Agriculture for Engineers

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Lesson 1. Nature and Origin of Soil

1.1 INTRODUCTION

Soil is defined as a dynamic natural body on the surface of the earth in which plants grow, composed of mineral and organic materials and living forms.

The soil is made-up of broken down rock material of varying degree of fineness and changed in varying degrees from the parent rocks by the action of different agencies such that the growth of vegetation is made possible.

1.2 ORIGIN OF THE EARTH

The earth is a minute part of the universe. Moving around the sun are nine spheroidal bodies called planets. Our earth is one of these nine planets. There are several hypotheses regarding the origin of these planets from the sun. According to the early **nebular**hypothesis, the solar system once existed as an incandescent mass of gases. During the process of cooling, it threw out rings of nebulae. These rings on disruption and further cooling condensed themselves into planets. The **'planetisimal**' hypothesis of Chamberlain and Moulton was proposed in 1900 and is the most generally accepted. Millions of stars rush at high velocities through space. One of these stars, probably bigger than our sun, happened to pass near enough to exert a gravitational pull on the sun and tear out a glowing mass of incandescent vaporous material into the limitless emptiness of space. The incandescent mass continues spinning in an elliptical path round the sun. These masses gradually cooled off into solid planetary nuclei or planetisimals. In the course of thousands of millions of years, most of these planetisimals combined by collusion and accretion and formed our solar system.

1.3 THE EARTH'S CRUST AND ITS COMPOSITION

Classically there are three divisions of earth's sphere corresponding to the solid, liquid and gas, which constitute the Earth. The solid zone is the **Lithosphere**. The outermost 10 mile strata of the lithosphere are called the 'earth crust'. The incomplete covering of water forming seas and oceans is the **Hydrosphere** and the gaseous envelope over the earth's surface is the **Atmosphere.**

The earth's crust is principally composed of mineral matter. Altogether, 109 elements known to us are found in earth crust in various combinations to form compounds. Oxygen is most abundant element but it usually occurs in combination with other elements. The composition of earth crust is given below (Table 1).

Table 1.1 : Composition of earth crust

Element	O	Si	Al	Fe	Ca	Mg	Na	K	Others
Per cent	46	27	8	5	4	2	3	3	2

Out of 109 elements known, 8 are sufficiently abundant as to constitute 98.6 per cent (by weight) of the earth's crust (up to 16 km). The two elements occurring in greatest abundance are non metallic (oxygen and silicon) and comprise nearly three-fourth (75%) of the total composition of the crust. Most of the hard, naturally formed substance of the earth is referred to as rock. Rock is composed of elements. The materials of the earth's crust fall into two principal categories, namely minerals and rocks.

In the process of cooling, the elements began to combine into compounds. The compounds so formed aggregated into large masses giving rise to a variety of minerals. These mineral masses got cemented or pressed into the rocks, as they are now present in the earth's crust. These rocks were then exposed to the action of weathering agencies over thousands of years. The disintegrated rocks gradually evolved into the soils. Therefore, knowledge of the important soil forming rocks and minerals and the processes of weathering is required.

1.4 COMPONENT OF SOILS (VOLUME BASIS)

The soil consists of four major components (Fig.1.1) i.e. mineral matter (45%), organic matter (5%), soil air (20-30%) and soil water (20-30%).

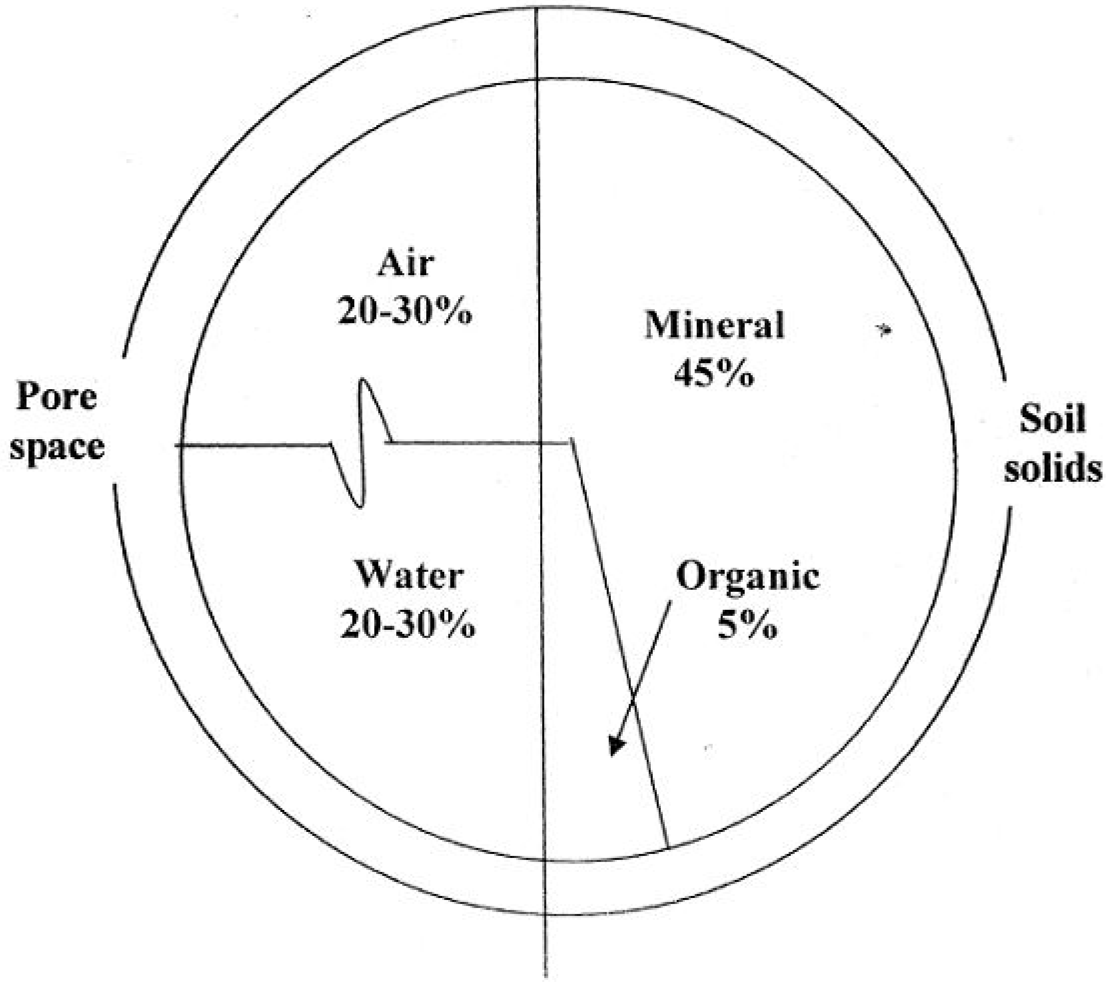


Fig.1.1 : Four major components of soils (volume basis)

1. Mineral matter

The minerals are extremely variable in size. Some are as large as the smaller rock fragments, others, such as colloids clay particles, are so small that they cannot be seen without the aid of an electron microscope.

2. Organic matter

Soil organic matter represents partially decayed and partially synthesized plant and animal residues. Such material is continually being broken down by the action of soil microorganisms. Consequently, organic matter is a transitory soil constituent and renewed constantly by the addition of plant residues.

3. Soil water

Soil water is the major component of the soil in relation to the Plant growth. The water is held within the soil pores. If the moisture content of a soil is optimum for plant growth, plants can readily absorb water. Soil water dissolves salts and makes up the soil solution, which is important as a medium for supplying nutrients to growing plants. There is an exchange of nutrients between the soil solids and the soil solution and then between the soil solution and plants roots.

4. Soil air

A part of the soil volume that is not occupied by soil particles, known as **pore space**, is filled partly with soil water and partly with soil air. As the pore space is occupied by both water and air, volume of air varies inversely with water. As the moisture content of the soil increases, the air content decreases and vice-versa.

Lesson 2. Rocks and Minerals

2.1 INTRODUCTION

A rock is consolidated mass of one or more minerals. Rocks are mixture of minerals and therefore, their physical and chemical compositions vary with the characteristics of minerals present in them. Rock is formed due to cooling and solidification of molten magma. It is mixture of one or more minerals. First igneous rocks are formed. Then it is converted to sedimentary or metamorphic rock.

Petrology is a science of rocks which consists of petrography deals with the description and petrogenesis- study of the origin of rocks.

2.2 CLASSIFICATION

Rocks are divided into three natural groups based on mode of origin or formation. These are:

1. Igneous rocks: formed from molten material on cooling
2. Sedimentary rocks: formed from sediments under pressure
3. Metamorphic rocks: formed from pre-existing rocks through action of heat and pressure

2.2.1 Igneous rocks (Latin ignis, means fire)

The igneous rocks are formed by solidification of molten material (magma). All rocks formed directly from molten material are called **igneous**. These rocks are first to form and hence they are called as oldest rocks. The igneous rock make up about 95 % of the earth's crust and about 88% of the mass of these rocks consist of feldspars, quartz and amphiboles.

Igneous rocks, on the basis of the depth of formation, are classified into:

(1) Plutonic - When the magma solidifies at great depth, about 2 to 3 miles deep under the surface of the earth, the igneous rock formed is called **plutonic** e.g. granite, synite, gabbro, norite etc. These are crystalline rocks as the sizes of crystals are big.

(2) Intrusive or dyke - When the magma solidifies at moderate depth is called **Intrusive or dyke** e.g. pegmatite, dolerite. The crystals are of smaller size in the rock. The rocks consolidated in vertical cracks and formed wall like masses are known **dykes**, whereas those consolidated in horizontal cracks are known as **sills.** In some cases the molten material is consolidated in irregular and narrow cracks is called a **vein** (Fig. 2.1)

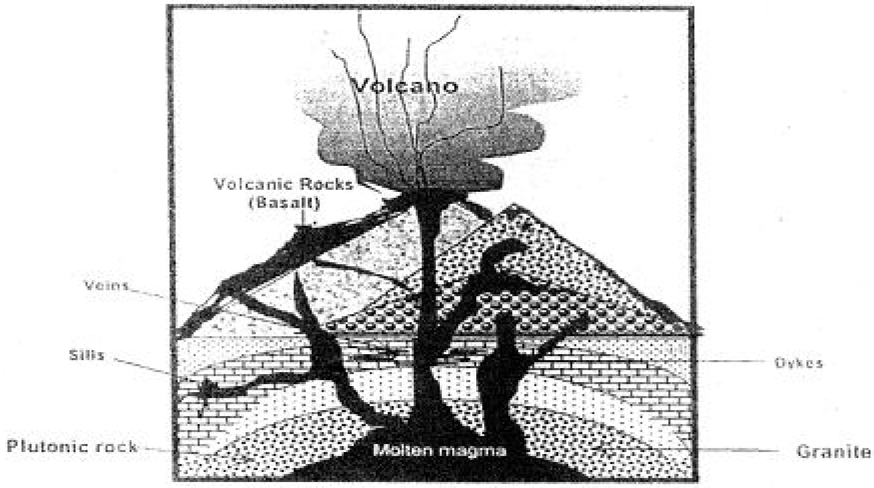


Fig.2.1: A schematic diagram of volcanic eruption showing the occurrence of plutonic (intrusive) and volcanic (extrusive) igneous rocks.

(3) Extrusive or effusive - When the solidification takes place on the surface of the earth as a result of volcanic activities, the igneous rock formed is called **Extrusive or effusive**e.g. rhyolite, pumis, chalcidian, basalt, trap. On the basis of percentage silica content, igneous rocks are divided into:

(a) Acidic: SiO_2 content is more than 65% e.g. granite, pegmatite, rhyolite

(b) Intermediate: SiO_2 content is between 55 and 65% (sub-acidic SiO_2 60% to 65%, e.g. syenite; sub-basic, SiO_2 55 to 60 % e.g., diorite)

(c) Basic: SiO_2 content is between 44 and 55 % e.g. basalt and

(d) Ultra basic: SiO_2 content is less than 44% e.g. picrite.

2.2.2 Sedimentary rocks (Latin sedimentas, means settling)

As soon as igneous rocks are exposed to weathering processes, they start breaking down physically and chemically into soluble and insoluble products when transported by water or glaciers form new deposits which in time become cemented and solidified into new forms of rocks called the **sedimentary rocks.** Stratification is the most common feature of these rocks, so they are also termed as **stratified rocks**. e.g. lime stone, sand stone, silt stone, shale and conglomerate.

Water plays important role information of these types of rocks so they are also known as aqueous rocks. The different layers are formed by sediment deposition, which are cemented together with silica, lime, iron oxide etc., although the sedimentary rocks form only 5% of the earth crust. They are of great importance because they occur extensively at or near the surface and are source of important product used in agriculture or industry.

Depending upon grain size sedimentary rocks are grouped as:

(1) Rudaceous: If the individual grains forming rocks are of the size of boulders and pebbles, called **rudaceous.** Grit - is composed of sharp and angular pebbles, Shingle- is composed of large rounded pebbles, **Conglqmemte**- consist of rounded or sub angular pebbles, and **Breccja** – angular fragments.

(2) Arenaceous: These rocks have individual grains of sand size e.g. sand stone.

(3) Argillaceous: These rocks have individual grain size of clay. In their formation, these may either have loose or consolidated rocks with various clays or loose sediments. China clay (Kaoline) - formed , from decomposition of feldspar, Pipe clay - Iron free clay, Fire clay - Free from lime and alkalies and Laterite - Reddish clay formed by decomposition of basalt and granite.

2.2.3. Metamorphic rocks

Metamorphic rocks are formed from igneous and sedimentary rocks through action of heat, pressure and chemically, active liquids and gases. Metamorphism may result in changes mainly physical, chemical or both. Heat, pressure and water are called agents of**metamorphism.** Thus, when igneous and sedimentary rocks are subjected to tremendous pressure and high temperature, metamorphism takes place and metamorphic rocks are formed. e.g.

1. Sands tone $\xrightarrow{\text{Heat \& Pressure}}$ Quartzite
2. Shale $\xrightarrow{\text{Pressure}}$ Slate
3. Lime stone $\xrightarrow{\text{Heat}}$ Marble
4. Granite $\xrightarrow{\text{Pressure}}$ Gneiss (complete foliation, distinct separable layers)
5. Basalt $\xrightarrow{\text{Pressure}}$ Schist (slight foliation, not distinct layers)

2.3 Occurrence of soil forming rocks

The composition of the upper 5 km of the Earth crust is as follows:

Sedimentary rocks - Shales 52 %

- Sandstones 15 %

- Limestones and dolomite 7 %

Igneous rocks - Granite 15 %

- Basalt 3%

Other rocks - 8%

So it is found that five kinds of rocks mentioned above occupy more than 9O% of the total continental area.

