

Study Material

For Semester – II

Name of the Teacher: Monami Haque

Subject: Environmental Science (Hons.)

Sl. No.	Paper	Unit	Topic	Sub-topic	Sources
1.	CC-04 (T)	Unit 2	Fundamentals of soil science	Soil formation	1. T. D. Biswas & S. K. Mukherjee. 2011. <i>Textbook of Soil Science</i> (22 nd Reprint). Tata McGraw Hill Education Private Limited. 2. V. N. Sahai. 2011. <i>Fundamentals of Soil</i> (4 th Edition). Kalyani Publishers.
2.				Classification of soil; Soil architecture	
3.				Physical properties of soil: <ul style="list-style-type: none"> • Soil texture; • Soil water holding capacity; • Soil temperature; soil colloids; • Soil acidity and alkalinity; • Soil salinity and sodicity; • Soil organic matter. 	
4.				Micronutrients of soil: <ul style="list-style-type: none"> • Nitrogen, • Sulphur, • Potassium and • Phosphorus economy of soil 	
5.				Soil biodiversity	

❖ Semester: II

➤ Paper: CC-04 (T), Unit 2

• **Topic: Fundamentals of soil science**

✓ **Sub-topic: Soil formation**

SOIL GENESIS, CLASSIFICATION AND SURVEY

8

A very brief reference was made in Chapter 1 to soil as a natural body and the origin of soil from rock. In this chapter, we will discuss soil as a natural body, i.e. the phenomena presented by it in its natural state. These phenomena are the consequence of the natural laws governing the origin, formation and distribution of soils on the earth's surface and are dealt with in a discipline called pedology. *Pedology* is a branch of soil science that specifically deals with soil genesis and classification.

8.1 SOIL GENESIS

no transformation of rocks into soil may be termed as soil formation.

- ① Soil genesis embodies two distinct phases. The first is weathering, i.e. disintegration and decomposition of rocks and rock minerals; the second is the development of soil by pedogenic factors and processes.

8.1.1 Rocks and Rock Minerals

The earth's atmosphere consists of gases completely enveloping it to a height of about 150 km. The hydrosphere includes sea, lake, stream and underground waters. Lithosphere is the hard crust of the earth consisting of rocks and rock minerals.

The rocks formed by cooling of the original molten material (magma) from the sun are termed *primary* or *igneous* rocks (e.g. granites, syenites, basalts, etc.). Some of the rocks were subjected to exogenous forces exerted by the atmosphere and hydrosphere, got weathered to secondary products, transported by the action of wind and surface water to be deposited in the oceanic basin or other terrestrial depressions. These products, in course of time, having successive layers of the same or different materials hardened due to increased pressure and

temperature with depth. They are grouped as *sedimentary rocks* (e.g. sandstone, limestone, etc.). Both igneous rocks and sedimentary rocks may be transformed into *metamorphic rocks* by endogenous factors, including high temperature and pressure (e.g. gneiss, schist, slate, etc.)

The approximate chemical composition of the principal minerals and elements detected in igneous rocks have been presented in Chapter 3 (Tables 3.1 and 3.2, respectively). The approximate percentages of important minerals present in igneous rocks are: feldspars (60%), pyroxenes and amphiboles (18%), quartz (12%), micas (4%) and others (6%). The mean chemical composition (%) of igneous rocks is as follows: SiO_2 59.07; Al_2O_3 15.22; Fe_2O_3 3.10; FeO 3.71; MgO 3.95; CaO 5.10; Na_2O 3.71; K_2O 3.11; H_2O 1.30; TiO_2 1.03; P_2O_5 0.30; MnO 0.11; others 0.29.

8.1.2 Weathering of Rocks and Rock Minerals and Soil Development

(Weathering is the disintegration and decomposition of rocks and rock minerals by physical, chemical and biological agents, singly or in combination.) Weathering and soil development proceed almost simultaneously in case of soft rocks, whereas in the case of hard rocks, weathering precedes soil development. In these processes, two types of weathering can be recognized, viz. geochemical and pedochemical. Geochemical weathering takes place before soil development and continues somewhat unperceptibly beneath the soil cover. Pedochemical weathering is the result of disintegration and transformation of minerals that takes place within the soil. The former is also termed as 'geogenesis' and the latter as 'pedogenesis'.

Physical weathering

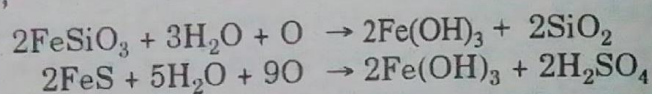
This results in the comminution of rocks and rock minerals. Granite, for example, subjected to physical weathering retains its original chemical and mineral composition. Changes in atmospheric temperature during day and night and also its seasonal variation cause surface expansion and contraction and breakdown of the big mass of rocks into smaller fragments. This process is common in arid regions. Similarly, alternate freezing and thawing in cold regions are the chief agents of physical

weathering. Other agencies of physical weathering are moving water or ice, mutual rubbing of rock fragments and air blast of sand grains. Physical weathering is more predominant in soil formation in the desert and arctic regions, where the soils are characterized by the presence of large proportions of coarse particles.

Chemical weathering

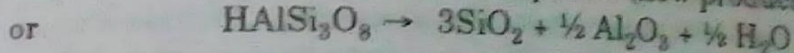
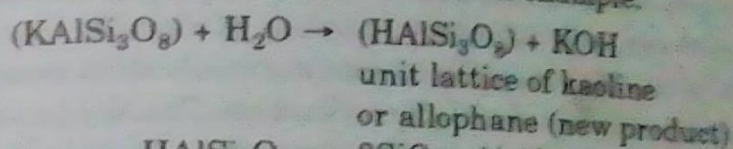
It gives rise to drastic alterations in the constituent minerals, partially or wholly, with the formation of secondary minerals which differ markedly from the primary minerals. The secondary products may be formed by alteration *in situ* or by precipitation from solutions under conditions favourable for it.

The principal reactions involved in chemical weathering are one or more of the following depending on prevailing conditions, namely, oxidation, reduction, hydration, hydrolysis, solution and carbonation. Oxygen is the most energetic oxidizing agent and brings about *oxidation* of elements such as Fe^{2+} to Fe^{3+} , for example,



The above reactions indicate the possibility of formation of hydrated ferric oxide, silica and even sulphuric acid as products of chemical weathering, if sulphur containing minerals are present. *Reduction* takes place under anaerobic conditions. Here iron and polyvalent elements are reduced to more soluble or mobile forms and are likely to be lost by leaching. Soil environment may so change that oxidation and reduction processes may alternate. Iron and manganese are particularly susceptible to such changes. *Hydration* is possible either by the bonding of water molecules to mineral lattices or to cations present in such minerals. Hydration may even alter the crystal structure. The notable examples are the formation of serpentine from olivine, and of gypsum from calcium sulphate. *Carbonation*, i.e. combination of cations with carbonic acid brings about a breakdown of mineral lattice. Although the atmosphere contains 0.03 per cent CO_2 , rain water may contain as high as 0.45 per cent CO_2 . In regions of high rainfall, the action of carbon dioxide on the decomposition of rocks may be quite considerable. Higher concentrations of CO_2 in rain water are capable of

reacting with sparingly soluble carbonates forming bicarbonates which are normally soluble. The dissolution of limestone in rain water is an example in point. *Hydrolysis* is the most important of the processes in chemical weathering. By hydrolysis, alkali and alkaline earth ions are replaced in the aluminosilicate lattice by hydrogen ions with the formation of aluminosilicic or ferrosilicic acid and liberation of alkali and alkaline-earth hydroxides. The silicic acids are either converted into secondary minerals, i.e. new products or are further decomposed into iron oxide, alumina and silica. Transformation of orthoclase feldspar may be cited as an example.



Biological weathering

It is, in the strict sense, physical and chemical weathering brought about by biological agents. Plant roots are one such potent agent (see Chapter 4). They do so in two ways. The growing roots of higher plants exert tremendous pressure in widening cracks and crevices in rocks and their penetration causes disruption of rocks. Minor forms of plant life thrive in such crevices and help further disintegration of rocks. The other important contribution of plant roots is generation of carbon dioxide after their decay. The CO_2 thus formed favours carbonation. This CO_2 is the result of activity of soil microorganisms which convert roots and other organic substances present in soil into humus. Autotrophic organisms derive carbon from atmospheric carbon dioxide and energy from inorganic constituents and in the process bring about mineral transformation. It has been reported that the rhizosphere activity of forest seedlings, grown in sand culture containing biotite as their sole source of potassium and magnesium, leads to transformation of biotite to kaolinite.

3

Weathering and stability of minerals The weathered products of rocks and rock minerals are called parent material for soil development. The various complex physical and chemical reactions lead to the breakdown of the minerals and formation of a

number of secondary minerals and/or clay minerals. The smaller the particle size of the parent material and higher the temperature, the more rapid is the rate of chemical weathering. The particle sizes of the products vary according to environment from those of the finest clay to coarse sand.

The minerals vary in their stability to weathering. The relative stability of the common minerals has been indicated in Table 3.2. Olivine is the most easily weatherable, whereas quartz is the most stable and resistant mineral. The relative stability of the minerals to weathering and to decomposition appears to be related to the degree of basicity, degree of linkage of tetrahedrons, and relative proportion of alumina to silica. Various listings of the relative stability of minerals to weathering follow closely the order of crystallization. The less basic the mineral, the more stable it is. The presence of ferrous iron or other oxidizable cations greatly reduces the structural stability.

Weathering and formation of secondary minerals The nature of weathering products, some of which may be stable and some partially stable, depends upon the nature of the reactants and pH of the weathering environment. Some of the products may be lost by leaching. Some of the soluble cations may get exchanged with those of primary minerals or secondary minerals and are retained. It is envisaged that the ultimate products of weathering are silica, alumina and soluble cations. Some of them may be removed from the site of reaction by leaching, but the rest may recombine under specific conditions to form secondary minerals. Some secondary minerals like mica and biotite may act as primary minerals and further transform themselves *in situ* into other secondary clay minerals. Thus, illite, vermiculite and subsequently montmorillonite are formed from mica, depending upon the environmental conditions.

Mica \rightleftharpoons illite \rightleftharpoons vermiculite \rightleftharpoons montmorillonite
Here, it should be noted that the two-dimensional structure remains intact.

All the processes, namely, weathering of primary minerals and resynthesis of secondary minerals either *in situ* or away from the place of weathering, take place simultaneously. But the nature and degree of each type of transformation depend on the prevailing conditions. Thus the presence of calcium and

magnesium and a general condition of base saturation are conducive to the formation of montmorillonite or smectite minerals. Again, clay minerals in hot dry and/or in cold dry climates, where chemical weathering is minimum, are the result of largely *in situ* reactions. Thus, kaolinite, a common product of exhaustive hydrolysis and leaching, is observed in some desert soils owing to *in situ* decomposition.

All kinds of mineral groups occur in different climatic zones, but their distribution varies. Thus, kaolinite is dominant in humid tropics. Association of clay minerals is quite common. Thus illite and chlorite predominate in the soils of the arid zone, montmorillonite in the semi-arid zones having calcium and magnesium in the environment, illite and vermiculite in humid regions in the alkaline earth environment; illite in highly acidic soils with favourable potassium environment.

The influence of the parent material on clay mineral formation is most conspicuous at the early stage of soil formation, but with the advancement of pedogenesis or profile development, the effect is progressively erased under the impact of more active soil forming factors. The dominance of illites from granites which are acidic rocks, and of montmorillonite from basic rocks has been mentioned; kaolinite is commonly derived from sedimentary rocks. However, under drastic leaching conditions, in the humid tropics, formation of kaolinite even from basic rocks has been reported.

The general conditions governing the formation of clay minerals may be summarized as follows. Under impeded drainage conditions and in the environment of high concentration of silica and magnesium, smectite-type of clay minerals are formed. Illite is formed under low pH environment containing a high concentration of potassium. Generally, the mica-type of minerals lead to the formation of illite under suitable conditions. In the absence of high concentration of magnesium and other bases, low pH condition and intensive leaching, kaolinite is the dominant clay mineral.

The parent material is acted upon for a sufficiently long time by the soil forming factors (see Section 8.1.3) such that soil formed is deep enough, the vertical section of the soil body shows characteristic and distinctive features. This vertical section of

the soil body above the parent material is called the *soil solum*, and that including the parent material but not parent rock, if any, is the *soil profile*. The term soil development commonly refers to the development of *soil profile* or *pedon*.

8.1.3 Factors of Soil Formation

Towards the end of the 19th century, Dokuchaev stated that "soil is the result of the combined activity and reciprocal influence of parent material, plant and animal organisms, climate, age of land and topography." These were termed as *soil formers* or *factors of soil formation*. The relation may be expressed as follows:

$$S = f(cl, o, r, p, t, \dots)$$

where *S*, soil formation, is a function of *cl* (climate), *o* (organisms), *r* (relief), *p* (parent material), and *t* (time or age of land). Jenny emphasized that a soil property is determined by the relative influence of these factors. Jenny specified temperature and rainfall as climate; flora and fauna as biosphere organisms; elevation, slope and depth of water table as relief. In this way, he could analyze quantitatively in young soils the effect of one of the factors on soil formation when that particular factor was dominant in relation to the others. In old soils, which have developed over a long time, say, hundreds or thousands or a few million years, some of the factors, such as, climate, relief, etc., may have changed markedly during the course of soil formation, and such analysis is not possible. The laterite cappings observed in the presently arid belt of Rajasthan are undoubtedly the relics of a past humid climate. The factors of soil formation are discussed briefly in the following paragraphs.

Parent material

Also called as the initial soil material, it refers to the unconsolidated mass from which the solum develops. The parent material has been defined by Jenny as "the state of soil system at time zero of soil formation." The parent materials may be formed in place by weathering of rocks, may be transported from the place of their origin and redeposited either before they become subject to modification by soil formers or during the process of modification, or by organic deposits. The parent materials transported

from their place of origin are named according to the main force responsible for the transport and redeposition. The material transported and deposited by the water is *alluvium*, found along major stream courses, at the bottom of slopes of mountains, and along small streams flowing out of drainage basins. *Colluvium* is used for poorly sorted materials near the base of strong slopes transported by the action of gravity. *Lacustrine deposits* consist of materials that have settled out of the quiet water of lakes. *Glacial drift* consists of all the materials picked up, mixed, disintegrated, transported and deposited through the action of glacial ice or of water resulting primarily from melting of glaciers. The wind blown materials are termed *loess* when the texture is silty and *aeolian sand* when these are primarily sand. The soils developed on such transported parent materials bear the name of the parent material viz. alluvial soils from alluvium, colluvial soils from colluvium, etc.

The parent materials, being the residual products of weathering contribute to minerals and other materials in soil formation. (The physical, chemical and mineralogical properties of parent materials have a significant effect on soil formation. The weatherability of primary minerals greatly influences the mineralogical composition of the coarse fraction of soil. The chemical composition of soil, particularly in case of recently developed soils and physically weathered soils, has some semblance to that of the parent material.) The mineralogical composition of fine sand fraction is an indication of the source of the parent material and also the uniformity of parent material in soil development. Sometimes parent materials may be from more than one source. The texture of the parent material determines, to a large extent, the depth of soil profile. The finer the texture, the higher is the rate of reaction. In general, soils are deeper on light textured parent material than on heavy textured parent material. This is often disturbed by other factors of soil formation. The chemical composition of soils depend, to a large extent, on the types of rock on which they have developed and their mineralogical composition.

Topography or relief

It implies relative elevation and had been defined as elevations or inequalities of land surface considered collectively. Soil slope

294 Textbook of Soil Science

another ridge, found in the Chhattisgarh area of Madhya Pradesh, can be cited as an example. The sequence consists of diverse types of soils, locally known as *Bhata* (red earth) on the top of the mound, followed by *Matasi* (yellow earth), *Darsa* (brown earth), and finally *Kanhar* (black) in the valley position of the slope.

Variations in aspects and elevation influence the climatic factor, i.e. exposure to sun, wind action, and rainfall and ultimately organic activity. Vegetation differs if the slope faces a certain direction, north or south. All these factors influence soil formation.

Climate

This includes precipitation, temperature, humidity and wind. Climatic factors determine the water supply through precipitation and evaporation, the temperature and total quantity of heat supplied through solar radiation. The climate also influences the natural vegetation over the earth's surface and consequently soil formation. There are many parallels in the distribution of climate, vegetation and soil on the earth's surface.

The earliest Russian workers were so convinced of the effect of climate on soil formation that they introduced the concept of zonality in soil classification. *Zonal soils* were groups of soils developed under similar climatic conditions and distributed in a climatic belt. Soils in this group possess well-developed profiles which reflect the influence of climate and vegetation. Russian chernozem is the best example of this group. In the zonal soils, if the soils express characteristics, defying the climate and vegetation under the influence of other local conditions, these were grouped as *intrazonal soils*. The local conditions may be excess of water, salt, calcium carbonate, etc. The soils which could not be grouped in any one of these two were classified as *azonal soils*. Alluvial soils belong to this group.

Rainfall or water from snow and temperature are the two main components of climate which play a vital role in soil development. In this respect, the total amount of water passing through the soil or the pedologically available water is important. Water acts both physically and chemically. The percolating water translocates clay and other soil constituents—the movement may be in any direction. This moulds the morphologi-

cal part of soil as a natural body as a part of the relief and an integral part of soil to the horizon. is the incline of the surface of the area to the horizon. Topography (relief) influences soil formation through its effect on drainage, runoff, soil erosion and microclimate, i.e. exposure of land surface to the sun and wind. A part of precipitation percolates downward (internal drainage) and a part is lost as surface runoff (external drainage). In the high relief position for hills and mountains, much of water is lost as surface runoff and very little of it takes part in soil formation. The transported parent material accumulates at the base of the high slope, where other factors of soil formation act on it. When the slope is relatively small, internal drainage is more and water acts in shaping the soil profile development. The depth of the soil solum is influenced by the degree of slope. Considering single slope, as the gradient decreases, the depth of solum increases. As a result, deep solum is generally observed in the plains and it decreases as the slope gradient increases. The soils on the upper portion of a slope are well drained, whereas those at the base, because of accumulation of finer soil particles from the upper slope portion, have moderately impeded drainage. Some of the soils formed on the upper slope portion, have moderately impeded drainage. Some of the soils formed at the basin area of the slope are washed down and get deposited at the basin area of the slope. The soils on the upper slope are less clayey, lower in pH, soluble salts and organic matter contents, lighter in colour and well drained, whereas those at the lower slope are more clayey, higher in pH, calcium carbonate and soluble salts content, darker in colour and have impeded drainage.

Milne developed the concept of *soil catena* to indicate a regular repetition of a sequence of soil properties in association with certain relief, the parent material may or may not be the same. The catenary sequence represents a complete drainage scale, showing variable drainage conditions from well drained soil at the mound of the slope to soil of impeded drainage at the base of the slope. A common example of catena occurs in the regularly undulating lands of the tropics, where the soils on ridges may be red loam, with black soils in the bottoms or valleys and the soils on the intermediate position showing intermediary characters. Such catenary association, occurring in consecutive bands along the slope from one ridge across a level valley to

cal, chemical and physical features of soil profile. In contrast to region of low rainfall, significant leaching by water takes place in areas of high rainfall. Intensity, duration and distribution of rainfall are the important factors.

Water and temperature control the nature and rate of weathering reactions. In this respect, the amount of water which is the difference between precipitation and potential evapotranspiration, is the controlling factor. Three situations may be envisaged, viz. (1) soil is water saturated, (2) the amount of water is sufficient to cause leaching, and (3) no leaching. In the leaching regime, some water moves through the soil at some time during the year and moves downward. In the non-leaching regime, water moves upward and is lost by evapotranspiration, leaving precipitated carbonates and soluble salts near the surface. Variable leaching over years leads to accumulation of these constituents in soil profiles. Movement of clay and other soil constituents also takes place by the leaching process. Thus, leaching, eluviation, illuviation and formation of many diagnostic horizons are through the agency of water.

The soil properties which are affected by climatic conditions are pH, base saturation of exchange complex, organic matter content, clay mineralogical composition, amount and nature of clay. The higher the precipitation and the lower the temperature, the higher is the organic matter content of soils (Sec. 5.2.2). If the temperature is low and unfavourable for biological decomposition of organic matter, accumulation of undecomposed organic matter on the surface soil is the result. In general, with increase in rainfall, there is decrease in pH, base saturation, content of carbonates and soluble salts but increase in that of clay. Genesis and transformation of clay minerals in relation to climatic conditions have already been discussed (Sec. 8.1.2).

Evaporation, transpiration and humidity modify the effect of precipitation by either reducing or increasing the quantity of water available for percolation and reaction. Meyer's N.S. Quotient (NSQ) (Sec. 5.2.2) which is the ratio of precipitation (in mm) to absolute saturation deficit (in mm mercury) and Thornthwaite's potential evapotranspiration (PE) index are some of the climatic indices used to quantify the effect of climate on soil formation. But, none of these indices can fully explain the effect. Attempts have been made to relate the components of

climate, viz. rainfall and temperature with a soil property. These relations hold good only when other factors do not vary much.

Organisms (biosphere)

It includes flora and fauna—the active soil formers. The plant roots penetrate the parent material and make channels which induce drainage of water and create favourable environmental conditions for biological activity. Root exudates and carbon dioxide solubilize some of mineral constituents, which are taken up by plant roots, translocated through the plant parts and returned to the soil by the decay of the plant bodies and deposited on the surface. The microorganisms play their role in the decomposition and transformation of organic matter (Sec. 4.6.1). The soils under forests and grasses are quite distinct from those without these vegetations. It is also established that forest changes the climate, the effect being interdependent. The vegetation consumes considerable amount of water and transpires into the atmosphere. At the same time, tree roots enable soil to retain water from runoff. Water movement influences soil formation. The organic matter status of soil has been utilized as a characteristic in determining some diagnostic soil horizons in soil taxonomy, viz. histic, mollic, etc. (Sec. 8.2.2.1).

The role of fauna in soil formation has not been studied in detail. Some fauna, harbouring soil, dig into the soil body and mix the materials of different horizons. The role of earth worms in soil granulation has been mentioned earlier (Sec. 4.6.5). Fauna also contribute to the biomass of soil, but its quantum is small. Other fauna which are known to appreciably influence soil formation are ants, termites and rodents. Ants and termites carry material from lower depths upwards and even to the surface. The burrows the rodents may affect the soil forming process.

