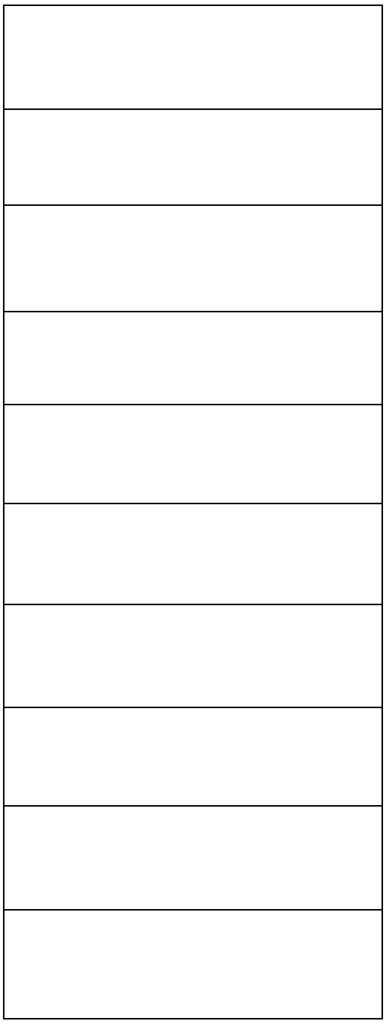
UNIT IV

A vertical section of soil through all its horizons and extending in to the parent material. A vertical exposure of the horizon sequence is termed as "**soil profile**".

A **soil horizon** is a layer of soil, approximately parallel to the soil surface, differing in properties and characteristics from adjacent layers below or above it.

Theoretical Soil Profile



O_i: Organic, slightly decomposed

O_e : Organic, moderately decomposed

O_a : Organic, highly decomposed

A : Top Mineral layer, mixed with humus, dark in color

E : Horizon of max. eluviation of silicate clays, sesquioxides etc.,

AB or EB: Transition to B, more like A or E than B.

BA or BE : Transition to A or E, more like B than A /E.

B : Illuviated B horizon, with clear expression

BC : Transition to C , more like B than C.

C : Zone of least weathering, accumulation of Ca ,Mg

R : Bed Rock

Soil profile is an historic record of all the soil forming processes and it forms the unit of study in pedological investigations. Practically, soil profile is an important tool for soil classification which is applicable for thorough understanding of the soils.

Five master horizons are recognized in soil profile and are designated using capital letters O, A, E, B and C. Sub-ordinate layers or distinctions with in these mater horizons are designated by lower case letter e.g., a, e, i, t, k etc.

O Horizons (Organic): It comprises of organic horizons that form above the mineral soil. They result from litter derived from dead plants and animals. **'O' horizons** usually occur in forested areas and are generally absent in grassland regions.

A - Horizon: It is the **topmost mineral horizon**. It contains a strong mixture of decomposed (humified) organic matter, which tends to impart a darker color than that of the lower horizons.

E - Horizon: It is an **eluviated** horizon. Clay and sesquioxides are invariably leached out, leaving a concentration of resistant minerals such as quartz. An 'E' horizon is generally **lighter in color** than the 'A' horizon and is found under 'A' horizon.

"B" – Horizon (Illuvial): The sub -surface 'B' horizons include layers in which illuviation of materials has taken place from above and even from below. In humid regions, the B horizons are the layers of maximum accumulation of materials such as sesquioxides and silicate clays. In arid and semi-arid regions $CaCO_3$, $CaSO_4$ and other salts may accumulate in the B horizon.

'C' – Horizon: It is the unconsolidated material underlying the 'Solum' (A & B). It may or may not be the same as the parent material from which the solum formed. The 'C' horizon is out side the zones of major biological activities and is generally little affected by the processes that formed the horizons above it.

'R'- Layer : Underlying consolidated rock, with little evidence of weathering.

