organic fertilizers. The process of "humification" can begin either naturally in soil, or in the production of compost. However, compost is an intermediate phase of actual **humus** and does not become completely converted to **humus** until more completely decomposed and worked into the ground. Whereas true **humus** has a homogeneous appearance, compost is rough-looking material, with coarse plant remains still visible to the naked eye.

Progression of compost ingredients to humus over time prior and after introduction to the soil:
 dead organic matter → compost → mulch (+ peat, etc.) = potting soil → humus

Inorganic fertilizers would be those factory-produced pellets and sprays heavy on so-called chemical ingredients such as sulfates. In truth everything is chemical, but the distinction between organic and inorganic is the subject of much debate and has given rise to several recognized certification agencies to inspect labeling and contents for man-made, or unnatural ingredients. Commercial fertilizers loaded with NPK (Nitrates, phosphates and potash) are dead give-aways of inorganic fertilizers.

Humus creates soil. It is not a coincidence that the word “humus” is part of every gardener’s vocabulary and that compost piles, one source of humus, are part of their gardens. Humus transmutes sterile dirt into fertile soil. **Humus** is difficult to define in precise terms--being a highly complex substance, the full nature of which is still not entirely understood. In basic terms it may be said to be completely decomposed compost, or natural, organic ingredients upon which microbes have effected Mother Nature’s chemistry. **Mulls, mor, and moders** are kinds of humus. [UC Davis] [Refer to <http://cwt33.ecology.uga.edu/publications/826.pdf>]. The actual **humus** in any soil, whether it be found on undisturbed mountains or prairies, or in someone’s backyard garden, is a very small percentage of the soil, but hopefully it will be the major component of the total **organic matter** in the soil.

According to one very good website, <http://www.up.wroc.pl/~weber/typy2.htm> :

Mor is the type of humus that occurs largely in soils of coniferous forests, but also in moorlands. This classification of humus develops under conditions of low-biological activity in the soil. Mineralization of organic matter proceeds slowly and creates layers. The structure maintained is largely that of vegetable material. Substantial thicknesses of litter may result. Acidophilic fungi and low-activity invertebrates participate in transformations of plant residues. **The C:N ratio (or C/N) of mor humus is always more than 20, or even 30-40, whereas pH is acid.**

Moder is a transitional form of humus between **mor** and **mull**, characteristic for sod-podzolic soils, loesses and mountain grassland soils. The organic horizons with **moder** humus consist of litter with low-thicknesses, just 2-3 cm, which gradually, without bounds, pass on to humus-accumulative horizons. **Moder** is a type of medium humified humus. Acidophilic fungi and arthropods participate in transformations of plant residues. **The C:N ratio equal 15-25.** Produced mineral-organic complexes are labile and weakly bounded with mineral portion of soil.

Mull is a type of humus characteristic for chestnut soils, phaeozems, rendzinas and others soils. This type of humus arise under grass vegetation. **Mull** is a well-humified organic matter, which is produced in very biologically active habitat. This type of humus is characterized by **neutral pH, C:N ratio nearing 10,** and an ability to create stable mineral-organic complexes. **Mull is a type of humus which occurs in soils under cultivation.**

Our modern notions about **humus** were first documented by a German scientist, Liebig. He spoke of "humus" as "a brown substance, easily soluble in alkalies, but only slightly soluble in water, and produced during the decomposition of vegetable matters by the action of acids or alkalies" (bases). This primitive definition correctly reflected certain attributes of the by-products of actual humus such as **humic acid** and **fulvic acid**. In simpler terms we might say that **humus** is typically dark material, often distinctly brown or even black, and may be sticky (when ground humidity is significant), spongy, or even jelly-like. To be true **humus** it must have an amorphous texture, with an indeterminate shape, as well as, structure, or character. That is to say, the decayed parent organic material has become so decomposed (by processes of hydrolysis, or by oxidation and reduction), and mixed together with minute mineral particles that it no longer resembles the vegetable and animal matter from which it originated.

Another characteristic of **humus** is that at its mature stage, it becomes relatively stable (i.e., it resists further decomposition because it is chemically protected/resistant), and may remain in the soil for centuries, or even millennia. Nevertheless, its chemical properties can become degraded, polluted or even destroyed by the application of excess "chemical fertilizer", particularly as toxins in man-made fertilizers devastate the bio-friendly bacteria **humus** contains. Its abilities to provide nutrients to plants that are readily bio-available, and water retention to the soil, are quite remarkable. The incorporation of **humus** into the soil uniquely contributes to the creation of a loose, crumbly texture, that better allows water to soak in, in the first-place, and nutrients to be retained.

