SOIL

INTRODUCTION

The fertility of the soil is derived from the soil's physical properties, the micro-organisms and the organic matter and humus in the soil. The type of parent material and the processes involved in creating soil from rock help determine the soils ability to grow plants.

SOIL ORIGIN

Most soils are derived from 3 common parent materials (rock types), these are igneous, sedimentary and metamorphic. Lastly there are organic soils, which are commonly called muck soils

WEATHERING

There are two principle categories; Physical weathering which is also called Disintegration and Chemical weathering which is also called Decomposition.

The process of Physical weathering breaks the rock into smaller fragments. Seasonal and daily temperature changes cause the rocks to fracture. Plant roots, animals and erosion by wind, water or ice break rocks into smaller fragments.

Chemical weathering refers to the rock undergoing a change in its chemical structure usually producing a softer particle. Chemical weathering is greatly affected by the climate, as the varying processes change with rainfall, temperature, vegetation, and soil organisms. Chemical weathering is rapid in a moist warm climate and slow in a dry or cold climate.

TEXTURE

This term refers to the soil constituents; sand, silt, and clay. The percentage of each component in a soil determines it texture class. Loam, which is a great soil for sustainable agriculture is composed of sand, silt, and clay in roughly equal parts. Clay dominates a soil texture class because of it's very small size and strong negative charge. Clay soils can have as little as 40% clay particles making them up with 60% made up by sand or silt but the sand and silt do not have as much influence on the "feel" of the soil as the clay.

BULK DENSITY OF A GOOD SOIL

25% air, 25% water, 45% mineral, 5% Organic matter

SOIL STRUCTURE

Mineral soil particles clump together forming aggregates, this in turn gives the soil it's structure. There will be pore spaces between the aggregates, which insures movement of air and water through the soil. A soil with good tilth will be approximately 50% pore space, half containing water and the other half containing air. The pores allow water to enter the soil then drain away from the roots after a rain, giving the plant roots a chance to respire (they use Oxygen and release Carbon dioxide), and take in water.

There are many substances in the soil that cause aggregation but plant root tips, organic matter, humus, microorganisms, earthworms and positively charged ions such as Calcium are the most important factors. By adding organic matter, humus or compost to the soil you will improve the structure, improve root growth, increase the microorganism population and attract earthworms. Organic matter will increase the number of pore spaces by; their bulky irregular shapes, and their ability to aggregate (glue) mineral soil particles together. O.M. is a low density material which loosens clay soils and binds sandy soils.

Road salt used during the very cold weather is NaCl which changes the soil structure causing the clay particles to pack closely together because the aggregation is lost. The soil becomes blocky or massive, having a higher bulk density where salt has been used.

Lime and dolomite are calcium supplements that improve soil aggregation and increase the number of pore spaces. Lime reduces the bulk density of the soil by increasing the number of pore spaces.

ORGANIC MATTER AND HUMUS

Organic matter (OM) is any material that was once alive whether it was plant or animal in origin. OM undergoes decomposition by the macro and microorganisms in the soil until it is converted to a new product called humus. Humus is an amorphous brown colloid (a very small and irregularly shaped particle). Humus resists further decomposition, so it is fairly stable and makes up 60-80% of the organic matter in a soil. Additional OM must be added to soil annually to maintain an adequate level of humus in the soil.

THE AFFECT OF ORGANIC MATTER AND HUMUS ON SOIL STRUCTURE

OM is bulky and does not compact easily so it loosens soil when it is added. In its original state OM improves infiltration and percolation because it forms channels which water moves along. It is bulky so soil particles are separated. OM decreases soil compaction, increases the number of large pores, allowing for better gas exchange and water infiltration between the atmosphere and the soil.

Humus is the end product of the decomposition of OM and it improves infiltration and percolation because it has glue-like properties causing it to aggregate soil particles together, thereby creating pores. It reduced soil compaction, increases tilth

The environmental conditions for living organisms (plant, animal and micro organism) are improved by the addition of OM to a soil. OM is food for organisms, it undergoes decomposition by the organisms in the soil eventually releasing nutrients for plant use.

