ANNEXURE - A

DEFINITION OF SOILS

Soils can be considered a three-phase system of solids, liquids, and gases. The solid phase consists of mineral and organic particles separated by a network of pores, some filled with gases-air with its carbon dioxide and oxygen being most important-and others filled with water. The proportions of each phase vary with the type of soil and are further modified by time, environment, and human, plant, and animal activities.

GENESIS OF SOILS

The lithosphere, the solidified crust of the earth, currently is exposed over aquarter of the surface of the earth, with the remaining three quarters covered by water or ice. Oxygen, silicon, aluminum, calcium, sodium, potassium, and magnesium are the most abundant elements in the crust, accounting for about 90 percent of the lithosphere, although over 80 elements combined into 2000 compounds are present, The rocky crust, the parent rock for soil formation, is slowly fragmented into smaller pieces and into individual minerals by the action of wind, water, ice, and temperature changes. These fragments are altered by mechanical and chemical processes, mixed with organic materials, and changed by biological processes to form the extremely variable substance we can call soil. Rates of soil formation from rock vary not only with the nature of the parent rock, but also with time. Many soils are, on a geological scale, very young and are still being developed. Depending on climatic conditions, the nature of the parent rocks, and a host of biotic factors.soil formation may be measured in eons, in centuries, or in decades. The establishment of a new home ·garden can be an example of soil formation within a few years.

The type of parent rock is of major importance in the type of soils developed in a particular location. Sedimentary rocks produce soils that tend to be neutral or slightly alkaline, while soils formed above igneous granites are usually more acidic.

PHYSICAL PROPERTIES

Texture

Many of the horticultural characteristics of soils depend upon the relative size of the mineral particles, termed texture; Texture is determined by the proportions of sand, silt, and clay that make up the soil. Sand is composed of compounds of silicon, primarily silicon oxides or quartz, Sand particles are comparatively large with a low surface-to-volume ratio (Table A.1).Because particles may be large and irregularly shaped, there can be a large volume of space between the grains. Water enters easily, but passes out just as easily, so sand has little water-holding capacity. The large space between particles also means that sand has low cohesiveness. Sand tends to hold low amounts of plant nutrients.

Silt is chemically heterogeneous, composed of particles of whatever the parent rock was. Being smaller in particle size than sand, water-holding capacity is higher because the space between the individual particles is smaller. Silts have moderate to high level s of nutrients with low to moderate cohesiveness.

Clay particles are very small, with a high surface-to-volume ratio. Water- holding capacity is high, space between the particles may be almost nonexistent, and there is great cohesiveness of the particles. Many clays are composed of aluminum compounds, although other minerals are involved. Clays may be rich in nutrients. The minerals bound to clay may not always be available to plants because they may be tightly bound by electrostatic charges to the surface of the particles. Clays are separated into two major groups, those that swell when wet (and shrink when dry) and those that rarely swell. Swelling clays are usually composed of finer particles that play important roles in nutrient retention and soil cohesiveness.

Table A-1

Size Classification of Mineral Soil Particles According to the U.S. Department of Agriculture systems

Particle Name	Diameter (mm)	Particles per gram	Surface Area (cm2/g)
Boulder	Over 250		
Cobble	250-60		
Pebble	60-4		
Gravel	4-2		
Fine Gravel	2-1	100	10
Coarse Sand	1.0-0.5	700	25
Medium Sand	0.50 -0.25	6,000	50
Fine Sand	0.25 –0.1	50,000	100
Very Fine Sand	0.1 – 0.05	700,000	200
Silt	0.05 – 0.002	6,000,000	500
Clay	Less than 0.002	90,000,000,000	8,000,000

Few soils are composed of only one particle type, but are mixtures at all three plus organic matter. Several methods are available for determining the ratios among particle groups and when the proportions are plotted on a textural triangle (Figure A-1), mineral soils can be classified in horticultural terms. Textural analyses refer to the soils in the upper meter (39 in.) of the soil, that region in which most plant roots grow.

Horticultural soils can also be classified simply by their feel. A handful of soil is mixed with water to the consistency of putty and squeezed into a ribbon between thumb and fingers. The ribbon that forms is related primarily to the clay content of the soil. If clay makes up more than 45 to 50 percent of the soil.the ribbon will be long and flexible due to the high cohesiveness of clay. Failure to form a ribbon indicates a soil with a high proportion of silt, and a gritty feel suggests that the sand content is high. Ribbons that start to form but then beak are indicative of silty loams.