2.4 MINERALS

Minerals are naturally occurring Solid homogeneous substances composed of atoms having an orderly and regular arrangement with definite chemical composition and a characteristic geometric form as Quartz (SiO_2), orthoclase ($KAlSi_3O_8$), calcite ($CaCO_3$) , olivine [($Mg, Fe)_2 SiO_4$] and gypsum ($CaSO_4 .2H_2O$)

2.4.1 Classification

Minerals can be classified on the basis of their amounts, mode of origin, composition and specific gravity are given below:

(A) On the basis of origin and mode of formation

1. Primary minerals

When a mineral arises from the cooling and solidification of a molten mass is called**primary minerals**. e.g. (i) orthoclase feldspar –$KAlSi_3O_8$ (ii) plagioclase feldspar- $NaAlSi_3O_8$, (iii) anorthite feldspar - $Ca(Al_2Si_2O_8)$, (iv) quartz - SiO_2 , (v) hornblende - $Ca_2Al_2Mg_2Fe_3 Si_6O_{22}(OH)_2$ (vi) muscovite – $KAl_3Si_3O_{1O}(OH)_2$, (vii) biotite - $KAl(Mg.Fe)_3 Si_3O_{1O}(OH)_2$ and (viii) augite - $Ca_2(Al_2.Fe_4(Mg.Fe)_4 Si_6 O_{24}$

2. Secondary minerals

When it arises through the metamorphism or weathering of Primary or other pre-existing minerals, it is called secondary minerals e.g. (i) calcite - $CaCO_{3,}$ (ii) magnesite - $MgCO_3$, (iii) dolomite - $CaMg(CO_3)_2$, (iv) silirite - $FeCO_3$, (v) gypsum - $CaSO_4.2H_2O$, (vi) apatite – $Ca_5(F,Cl)(PO_4)_3$, (vii) limonite - $Fe_2O3.3H_2O$, (viii) hematite- Fe_2O_3 and (ix) gibbsite – $Al_2O_3. 3H_2O$

3. Silicate clay minerals: kaolinite - $Al_4 [Si_4O_{10}] (OH)_8$, montmorillonite – $Al_2 [Si_4O_{1O}] (OH)_2.4H_2O$ and hydrous mica - $K_2Al_4 (AlSi_7)O_{2O} (OH)_4$

(B) On the basis of chemical composition

According to their chemical composition, minerals are divided into eight groups.

1. Silicate: These are the salts of silicic acid ($H4SiO4$). e.g. (i) muscovite – $KAl_3Si_3O_{10}(OH)_2$, (ii) biotite - $KAl(Mg.Fe)_3 Si_3O_{1O}(OH)_2$, (iii) epidote - $Ca_2(Al,Fe)Al_2O(OH)(SiO_4)(Si_2O_7)$, (iv) orthoclase feldspar – $KalSi_3O_8$, (v) zeolite – $CaAlSi_3O_{1O}.7H_2O$, (vi) olivine - $(Mg,Fe)_2SiO_4$ and (vi) amphibole - $(Na,Ca)_2.(Mg,Fe,Al)_5(Si,Al)_8O_{22}(OH)_2$

2. Native elements: The minerals of this group are made up of only one element. (i) graphite - C, (ii) diamond - C and (iii) sulphur - S.

3. Oxides: e.g. (i) quartz - SiO_2, (ii) hematite - Fe_2O3, (iii) geothite - $Fe_2O3. H_2O$, (iv) Limonite - $Fe_2O3\ 3H_2O$, (v) magnetite - Fe_3O_4, (vi) pyrolusite - MnO_2, (vii) rutile - TiO_2 and (viii) gibbsite – $Al_2O_3.3H_2O$

4. Sulphate: e.g. (i) gypsum - $CaSO_4. 2H_2O$, (ii) barite - $BaSO_4$ and (iii) gypsum anhydrite - $CaSO_4$,

5. Carbonate: e.g. (i) calcite - CaCO3. (ii) magnite - $MgCO_3$ and (iii) dolomite -$CaMg(CO_3)_2$.

6. Sulphide: e.g. (i) copper pyrite - CuS_2 and (ii) iron pyrite - FeS_2

7. Phosphate: e.g. (i) apatite – Ca_5 (F,Cl,OH,O)$(PO_4)_3$ Apatite is the source of P in soils.

8. Halides: e.g. (i) flurorite (Flurospar) - CaF_2 , (ii) rock salt (Halite)- NaCl and KCl

(C) Based on specific gravity

Depending on chemical properties minerals have different specific gravity. Based on Specific gravity (g/cm^3) mineral can be grouped into (i) Light minerals: The minerals having sp. gravity < 2.85 are called light minerals: e.g . quartz (2.6), feldspar(2.65), muscovite (2.5 to 2.75) and (ii) Heavy minerals: The minerals having sp. gravity> 2.85 are called **heavy minerals** e.g. hematite (5.3) pyrite (5.0), limonite (3.8), augite (2.9-3.8), olivine (3.5).

2.4.2 Clay minerals

Naturally occurring inorganic materials (usually crystalline) found in soils. There are mostly newly formed crystals reformed from the soluble 'products of the primary minerals and considered secondary minerals having a significant surface area.

The clay fraction of the soil particles has a diameter less than 0.002 mm. The mineral present in clay fraction of the soil is called **clay minerals.** Clay minerals use the most important secondary minerals. They are colloidal and crystalline in nature. They carry a negative electrical charge on their surface. Most of the physical, chemical and morphological properties of soils are influenced by these clay minerals.

Clay minerals are hydrous aluminium silicate, frequently with some replacement of aluminium by iron and magnesium. The three most important groups of silicate clay minerals are kaolinite (1:1 lattice non-expanding type), montmorillonite (2:1 lattice expanding type) and illite (2:1 lattice non-expanding type). The relative occurrences of minerals in soil are given in Table 2.1.

Table 2.1: Relative occurrences of minerals in soil

S. No.	Name of minerals	Distribution (%)
1	Feldspars	60
2	Quartz	12
3	Amphiboles and pyroxenes	17
4	Micas	4

5	Silicates	6
6	Rest of the minerals	1

Lesson 3. Soil Forming Processes

3.1 INTRODUCTION

Weathering is a natural process of breakdown and transformation of rocks and minerals into unconsolidated residues, called **regolith**. In other words, the process of transformation of solid rocks into soils is known as weathering. Weathering processes are two types: (1) physical weathering brought about by the mechanical action of the various weathering agents, is designated as **disintegration,** and (2) chemical weathering is designated as **decomposition**.

3.2 PHYSICAL WEATHERING

It is a mechanical process, causing disruption of consolidated massive rocks in to smaller bits without any corresponding chemical change. Various weathering agents are:

1. **Temperature**: The alternate expansion and contraction of rocks due to variation in temperature produce cracks. The number of cracks slowly increases and the rock gets broken in to pieces. This phenomenon is referred to as 'exfoliation'. The dark coloured rocks are subjected to fast changes in temperature as compared with light colored rocks. The cubical coefficient of expansion of feldspar and quartz present in most of the rock is 1 : 2.
2. **Water**: In cold region, water freezes in rock joints and cracks. On freezing, the water expands in volume by about 9.0 per cent with a force of 150 tons per square foot. Due to this tremendous pressure the rock splits and is broken up into a loose mass of stones. The moving water has a tremendous transport capacity which by rolling action grinds the rocks into pieces. A current moving at a speed of 15 cm, 30 cm, 1.2 m and 9 m / sec can carry fine sand, gravel, stone (1 kg) and boulders of several tons, respectively. Water through its erosion forces removes weathered parts of rock, thereby exposing fresh surface to weathering. The excavation and destructive action of water is called**denudation.**
3. **Wind:** Wind carrying particles in suspension and blowing constantly over the rock at great speed exerts a grinding action, thereby the rock gets disintegrated. Loosely balanced rock boulders sometimes roll down by the action of wind and break in to pieces. At a velocity of 5 m/sec particles of 0.25 mm size are transported, while at a velocity of 10 m/sec, the wind can carry particles of 1mm size.

3.3 CHEMICAL WEATHERING

Chemical weathering takes place mainly at the surface of rock minerals with the disappearance of certain minerals and the formation of secondary products. This is called chemical transformation. No chemical weathering is possible without the presence of water. The rate of chemical reaction increases with dissolved carbon dioxide and other solute in water, and with increases in temperature. The principal agents of chemical weathering are described below.

(a) **Solution**:

Some substances (halite, NaCl) present in the rock are readily soluble in water. When the soluble substances are removed by the continuous action of water, the rock no longer remains solid and falls to pieces very soon.

(b) **Hydration:**

Hydration means chemical combination of molecules with a particular mineral. Soil forming minerals occurring in rocks undergo hydration when exposed to humid condition e.g.

$$\underset{\text{Hematite (Red)}}{2Fe_2O_3} + \underset{\text{Water}}{3HOH} \longrightarrow \underset{\text{Limonite (Yellow)}}{2Fe_2O_3\ 3H_2O}$$

Due to this reaction the minerals increases in volume and become soft and more readily weatherable.

(c) **Hydrolysis**:

it is one of the most important processes in chemical weathering. Hydrolysis depends on the partial dissociation of water in to H-ions. Increases in H-ion concentration resulting in the accelerated hydrolytic action of water. Water thus, acts like a weak acidon silicate, e.g.

$$\underset{\text{Orthoclase}}{KAlSi_3O_8} + \underset{\text{Water (dissociated)}}{HOH} \longrightarrow \underset{\text{Acid silicate clay}}{HAlSi_3O_8} + \underset{\text{Potassium hydroxide}}{KOH}$$

$$\underset{\text{Al-oxide clay}}{2HAlSi_3O_8} + 8\ HOH \longrightarrow \underset{\text{Salicic acid}}{Al_2O_3\ .3H_2O} + 6H_2SiO_3$$

The products of hydrolysis are either wholly or partially leached by pre-cooling water. They may also recombine with other constituents to form clay. In a way, hydrolysis may be considered as **principal agent of clay formation.**

(d) **Oxidation:**

Oxidation means addition of oxygen is more active in the presence of moisture and results in hydrated oxides. Soil-forming minerals , containing iron, manganese etc. are more subjected to oxidation, e.g.

$$\underset{\text{Ferrous Oxide}}{4FeO} + \underset{\text{Oxygen}}{O_2} \longrightarrow \underset{\text{Ferric Oxide}}{2Fe_2O_3}$$

$$\underset{\text{Magnetite}}{4Fe_2O_4} + \underset{\text{Oxygen}}{O_2} \longrightarrow \underset{\text{Hematite}}{6Fe_2O_3}$$

A rusty-looking (red) crust is formed on the surface of the rock. The crust thickens and then slowly gets separated from the parent rock. As process continues, the change produced in the mineral weakens the rock and ultimately the rock itself crumbles to pieces.

(e) **Reduction**: This means the removal of oxygen. Under condition of excess water (less or no oxygen), reduction takes place e.g.

$$\underset{\text{Ferric oxide}}{2Fe_2O_3} \longrightarrow \underset{\text{Oxygen}}{O_2} + \underset{\text{Ferrous oxide}}{4FeO}$$

(f) **Carbonation**: carbon dioxide dissolved in water, it forms carbonic acid:

$$\underset{\text{Water}}{H_2O} + \underset{\text{carbon dioxide}}{CO_2} = \underset{\text{carbonic acid}}{H_2CO_3}$$

The carbonic acid or carbonated water attacks many rocks and minerals and brings them into solution. Limestone, which is insoluble in water, is dissolved readily by carbonated water and is thus, removed from the parent rock.

$$\underset{\substack{\text{Calcite}\\ \text{(Slightly soluble)}}}{CaCO_3} + \underset{\text{Carbonic acid}}{H_2CO_3} \longrightarrow \underset{\substack{\text{Calcium bicarbonate}\\ \text{(Readily soluble)}}}{Ca\,(HCO_3)_2}$$

3.4 SOIL FORMING PROCESSES (Pedogenic processes)

Most natural processes, such as the upliftment of a mountain mass and the tilling of an island in sea, take place rather slowly. In contrast, the pedogenic processes, work faster than the geological processes in changing lifeless parent material into true soil full of life. The pedogenic processes are extremely complex and dynamic involving many chemical and biological reactions, and usually operate simultaneously in a given area. One process may counteract another, or two different processes may work simultaneously to achieve the same result. The ultimate result of soil formation is profile development.

A. Fundamental soil forming processes

(1) Humification

Humification is the process of decomposition of organic matter and synthesis of new organic substances. It is the process of transformation of raw organic matter into formation of surface humus layer, called A_O- horizon. The percolating water passing through this layer dissolves certain organic acids and affects the development of the lower A-horizon and the B- horizon.

(2) Eluviation and illuaviation

Eluviation is the process of removal of constituents by percolation from upper layers to lower layers. This layer of loss is called **eluvial** and designated as the A-horizon. The eluviated producers move down and become deposited in the lower horizon which is termed as the **illuvial** or B-horizon. The eluviation produces textural differences. The process of illuviation leads to the textural contrast between A_2 and B_1 horizon.

B. Specific soil forming processes

(1) Podsolisation

It is a type of eluviation in which humus and sequioxides become mobile, leach out from upper horizons and become deposited in the lower horizons. This process is favoured by cool and wet climate. It requires high content of organic matter and low alkali in the parent material. The process increases the proportion of silica, sesquioxide in A-horizons and accumulation of clay, iron and aluminum in B-horizons.

(2) Laterisation

In this process, silica is removed while iron and alumina remain behind in the upper layers. Laterisation is favoured by rapid decomposition of parent rocks under climates with high temperature and sufficient moisture for intense leaching, such as found in the tropics. The soil formed in this process is acidic in nature.

(3) Clacification

In this process, there is usually an accumulation of calcium carbonate in the profile. This process is favoured by scanty rainfall and alkali in parent material.

(4) Gleization

The term *glei*is of Russian origin, which means blue, grey or green clay. The*gleization*is aprocess of soil formation resulting in the development of a glei (orgley horizon) in the lower part ofthe soil profile above the parent material due to poor drainage condition (1ack of oxygen) and where waterlogged conditions prevail. Under such condition, iron compounds are reduced to soluble ferrous forms. This is responsible for the production of typical bluish to grayish horizons with mottling of yellow and *I* or reddish brown colours.

(5) Salinization

Salinization is the process of accumulation of salts, such as sulphates and chlorides of calcium, magnesium, sodium and potassium, in soils in the form of salty (salic) horizons. It is quite common in arid and semi arid regions. It may also take place through capillary rise of saline groundwater and by inundation with seawater in marine and coastal soils. Salt accumulation may also result from irrigation or seepage in area of impeded drainage.

(6) Desalinization

It is the removal by leaching of excess soluble salts from horizons or soil profile by ponding water and improving the drainage conditions by installing artificial drainage network.

(7) Solonization (Alkalization)

The process involves the accumulation of sodium ions on the exchange complex of the clay, resulting in the formation of sodic soils *(solonetz)*.

(8) Solidization (dealkalization)

The process refers to the removal of Na^+ from the exchange sites. This process involves dispersion of clay. Dispersion occurs when Na^+ ions becomes hydrated. Much of the dispersion can be eliminated if Ca^+ and Mg^{++} ions are concentrated in the water, which is used to leach the **solonetz**. These Ca and Mg ion can replace the Na on exchange complex, and the salts of sodium are leached out.

(9) Pedoturbation

Another process that may be operative in soils is pedoturbation. It is the process of mixing of the soil e.g. argillipedoturbation is observed in deep black soils.

Lesson 4. Classification of Soil - Taxonomy Orders

4.1 INTRODUCTION

In order to overcome different anomalies in earlier system of soil classification a new comprehensive system has been developed. Initially started in 1951, several approximations were made after taking critical suggestions from pedologists of different countries. The 7^{th} approximation was published in 1960 with supplements in 1964 and 1967. "Soil Taxonomy - A Basic System of Soil Classification for Making and Interpreting Soil Surveys" was published in 1975. The 7^{th} approximation lays more stress on the morphology of soils themselves rather than on the environmental factors.