Time or age of land

A soil body at any point of time reflects the combined influence of soil forming processes and impression of soil forming factors in its profile development. This span of period from the inception or zero point of soil development to the present stage is termed age. Jenny expressed soil age in terms of the pedogenic factor.

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time. Soil formation is a very slow process. Age may vary from a few years to several thousand years. Radiocarbon dating, pollen analysis, or carbonate carbon in caliche layers are used to arrive at an approximate age of soil. Rate of soil development is more rapid on permeable, unconsolidated parent material in a warm and humid climate than on hard rock, and hence in the case of the latter, the length of time should have to be very great. Conditions that hasten the rate of soil development are: warm, humid climate, forest vegetation, permeable and unconsolidated parent material low in lime content, flat topography with good drainage. Factors which tend to retard soil development are extremes of cold and dry climate, impermeable and consolidated parent material high in lime and steep slopes.

Mohr and van Baren recognized five stages of development of tropical soils. These different stages are characterized by discernible mineralogical features which permit the following broad groups according to the stage of development.

1. *Initial stage*—unweathered parent material.
2. *Juvenile stage*—weathering just started, but much of the original material is still unweathered.
3. *Virile stage*—easily weatherable minerals have been decomposed for the greater part, the clay content has increased and a certain mellowness is discernible. The content of soil components less susceptible to weathering is still appreciable.
4. *Senile stage*—decomposition arrives at a final stage, and only the most resistant minerals have survived.
5. *Final stage*—soil development has been completed and the parent material is fully weathered.

In pedology, the age of the soil is the stage of soil development irrespective of the time taken. Thus, a *young soil* means the soil where the factors of soil formation and pedogenic processes are still operative and changing the properties of soil in the profile and the processes have not made a distinct impression on the soil profile. The horizons are not well demarcated. A *mature soil* represents a steady state in respect of the parent material. Time factor has no relevance after the soil reaches its maturity. In mature soil, the different genetic horizons are clearly discernible. In young soil, clay from primary minerals is still being actively formed, whereas in mature soil the clay is more or less in equilibrium with the primary minerals. Further, in mature

soils, clay content increases with depth of profile, accumulating at an intermediate depth, whereas in young soils, clay content decreases with depth.

If the soil solum is removed by erosion or deposited over by a fresh transported parent material, a new cycle of soil formation takes place over the buried soil.

8.1.4 Soil Forming Processes

The fundamental processes of soil formation are (i) addition of organic and mineral matter to the soil; (ii) losses of these materials from the soil; (iii) translocation of these materials from one point in the soil profile and deposition at another; and (iv) transformation of the mineral and organic matter in the soil and formation of definite layers or these processes bring about certain specific features by means of a variety of reactions. The fundamental processes together with the more important specific processes and reactions are listed in Table 8.1 to show their relationships.

The fundamental processes are accumulation of humus or decayed organic material, eluviation, illuviation, and horizonation. *Humification* is the process of decomposition of organic matter and synthesis of new organic substances. Soil genesis is associated with the origin and development of the biosphere. In a specific situation, viz. under forest in a temperate climatic zone, there is accumulation of undecomposed as well as humified organic matter. The soil humus is dispersed to a certain extent throughout the solum. *Eluviation* is the mobilization and translocation of certain constituents, viz. clay, Fe_2O_3 , Al_2O_3 , SiO_2 , humus, $CaCO_3$, other salts, etc. from one point of soil body to another. *Illuviation* is the immobilization and accumulation of the eluviated constituents at a depth beneath the soil surface.

A number of other processes operate in the course of soil formation. *Calcification* and *gypsification* are the soil forming processes of arid and semi-arid regions and refer to the formation and accumulation of calcium carbonate and gypsum, respectively. Most parent materials in these climatic regions are rich in lime and gypsum. Low rainfall is unable to move them downwards. In regions where some water percolates through the soil profile, *decalcification* takes place leading to the formation

Table 8.1 Soil forming (pedogenic) processes and reactions

Fundamental processes	Specific processes	Reactions
Humus accumulation on the surface, formation of the A ₁ horizon	Calcification	Migration of soil constituents (clay, silt, humus, ions)
	Decalcification	
Eluviation, leaching of soil materials from surface, formation of the A horizon	Silication	Addition to the soil body
	Podzolization	Losses from the soil body
	Laterization (Ferritization)	Translocation within the soil body
	Salinization	Decomposition and transformation of organic matter
Illuviation, accumulation of leached materials from A horizon, formation of the B horizon	Desalinization	Solubilization
	Alkalinization (Solonization)	Precipitation
	Desalkalinization (Solodization)	Oxidation and reduction
Horizonation, differentiation of soil in different horizons along the depth of the soil body	Leesavage	Carbonation
	Pedoturbation	Hydration
	Argillation	Adsorption
		Ion exchange
		Mineralisation
		Immobilization
		Ammonification
		Nitrification
		Denitrification
		Nitrogen fixation
	Transformation of soil minerals	

of calcic horizon or *Eypsic* horizon down below. In humid regions, calcium carbonate reacts with water containing dissolved carbon dioxide to form soluble bicarbonate which may be completely leached out of the soil profile. *Podzolization* (in Russian, *pod* means "under" and *zola* means "ash") is the process of eluviation of oxides of iron and aluminium and also of humus under acid condition (pH 4-5), removal of carbonates by organic acids formed by organic matter, and illuviation of the sesquioxides and humus in subsurface horizons. Abundant organic matter, commonly found under forest, cool climate and abundant water under humid climatic condition are favourable for such processes. The eluviated horizon assumes a bleached grey appearance and is left in a highly acid, siliceous condition.

Because of the grey colour and ashy appearance, the term *podzol* has been used for such soils. *Laterization*, in contrast to *podzolization*, is the process of desilication, i.e. the removal of silica and accumulation of sesquioxides. Hydrolytic separation of silica following its removal by leaching in the presence of bases, resulting in a relative accumulation of sesquioxides and formation of 1 : 1-type clay minerals of the kaolinitic group are characteristics of such a process which operates in the hot and humid climatic conditions of the tropical and subtropical regions of the world. The word *laterite* was originally suggested by Buchanan in 1807 as a name for a highly ferruginous deposit first observed in Malabar (India). The word is derived from the Latin word, *later*—a brick and obviously refers to its use as a building material and not to its colour. *Salinization* is the process of accumulation of soluble salts in soil. The intensity and depth of accumulation vary with the amount of water available for leaching. Salinization is quite common in arid and semi-arid regions. Salinization may also take place through capillary rise of saline ground water and by inundation with sea water in marine and coastal soils. Salt accumulation may also result from irrigation or seepage in areas of impeded drainage. *Desalinization* is effected by leaching of soluble salts from soil, either with rain water or with irrigation water of good quality. Drainage is essential for desalinization. *Alkalinization* (*solonization*) is the process by which soils with high exchangeable sodium and pH greater than 8.5 are formed, often sodium carbonate and sodium bicarbonate are formed in extreme cases of alkalinization. Such soils are called *sodic soils* or *alkali soils*. *Dealcalization* (*solodization*) is effected by intensive leaching and degradation which takes place in older soils. In this process exchangeable sodium is replaced by hydrogen ions. There is a simultaneous process of *argillation* which results in the leaching of dispersed clay particles from the upper to the lower horizons, giving rise to a textural horizon. *Glaziation* is the process of reduction, due to anaerobic condition, of iron in waterlogged soils with the formation of mottles and concretions of iron and manganese.

The soil forming processes which lead to the formation, transformation and rearrangement of soil materials in a soil body leave their imprint on the different genetic soil horizons

which constitute the soil morphology. *Horizonation* includes those processes by which the soil materials are differentiated into several horizons in a soil profile. The soil horizons may be pronounced to be observed visually or may have to be differentiated by means of certain soil characteristics (discussed under soil morphology). Intermixing of soil horizons takes place in certain soils due to external factors. This process of mixing in the soil body has been termed *pedoturbation*.

8.1.5 Soil Morphology

Soil morphology is the description of the soil body, its appearance, features, and general characteristics as expressed in the profile of a soil. The morphology of the soil is expressed by number, kinds and arrangements of the different horizons and their observable and measurable characteristics. A soil horizon is "a layer of soil, approximately parallel to the soil surface, with characteristics produced by soil forming processes". Soil horizons extend in space, horizontally, laterally and vertically as soil is a three-dimensional component of the landscape. An individual soil body may be bounded laterally by other soil bodies or by non-soil materials. A soil individual is a natural unit in the landscape characterized by position, size, slope, profile and other features.

Soil profile is studied in the field from a freshly exposed pit. The problem is what should be the unit for description and selection of a profile site and soil samples to represent a particular soil unit. As a partial solution to this problem, the concept of *pedon* was introduced by the USDA Soil Survey Staff and described in the Soil Taxonomy (Sec. 8.2.2). A *pedon* is the smallest volume that can be recognized as a soil individual and "has the smallest area for which we should describe and sample the soil to represent the nature and arrangement of its horizons and variability in other properties that are presented in the sample. A pedon is comparable to a unit cell of a crystal. It has three dimensions. Its lowest limit is the somewhat vague limit between the soil and net-soil below. Its lateral dimensions are large enough to represent the number of any horizons and variability that may be present. The area of a pedon ranges from 1 to 10 m², depending on the variability in the soil" (Soil Taxonomy). A schematic sketch of a pedon is shown in Fig 8.1.

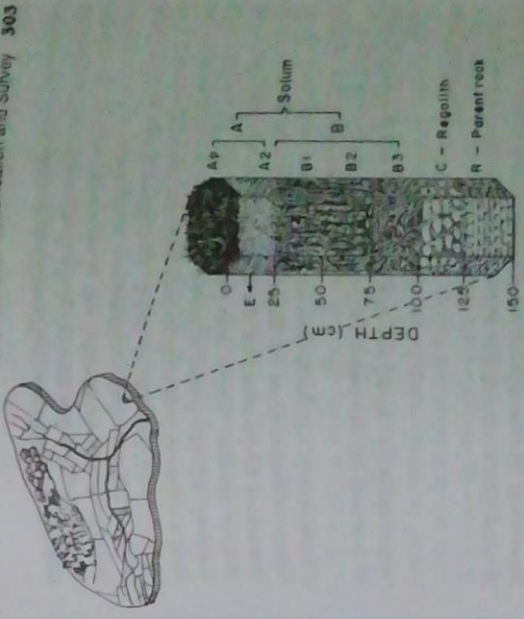


Fig. 8.1 A typical pedon (Courtesy Dr. R.L. Karale)

Thus, the concept of pedon includes the vertical and lateral extent of soil, whereas that of a profile does for the vertical extent only. A group of similar pedons that are bounded on all sides by 'non-soil' or by pedons of unlike character is called a *polypedon*.

The profile characteristics studied in the field consist of locating the soil horizons, based on colour differences. Where vertical colour differentiation is not possible, horizons are differentiated on the basis of variations in other soil characteristics. Each of these horizons is then described in terms of thickness, colour (Munsell notations), texture, structure, consistency, pH, carbonate, clay film, roots, krotovinas, pores, wetness, presence of mottlings and concretions, artefacts, etc. Besides genetic soil horizons, many soils may have layers of soil inherited from parent material or deposition of soil from other source. The external soil characteristics studied are form, linearity, and percent gradient of slope, erosion, drainage condition, and ground

✓ **Sub-topic:** Classification of soil; Soil architecture

SOIL CLASSIFICATION

Soils are one of the greatest basic natural resources of any nation. Soils are very much diverse so it is necessary to classify them in a systematic and orderly arrangement. The details and exactness of soil classification depend upon the extent of knowledge about the soils. Thus, soil classification is dynamic in nature and keeps on changing and adjusting as knowledge and understanding of the soil increases.

A. Old Classification

Geological Approach. The earliest was the geographical system according to which the soils were divided into groups depending upon the geological materials or rocks from which the soil was derived. According to this system, soils were divided into two main groups : (1) sedentary and (2) transported. The classification was further improved and soils were grouped into red soils, black soils (regurs), laterite and lateritic soils, delta soils, desert and tarai soils.

B. Modern Classification System

1. Physical Classification. According to this system, soil is divided into a number of groups or classes such as sand, clay, loam etc. It takes into account the mechanical composition of the upper 6 or 7 inch layer of soil only. This system is good enough for agricultural purposes but does not meet the requirements of soil science. As it does not take into consideration it has very limited use.

2. Genetical Classification. The basis of this classification depends on the genesis or origin of the soil and its subsequent development. These classification systems are based upon the study of the soil profile which is the ultimate product and reflection of all the soil-forming factors and processes. The soils are classified into well-defined categories, the higher categories are order, sub-order, great soil group and sub-group. They give a general understanding of the soils over large areas. The lower categories are families, series, types and phases. They are more important in recognising local differences and assessing productive capacities of soil.

At the order level, the soils are classified into zonal, azonal, and intrazonal groups. Zonal soils are more or less mature i.e., well-developed horizon differentiation, colour and structure etc. Zonal soils are developed under the influence of climate and vegetation. Azonal soils are still immature and have not yet developed their profile characteristics. Such soils are found on steep rocky slope, on fresh alluvial deposits. Azonal soils may be found in any climatic region. Intrazonal soils have a distinct profile and their characteristics are more influenced by local conditions of relief (topography) or parent material than by the normal effects of climate and vegetation.

The soils are further sub-divided into great soil group (Table 21.1)

Table 21.1 : Scheme for genetic soil classification

Order	Great soil group
ZONAL	<ol style="list-style-type: none"> 1. Desert soil 2. Grey soil 3. Chestnut soils 4. Chernozem (black) soil 5. Laterite soil 6. Podsols 7. Brown earth 8. Tundra soil
INTRAZONAL	<ol style="list-style-type: none"> 1. Saline and alkaline soil 2. Rendzina soil 3. Bog or Marsh soil
AZONAL	<ol style="list-style-type: none"> 1. Lithosols 2. Regosols (dry sands) 3. Alluvium soil

Marbut proposed a modification and divided zonal soils into two main orders : (1) padalfers, and (2) pedocals. Pedalfers are soils developed in humid regions under conditions of free drainage where calcium and other are leached out. Pedocals are soils where calcium carbonate and other bases accumulate at some depth in soil profile due to restricted drainage (Table 21.2).

TABLE 21.2 : Marbut's system of soil classification

Soil order	Sub-order	Soil group
I. ZONAL SOIL	<ol style="list-style-type: none"> 1. Arctic pedalfers 2. Temperate pealfers 	<ol style="list-style-type: none"> 1. Tundra soil 1. Podsol soils 2. Brown and grey podsol soils
(a) Pedalfers	<ol style="list-style-type: none"> 3. Tropical pedalfers 	<ol style="list-style-type: none"> 1. Yellow and red podsol soils 2. Laterite soils
(b) Pedocals	<ol style="list-style-type: none"> 4. Transition pedalfers 1. Temperate pedocals 2. Tropical pedocals 	<ol style="list-style-type: none"> 1. Degraded chernozem soils 1. Chernozem soils 2. Chestnut soil 1. Brown soils 2. Desert soils
II. INTRAZONAL SOIL	<ol style="list-style-type: none"> 1. Halomorphic 2. Hydromorphic 	<ol style="list-style-type: none"> 1. Saline and alkaline soils 1. Bog or marsh soil 2. Meadow soils
III. AZONAL SOIL	<ol style="list-style-type: none"> 3. Calomorphie Or Calcimorphie 	<ol style="list-style-type: none"> 1. Rendzine soils 2. Brown forest soils 1. Lithosols 2. Regosols (dry sands) 1. Alluvial soils

SOIL CLASSIFICATION-7TH APPROXIMATION

The soil survey staff of the United States Department of Agriculture has proposed a new natural soil classification system called. "Soil classification, A comprehensive system—7th Approximation, 1960."

The 7th approximation lays more stress on the morphology of soils themselves rather than on the environmental factors. The system classifies the soils into several categories as orders, sub-orders, great groups, sub-groups, families, series and phase (type).

Example of the Classification of a Miami Silt Loam Soil

Order	Alfisol
Sub-order	Udalf
Great group	Hapludalf
Sub-group	Typic Haludalf
Family	Fine loamy, mixed
Series	Miami
Phase	Miami, eroded phase

Characteristics of Soil Classification-7th approximation

1. It is a natural classification of soil.
2. The classification is based on properties of the soils.
3. The properties selected should be observable or measurable. Properties which can be measured quantitatively should be preferred.
4. The properties selected should be those that either affect soil genesis or result from soil genesis.
5. The properties with the greater significance to plant growth should be selected for the higher category.
6. The classification system is flexible.

The various soil orders in which world soils have been divided into are given in Table 21.3.

TABLE 21.3 Revised soil orders of 7th Approximation (Baldwin et.al.)

Order	Soil group
1. Entisols	Azonal soils, Alluvial soils, Regosols
2. Vertisols	Grumosols (regurs or black cotton soil in India), black earth Indonesia)
3. Inceptisols	Andosols, Brown forest
4. Aridisols	Desert soils, Reddish Desert, Brown and Reddish-Brown soils.
5. Mollisols	Chestnut, Chernozem, Rendzina, some Brown soils.
6. Spodosols	Podisols, Brown podsollic soils, ground water podisols.
7. Alfisols	Grey-Brown podsollic soils, Non-calcic soils, Grey Wooded soils, Degraded chernozem, some Half-Bog soils.
8. Ultisols	Red yellow podsollic soils. Reddish-Brown Lateritic soils (U.S.A.), some Half-Bog soils.
9. Oxisols	Latosols and Laterite soils
10. Histosols	Organic soils, Bog soils

Note : The soils in italicised letters are the soils found in India.

C. New Classification System—Soil Taxonomy

The comprehensive soil classification, called Soil Taxonomy maintains the natural body concept. This system has two important features (a) the system is based on soil properties that are easily verified, and (b) the unique nomenclature system.

Categories of the System. There are six categories of classification in Soil Taxonomy (i) order (ii) sub-order (iii) great group (iv) sub-group (v) family, and (vi) series. These categories may be compared with those used for the classification of plants.

Comparison of the classification of common cultivated plant, white clover (*Trifolium repens*) and a soil, Miami Series.

Plant classification		Soil classification	
Phylum	Pterophyta	Order	Alfisols
Class	Angiosperme	Sub-order	Udalfs
Suclass	Dicotyledoneae	Great group	Hapludalfs
Order	Rosales	Sub- group	Typical Hapludalfs
Family	Leguminosae	Family	Fine loam., mixed., Miami
Genus	<i>Trifolium</i>	Series	Miami., eroded phase
Species	<i>repens</i>	Phase*	

*Phase is used in field surveying.

(i) **Order.** The order is based on soil forming process. In a given order, soil properties are similar in their genesis. For example, soils that developed under grassland vegetation and are characterised by a thick, dark surface horizon with high metallic cations. Soils with these properties are included in the order, Mollisols. There are following eleven soil orders in soil taxonomy :

Soil Orders and their Major Characteristics

Name	Major characteristics
1. Entisols	Little profile development,, Ochric epipedon common.
2. Inceptisols	Embryonic soils with few diagnostic features, Ochric or umbric epipedon; Cambic horizon.
3. Mollisols	Mollic epipedon,, high base saturation, dark soils, some with argillic or natric horizons.
4. Alfisols	Argillic or natric horizon; high to medium base saturation.
5. Ultisols	Argillic (clay) horizon, low base saturation.
6. Oxisols	Oxic horizon, no argillic horizon, highly weathered.
7. Vertisols	High in swelling clays, deep cracks when soil dry, dark colour.
8. Aridisols	Dry soil, ochric epipedon, sometimes argillic or natric horizon.
9. Spodosols	Spodic horizon commonly with Fe, Al, and humus accumulation, forest.
10. Histosols	Peat or bog; more than 30% organic matter (organic soil).
11. Andisols*	From volcanic ejects, dominated by allophane or Al-humic complexes.

* Recently added as a soil order.

Sub-order. The sub-orders are sub-divisions of orders. The sub-order indicates genetic homogeneity. Climatic environment, vegetation and wetness help in determining the genetic processes. Forty seven sub-orders have been recognised.

Great group. Diagnostic horizons are the primary bases for differentiating the great group in a given sub-order. Nearly 230 great groups are recognised.

Sub-group. The sub-groups are sub-divisions of the great groups. There are more than 1200 sub-groups.

Family. The family is differentiated on the basis of texture, mineralogy, temperature and soil depth. Some 6600 families are recognised.

Series. The series is a sub-division of the family and is the most specific unit of classification. Differentiating characteristics are primarily based on the kind and arrangement of horizons. About 16,800 soils series are recognised.

KEY POINTS

Soils Classification. (1) Geological approach (2) Physical Classification (3) Genetical Classification—(A) Zonal—(i) desert soil (ii) grey (iii) chestnut soils (iv) chernozem soil (v) laterite soil (vi) podsol (vii) brown earth (viii) tundra soil (B) Intrazonal—(i) saline and alkaline soil (ii) rendzine soil (iii) bog or marsh soil (C) Azonal—(i) Lithosols (ii) regosols (dry soils) (iii) alluvium soil.

7th Approximation. The system classifies the soils into several categories as orders, sub-orders, great groups, sub-groups, families, series, and phase (type).

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✓ **Sub-topic: Physical properties of soil:**

Soil texture, Soil water holding capacity, Soil temperature, soil colloids, Soil acidity and alkalinity, Soil salinity and sodicity, Soil organic matter.

2

PHYSICAL PROPERTIES OF SOILS

Physical properties (mechanical behaviour) of a soil greatly influences its use and behaviour towards plant growth. The plant support, root penetration, drainage, aeration, retention of moisture, and plant nutrients are linked with the physical conditions of the soil. Physical properties also influence the chemical and biological behaviour of all soils.

The physical properties of a soil depend on the amount, size, shape, arrangement and mineral composition of its particles. The physical properties also depend on organic matter content and pore spaces. Following are the important physical properties of soils :

1. Soil texture
2. Soil structure
3. Soil density
4. Soil porosity
5. Soil consistence
6. Soil colour
7. Soil temperature.

MECHANICAL ANALYSIS

The mineral component constitutes the soil mass. The mineral portion consists of particles of various sizes. According to the size, the soil particles are grouped into gravels, sands, silts and clays which are termed as *soil separates*. The process of determining the amounts of individual soil separates below 2 mm in diameter is called a *mechanical analysis*.

To make a mechanical analysis, a sample of soil is broken up. This is usually done by crushing the soil lightly in a wooden mortar. The material is next passed through a 2 mm sieve to separate stone and gravel. The soil passing through the sieve is taken for mechanical analysis. The organic matter and other binding materials are also removed from the soil before the mechanical separation.