Sub – Ordinate Distinctions with in Master Horizons:

p: plough layer disturbance
h : illuvial accumulation of organic matter
n : accumulation of sodium
t : accumulation of silicate clays
s : illuvial accumulation of organic matter and sesquioxides
y : accumulation of zypsum
z : accumulation of soluble salts

SOIL STRUCTURE

Soil Structure may be defined as 'the arrangement of primary particles (sand, silt and clay), secondary particles (aggregates) and voids (pores) in to a certain definite pattern under field conditions'. In the broad sense, **Soil Structure** denotes: a) the size, shape and arrangement of particles and aggregates; b) the size, shape and arrangement of the voids or spaces separating the particles and aggregates; and c) the combination of voids and aggregates in to various types of structures.

Peds – Natural aggregates which vary in their water stability.

Clod – It is used for a coherent mass of soil broken in to any shape by artificial means such as by tillage.

Fragment - It is a broken ped.

Concretion – It is a coherent mass formed with in the soil by the precipitation of certain chemicals dissolved in percolating waters. Concretions are usually small like shotgun lead pellets.

- **Classification of Structure:** Classification of soil structure for field description is based on

i) the type as determined by the shape and arrangement of peds

ii) the class, as differentiated by the size of the peds and

iii) the grade, as determined by distinctness and durability of peds.

(i) TYPES: As per the geometric shape, the aggregates can be broadly divided in to two types.

1. Simple structure 2. Compound structure

1. Simple structure: In this the natural cleavage plains are absent or indistinct.

a. Single grain structure: Occur in sandy soils

b. Massive structure: Coherent mass with high bulk density occur in soil crusts, paddy soils

c. Vesicular or honeycomb structure: Massive or loose aggregates of nodular ferruginous mass seen in laterites.

2. Compound Structure: The natural cleavage plains are distinct. Described with relative length of horizontal and vertical axes and shape of peds.

a. Spheroidal: Small rounded peds with irregular faces and are usually separated from each other in a loosely packed arrangement. When spheroidal peds are porous, the structure is called as Crumb, while less porous peds are called granular. Usually granular peds are <1cm, while crumb peds are<0.5 cm in diameter. The diameter typically ranged from 1.0 to 10.0 mm.

Granular and crumb structures are characteristic of many surface soils (A horizon) particularly those high in organic matter. They are prominent in grassland soils and soils that have been worked by earth worms. This structure is invariably subjected to management practices.

b. Plate like: Relatively thin horizontal peds or plates characterize this structure. The thicker units are called Platy and thinner ones are called Laminar. The platy types are often inherited from parent materials, especially those laid down by water or ice. Sometimes, compaction of clayey soils with heavy machinery can create platy structure. Found in surface layers of some virgin soils.

c. Block Like: Blocky peds are irregular, roughly cube -like and range from 5 to 50 mm across. The individual block are not shaped independently but are molded by the shapes of the surrounding blocks. When the edges of the blocks are sharp and rectangular faces distinct, they are called angular blocky, and when faces and edges are some what rounded they are referred as subangular blocky. These types are usually found in B horizons, where they promote good drainage, aeration and root penetration.

d. Prism – Like: These are vertically oriented pillar like peds with varying heights among different soils and may have a diameter of 150 mm or more.

In columnar structure pillars have distinct rounded tops, and in invariably found in subsoils high in sodium (nitric horizon). If the tops of the pillars are relatively angular and flat horizontally, the structure is designated as Prismatic. These structures are associated with welling types of clay and commonly occur in sub surface horizons in arid and semi-arid regions.