4.2 CHARACTERISTICS OF SOIL CLASSIFICATION-

7^{th} 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 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.

4.3 CATEGORIES

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.

(i) Order: The order is based on soil forming process. In a given order, soil properties are similar in their genesis. There are following eleven soil orders in soil taxonomy (Table 4.1).

Table 4.1: Soil orders, its formative elements and their major characteristics

	Soil order	Formative element	Major characteristics
1	Entisols	**ent**	Little profile development, Ochric epipedon common
2	Inceptisols	**ept**	Embryonic soils with few diagnostic

			features, Ochric or umbric epipedon; Cambic horizon
3	Mollisols	**oll**	Mollic epipedon, high base saturation, dark soils, some with a horizons
4	Alfisols	**alf**	Argillic or nitric horizon; high to mediumbase saturation
5	Ultisols	**ult**	Argillic (clay) horizon; low basesaturation.
6	Oxisols	**ox**	Oxic horizon, no argillic horizon, highlyweathered.
7	Vertisols	**ert**	High in swelling clays, deep cracks whensoil dry, dark colour.
8	Aridisols	**id**	Dry soil, ochric epipedon, sometimes argillic or nitric horizon.
9	Spodosols	**od**	Spodic horizon commonly with Fe, Al, and humus accumulati
10	Histosols	**ist**	Peat or bog; more than 30% organic matter(organic soil).
11	Andisols*	**and**	From volcanic ejects, dominated by allophane or Al-humic complexes.
12	Gelisols	**el**	Permafrost often with cryoturbation (frostchurning)

*Recently added as a soil order.

(ii) 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 recognized (Table 4.2).

Table 4.2: Formative elements in names of suborders.

Formative Element	Derivatives	Connotation of formative element
alb	L. albus, white	Presence of albic horizon (a bleached eluvial horizon)

anthr	Gk.anthropos, human	Presence of anthropic or plaggen epipedon
aqu	L. aqua, water	Characteristics associated with wetness
ar	L. arare, to plow	Mixed horizon
arg	L. argilla, white clay	Presence of argillic horizon (with illuvial clay)
calc	L. calcis lime	Presence of calcic horizon
camb	L. cambriar, to change	Presence of cambric horizon
cry	Gk. kryos, icy cold	Cold
dur	L. durus, hard	Presence of a duripan
fibr	L. fibra, fibre	Least decomposed stage
fluv	L. fluvius, river	Floodplain
fol	L. folia, leaf	Mass of leaves
gyps	L. gypsum, gypsum	Presence of gypsic horizon
hem	Gk. hemi, half	Intermediate stage of decomposition
hist	Gk. histos, tissue	Presence of histic epipedon
hum	L. humas, earth	Presence of organic matter
orth	Gk. orhos, true	The common ones
per	L. per, throughout time	Of year-round humid climates, perudic moisture regime
psamm	Gk. psammos, sand	Sand textures

rend	Modified from rendzina	Rendzinalike-high in carbonates
sal	L. sal, salt	Presence of salic · (saline) horizon
sapr	Gk. sapros, rotten	Most decomposed stage
torr	L. torridus, hot and dry	Usually dry
turb	L. turbidus, disturbed	Cryoturbation
ud	L. udus, humid	Of humid climate
ust	L. ustus, burnt	Of dry climates, usually hot in summer
vitr	L. vitreus, glass	Resembling glass
xer	Gk. xeros, dry	Dry summers, moist winters

(iii) Great group: Diagnostic horizons are the primary bases for differentiating the great group in a given sub-order. Nearly 230 great groups are recognized.

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

(v) Family: The family is differentiated on the basis of texture, mineralogy, and temperature and soil depth. Some 6600 families are recognized.

(vi) 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 arrangement of horizons. About 16,800 soils series are recognized.

4.4 Nomenclature in soil taxonomy:

1. **Order**: ends with - Soil e.g. arid soil.

2. Sub-order: It is composed of formative element of order + any differentiating character like temperature, moisture, drainage, diagnostic horizon etc. e.g. Aquolls wet soil-Mollisols (oil), Aquents wet soil- Entisols (ent), Argid aridi soil (id).

3. Great group: It is composed of order + sub-order + one or more specific characters which modify the sub-order e.g. Argiaqoll Molli soil –order, aqoll - sub-order wetness, Arg -argillic horizon.

4. Sub-group: It is identified with a binomial nomenclature. e.g. A 'Typic' adjective is used when sub-group represent a 'Central concept' of the great group. e.g. Typic Argiaqoll. There are integrated between different sub-groups or between great groups in the same order.

5. Family: In nomenclature of family- we have textural class, mineralogy, temperature regime and some time reaction, drainage class and topography. e.g. Fine-clay/Very fine clayey, mixed montmorillonitic, calcareous, hyperthermic, Typic Chromustert.

6. Series: Name of the series is given on the basis where it is described. e.g.

Soil Series	Sub-group	Great group	Sub-order	Order
Bodali	VerticUstorthents	Ustorthents	Orthents	Entisols
Eru	TypicChromusterts	Chromusterts	Usterts	Vertisols
Ilav	TypicUstorthents	Ustochrepts	Orthents	Inseptisol
Dandi	TypicHalaquepts	Halaquepts	Aquepts	Inseptisol

4.5 SOILS OF INDIA

Soils of India have been divided into the following eleven major groups:

(1) Red soils (2) Lateritic soils (3) Black soil (4) Alluvial soils (5) Desert soils (6) saline and alkaline soils (7) Peaty and marshy soils (8) *Tarai* soils (9) Brown hill soils (10) Sub-mountain soils (11) Mountain meadow soils.

Lesson 5. Soil Physical Properties and Soil Particle Distribution - I

5.1 INTRODUCTION

Physical properties of a soil greatly influence its use and behavior 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 behavior 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. The important physical properties of soils are (1) soil texture (2) soil structure (3) soil consistence (4) soil density (5) soil porosity and (6) soil colour.

5.2 SOIL TEXTURE

Soil texture refers to the relative proportion of particles of various sizes in a given soil or it refers to the relative percentage of sand, silt and clay in a soil.

A. Classification of soil separates

There are a number of systems of naming soil separates. They are: (a) The American system developed by USDA, (b) The English system, and (c) The International system. The international system which is commonly followed in India is given in Table 5.1.

Table 5.1: International system of naming soil separates

Soil Separate	Diameter range (mm)
Coarse sand	2.00 to 0.200
Fine sand	0.200 to 0.020
Silt	0.020 to 0.002
clay	< 0.002

Particle Size Analysis (Mechanical Analysis)

The mineral component constitutes the soil mass. This 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**. It is based on Stocke's law (1851) i.e. when soil particles are suspended in water they tend to sink and their velocity (V) of settling is proportional to the square of the radius (r) of each particle. The relation between the diameter of a particle and its settling velocity is given below:

$$V = \frac{2}{9} \times \frac{g\,(ds - dw)r2}{\eta}$$

Where, V == velocity of settling particle (cm/sec)

g == acceleration due to gravity (981 cm/sec^2)

ds ==density of soil particle (2.65 g/cc)

η ==coefficient of viscosity (0.0015 at 4°C)

dw == density of water (1.0 g/cc); r ==radius of spherical particle (cm)

To make a mechanical analysis, a sample of soil is crushed lightly in a wooden mortar. The material is next passed through the sieve is taken for mechanical analysis. The organic matter and other binding materials are 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 and hydrometer method. Pipette method is universally employed for carrying out mechanical analysis of soil.

B. Characteristics and physical nature of soil separates

Sands are large sized particles and have the large size of pore spaces. Hence, they facilitate percolation and encourage aeration. Their water holding capacity is low. They do not possess plasticity. Clay particles are smaller 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 (Table 5.2).

Table 5.2: Comparative characteristics of different soil separates

S. No.	Characteristics	Sand	Silt	Clay
1	Size (mm)	2.0-0.02	0.02-0.002	<0.002
2	Visibility	Visible by naked eye	Visible by ultra microscope	Visible by mic

3	Water holding capacity	Low	Medium	High
4	Total pore space	Least	Medium	Highest
5	Size of pore	Large	Medium	Very small
6	Air & water movement	Very rapid	Moderate	Slow
7	Plasticity, swelling, cohesion etc.	Very low	Moderate	Very high
8	Feel on rubbing between thumb and fingers	Gritty	Feel Like flour or talcum powder	Feel very plasti become hard u dry condition
9	Tillage	Easy	Moderate	Difficult
10	Fertility	Very low	Moderate	High
11	Minerals	Quartz dominates	Feldspar, Mica, hematite, Quartz	Kaolinite, montmorillonit illite
12	Chemical activity	Chemically inactive	Slightly active	Chemical activ

C. Textural classes

Textural names are given to soils based on the relative proportion of sand, silt and clay. So that are preponderantly clay are called clay (textural class); those with high silt content are silt (textural class); those with a high sand percentage are sand (textural class). A soil that does not exhibit the dominant physical properties of any of those three groups is called loam. The textural triangle (proposed by USDA) is used to determine the soil textural name after performing mechanical analysis in the laboratory (Fig. 5.1).

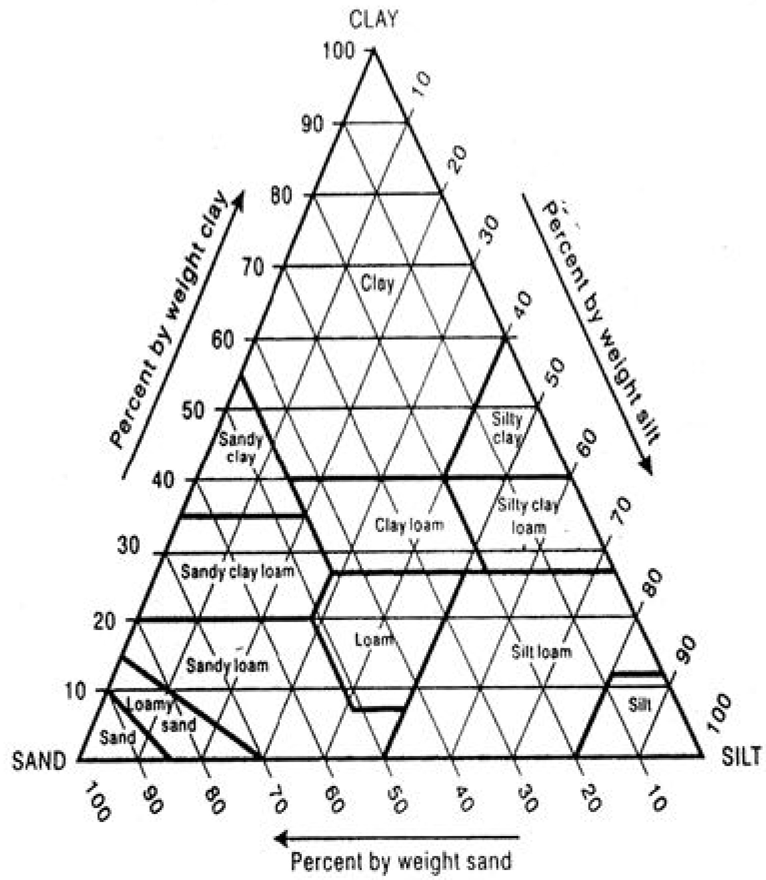


Fig. 5.1 Triangular textural diagram

5.3 SOIL STRUCTURE

The arrangement of soil particles and their aggregate into certain defined patterns is called**soil structure**. The primary soil particle sand, silt and clay usually occur grouped together in the form of aggregates. Natural aggregates are called **peds** where as **clod** is an artificially formed soil mass. Soil structure is studied in the field under natural conditions and it is described under three categories (Fig.5.2).

(1) Type: Shape or form and arrangement pattern of peds (in details)

(2) Class: Size of peds

(3) Grade: Degree of distinctness of peds.

A. Types of soil structure

There are four principal forms of soil structure -

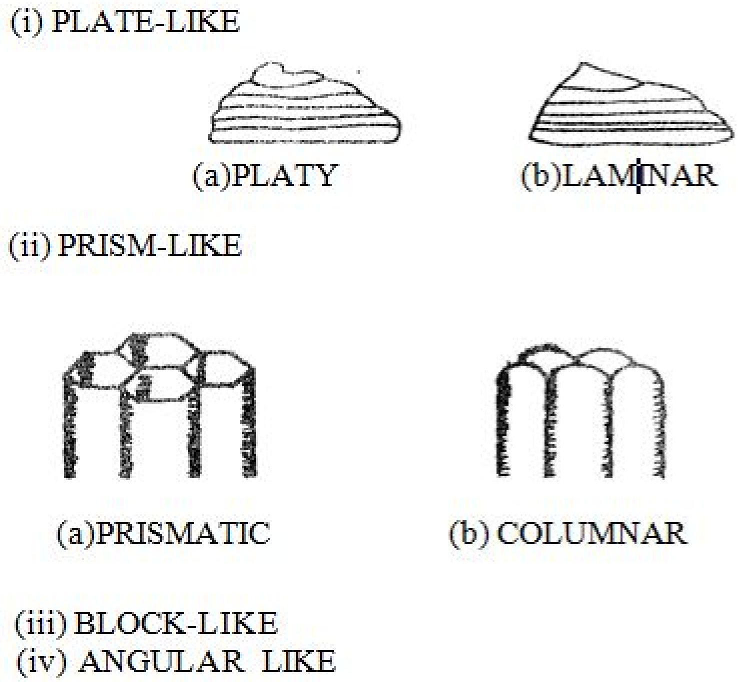


Fig.5.2: Types of soil structure

(i) **Plate like structure**: In this structural type of aggregates are arranged in relatively thin horizontal plates. The horizontal dimensions are much more developed than vertical. When the unit is thick, they are called **platy**, and when thin, **laminar** (fig.7). Platy soil structure is most notice able in the surface layers of virgin soils but may be present in the sub soil. Platy type is often inherited from the parent material, especially those laid down by water (fig.8).

(ii) **Prism like**: The vertical axis is more developed than horizontal, giving a pillar like shape. When the top of such a ped is rounded, the soil structure is termed as **columnar**, and when flat, **prismatic**. They commonly occur in sub soil horizons in arid and semi arid regions.

(iii) **Block like**: All these dimensions are about the same size and the peds are cube like with flat or rounded faces. When faces are flat and the edges sharp angular, the structure is named as **angular blocky**. When the faces and edges are mainly rounded it is called **sub angular blocky**. These types usually are confined to the sub soil and characteristics have much to do with soil drainage, aeration and root penetration.

(iv) **Spheroidal (sphere-like)**: All rounded aggregates (peds) may be placed in this category, although the term more properly refers to those not over 0.5 inches in diameter. These rounded complexes usually lie loosely and separately. The aggregates of this group usually termed as granular which are relatively less porous, when the granules are very porous, the term used is crumby (fig.9 a,b,c).