The formal designation of soil textures indicates the coarseness or fineness of soils, but not whether they are, in common terminology, heavy or light. These terms refer more to the ease of working or tilling soils than to texture, although heavy soils are almost always high in clay (when they aren't excessively stony).

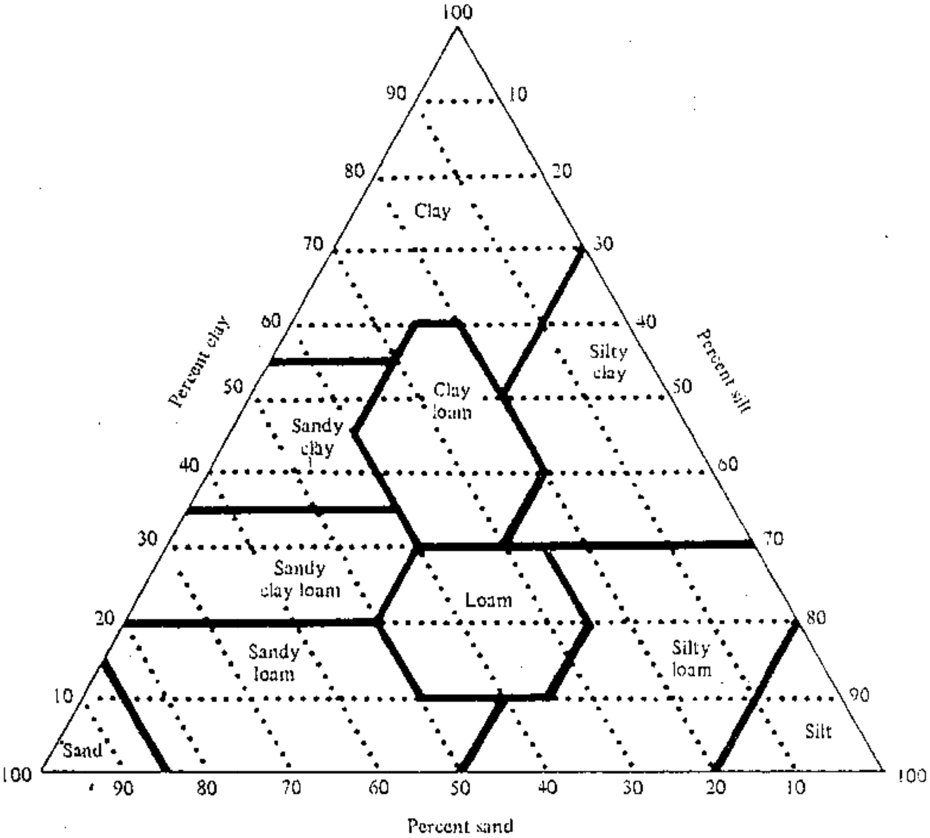

Fig A-1 Soil Texture Triangle

Pore space is usually determined by measuring the bulk density of the soil. Commonly expressed as the weight of oven-dry soil divided by the volume of oven-dry soil, or grams per cubic centimeter (g/cm3), soils with low bulk densities have large pore space volumes. A good horticultural soil will have a bulk density of 1.0 to 1.5 g/cm3 and a pore spacefraction of 0.4 to 0.6 (i.e., close to one-half of the total soil volume is pore space). The bulk density of heavy clay soils ranges from 1.0 to 3.0 g/cm3 and tillable silty loams range from 1.6 to 1.9 g/cm3.

WATER RELATIONS

From a plant's point of view, the soil in which it grows provides anchorage for its roots, a supply of air, and is the source of water and nutrients. The role of nutrients and of water in plant development is discussed later, but it is useful here to examine some of the water relations of soils. Water can exist in soils in all three physical phases, solid (ice), liquid, and vapor. Ice plays an important role in fragmenting rocks during soil genesis, and liquid and gaseous water are both involved in water retention, water movement through soil, and water uptake by plants. It should be remembered that soil water always contains dissolved minerals and gases. This soil solution is taken up by plants and is the source of minerals required by plants.