Humus holds 4X it's weight in water or 90% of its volume making it the most important ingredient in a healthy moist well drained soil, which reduces leaching. Though, the water is held by the humus, it is freely given to the plants when the roots intercept damp humus.

OM and humus moderate soil temperature, because of the dark colour and water retention, heating up slowly in the heat of a summer day and cooling down slowly in the fall.

Humus is a negatively charged colloid but it can retain both positive and negative ions in the soil. Humus improved soil nutrient level, as it is both a source and a reservoir of the nutrients a plant needs, (except Oxygen, Carbon Dioxide, and water). Humus even retains nutrients in forms that clay can't.

A soil with just 5% OM and humus in it will have a good soil structure and therefore good tilth, allowing water to infiltrate and percolate freely into and through the soil, retaining water, and nutrients. A soil with OM and humus will a large number of living organisms in it, it will be healthy.

The best time to amend soil is in the fall. Dig compost or OM into the soil in September or October, this will allow the freeze-thaw action of winter to break the large lumps of soil into smaller, stable aggregates. Plants the bed as soon as the soil warms up in the spring.

Amending the bed soil in spring is the second choice but the soil may be cold and damp, which may increase compaction but more importantly it will not have time to form stable aggregates before planting up.

ORGANISMS

BACTERIA

Soil health is dependent on bacterial health. They also help improve the soil's structure by holding (aggregating) soil particles together in the sticky substances they exude. Bacteria are the smallest and most numerous organisms in a compost pile or soil. There are over 1000 genera and over 5000 species of bacteria identified. Bacteria comprise 80-90% of the soil's microorganism population, accounting for approximately 100 Kg to 1000Kg of live bacteria per acre. Bacteria live in the top 15-20cm of the soil and under good soil conditions can double their population every hour. Soil borne bacteria include free-living photosynthetic organisms, decomposers, mutualistic/symbiotic bacteria (which for a mutually beneficial relationship with plants), chemolithotrops (which chemically weather rocks and mineral soil particles), and pathogens.

Bacteria help retain nutrients in the soil in a number of ways; 1) they decompose freshly fallen organic matter, immobilize the nutrients by incorporating them into their own tissues where they will be released after death, thereby reducing nutrient loss by water erosion 2) they fix atmospheric elements such as Nitrogen passing it directly to a host plant and 3) some release nutrients from the mineral soil particles.

FUNGI

Fungi includes; yeasts, moulds and mushrooms. Tens of thousands of soil borne species have been identified, with a vast many more unknown at the moment. There are fungi that decompose dead OM and others that live with living plants in a symbiotic relationship. In all cases they require aerated soil to metabolize nutrients. The hyphae of fungi are thin threadlike structures that grow throughout the soil improving the structure by aggregating soil particles together. As important decomposers they are active in the creating of humus.

Penicillium a soil fungi was the source of the first antibiotic; Penicillin.

EARTHWORMS

There are approximately 7000 species classified, the three we are familiar with are; the night crawler (*Lumbricus terrestris*) a European worm that has displaced the native species and is now the most abundant worm in our gardens, they burrow below the frost line (1-2m deep) for the winter. Then there are the red worms (*Allolobophora caliginosa*) that have shallow burrows, in the top 10-30 cm, and finally the compost worm (*Eisenia foetida*), called red wigglers commercially.

They are egg-laying, hermaphrodites with both male and female sex organs on each individual. Earthworms eat their way through the soil digesting OM, detritus, and the microorganisms on these foods. Fungi and bacteria on decaying OM is the principle food source Depending on the species they can eat between 2 to 30 times their body-weight per day. In this way they construct vast burrows reducing erosion by improving water infiltration, percolation, and by combining the inorganic and organic substances.

Earthworms are the most important macro-animals in the soil, because they improve soil structure profoundly and the castings are the best formulated fertilizer for plants, and have a greater percentage of OM and bacteria in them than the surrounding soil. Earthworm castings aggregate the mineral soil particles with the organic substances ingested, creating stable soil aggregates. Worms increase the nutrient availability by releasing the elements locked up in the mineral soil particles through the grinding action and the digestive enzymes in the digestive tract.