Furthermore, it importantly permits sufficient air to be incorporated into soil. **Humus** does this by adding to the soil structure by coating mineral particles and holding them together; and thus serves as a major reservoir of plant nutrients.

Of all these factors, however, it is certain acids that **humus** produces, allowing for the more rapid breakdown of minerals, and their solubility that is of paramount importance. In the humification process microbes such as bacteria are steadily at work in decomposing organic material and manufacturing the valuable **humic acid** and **fulvic acid** by-products that actually perform the resultant chelation of these minerals.

However, **humus** content may be reduced by hot weather, or intense cultivation without replacement of organic matter, or erosion of topsoil. Soil becomes sterile over time as the number and activity of these same micro-organisms in the soil is also depleted by these actions. In their absence the production of nutrients in the soil is severely curtailed.

While fertilizer provides nutrients to plants, it does not solve the soil fertility problem. Supporting resident micro-life in the soil is the only long-term solution. Topdressing lawns and perennial beds with compost and mulch and incorporating it into cultivated soil every year provides a home and nutrients for these organisms so they can do their part to increase the soil's fertility. Soil rich in **humus** is alive. It supports active microorganisms to process nutrients and harbors beneficial macro-organisms such as ants and ground spiders that prey on soil-dwelling pest larvae and eggs.

Humus creates a soil environment that supports beneficial nematodes and also bacteria such as milky spore that homeowners introduce into lawns to combat white grubs. Many other resident microbes attack and control disease pathogens that lurk in the soil. Topdressing and mulching lawns and gardens with organic material such as chopped leaves, compost or shredded bark products discourages soil pest problems.

<http://aggie-horticulture.tamu.edu/extension/newsletters/hortupdate/julaug01/art3jul.html>

Humus and pH. The acidity or alkalinity of soils, expressed as **pH**, affects how accessible their nutrients are to plants. A “basic” soil (**pH** higher than 7.0) progressively inhibits the uptake of iron, boron, copper and other elements necessary for plant health depending upon how much alkalinity is present. Excessive acidity (**pH** lower than 6.0) discourages plant absorption of other nutrients. Temporarily altering **pH** levels by adding either Sulfur to increase acidity or calcium carbonate (CaCO_3) to reduce acidity, is only a short-term remedy. Ultimately it is the maintenance of healthy humus that will grant long-term effects. “Soil **pH** is primarily controlled by the concentration of free hydrogen ions in the soil matrix. Soils with a relatively large concentration of hydrogen ions tend to be acidic. Alkaline soils have a relatively low concentration of hydrogen ions. Hydrogen ions are made available to the soil matrix by the disassociation of water, by the activity of plant roots, and by many chemical weathering reactions.”

<http://www.physicalgeography.net/fundamentals/10t.html>

Surfactant, or “wetting agent” If someone desired to make a foliar product using the organic and clay complex quarried by Window Peak Trace Minerals, to make the product more soluble and to give more leaf penetration, he or she would need the following information:

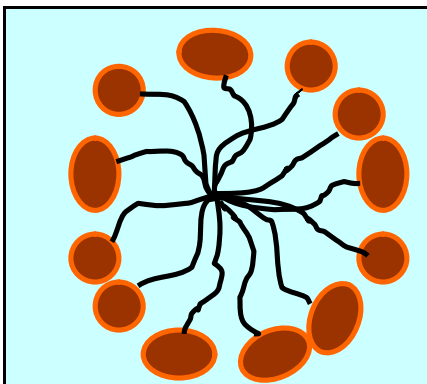
Step 1) The results of an **Electrical Conductivity** test measuring to pH in solution.

The “**EC**” test should reveal the parts per million that are soluble enough to go into solution. From this a determination may be made about how much rainfall or irrigation is required, to allow the nutrients to move through the water, and onto and into the plant roots. These tabulations and calculations would allow one to estimate approximately how many pounds per acre should be applied annually, and such a test as this will help to determine the solubility of the product without surfactants. The following standards are recommended for conducting the test:

- pH Meter Buffed with 4 pH and 6 pH Buffer
- EC Meter Buffed with 800 ppm **Total Dissolved Solids** (“**TDS**”) Solution
- Water used for conducting all tests with a TDS reading of 40 ppm and a pH of 6.00

2) The task is to determine what nutrients are mobile and not tied up in the soil. The next few lines should help to understand such a goal.