There are several methods of mechanical analysis viz., Sieve method, Sedimentation method, Decantation method, Centrifugal method, Pipette method, Hydrometer method etc. Pipette and sedimentation methods are universally employed for carrying out mechanical analysis of soil.

Significance of mechanical analysis. Stone and gravel which remain on the 2 mm sieve when the sample is prepared for mechanical analysis are not of much significance unless they are present in large quantities exceeding 10 per cent. When present to this extent, there is an advantage. They facilitate drainage and tillage. When present in quantities larger than this, they make the soil too open and loose. This makes the soil susceptible to over drainage. Being pieces of unweathered rock and minerals they reduce the quantities of available plant ingredients in a soil.

Mechanical analysis helps in deciding the textural classes name—that is, sand, sandy loam, loam, sandy clay loam, sandy clay etc.

Soil separates viz., sand, silt and clay play a important role in the determination of physical properties of soil and cultivation (See role of texture).

SOIL TEXTURE

Definition of Soil Texture

1. Soil texture refers to the relative proportion of particles of various size in a given soil.
2. Soil texture refers to the relative percentage of sand, silt and clay in a soil.

Classification of Soil Separates

There are a number of systems of naming soil separates. They are : (a) The American system developed by U.S.D.A., (b) The English system, and (c) The International system. The international system which is commonly followed in India is given in the Table 2.1

TABLE 2.1 : International system of naming soil separates

Soil Separate	Diameter range (mm)
1. Coarse sand	2.00-0.20
2. Fine sand	0.20-0.02
3. Silt	0.02-0.002
4. Clay	Below 0.002

Characteristics of Soil Separates

(i) **Physical nature of soil separates.** Sands are large-sized particles and have the large size of the pore spaces. Hence, they facilitate percolation and encourage aeration. Their water-holding capacity is low. They do not possess plasticity.

Clay particles are smallest in size and possess fine pore spaces. With decreasing particle size, there is decrease in aeration and percolation rate. The water-holding capacity of clay is very high. Properties such as plasticity, swelling, cohesion etc., are very high.

Silt particles are intermediate in size. Silts also show properties somewhat intermediary between sands and clays.

(ii) **Mineralogical characteristics.** Quartz commonly dominates the finer grades of sand as well as the silt separate. In addition, variable quantities of other primary minerals usually occur, such as feldspars and micas. Hematite and limonite minerals

may be present. These impart various shades of red and yellow if present in sufficient quantity.

Coarse clay fractions are composed of minerals such as quartz and the hydrous oxides of iron (hematite and limonite) and aluminium. Another is the complex aluminosilicates. Three main mineral types—*Kaolinite*, *illite* and *montmorillonite*—are at present recognised.

(iii) **Chemical makeup.** Since sand and silt are dominantly quartz (SiO_2), these two fractions are generally inactive chemically. On the other hand, clay particles are very active. Clays consist principally of secondary products of weathering. Chemically, *Kaolinite* and *montmorillonite* are aluminium silicates. They also carry in addition sodium, iron, magnesium.

TABLE 2.2 : Comparative characteristics of sand, silt and clay

Sl No.	Characteristics	Sand	Silt	Clay
1.	Size (mm)	2.0-0.02	0.02-0.002	Below 0.002
2.	Visibility	Visible by naked eyes	Visible by microscope	Visible by ultramicroscope
3.	Water-holding capacity	Low	Medium	High
4.	Total pore space	Least	Medium	Highest
5.	Size of pore	Large	Medium	Very small
6.	Movement of air and water	Very rapid	Moderate	Slow
7.	Plasticity,, swelling,, cohesion etc.	Very low	Moderate	Very high
8.	Feel on rubbing between thumb and fingers	Gritty	Like flour or talcum powder	Feels very plastic and sticky when wet and become hard under dry condition
9.	Tillage	Easy	Moderate	Difficult
10.	Fertility	Very low	Moderate	High
11.	Minerals	Quartz dominates	Feldspar, mica, hematite, limonite, quartz	Kaolinite, montmorillonite and illite
12.	Chemical activity	Chemically inactive	Slightly active	Very active

Textural Classes

According to the proportion of sand, silt and clay, a soil is given a name to indicate its *textural composition*. On this basis, soils are classified into 3 fundamental and broad textural classes : Sands, loams and clay. On the basis of these, additional class names have been devised. There are two main systems of naming soils according to their texture. In U.S. Department of Agricultural Classification System, textural classes are : Sand, loamy sand, sandy loam, loam, silt loam, silt clay loam, sandy clay, silty clay and clay. The classification is from coarse to fine texture (Table 2.3).

TABLE 2.3. : Textural Classes proposed by U.S. Department of Agriculture

Common name	Texture	Basic soil textural class name
Sandy soils	Coarse	Sandy Loamy sands
	Moderately coarse	Sandy loam Fine sandy loam
Loam soils	Medium	Very fine sandy loam Loam
		Silt loam Silt
	Moderately fine	Clay loam Sandy Clay loam Silty Clay loam
Clayey soils	Fine	Sandy Clay Silty Clay Clay

In the American system as developed by the U.S. Bureau of Soils, ten textural classes are proposed. Textural classes based on the relative percentage of sand, silt and clay in a soil are given in Table 2.4.

TABLE 2.4 : Textural Classes proposed by U.S. Bureau of Soils

Textural group	Sand %	Silt %	Clay %
1. Sand	80-100	0-20	0-20
2. Sandy loam	50-80	0-50	0-20
3. Loam	30-50	30-50	0-20
4. Silt loam	0-50	50-100	0-20
5. Sandy Clay loam	50-80	0-30	20-30
6. Silty Clay loam	0-30	50-80	20-30
7. Clay loam	20-50	20-50	20-30
8. Sandy Clay	50-70	0-20	30-50
9. Silty Clay	0-20	50-70	30-50
10. Clay	0-50	0-50	30-100

Determination of Textural Class

In the field, texture is commonly determined by 'feel' method. The soil is rubbed between thumb and fingers, preferably in the wet condition—sand feels gritty and its particles can be easily seen with the naked eye. The silt when dry feels like flour or talcum powder and is slightly plastic when wet. Clayey material feels very plastic and exhibit stickiness when wet and are hard under dry conditions. A more accurate and fundamental method is 'laboratory' method which is based on mechanical analysis.

The texture of a soil horizon is an almost permanent character. The size of particles in mineral soil is not subject to readily change. Thus, a sandy soil remains sandy and a

clay soil remain a clay. Texture cannot be altered and thus is considered as basic property of a soil.

SOIL STRUCTURE

Definition of Soil Structure

The arrangement of soil particles and their aggregate into certain defined patterns is called structure.

The primary soil particles—sand, silt and clay—usually occur grouped together in the form of aggregates. Natural aggregates are called *peds*, whereas *clod* is an artificially formed soil mass. Structure is studied in the field under natural conditions and it is described under three categories :

1. Type—Shape or form and arrangement pattern of peds.
2. Class—Size of peds.
3. Grade—Degree of distinctness of peds.

Types of Structure

There are four principal forms of soil structure :

(a) **Plate-like.** In this structural type of aggregates are arranged in relatively thin horizontal plates. The horizontal dimensions are much more developed than the vertical. When the units are thick, they are called platy, and when thin, laminar (Fig. 2.1).

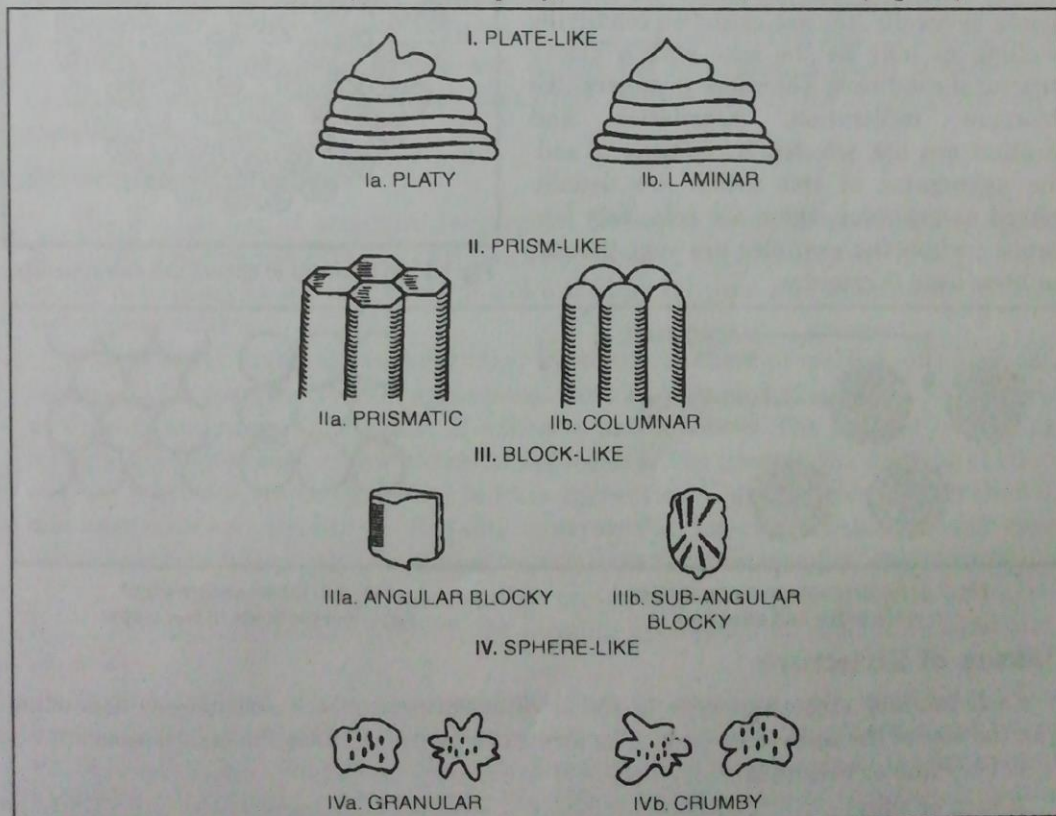


Fig. 2.1 Types of soil structure.

4

SOIL WATER

Water contained in soil is called soil moisture. The water is held within the soil pores. Soil water is the major component of the soil in relation to the plant growth. If the moisture content of a soil is optimum for plant growth, plants can readily absorb the soil water. Not all the water, soils can hold is available to plants. Much of water remains in the soil as thin film. Soil water dissolves salts and makes up the soil solution, which is important as medium for supplying nutrients to growing plants.

RETENTION OF WATER BY SOIL

The soils hold water (moisture) due to their colloidal properties and aggregation qualities. The water is held on the surface of the colloidal and other particles and in the pores. The force responsible for retention of water in the soil after the drainage has stopped are due to surface tension and surface attraction and are called *surface moisture tension*. This refers to the energy concept in moisture retention relationships. The force with which water is held is also termed as *suction*. The water is retained in the soil in following ways :

1. Cohesion and Adhesion Forces. These two basic forces are responsible for water retention in the soil. One is the attraction of molecules for each other *i.e.*, cohesion. The other is the attraction of water molecules for the solid surface of soil *i.e.*, adhesion. By adhesion, solids (soil) hold water molecules rigidly at their soil—water interfaces. These are molecules in turn hold by cohesion. Together, these forces make it possible for the soil solids to retain water.

2. Surface Tension. The phenomena is commonly evidenced at water—air interfaces. Water behaves as if its surface is covered with a stretched elastic membrane. At the surface, the attraction of the air for the water molecules is much less than that of water molecules for each other. Consequently, there is a net downward force on the surface molecules, resulting in sort of a compressed film (membrane) at the surface. This phenomena is called surface tension.

3. Polarity or Dipole Character. The retention of water molecules on the surface of clay micelle is based on the dipole character of the molecule of water. The water molecules are held by electrostatic forces that exist on the surface of colloidal particles. By virtue of their dipole character and under the influence of electrostatic forces, the molecules of water get oriented (arranged) on the surface of the clay particles in a particular manner. Each water molecule carries both negative and positive charges. The hydrogen end of a water molecule is positive while oxygen end is negative. The clay particle is negatively charged. The positive end of water molecule gets attached to the

negatively charged surface of clay and leaving its negative end outward. The water molecules attached to the clay surface in this way present a layer of negative charges to which another layer of oriented water molecules is attached (Fig. 4.1). The number of successive molecular layers goes on increasing as long as the water molecules orientate. As the molecular layer gets thicker orientation becomes weaker, and at a certain distance from the particle surface the water molecules cease to orientate and capillary water (liquid water) begins to appear.

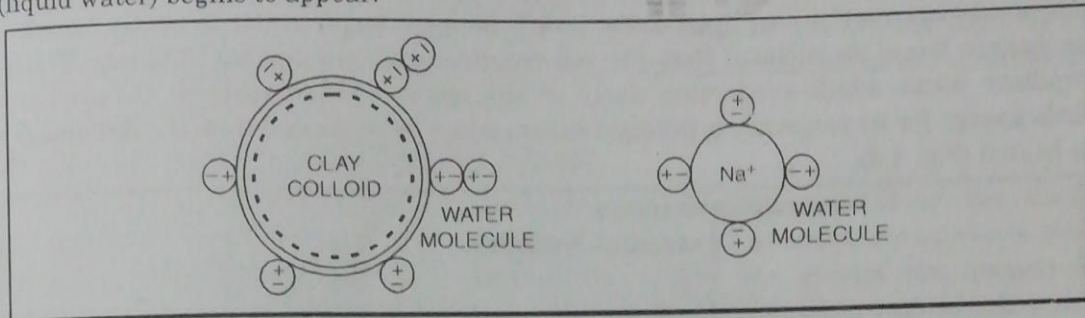


Fig. 4.1. Orientation of water molecules on the surface of clay micelle and cation.

Due to the forces of adsorption (attraction) exerted by the surface of soil particles, water gets attached on the soil surface. The force of gravity also acts simultaneously, which tries to pull it downwards. The surface force is far greater than the force of gravity so water may remain attached to the soil particle. The water may remain attached to the soil particle or move downwards into the lower layers, depending on the magnitude of the resultant force.

Depending upon the physical forces and the mode of retention, soil water may be divided into 3 categories *viz.*, (1) gravitational water, (2) capillary water, and (3) hygroscopic water.

PHYSICAL CLASSIFICATION OF SOIL WATER

From a physical point of view the terms gravitational, capillary and hygroscopic waters are identified. The forms of soil moisture are :

1. Gravitational water. Gravitational water occupies the larger soil pores (macro pores) and moves down readily under the force of gravity. Water in excess of the field capacity is termed gravitational water. Gravitational water is of no use to plants because it occupies the larger pores. It reduces aeration in the soil. Thus, its removal from soil is a requisite for optimum plant growth.

2. Capillary water. Capillary water is held in the capillary pores (micropores). Capillary water is retained on the soil particles by surface forces (Fig. 4.2). It is held so strongly that gravity cannot separate it from the soil particles. The molecules of capillary water are free and mobile and are present in a liquid state. Due to this reason it evaporates easily at ordinary temperature.

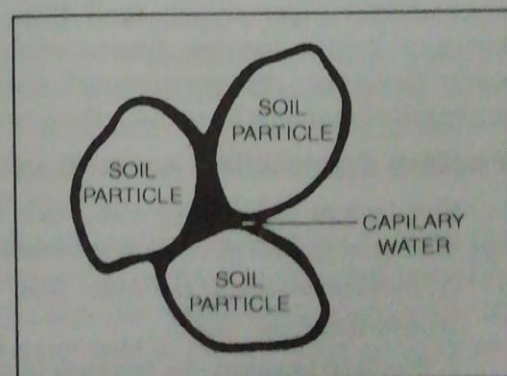


Fig. 4.2. Capillary water held by soil particles.

Though, it is held firmly by the soil particle, plant roots are able to absorb it. Capillary water is, therefore, known as available water.

3. Hygroscopic water. The water held tightly on the surface of soil colloidal particles is known as hygroscopic water. It is essentially non-liquid and moves primarily in the vapour form. Hygroscopic water held so tenaciously by soil particles that plants cannot absorb it. Some microorganism may utilise hygroscopic water. As hygroscopic water is held tenaciously by soil particles that plants cannot absorb it. Some microorganism may utilise hygroscopic water. As hygroscopic water is held tenaciously by surface forces its removal from the soil requires a certain amount of energy. Unlike capillary water which evaporates easily at atmospheric temperature (it requires very little energy for its removal), hygroscopic water cannot be separated from the soil unless it is heated (Fig. 4.3).

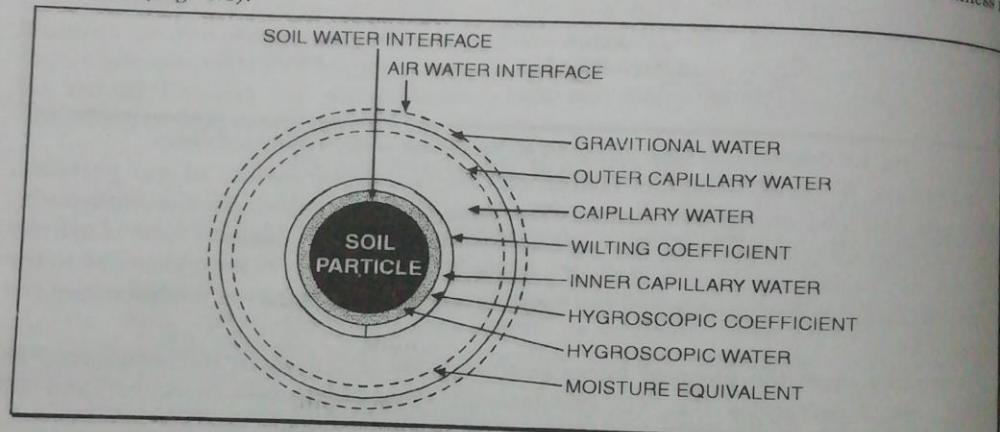


Fig. 4.3. Different forms of soil water.

Factors Affecting Gravitational Water

1. *Texture* plays a great part in controlling the rate of movement of gravitational water. The flow of water is proportional to the size of particles. The bigger the particle, the more rapid is the flow or movement. Because of the larger size of pore (tube), water percolates more easily and rapidly in sandy soils than in clayey soils.

2. *Structure* also affects gravitational water. In platy structure movement of gravitational water is slow and water stagnates in the soil. Granular and crumbly structure help to improve gravitational water movement. In clayey soils having single-grain structure, the gravitational water percolates more slowly. If clay soils form aggregates (granular structure), the movement of gravitational water improves.

Factors Controlling Amount of Capillary Water

The amount of capillary water that a soil is able to hold varies considerably. There are four main factors that are responsible for variation in the amount of capillary water:

- | | |
|--|---------------------|
| (1) Surface tension of the water film, | (2) Soil texture, |
| (3) Soil structure, and | (4) Organic matter. |

1. **Surface tension.** An increase in surface tension increases the amount of capillary water.

2. **Soil texture.** The finer the texture of a soil the greater the amount of capillary water it holds. This is mainly due to the greater surface area and a greater number of micro pore spaces.

3. **Soil structure.** Platy structure contains more water than granular structure.

4. **Organic matter.** The presence of organic matter helps to increase the capillary capacity of a soil. Organic matter itself has a great capillary capacity. Undecomposed organic matter is generally porous having a large surface area which helps to hold more capillary water. The humus that is formed on decomposition has a great capacity for absorbing and holding water. Hence, the presence of organic matter in soil controls the amount of capillary water.

Factors Affecting Hygroscopic Water

Hygroscopic water is held on the surface of colloidal particles by the dipole orientation of water molecules. The amount of hygroscopic water varies inversely with the size of the soil particles. The smaller the particle the greater the amount of hygroscopic water it adsorbs. Fine texture soils like clay contain more hygroscopic water than coarse texture soils.

Not only the amount of clay but also its nature influences the amount of hygroscopic water. Clay minerals of the montmorillonite type with their large surface area adsorb more water than those of the kaolinite type, while illite minerals are intermediate.

SOIL-MOISTURE RELATIONSHIPS UNDER FIELD CONDITION

Earlier classification divided soil water into gravitational, capillary and hygroscopic water. The hygroscopic and capillary waters are in equilibrium with the soil under given condition. The *hygroscopic coefficient* and the maximum capillary capacity are the two equilibrium points when the soil contains the maximum amount of hygroscopic and capillary waters respectively. The amount of water that a soil contains at each of these equilibrium points is known as a soil moisture constant. The soil moisture constants, therefore, represent definite soil moisture relationships and retention of soil moisture in the field.

The three classes of water (gravitational, capillary and hygroscopic) are, however, very broad and do not represent accurately the soil-water relationship that exists under field conditions. Though the *maximum capillary capacity* represents the maximum amount of capillary water that a soil holds, the whole of capillary water is not available for the use of the plants. A part of it, at its lower limit approaching the hygroscopic coefficient, is not utilised by the plants. Similarly a part of the capillary water at its upper limit is also not available for the use of plants. Hence, two more soil constants, viz., *field capacity* and *wilting coefficient*, have been introduced to express the soil-plant-water relationships as it is found to exist under field conditions (Fig. 4.4).

1. **Field capacity.** Assume that water is applied to the surface of a soil. With the downward movement of water all macro and micro pores are filled up. The soil is said to be saturated with respect to water and is at *maximum water-holding capacity* or *maximum retentive capacity*. It is the amount of water held in the soil when all pores are filled.

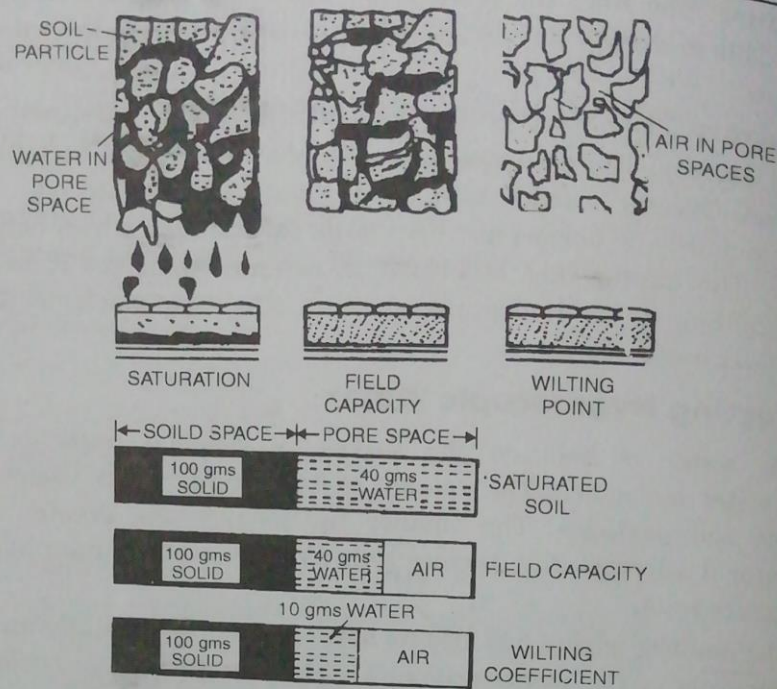


Fig. 4.4. Solid-water-air relationships.