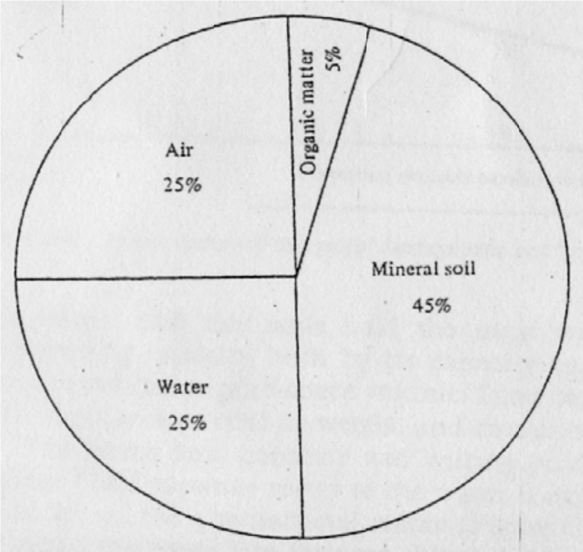

Fig A-2 Proportion of Soil Constituents

CHEMICAL PROPERTIES

Water, H20 or HOH, dissociates into two electrically charged particles or ions, one hydrogen ion (H+) and one hydro1tide ion (OH-). In pure water the number' of ions is very small relative to the number of un-dissociated molecules. One water molecule in over 500 million is dissociated; 1.0 mole of pure water (18 g) contains only 0.000001 moles of each ion, a number conveniently expressed as an exponential, 1 x 10-7.

Because of the difficulty of dealing with extremely small numbers, the concentration or activity of the hydrogen ions is given on a pH scale defined as:

$$pH = -\log [W]$$

For pure water, the pH can be calculated as follows:

$$pH = \log (1/0.0000001)= \log 10,000,000 = 7$$

Since a log scale is used, a full unit change in pH is a 10-fold change in the concentration of a hydrogen ion (Table A-2).

Water in soils is not pure, but contains many Inorganic and organic chemicals that supply hydrogen or hydroxide ions which contribute to the total concentration of these ions in solution. The addition of hydrochloric acid (H+Cl-), for example, supplies additional hydrogen ions; the pH of the solution decreases as the concentration of H+ increases. When an alkali such as sodium hydroxide (Na+OH-) is added, some ofthe OH- combines with H- present in the solution to form water, and the pH increases as the number of H+ ions decreases. Soils at pH 7 are neutral in reaction (having an equal number of H+ and OH- ions) soils with pH values below 7 are acidic and those with pH values above are alkaline. In plant science, soils with H values from ph 6.5 to 7.5 are considered neutral.Acid soil range from ph6.5 to 4.0 and alkaline soils from 7.5 to 8.5. Soils with values below 3.5 or above 8.5 very rarely show good productivity.

The pH reaction of soils depends on many factors. Soils in areas of high rainfall tend to be more acidic than those of dry areas because alkaline components-sodium. Potassium, calcium, and magnesium-are relatively easily leached. Soils witha high aluminum content or those formed from granitic parent rock are acidic, while those formed from limestone with a high calcium component are alkaline.

Table A-2
Hydrogen Ion Concentration and pH

H+ (moles/l)	pH	Soil Reaction	Substance With given pH	Soil types
10	0		Battery acid	
10-1	1			
10-2	2		Vinegar	
10-3	3	Acid toxicity	Lemon juice	Acidic peats
10-4	4	Very acidic	Orange juice	
10-5	5	Strongly acidic	Boric acid	Rainy region
10-6	6	Mildly acidic	Milk	Agriculture Horticulture
10-7	7	Neutral	Pure water	
10-8	8	Mildly alkaline	Sea water	
10-9	9	Strongly alkaline	Laundry soap	Arid region
10-10	10	Alkali toxicity	Laundry bleach	
10-11	11			
10-12	12		Ammonia	
10-13	13		Lye solution	
10-14				

Table A-3
Horticulture Soils Grouped Ph

Group	pH range	Type	Optimum for Representative plants
Medacid	4.0-5.5	Very low calcium Swamplands	Orchids, beets, heath family, swamp and mountain plants
Subacid	5.5-6.0	Low calcium Abandoned fields, uplands	Cereal grains, maples, woodland flowers
Minacid	6.0-7.0	Moderate calcium Garden loams, meadowlands	Most vegetables and ornamentals, lawn grass
Circumneutral	6.5-8.0	High calcium semitropical	Most fruits and nuts trees, food & forage legumes, asparagus