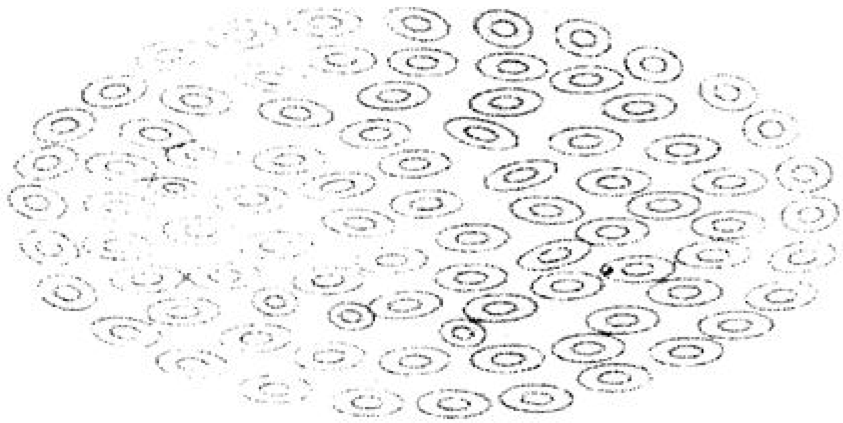


Fig.5.3: Example of sphere like structure

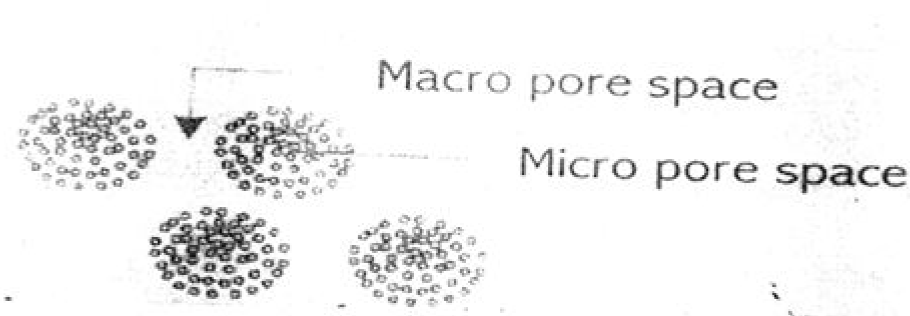


Fig 5.4 **Arrangement of particles in sphere like structure**

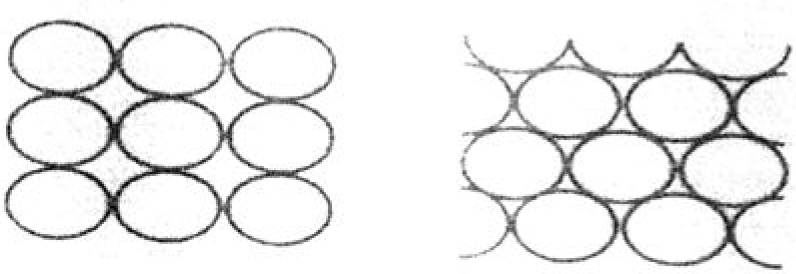


Fig 5.5 **Arrangement of sphere particles in two ways**

B. Structure Formation

The mechanism of structure (aggregate) formation is quite complex. In aggregate formation a number of primary particles such as sand, silt and clay are brought together by the cementing or binding effect of soil colloids to form a compound or secondary particles. It is mainly the arrangement of these secondary particles that imparts structure to a soil mass. The cementing materials taking part in aggregate formation are colloidal clay, iron and aluminum hydroxides and organic matter.

The mineral colloids (colloidal clay) by virtue of their properties of adhesion and cohesion, stick together to form aggregates. Sand and silt particles cannot form aggregates as they do not possess the power of adhesion and cohesion. The amount and nature of colloidal clay influence the formation of aggregates. The greater the amount of clay in a soil, the greater is the tendency to form aggregates. Clay particles smaller than 0.001 mm aggregates very readily.

Iron and aluminum hydroxide act as cementing agent in binding the soil particles together. These are also responsible for the formation of aggregates by cementing sand and silt particles. Organic matter plays an important part in forming soil aggregates. The humic acid and other sticky product produced during the decomposition of organic matter help in aggregate formation.

C. Factors affecting Soil Structure

The following factors influence the formation of soil structure in the arable condition.

(1) **Climate**: Climate influence the aggregate formation, in arid region, there is very little aggregation of primary particles while in semi arid region, the degree of aggregation is greater than arid region.

(2) **Organic matter**: Organic matter improves the soil structure in both sand and clay soils. During the decomposition the byproduct produced help in binding the various particles, while in clay soils it modifies the cohesion properties and their by improve the soil structure.

(3) **Tillage**: Cultivation or use of implements influence the soil aggregate, if at high moisture content tillage is carried out big clods may come out while at too low moisture will break the aggregates. Use of heavy implements will break the soil structure.

(4) **Plant roots**: The root secretions may also act as cementing agents and binds various soil particles. The plant roots, on decay, may also bring about granulation due to the production of sticky substances.

(5) **Fertilizers**: Certain fertilizer like sodium nitrate destroys the soil aggregates while calcium ammonium nitrate helps in the development of soil structure.

(6) **Wetting and drying**: When a dry soil is wetted, the soil colloids swell on absorbing water. On drying, shrinkage produced strains in the soil mass give rise to crack which break it up into clods and granules of various sizes.

D. Importance of Soil Structure

Soil structure influences indirectly by the formation of an array of pores of various shapes and sizes. These pores are controlling factors governing water, air and temperature in soil. The roles of soil structure in relation to plant growth are as under:

1. Soil structure influences the amount and nature of porosity.

2. Structure controls the amount of water and/air present in soil.

Not only the amount of water and air dependent on soil structure, but also their movement and circulation are also controlled by soil structure.

3. It affects tillage practices.

4. Structure controls runoff and erosion.

5. Platy structure normally hinders free drainage whereas sphere like structure helps in drainage.

6. Crumby and granular structure provides optimum infiltration, water holding capacity, aeration and drainage. It also provides good habitat for microorganism and supply nutrients.

Lesson 6. Soil Physical Properties and Soil Particle Distribution -II

6.1 SOIL CONSISTENCE

Soil consistence represents at varying moisture conditions, the degree and kind of cohesion and adhesion of soil material. **Cohesion**refers to the attraction of substances of like characteristics such as that are of one water molecule for another. **Adhesion** is attraction of unlike materials, for example, attraction between soil and water molecule. Consistence of soil depends on the texture, colloids, structure and especially the moisture content of soil. The consistency of soil is generally described at three soil moisture levels viz., wet, moist and dry.

A. Consistency when soil is wet

When soil is at field capacity the consistency is described m terms of stickiness and plasticity.

Stickiness: The quality of adhesion to other objects is called stickiness. The degree of stickiness is identified by the following terms: non sticky, slightly sticky, sticky and very sticky.

Plasticity: Plasticity is the capacity of the soil to mould. When stress is applied, the shape changed and after removing the stress it keep the changed shape, Terms used to describe the degree of plasticity are: non plastic, slightly plastic, plastic and very plastic.

B. Consistency when soil is moist

For slightly wet condition of the soil (moisture content between air dry and field capacity) consistency is described in the following terms.

Type	Characteristics
Loose	Non coherent
Very friable	Coherent but easily crushed
Friable	Easily crushed
Firm	Crushed under moderate pressure
Very firm	Crushed only under strong pressure
Extremely Firm	Resist crushing between thumb and forefinger

C. Consistency when soil is dry

Under dry condition of the soil (air dry) consistency is characterized by rigidity and hardness.

Type	Characteristics
Loose	Non coherent
Soft	Breaks under slight pressure between thumb and fore finger to a powdery mass
Slightly hard	Breaks under pressure
Hard	Breaks with difficulty under pressure
Very hard	Very resistant to pressure can not be broken between thumb and fore finger
Extremely	Extreme resistance to pressure cannot be broken in the hand hard.

D. Significance of soil consistence

Optimum soil consistence increases water holding capacity and plant food material. Thus, it increases the fertility of the soil.

E. Soil Crusting and Crust Formation

Soil crust is the thin compact layer of higher bulk density formed at the soil surface following dispersion of natural soil aggregates as a result of wetting or impact of raindrops or sprinkler irrigation and its subsequent rapid drying due to radiant energy of the sun.

When raindrops 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. Also, the dispersed soil may remain in suspension, coarse particles start to settle out but fine clay particles remain in suspension. As the water evaporates, clay settles on the top of coarse particles, forming a crust on drying. The soil particles tend to pull together due to surface layer with decreased porosity. Soil crusting is a major structural feature of soils of arid and semi-arid regions. Improved management of soil organic matter and use of certain amendments can help to prevent clay dispersion and crust formation.

6.2 SOIL DENSITY

Density represents weight (mass) per unit volume of a substance.

Density= Mass / Volume

Soil density is expressed in two well accepted concepts (A) particle density and (B) bulk density.

A. Particle density: The weight per unit volume of the solid portion of soil is called**particle density**. Particle density is also known as true density. Generally, particle density of normal soils is 2.65 g/cc. This is high when heavy mineral is present in the soil viz. magnetite and limonite. Increase in the organic matter the soil decreases the particle density. Particle density varies with texture of soils (Table 6.1).

Table 6.1 : Particle density of different soil textural classes

Textural class	Particle density (g/cc)
Coarse sand	2.655
Fine sand	2.659
Silt	2.798
Clay	2.837

B. Bulk density: The oven dry weight of a unit volume of soil inclusive of pore spaces is called **bulk density**. The bulk density of a soil is always smaller, than its particle density. Bulk density normally decreases as mineral soils become finer in texture. The Bulk density of organic matter is about 0.5 g/cc. The bulk density varies indirectly with the total pore space present in the soil and gives a good estimate of porosity of soil. Bulk density is of greater important than particle density in understanding the physical behavior of soils. Soils with low bulk densities have favorable physical conditions (Table 6.2).

Table 6.2: Bulk density of different soil textural classes

Textural class	Bulk density (g/cc)	Pore space (%)
Sandy soil	1.6	40
Loam	1.4	47
Silt loam	1.3	50
Clay	1.1	58

Using the bulk density of any soil the weight of that soil can be calculated unto the desired depth.

Example: If the bulk density of the cultivated field is 1.48 glee what will be the weight of hectare filed (soil) to the depth of 15 cm.

Volume of the soil (Field) of hectare filed (soil) to the = Length x Width x Depth

depth of 15 cm. = 100 x 100 x 0 .15

= 1500 cubic meter

1 cubic meter = 1 x 100 x 1 x 100 x 1 x 100 = 1000000 cubic centimeter

1500 cubic meter= 1500 x 1000000 = 1, 50, 00, 00,000 cubic centimeter

Weight of 1 cubic centimeter = 1.48 g

So in this case weight 1, 50, 00, 00,000 cubic centimeters will be

= 1, 50, 00, 00, 000 x 1.48 (Volume of 15 cm Hectare furrow x Bulk density)

= 2,22,00,00,000 g

i.e. 2, 20, 20, 00,000/1,000 = 22, 20,000 kg/ha to the depth of 15 cm

6.3 POROSITY OF SOIL

A. Pore space

The volume of soil mass that is not occupied by soil particles is known as **pore space**. This space is occupied either by air or water. It directly controls the amount of water and air in the soil and thus indirectly controls plant growth and crop production. There are two types of pore (i) Macro pore and (ii) Micro pore and both are important for crop growth.

(i) Macro pore or non capillary pore: Pores more than 0.06 mm in diameter are considered as macro pores. These pores allow readily movement of air and water and do not hold much water under normal condition. Sands and sandy soils have a large number of macro pores.

(ii) Micro pore or capillary pore: In contrast, in the micro pores, movement of air and water is restricted to some extent. Clays and clayey soils have a greater number of micro pores. Size of the individual pores, rather than total pore space in a soil is more significant in its plant growth relationship. Equal distributions of micro and macro pores are much desirable for better aeration, permeability, and drainage and water retention.

B. Soil porosity: Soil porosity is the percentage pores space. Porosity refers to that percentage of soil volume which is occupied by pore spaces. It can be calculated by the formula:

$$\text{Porosity} = 100 - \frac{\text{Bulk density}}{\text{particle density}} \text{X } 100$$

Since, % pore space + %solid space= 100 and

% pore space = 100 - % solid space

Example: A soil having bulk density of 1.3 and particle density of 2. 65 have the following percentage of pore space.

C. Factors affecting the soil porosity

(i) Soil texture: in sandy soils, pores are quite large, thus total pore space is less. In fine textures soils, there is possibility of more granulation and more total pore space because there are macro pores between individual particles and within granuals micro pores (Table 5.5).

Table 5.5: Relation between textural class and pore space

Textural class	Clay content	Av. Pore space (%)
Heavy clay	>55	51.09
Clay	40-55	48.45
Sandy clay loam	20-30	45.45
Sand	<10	42.54

(ii) **Soil structure**: Good aggregated soil structure is having greater pore space than the soil having single grain structure or structure less. Soil with same size aggregate but one is single grain structure while other is aggregate structure, more space will be in later on because of additional pore space between the primary particles. Granular or crumbly type of structure has more porosity than plate like.

(iii) **Arrangement of soil particle**: When the spheres like particles are arranged in columnar form it gives the most open system of packing. Thus, the number of pore space will be less. When the particles are arranged in the pyramidal form it gives the closest system of packing. So in this system porosity would be more.

(iv) **Organic matter**: Increasing in the organic matter content in the soil, increase in the percentage of pore space.

(v) **Micro-organisms**: Micro-organisms like earthworm and insects increase the macro pores in the soil.

(vi) **Depth of the soil**: Pore space in the sub-soil is generally low compared to surface soil layers.

(vii) **Cropping**: Cropping tends to lower the total pore space in comparison to virgin or un-cropped soils. This reduction is associated with a decrease in the organic matter content. Continuous cropping often results in a reduction of large or macro pore spaces (Table 6.4).

Table 6.4 : Effect of continuous cropping on total pore space

Soil Treatment	Organic matter %	Pore space %		
		Total	Macro	Micro

Virgin Soil	5.6	58.3	32.7	25.6
Cultivated Soil	2.9	50.2	16.0	34.2

6.4 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. The soil colour is best determined by the comparison with the Munsell colour.

The colour of the soil is a result of the light reflected from the soil. Soil colour rotation is divided into three parts:

Hue: It denotes the dominant spectral colour (red, yellow, blue and green)

Value: It denotes the lightness or darkness of a colour (the amount of reflected light)

Chroma: It represents the purity of the colour (strength of the colour)

The Munsell colour notations are systematic and letter designations of each of these three variables (Hue, Value and Chroma). For example, the numerical notation 2.5YR5/6 suggests a hue of 2.5 YR, value of 5 and chroma of 6.The equivalent or parallel soil colour name for this Munsell notation is red.

A. Soil colour and composition

(a) Black and dark gray colour: The variations from black to dark gray 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.

(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 occurs in ill drained soil.

(f) Mottling colour: Colour variation or mottling in soils indicates alternating oxidizing and reducing conditions due to a fluctuating water table.

Lesson 7. Soil Inorganic Colloids

7.1 INTRODUCTION

The colloidal state refers to a two-phase system in which one material in a very finely divided state is dispersed through second. e.g. (i) solid in liquid: clay in water (dispersion of clay in water) and (ii) liquid in gas: fog or clouds in atmosphere. The clay fraction of the soil contains particle less than 0.002 mm in size. Particles less than 0.001 mm a size passes colloidal properties and is known as ***soil colloids***.