Sometime, after application of water in the soil all the gravitational water has drained away, then the wet soil is almost uniformly moist. The amount of water held by the soil at this stage is known as the *field capacity* or *normal moisture capacity* of that soil. It is the capacity of the soil to retain water against the downward pull of the force of gravity. At this stage only micro pores or capillary pores are filled with water and plants absorb water for their use. At field capacity water is held with a force of 1/3 atmosphere. Water at field capacity is readily available to plants and microorganism (Fig. 4.5.).

2. Wilting coefficient. As the moisture contents falls, a point is reached when the water is so firmly held by the soil particles that plant roots are unable to draw water. The plant begins to wilt. At this stage even if the plant is kept in a saturated atmosphere it does not regain turgidity and wilts unless water is

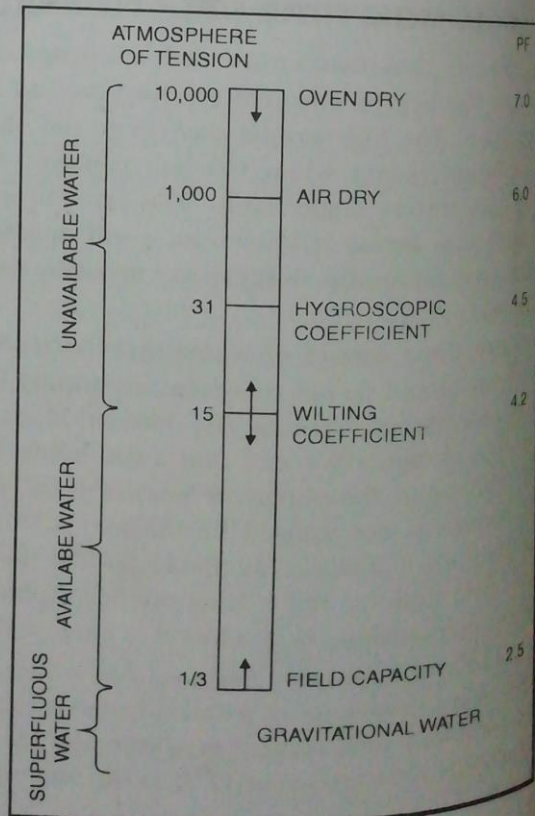


Fig. 4.5: The soil moisture constants

applied to the soil. This stage at which this occurs is termed the *Wilting Point* and the percentage amount of water held by the soil at this stage is known as the *Wilting coefficient*. It represents the point at which the soil is unable to supply water to the plant. Water at wilting coefficient is held with a force of 15 atmosphere.

Between the wilting percentage (15 atmosphere) and the field capacity (1/3 atmosphere), the water is available to plants.

3. Hygroscopic coefficient. The hygroscopic coefficient is the maximum amount of hygroscopic water absorbed by 100 gm of dry soil under standard conditions of humidity (50% relative humidity) and temperature (25°C). The tension is equal to a force of 31 atmospheres. Water at this tension is not available to plant but may be available to certain bacteria.

BIOLOGICAL CLASSIFICATION OF SOIL WATER

There is a definite relationship between moisture retention and its utilisation by plants. This classification is based on the availability of water to the plant. Soil moisture can be divided into three parts ;

1. Available water. The available water is that water which lies between wilting coefficient and field capacity. It is obtained by subtracting wilting coefficient from moisture equivalent (Fig. 4.5).

2. Unavailable water. The unavailable water includes the whole of the hygroscopic water plus a part of the capillary water below the wilting point.

3. Super-available or Superfluous water. The water beyond the field capacity stage is said to be super-available. It includes gravitational water plus a part of the capillary water removed from large interstices. This water is unavailable for the use of plants. The presence of super-available water in a soil for any extended period is harmful to plant growth because of the lack of air.

While the various terms employed to describe soil water physically and biologically are useful in a practical way, but they are semi-quantitative. For example, measurement of field capacity tends to be arbitrary. Measurement of field capacity is affected by initial soil moisture before wetting the soil, removal by plants and surface evaporation etc. These facts stress that there is no clear line of demarcation between different "forms" of soil water.

SOIL WATER POTENTIAL

The retention and movement of water in soils, its uptake and translocation in plants and its loss to the atmosphere are all energy-related phenomena. The more strongly water is held in the soil, the greater is the heat (energy) required. In other words, if water is to be removed from a moist soil, work has to be done against adsorptive forces. Conversely, when water is adsorbed by the soil, a negative amount of work is done. The movement is from a zone where the free energy of water is high (standing water table) to one where the free energy is low (a dry soil). This is called *soil water energy concept*. Free energy of soil water is affected by (i) Matric (solid) force i.e., the attraction of the soil solids for water (adsorption)— which markedly reduces the free energy (movement) of the adsorbed water molecules. (ii) Osmotic force i.e., the attraction of ions and other solutes to reduce the free energy of soil solution. Matric and Osmotic potentials are negative and reduce the free energy level of the soil water. These negative potentials are

Hard : breaks with difficulty under pressure

Very hard : very resistant to pressure : cannot be broken between thumb and forefinger

Extremely hard : extreme resistance to pressure; cannot be broken in the hand.

SOIL COLOUR

The colour of soil varies widely. It is an easily observable characteristic and is an important criterion in description and classification of soils.

Colour of a soil is inherited from its parent rock material (termed as *lithochromic*); for example, red soils developed from red sand stone. Often the soil colour is a result of soil forming process and is termed as *acquired* or *pedochromic*

Soil Colour and Composition

(a) **Black and dark grey colour.** The variations from black to dark grey colour of soil are mainly due to organic matter.

(b) **Brown colour.** This is the most common soil colour and is due to a mixture of the organic matter and iron oxides.

(c) **Red-yellow colour.** Red colour is associated with unhydrated ferric oxides, whereas yellow colour indicates some degree of hydration (Table 2.10).

TABLE 2.10 : Variation in Ferric Oxide Colour with Degree of Hydration

Haematite	$\text{Fe}_2 \text{O}_3$	Red
Turgite	$2\text{Fe}_2 \text{O}_3 \cdot \text{H}_2 \text{O}$	Red or Reddish-brown
Goethite	$\text{Fe}_2 \text{O}_3 \cdot \text{H}_2 \text{O}$	Yellowish—brown
Limonite	$2\text{Fe}_2 \text{O}_3 \cdot 3 \text{H}_2 \text{O}$	Yellow,, Brown
Xanthosiderite	$\text{Fe}_2 \text{O}_3 \cdot 2 \text{H}_2 \text{O}$	Yellow
Limnrite	$\text{Fe}_2 \text{O}_3 \cdot 3 \text{H}_2 \text{O}$	Yellow

(d) **White colour.** Silica and lime generally impart white colour.

(e) **Bluish and greenish colour.** Some of the bluish and greenish colours are due to the presence of ferrous compounds. This reducing condition occur in ill-drained soil.

(f) **Mottling colour.** Colour variegation or mottling in soils indicates alternating oxidising and reducing conditions due to a fluctuating water table.

SOIL TEMPERATURE

Sources of Soil Heat

1. **Solar Radiation.** The main source of soil heat is the energy of sun's rays (radiant energy) that reach the earth after they pass through the atmosphere. The exposure of the earth to the heat of the sun warms the surface of the soil on which the rays fall.

2. **Conduction.** The interior of the earth is very hot, the conduction of this heat to the soil is very slow. Generally, during night, the surface soil becomes cooler than sub-surface soil (sub-soil). Thus, heat flows from sub-soil (warmer layers) to soil (cooler layers).

3. **Biological and chemical reaction.** Some amount of heat is liberated in the chemical and biological process.

4. **Rain.** The occurrence of warm rain during the winter months may raise the temperature of the soil.

Loss of Soil Heat

1. **Radiation.** The quantity of heat so absorbed by the soil does not remain constant. A part is lost to the air by radiation.

2. **Conduction.** Some heat is transmitted to lower layers of soil by conduction.

3. **Evaporation.** In the process of evaporation of soil water, a large amount of heat is used. This results in a cooling effect especially at the surface.

4. **Rain.** During summer months, generally rain has a cooling action in soil, because rain will usually have a lower temperature than soil.

Factors affecting Soil Temperature

1. **Soil texture.** Sandy soils, in general, warm up quicker than clayey or fine-grained soils. A fine-grained soil carries a large amount of water they are for this reason also slow to warm. Soil moisture is the most vital controlling factor in soil temperature. *Specific heat* is the amount of heat required to raise the temperature of one gram of a substance by 1°C. The specific heat of dry soil is less than moist soil. Hence, moist soils are cooler than dry soils.

2. **Soil structure.** Soil structure also affects soil temperature by controlling the pore space. Soils having good structure (granular or crumby) warm up more rapidly because there is no water-logging.

3. **Soil composition.** The soil is composed partly of mineral matter and partly organic. The specific heat of mineral substances is less than that of organic materials (specific heat of iron is 0.11) whereas of humus is 0.44). Hence, mineral soils get heated more readily than organic soils.

4. **Soil colour.** Dark-coloured soils usually warm up more readily than light-coloured soils. As they possess a greater capacity for absorbing the sun's heat.

5. **Soil moisture.** Specific heat of water is higher than soil. Moist soils have a higher specific heat than dry soils. Consequently, a moist soil has lower temperature than dry soil. The evaporation of water rather helps to lower the temperature of a moist soil. Moist soil gets heated more slowly.

6. **Slope of the land.** The topography of the land, more particularly the ground slope, also affects the temperature of the soil.

7. **Vegetative cover.** Soils that are covered with vegetation absorb less heat than those that are bare. Vegetation acts as an interceptor and retards the warming of the soil surface.

On the other hand, plant cover prevents the soil from getting cool as it retards the loss of heat. Hence, soils carrying a dense plant cover are cooler in summer and warmer in winter than unprotected soils. Bare soils cool off more rapidly than those covered with vegetation.

8. **Climate.** Climate has a great effect on soil temperature. Soils in temperate (cool) regions are cooler than those in tropical (warm) regions.

9. **Season.** Soil temperature varies with different seasons of the year. It will be noticed that there is a close similarity between the variation in soil temperature, more

especially of the surface soil and the variations in air temperature. During the cold months of December and January when the air temperatures are low, the soil temperatures are also low. The temperature of the surface soil is always higher than the air temperature.

Control of Soil Temperature

Regulation of soil temperature is possible upto some extent, under field conditions. The control of the amount of water in soil helps to regulate its temperature. Water-logged soil has a low temperature. The only way to *increase* the temperature of such soils is to remove excess water by providing suitable *drainage*. The removal of excess water lowers its specific heat and thus, increases the temperature. The increase in the air content of the soil also helps to increase the soil temperature by lowering the specific heat. The temperature of surface soil can be modified by altering its *colour*. A black substance like charcoal powder when spread on the surface of the soil increases its temperature as it allows less reflection and hence, a greater absorption of heat. Soil temperature can also be regulated by applying straw *mulch*. During the day time, mulch keeps the surface soil cooler by intercepting sun rays. At night however, it keeps the soil warmer by cutting off the outgoing radiation.

On the other hand, *vegetative cover* and mulch keep the soil temperature low. The shade helps in protecting young seedlings and shallow-rooted crops such as tea, coffee and tobacco etc., from the intense heat during summer. Use of *irrigation* water also lowers the soil temperature and protect the crop from dry spells. The temperature of surface soil can also be lowered by altering its *colour*. Spreading a thin layer of a white substance like chalk lowers the temperature by reflecting much of the incoming radiant energy.

ROLE OF PHYSICAL PROPERTIES IN SOIL FERTILITY

Importance of Physical Properties

Physical properties of a soil have great influence on fertility of soil, plant growth and productivity.

1. Role of Texture. Texture has good effect on management and productivity of soil. Sandy soils are of open character, usually loose and friable. Such type of the texture is easy to handle in tillage operations. Sand facilitates drainage and aeration. It allows rapid evaporation and percolation. Sandy soils have very little water-holding capacity. Such soils cannot stand drought and are unsuitable for dry farming. In sandy soil, few crops can be grown such as potato, groundnut and cucumbers.

Clay particles play a very important role in soil fertility. Clayey soils are difficult to till and require much skill in handling. When moist clayey soils are exceedingly sticky and when dry, become very hard and difficult to break. They have fine pores, and they are poor in drainage and aeration. They have a high water-holding capacity and poor percolation which usually results in water-logging. They are generally very fertile soils. In respect of plant nutrients content. Rice, jute, sugarcane can be grown in this soil very successfully.

Silt is a very valuable constituent of the soil. Good loamy soils contain about 30 to 50 per cent silt. An ideal loam may be defined as a mixture of sand, silt and clay particles which exhibits light and heavy properties in about equal proportions. In drainage, absorption of water, water-holding capacity they are intermediate between sandy soils

5

SOIL COLLOIDS

The colloidal state refers to a two-phase system in which one material in a very finely divided state is dispersed through second. Examples are :

Solid in liquid—Clay in water (dispersion of clay in water).

Liquid in gas—Fog or clouds in atmosphere.

The clay fraction of the soil contains particles less than 0.002 mm in size. Particles less than 0.001 mm size possess colloidal properties and are known as *soil colloids*.

NATURE OF COLLOIDS

Soil colloids are two kinds : (1) Inorganic (minerals) and (2) Organic (humus). The two together form the colloidal complex of the soil. In almost all soils the inorganic colloidal form a major portion of the colloidal complex. On the other hand, in peat soils, it consists almost entirely of organic colloids. Colloidal particles float in a medium and do not tend to settle. Some large colloidal particles may settle very slowly. Colloids are referred as the dispersed systems. The substance in solution is termed as the dispersed phase while the medium in which the particles are dispersed is called the dispersion medium. The commonest colloids are those containing minute solid or liquid particles suspended in liquid or gas medium. Soils formed in tropical and semi-tropical regions the whole of the colloidal complex consists almost entirely of inorganic colloids. Whereas soil formed in temperate regions usually contain more organic colloids than those formed in tropical and sub-tropical regions. In a broad way, two groups of clay are recognised—*silicate clay as characteristic of temperate regions, and the iron and aluminium hydrous oxide clays found in tropical and semi-tropicals.*

CHEMICAL COMPOSITION AND STRUCTURE OF COLLOIDS

The constitution of colloids are inorganic and organic :

(I) **Inorganic Colloids.** The chemical analysis of clay indicates the presence of four main constituents : silica, alumina, iron and combined water. These make up from 90 to 98 per cent of the colloidal clay. The colloidal matter of soil contains a higher proportion of important plant nutrients such as Mg^{++} , Ca^{++} and K^+ /

The shape of the individual particles is plate or flake-like (Fig. 5.1). Clay colloids are

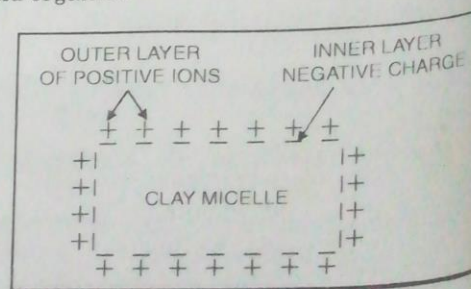


Fig. 5.1 Diagrammatic representation of colloidal clay crystals.

negatively charged (anions) and therefore attract a large number of positively charged ions (cations). The minute clay colloids particles, referred as *micelles* (micro cells), ordinarily carry negative charges.

Structure (constitution) of colloidal clay minerals are of two type :

(a) (The *two-layer types* (1:1 type) consists of one layer of silicon and oxygen atoms (SiO_2) and other layer of aluminium and oxygen atoms (Al_2O_3), all in definite arrangement. Example : Kaolinite clay (Fig. 5.2). In this type of structure, there is non-expanding space between the sheets for the activity, thus, cation exchange capacity is low in kaolinite clay (Table 5.1))

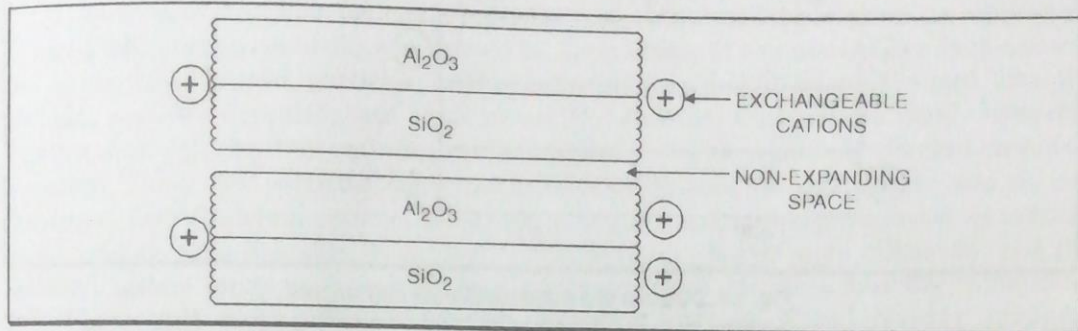


Fig. 5.2. Diagram of Kaolinite clay crystal.

(b) *Three-layer (2 : 1 type) clay* crystal have two outside layers made of silicon and oxygen (SiO_2) and the middle layer of aluminium and oxygen (Al_2O_3). *Montmorillonite* (Fig. 5.3) is the best known example of this type. In this type, there is expanding space between the sheets. The cation exchange capacity is therefore greater in montmorillonite than kaolinite. The plasticity of montmorillonite is also higher because water can enter between the sheets.)

In three-layer type, there is another group called hydrous mica. Illite is the most important example of this group. Illite has similar structure as montmorillonite (2 : 1 latic structure). The structure is non-expanding type. Illite is in between Kaolinite and montmorillonite type with regards to soil properties (Table 5.1).

(c) *Chlorites (2 : 1 : 1 types minerals)*. The typical crystal unit is composed of one 2 : 1 unit (like mica or montmorillonite), and one octahedral unit. brucite layer. Magnesium dominates the octahedral sheet in the 2:1 units.

Chlorites are basically iron-magnesium silicates with some aluminium present. In a typical chlorite clay crystal, 2:1-type layers, alternate with a magnesium-dominated trioctahedral sheet, giving a 2:1:1 ratio (Figure 5.3). This mineral is sometimes called 2-2 type mineral.

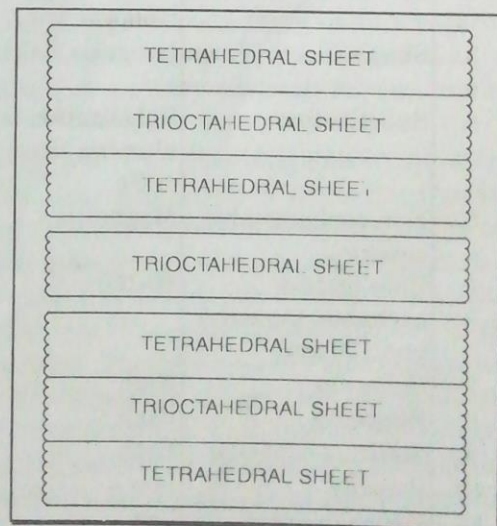


Fig. 5.3 Diagram of a chlorite

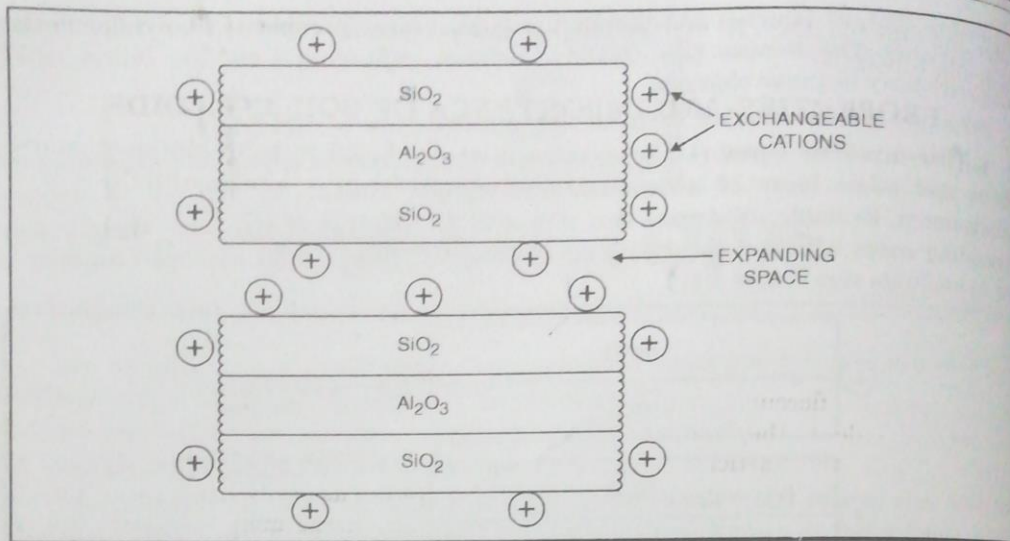


Fig. 5.4. Diagram of a montmorillonite clay crystal.