- A farmer's most valuable asset is the soil.
- A crop harvested each year has removed many nutrients and minerals from the soil.
- Many of the essential elements are only required in trace amounts.
- Since the so-called "**macro minerals**" and many of the trace elements are antagonistic to one another, it is important to understand these relationships, as well as the actual condition of the soil, in order to properly formulate subsequent **mineral** applications.
- A broad, balanced approach is the safest.
- By offering vegetation an ample menu of elements from which to choose, a given plant species may select a-la-carte what it requires, keeping antagonistic elements in check by balancing what it absolutely needs to uptake with what should remain in the soil, to combat the effects of the potentially wrong dosages of elements also present.
- Chelation helps make essential elements bio-available while unchelated elements may be kept in check due to their low absorption rate.
- Colloids may aid in the nutrient transport mechanism, particularly in the presence of fulvic acid and to a lesser extent, humic acid.



**Heads and tails
of a micelle**

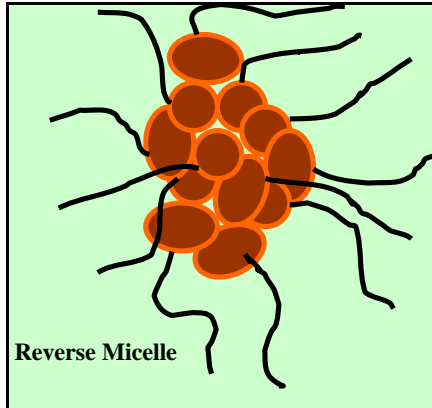
The term *surfactant* is a blend of three words, i.e., 'surface active agent'. *Surfactants* are usually organic compounds that are **amphiphilic**, meaning they contain both **hydrophobic** groups (their "tails") and **hydrophilic** groups (their "heads"). Therefore, they are partially soluble in both organic solvents and water. The term *surfactant*, reportedly was coined by Antara Products in 1950.

Surfactants often are classified into four primary groups; anionic, cationic, non-ionic, and **zwitterionic** (dual charge). <http://en.wikipedia.org/wiki/Surfactant>

“*Surfactants* reduce the surface tension of water by adsorbing at the liquid-gas interface. They also reduce the interfacial tension between oil and water by adsorbing at the liquid-liquid interface.” Many surfactants can also assemble into aggregates within the bulk solution. A name for some of these aggregates is *micelles*.

3) The next step is to see how much dissolved clay complex gets into the plant. In order to dive into such a project one would need to design a plant uptake test employing visual inspections and a refractometer. “Part uptake” is established by the decrease in **parts per million** and ions in the solution tank in the hydroponics system, for example.

CMC, CEC and C:N ratio: “The concentration at which **surfactants** begin to form **micelles** is known as the ‘critical micelle concentration’ or ‘**CMC**’. When **micelles** form in water, their tails form a core that is like an oil droplet, and their (ionic/polar) heads form an outer shell that maintains favorable contact with water. When surfactants assemble in oil, the aggregate is referred to as a **reverse micelle**. In a **reverse micelle**,



the heads are in the core and the tails maintain favorable contact with oil.

Cation exchange capacity (“**CEC**”) means the capacity of a soil to retain cations. **Clay** particles and soil organic matter are negatively charged and thus tend to attract cations. These cations, which otherwise could be leached from the soil, remain available to plant roots. [UC Davis] **CEC** is an important datum derived from the testing of agricultural additives.

Humus increases the soil's [cation exchange capacity](#) (**CEC**), hence its ability to store nutrients by [chelation](#) as [clay](#) particles can do. Thus, while these nutrient [cations](#) are accessible to plants, they are held in the soil safe from leaching away by rain or irrigation. We are told that **humus** can hold the equivalent of 80-90% of its weight in moisture, and therefore increases the soil's capacity to withstand drought conditions. The biochemical structure of **humus** enables it to moderate – or buffer – excessive [acid](#) or [alkaline](#) soil conditions. <http://en.wikipedia.org/wiki/Humus>

Cation exchange capacity (**CEC**) is a useful indicator of soil fertility because it shows the soil's ability to supply three important plant nutrients: Calcium (Ca^{++}), Magnesium (Mg^{++}), and Potassium (K^+). These also happen to be three of the five most abundant exchangeable cations in the soil—the other two being Sodium (Na^+) and Aluminum (Al^{+++}). [The number of + signs indicates the amount of charge the element possesses.]