SALINITY AND SODICITY

Independent of the chemical nature of the compounds involved, soils that- contain high concentrations of salts present problems to the grower. By definition, soils in which more than 15 percent of the total cation exchange sites are occupied by sodium ions are considered to be sodic (sometimes called alkali soils), and those in which the sites are occupied by other cations in sufficiently high concentrations to impair plant growth are considered to be saline. Saline soils may result from the accumulation of almost any ionic substance, although those in which the excess salts are from sodium, potassium, or lithium usually have the additional problem of disruption of soil structure by de-flocculation of soil colloids and loss of adequate pore space. Occasionally, soils are found which are both saline and sodic.

Saline and sodic soils are found primarily in arid or semiarid regions where rainfall is limited and where extensive leaching does not occur. Even in regions with adequate precipitation, poor drainage conditions can lead to the accumulation of salts. Lands irrigated with water containing salts may, over a period of years, become saline or sodic. Soils near marine waters may become sodic as the fresh water is removed, allowing the infiltration of sea water.

LIFE IN THE SOIL

So far we have considered only the inorganic characteristics of soils, although we have mentioned how the presence of organic matter affects some of these characteristics. Many plants can grow satisfactorily under experimental conditions or in hydroponic culture in the complete absence of organic substance, but few plants do well in soils lacking organic matter. Microorganisms, plants, and animals all play roles in determining soil characteristics and productivity. For our purposes, we can separate organic soil constituents into two groups, those that are alive and those that are dead.

The numbers of living organisms in soil are staggering. In a gram of a good horticultural soil, there may be over 2 billion bacteria, 400,000 fungi, 50,000 algae, and 30,000 invertebrates, plus roots and other plant parts (Table A-4). There are also uncountable numbers of virus particles. Soil organisms are not uniformly distributed since soils are themselves not homogeneous. They are concentrated in films on the surface of soil particles and congregate on fragments of decaying biotic debris. The species and numbers of soil organisms vary with the season and with environmental conditions; fewer are found during droughts and in the winter than in periods of optimum moisture and temperature. Changes in plant cover also affect the organisms in the soil. Conversion of a forest to an agricultural pasture results in alterations in the flora and fauna of the soils. Modifications of soils by fertilization, tilling, liming, and irrigation also alter the composition of the biota.

Table A-4

Kinds & Amounts of Organisms & Organic Matter Typical Of a Horticultural Loam Soil in the North Temperature Zone

ORGANISMS	Dry weight	
	PERCENT	Kg/ha
Bacteria	0.1-0.2	2,000-3,000
Fungi	0.1-0.2	2,000-3,000
Algae	0.0001-0.0005	5-10
Invertebrates	0.001-0.005	10-50
Vertebrates	0.0001-0.0005	1-5
Plants root	0.5-5.0	5,000-50,000
Organic matter	4.0-8.0	75,000-150,000

Table A-5
Carbon to Nitrogen Ratio of Common Mulching Materials

Description	Percent Carbon (C)	Percent Nitrogen (N)	C:N ratio
Green cover crops			
Alfalfa	40	2.0	20:1
Clovers	40	3.0	13:1
Grasses	40	1.0	40:1
buckwheat	38	2.0	19:1
Mulches			
Peat moss	48	0.8	58:1
Fresh grass clippings	40	2.0	20:1
Dry leaves	40	1.0	40:1
Mixed mature compost	15	1.0	15:1
Straw	40	0.5	80:1
Sawdust	200	0.5	400:1
Rotted manures	30	1.5	20:1

ACIDIFICATION AND ALKALIZATION

Tolerance of plants to pH is fairly wide, ranging from about pH 4 (fairly acidic) to pH 8 (moderately alkaline). Many cultivated plants have a much narrower range. It is necessary to modify soil pH to ensure nutrient availability, reduction of metal toxicities, growth of desirable microorganisms, and conditions for in- creased crop productivity. The pH optimum for horticultural plants is species- dependent, but most will thrive at pH values between 5.5 and 7.0 and alteration of pH of soils within this range may not be necessary. Some alteration may be desirable to obtain the optimum for a specific crop, and alteration will be necessary for acid-loving plants since their optimum values range from 4.0 to 5.5. Decisions on modifying soil pH should always be made on the basis of a soil analysis.