TABLE 5.1 : Properties of different types of clay minerals

Sl. No.	Property	Montmorillonite	Illite	Kaolinite
1.	Structure	2:1 lattice (expanding type)	2:1 lattice (non-expanding type)	1:1 lattice (non-expanding type)
2.	Size (micron)	0.01-1.0 (fine particle)	0.1-2.0 (medium particle)	0.1-5.0 (coarse particle)
3.	Shape	Irregular flakes	Irregular flakes	Hexagonal crystals
4.	Substitution	Substitution in alumina sheet by Mg or Fe	Substitution in silica layer by aluminium	No substitution
5.	Non-exchangeable cations	Magnesium	Potassium	None
6.	Base (cation exchange capacity) (me/100 gm)	80-100	15-40	3-15
7.	Cohesion	High	Medium	Low
8.	Plasticity	High	Medium	Low
9.	Swelling capacity	High	Medium	Low
10.	Porosity	Low	Medium	High
11.	Permeability	Low	Medium	High

(II) Organic Colloids. Organic colloids are chiefly due to presence of humus in soil. Humus is the product of decomposition of plant and animal residues. Humus colloids are composed of carbon, hydrogen, oxygen and nitrogen, instead of silicon, aluminium and oxygen, as in clay colloids. Organic soil colloids have higher adsorptive properties for

water and cations (Ca^{++} , K^+ etc.) and higher cation exchange capacity than colloidal clay (inorganic colloids). 7

PROPERTIES AND IMPORTANCE OF SOIL COLLOIDS

1. Brownian movement. Colloidal particles are found to be in continual motion. The oscillation is due to the collision of colloidal particles or molecules with those of the liquid in which they are suspended. This movement is mainly responsible for the coagulation or flocculation of colloidal particles. When the particles in suspension collide with each other and form a loose aggregate of floc.

2. Flocculation. The colloidal particles are coagulated by adding an oppositely charged ion. Formation of flocs is known as flocculation. If the cations are held close to the negatively charged particles, the negative charge would be neutralised and the colloidal particles flocculate and settle down. Na^+ (Sodium Cations) are highly hydrated and are monovalent; they are not so closely bound with the negatively charged immobile particles. Thus, the particles continue to offer resistance to aggregation and do not flocculate. Ca^{++} (Calcium cations) are divalent and are not as easily displaced as sodium. Thus, calcium ions are able to neutralise the negative charge more efficiently and the colloidal system tends to flocculate. In a similar manner, trivalent ions like aluminium (Al^{+++}) are still more efficient in flocculation of colloids. Thus, Na-clay produces deflocculation and Ca-clay encourages aggregation.

The phenomenon of flocculation plays an important part in the cultivation of soils. When clay particles are flocculated, soil develops small clods of a crumbly nature. Such a soil allows free movement of air and water. If the particles are deflocculated, the aggregates get dispersed, the soil gets water-logged, the movement of air and water is impeded.

3. Electrical charge. Colloidal particles often have an electrical charge, some positive and some negative. When clay colloids suspended in water, they carry a negative electric charge. Colloidal clay develops negative electric charge due to dissociation of hydroxyl groups attached to silicon in silica sheets of the clay mineral leaves residual oxygen (O^-) carrying a negative charge.

4. Adsorption. Colloidal particles possess the power of adsorbing gases, liquid and even solids from their suspension. The phenomenon of adsorption is confined to the surface of colloids particles. Larger the surface area (area per unit weight) greater the adsorption for water, nutrients etc. For example, take a cube of 1 cm edge. The surface area exposed by this cube is equal to 6 sq. cm. When this cube is sub-divided into 8 cubes of edges 0.5 cm, the surface area exposed is 12 sq. cm. Thus, the smaller the size of the particle the greater the surface area exposed by them. The adsorption of ions is governed by the type and nature of ion and the type of colloidal particle. In the case of cations, the higher the valence of the ion, the more strongly it is absorbed. Exchange or replacement of cation would be difficult from colloidal particle. That is why divalent ions like calcium and magnesium (Ca^{++} & Mg^{++}) are held more strongly than monovalent ion, sodium and potassium (Na^+ and K^+). Aluminium (Al^{+++}), a trivalent cation, is most easily adsorbed. Hydrogen ions (H^+) behave as polyvalent ions so are adsorbed more strongly than even Ca^{++} . Adsorption of anions (H_2PO_4^- , HPO_4^- etc.) increases with the lowering or increasing of pH. The adsorption of phosphate ions is the lowest when the medium is neutral; it increases when the pH either falls or rises, due to fixation by iron and

aluminium hydroxides in acid range and by calcium in alkaline range. Among the clay minerals, kaolinitic clay has a greater anion adsorbing capacity than montmorillonite or illitic clay.

The property of adsorption plays an important role in soil fertility. Due to this property soil is able to hold water and nutrients and keep them available to plants.

5. **Non-permeability.** Colloids, are unable to pass through a semipermeable membrane. The membrane allows the passage of water and of the dissolved substance through its pores, but retains the colloidal particles.

6. **Cohesion and adhesion.** Unlike sand, clay particles possess the properties of cohesion and adhesion. While forming aggregates, the colloidal clay particles unite with each other by virtue of the property of cohesion. Clay particles envelop sand particles under the force of adhesion. The force of cohesion and adhesion are developed in the presence of water. When colloidal substances are wetted, water first adheres to the particles and then brings about cohesion between two or more adjacent colloidal particles. Soil when dried, the particles remain united because of the force of molecular cohesion. These two forces help in the retention of water in the soil and thus used by plants and microorganisms.

7. **Swelling.** A soil colloid when brought in contact with water they imbibe a certain quantity of water and swell and increase in volume.

8. **Plasticity.** Soil colloidal particles may present in gel condition possess the property of plasticity. Due to this property clay-colloids can be moulded in any shape.

KEY POINTS

Soil Colloids. The colloidal state refers to a two-phase system in which one material in a very finely divided state is dispersed through a second. Example, clay in water (solid in liquid) ; fog in air (liquid in gas) etc. Soil particles less than 0.001 mm size possess colloidal properties and are known as soil colloids.

Nature of Colloids. Soil colloids are of two kinds : (1) inorganic (minerals) and (2) organic (humus). The two together form the colloidal complex of the soil. In mineral soils and soils formed in tropical and semi-tropical regions consists almost of inorganic colloids. On the other hand, a peat soil or soils formed in temperate regions usually contain more organic colloids.

Chemical Composition of Clay (Constitution of mineral colloids). Clay have four main constituents ; silica, alumina, iron and combined water. Clay colloids are negatively charged and therefore attract positively charged ions (cations) like Ca^{++} , Mg^{++} and K^{+}

Structure (Type) of Clay Mineral. (1) *Two-layer type* consists one layer of silicon and oxygen atoms (SiO_2) and the other layer of aluminium and oxygen atoms (Al_2O_3). Example : Kaolinites clay. In this type, cation exchange capacity is low because of non-expanding space between 2-layers. (2) *Three-layer clay type* have two outside layers made of SiO_2 and middle layer of Al_2O_3 e.g., Montmorillonite clay. Due to expanding space between the sheets, cation exchange capacity is greater. In three-layer type, there is another non-expanding group called Illite.

Chlorites (2 : 1 : 1 -type minerals). In a typical chlorite clay crystal, 2:1-types layers alternate with a magnesium dominated trioctahedral sheet, giving a 2:1:1 ratio.

Properties and Importance of Soil Colloids. (1) Brownian movement (2) Flocculation (3) Electrical charge (4) Adsorption (5) Non-permeability (6) cohesion and adhesion (7) Swelling (8) Plasticity.

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8

ACID SOIL

Acid soil is a base unsaturated soil which has got enough of adsorbed exchangeable hydrogen ions (H⁺) so that to give soil a pH of lower than 7.0.

Soil acidity is common in all regions where precipitation is high enough to leach appreciable quantities of exchangeable base-forming cations (calcium, magnesium etc.) from the soil layers of the soils. The condition is widespread and influence is pronounced on plants.

In acid soils, most of the plant nutrients become unavailable and consequently plant growth is affected.

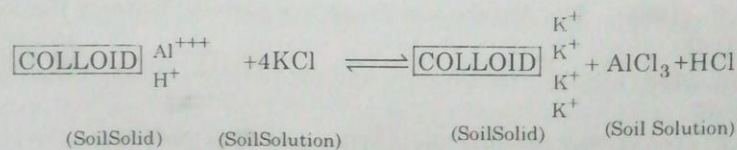
NATURE OF SOIL ACIDITY (CLASSIFICATION OF SOIL ACIDITY)

There are three types of soil acidity according to the presence of ions :

(i) **Active Acidity.** H⁺ ions remain freely present in soil solution and produce limited acidity.

The active acidity is a measure of the H⁺ ion activity in the soil solution at any given time. However, the quantity of H⁺ ions owing to active acidity is very small compared to the quantity in the exchange and residual acidity forms. Even though the concentration of hydrogen ions owing to active acidity is extremely small, it is important because this is environment to which plants and microbes are exposed.

(ii) **Exchangeable acidity.** In very acidic soils, exchangeable hydrogen and aluminium ions are present in large quantities. But the quantity of easily exchangeable hydrogen and aluminium ions are in quite less quantity in moderately acid soils. In this type of acidity higher amount of limestone is required to neutralise the acid soil in comparison to active acidity.

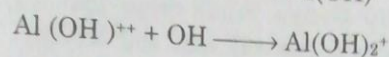
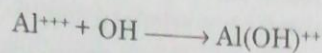


(iii) **Residual acidity.** Residual acidity is that which remains in the soil after active and exchangeable acidity has been neutralised. Residual hydrogen and aluminium atoms that are found in non-exchangeable forms by organic matter and silicate clay. The residual acidity is commonly far greater than either active or exchangeable acidity. The Limestone requirement is very high (1000 to 100,000 times greater than active and exchangeable acidity) to neutralise the residual acidity in the soil.

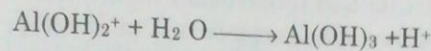
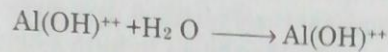
Sources of Hydrogen Ions

Soil acidity is caused by ionisable hydrogen ions. Exchangeable hydrogen ions (which along with other such cations) are present in the soil to neutralise the negative charge arising from isomorphous substitution. They are displaceable by any cation which is added in fairly high concentration.

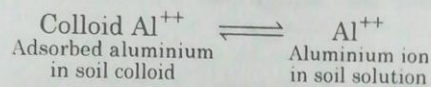
Moderately Acid Soils. The exchangeable hydrogen ions are main sources of hydrogen ions in moderately acid soil (pH value between 5.0 and 6.5). Moderately acid soils have higher percentage of base saturation (Ca^{++} , Mg^{++} etc.) than the strongly acid soils. The aluminium can no longer exist as ions but is converted to aluminium hydroxy ions (as shown in reaction).



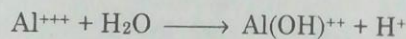
In the soil solution, aluminium hydroxy ions produce hydrogen ions by the hydrolysis reaction.



Strongly acid soils. Aluminium becomes soluble at very acid soil conditions (pH less than 5.0). Aluminium is either tightly bound by organic matter or is present in the form of aluminium or aluminium hydroxy cations. These exchangeable ions are adsorbed by the negatively charged soil colloids. The adsorbed aluminium ions are in equilibrium with aluminium ions in the soil solution.



In the soil solution, aluminium ions produce hydrogen ions by the following hydrolysis reaction :



The H^+ ions lower the pH value of the soil solution.

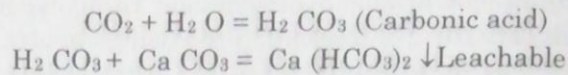
Acid sulphate soils. In case of acid sulphate soils (pH less than 3.5), the acidity is due to dissolved or free acidic substances, such as sulphuric acid, ferric and aluminium sulphate. The sulphuric acid is produced by oxidation of sulphur and sulphide. Acid sulphate soils occur in some of the lowlying areas of Kerala.

DEVELOPMENT AND FORMATION OF ACID SOILS

Acid soils are formed under natural conditions as well as artificially by the continuous use of acid-forming fertilizers. Following reasons may cause soil acidity :

1. Leaching due to Heavy Rainfall. The magnitude of leaching is the main factor for the development of acid soil. The rainfall carries lime and other bases (Ca^{++} , Mg^{++} etc.) downward beyond the reach of plant roots. When all the soluble bases are lost, the H^+ ions of the carbonic and other acids developed in the soil replace the basic cations of the colloidal complex. As the soil gets gradually depleted of its exchangeable bases through constant leaching, it gets desaturated and becomes increasingly acid. Thus, the regions

having an annual rainfall of 100 cm (40 inches) or more (humid region) have a percentage of acid soils.

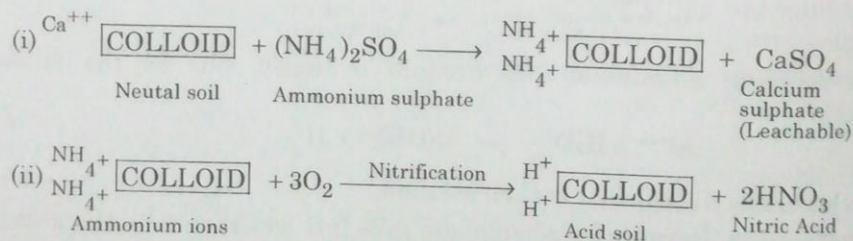


2. Microbiological. Several microorganisms are responsible for many processes such as decomposition of organic residues and nitrification. As a result of microbial activity, acids are constantly being formed. If these acids are not neutralised by bases (Ca⁺⁺, Mg⁺⁺ etc.) then cause of soil solution to be acid.

3. Origin of Acid from Acid Parent Rock Material. Some acid soil has developed from parent rock materials which are of acid nature such as granite. Here the leaching effect is predominating is creating acidity.

4. Removal of Bases by Crops. Some crops like sugarbeet absorb bases from soil. Due to removal of bases from the soil, acid soil develop.

5. Continuous Application of Acid-Forming Fertilizers. The use of ammonium sulphate and ammonium nitrate increase soil acidity. When nitrogenous fertilizers of ammoniacal nature added to soil, they are nitrified and nitric acid is liberated. The acid developed reacts with calcium and other bases to form calcium and other nitrates. Being soluble, they are either removed by crops or lost in drainage. At the same time, a part of the NH₄⁺ ions are adsorbed by the soil colloidal material. The ammonium ions adsorbed replace calcium and other cations, which are leached down. The ammonium ions of the colloidal material get nitrified and form nitric acid. The residual anions give rise to acids like sulphuric and hydrochloric which further deplete the soil solution at the colloidal complex of their bases. On these accounts, the clay gets desaturated, H⁺ concentration increases and the soil pH is lowered. the reactions involved may be expressed as under :



EFFECTS OF SOIL ACIDITY ON PLANTS

The effects of soil acidity may be direct or indirect.

Direct Effects. (a) Toxic effect of H ions on root tissues ; (b) influence of soil acidity on the permeability of the plant membranes for cations ; and (c) disturbance in the balance between basic and acidic constituents through the roots. (d) Aluminium (Al) has toxic effect on plants. Al³⁺ ions precipitate nucleic acid by forming strong complexes. Al is bound to the P in DNA which inhibits cell division by interfering with nucleic acid replication. Al also limits both rooting depth and degree of root branching besides increasing susceptibility to drought.

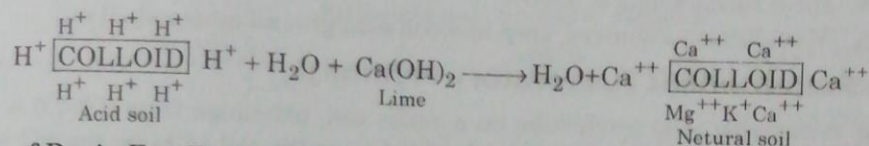
Indirect Effects. (a) Adverse effects on the availability of various nutrients i.e. phosphorus, copper, zinc etc., (see for details in the soil reaction chapter ; influence of soil reaction on availability of nutrients), (b) High solubility and availability of elements like

aluminium, manganese and iron in toxic amount due to high soil acidity (see influence of soil reaction on availability of nutrients under soil reaction chapter). (c) Beneficial activities of soil microorganisms adversely affected. These activities are (i) decomposition of organic matter (ii) nitrification (iii) nitrogen-fixation (d) prevalence of plant diseases.

RECLAMATION OF ACIDIC SOILS

The acid soil can be managed in the following ways :

1. Addition of Liming Material. Soil acidity is the result of the accumulation of a predominance of H ions over OH ions. The bulk of H ions are held in close association with the colloidal complex. When lime is added to moist soil, the soil solution becomes charged with calcium ions. These active Ca-ions exchange take place with hydrogen ions in the exchange complex. Hydrogen combines with OH-ions to form neutral water or with CO₃ to form unstable H₂CO₃, which is readily changed to H₂O and CO₂. The reaction is given below :



2. Use of Basic Fertilizer. Use of basic fertilizers like sodium nitrate, basic slag etc. reduces the acidity in soils.

3. Use of rock phosphate. Phosphate fertilization is almost essential for sustaining crop production in acid soils. As it is known that acid soils fix phosphorus in the soil. Application of rock phosphate in acid soil, soils provide an ideal situation for release of Phosphorus (P) from rock phosphate (RP). The efficiency of rock - phosphate increase with increasing fineness. A low pH (below 5.0) facilitates release of phosphate from rock phosphate and the effectiveness decreases with increasing pH above 5.0. It is advisable to apply rock-phosphate several months ahead of liming to permit dissolution of rock phosphate at low pH.

Rock phosphate is preferred source of Phosphorous(P) in acid - soils as it is a cheaper source and contains 30 to 50% CaO. CaO increase available calcium (Ca) in the soil, thus raises soil pH and lowers exchangeable Al content.

4. Soil Management. Proper soil and water management checks leaching of bases and enhances decomposition of organic matter.

5. Growing of Acid Tolerant Crops. In acid soils, acid tolerant crops should be grown. Choice of crops may be done according to soil pH. Crops can be divided into following groups :

(a) *Highly acid tolerant crops.* Rice, potato, sweet potato, oat, castor, Echinochloa, Paspalum etc.

(b) *Moderately acid tolerant crops.* Barley, wheat, maize, turnip, brinjal, cow pea, mung beans, pigeon peas, pea nuts etc.

(c) *Slightly acid tolerant crops.* Tomato, carrot, red clover etc.

6. Increasing the efficiency of nitrogen and potassic fertilizers in acid soils. The need for nitrogen fertilizer can be minimized by introducing acid tolerant N-fixing legumes in the cropping system besides improving the efficiency of fertilizer nitrogen. Higher nitrogen (N) rates are recommended in high rainfall areas to compensate leaching losses. Split application of N definitely improves recovery.

The efficiency of potassium fertilizer can be increased by split application of fertilizer. The split application is quite essential in acid soils having sandy texture. The crop residues should not be removed from the field.

7. Water management. Acidification can be prevented by continuous flooding or saturation. Where that is not possible, the soils are drained and leached to remove the acid material. After submergence the soil pH rises due to precipitation of aluminium hydroxide and by the reduction of ferric ion.

Liming Materials. The common liming materials are :

1. Limestone (CaCO_3)
2. Quick lime (CaO)
3. Hydrated (Slaked) lime [$\text{Ca}(\text{OH})_2$]
4. Dolomitic limestone [$\text{CaMg}(\text{CO}_3)_2$]
5. Blast furnace slag (CaSiO_3)
6. Miscellaneous sources, such as wood ash, ground oyster shell etc.

Lime Requirement (Laboratory Method)

For reasonable crop production on an acidic soil, pH range from 6.0-7.0 is considered good. The amount of lime required to be added to acidic soil to raise the pH to a desired value is known as lime requirement. The buffer method is used for determining lime requirement. In this method, 5 gm of soil to which 5 ml of distilled water and 10 ml of the extractant buffer added is stirred continuously for 10 minutes and the pH of the suspension is determined. Lime requirement in terms of pure Calcium Carbonate can be seen from a table [Source : Shoemaker, H.E., McLean E.O. and Partt, P.F. (1961)]. Buffer method for determining lime requirement of soils with appreciable amount of extracted aluminium (Proc. Soil Sci. Soc. Amer; 25, 274).

Table : 8.1. Lime Requirement for Acidic Soils

pH of soil-buffer suspension (soil taken from the field)	Lime required to bring pH down to indicated level (Calcium carbonate) in tonnes per acre		
	pH 6.0	pH 6.4	pH 6.8
6.7	1.0	1.2	1.4
6.6	1.4	1.7	1.9
6.5	1.8	2.2	2.5
6.4	2.3	2.7	3.1
6.3	2.7	3.2	3.7
6.2	3.1	3.7	4.2
6.1	3.5	4.2	4.8
6.0	3.9	4.7	5.4
5.9	4.4	5.2	6.0
5.8	4.8	5.7	6.5
5.7	5.2	6.2	7.1
5.6	5.6	6.7	7.7
5.5	6.0	7.2	8.3
5.4	6.5	7.7	8.9
5.3	6.9	8.2	9.4

5.2	7.4	8.4	10.0
5.1	7.8	9.1	10.6
5.0	8.2	9.6	11.2
4.9	8.6	10.1	11.8
4.8	9.1	10.6	12.4

Lime Requirement (Field Method)

The actual dose of liming material is least fixed from field trials on liming and crop response. In a field trial, on different soil textures, lime requirement has been determined (See Table 8.1 and 8.2).

TABLE 8.2 : Dose of Limestone for Different Soil Texture Classes (Field Method)

Soil pH	Pounds of Limestone required per acre of different soil textural classes		
	Sandy loam	Loam	Clay loam
5.0	1,125	1,687	2,625
5.2	975	1,462	2,275
5.4	825	1,237	1,923
5.6	675	1,012	1,575
5.8	525	787	1,225
6.0	375	562	885
6.2	225	337	525

Method of Applying Lime

The most efficient way to use lime is to apply small amounts every year or alternate, but this liming programme increase the cost of application. Lime can be applied at any stage in the cropping system, but normally it is applied one or two months before the sowing of crop.

It is desirable that newly spread lime be well-mixed with the whole plough layer. When excessively large amounts of lime are applied to sandy soils low in humus, injury to plant growth sometimes occurs due to boron, iron, manganese, copper, zinc etc. Overliming injury may be reduced by application of large amount of compost, farm yard manure, phosphorus, boron etc.

Efficiency of Liming Material

The efficiency depends on the following :

(a) **Chemical composition.** Oxides and hydroxides are the best as it dissolves immediately upon coming in contact with water.

, **Fineness.** The fine materials are quicker in correcting soil pH.

What Lime does in the Soil ? The main effect of lime on acid soils are :

1. Lime makes phosphorus more available.
2. Lime increases the availability of nitrogen, as increase in nitrification and nitrogen-fixation.
3. Organic matter decomposition increases.
4. Lime makes potassium more efficient on plant nutrition.

5. Beneficial soil bacteria are encouraged.
6. Harmful aluminium and manganese and iron are rendered insoluble and harmless when a soil is well supplied with lime.
7. Calcium and magnesium become available.
8. Flocculating power of soil increases.
9. Improves the physical condition of the soil
10. Checks soil erosion.
11. Fertilizer effectiveness increases.
12. Plant diseases favoured by acid soil decrease.