Plant roots and fungi grow in the burrows because it is easier than growing through the soil plus it will have packets of nutrients.

Earthworms live in moist aerated soils, which receive a regular supply of manure or compost. They prefer a pH range of 5.5-8.5 but they need plenty of calcium in the soil for the gland near the mouth. This gland secretes calcium into the digestive tract where it is incorporated into the castings. 10* C is the optimum temperature for *Lumbricus terrestris*, one of the reasons along with rainfall for the fact that we see them most often in the spring and fall.

Earthworms do not like; acidic soils, sandy soils, ingesting ammonia fertilizers, carbamate based insecticides and tilling. To encourage earthworms do not dig in the garden to often.

ANTS, WASPS AND BEES

There are 10's of thousands of species in these insect groups, many building nests in the soil thereby improving soil aeration. There are species that are predators, herbivores and consumers of decaying matter. Due to the cycling of matter from the surface to inside the soil they greatly improve the soil structure and fertility.

ENVIRONMENTAL REQUIREMENTS

The conditions, which are optimum for plant growth are also optimum for the micro and macro organisms. These are;

OXYGEN Bacteria use 70% of the Oxygen in the soil whereas plant roots use only 30%

FOOD Organisms digest organic matter, so if the soil is depleted there will be a decrease in the decomposer populations.

MOISTURE The organisms live in the moisture film that adheres to soil particles, and organic matter, so the soil or compost pile must be evenly moist for them to survive. On the other hand they need Oxygen to be able to respire, so the soil or compost cannot be flooded.

TEMPERATURE There are microorganisms that survive in temperatures ranging from 0-100* C but most like a moderate temperature range between 5 and 45*C, 20-30*C

PH pH refers to the acidity or alkalinity of a material, 1-5 is very acidic, 7 is neutral, 8-14 is very alkaline. Nutrients are locked up or released in the soil when the pH changes, for example iron and aluminium are in over abundance in the soil at low pH range of 3-5. Most plants and microbes prefer a pH range of 6.5-7.5.

WATER MOVEMENT

Water movement into and through the soil is dependent on many factors such as the soil texture, structure, vegetation, climate and more. Plants require a vast amount of water to supply nutrients and to maintain turgor pressure (the water pressure inside the cells that help hold the plant upright).

INFILTRATION

Infiltration refers to water entering the soil at the surface. A loose soil with many large pore spaces will have a fast infiltration rate because water can enter quickly. The texture of the soil helps determine the structure, a soil with a lot of clay will have small fine pores, which slows the rate on infiltration. In fact in a clay soil the infiltration rate can be as slow as 0.1"/ hour. A loam soil (with equal parts of sand, silt, and clay with organic matter and humus) will have micro and macro pores so the infiltration rate is good at 0.5"-1"/hour. A sandy soil has a very rapid rate exceeding 1"/hour.

FACTORS AFFECTING INFILTRATION

The rate of infiltration is affected by many other factors. The type of vegetation covering the soil influences the movement of water, for example grasses allow water to trickle down their stems and enter the soil gently at the stem base, but broadleaf ground covers shed the rain water so that it spills off the edges of the leaves, concentrating the water to the outside edges of the plants. This phenomenon is easily seen under large broadleaf trees where the rain is shed off the crown so that the soil immediately below the tree is much dryer than out beyond the tree.

A soil with plenty of organic matter and humus in it will be loose with many pores so infiltration is significantly improved by adding these components to a soil, amending the soil to loosen it and improve infiltration.

PERCOLATION

Percolation refers to the downward flow of water through soil. Once a soil is saturated the water moves downward due to gravity. **It is important to realize that water moves downward only after the upper layer of soil is saturated.** The water in the soil is properly called soil solution because it has nutrients and minerals dissolved into it. This water moves freely through the large pores carrying the nutrients and minerals downward with it, leaching them away from the plant roots.

AVAILABLE WATER

This term refers to soil solution that remains in the soil after the gravitational water has percolated downward. This soil solution is held in small pores forming a continuous film surrounding soil particles and aggregates, and is readily available to plants. The soil solution can move in any direction from an area with more to an area with less soil solution so the small pores are replenished as roots take up the soil solution. It is the flow of soil solution, which can 'wick' along small pores but is blocked if the capillaries don't line up or comes to a large air filled pore.