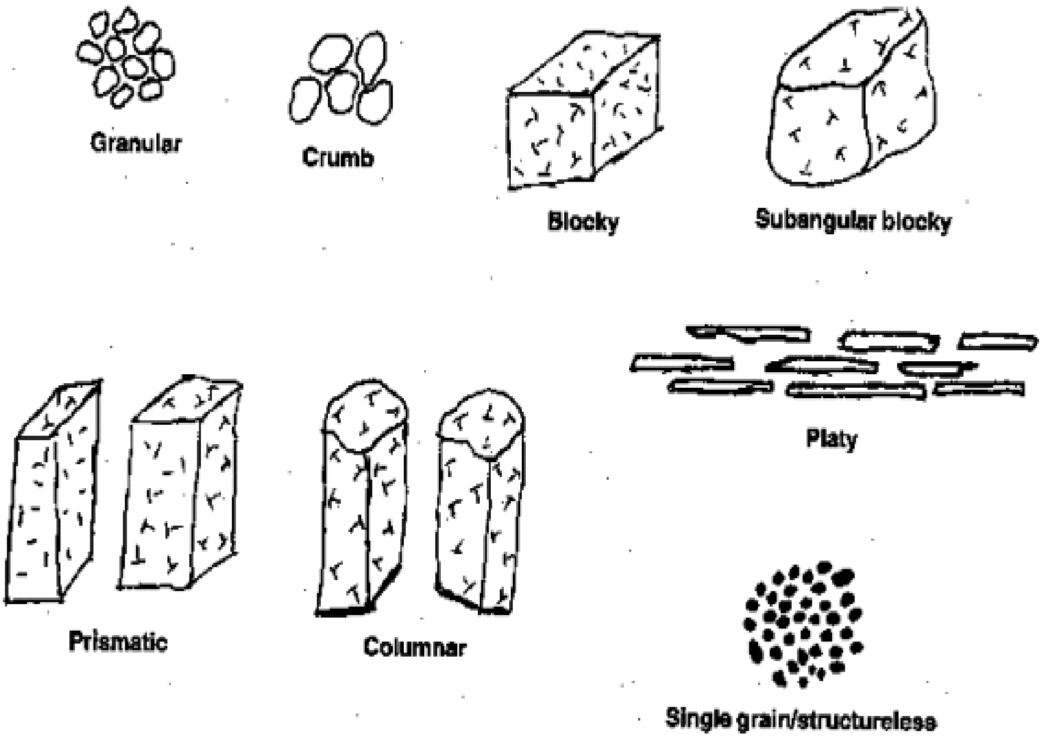


Fig. 4.1 Types of soil structure

(ii) CLASS: Based on the size of the individual peds, the primary structural types are differentiated in to five sub-classes.

Size or class	Granular(mm)	Platy(mm)	Blocky(mm)	Prismatic(mm)
Very fine or very thin	<1	<1	<5	<10
Fine or thin	1-2	1-2	5-10	10-20
Medium	2-5	2-5	1-20	20-50
Coarse or thick	5-10	5-10	20-50	50-100
Very coarse or very thick	>10	>10	>50	>100

In case of granular structure, < 1.0 mm is very fine; 1-2 mm is fine and 2-5 mm is medium class. The terms thin and thick are used for platy type (very fine <1 mm and very thick >10 mm), while the terms fine and coarse are used for other structural types (very fine blocky <5 mm and very coarse blocky >50 mm).

(iii) GRADES: Grade determines the degree of distinctness and durability of individual peds.

a.Weak: Poorly formed, non-durable, indistinct peds and break in to a mixture of a few entire and many broken peds and much unaggregated material.

b.Moderate: Moderately well developed peds which are fairly durable and distinct.

c.Strong: Very well formed peds, which are quite durable and distinct.

- **Importance of soil structure**

1. Influences the amount and nature of porosity in soils.
2. Governs the water and air permeability in to soils.
3. Influences water holding capacity, soil-water relationship and growth of microorganisms.
4. Influences soil drainage and availability of plant nutrients.

Management of soil structure: Soil structure management aims at the improvement and maintenance of soil structure, which are the major challenges in cultivated lands. The general principles relevant to structure management are :

1. Tilling soils at optimum moisture conditions to ensure least destruction of soil structure.
2. Suitable tillage and minimum tillage practices to minimize the loss of aggregate stabilizing organic substances.

3. Covering soil surface with organic materials (mulch) to mitigate the beating action of rain and to add organics to soil.
4. Incorporation of crop residues and animal manures in to soil, which upon decomposition, would stabilize soil aggregates.