7.2 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 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 or 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, then negative charge would be neutralized and the colloidal particles flocculate and settle down. Addition on any electrolyte brings all such dispersed particles flocculate and settle down. If the particles are deflocculated, the aggregates get dispersed, the soil gets water-logged, and 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, it carries a negative electric charge. Colloidal clay develop 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 posses the power of adsorption gases, liquid and even solids from their suspension. The phenomenon of adsorption is confined to the surface of colloidal particles, larger the surface area grater the adsorption for water, nutrients etc.

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 (Ca^{+2} & Mg^{+2}) are held more strongly than monovalent ion (Na^{+} & K^{+}). A trivalent cation (Al^{+3}) is most readily absorbed. Hydrogen ions (H^{+}) behave as polyvalent ions so are adsorbed more strongly than even $Ca^{+2.}$ Adsorption of anions (H_2PO_4, HPO_4^{-2}etc.)

increases with the lowering or increasing of pH. The adsoption 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 aluminum hydroxides in acid range and by calcium in alkaline range. Among the clay minerals, kaolinitic clay has a greater anion adsorbing capacity than montmorillonitic or illitic clay.

The property of adsorption plays an important role in soil fertility. Due to his property soils is able to held water and nutrients and keep them available to plant.

(5) Non-permeability: Colloids are unable to pass through a semi permeable membrane. The membrane allows the passage of water and of the dissolved substance through its pores, but remains the colloidal particle.

(6) Cohesion and adhesion: Unlike sand, clay particles possess the properties of cohesion. 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 and adhesion. The force of cohesion and adhesion are developed in the presence of water. When colloidal substances are wetted, water 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 microorganism.

(7) Swelling: A soil colloid when brought in contact with water they imbibe a certain quantity of water and swell and increases 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.

7.3 NATURE OF COLLOIDS

Soil colloids are of two kinds: (1) inorganic (minerals) and (2) organic (humus).

(1) **Inorganic colloids : (a)** Silicate clays (dominant in temperate regions) and **(b)** Iron and aluminum hydrous oxide clays (occurs in tropical and sub- tropical region soils)

(2) **Organic colloids :** Humus (dominant in temperate region soils)

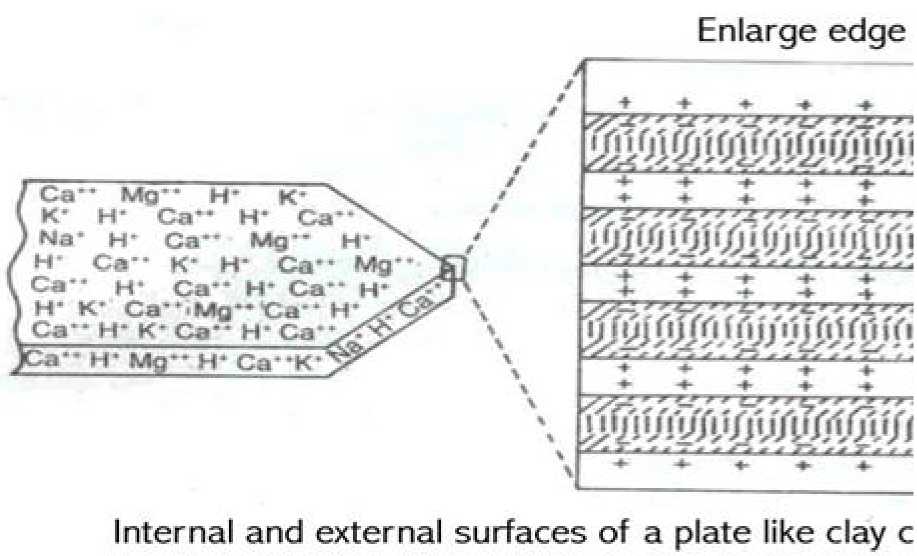
The two together form the colloidal complex of the soil. In almost all soils the inorganic colloids form a major portion of the colloidal complex. On the other hand, in peat soils, it consists almost entirely of organic colloids. Colloidal particles float in a medium and do not tend to settle. Colloids are referred as the dispersed system. The substance in solution is termed as the dispersed phase while the medium in which the particles are dispersed is called the ***dispersion medium.*** Soils formed in temperature regions usually contain more organic colloids than those formed in tropical and sub-tropical regions. In a broad way, two groups of clay are recognized silicate clay so characteristic of temperature regions and the iron and aluminium hydrous oxide clays found in tropical and semi-tropical.

A. Chemical composition and structure of colloids

The constitutions of colloids are (1) inorganic and (2) organic

1. Inorganic colloids

The chemical analysis of clay indicates the presence of 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 the important plant nutrients such as Mg^{+2}, Ca^{+2} and K^{+}. The shape of the individual particles is plate or flake-like.



The minute colloidal clay particle is technically called micelle and it possesses negative charges. The magnitude of –ve charge is different under conditions. Normally, as the pH increases, negative charges increases. Due to the formation of –ve charge, clay particle attracts +ve charged ions and thus it forms an ionic double layer.

Composition of silicate clay minerals

On the basis of number and arrange of silica and alumina sheets. Silicate clay may be classified into two types: (a) two layer type (1:1) and (b) three layer type (2:1)

The silicate clay minerals are composed of two types of sheets, (1) silica sheet (tetrahedral) and (2) alumina sheet (octahedral).

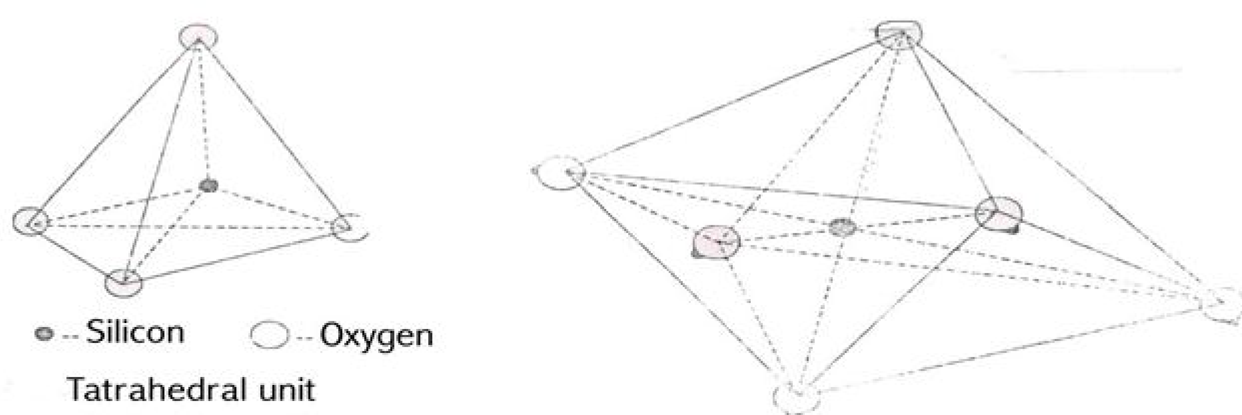


Fig. 7.1: (1) Silica sheet (tetrahedral) and (2) Alumina sheet (octahedral)

In a silica sheet one silicon cations is surrounded by four oxygen anions. The four-sided configuration is called as a ***silica tetrahedron***. An interlocking of a series of such silica tetrahedron horizontally by shared oxygen anions gives a tetrahedral sheet. Similarly in alumina sheet aluminium (or magnesium) ion is surrounded by six oxygen or hydroxyls gives an eight-sided configuration termed as **alumina octahedron**. Numerous octahedrons linked together horizontally give an octahedral sheet.

The tetrahedral and octahedral sheets are bound together in various combinations in different silicate clay by shared oxygen anions; such association is known as ***crystal units***.

(a) The two layer type (1:1)

It consists of one layer of silicon and oxygen atoms (SiO_2) and the other layer of aluminum and oxygen atoms (Al_2O_3), all in definite arrangement. e.g. kaolinite clay. 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.

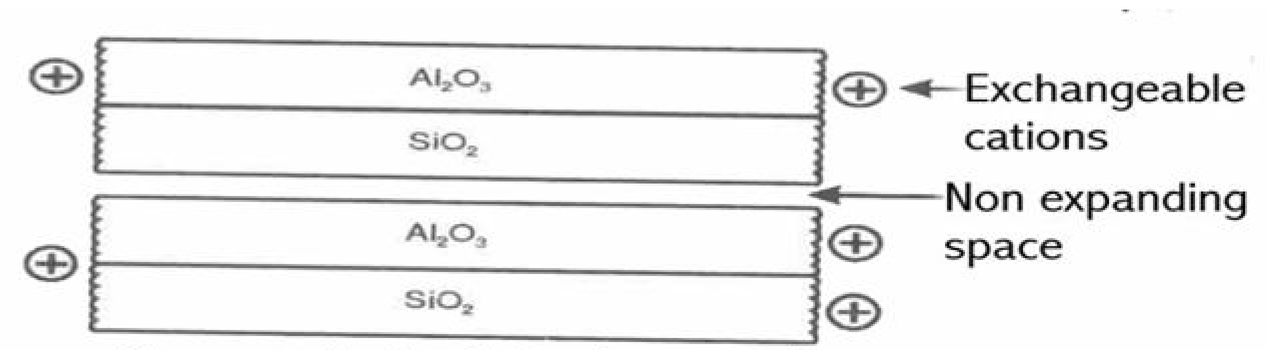


Diagram of a kaolinite clay crystal

(b) Three layer type (2:1)

Clay crystals have two outside layers made of silicon and oxygen (SiO_2) and the middle layer of aluminum and oxygen (Al_2O_3). i.e. montmorillonite. 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.

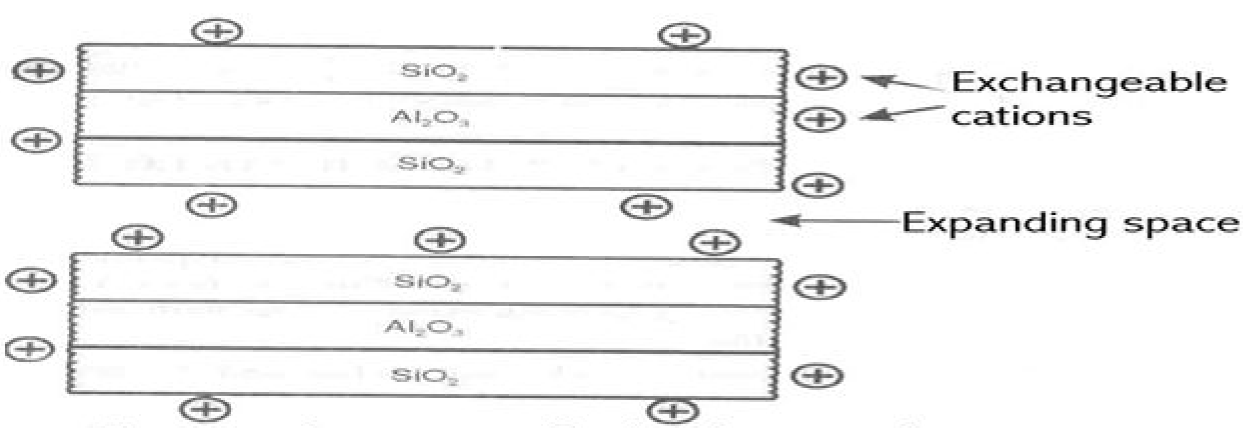


Diagram of a montmorillonite clay crystal

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 lattice structure). The structure is non-expanding type. Little is in between of kaolinite and montmorillonite type with regards to soil properties (Table 7.4).

Table 7.4: Properties of different types of clay minerals

Sr. No.	Property	Kaolinite	Montmorillonite	Illite
1	Structure	1:1 lattice (non expanding type)	2:1 lattice (expanding type)	2:1 lattice (non expanding type)
2	Size(micron)	0.1-5.0 (course particle)	0.01-1.0 (fine particle)	0.1-2.0 (medium particle)
3	Shape	Hexagonal crystals	Irregular flakes	Irregular flakes
4	Surface area (m^2/g)	5-20	700-800	11-120
5	Substitution	No substitution	Substitution in alumina sheet by Mg or Fe	Substitution in silica layer by alluminum
6	Non exchangeable cations	None	Magnesium	Potassium
7	Cation exchange capacity (me/100g)	3-15	80-100	15-40
8	Anion exchange capacity (me/100g)	High	Low	Medium
9	Cohesion	Less	High	Medium
10	Plasticity	Less	High	Medium
11	Swelling capacity	Less	High	Medium
12	Porosity	High	Low	Medium

13	Permeability	High	Low	Medium

Lesson 8. Charges on Soil Colloids

8.1 INTRODUCTION

Colloidal particles often have an electrical charge, some positive and some negative. When clay colloids suspended in water, it carries 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.

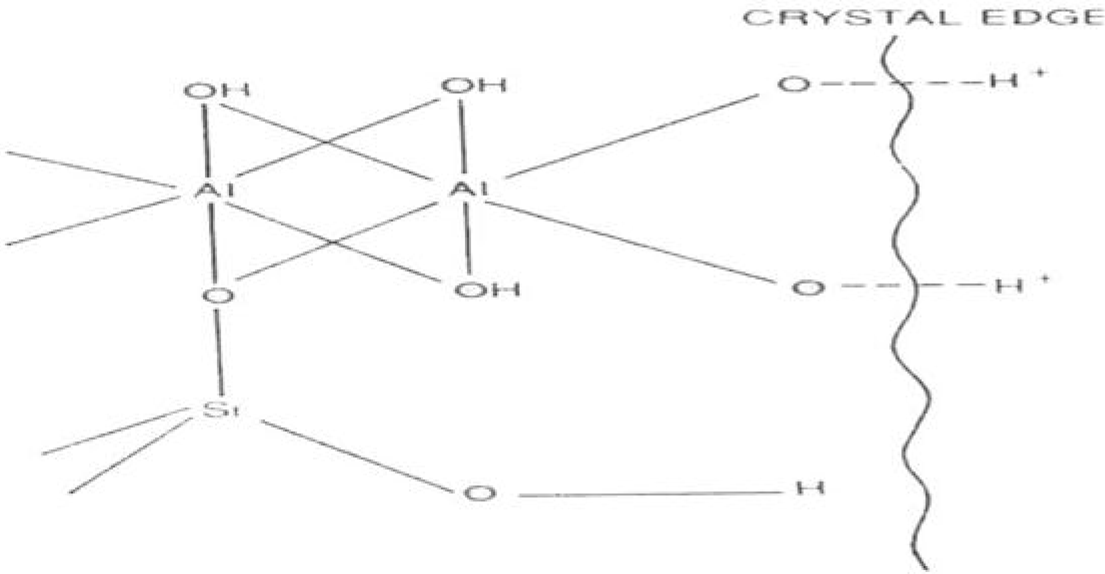
8.2. In organic colloids

8.2.1 Sources of negative charges on silicate minerals

There are two ways to account for the negative charges associated with silicate clay minerals.