Acidification of soils can be done by several methods. Organic materials that provide hydrogen ions, such as conifer needles, bark mulches. Sawdust mulches, cottonseed meal, oak leaves, and peat (sphagnum moss) are frequently used. Their acidifying potential is high and long lasting, but they are slow acting since they must break down before releasing hydrogen ions. Much quicker, but not as long lasting, are a variety of inorganic chemicals (Table A-8). Among the least expensive is elemental sulfur, also called flowers of sulfur. Its use in poorly;' drained or heavy soils is questionable since the sulfur may be converted by microorganisms into toxic compounds. Ammonium sulfate [$(NH4)2SO4$], ammonium nitrate ($NH4No3$), and ferrous sulfate ($FeSO4$) are used for small areas, and urea or liquid ammonia are used for agricultural lands. It is difficult to predict the effects of these chemicals and the amounts to be applied since soil depth organic matter content, cation exchange capacity, and other factors are involved soil tests are vital.

Many crop plants do best at pH values near neutrality. Soils that are subjected to leaching of basic cations or that have been cropped for many years may require upward adjustment of pH. With few exceptions, lime is the substance of choice to reduce acidity. It is inexpensive, readily available, easy to handle, and very effective. Lime is a generic term covering ground limestone or calcium carbonate (CaCO3)), slaked lime or calcium oxide (CaO), hydrated lime or calcium hydroxide [Ca(OH)2], and dolomitic. Limestone, which is a mixture of calcium carbonate and magnesium carbonate (MgCO3). Other liming substances include marl, ground oyster shells, hardwood ash, basic slag, and egg shells. All of these act. similarly by increasing the base saturation level of the soil and converting the exchangeable hydrogen ions into water. In order to determine the amount to he applied, a soil test is conducted. The liming substances have different neutralization capacities based on weight, but similar capacities based on the calcium content (Tables A-6 and A-7).

Limestone has a more immediate effect if it is finely ground, although this increases the chance of its being blown away during and after spreading. A compromise grind of 90% capable of passing a 20 mm screen and 25 % passing a 0.15 mm screen is usually used. Coarser grind are also available and less expensive. Lime does not move horizontally in soils to any extent and its vertical movement is limited even when it has dissolved in soil water.

Table A-5
Some Characteristic of Common Soil Acidifying Materials

	Sulfur **S**	**Ferrous sulfate** $\mathbf{FeSO_47H_2O}$	**Aluminum sulfate** $\mathbf{Al_2(SO_4)_3}$	**Ammonium nitrate** $\mathbf{NH_4NO_3}$
Solubility	Low	Moderate	High	High
Effect on pH	Slow	Moderate	High	High
Corrosivity	None	None	None	None
Effective time	long	Moderate	Moderate	Moderate

Table A-6
Filed Estimation of Calcium Carbonate ($CaCO_3$) Content of Soil

Percent CaCO3	Sound	Effervescence
0.1	None	None
0.5	Faint	None
1.0	Faint-Low	None
2.0	Distinct	Visible bubbles
3.0	Quite Distinct	Small bubbles
5.0	Very Distinct	Moderate bubbling
8.0	Very Distinct	Vigorous bubbling

Table A-7

AMOUNT OF ACIDFING SULPHUR OR ALKALINIZING LIMESTONE NEEDED TO ALTER SOIL pH

To change upper 20cm		**Sandy loam**		**Silty loam**		**Clay loam**	
From pH	**To pH**	**Lime^2**	**Sulfur**	**Lime^2**	**sulfur**	**Lime^2**	**Sulfur**
4.0	5.6	250	----	400	----	500	----
5.0	6.5	170	----	280	----	325	----
6.0	6.5	70	----	110	----	120	----
7.0	6.5	----	5	----	8	----	15
8.0	6.5	----	60	----	75	----	100

MULCHES AND COMPOSTS

The optimum %age of organic matter in a productive soil varies somewhat with climate, soil type and the nature of the crop, but generally it is about 5 to 15 %. As soils are tilled as microorganism gradually utilized the humus and other organic matter, and as leaching or erosion occurs, the amount of the organic fraction decreases. Among the many consequences of this are

1. Decreased soil porosity
2. Disruption of soil aggregates and loss of granularity
3. Decreased water-holding capacity
4. Decreased aeration
5. Increased erosion potential
6. Increased water evaporation
7. Decreased water buffering
8. Increased leaching nutrients
9. Alteration in favorable microorganism population
10. Increased temperature variations

These changes are more rapid in soils of tropical areas where temperature and rainfall are high but occur fairly rapidly even in temperature zones. For good productivity organic matter should be replaced.