Soil pH is important for CEC because as pH increases (becomes less acid), the number of negative charges on the colloids increase, thereby increasing CEC. <http://www.ricecrc.org/reader/soil-types-structure/ss393-cation-exchange.htm>

C:N ratio of plant materials gives the ratio of Carbon to Nitrogen in plant tissue. The carbon content of most plant material is between 40 and 50% while the Nitrogen content of plant material is much more highly variable. Since Nitrogen is needed by microbes to decompose plant tissue, the higher the **C:N** ratio (suggesting low nitrogen levels) the more slowly the material decomposes. On the average [soil humus contains approximately 5% Nitrogen](#), but the **availability of Nitrogen** in humus is determined as follows:

As already stated, the level of [available](#) Nitrogen in the soil is extremely variable. This is because levels are influenced by soil temperature, soil moisture, the **C:N** ratio of any fresh organic matter added to the soil, the extent of microbial activity in the soil (which is in turn influenced by soil temperature), and other variables. As humus decomposes, the nutrients in it are released into the soil in available forms. For example, in many parts

of the state of Iowa known for its **clay soil**, about 3% of the soil humus is decomposed each year therefore about 3% of the total Nitrogen in that humus becomes available each year.

The **C:N ratio of soils** is influenced by many factors:

- The **C:N** ratio is highest when the organic matter added to the soil each year is low in Nitrogen (wide **C:N** ratio).
- The **C:N** ratio of the **A horizon** of a “forest-derived” soil averages 20:1. Because the **C:N** ratio of grasses is much narrower, the **C:N** ratio of the **A horizon** of a “grass-derived” soil averages 12:1.
- The low **C:N** ratio of the **B horizon** of most soils (8:1) is due to microbes having decomposed much of the vegetative material. A higher proportion of this humus is composed of dead microbial tissue.
http://www.pals.iastate.edu/agron154/Agron_154/Unit_22/terms.htm

100	C	High	Carbon	C
1	N			
25	C	Medium	Nitrogen	N
1	N			
7	C	Low		
1	N			

C:N Ratio – What does it mean?

http://www.fibl.org/english/publications/training-manual/pdf/Tran_4-4.pdf

Applying organic matter with excess carbon to the soil can create problems. In order to “complete the nitrogen cycle and continue decomposition, the microbial cells will draw any available soil nitrogen in the

proper proportion to make use of available carbon. This is known as ‘robbing’ the soil of nitrogen, and delays availability of nitrogen as a fertilizer for growing plants until some later season when it is no longer being used in the life-cycles of soil bacteria.”

[Iowa State University]

Organic matter is affected by the presence of both carbon and nitrogen in the course of decomposition. The **C:N** ratio represents the relative proportion of these two elements. For example, compost having 25 times as much carbon as nitrogen is said to have a **C:N** ratio of 25 to 1 (= **C:N** ratio of 25). Some of the carbon present may be so resistant to biological attack that its presence is not significant. It is actually the ratio of available carbon to available nitrogen that is the important relationship. This is because the very organisms that decompose organic matter use Nitrogen for building cell structure, but utilize Carbon as their source of energy. Thus, they need more Carbon than Nitrogen. If too much available Carbon is present, decomposition slows as the Nitrogen is used up and some organisms begin to die along the way. However, organisms may form new cell material using their stored Nitrogen, but in the process, more carbon is burned. Meanwhile the amount of Carbon is reduced while Nitrogen is recycled. The bottom line is that decomposition takes longer than normal when the initial **C:N** ratio oscillates significantly above 30.

For **C:N** ratios in feedstocks, see:

http://whatcom.wsu.edu/ag/compost/fundamentals/needs_carbon_nitrogen.htm

Conclusions:

Both the rate of decomposition and the amount of humus formed are related to the **C:N** ratio of the residue. When all other conditions are equal, the rate of decomposition increases as the **C:N** ratio narrows.

“Since organisms use about 30 parts Carbon for each part of Nitrogen, an initial **C:N** (available quantity) ratio of 30 promotes rapid composting and would provide some Nitrogen in an immediately available form in the finished compost. Researchers report optimum values from 20 to 31.” [**Washington State University**]

Here are four conditions that are constant for all residue decomposition:

1. A maximum of 35% of the Carbon in fresh organic material will be converted into soil humus **if** there is sufficient Nitrogen present.
2. A minimum of 65% of the Carbon in fresh organic material will be given off to the atmosphere as carbon dioxide (**CO₂**) due to microbial respiration.
3. The humus formed from the decomposition of fresh organic material will contain approximately 50% Carbon and 5% Nitrogen. In other words, the **C:N** ratio of the humus is **10:1**.
4. Most fresh plant material contains 40% carbon. The C:N ratio varies because of differences in Nitrogen content, **not** Carbon content.