(1) Dissociation of OH ion at the exposed crystal edges

This involves the unsatisfied valences at the broken edges of silica and alumina sheets. The external surfaces of mineral (kaolinite) have some exposed oxygen and hydroxyl groups which act as exchange sites. These groups are attached to Si and Al atoms within their respective sheets. At high pH, the H of these OH radicals dissociates slightly and colloidal surface is left with a –ve charge carried by the oxygen. The loosely held H is readily exchangeable (Fig. 8.1). This situation may be represented as follows:



OR

One O valence is

satisfied within -O- ....H^+ Adsorbed Hydrogen

the crystal by Al or Si

-ve charged crystal surface

Fig. 8.1 : Dissociation of OH^- at crystal edge

The presence of such group gives the clay a negative charge. The phenomenon accounts for most of the adsorbing capacity of 1: 1 type of colloidal clays. These are pH dependent charges of inorganic colloids. The magnitude of pH dependent charges varies with the type of colloids. It accounts for most of the charges of the 1: 1 type minerals and up to one forth of that of the 2: 1 types.

(2) Ionic substitution (isomorphous substitution)

The overall –ve charge carried out by clay crystal is the substitution of one atom by another similar size in a crystal structure of the minerals is known as ionic or isomorphous substitution. In 2: 1 type minerals magnesium atoms have substituted for the aluminum atoms in the alumina sheet. The substitution is on the basis of one Mg++ atom for each Al+++ atom replaced. Therefore, each substitution is results in an unsatisfied negative valence because a three valent atom is replaced by a two valent one. This is shown below.

Alumina sheet Alumina sheet

(No substitution) (Mg substituted for Al)

$O^{--}Al^{+++}OH^{-}$ $O^{--}Mg^{++}OH^{-}$

No net charge one excess negative charge

Similarly, in minerals such as beidellite and illite the substitution of three-valent atom such as Al for one of the four-valent silicon atoms in silica sheet leaves an unsatisfied negative valance. This represents below.

Silica sheet Silica sheet

(No substitution) (Al substituted for Si)

$O^{--}Si^{++++}O^{--}$ $O^{--}Al^{+++}O^{--}$

No net charge one excess negative charge

The charges resulting from ionic substitution are not pH dependent. So they are referred to as ***permanent charge.***

The source of negative or positive charge for kaolinite is the same and hence there is little difference in CEC and AEC. In kaolinite, pH dependent is the only source while in montmorillonite negative charge is mainly due to ionic substitution and only ¼ by dissociation of OH ion and therefore there is a wide difference between CEC and AEC in the montmorillonite .

The silicate clay minerals thus, posses negative charges due to isomorphous

Substitution and dissociation of OH ion. 'They can attract positively charged cations like Ca^{+2}, Mg^{2+}, K^+, Na^+, H^+. NH_4^+. These Cations are adsorbed on the clay surface. They are in exchangeable and available to the plants.

The cations and water are absorbed on the clay surfaces. In general the cations adsorbed on the surface of silicate clays are in the order of:

$$H^+ > Al_3^+ > Ca^{+2} > = Mg^{2+} > K^+ = NH_4^+ > Na^+$$

Certain cations are especially prominent under natural conditions.

(i) Humid region soils $Al_3^+ > H^+ > Ca^{+2} = Mg^{2+} > K^+ > Na^+$

(ii) Well drained and semi arid soils $Ca^{+2} > Mg^{2+} > Na^+ > K^+ > H^+$

(iii) Sodic or Alkali soils $Na^+ > Ca^{+2} > Mg^{2+} > K^+ > H^+$

8.3 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, aluminum and oxygen, as in clay colloids.

Organic soil colloids have higher adsorptive properties for water and cation exchange capacity than inorganic colloids. Humus is a temporary intermediate product left after considerable decomposition of plant and animal residues. Temporary because the organic substances remain continue to decompose slowly. The humus is usually referred to as an organic colloid and consists of various chains and loops of linked carbon, hydrogen atoms. Humus is amorphous and the size of the individual micelle is variable. Humus has three components viz., fulvic acid, humic acid and humin. The charge on humus colloids is pH dependent. Under strongly acid conditions hydrogen is rigidly bound and not easily replaceable by other cations. Humus colloid, therefore, exhibits a low negative charge.

Lesson 9. Ion Exchange in Soil

9.1 INTRODUCTION

Soil colloids are the seat of reaction. Ion exchange (cation and anions) takes place in colloids. The phenomenon of ion exchange is of great importance in agriculture. It has considerable influence on the liberation of plant nutrients such as Ca, K, P etc. It controls soil structure and crumb formation. It is also responsible for imparting a stable structure. It controls the processes plays an important role in the reclamation of acid and alkali soils. It also influences the effect of fertilizers and fertilizer practices.

Ion exchange is two types: (1) cation exchange or base exchange and (2) anion exchange or acid exchange. Ion exchange is a reversible process in which cation and anion exchanged between solid and liquid phase.

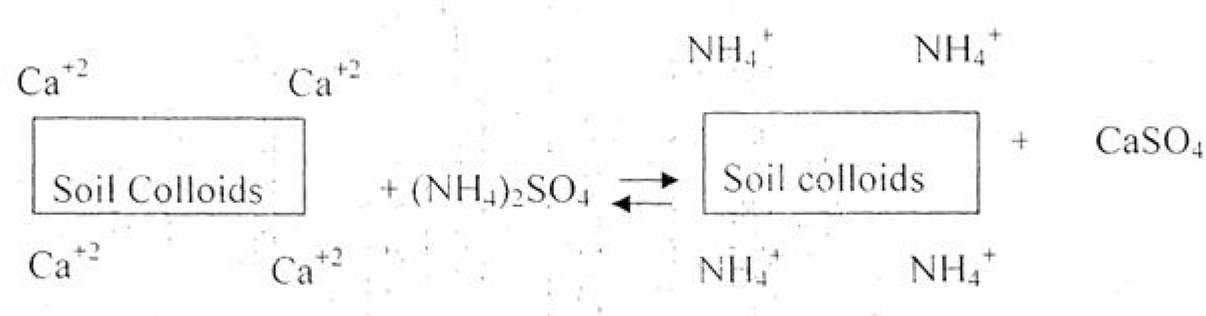
9.2 CATION EXCHANGE OR BASE EXCHANGE

In a near neutral soil, Ca is remaining adsorbed on colloidal particle H ion generated as organic and mineral acid formed due to decomposition of organic matter. In colloid, H ion is adsorbed more strongly than is the Ca and H is chemically equivalent.

The reaction is as follow:

$$Ca-\text{Clay Micelle} + 2H^+ \rightleftharpoons \begin{matrix} H \\ H \end{matrix} > \text{Clay Micelle} + Ca^{2+}$$

This phenomenon of the exchange of cations between soil and salt solution is known as**calion exchange** or **Base Exchange** and the cations that take part in this reaction are called**exchangeable cations.** It is the interchange between a cation in solution and another cation on the surface of clay or organic matter (colloids). **Thompson and Way (1892)** first recognised cation exchange phenomenon. They passed a solution of $(NH_4)_2SO_4$ through a soil column and found that effluent contained no $NH4^-$ salt but $CaSO_4$. This phenomenon is always in equivalent quantities of ions.



A. Types of silicate clay mineral

In case of kaolinite, monovalent cations are more strongly held than divalent, while in case of montmorillonite, divalent cations are strongly held than monovalent cations. The normal order of adsorbed cations on clay particles is:

$H^+ > Al^{+3} > Ca^{+2} = Mg^{+2} > K^+ = NH_4^+ > Na^+$.

B. Significance of cation exchange

Cation exchange is an important reation in soil fertility, in causing and correcting soil acidity and basicity. In changes altering soil physical properties, and as a mechanism in purifying or altering percolating Waters. The plant nutrients like calcium, magnesium and potassium are supplied to plants in large measure from exchangeable forms.

Cation exchange is very important in soils because of the following relationships:

(l) The exchangeable K is a major source of plant K.

(2) The exchangeable Mg is often, a major source of plant Mg.

(3) The amount of lime required to raise the pH of an acidic soil is greater as the CEC is greater.

(4) Cation exchange sites hold Ca^{+2}, Mg^{+2}, K^+, Na^+ and NH_4^+ ions and slow down their losses by leaching.

(5) Cation exchange sites hold- fertilizer K+ and NH_4^+ and greatly reduces their mobility in soils.

(6) Cation exchange sites adsorb many metals (Cd^{+2}, Zn^{+2}, Ni^{+2} and Pb^{+2}) that might be present in wastewater. Adsorption removes them from the percolating water, thereby cleansing the water that drains into groundwater.

9.3 Anion exchange

The process of anion exchange is similar to that of cation exchange. Under certain conditions hydrous oxides of iron and aluminium shows evidence of having positive charges on their crystal surfaces. The positive charges of colloids are due to addition of hydrogen (H^+) in hydroxyl group (OH^-) resulted in net positive charge (OH^{2+}). This positive charge will attract anions. The capacity for holding anions increases with increase in acidity. The lower the pH the greater is the adsorption. All anions are not adsorbed equally readily. Some anions such as H_2PO_4 are adsorbed very quickly at all pH values in the acid as well as alkaline range, Cl^- and SO_4^{--} ions are adsorbed slightly at low pH but none at neutral soil, while NO_3^- ions are not adsorbed at all. Hence, at the pH commonly prevailing in cultivated soils- nitrate (NO_3), chloride (Cl) and sulphate (SO_4) ions are easily lost by leaching. In general, the relative order of anion exchange is:

$OH^- > H_2PO_4^- > SO_4^- > NO_3^-$

$$R.OH + HCl \longrightarrow R.OH_2 + Cl^-$$
$$R.NH_2 + HCl \longrightarrow R.NH_3 + Cl^-$$

This adsorbed negatively changed anion is replaceable as under:

$R.OH^+_2 +$	$Cl^- + H_2PO_4^-$	$\longrightarrow$	$R.OH_2 . H_2PO_4$	$+ \quad Cl^-$
(R=Al, Fe)	soil solution		on exchange complex	soil solution

In this way there is fixation of phosphate ion, in which OH ion of silicate clay mineral is substitute by H_2PO_4 ion by isomorphrous substitution. The H_2PO_4 ion becomes a part of the silicate clay minerals and the phosphate fixed by this way is known as colloid bound phosphate. This phosphate is not exchangeable and available to the plant. The anions like NO_3 and OH are not bound at pH above 7. The adsorbing power of anions is in the order of:

$Cl^* = NO_3^* < SO_4 < PO_4$

* are not held by the soil colloids and are lost due to the leaching.

or $OH > H_2PO_4 > SO_4 > NO_3$ (relative order of anion exchange)

Importance of anion exchange in nutrient availability

The phenomenon of anion exchange assumes in relation to phosphate ions and their fixation. The exchange is brought mainly by the replacement of OH ions of the clay minerals.

OH Clay + H_2PO_4	$\longrightarrow$	H_2PO_4 Clay + OH
Available		Unavailable

The adsorption of phosphate ions by clay particles from soil solution reduces its availability to plants. This is also known as colloid bound phosphate fixation. The phosphate ion again becomes available when lime is applied to increase the pH of acidic soil.

The OH ion originated not only from silicate clay minerals but also from hydrous oxides of iron and aluminum present in the soil. The phosphates ions react with the hydrous oxides also get fixed forming insoluble hydroxyl phosphate of ion and aluminum. Which is called saloid bound phosphate.

$$\underset{}{Al(OH)_3} + \underset{\text{Available}}{H_2PO_4^-} \longrightarrow \underset{\text{Unavailable}}{Al(OH)_2.H_2PO_4} + OH^-$$

If the reaction takes place at a low pH under strongly acid conditions, the phosphate ions are irreversibly fixed and are totally unavailable for the use of plants.

Lesson 10. Soil Organic Matter

10.1 INTRODUCTION

Organic matter in the soil comes from the remains of plants and animals. As new organic matter is formed in the soil, a part of the old becomes mineralized. The original source of the soil organic matter is plant tissue. Under natural conditions, the tops and roots of trees, grasses and other plants annually supply large quantities of organic residues. Thus, higher plant tissue is the primary source of organic matter. Animals are usually considered secondary sources of organic matter. Various organic manures, that are added to the soil time to time, further add to the store of soil organic matter.

10.2 COMPOSITION OF PLANT RESIDUES

Composition of organic residues has un-decomposed soil organic matter (mainly plant residues together with animal remains. i.e. animal excreta etc). The moisture content of plant residues varies from 60 to 90 % (average 78 %) and 25 % dry matter (solid). Plant tissues (organic residues) may be divided into 1) organic and (2) inorganic (elemental) composition. The compounds constituting the plant residues or undecomposed soil organic matter is shown in the following diagram.

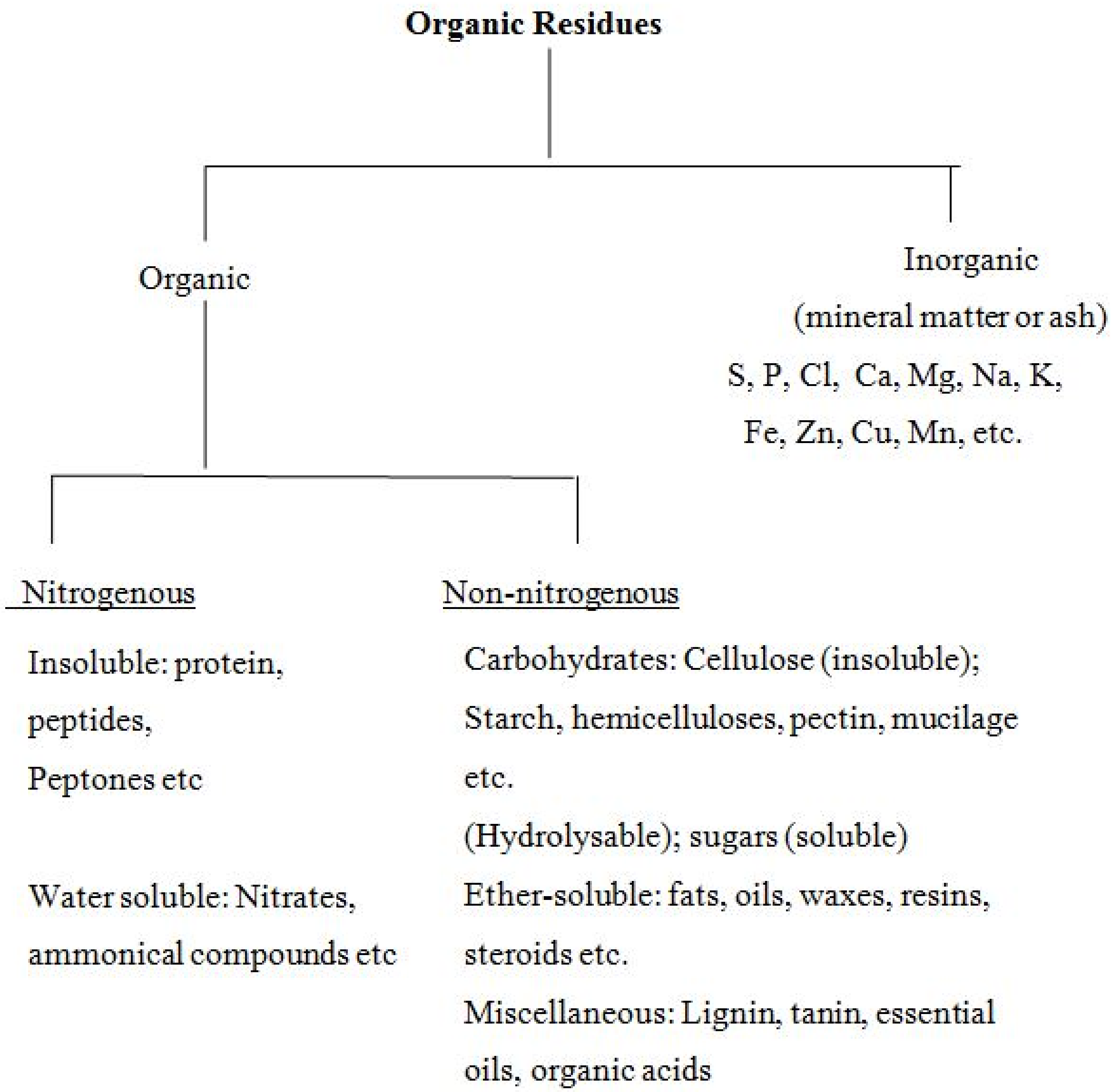


Fig. 10.1 Compounds constituting the plant residues or un-decomposed soil organic matter

10.3 DECOMPOSITION OF ORGANIC MATTER

The organic materials incorporated in the soil do not remain as such very long. They are at once attacked by a great variety of microorganisms, worms and insects present in the soil especially if the soil is moist. The microorganism for obtaining their food, break up the various constituents of which the organic residues are composed, and convert them into new substances, some of which are very simple in composition and others highly complex. The whole of the organic residues is not decomposed all at once or as a whole. Some of the constituents are decomposed very rapidly, some less readily, and others very slowly.