Note: COLE (Coefficient of Linear Extensibility): The expansiveness of a soil can be quantified as the coefficient of linear extensibility. If the value is >0.03 it indicates that soils are black soils with considerable expandable minerals (smectite). If > 0.09, it indicated Vertisols.

$$COLE = \left[\frac{(L_m - L_d)}{L_d}\right] \times 100$$

L_m = Length of bar shaped soil, when moistened to its plastic limit

L_d = Length of bar shaped soil, when air dried.

Soil crusting: Soil crusting is the phenomena associated with deterioration of soil structure, where the natural aggregates break and disperse due to impact of rain drops, followed by rapid drying due to radiant energy of the sun.

When the rain drops strike the exposed dry soil surface, there is disintegration and dispersion of the aggregates. The finer clay particles move down along with infiltrating water and clog the pores, immediately beneath the surface thereby sealing the soil surface. Later when drying starts surface tension forces pull the soil particles together, tending to form a dense and strong layer known as soil crust. Larger is the rain drop thicker may be the crust. Invariably crust thickness is about 5.0 mm. Soil crust strength can be evaluated by using penetrometer, balloon pressure technique and modulus of rupture test.

❖ SOIL AIR

- Soil is composed of solid, liquid and gaseous constituents in various proportions.
- The size and arrangement of soil particles or soil aggregates will determine the pore space.
- It is the part of the soil, not occupied by soil solids.
- This pore space is normally occupied by soil water and soil air in reciprocally varying amounts.
- The degree of continuity of both soil water and the soil air is of great importance in determining the physical properties of soil.

Composition: The composition of soil air is not the same as that of the atmosphere. The plant life and microorganism cause the soil atmosphere to become dynamic with respect to the ratio of oxygen to carbon-dioxide. The principal components of soil air are nitrogen, oxygen, inert gases, carbon dioxide, water vapour and hydrogen. Methane, hydrogen sulfide etc., are present in negligible quantities.

Gases	Soil air (%)	Atmospheric air (%)
Nitrogen	79.20	79.00
Oxygen	20.60	20.97
Carbondioxide	0.50 (variable)	0.033
Other gases	traces	-

Gaseous exchange in soil

The exchange of gases in between soil air and atmospheric air is referred to as soil aeration. This is very important for growth of plants and soil microorganisms and biological activities. Two mechanisms have been identified in the interchange of gases between soil voids and the atmosphere i.e. mass flow and diffusive flow.

Mass flow : Mass flow of gases in to and out of the soil occurs whenever there is a difference in total pressure between the soil air and atmosphere. This difference is mainly due to expansion and contraction of soil gases due to changes in temperature and barometric pressure, air replacement through rainfall, irrigation and drainage.

Diffusion : Diffusion is the random movement of molecules (molecular motion) of a gas or of a liquid. Net movement of gases by diffusion occurs when the partial pressures of individual gases in two neighboring systems are different, but the total pressure is the same in both. Diffusion accounts for >90% of gaseous exchange. In soils, due to biological activity, there is a continuous production of CO_2 at the exhaustion of oxygen. This results in the increased partial pressure of CO_2 and reduced partial pressure of oxygen. It leads to continuous interchange of CO_2 and O_2 in between soil and atmosphere.

According to Fick's law, diffusion is a function of the concentration gradient, the diffusion co-efficient of the medium, and the cross sectional area.