Table A-8

Approximate Composition of Common Mulching Materials

Description	Nutrients(as present of dry weight)			
	Nitrogen	Phosphorus	Potassium	Present dry weight
Cow manure	1.5	0.4	0.8	20-30
Horse manure	2.0	0.3	2.0	20-30
Sheep manure	4.0	0.6	3.0	25-40
Poultry manure	4.0	2.0	2.0	30-40
Bone meal	0.1	10.0	0	100
Dried blood	13.0	1.0	1.0	100
Hay and straw	2.0	0.3	2.0	90
Cottonseed meal	6.0	1.0	2.0	100
Peanut hulls	2.0	0.1	0.7	100
Dried kelp	0.6	0	1.0	100
Wood ash	0.0	2.0	6.0	100
Hardwood sawdust	0.2	0.1	0.2	100
Softwood sawdust	0.1	0.1	0.1	100

Table A-9

CHEMICAL COMPOSITION OF PLANT –DERIVED SOIL ORGANIC MATTER COMPARED WITH THE PLANT TISSUE

Compounds	Present dry weight	
	Soil organic matter	Living plant tissue
Cellulose	30-60	2-8
Hemicelluloses	15-30	0-2
Lignins	15-30	30-50
Proteins	2-12	1-5
Fats and waxes	1-5	1-4

SOIL MIXES FOR HOMES AND GREENHOUSES

Few house or greenhouse plants do well in soil dug out of the garden. Garden soils are usually too heavy and have variable composition. To standardize and control the substrate, potting mixes have been developed, Some containing soils and some soilless. A variety of all purpose and specialty mixes are commercially available, but for general use and volume production they are not cost efficient, and some contain sewage sludge’s contaminated with household and industrial waste.

Potting mixes also called growing mixtures or soil mixes have advantages over top soil. They can be reproduced and are stable have excellent porosity, water holding capacity, cation exchange capacity and pest free. Because they are light in weight, large plants may topple or pulled from the pot, but the advantages outweigh the disadvantages.

Most potting mixes contain both plant-derived and inorganic materials with high water-holding capacity, resistance to compaction and high cation exchanges (Table A-10). Milled peat moss, leaf mold, shredded bark, humus, well-rotted manure, and wood chips are used. Inorganic constituents, such as sharp builder's sand, vermiculite, perlite, scoria (ground lava rock), and ground granite, improve drainage and increase pore volume. Small amounts of other substances are added to regulate pH and supply trace elements or nutrients

Table A-10

POTTING MIXING FOR HOUSE PLANTS , GREENHOSE, AND GARDEN TRANSPLANT USE

Ingredient	**Cornell peat-lite**	**University of California C**	**John innes**	**Humus mix**	**Succulent and cacti mix**	**Epiphyte mix#1**	**Epiphyte mix#2**	**General house plant mix**	**Perennial container mix**	**Cornell seed starting mix**	**John innes seed compost**	**Rooting cutting mix#1**	**Root cutting mix#2**	**Coniferous bonsai mix**
Major ingredient														
Sphagnum peat(shredded)	2	1	3	1	1	1	1	1	1	1	1	1	1	1
Sharp sand (0.5-1-0mm)		1	2	1	1			1	1		1	1	1	1
Bark (shredded)									1					
Leaf mould or humus				1	1	1	1	1/2	1					
Sandy loam soil			7				1	2			2	1		1
Vermiculite	1			1		1							1	
Perlite	1													
Additives														
Dolomitic lime(ground)	20	300	250			75	150	100	50	50	100			
20 present superphosphate	50	50	50				50		75	25	100			25
Chelated iron	5	5					5		5	5				5
Fritted trace element	1								1					