A. Decomposition of soluble substances:

Sugar and water-soluble nitrogenous compounds are the first to be decomposed as they offer a very readily available source of carbon, nitrogen and energy for the microorganisms. Thus, when glucose is decomposed under aerobic conditions the reaction is as under:

$$\text{(1) Sugar + Oxygen} \xrightarrow[\text{condition}]{\text{aerobic}} \text{Carbon dioxide + Water}$$

1. Ammonification:

The transformation of organic nitrogenous compounds into ammonia is called ammonification. During the course of action under aerobic conditions by heterotrophic organisms, oxygen is taken up and carbon dioxide is released. Ammonification process involves a gradual simplification of complex compounds. The ammonification occurs as a result of action of enzymes produced by microorganisms. Their action is chiefly hydrolytic and oxidative (in presence of air).

Organic nitrogen ---> NH3 or protein ---> polypeptides ----> amino acids ----> ammonia or salts

2. Nitrification:

The process of conversion of ammonia to nitrite (NO_2) and then to nitrate (NO_3) is known as **nitrification.** The production of nitrate is more rapid than that of nitrite, while the formation of ammonia is the slowest process. That is why soil usually contains more nitrate nitrogen than nitrite at any time. Nitrification is an aerobic process involving the production of nitrates from ammonium salts. It is the work of autotrophic bacteria.

$$\underset{\text{Ammonia}}{NH_3} \xrightarrow{\text{Nitrosomonas}} \underset{\text{Nitrite}}{NO_2} \xrightarrow{\text{Nitrobacter}} \underset{\text{Nitrate}}{NO_3}$$

The reactions are:

$$NH_4^+ + O_2 \longrightarrow NO_2^- + 2H^+ + H_2O + \text{energy (66 k cal)}$$

$$NO_2^- + O_2 \longrightarrow NO_3^- + \text{energy (18 k cal)}$$

The process which involves conversion of soil nitrate into gaseous nitrogen or nitrous oxide is called **denitrification.**

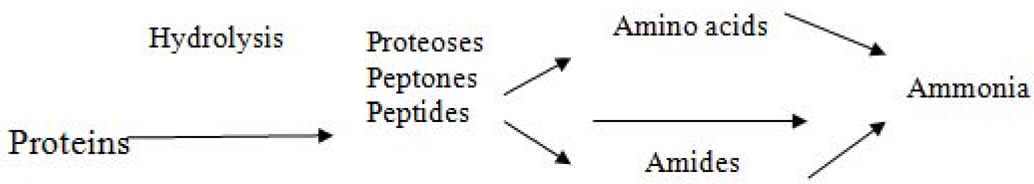
$$\text{Nitrate} \longrightarrow \text{Nitrogen gas}$$

Water-logging (e.g., rice field) and high pH will increase nitrogen loss by denitrification.

B. Decomposition of insoluble substances

1. Breakdown of protein

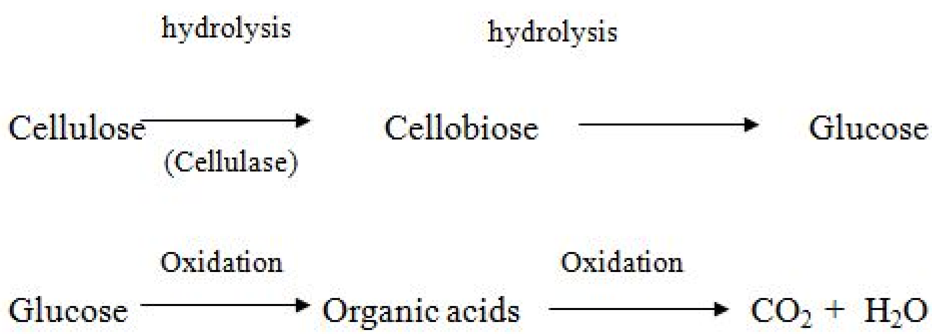
Proteins are complex organic substances containing nitrogen, sulphur, and sometimes phosphorus, in addition to carbon, hydrogen and oxygen. During the course of decomposition of plant materials, the proteins are first hydrolyzed to a number of intermediate products. e.g. proteoses, peptides, etc., collectively known as polypeptides.



The process of conversion of proteins to amino acids is known as aminization.

2. Breakdown of cellulose

Cellulose is the most abundant carbohydrate present in plant residues. The microorganisms break up cellulose into cellobiose and glucose. Glucose is further attacked by organisms and converted into organic acids.



The decomposition of cellulose in acid soils proceeds more slowly than in neutral and alkaline soils. It is quite rapid and well-aerated soil and comparatively slow in those poorly-aerated.

3. Breakdown of hemi-cellulose

When subjected to microbial decomposition, hemicelluloses are first hydrolyzed to their component sugars and uronic acids. The sugars are further attacked by microorganisms. They are converted to organic acids, alcohols, carbon dioxide and water.

The uronic acids are broken down to pentose and carbon dioxide. The newly synthesized hemicelluloses thus form a part of the humus. Hemicelluloses decompose faster than cellulose

4. Breakdown of starch

Chemically it is glucose polymer. It is first hydrolyzed to maltose by the action of enzymes (amylases). Maltose is next converted to glucose by another enzyme (maltase). Glucose being soluble in water is utilized for growth and other metabolic activities.

C. Decomposition of ether-soluble substances

Fats are first broken down by microorganisms through the agency of enzyme lipase into glycerol and fatty acids. Glycerol is next oxidized to organic acids which along with the other fatty acids are finally oxidized to carbon dioxide and water.

D. Decomposition of lignin

Lignin is deposited on the cell wall to impart strength to the skeleton framework of plant. Lignin decomposes slowly, much slower than cellulose. Complete oxidation of lignin gives rise to carbon dioxide and water.

E. Simple decomposition products

As the enzymic changes of the soil organic matter proceed, simple products begin to manifest themselves. Some of these, especially carbon dioxide and water, appear immediately. Others such as nitrate-nitrogen accumulate only after the peak of the vigorous decomposition is over. The more common simple products resulting from the activity of the soil microorganisms are as follows:

Carbon : CO_2, CO_3^- HCO_3^- , elemental carbon

Nitrogen: NH_4^+, NO_2^- , NO_3^- , gaseous nitrogen

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

Phosphorus: $H_2PO_4^-$, HPO_4^-

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

10.4 Mineralization of organic sulphur:

Many organic compounds especially those of a nitrogenous nature, carry sulphur, Heterotrophic bacteria simplify the complex organic compounds, and then autotrophic bacteria (sulphur bacteria) oxidize it into sulphate form.

$$\underset{\text{Sulphur}}{S + 2O_2} \xrightarrow{\text{Enzymetic oxidation}} \underset{\text{Sulphate}}{SO_4}$$

10.5 Mineralization of organic phosphorus:

A large proportion of the soil phosphorus is carried in organic combinations. Upon attack by microorganisms, the organic phosphorus compounds are mineralized; that is, they are changed to inorganic combinations. It depends upon soil pH. As the pH goes up from 5.5 to 7.5 the available phosphorus changes from $H_2PO_4^-$ to HPO_4^{-2} ,both of these are available to higher plants.

Lesson 11. Soil Reaction and Soil Problems

11.1 INTRODUCTION

Soil reaction is the most important single chemical characteristic influencing many physical and chemical properties of soil. Plant growth and microorganism activity depend upon soil reaction. Three conditions possible in the soil are: Acidity, neutrality and alkalinity.

11.2 SOIL REACTION

Soil reaction is measured by pH of a suspension of a soil in water. The reaction of a solution represents the degree of acidity or basicity caused by the relative concentration (or activity) of hydrogen (H^+) or hydroxyl (OH^-) ions present in it. Acidity is due to the access of H ions over OH ions, and alkalinity is due to the excess of OH ions over H ions. A neutral reaction is produced by an equal activity of H and OH ion.

The most convenient method of expressing the relationship between H^+ and OH^- is pH. pH is defined as the logarithm of the reciprocal (or negative logarithm) of the hydrogen ion concentration in gram per litre ; represented in equation form as follows:

At neutrality, the hydrogen-ion concentration is: 0.0000001 or 1 X 10^{-7} gram of hydrogen per litre of solution. Substituting this concentration into the formula,

$$pH = \log \frac{1}{0.0000001}$$

pH = log 10,00,000 = 7

At a pH of 6 there is 0.0000001 gm of active hydrogen, or 10 times more than the concentration of H^+ than at a pH of 7. At each smaller pH units, the H^+ increases by 10 in concentration. It therefore follows that a pH of 6 is 10 times more than a pH of 7. A pH of 5 is 10 times more acid than a pH of 7; a pH of 5 is 10 times more acid than a pH of 6, and so on.

The pH value, therefore, represents the amount of free or active acidity and not the total quantity of potential (or combined) acidity. In other words, it represents the intensity of acidity of a solution. In this scale, the pH value ranges from 0-14, where pH 0 represents the highest limit of active acidity and pH 14 the highest degree of basicity (or alkalinity). Neutrality represents pH 7 (Fig. 11.1). Therefore, pH 7 shows a neutral reaction. When the pH is less than 7, the solution is acidic, when it is above, it is alkaline.

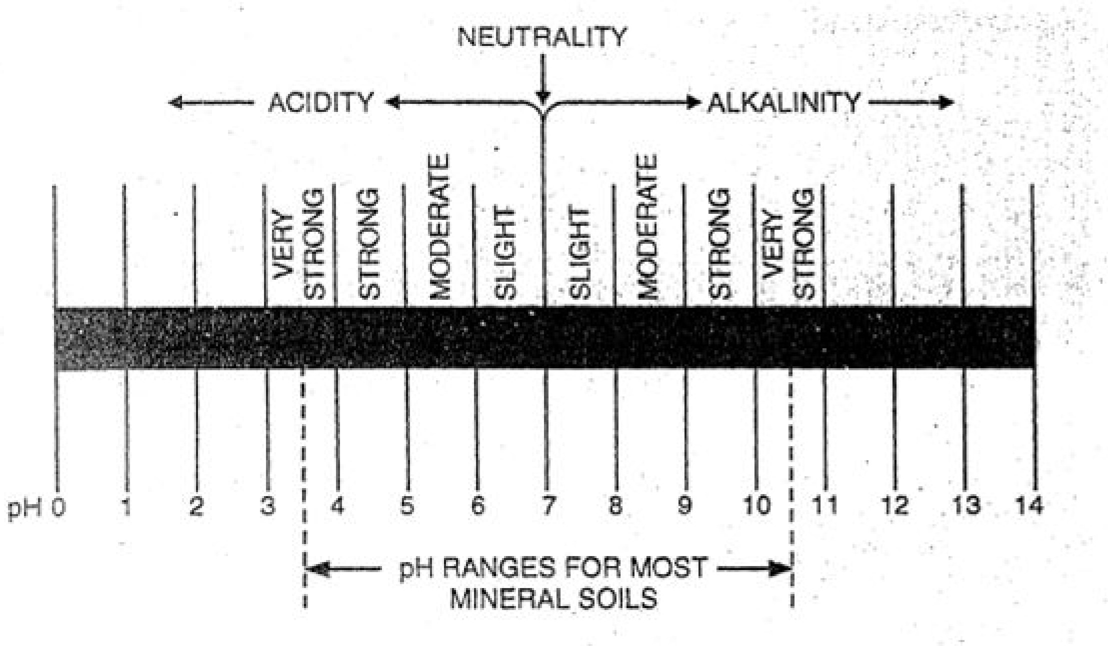


Fig. 11.1 Ranges in pH

Table 11.1 : Relationship between pH and pOH

pH	Acidity	Alkalinity	pOH
0	1.0	0.00000000000001	14
1	0.1	0.0000000000001	13
2	0.01	0.000000000001	12
3	0.001	0.00000000001	11
4	0.0001	0.0000000001	10
5	0.00001	0. 000000001	9
6	0.000001	0.00000001	8
7	0.0000001	0.0000001	7
8	0.00000001	0.000001	6
9	0.000000001	0.00001	5

10	0.0000000001	0.0001	4
11	0.00000000001	0.001	3
12	0.000000000001	0.01	2
13	0.0000000000001	0.1	1
14	0.00000000000001	1.0	0

11.3 INFLUENCE OF SOIL REACTION ON AVAILABILITY OF NUTRIENTS

The main effect of soil reaction is on the availability of plant nutrients is the soil. Another indirect effect occurs through the activity of microorganisms. Most microorganism function at their best within a pH range 6.0 to 7.5. If soil reaction is changed beyond this range, the microorganisms become functionless. Consequently, the supply of some of the essential plant nutrients like nitrogen is considerably reduced

1. Nitrogen:

Plant absorbs most of their nitrogen in the form of nitrate whose availability depends on the activity of nitrifying bacteria. The microorganisms responsible for nitrification are most active when the pH is between 6.5 and 7.5. They are adversely affected if the pH falls below 5.5 and greater than 9.0. Nitrogen-fixing bacteria (Azatobactor) also fail to function below pH 6.0 and 7.5. When the reaction is above or below the range, availability is reduced.