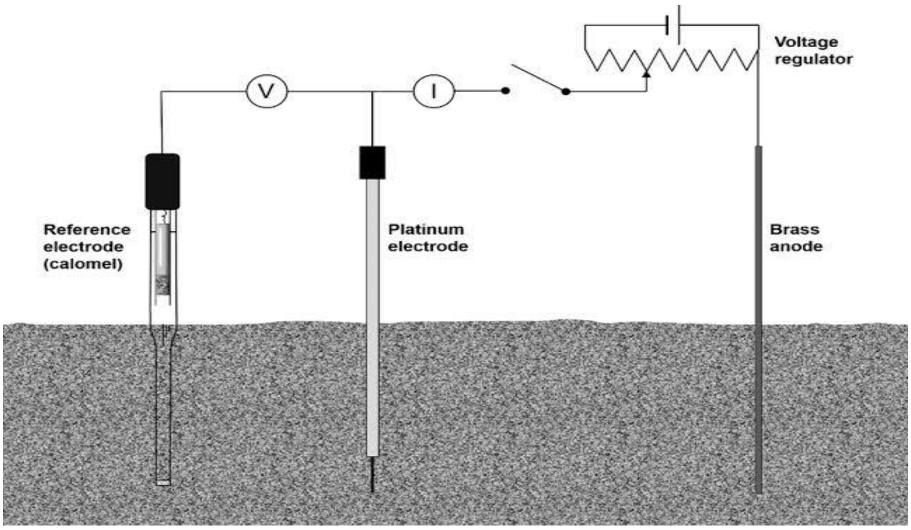
$$dQ = DA\left(\frac{dc}{dx}\right)dt$$

where dQ is the mass flow (moles) during the time at across area A (sq.cm), dc/dx the concentration gradient [moles/cc (cm)], and D the proportionally constant or diffusion coefficient (sq.cm/sec).

Measurement of ODR

The equipment for the measurement of oxygen diffusion rate consists of the platinum microelectrode, the reference electrode, the voltmeter, the ammeter, the variable resistor and the battery. When a certain electrical potential is applied between a reference electrode and a platinum electrode inserted in the soil, oxygen gets reduced at a platinum surface resulting in a current flowing in between the electrodes. This current is proportional to the rate of oxygen reduction, that is, the current is governed by the rate of oxygen diffusion to the electrode.

Each molecule of oxygen which diffuses to the surface of the electrode takes up four electrons and reacts with hydrogen ions to form water in an acid solution, or, reacts with water to form a hydroxyl ion in an alkaline solution.



In an acid medium: $O_2 + 4H^+ + 2e^- = 2H_2O$

In neutral or alkaline soils: $O_2 + 2H_2O + 4e^- = 4OH^-$

It is found that root growth ceased when the ODR dropped to about 20 x 10^{-8} g/cm^2/min.

Management of soil aeration

1. ODR should be at least 30 x 10^{-8} g/cm^2/min.
2. Oxygen concentration in the soil air should be at least 10%.

❖ SOIL TEMPERATURE

Solar radiation is the source of soil heat. The flux of heat (colories or joules) into and out of the soil determines the soil thermal regime, which is characterized in terms of soil temperature (°C). On an average only 50% of solar radiation reaches the earth, because of clouds and dust particles intercept the sun rays. This energy is primarily utilized to evaporate water from soil or leaf surface or is radiated or reflected back to the sky. Only about 10% is absorbed by soil, which is of critical importance to soil processes and to plants growing on the soil. The fraction of incident radiation that is reflected by the land surface is termed the "**Albedo**", and ranges from 0.1 to 0.2 for dark coloured, rough soil surfaces to as high as 0.5 or more for smooth, light coloured surfaces.

Heat capacity or Thermal capacity: The "heat capacity" of a soil is defined as the ratio of heat supplied to a body to the corresponding rise in its temperature.

$$e = \frac{\Delta Qh}{\Delta T}$$

The heat capacity per unit mass of a body is called the "specific heat" (e) and is defined as the quantity of heat required to raise the temperature of a unit body through 1°C.

The heat capacity is expressed as quantity of heat required to raise the temperature of unit volume of soil by 1°C and is known as **"Volumetric heat capacity"** or simply the "heat capacity" (gram calorie) C_v = J/m^3/°C or Cal/cm^3/°C. The specific heat is the heat capacity of a substance in relation to that of water.

Specific heat of water = 1.00 cal/g ;**Soil forming minerals** = 0.2 cal/g;**OM** –0.46 cal/g ; **Air** – 2.4 cal/g; **Dry soil** – 0.233 cal/g; **Soil with 50% moisture** – 0.53 cal/g

Practically all substances have heat capacities lesser than that of water.