Using these relationships, the quantity of humus formed from the addition of a known amount of plant residue can be calculated. [**Kansas State University**]

An interesting note: “It has been estimated that natural biological Nitrogen fixation supplies approximately 175,000,000 tons of Nitrogen per year to the world's agricultural needs.(1) Man-made chemical Nitrogen fixation, through the Haber-Bosch and similar processes, provides 50,000,000 metric tons per year and approximately 40,000,000 tons per year are produced by natural physico-chemical fixation, e.g. lightning, ultraviolet radiation, etc., which converts Nitrogen and Oxygen into oxides of Nitrogen.”

<http://digicoll.library.wisc.edu/cgi-bin/EcoNatRes/EcoNatRes-idx?type=div&did=ECONATRES.0003.0206.0061&isize=text>

For the next section, first take a look at: www.colloidaltraceminerals.net

Cations and Colloids: “Humus tends to bond strongly to **clay**. While bonded it resists decomposition. For this and other reasons, soils higher in clay tend to be higher in organic matter.” [Iowa State University]

We know that clay is comprised of colloidal material, and some say that **humus** itself is also [http://en.wikipedia.org/w/index.php?title=Humus&action=edit§ion=1] a **colloidal** substance, but others state that this characterization constitutes a basic misunderstanding about the application of terminology. “The term **colloids** is being mistakenly used to refer to Fulvic Acid complexes, which are readily absorbable and in the perfect electrolyte form to react with cells.” [http://www.msminerals.com/v200/include/FATMM.pdf]

According to a New Zealand company that is a major advocate of foliar sprays, “Humus is a structureless colloidal material resulting from the decomposition (humification) of any type of dead organic matter (mostly plant residues and animal remains). It is a complex mixture including proteins, lignin (plant cell walls); fats, carbohydrates, and organic acids. These acids, humic acids and chelates, provide a storehouse of essential plant nutrients.” [http://foliarfert.com/pages/humus.htm],

The connection between **clays** and **humus** and the formation of **colloidal substances** capable of increasing bioavailability of nutrients is spelled out by some other nice folks “downunder” from **New South Wales** [http://www.ricecrc.org/reader/soil-types-structure/ss393-cation-exchange.htm].

Cations are held by negatively charged particles of clay and humus called **colloids**. Colloids (in turn consist of thin, flat plates, and) for their size have a comparatively large surface area. For this reason they are capable of holding enormous quantities of **cations**. They act as a storehouse of nutrients for plant roots. As plant roots take up **cations**, other **cations** in the soil water replace them on the **colloid**. If there is a concentration of one particular **cation** in the soil water, those cations will force other cations off the **colloid** and take their place. **The stronger the colloid's negative charge, the greater its capacity to hold and exchange cations, hence the term cation exchange capacity (CEC).**

Sand on the other hand has no capacity to exchange cations because it has no electrical charge. This means sandy soils such as **podzolic topsoils** have very low **CEC**, but this can be improved by adding organic matter.

(**Podzolic soil** = member of a group of soils that are gray in color, have an ashy appearance, and extend immediately south of the tundra regions of the Northern Hemisphere. Although characteristically capped with an abundant surface accumulation of organic matter, these soils are often severely leached and highly acid.) [Columbia Encyclopaedia]. Recalling that another form of sand, silica, is the basis for **Diatomite**, it is not surprising then why clays, particularly **Montmorillonite** with its affinity for organic matter, are far superior for growing orchids and all other vegetation.

Hheavy Metals and Chelation: The domain of the New South Wales governmental Agency further informs that:

Aluminium (Al^{+++}) and Sodium (Na^{++}) **cations** are not plant nutrients, so are not wanted by the plant. Aluminium is not present as a cation when soil pH (CaCl_2) is over 5 because it is precipitated out of the soil solution. It is only at pH (CaCl_2) levels below 5 that it may become available as a cation,... This is one reason why it is important to maintain pH levels at 5.0 or more.

Therefore, it would seem that Aluminum content of the soil generally, is not a concern provided that the soil's pH is approaching neutrality, or on the alkaline side.) However,

when exchangeable Sodium is present in quantities greater than about 5% of the **CEC**, it makes the **clay** particles unstable in rainwater. This shows up as dispersion or cloudiness in water. Dispersive soils have poor water entry and drainage and set hard on drying. If a soil has a low **CEC** and high Sodium levels, up to half the **cations** in the soil may be in the water around the soil particles, and not actually held by the particles. These cations are very susceptible to being leached or drained away in the soil water. [**Lines-Kelly, 1993**]

In consequence, one must be careful when choosing amongst certain clays for agricultural purposes, some of which may have a high Sodium content. There would seem to be a compelling argument when selecting **clays** to be used as remineralizers, to lean toward **Montmorillonite** with an enviable **CEC** (and extremely low Sodium, i.e., 1% <), instead of **Bentonite** (often between 5% - 10% Sodium).