RETENTION

The texture of the soil affects retention, a course textures soil has many large pores so the bulk of the water drains freely downward because of gravity whereas a fine textured soil will not allow rapid drainage instead the small pores fill with soil solution. This is one reason clay soils (the finest soil particles) hold a great deal of water unfortunately much of it is unavailable to plants, because it is held too firmly to the clay particles.

Whether a soil is course or fine textured the structure and water retention is greatly improved by the addition of organic matter and humus because organic matter and humus retain large amounts of soil solution.

IRRIGATION

The rate of irrigation should not exceed the infiltration rate otherwise soil erosion will occur. A steady gentle rain wets the soil deeper than a quick sudden thunderstorm even if equal amounts precipitate because the water has a chance to infiltrate.

The soil texture must be taken into account if irrigation is used; the water must be applied close to the plant in a course textured soil because the movement is downward on the other hand the irrigation can be between two rows in a clay based soil because the water will move outward

Always water the soil not the plant.

PERCHED WATER TABLE

This occurs when two dissimilar soil texture classes are laid one on top of the other. A barrier forms between the layers because the pore size are different and the pores do not line up so water can not move in the capillaries from one soil texture class to the other. The water percolates through in the upper layer but the second layer will not begin to wet until the first layer is saturated, this create a perched water table. It occurs in flowerpots because the bottom is clay or plastic which is dissimilar to the potting soil, and in the landscape where a special soil is added to a bed but not mixed in. Golf course putting greens are designed with a perched water table to reduce the amount of water needed to keep the grass healthy.

Many new homes have the lawn on a perched water table because there is a 4" layer of topsoil over the original soil (which may be compacted by the bulldozers used during construction).

If the homeowner waters the lawn at a rate that exceeds infiltration they may cause erosion of the topsoil out from under the roots of the lawn!!!

NITROGEN

Encourages leaf growth in plants, but if too much is applied the plant will fast growing producing weakened stems. This makes them prone to insect and disease attacks.

When plants are suffering from Nitrogen deficiency the roots and shoots are stunted. Plants take the Nitrogen from the old leaves move it to the growing tip and use the Nitrogen in the new leaves. This causes the old leaves to become yellow and drop. The new leaves will become progressively smaller over time.

Nitrogen is stored on clay and humus. It is derived from fertilizers, manure, compost, organic matter and the atmosphere. In a natural soil up to 80% of the soil Nitrogen comes from the atmosphere; either soil microbes incorporate it into their bodies or it comes down in the rain as ammonium or nitrate.

Nitrogen is volatile meaning that it goes into a gaseous state easily especially in hot dry soils. It also leaches very easily draining into the waterways where it damages the aquatic ecosystem. For these reasons it is best to use Nitrogen carefully.

PHOSPHORUS

Phosphorus increases root growth and therefore improves water uptake by the plant. It promotes flowering and fruiting so it improves crop production. Lastly it improves plant hardiness against cold weather. Plants suffering from deficiency will be stunted and late maturing.

Phosphorus comes from compost, manure, bonemeal and rock. Place the phosphorus near the root zone because it does not leach easily and does become unavailable over time.

POTASSIUM

Potassium makes strong stems and vigorous roots, increases winter hardiness, and increases disease resistance. In many plants the edges of the leaves go yellow when the plant is suffering a deficiency. Lodging is another deficiency phenomenon where the stem breaks off neatly, suddenly.

Potassium is derived from rock, compost, and manure.

CARBON : NITROGEN DEPRESION

Micro-organism populations grow rapidly when plenty of food (Carbon materials) are in the soil, but to do so they take all the available Nitrogen from the soil to build proteins in their bodies. Once they have died and decomposed the Nitrogen is released into the soil.

If wood chips or straw are added directly into the soil the annuals, and vegetables would struggle to grow in the spring because they would not be able to get enough Nitrogen for their growth for 6-8 weeks after the carboniferous material was added.

Compost carbon materials before adding to the soil or give the plants additional Nitrogen until mid summer when the C:N ratio comes back into balance.