Thermal conductivity is defined as the quantity of heat passing in a unit time through a unit area of soil under a unit temperature difference between the faces and is expressed as Joules /meter/second/°C. Thermal conductivity of a soil depends on its water content, texture, structure, mineralogical composition, organic matter content and compaction.

Thermal conductivity increases with increased water content, till about 50% of the soil saturation. It is observed to decrease with a reduction in particle size. Thermal conductivity of soil varies in the order : Sand > loam > clay > peat.

Management of soil temperature

The soil temperature depends upon the heat flux in to the soil and the heat transfer processes occurring in the soil and in between the soil and atmosphere, which in turn, depend upon the thermal characteristics of the soil solids, gases and water. The soil thermal regimes greatly modify the microclimate of the area and exercise a major influence on growth and development of plants, particularly during germination and early seedling development stages.

Soil temperature can be modified by:

a) regulating energy balance on the soil surface

b) changing the soil thermal properties and

c) heating the soil through artificial means.

Temperature regulation by energy balance

The energy balance on the soil surface and therefore be modified through tillage and shaping of fields, mulching and vegetation; and shading and row spacing.

Tillage and shaping of fields

Since both slope and direction affect soil temperature and heat flux, soil thermal regimes can be modified by specific tillage practices such as ridges and shaping. Comparatively high temperature is recorded on ridges as compared to furrows.

Mulching and vegetation

From the energy point of view, mulching is the application or creation of a soil cover that constitutes a barrier to the transfer of heat or water vapour, where as the vegetation intercepts a considerable part of the incoming radiation. Vegetation and mulching affect the soil thermal regimes by 1) interception of the incoming radiation 2) changes in albedo conditions and 3) reduction in latent heat transfer by evaporation. The mulches commonly used include : soil, stubble, straw, weed or trash, gravel, plastic (black, transparent, opaque etc.) paper (different textures and colors) asphalt and aluminum foils. In general, light coloured mulches will increase albedo of the surface, thereby reduces soil temperature.

1. Black plastic mulch – reduces out going temperature (heating)
2. Paper and straw mulches – increases outing temperature (cooling)
3. Aluminum foil mulch – sharply increases out going temperature (cooling)

4. Transparent plastic mulch – green house effect
5. Opaque mulches – thermal insulators (decreases maximum temperature and increases minimum temperature)

Modification of soil thermal properties

Soil thermal characteristics can be modified by changing soil physical conditions through tillage practices, soil compaction, irrigation and drainage. Tillage will loosen soil, increase the soil porosity and decrease the soil thermal conductivity and heat capacity.

Importance of soil temperature:

1. Too low or too high temperatures affect the germination of seeds. Different crops have different optimum temperature for germination.
2. Absorption of water and nutrients is decreased under low temperatures.
3. Temperature influences nutrient availability by affecting the weathering of minerals and decomposition of organic matter.
4. Low soil temperature results in white succulent roots with less branching.
5. Low temperature enhances disease incidence by parasitic fungi.
6. Soil microbial activity and decomposition of organic matter is restricted below 10°C and ceases below 5°C.
7. Biological nutrient transformations like nitrification, ammonification etc are affected by very high or low temperatures.