Montmorillonite in particular has a vast array of nutritional uses, and yet is an Aluminum silicate. But, unlike ordinary clays, **Montmorillonite** also contains a profusion of nearly all other naturally-occurring elements, albeit in trace amounts, complexed with organic matter, or in other words, "chelated".

What is chelation, exactly?

Chelates are molecules consisting of organic material that has trapped certain highly reactive trace metal cations. The otherwise inorganic elements encapsulated in the new molecule are actually suspended between **amino acids**, or hooked onto **proteins**. This arrangement prevents the heavy metals and other chelated elements from entering into unwanted chemical reactions and forming insoluble compounds, which are unavailable. The result of the compound is essentially a new mineral. Chelated minerals have quite different qualities from the individual elements thus bound up. One quality is bio-availability of the individual ingredients, i.e., the ability of the resultant molecule to be absorbed by the small intestine and be uptaken by plant roots.

Bio-availability can be increased or decreased depending on the mineral-chelate complex formed. Natural chelating agents do not share the problems created by synthetic chelation and man-made chemicals. Although Mother Nature's chelation has been around for millennia, it is still the benchmark or state-of-the-art technology for delivering selected mineral and trace elements with maximum bio-availability, tolerability, and safety.

Chelated minerals applied as a foliar spray will address plant deficiencies more accurately and with greater speed than any other nutrient. If a yield-limiting deficit is suspected or established, an application of a naturally-balanced formula of chelated minerals in trace amounts will introduce catalysts and create synergies with the prevailing fertilizers to allow them to perform optimally and correct the problem. Just having elements present in the soil is not enough. They must be bio-available.

These elements are far more easily absorbed by plant roots and leaves in this chelated form because of changes in the electrical charge from the trace minerals as a result of their organic encapsulation. The chelation process removes the positive charge from the metals, allowing the neutral or slightly negatively charged, chelated molecule to slide through the pores on the leaf and root surface more rapidly.

These pores are negatively charged, so there is a problem with fixation of unchelated positively charged minerals at the pore entrance. <http://foliarfert.com/pages/chelates.htm>

There is no such restrictive barrier for the neutral, chelated mineral. Besides this type of presentation being more attractive to the cell wall it still permits the tissues to control dosage. The peculiar molecule structure allows tissues to selectively admit ions by breaking their bonds and freeing them for absorption without the risk of overdose which could be the case if unchelated ions were ingested in mass. Unwanted atoms are simply left on the molecule or the molecule is not admitted at all. Furthermore, the electrical charge problem is ameliorated as explained in the preceding paragraphs.

To George Crile (research scientist and author of *A Bipolar Theory of Living Processes*), is attributed the discovery that all living cells are like miniature batteries. Crile demonstrated that the nucleus of the cell is comparatively acidic while that the cytoplasm of the cell is more or less alkaline. The nucleus and the cytoplasm are separated by a semi-permeable membrane. The nucleus acts as the positive element and the cytoplasm acts as the negative element. This creates a true bipolar mechanism much like a battery.

Crile also tabulated evidence showing that the performance, integrity, and structure of living cells are dependent on the maintenance of normal electrical potential.

Fulvic acids chelate metal ions and are electrolytic in nature, lending themselves easily to dispersion in water mediums. By changing cation metallic minerals (with a positive charge) into anion nonmetallic minerals (with a negative charge), fulvic acids produce a hydrophilic colloidal/ionic mineral with superior electrical potential!
<http://minerallogic.com/cell.htm>

Lots of Aluminum in the soil. As we have already seen given the proper pH the concern about the high Aluminum content of clays is unfounded. (The following are edited excerpts from *Aluminum, Friend or Foe?* [Kenneth D. Westwood, 1997]. Undocumented information having been disseminated throughout the health food industry regarding “Aluminum Toxicity”, has unduly alarmed health-conscious individuals, particularly in the USA.