Loss (or neutralization) of lime in the acid soils. Lime is neutralized or lost from the soil by the following activities :

- (i) Top soil having higher based saturation is lost by erosion.
- (ii) Neutralization of lime by the acid formed by carbon dioxide in water.
- (iii) Neutralization by acid forming fertilizers (e.g. ammonium fertilizers).
- (iv) Neutralization by acids dissolved in rainfall.
- (v) Leaching loss of lime (very less loss).
- (vi) Removal by crops. Uptake of Ca by crops varies from 20-300 kg/ha.

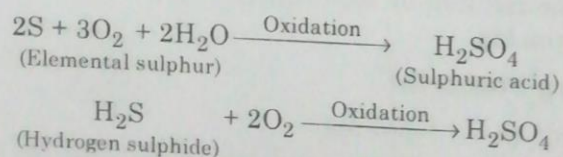
Crop Response to Lime. The use of lime on acid soil increases the yield of most crops. Legumes greatly and sugarcane appreciably respond to lime application. Lime application substantially increased the yield of maize, wheat, gram, soyabean and groundnut. The response to liming on jowar, moong, arhar, masoor, marua, cotton, barley, linseed and mustard was also encouraging.

Extent of the Problem. The acid soils in India are located in Kerala, Assam, Manipur, Tripura, some districts of West Bengal, Bihar, Jharkhand and Orissa.

In Jharkand, acid soils are found in Chhotanagpur and Singhbhum. In Bihar tarai area of north Bihar, north-east area of Purnea and uplands of south Bihar.

ACID SULPHATE SOILS

Acid sulphate soils are extremely acid soils. They have a pH which is less than 4.0 in some layer (in the upper 50 cm) of the profile. The acidity is due to presence of sulphuric acid and iron and aluminium sulphates. They are derived from marine sediments high in pyrites and poor in bases. Sulphur oxidation is an acidifying process. The reactions are as follows :



During the submerged period, sulphates (SO_4^{2-}) in the water are reduced to sulphides (S^{2-}), in which form they are stabilised generally as iron sulphides (FeS). When these areas are drained, the sulphides or elemental sulphur (S) are oxidised forming sulphuric acid. The soil pH may drop to level as low as 1 or 2 (highly acidic condition). Obviously plant growth cannot occur under these conditions. Sizeable areas of these kinds of soils, *cat-clays*, are found in *South-east Asia*.

Most soils will retain sulphate (this is the form taken up by plants). The mechanism of adsorbing sulphate is simple. Sulphate or acid sulphate ions replace hydroxyl (OH) held by aluminium ions (Al).

Characteristics. Acid sulphate soils are usually clay. The organic carbon content varies from 1.5 to 18%. The cation exchange capacity is 10-25 meq/100 gm. Available nitrogen and phosphorus are low. There may be toxicity of iron, aluminium, H₂S in these soils. These soils when submerged, are nearly neutral in reaction but when these are drained and dried they become extremely acidic and lethal to crop plants.

Reclamation. These soils can be managed for growing of crops. Reclamation measures depend on the degree of water control. If water is available, the soils are kept continuously flooded or saturated to prevent acidification. Where that is not possible, the soils are drained and leached to remove the acid materials. The soils are then limed, fertilised with nitrogen, phosphorus and crops grown in the wet season.

Crop management. Rice is the most important crop which can tolerate flooding and water logged condition. Under flooded condition, acidity is low (pH is higher).

Broadcasting of rice seed is avoided under dry land condition because aluminium toxicity may affect the seedlings. Transplanting should be preferred under puddle wet land condition.

In temperate regions with at least 20 cm top soil (pH 4.5) grassland development may be encouraged. Rye grass and Bermuda grass are tolerant to moderately acidic condition and slightly saline condition.

In situation where water table control is impractical or fresh water is not sufficient for crop production, forestry remains an important option.

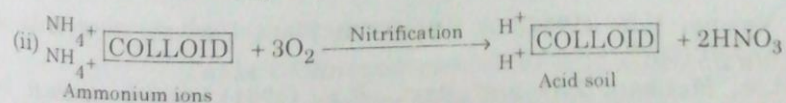
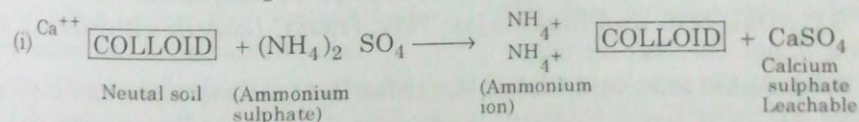
KEY POINTS

Acid soil. Acid soil is a base unsaturated soil which has got enough of adsorbed exchangeable hydrogen ions so that to give soil a pH of lower than 7.0.

Source of Hydrogen Ions. Soil acidity is caused by ionisable hydrogen ions. The sources of H ions are *Moderately acid soil, Strongly acid soils and Acid sulphate soils.*

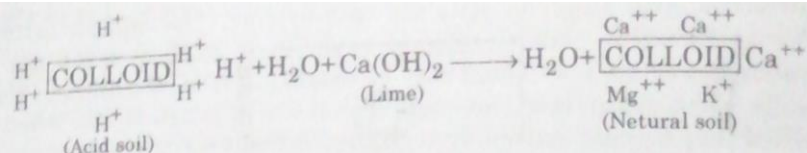
Nature of Soil Acidity. (1) Active acidity (H⁺ remains freely present in soil solution) (2) Exchangeable acidity and (3) Residual acidity.

Development and Formation of Acid Soils. (1) Leading due to heavy rainfall (2) microbiological action (3) acid parent rock material (4) removal of bases by crops (5) application of acid-forming fertilizer (reaction given below) :



Effects of Soil Acidity on Plants. (1) Toxic effect of H⁺ on root tissues (2) Effect on permeability of plant membrane (3) Adverse effect on the availability of nutrients i.e., P, Cu, Zn etc. (4) Al, Mn and Fe become available in toxic amount (5) activities of soil microorganisms adversely affected.

Reclamation of Acid Soils or Management. (1) Addition of lime (reaction given below) :



(2) Use of basic fertilizer, e.g. sodium nitrate (3) Soil and water management (4) Growing of acid tolerant crop, e.g., rice, potato, barley, wheat etc.

Lime requirement, (a) Laboratory and (b) field method.

Methods of Applying Lime. Lime should be applied one or two months before the sowing of crop. Lime should be well-mixed in the soil.

Efficiency of Liming Material. (a) Chemical composition, e.g., oxides or hydroxides (b) fineness of liming material.

Effect of Lime on Acid Soil. (1) Lime makes P more available (2) increases availability of N, K, Ca, Mg etc. (3) encourages the activities of soil microorganisms (4) renders Al, Fe and Mn insoluble and harmless (5) increases flocculation (6) improves physical condition of soil (5) checks soil erosion (8) increases fertilizer effectiveness (9) decreases plant diseases.

Acid Sulphate Soils. These soils are extremely acid soils (pH below 4.0). The acidity is due to the presence of sulphuric acid and iron and aluminium sulphates.

Management of Acid Sulphate Soil. When submerged, these soils are nearly natural in reaction. In order to keep these soils normal, the soils are kept flooded or saturated. Liming of soils are also effective in keeping soil normal.

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9

SALINE AND ALKALINE SOIL

Saline and alkaline soils are those that have a alkaline reaction or whose pH is greater than 7.0. This is due to the presence of an excess of sodium salts or to the predominance of sodium among exchangeable bases. Saline and alkali soils occur most commonly under arid climate (Table 9.1).

NATURE AND CLASSIFICATION

The presence of an excess of sodium salts and the predominance of sodium in the exchangeable complex are divided into the two main groups :

- (1) Saline soils and
- (2) Alkaline soils.

(1) **Saline Soils.** Saline soils contain an excess of sodium salts, but its colloidal material is not yet sodiumised.

(2) **Alkali Soils.** In the case of alkali soils, the exchange complex contains appreciable quantities of exchangeable sodium. Such soils may or may not contain excess salts. Alkali soils may be divided into following groups :

(a) *Saline-alkali soils.* When they contain soluble salts in excess they are known as saline-alkali soils.

(b) *Non-saline-alkali soils (Alkali soil).* When they do not contain soluble salts, they are called non-saline-alkali soils.

(c) *Degraded alkali soils.* Under certain circumstances the clay complex of some alkali soils is broken down to give rise to degraded alkali soils. The various types of alkaline soils are shown diagrammatically as under :

**Table : Characteristics of salt affected soils
(Saline and Alkaline soils)**

Nature of Soil	Soil characteristics		ESP
	pH	EC	
Saline	< 8.5	> 4 mmhos/cm	< 15
Alkali	> 8.5	< 4 mmhos/cm	> 15
Saline - Alkali	8.5	> 4 mmhos/cm	> 15

**Salt affected Soils
(Saline and Alkaline Soils)
(pH greater than 7.0)**

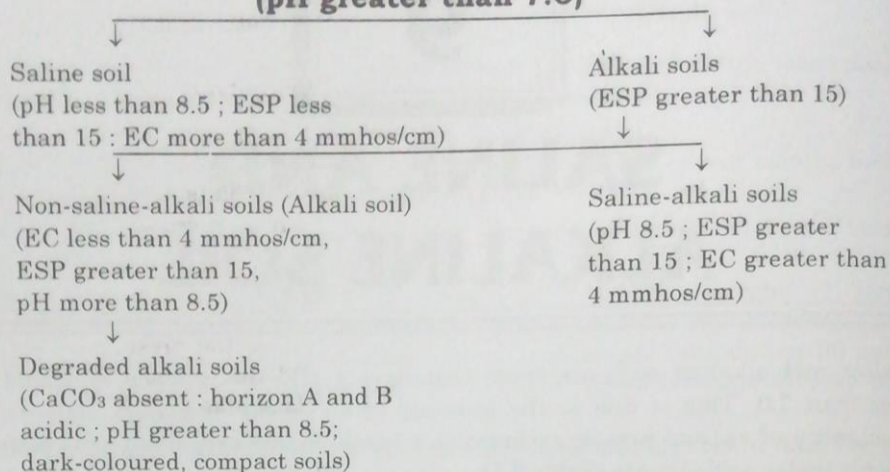


TABLE 9.1 : Area under saline and alkaline soils (lakh hectares)

State	Area	State	Area
1. U.P.	12.95	9. Karnataka	4.04
2. Gujarat	12.14	10. M.P.	2.24
3. W. Bengal	8.50	11. A.P.	0.42
4. Rajasthan	7.28	12. Delhi	0.16
5. Punjab	6.89	13. Kerala	0.04
6. Maharashtra	5.34	14. Bihar	0.04
7. Haryana	5.26	15. Tamil Nadu	0.04
8. Orissa	4.04		
		Total	<u>69.49</u>
			or
			7.00 million hectates

Source : Fertilizer News, Vol. 21 (9); PP. (15-23).

CHARACTERISTICS

A. Saline Soil

When the soil contains excess of sodium salts and clay complex still contains exchangeable calcium, the soil is known as saline soil or white alkali or brown alkali soil. The process of accumulation of salts leading to the formation of soils is known as salinization.

- (i) Saline soils contain usually chloride, sulphate, bicarbonates and sometime nitrates of sodium. The presence of chloride and sulphate of sodium gives a white colour on the soil surface. When nitrates are in excess they give a brown colour to the soil.
- (ii) Exchangeable sodium percentage (ESP) is very low, being less than 15% of the total cation exchange capacity (C.E.C.).

- (iii) As a consequence of low ESP, generally pH varies between 7.5 and 8.5.
- (iv) Total soluble salt content is more than 0.1%. It is high enough to interfere with normal growth of most plant species.
- (v) Electrical conductivity (E.C.) of solution extract (saturated soil) is 4 or more mmhos/cm.
- (vi) Saline soils remain in a flocculated condition (granulated). It is permeable to water and air.
- (vii) Saline soils usually have a surface crust of white salts, especially in the season when the net movement of soil moisture is upward. Salts dissolved in the soil water move up to the surface, where they are left as a crust when the water evaporates.

B. Alkali Soil (Sodic Soil)

(a) Non-saline-alkali soils. The characteristic features are the presence of colloidal complex that is saturated with exchangeable sodium, and the absence of appreciable quantities of soluble salts. These soils are often called 'black alkali' soils, because they are black, owing to the effect of the high sodium content which causes the dispersion of the organic matter. These soils are also called typical usarsoils. These soils contain sodium carbonates (Na_2CO_3) in abundance.

- (i) Exchangeable sodium percentage is greater than 15%.
- (ii) Consequently pH ranges from 8.5 to 10 (strongly alkaline).
- (iii) Total soluble salt (sodium) content is less than 0.15.
- (iv) Electrical conductivity (EC) is usually less than 4 mmhos/cm.
- (v) Colloidal complex is deflocculated and dispersed. The clay swells and chokes the soil pores. Hence, permeability to water and air is poor (or infiltration and aeration is slow).
- (vi) The presence of free sodium carbonate has a toxic effect on plant roots. Also, the high pH and poor physical condition of soil adversely affect plant growth.
- (vii) Sodium carbonate absorbs organic matter, so there is great depletion of organic matter. Therefore, these soils are almost barren (*Usar*).

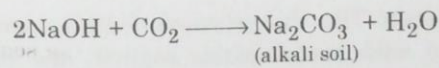
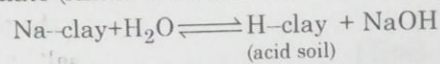
(b) Saline-alkali soils. These soils are both saline and alkali. There can be all stages in transition with varying degree of dominance of salt content and pH. According to movement of soluble salts, formation of saline-alkali and non-saline alkali soils depends. Soil contains Na-clay as well as excess soluble salts. If the soluble sodium salts are not leached out due to the insufficiency of rain water, they remain in the soil. The soil thus contains Na-clay and excess soluble salts in solution. Such soils are known as saline-alkali soils. They are thus, developed as a result of the combined process of salinization and alkalization. In spite of the presence of sodium clay (Na-clay) the soil remains friable and possesses aggregate (flocculated). This is because the presence of sodium salts does not allow the sodium clay to get dispersed and keeps it flocculated. Thus, this soil behaves more or less like saline soils. If due to much water soluble salts are leached down, and soil contains Na-clay only. Thus, this soil behaves more or less as non-saline-alkali soil. Therefore, the soil structure becomes unfavourable for the entry and movement of air and water. Usually these soils have the following characteristics :

- (i) Exchangeable sodium is more than 15%.

- (ii) A variable pH, usually above 8.5, depending upon the relative amounts of exchangeable sodium and soluble salts. When soluble salts are leached downward, the pH will rise above 8.5, but when the soluble salts again accumulated, the pH again falls to 8.5.
- (iii) Generally soluble salts content is more than 0.1%.
- (iv) Electrical conductivity is greater than 4 mmhos/cm.

C. Degraded Alkali Soils.

The soil does not contain free calcium carbonate (CaCO_3). As a result of prolonged leaching under this condition, Na-clay hydrolyses NaOH which combines with CO_2 or soil air and forms sodium carbonate (Alkaline condition).



Sodium carbonate (Na_2CO_3) dissolves humus. Humus (organic matter) is deposited in the lower layer. The lower layer thus, acquires a black colour.

At the same time, a part of exchangeable sodium of the surface layer is replaced by hydrogen. H-clay (acid soil) formed in this way does not remain stable. The process of break-down of H-clay under alkaline condition is known as *solodization* and the soil as formed is called *Solod*, *Soloth* or *degraded alkali soil*.

- (i) The soil reaction of the surface layer is acidic (pH 6.0). This layer is usually very thin, hardly a few inches in depth.
- (ii) The lower layer which constitutes the main soil body has a high pH (more than 8.5).
- (iii) ESP is greater than 15%.
- (iv) EC less than 4 mmhos/cm.
- (v) The lower layer has black colour.
- (vi) It develops columnar (prism-like) structure.
- (vii) Soils become compact and has low infiltration, and permeability.

FORMATION

Origin or development of saline and alkaline soil depends upon following factors :

(i) **Arid and Semi-arid Climate.** Alkaline soils are those that have an alkaline reaction or whose pH is greater than 7.0. Alkalinity is due to sodium salts in soil solution or the presence of sodium clay or both. They are formed in arid and semi-arid regions which have very low rainfall and high evaporation. The low rainfall in these regions is not sufficient to leach out the soluble products of weathering and hence, the salts accumulate in the soil. During rain, the salts dissolve in rain water and move down in the lower layers. However, due to the limited rainfall, the downward movement is restricted to a short distance only. In dry weather, the salts move up with the water and are brought up to the surface where they are deposited as the water evaporates.

(ii) **Poor Drainage of Soil.** During the periods of high rainfall, the salts are leached from the upper layer and, if the drainage is impeded, they accumulate in the lower layer.

When water evaporates, the salt is left in the soil. Such soils are generally developed in low-lying areas or in basin shaped areas.

(iii) **High Water Table.** The ground waters of arid regions usually contain considerable quantities of soluble salts. If the water table is high, large amounts of water move to the surface by capillary action and the evaporated, leaving soluble salts on the surface.

(iv) **Overflow of Sea Water over Lands.** Lowlying areas near the sea which get sea water during tides. Salt water accumulates and enrich the soils with salts.

(v) **Introduction of Irrigation Water.** The ground water of arid regions are generally saline in nature. With injudicious irrigation the percolating water may get linked with the saline ground water. During dry weather the soluble salts of the ground water may, thus, get carried to the surface and increase the salinity of the land.

The irrigation water may be itself rich in soluble salts and add to the salinity of the soils.

(vi) **Salts Blown by Wind.** In arid regions near the sea, lot of salt is blown by wind year after year and get deposited on the lands. Due to low rainfall they are not washed back to sea and thus, add salinity to the land. The salinity of Rajasthan has developed to a great extent, due to this reason.

(vii) **Saline Nature of Parent Rock Materials.** If soils develop from saline nature of parent rock materials, soil would be saline.

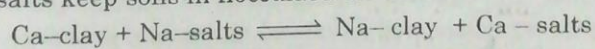
(viii) **Excessive Use of Basic Fertilizers.** Use of alkaline fertilizers like sodium nitrate, basic slag etc., may develop alkalinity in soil.

(ix) **Humid and semi-humid Regions.** Alkaline soils develop in other areas also, e.g., in semi-humid and temperate regions, especially in depressions where drainage is defective and where the underground water table is high or close to the surface.

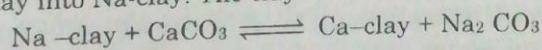
There are three distinct stage in the evolution of saline and alkali soils. They are as follows :

1. **Saline soils (Salinization).** Soil contains excess of sodium salts while the clay-complex (soil-colloid) still contains exchangeable calcium and magnesium. In these soils the colloids are not damaged by sodium.

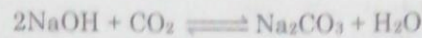
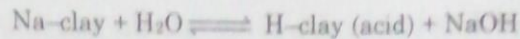
2. **Saline-alkali soils.** When soluble sodium salts accumulate in a soil over a prolong period, form sodium clay (sodium becomes the predominant cation in soil solution). If the soluble salts (sodium) are not leached out due to the insufficiency of rain, they remain in the soil. They are thus, developed as a result of the combined process of salinization and alkalization. Sodium salts keep soils in flocculaed conditions.



3. **Alkalinization (non-saline-alkali soils).** When soluble salts (from saline-alkali soils) are removed by leaching as a result of the increase in rainfall, it gives rise to non-saline-alkali soil (only Na-clay in the soil colloids). Calcium carbonate (CaCO_3) reacts with Na-clay and give rise to Ca-clay and sodium carbonate (Na_2CO_3). Due to low CaCO_3 , Na_2CO_3 converts Ca-clay into Na-clay. The clay is thus sodium saturated.



If CaCO_3 is absent, it forms *degraded alkali soils*. Na-clay hydrolyses (during leaching) and liberates NaOH which combines with the CO_2 and forms sodium carbonate.



DETRIMENTAL EFFECTS OF SOIL SALINITY AND ALKALINITY

Saline Soils

(i) **Absorption of water and nutrients.** Excessive salts in the soil solution increase the osmotic pressure of soil solution in comparison to cell sap. This prevents absorption of moisture and nutrients in adequate amounts by the roots.

(ii) **Salt toxicity.** When the concentration of soluble salts increase to high level then it produces toxic effect directly to plants. Saline soils are usually barren but potentially productive soils.

Alkali Soil (Saline-alkali and non-saline-alkali).

(i) **Dispersion of soil particles.** Under alkali soil conditions, the damage is not due to salt concentration. The sodium adsorbed by clay and colloids causes dispersion of clay which results in a loss of desirable structure and development of compact soil.

(ii) **Physical properties affected.** Due to compactness of soil, aeration, permeability, drainage and microbiological activity are reduced.

(iii) **Availability of plant nutrients reduced.** The high pH in alkali soil causes a reduction in the availability of plant nutrients such as phosphorus, calcium, nitrogen, iron, copper, manganese and zinc (consult soil reaction chapter for the details ; influence of soil reaction on availability of nutrients).

Under saline-alkali conditions there may be actually transitional stages, from high salinity-low alkalinity to low salinity-high alkalinity. Under such conditions, the crops may suffer due to high salinity as well as to unfavourable effects of alkalinity.

RECLAMATION

Schoonover (1959) in his study of soil problems in India, has listed the following technical requirements for reclamation of saline and alkali soils :

1. Adequate drainage.
2. Availability of sufficient water to meet crop use and also leach the salt below the root zone in the soil.
3. Better than average soil management to include perfect land levelling, good bunding for irrigation and advanced agronomic practices.
4. Protection and reclamation to be taken in large blocks.
5. Irrigation water should be of good quality.

I. Saline Soil Reclamation and Management

Saline soils in which the soluble salts contain appreciable amounts of calcium and magnesium do not develop into alkali soils by the action of leaching water. The reclamation is comparatively easy in such soils. The main problem is to leach the salts downward below the root zone and out of contact with subsequent irrigation water. Following methods may be used for removal of salts :

(A) Mechanical Methods

(i) **Flooding and leaching down of the soluble salts.** The leaching can be done by first ponding the water on the land and lowering it to stand there for a week. Most of the soluble salts would leach down below the root zone. After a week, standing water (dissolved with soluble salts) is allowed to escape. Such, 2 to 3 treatments are given to reclaim highly saline soils. Sometimes gypsum is also added to flood water when the soluble salts are low in calcium to check development of alkalinity.