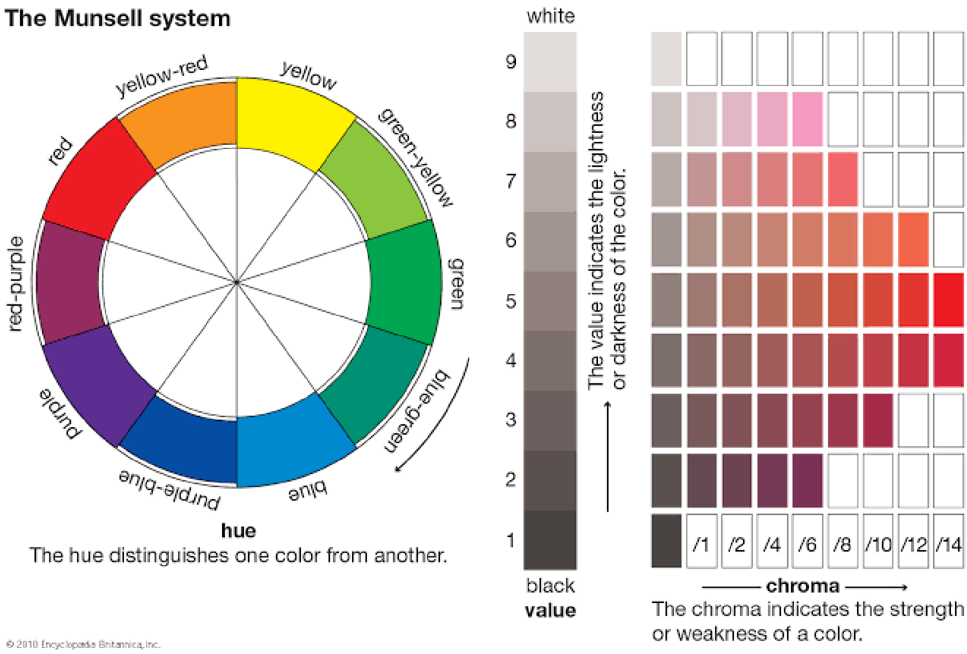
❖ SOIL COLOUR

Soil color is one of the characteristics of soil and is frequently used to describe soil. Soil color, as such, does not have any influence on plant growth, but through its influence on soil temperature and soil moisture, it indirectly influences the plant growth. Soil colour can be an indicator of the climatic condition under which a soil was developed or of its parent material (litho chromic color). Soil color is also taken as criteria for assessing soil productivity. Practically all colours occur in soils, except pure blue and pure green. Predominantly, soil colors are not pure but mixtures, such as grey, brown and rust. Frequently, two or three colours occur in patches, which is called as "**mottling**".The colour of the soil is a composite of the colours of its components.

a. Humus – brown or dark brown.

b. Iron oxides – red, rust – brown, or yellow depending upon degree of hydration.
c. Reduced iron – blue green
d. Quartz - white
e. Lime stones – white, gray or sometimes olive green.

Colour components: As the soil color is the important parameter, used to classify the soils, a standard system for accurate colour description has been developed using Munsell color charts. In this system, a small piece of soil is compared to standard colour chips in a soil colour book. Each colour chip is described by the three components of colour i.e., **hue, value and chroma.**



Hue refers to the dominant spectral colour or quality which distinguishes red from yellow etc.

Value or brilliance expresses apparent lightness as compared to absolute white. It refers to relative brightness or darkness of colour with in a scale of (0 –10) as compared to absolute white. I t refers to gradations white to black (lightness or darkness).

Chroma defines the gradations of purity of colour , or the apparent degree of departure from neutral grays to white (intensity or brightness) (strength of colour), with in a scale ranging from (0 – 20).

The numerical notation 2.5 YR 5/6 suggests a hue of 2.5 YR, value of 5 and chroma of 6.

Significance of soil colour

1. Colour is taken as a diagnostic criterion for classifying soils e.g. the comprehensive system uses color as formative element in its nomenclature as alb (white), ochr (light coloured), umbr (dark), sambr (dark).
2. Soil color can be guide to the climatic soil group, to the parent material, or to the physiographic location.
   a) Humid temperate regions – Grayish;
   b) Tropics and sub tropics – red and yellow
3. The productivity of the soils is assessed based on soil color e.g. dark color is an indication of high productivity.

   Black > brown > rust brown > gray brown > red > gray >yellow > white.
4. Colour indicates the presence / domination of the constituent minerals in the soil e.g. light colour results from preponderance of quartz mineral, red colour remits from domination of iron rich compounds.
5. Colour is used to describe soil profile.
6. Soil color is indicative of presence of excessive salts.
7. Soils derived from basic rocks are darker than soils derived from acidic rocks.