- Fact:** Aluminum is one of the most abundant elements on Earth, and is a major component in all soils, clays and non-clays alike, with one seventh of the Earth’s crust being made up of that element.
- Fact:** It is never found in its pure form (typically extracted for industrial purposes from the mineral bauxite), but is always combined with other elements--silicon being one of the most common.
- Fact:** Aluminum combines with Silicon and Oxygen, to make up the major constituent in Montmorillonite clay, and other members of the Smectite family of clays.
- Fact:** These “Healing Clays” have been known to diverse peoples for their medicinal properties (both externally and internally) on at least three continents for thousands of years.
- Fact:** Any clay compound found in health food stores contains very high levels (tens of thousands of parts per million) of Aluminum.
- Fact:** Aluminum enters the food chain at every level, be it plant or animal.
- Fact:** Any element when used in excess becomes toxic whether it is considered to be a macro nutrient, or one that is essential only in trace amounts, i.e., micro nutrient.

However, if natural compounds of “organic” Aluminum were toxic or hazardous to human health, life as we know it on planet Earth would cease. The fact that most natural compounds of Aluminum are inert and pass through the system without harm coupled with the fact that Aluminum compounds are so prevalent, points to the absurdity of the claim that all forms of Aluminum are toxic (poison).

- Fact:** Most food crops contain 20-200 parts per million of Aluminum; with beans testing 1640 ppm (**46.5 mcg** per ounce).

Dr. Melvin N. Westwood (Internationally recognized, Oregon State University scientist), observed that of the thousands of analysis of plant and fruit fibers which he has tested, not one sample has ever shown the absence of Aluminum. Since **all** seeds contain that element he has expressed grave doubt that samples run in an “Aluminum-free” culture could be grown.

- Fact:** All green-leafy vegetables used in salads and green-drinks contain “high” levels of Aluminum.
- Fact:** Onions are especially high in Aluminum, and the strawberry receptacle is loaded with natural compounds of “organic” Aluminum.
- Fact:** Reported in parts per million, mint leaves may contain 160 ppm. Plantain leaves typically contain 56ppm, and beets 28ppm while beet leaves have 72ppm. Various marine algae test at between 40-98 ppm of Aluminum
- Fact:** Even our good friends such as spinach contain 102 ppm of Aluminum.

If natural forms of Aluminum are toxic why do we classify most of the above as health foods?

The Alzheimer's Myth: With legumes being especially high in Aluminum (e.g., beans) ppm) all ethnic groups eating legumes as a staple part of their diet would manifest epidemic numbers suffering from Alzheimer's disease if natural forms of Aluminum contributed in any way to this disease. If Aluminum toxicity were possible from the garden there wouldn't be very much else on earth to eat.

Fact: Nutrients always work as a team.

Fact: When there is an abnormal concentration of one element, it results in an upset metabolic balance.

Human effort to produce super concentrates of any nutrient, at best may be disregarding both the synergistic and catalytic properties of various elements. At worst, by failing to complex certain elements together, and maintain some semblance of balance, our pharmaceutical formulators might be overriding the system's ability to deal with a particular element in high concentration, and be creating a deadly poison, albeit one whose effects are slow to appreciate.

Two examples:

Fact: 1) "Organic" Arsenic in trace amounts is essential, yet in higher concentrations is a poison.

Fact: 2) Selenium in trace amounts is absolutely essential, yet the same element in high concentrations is also a deadly poison. (Scientists like Dr. Westwood are quick to point out that we should not mistakenly assume that because certain elements are lethal in high concentrations, that they are also harmful in "trace" amounts.)

All trace elements found in organic beds of ancient origin must be assumed to be of importance.

Fact: These elements have been placed there by nature and not by man.

Supporting Conclusion: Because we find natural forms of Aluminum in all our food chains we cannot assume that "plant derived" Aluminum is non-essential. To refine out Aluminum, Arsenic and other trace elements from minerals extracted from naturally-occurring organic beds, or sediment, is to change from a "natural" to an "unnatural" state.

Fact: Since "organic" Aluminum is in all plant foods without exception, one of the surest methods of determining whether a product is natural is the presence (or absence) of Aluminum. If there is no Aluminum it cannot be natural.

Hypothesis: In all likelihood, Aluminum (as obtained by, and contained in plants) may yet prove to be one of our closest friends (especially in the complex with **fulvic acid**).

Reactive mineral surfaces in natural soil and aquatic environments are coated to a large extent with natural organic matter, such as humic substances. ...One important aspect is the question whether metal sorption is additive, or whether specific interactions between metal ions and fulvic acid at the mineral surface lead to non-additive behavior. Predicting the fate of metal contaminants therefore requires a quantitative understanding of the interactions between metal cations, humic substances, and mineral surfaces.

http://www.ito.ethz.ch:16080/SoilChem/bcresear/bcresear_ilona.html and <http://ilona.heidmann.info/Thesis.htm>

In conclusion, soil is a complex material with many components, each with subsets of their own. Apart from fairly homogeneous deposits such as sand dunes and obvious clay deposits, we have seen that soil is generally a combination of these mineral forms along with silt and organic matter, air spaces or trapped gasses, and moisture.