(ii) **Scrapping of the surface soil.** When the soluble salts accumulate on the soil surface, scrapping helps to remove salts. This is a temporary cure and salinity again develops on such lands.

(B) Cultural Methods (Crop, Soil and Water Management)

(i) *Providing proper drainage.* If the soil is not free draining, artificial, drains are opened or tile drains laid underground to help wash out the salts.

(ii) *Use of salt free irrigation water.* Salt free good quality of irrigation water should be used.

(iii) *Proper use of irrigation water.* It is known that as the amount of water in the soil decreases the concentration of salts in the soil solution increases, thus, moisture should be kept at optimum field capacity.

(iv) *Planting or sowing of seeds in the furrow.* The salt concentration even in smaller amounts, is most harmful to the germinating seedlings. Water generally evaporates from the highest surface by capillarity and hence, these points have maximum salt concentrations. If the seeds or seedlings are planted inside the furrows, they escape the zone of maximum salt concentrations and thus, can germinate and develop properly during their early growth stage.

(v) *Use of Acidic Fertilizer.* In saline soil, acidic nature of fertilizers (e.g., Amonium sulphate) should be used.

(vi) *Use of organic manures.* The organic manures have very high water-holding capacity. When sufficient amount of these manures are added the water-holding capacity of soil increases and as a result the conductivity of the soil solution decreases.

(vii) *Ploughing and levelling of the land.* Ploughing and levelling of the land increases the infiltration and percolation rate. Therefore, salts leach down to the lower levels.

(viii) *Retardation of water evaporation from soil surface.* Water may be conserved in the soil retarding the water evaporation. Thus, salts may remain in the lower level with the water.

(ix) *Growing of salt tolerant crops.* (a) High salt tolerant crops : Paragrass, barley, sugarbeet, etc.

(b) *Moderately salt tolerant crops* : Wheat, rice, sorghum, maize, flax etc.

(c) *Low salt tolerant crops* : Beans, radish, white clover etc.

(d) *Sensitive crops* : Tomato, potato, onion, carrot etc.

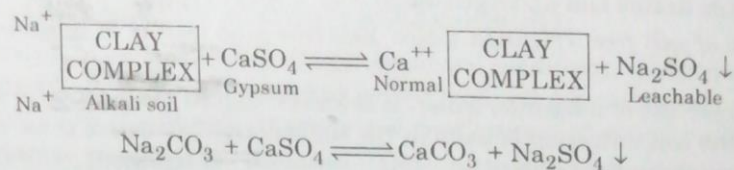
II. Reclamation and Management of Alkali (Saline-alkali and non-saline-alkali) Soils

Alkali soils cannot be reclaimed by mere flooding the land. In the case of saline-alkali

soils, flooding is likely to do more harm. Leaching (flooding) down of soluble salts make the soil alkaline (only Na-clay remain in the soil). Soils get dispersed and become compact (impervious). In alkali (non-saline-alkali) soils, exchangeable sodium Na-clay is so great as to make the soil almost impervious to water. But even if water could move downward freely in alkali soils, the water alone would not leach out the excess exchangeable sodium. The sodium-cation must be replaced by calcium-cation and then leached downward. Following chemical methods are used for reclaiming the alkali soils :

(A) Chemical Methods

(i) *Application of gypsum.* By cationic exchange, calcium is often used to replace sodium in alkali soil. If the soil has no reserve of calcium carbonate, the addition of gypsum (calcium sulphate) is necessary. When gypsum is used as a reclaiming agent, calcium replaces the exchangeable sodium and converts the clay back into calcium-clay (Ca-clay).



Sodium sulphate goes into solution and is then removed by washing it out with water or leaching down with water with the help of artificial drains. Addition of gypsum improves physical conditions of soil. Soils become flocculated and drainage improves, pH is lowered down to a desirable level.

Gypsum requirement is alkaline soil. For reasonable crop production on a sodic soil, the lowering of the ESP to the level of 10 is considered sufficient. The amount of gypsum required to be added to a sodic soil to lower the ESP to a desired value is known as gypsum requirement. It is expressed in milliequivalent of Ca^{++} per 100 gm of soil.

Gypsum requirement can be calculated from the data on CEC and ESP of the soil. For a sodic soil, suppose, CEC = 30 and ESP = 60, gypsum requirement to lower the ESP to 10, will be :

$$\left| \frac{60 - 10}{100} \right| \times 20$$

or = 10 m.e. of Ca^{++} per 100 gm soil.

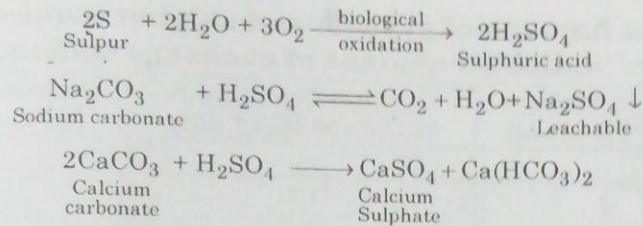
Besides gypsum that is best soil amendment for sodic soil, several other materials may be used for reclaiming alkaline soils. Gypsum equivalents of some such materials are given below :

Amendment	Gypsum equivalent
1. Gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$)	1.00
2. Sulphur (S)	0.19
3. Sulphuric acid (H_2SO_4)	0.57
4. Iron sulphate ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$)	1.62
5. Iron pyrite (FeSO_2)	0.63

(ii) *Use of sulphur.* In the case of alkali soil that contains free calcium carbonate, addition of sulphur, sulphuric acid, iron and aluminium sulphate, green manure (produce

acidity) etc. reclaim the soil very effectively. The acidity developed during the course of their decomposition of soil, neutralises alkalinity. At the same time brings calcium carbonate into solution which then reacts with the sodium clay and converts it into calcium clay.

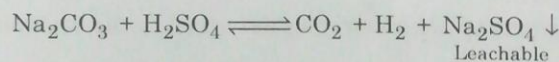
When sulphur is spread on the soil, it is oxidised to sulphuric acid, which converts sodium carbonate into sodium sulphate. If calcium carbonate is not present in the soil, it should be added artificially when sulphur is used for reclamation. Reactions are as follows:



In above mentioned both cases, it is necessary to leach out the sodium salts, formed as a result of bases exchanges with the help of artificial drains.

(iii) *Addition of organic matter.* The addition of organic matter increases acidity, thus, helping in lowering the pH. Organic matter is especially helpful where sulphur is added to correct the alkalinity. The organic matter supplies food for the bacteria that stimulates the oxidation of sulphur to the sulphate form. The combination of sulphur, organic matter and gypsum has also been used with success.

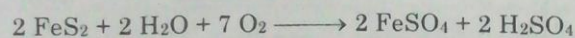
(iv) *Use of sulphuric acid.* Sulphuric acid changes the sodium carbonate to the less harmful sulphate and also tends to reduce the intense alkalinity. It should be used in the presence of calcium carbonate.



(v) *Addition of molasses.* Addition of molasses in the soil provide the source of energy for microorganism which on fermentation produce organic acids. The organic acids reduce alkalinity.

(vi) **Use of Pyrite.** Pyrite is a mineral containing iron and sulphur and generally it has a chemical composition of FeS_2 . Pyrite is found all over the world in igneous and metamorphic rocks and at some places as sedimentary deposits as well.

Pyrite is pyrophoric in nature, produces sulphuric acid and iron sulphate on coming in contact with air and water. The sulphuric acid so produced reacts with the native $CaCO_3$ of these soils to produce soluble calcium which then replaces sodium from the exchange complex.



Pyrite application in non-calcareous alkali soil is not affective because they lack free $CaCO_3$ to be dissolved by H_2SO_4 to produce Ca needed for the replacement of Na from exchangeable complex of sodic soils.

Pyrite application is recommended in the summer season because oxidation of Pyrite is rapid in the temperature range of 25° to $40^\circ C$. The activities of microorganism (Thiobacilli) are high in the above temperature range. Low temperature in winter season retards oxidation.

Pyrite should not be applied in the rainy season or in Paddy field. The activity of microorganism (Thiobacilli) decreases at very low at anaerobic (water logged) condition. The activity of microorganism is high in moist soil with good aeration and moderate temperature.

Dose of Gypsum and Sulphur. On an average for every one milliequivalent of sodium to be replaced, 1.7 tons of gypsum or 3.2 tons of sulphur is required. The amount of gypsum and sulphur required to replace different amount of exchangeable sodium are given in the Table 9.2.

TABLE 9.2 : Amount of gypsum and sulphur required to replace, indicated amount of exchange sodium

Exchangeable Sodium m.e. per 100 gm of soil	Gypsum Tons/acre-ft (4,000,000 lbs of soil)	Sulphur Tons/acre-ft (4,000,000 lbs of soil)
1	2	3
1	1.7	0.32
2	3.4	0.64
3	5.2	0.96
4	6.9	1.28
5	8.6	1.60
6	10.3	1.92
7	12.0	2.24
8	13.7	2.56
9	15.5	2.88
10	17.2	3.20

(B) Cultural Method

Same cultural practices are followed as described in the reclamation of saline soils.

KEY POINTS

Saline and Alkaline Soils. In saline and alkaline soils there is presence of an excess of sodium salts or predominance of sodium among exchangeable bases and pH is greater than 7.0.

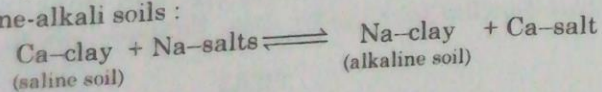
Nature and Classification

Characteristics	Saline soil	(Alkali) Non-saline-alkali	Saline-alkali soil	Degraded alkali soil
1	2	3	4	5
1. Content (Soil)	Excess of sodium soluble salts	Absence of soluble salt	These soils are both saline and non-saline-alkali soil. It is a stage of transition.	roman H sup + ion in upper layer roman Na sup + (lower layer)

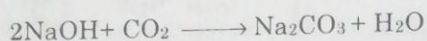
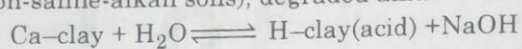
			Soil contains roman Na sup + clays as well as soluble salts.	
2. Exchan- ged Ca/Na	Ca	Na	—	—
3. Colour of soil	White	Black	—	Black lower layer
4. Presence of salts in the soil	Sodium chloride,, sulphate etc.	Sodium carbonate	—	Sodium carbonate (lower level)
5. Exchange- able Sodium Percentage (ESP)	Less than 15%	More than 15%	More than 15%	More than 15%
6. pH	7.5 to 8.5	8.5 to 10	8.5 or above	More than 8.5 (lower layer)
7. Total soluble salt content	More than 0.1%	Less than 0.1%	More than 0.1%	Less than 0.1%
8. Electrical conductivity (EC) of solution	4 or more mmhos/cm.	Less than 4 mmhos/cm.	4 or more mmhos/cm.	Less than 4 mmhos/cm.
9. Physical condition of soil	Floccula- ted condition,, permeable to water and air.	Defloccu- lated condition permeability to water and air is poor.	This type of soil may become flocculated or deflocculated depends upon the presence of sodium salts and Na- clay	Compact (defloccu- lated) low infiltration and premeability
10. Organic matter content	Slightly less than normal soil	Very less quantity	Variable	Low
11. Other name	White alkali,, Brown alkali	Black alkali,, typical user,, alkali soil,, sodic soil.	Usar soil	Solod,, Soloth

Formation of Saline and Alkaline Soil. (1) Arid and semi-arid climate (2) poor drainage of soil (3) high water table (4) overflow of sea water over lands (5) introduction of irrigation water (6) salts blown by wind (7) saline nature of parent rock materials (8) excessive use of basic fertilizers (9) humid and semi-humid regions.

Stages in the Evolution of Saline and Alkaline Soil. (1) Saline soils (salinization) (2) Saline-alkali soils :



(3) Alkalinization (non-saline-alkali soils), degraded alkali soils :

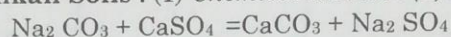


Detrimental Effects of Soil Salinity and Alkality. (A) Bad effect of saline soil (1) absorption of water and nutrients (2) salt toxicity. (B) Bad effect of alkali soil : (1) physical properties affected (2) availability of plant nutrients reduced.

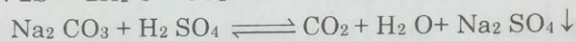
Reclamation of Saline and Alkali Soils : (A) Management of saline soil. (1) *Mechanical methods*—flooding and leaching down of soluble salts and scraping of the surface soil.

II. *Cultural methods.* Providing proper drainage, use of salt free irrigation water, proper use of irrigation water, planting or sowing of seeds in the furrow, use of acidic fertilizer, use of organic manure, ploughing and levelling of land, retardation of water evaporation from soil surface, and growing of salt tolerant crops.

(B) Management of Alkali Soils : (1) *Chemical Method.* (a) *Application of gypsum :*



(b) *Use of sulphur :* $2\text{S} + 2\text{H}_2\text{O} + 3\text{O}_2 \longrightarrow 2\text{H}_2\text{SO}_4 \downarrow$



(c) Addition of organic matter.

(d) Use of sulphuric acid : $\text{Na}_2\text{CO}_3 + \text{H}_2\text{SO}_4 \rightleftharpoons \text{CO}_2 + \text{H}_2\text{O} + \text{Na}_2\text{SO}_4 \downarrow$

(e) Addition of molasses.

(II) *Cultural Method.* Same as the saline soils.

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11

ORGANIC SOILS (HISTOSOLS)

Soil can be classified into groups—*mineral and organic*, on the basis of organic matter content. In the mineral soils, organic matter content may vary from 0-20 per cent.

Organic soils occupy less than 1% of the world's land area. Generally, in these soils, organic matter content is more than 20%. Organic soils are highly productive soils particularly for vegetables and flowers, provided properly managed.

FORMATION OF ORGANIC SOILS

Organic deposits accumulate in marshes, bogs and swamps by decaying of water loving plants such as mosses, grasses, pondweeds, shrubs and trees since generations. Microorganisms break down the organic tissues and aid in the synthesis of organic matter and humus.

CLASSIFICATION OF ORGANIC SOILS

On the basis of stage of breakdown of original plant materials, organic soils have been classified into following two groups :

1. **Peat soil.** Organic soils, which have slightly decayed or non- decayed plant materials are called peat soils. In peat soils, original plant deposits can be identified, especially in the upper horizons. Peat soils are coarse textured or fine- textured depending on the nature of deposited plant residues.

2. **Muck soil.** Organic soils having markedly decomposed original materials are termed as muck soil. Muck soils are usually fine- textured because of well decomposition of original plant deposits.

In the comprehensive *Soil Taxonomy* classification system, organic soils are identified as the order Histosols.

CHARACTERISTICS OF ORGANIC (PEAT AND MUCK) SOILS

(A) Physical Characteristics

(i) **Colour.** The colour of cultivated organic soils is dark brown to deep black.

(ii) **Bulk density.** The bulk density of organic soils is quite low in comparison to mineral soils. Bulk density of well composed organic soil is only 0.20-0.30 compared to 1.3-1.5 for mineral soils. Thus, organic soils are light weight when dry.

(iii) **Soil structure.** The surface layer of organic soils are granular or crumby. Its cohesion and plasticity are low compared to mineral soils. Organic soils are therefore, porous, open and easy to cultivate.

(iv) **Water-holding capacity.** Compared to mineral soils, organic soils having high water-holding capacity. Therefore, a given layer of organic soil at optimum moisture will supply only slightly more water to plants than a comparable mineral soil.

(B) Chemical Characteristics

(i) **Cation exchange capacity.** Cation exchange capacity of organic colloides are higher than those for the inorganic colloids (Table 11.1).

TABLE 11.1 : Cation exchange data for representative organic and mineral soils

Exchange characteristics	Weight basis	
	Organic soil	Mineral soil
Exchangeable Ca	150	8
Other exchangeable bases, Mg	40	3
Exchangeable H and Al	60	5
Cation exchange capacity	250	16
Percentage base saturation	76	69
pH	5.0-5.2	5.6-5.8

(ii) **Soil pH.** pH of an organic soil at a given percentage base saturation is generally lower than that of a representative mineral soil. Organic soils are highly acidic with a pH value less than 5.5.

(iii) **Buffering capacity.** Histosols have a higher buffering capacity than mineral soils.

(iv) **Carbon-Nitrogen ratio.** The representative organic soil possesses a high carbon-nitrogen ratio (20:1) compared to 12:1 for a representative mineral soil. Even so organic soils show vigorous nitrification (nitrate release) in spite of their high C/N ratio. Apparently some of the carbon in peats is very resistant to microbial attack and is not readily usable by general purpose decay organisms. Consequently, these organisms are not excessively encouraged, and they do not tie up the nitrates.

(v) **Availability of nutrients in organic soils.** Nitrogen. Nitrogen content in organic soils are high in comparison with a mineral soil.

Phosphorus and Potassium. Both the phosphorus and potassium content of an organic soil are low as compared to a mineral soil. Unlike mineral soils, organic soils do not fix phosphorus and potassium.

Calcium. Organic soils are comparatively high in calcium. In spite of this high lime content, the majority of organic soils are distinctly acidic. Owing to high cation adsorption capacity of organic soils that they may be at a low percentage base saturation and carrying large amounts of exchangeable calcium. At the same time, the percentage base saturation is such as to assure a decidedly acid condition (Table 11.2).

TABLE 11.2 : Organic matter and nutrient contents for representative Peat (organic soil) and a Mineral surface soil

Constituent	Peat	Mineral
	g/100 g soil	g/100 g soil
Organic matter	80.00	4.00
Nitrogen	2.50	0.15
Phosphorus	0.15	0.05
Potassium	0.10	1.70
Calcium	2.00	0.40
Magnesium	0.30	0.30
Sulphur	0.60	0.04

MANAGEMENT OF ORGANIC SOILS

The productivity of organic soils depends upon proper management. All sorts of crops can be grown on organic soils but it is especially suitable for vegetable, flowers and pasture.

(i) **Tillage operation.** Organic soils are porous and open, therefore, generally needs packing rather than loosening. A soil compacting roller is an important implement in management of organic soils. The compacting of soils allows the roots to come into closer contact with the soil and facilitate the capillary movement. Compacting of soil also tends to reduce the blowing of the soil during dry weather.

(ii) **Water management.** A reasonably high water table (between 45 and 75 cm from the soil surface) assures a ready water supply for vegetables and other shallow-rooted crops grown on organic soils. It also reduces wind erosion and oxidation of organic matter from the soil surface.

(iii) **Use of lime.** Ordinarily, use of lime in organic soils is less in comparison to mineral soils because organic soils are usually adequately supplied with calcium. But acidic muck soils contain high inorganic matter and result in dissolution of iron, aluminium and manganese to the extent of toxicity. Under these conditions, liming is necessary to obtain normal plant growth.

(iv) **Use of fertilizers.** Organic soils are very low in phosphorus and potassium elements, therefore, phosphatic and potassic fertilizers should be applied. Nitrogen is needed in organic soils when succulent vegetables are grown.

(v) **Use of micronutrients.** Organic soils need some of the micronutrients such as copper, zinc, manganese and boron.

KEY POINTS

Organic soils (Histosols). Organic soils occupy less than 1% of the world's land area and organic matter content is more than 20%.

Formation of Organic soils. Organic deposits accumulate in marshes, bogs and swamps by decaying of water loving plants.

Classification of Organic soils. Classified in two groups :

1. *Peat soils* have slightly decayed or non-decayed plant materials.
2. *Muck soils* have markedly decomposed original plants materials.

Characteristics of Organic Soils

(A) Physical characteristics. (i) Colour—dark brown (ii) Bulk density—lower than mineral soils (iii) Structure—granular or crumby (iv) Water-holding capacity—high compared to mineral soils.

(B) Chemical characteristics. (i) Cation exchange capacity—higher than mineral soils (ii) pH—lower (iii) Buffering capacity—higher (iv) C/N ratio—higher (v) Availability of nutrients— N and Ca content are higher but P and K are lower in comparison to mineral soils.

Management of Organic Soils

- (1) Tillage operation
- (2) Water management
- (3) Use of lime
- (4) Use of fertilizers
- (5) Use of micronutrients.

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SOIL MICROORGANISM

Soil is a living body because soil consists of *microflora* such as *bacteria*, *actinomycetes*, *fungi* and *algae*. Besides, soil also has *microfauna* such as *protozoa* and *nematodes*. *Macroorganisms* (large animals), viz, *mites*, *millipeds*, *centipeds*, *snails*, *mice* also live in the soil. The number of soil microorganism is quite high.

Raw organic matter in the soil is not directly available to the plants. Raw organic matter is broken down first into *humus* by microorganisms, then into simpler products before it can be utilized. The life in the soil is responsible for making numerous transformations which change plant nutrients to more readily available forms.

CLASSIFICATION OF SOIL MICROORGANISMS PLANTS

Bacteria

- (1) *Heterotrophic Bacteria*
 - (A) Nitrogen-fixing bacteria
 - (i) Symbiotic, e.g., *Rhizobium*
 - (ii) Non-symbiotic
 - (a) Aerobic, e.g., *Azotobacter*
 - (b) Anaerobic, e.g., *Clostridium*
 - (B) Non-nitrogen-fixing bacteria
 - (i) Aerobic, e.g., *ammonifiers*
 - (ii) Anaerobic, e.g., *denitrifiers*
- (2) *Autotrophic Bacteria*
 - (i) *Nitrifying bacteria*
 - (ii) *Iron bacteria*
 - (iii) *Hydrogen bacteria*
 - (iv) *Sulphur bacteria*
 - (v) *Manganese bacteria*
 - (vi) *Methane bacteria*
 - (vii) *Carbon monoxide bacteria*.

Fungi

- (i) *Yeast*
- (ii) *Mold*
- (iii) *Mushroom fungi*.

Algae

- (i) *Green*

- (ii) Blue-green
- (iii) Diatoms.

ANIMALS

Micro-Animals

- (A) Protozoa
 - (i) Paramecium
 - (ii) Euglena
 - (iii) Amoeba.
- (B) Nematodes

Macro-Animals

- (i) Earthworms
- (ii) Mites
- (iii) Centipedes
- (iv) Milipedes
- (v) Snails
- (vi) Mice
- (vii) Termite.

SOIL MICROORGANISM OF PLANT NATURE

The microbes in this class of microflora are bacteria, fungi, algae and actinomycetes. Of these, bacteria are the most abundant in soil, next in order are actinomycetes, followed by fungi (Table 13.1). Algae are found under specific situations.

TABLE 13.1 : Number of bacteria, fungi and actinomycetes in soil

Soil microorganisms	Location	Number/g
Bacteria	Rhizosphere	6778×10^6
	Non-rhizosphere	25×10^6
Fungi	Rhizosphere	918×10^3
	Non-rhizosphere	68×10^3
Actinomycetes	Rhizosphere	83×10^6
	Non-rhizosphere	1×10^6

The soil environment under the influence of plant roots is called the *rhizosphere*. The rhizosphere is not a well-defined uniform region, but a zone of microbial gradient extending from the root surface having maximum microbial population in soil.

Bacteria

These are very small organisms and occur everywhere. In the soil, bacteria are estimated to average one billion per gram of soil. Bacteria are mostly unicellular and vary widely in their size and shape. The bacteria are (1) spherical (2) spiral and (3) rod-shaped. A bacterial cell consists of a small speck of protoplasm and has no nucleus. The bacteria are of two types.

(a) Autotrophic Bacteria. These bacteria manufacture their food (complex compounds) by using very simple inorganic substances. Autotrophic bacteria oxidise

ammonia, nitrate, sulphur, manganese, iron, carbon monoxide, hydrogen and methane, so that plant can utilize these substances.

(b) **Heterotrophic Bacteria.** These bacteria depend upon organic matter or living body for their food. These bacteria decompose the organic wastes and dead bodies of plants and animals and release chemical elements locked up in them. Functionally, they bring about mineralisation of organic matter through hydrolysis and oxidation and release nitrogen, phosphorus and other nutrients in form available to plants. They also fix atmospheric nitrogen in the soil.

Fungi

These are non-green plant (no chlorophyll) ; thus, they cannot manufacture their own food and so they depend on others for their food. Some are parasites, taking food from living organism, and others are saprophytic deriving nutrients from dead remains of plants and animals. Fungi are estimated to average one million per gram of soil.

They decompose the organic matter in form available to the plants. The chemical substances such as streptomycin, a widely used antibiotic, is obtained from soil fungus called *Streptomyces* and *Penicillin* from *Penicillium fungus*.

Algae

They contain chlorophyll and therefore, they manufacture their own food. Some algae are unicellular and some algae are multicellular. Algae are commonly found in fresh water ponds, damp soil, such as paddy fields. They add organic matter to the soil and fix atmospheric nitrogen. Algae are estimated to average 100 thousand per gram of soil. The main groups of algae are : 1. Green, 2. Blue-green, 3. Yellow-green, and 4. Diatoms.

Actinomycetes

Actinomycetes have characteristics which are transitional between bacteria and fungi. They are next to bacteria in abundance in soil. Of the genera commonly found in soils, the *streptomyces* is more abundant.

SOIL ORGANISM OF ANIMAL NATURE

Microorganism

Protozoa. This phylum includes microscopic animals consisting of single celled bodies. They live chiefly in water and the soil. *Amoeba*, *Paramecium*, *Euglena* etc., are free-living forms. Soil protozoa feed either on soil organic matter or on bacteria, thus, regulating the number of the bacteria in the soil.

Nematodes. They live in soil and water and cause disease in many crop plants such as rice, tomato etc.

Macroorganism

Earthworm. They are found in moist soil containing decaying organic matter. Earthworms make burrows by eating through the soil. The soil is finely ground in its gizzard (grinding mill), moved through its alimentary canal. In the burrowing process, they bring the sub-soil to the surface and add it to the top soil. The burrows improves the aeration of soil. Further, the larger soil particles are made smaller by grinding process and thus the water-holding capacity of the soil is also improved. Nitrogen waste products of the worm are also added to the soil, thus increasing its nitrogen content.

Worm and Insects. They feed on plants and their remains. Termites are very harmful to the crops as they damage the roots.

Insects and some other large animals promote aeration and water percolation.

ACTION OF SOIL-ORGANISMS

The activities of soil flora and fauna are intimately related. Soil organisms are involved in the degradation of higher plant tissue. Microorganisms are primary, secondary and tertiary consumers of plant and animal tissues.

Primary Consumers. Plant leaves, stalks and bark pieces when drop to the ground, it is subject to co-ordinated attack by microflora and detritivores, animals. These animals, which include earthworm, mites and woodlice chew the tissue, opening it up to more rapid attack by the microflora. Herbivores (plant eating animals) and microflora are termed *primary consumers*. *The action of the microflora are mostly chemical while the action of fauna are both physical and chemical.*

Secondary and Tertiary Consumers. The primary consumers are themselves food sources for the predators and parasites that exist in the soil. Predators and some parasites are *secondary consumers*; the group includes small plants such as bacteria, fungi, algae and lichens. Carnivores are centipedes, which eat other animals such as small insects, spiders, nematodes, snails and earthworms.

The secondary consumers are prey for still other carnivores, called *tertiary consumers*. For examples, ants consume centipedes, spiders and mites which themselves can prey on primary or other secondary consumers. Again the microflora are intimately involved in the decomposition of organic material associated with the fauna. The microflora also attack the finely shredded organic material and therefore, called as the ultimate decomposers.

FUNCTIONS OF SOIL MICROORGANISM

The functions or role of soil microorganism can be divided into (i) beneficial function and (ii) harmful function.

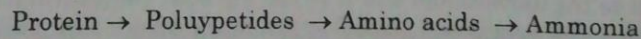
I. Beneficial Function of Soil Microorganism

The beneficial role of soil microorganism are :

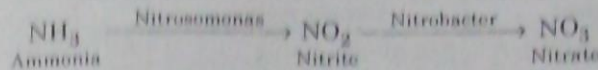
- (a) Change and decomposition in organic matter
- (b) Fixation of atmospheric nitrogen
- (c) Formation and development of soil.

(a) Change and decomposition in organic matter. The organic materials when incorporated in the soil are attacked by the microorganisms. The microorganisms break up the various constituents of the organic materials and convert them into new substances.

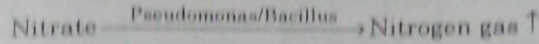
(i) *Ammonification.* The change of organic nitrogenous compounds into ammonia is called ammonification. The ammonification occurs as a result of action of enzymes produced by microorganisms in the presence of air.



(ii) *Nitrification.* The conversion of ammonia to nitrate (NO_3) is known as nitrification. Autotrophic bacteria performed this transformation. It is an aerobic process.



Denitrification. The conversion of soil nitrate into gaseous nitrogen or nitrous oxide is known as denitrification. It is an anaerobic process performed by bacteria belonging to genera *Pseudomonas*, *Micrococcus* and *Bacillus*.



Decomposition of Simple Products. The more common simple products resulting from the activity of the soil microorganisms are as follows :

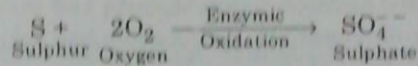
Carbon : CO_2 , CO_3^{2-} , HCO_3^- , elemental carbon

Sulphur : S, H_2S , SO_3^{2-} , SO_4^{2-} , CS_2

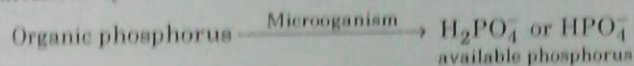
Phosphorus : H_2PO_4^- , HPO_4^{2-}

Others : H_2O , O_2 , H_2 , H^+ , OH^- , K^+ , Ca^{++} , Mg^{++} etc.

Mineralization of Organic Sulphur. Autotrophic bacteria (sulphur bacteria) oxidise sulphur into sulphate form.



Mineralization of Organic Phosphorus. Organic phosphorus compounds mineralized by the action of microorganism into inorganic phosphorus.



(For details see decomposition of organic matter in the Chapter 'Organic Matter').

(b) **Fixation of Atmospheric Nitrogen.** The conversion of elemental nitrogen to readily available form by nitrogen-fixing microorganisms is called biological nitrogen-fixation. The nitrogen fixed by microorganisms in the soil is known as 'bio-fertilizers'. The nitrogen-fixing microorganisms are : (I) Bacteria (II) Algae and (III) Mycorrhizae (fungus root).

(I) **Bacteria.** There are two main groups of bacteria which fix atmospheric nitrogen—symbiotic and non-symbiotic. Addition of nitrogen in the soil by bacteria is called 'bacterial-fertilizers'.

(i) *Symbiotic Nitrogen-fixing Bacteria.* This group of bacteria (*Rhizobium*) fix nitrogen in association with leguminous plants, called symbiotic bacteria. They are root nodule bacteria. The *Rhizobium* bacteria living in the soil enter the root hairs of leguminous plants, develop into colonies and form small nodules on the roots. They take their food (carbohydrate) from the leguminous plants and absorb nitrogen from the atmosphere. They produce nitrogenous compound (available form of nitrogen) and supply to the leguminous host plants. Both the legume (pulse) crop and bacteria are benefitted by the association, known as 'symbiosis'. The legume roots excrete available nitrogenous compound to the soil and enrich it. The nodules of the legumes decay and become part of the soil. This process also adds nitrogen to the soil.

There are different strains of legume—*Rhizobium* bacteria and specific strain works best with specific leguminous crop. The strains of *Rhizobium* and their association with leguminous crops are given below :

Species name	Group name	Leguminous crops
<i>Rhizobium leguminosarum</i>	Pea group	All types of pea,, lentil and broad bean
<i>R. japonicum</i>	Soyabean group	Soyabean
<i>R. phaseoli</i>	Phaseolus group	Kidney and garden beans
<i>R. trifoli</i>	Clover group	White clover
<i>R. meliloti</i>	Alfalfa group	Lucern

When a legume is introduced in a new locality, it is necessary to inoculate the seed with proper *Rhizobium* culture otherwise crop may not produce nodules and not thrive. In the absence of proper *Rhizobium* culture, the seed can be mixed with the soil obtained from an area where the particular group of legumes grow well. The amount of nitrogen added to the soil by *Rhizobium* bacteria varies from 50-150 kg per hectare.

(ii) *Non-symbiotic Nitrogen-Fixing Bacteria.* *Azotobacter* and *Clostridium* are the most important non-symbiotic nitrogen-fixing bacteria. These bacteria work independently of any host crop.

Azotobacter is an aerobic nitrogen-fixing bacteria and thrives well in neutral soil. It is susceptible to a deficiency of phosphate. *Azotobacter* has been found to fix a considerable amount of nitrogen.

Clostridium is anaerobic which can adapt even in acid soil and fix nitrogen. This microorganism is fixing less amount of nitrogen than *Azotobacter* because of anaerobic fermentation releases only a small amount of energy. Whereas aerobic change produces large amount of energy which helps to fix more nitrogen.

(II) **Algae.** Blue-green algae is capable of fixing atmospheric nitrogen to the soil. The main genus of algae which fix nitrogen are *Anabaena*, *Nostoc* and *Cylindrospermum*. The blue-green algae utilise a variety of nitrogen sources, besides the free nitrogen from atmosphere. They prefer usually neutral or slightly alkaline soil.

In water-logged rice field, algae grow well and fix about 20-30 kg nitrogen per hectare. Nitrogen-fixation has been found to be greater in the presence of the crop than in the absence. *Cylindrospermum* is also found in maize and sugarcane fields. Algae culture may be inoculated in a field to increase the soil fertility. The algal material after decomposition add organic matter to the soil and improves the physical condition of the soils.

(III) **Mycorrhizae (Myco = fungus ; rhiza = root).** Mutually beneficial association between certain fungi and roots of higher plants is called mycorrhizae (fungus roots). By this symbiotic association, fungi get sugars and organic exudates from the roots of higher plant. In return, the fungi provide several essential nutrients, including phosphorus, calcium, magnesium, zinc, copper, manganese and iron to the roots of plant.

Mycorrhizae are divided into two types : *ectomycorrhiza* and *endomycorrhiza*. The *ectomycorrhiza* group includes *Amanita*, *Boletus* etc., primarily associated with trees, such as oak, fir, pine etc. This group develops externally forming a mantle outside the roots. The hyphae of the fungi penetrate the roots and develop around the cells of the cortex but do not penetrate these cell walls.

The *endomycorrhiza* group are called vesicular-arbuscular mycorrhizae (VAM). It penetrates the root cell walls, enters the root cells and forms hyphal masses within the

cell. Almost 90 per cent of plants, including the most important agricultural field and fruit crops (wheat, maize, cotton, sugarcane, potato, dryland rice, beans, alfalfa, apple, grapes, citrus, coffee, rubber etc.) have VAM association. They increase the uptake of phosphorus, enhance resistance against drought and certain root-infecting fungus. The growth and biomass production of plants are also increased in the association of VAM fungus.

Microscopic examination of mycorrhizae shows the presence of aseptate, branched and hyaline mycelia. The fungus also produces spherical doublewalled chlamydospore. The root cortical cell walls of host plants are penetrated by the hyphae of VA mycorrhizae. Inside the plant cell highly branched, small structures known as *arbuscules* are formed by the fungi. These structures are considered to be the site of transfer of mineral nutrients from the fungi to the host plants. Other structures, called *vesicles*, serve as storage organs for the plant nutrients and other products.

(c) Formation and Development of Soil.

(i) *Decomposition of Rock and Minerals.* The microorganisms help in weathering of rocks and formation of soil.

(ii) *Decomposition of Organic Matter.* They help in decomposition of organic matter into simpler and available forms.

(iii) *Soil Structure Improvement.* Bacteria, fungi and algae aid in the development of desirable soil structure by their secretions of gummy substances. Addition of organic matter in the soil also helps in the development of good soil structure.

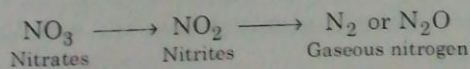
(iv) *Movement of Soil Material.* Organic acids and carbondioxide that are released by decomposition make insoluble phosphates and other unavailable compounds more available to plants.

II. Harmful Role of Soil Microorganism

There are following harmful effects of microorganism :

(a) Denitrification (b) Development of plant disease (c) Formation of toxic compounds and (d) Competition for nutrients.

(a) **Denitrification.** The biological reduction of nitrate to gaseous nitrogen is called denitrification. Denitrifying bacteria that live in the soil under anaerobic condition which convert available nitrogen to unavailable form (molecular nitrogen or oxides of nitrogen) and hence, undesirable in agriculture. Water-logging in rice fields will increase nitrogen losses due to denitrification. Nitrate fertilizers, therefore, should not be applied in rice fields.



(b) **Development of Plant Disease.** Plants of great economic importance to man are destroyed by microorganisms. The blight disease of rice, apple and pear is caused by bacteria. Fungi cause more serious damage to crop plants. For example, smuts and rusts of cereal crops and late **blight of potatoes**.

(c) **Formation of Toxic Compounds.** Under anaerobic conditions toxic substances such as methane, hydrogen sulphide are formed due to improper decomposition of organic matter.

(d) **Competition for Nutrients.** Soil microorganisms utilise carbon, hydrogen, oxygen, nitrogen, phosphorus for their growth and development. Competition for plant nutrients between microorganisms and crop plants is quite high. At the time of decomposition, microorganisms uptake more quantity of nutrients ; as a result, plants get insufficient nutrients for their growth.

CONDITIONS INFLUENCING MICROORGANISM ACTIVITY

The factors affecting microorganisms growth and activity are :

(1) **Moisture.** Moisture is essential for all life processes. Micro organisms are not exception. In the soil, about half the pore spaces occupied by water and half by air, has been found most favourable condition for microorganisms, especially bacteria.

(2) **Air.** Aerobic organism require oxygen for their growth and activity.

(3) **Temperature.** Microorganisms are most active and multiply fast at the optimum temperature which ranges between 30–C to 37–C. Generally, their activity stops below 5–C or above 55–C.

(4) **Soil pH.** Neutral condition of soil is most suitable for soil microorganism. Very acidic and alkaline condition of soils are not favourable for microorganisms.

(5) **Nutrients.** Microorganisms require carbohydrate, phosphorus, nitrogen and sulphur for building up their body cells.

(6) **Organic Matter.** Bacteria live on the organic matter in the soil and are very active when fresh organic matter is added to soil.

Effects of Agricultural Practices on Soil Organisms

Cultural practices such as interculturing, weeding, ploughing operations facilitate air movement in the soil and thereby increase micro and macroorganism activities.

Judicious application of irrigation water and soil drainage increase the biological activities in the soil.

Application of manures and fertilizers applied to soil for increasing the crop production also increases the microbial population in the soil. Nutrients supplied by manures and fertilizers are beneficial to crops and organisms. For example, phosphatic fertilizer applied to leguminous crop berseem increase the activity of nitrogen-fixing bacteria.

Other practices, such as adding lime to acidic soil and gypsum to alkaline soil increase the activities of microflora.

Monocropping, generally increases the number of particular group of microbes. Monoculture may reduce diversity of microbes in the soil. Crop rotation increases the species diversity in the soil.

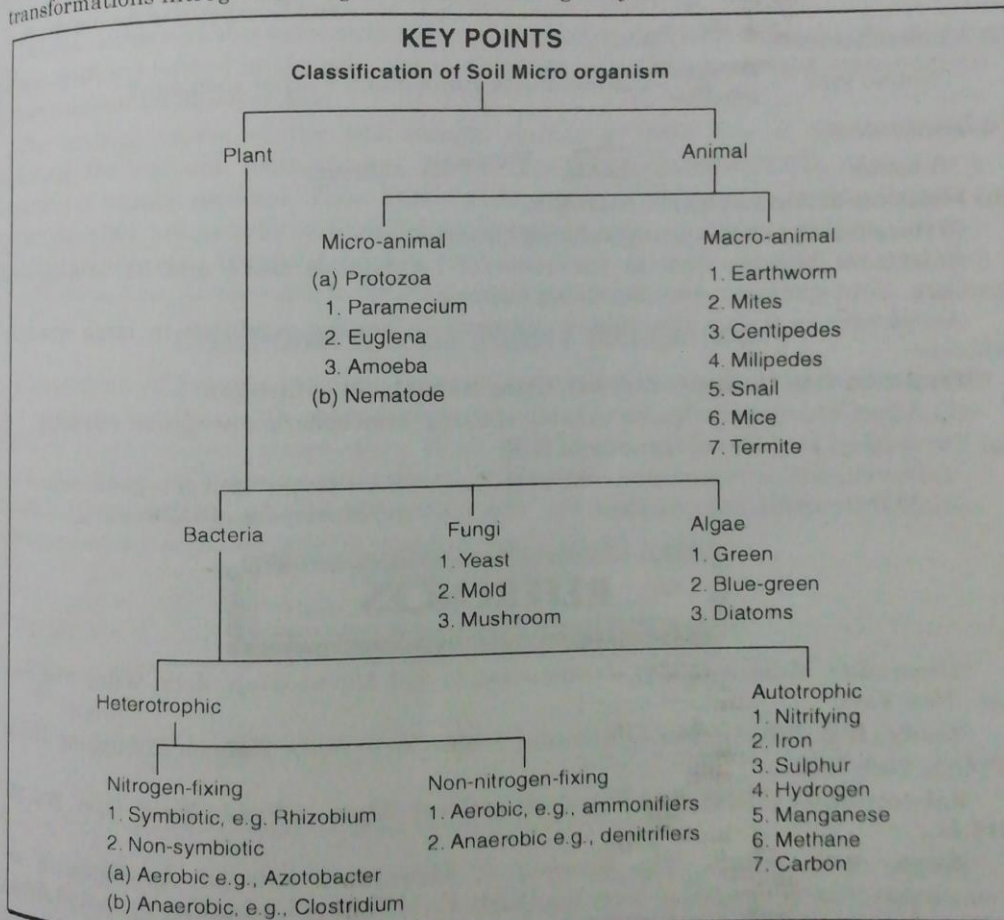
Excess tillage and soil erosion decrease the microbial population in the soil. Application of pesticides (chemicals) to control pests, diseases and weeds can sharply reduce the number of organisms in the soils at least on a temporary basis.

NITROGEN CYCLE

The nitrogen cycle is an important phenomena, in which nitrogen is in constant circulation.

Plants absorb nitrogen in the form of nitrate and ammonia from soil. The plant tissues containing protein are used as food by animals and animals excrete it as dung and urine. Nitrogen is returned to the soil as dung and urine (in form of manures). The dead remains also get back to the soil.

Nitrogen compounds (nitrates) in the soils and manures are reduced (denitrification) and free nitrogen (gas) is liberated into the atmosphere. Nitrogen gas again gets back to the soil in the form of nitrate-nitrogen by the action of microorganisms. Bacteria and blue-green algae fix atmospheric nitrogen into the soil. Nitrogen is also added to the soil by rains. Rains convert nitrogen gas into ammonia and oxides of nitrogen. The sequences of transformations nitrogen undergoes is called 'nitrogen cycle'.



Conditions influencing Microorganism Activity. (i) Moisture (ii) Air (iii) Temperature (iv) Soil pH (v) Nutrients (vi) Organic matter.

Nitrogen Cycle. The nitrogen cycle is a phenomena in which nitrogen is in constant circulation between atmosphere and soil. Plants absorb nitrogen (nitrate) from the soil and return back the nitrate in the form of their dead remains (leaves, roots etc.).

Functions of Soil Microorganisms

- Beneficial function**
- (a) Change and Decomposition in Organic matter**
- (1) Aminizaion :
- Complex oganic nitrogen compound $\xrightarrow{\text{Enzymic digestion}}$ Amonio acid + other compound
- (2) Ammonification :
- Amino acid $\xrightarrow{\text{Enzymic hydrolysis}}$ Ammonia or Ammonium + other compound
- (3) Nitrification :
- Amonia $\xrightarrow{\text{Nitrosomonas}}$ Nitrite $\xrightarrow{\text{Nitrobacter}}$ Nitrate
- (b) Fixation of Atmospheric Nitrogen**
- (i) *Bacteria*. Symbiotic nitrogen-fixing bacteria :
Rhizobium bacteria live in the roots of leguminous crops and fix atmospheric nitrogen. Notn-symbiotic nitrogen-fixing bacteria :
Azotobacter is fixing atmospheric nitrogen in aerobic condition in large quantity whereas
Clostridium is anaerobic bacteria, fixing less amount of nitrogen.
- (ii) *Algae*. Blue-green algae is capable of fixing atmospheric nitrogen in wet soils.
- (c) Formation and Development of Soil**
- (i) Decomposition of rock and minerals (ii) Decomposition of organic matter
 (iii) Soil structure improvement (iv) Movement of soil material.

- Harmful function**
- (i) Denitrification :
Nitrates-gaseous nitrogen
- (ii) Development of plant diseases
- (iii) Formation of toxic compounds
- (iv) Competition for nutrients.

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