To determine a soil type some simple equations are available to make a generalization about a soil sample. As an illustration take for instance what is meant by **clay loam**. Typically loamy soil is about 35% clay and 32% sand on average, meaning that the residual of 33% is silt.

- 1) Multiply each of the relative percentages by the individual particle diameter.
- 2) Add the resultant numbers and you get a weighted average particle diameter.
- 3) In this case we get a result of .063125. This might actually be an overestimate, as fine particles (such as clay) can fill-in, in between large particles like sand.

Sand, typically	$(0.175) \times (.32) = .056000$
Clay	$(.0015) \times (.35) = .000525$
Silt	$(0.02) \times (.33) = .006600$
	<u>.063125</u>

Using the Soil Textural Triangle posted by Washington State University on its webpage: <http://cru.cahe.wsu.edu/CEPublications/pnw0475/fig1.pdf>. We can get the relative percentages we need for further calculations by first:

- 1) Searching out the name of the soil type for which we wish to quantify texture
- 2) Looking along the Y Axis (for the clay %) to the horizontal midpoint of the appropriate block
- 3) The looking along the X Axis (for the sand %) to the vertical midpoint of the appropriate block.
- 4) Adding these two percentages and subtracting the sum from 100 to give us the probable silt proportion according to popular definition.
- 5) Consulting <http://www.newton.dep.anl.gov/askasci/env99/env201.htm> for additional particle sizes and those cited in this article.

For **sandy loam** the same series of calculations gives a weighted average diameter of 0.12 mm (rounded off), as follows:

Sand, typically	$(0.175) \times (.65) = .113750$
Clay	$(.0015) \times (.27) = .000405$
Silt	$(0.02) \times (.08) = .001600$
	<u>.115755</u>

The Soil Textural Triangle is a useful resource and a fun one to know about.

Bibliography

Australian Soil Identification Spreadsheet

<http://www.usyd.edu.au/su/agric/ACSS/sphysic/asis/glossary.html#Top> Glossary of ASIS terms

(podzolic soil) **Columbia Encyclopedia** <http://www.bartleby.com/65/po/podzol.html>

University of California at **Davis** (Soil Terms, 2003)

<http://trc.ucdavis.edu/bajaffee/SSC112/soil%20terms.htm>

Iowa State University:

http://www.pals.iastate.edu/agron154/Agron_154/Unit_22/terms.htm

Kansas State University <http://www.oznet.ksu.edu/agronomy/soils305/cnratio.htm>

New South Wales Dept. of Primary Industries (2002) <http://www.ricecrc.org/reader/soil-types-structure/ss393-cation-exchange.htm>

Texas A&M University System, (*Taken from: National Garden Bureau, Liz Ball, author*) This article appeared in the **July/August 2001 issue of *Horticulture Update***, edited by **Dr. Douglas F. Welsh**, and produced by Extension Horticulture, Texas Agricultural Extension Service, College Station, Texas.

<http://aggie-horticulture.tamu.edu/extension/newsletters/hortupdate/julaug01/art3jul.html>

USDA <http://soils.usda.gov/technical/manual/contents/chapter3g.html#60>

Washington State University

http://whatcom.wsu.edu/ag/compost/fundamentals/needs_carbon_nitrogen.htm

Westwood, Kenneth D., *Aluminum, Friend of Foe?* ©1997 **Fulvica BioScience** (as republished in *Fulvic Acid-- the Miracle Molecule*)

<http://www.msminerals.com/v200/include/FATMM.pdf>

From the *Soil Sense leaflet 3/93, Agdex 530* (produced by **Rebecca Lines-Kelly**, formerly soils media officer), **Wollongbar Agricultural Institute**, for **CaLM** and **NSW Agriculture**, North Coast region, under the National Landcare Program, September **1993**. <http://www.ricecrc.org/reader/soil-types-structure/ss393-cation-exchange.htm>

http://souran.bur.hiroshima-u.ac.jp/Profiles/0101/0000545/pblc_e1.html

Hydrolysis of para-substituted benzonitriles in water

Sedimentary humic acid and fulvic acid as surface active substances.

Determination of organically-associated trace metals in estuarine seawater by solvent extraction-atomic absorption spectrometry.