2. Phosphorous:

The phosphate ions react with iron and aluminum and insoluble phosphates of these elements are formed and become unavailable.

$$Al^{+++} + \underset{\text{(Soluble)}}{H_2PO_4^-} + 2H_2O \rightleftharpoons 2H^+ + \underset{\text{(Insoluble)}}{Al(OH)_2.H_2PO_4}$$

The phosphates react with hydrated oxides of iron and aluminum and form insoluble hydroxyl-phosphates of iron and aluminum. Unavailability of phosphorus is called*phosphorus-fixation.*

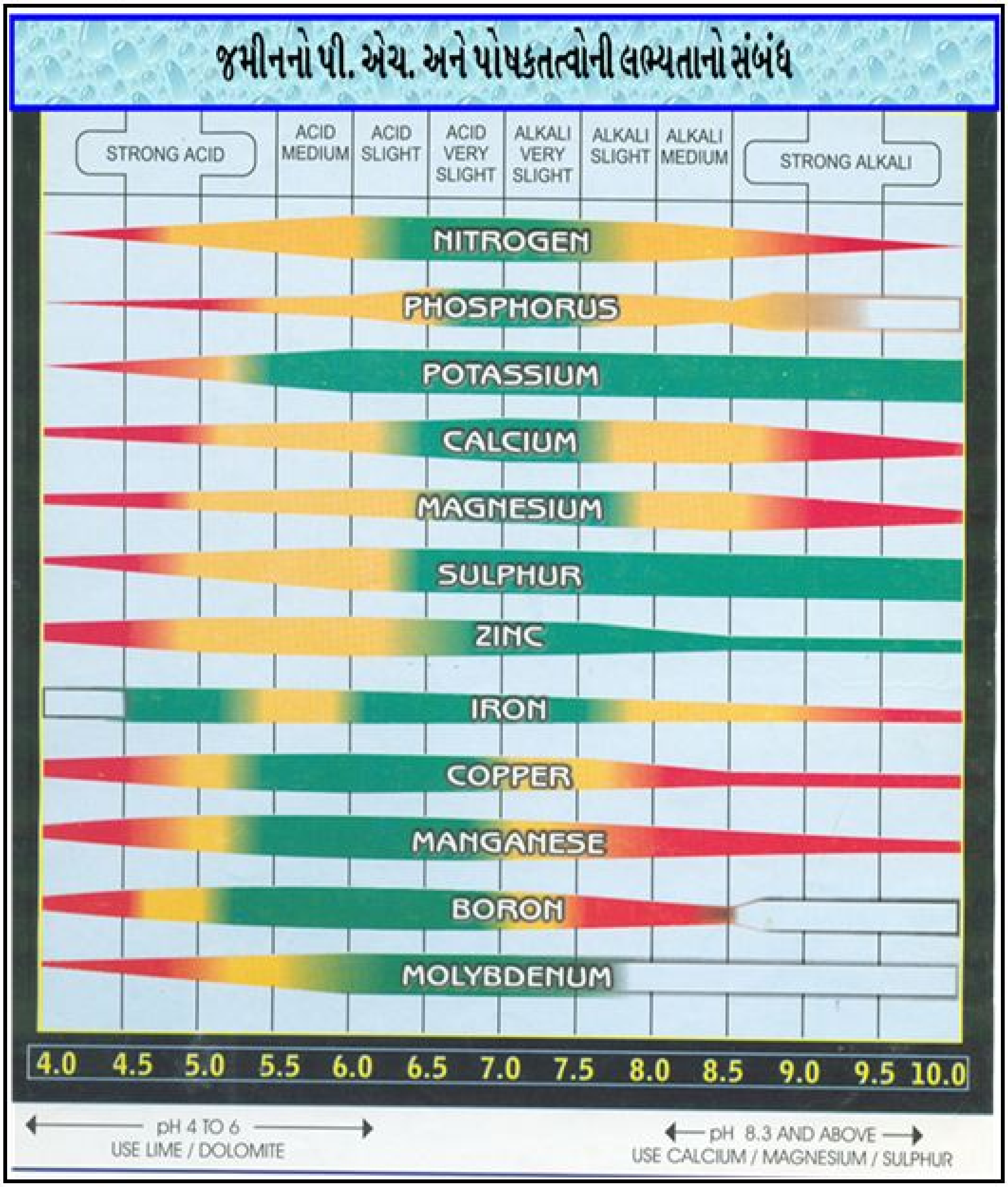
Fixation of phosphate takes place even when the soil is *alkaline* (high pH). Phosphate ion combines with calcium ion and calcium (or magnesium) carbonates and form insoluble calcium (or magnesium) phosphate.

3. Potassium:

The availability of potassium does not influence by soil reaction to any great extent. In alkaline soil, particularly if the alkalinity is due to $CaCO_3$ (or is brought about by over liming in add soil), the solubility of soil potassium is depressed (results in non-availability).

4. Calcium and Magnesium:

Acid soils are poor in available calcium and magnesium. In alkaline soil (pH not exceeding 8.5) availability of Ca and Mg. nutrients is always high. When the pH is above 8.5, the availability of these nutrients again decreases.



Relationship between soil reaction and nutrient availability in soil

Fig 11.2 Relationship between soil reaction and nutrient availability in so

5. Sulphur:

The availability of sulphur is not affected by soil reaction as sulphur compounds are soluble in the whole pH range. However, it is more soluble in acid soil and lost in leaching.

6. Micronutrients:

In general, the availability of boron, copper and zinc is reduced in alkaline soils and that of molybdenum in acid soils. The availability of boron, copper and zinc progressively decreases as the soil pH increases. Their availability also decreases under highly acid condition when the pH is below 5.0. The availability of molybdenum is more available in neutral and alkaline soils.

11.4 SOIL PROBLEMS

Soil is affected with three types of problems namely (i) Saline soil, (ii) Sodic soil and (iii) Acid soil.

11.4.1 SALINE SOILS

Causes of Salinization: Salinization or the accumulation of the salts occurs in the following ways:

1. Primary minerals: During the process of weathering, which involves hydrolysis, hydration, solution, oxidation and carbonation various constituents (Ca, Mg and Na) are gradually released and made soluble.

2. Arid and semi-arid climate: The low rainfall in these regions is not sufficient to leach out the soluble weathered products and hence the salt accumulates in the soils.

3. Sea as a source of salts: The Ocean is the source of the salts in low-lying area along the margin of seacoasts. Sometimes salts is moved inland through the transportation of spray by winds be called cyclic salts.

4. Low permeability of the soil: This causes poor drainage by impeding the downward movement of water. This results into continuous deposition of soluble salts in the soils.

5. Ground water: Ground water contains large amounts of water soluble salts which depend upon the nature and properties of the geological material with which water remains in contact where water table and evapotranspiration rate is high, salts along with water move upward through capillary activity and salts accumulation on the soil surface.

6. Irrigation water: The application of irrigation water without proper management (i.e. lack of drainage and leaching facilities) increases the water table and surface salt content in the soils.

11.4.2 SODIC SOILS

Causes of Alkalinity: Process where exchangeable Na content in soil increased due to precipitation of Ca and Mg as carbonate (Na_2CO_3 or $NaHCO_3$) by low of mass action, Ca and Mg replaced by Na on exchange complex. This soil occurs mainly due to use of alkali or sodic water for irrigation, excessive use of basic fertilizers. It also developed where drainage is defective and where the underground water table is high or close to the surface.

Characterization of salt affected soils:

Characteristics	**Saline soil**	**Non-saline alkali soil**	**Saline-alkali soil**

Content in soil	Excess soluble salts	Exchangeable sodium on the soil complex	Exchange Na on clay as well as soluble salts.
ECe (dS/m)	> 4	< 4	> 4
Soil pH	Less than 8.5	8.5-10	More than 8.5
ESP	Less than 15	More than 15	More than 15
Sodium adsorption ratio (SAR)	Less than 13	More than 13	More than 13
Total soluble salt content	More than 0.1 %	Less than 0.1 %	More than 0.1 %
Dominant salts	Sulphate (SO_4^{2-}), chloride (Cl^-) and nitrates (NO_3^-)	Sodium carbonate (Na_2CO_3)	-
Organic matter content	Slightly less than normal soils	Very low due to the presence of sodium carbonate (Na_2CO_3)	Variable
Colour	White	Black	-
Physical condition of the soil	Flocculated condition, permeable to water and air. Soil structure optimum.	Deflocculated condition, permeability to water and air is poor. Very poor soil structure.	Flocculated or deflocculated depending upon the presence of sodium salts and Na-clay
Other name	White alkali (Solonchak)	Black alkali (Solonetz)	Usar

11.5 CROP GROWTH ON SALT AFFECTED SOILS

1. On saline soils: The crop growth on salt affected soils is poor due to following reasons:

(A) Water availability theory: Due to high salt concentration plants have to spent more energy to absorb water and to exclude salt from metabolically active sites. At the same time various nutrient elements become unavailable to plants.

(B) Osmotic inhibition theory: The presence of excess solutes in the plant decreases the free energy of unit mass of water.

(C) Specific toxicity theory: According to the specific toxicity theory, soil salinity exerts a detrimental effect on plants through the toxicity of one or more specific ions (cations as well as anions) in the salts present in excess. Accordingly, there may be toxicity of chlorides, bicarbonates and boron.

2. On alkali soils: The reasons of low crop production on such soils are as follows:

(A) Adverse physical conditions: The alkali soils have poor physical conditions. The permeability of air and water and the hydraulic conductivity are at a lower most state due to breakdown of aggregates and dispersion of individual clay-colloids. The breakdown of aggregates is due to dissolution of organic matter, which acts as a cementing agent for binding individual clay particles, due to formation of alkali solution. The dispersed clay plugs all the macro and micro capillaries thereby hampering the movement of air and water. The downward movement of water is practically zero and hence they remain waterlogged when irrigation is given or water is added through rain. On drying, such soils form very large clods, which are very hard in nature. The tillage operations are very difficult to carry due to increase in bulk density, which is due to deflocculation of clay. Because of very adverse physical conditions, the germination as well as the root growth is considerably reduced.

(B) High sodium on exchange complex: Excess amount of sodium reduces the

crop growth considerably due to plants exhibit the deficiency of Ca.

(C) Effect of high pH: The high pH reduces the availability of P, Zn, Cu, Mn and Fe. The microbial activity is also at standstill due to unfavourable pH and the processes of mineralization, ammonification or nitrification are practically negligible. The higher concentration of OH^- ion itself is not favourable to crop growth.

11.6 METHODS OF RECLAMATION

I. Mechanical/physical

- Construction of embankment to prevent tidal sea water
- Land leveling and contour bunding.
- Establishment of drainage network
- Breaking of hardpan in the subsurface layer through boring auger hole
  - Scrapping of salt crust
  - Deep tillage, sub soiling, profile inversion
  - Use of soil conditioners e.g. sand, *tanch*, ash, manures and synthetic polymers like PVAC, PAM, and PVPC
    - Use of amendments
    - Use of manures

- Green manure
- Selection of salt tolerant crops after afforestation

II. Chemical

III. Biological

A. Different types of chemical amendments:

1. Soluble calcium salts e.g.

(i) Calcium chloride ($CaCl_2.2H_2O$)

(ii) Gypsum ($CaSO_4.2H_2O$)

(iii) Calcium sulphate ($CaSO_4$)

2. Acid or acid formers e.g.

(i) Sulphur (S)

(ii) Sulphuric acid (H_2SO_4)

(iii) Iron sulphate ($FeSO_4.7H_2O$)

(iv) Aluminium sulphate ($Al_2(SO_4)_3.18H_2O$)

(v) Lime sulphur (calcium poly sulphide) (CaS_5)

(vi) Pyrites (FeS_2)

B. Advantages and disadvantages of amendments:

Gypsum is the most common amendment used for reclaiming saline-sodic as well as non-saline sodic soils. It is a low cost amendment and the rate of reaction in replacing Na is limited on its solubility in water, which is about 0.25 % at ordinary temperature. While applying gypsum, mixing it in shallow depth (upper 10 cm depth) is more effective. It is applied by broadcast method or incorporated by disc plough. Gypsum is applied at the time of ponding or leaching. Gypsum directly prevents crust formation, swelling, dispersion and acts as mulch in case of surface application and indirectly increases porosity, structural stability, infiltration and hydraulic properties, soil tilth, drainage and leaching and reduces dry soil strength.

C. Quantity of amendments to be added:

These are evidences to show that even 50 % of the theoretical gypsum requirement for replacement of exchangeable Na in alkali soils has improved their physical properties and assisted response to management practices. Generally, 50 to 75 % of GR (as determined by Schoonover's method) has been found most satisfactory in many types of soils. The equivalent proportion of different amendments in relation to 1 ton of gypsum is as follows:

Amendments

Gypsum
Sulphuric acid
Sulphur
$FeSO_4.7H_2O$
Aluminium sulphate
Limestone ($CaCO_3$)
Lime sulphur (Calcium polysulfide containing 24 % S)

D. The organic amendments: Green manuring with Dhaincha (*Sesbania aculeata*) has been found most successful. The juice of green plants can neutralize high alkalinity, its initial pH being 4.01, with only slight rise even within a month. In black cotton soil, it thrives well under moderately saline conditions and can with stand high alkalinity, water logging or drought so that it is remarkably suited in that region to alkali soils, characterized by such adverse conditions. Sulphurated hydrogen is generated by the decomposition of Dhaincha. The selection of crop is based on tolerance of a crop to either salinity or sodicity. The list of salt tolerant is given below:

ECe (dS/m) **(50% yield reduction)**	**Crop**
14-18	Barley, Sugar beet, Cotton, Wheat
8-12	Safflower, Sorghum, Soybean, Rice, Tomato
4-7	Corn, Cabbage, Potato, Sweet potato, Carrot, Onion

The tolerance of various crops to ESP is given below:

ESP	**Class**	**Crop**

2 – 10	Very sensitive	Deciduous fruits, Nuts, Citrus, .
10 – 20	Sensitive	Beans
20 – 40	Moderately tolerant	Clover, Oats, Tall fescue, Rice,
40 – 60	Tolerant	Wheat, Cotton, Alfalfa, Barley,
More than 60	Highly tolerant	Crested wheat grass, Fairway w

11.7 ACID SOILS

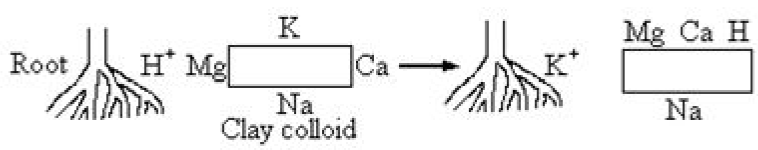
A. Causes of Soil Acidity

1. Excessive rainfall: The considerable loss of bases due to intensive rainfall and leaching reduces the pH of the soil as well as increase the concentration of H^+ on exchange complex.

2. Ionization of water: The water may ionize and contribute H^+ on exchange complex as follows :

$$H_2O \rightarrow HOH \rightarrow H^+ \ OH^- \rightarrow H^+[\mathbf{X}] + \text{Bases} + OH^-$$

3. Contact exchange: The contact exchange between exchangeable H on root surface and the bases in exchangeable form on soil particle may take as follows



4. Soluble acid production**:** The decomposition of organic matter in the soil produces many organic as well as inorganic acids. These acids may contribute H on exchange complex.

5. Use of nitrogenous fertilizers: Continuous use of nitrogenous fertilizers containing NH_4-N or giving NH_4-N on hydrolysis (i.e. urea) produces various acids in soils.

6. Oxidation of FeS : FeS or iron poly sulphide accumulates under anaerobic conditions as a result of reduction of Fe^{3+} and SO_4. Under aerobic conditions, they will be oxidized and will produce H_2SO_4. Under such conditions, soil pH values of 2 to 4 are frequently observed.

7. Hydrolysis of Fe^{3+} and Al^{3+}: The Fe^{3+} and Al^{3+} ions may combine with water and release H^+ and produce acidic condition in soil.

8. Acidic parent material: Some soils have developed from parent materials which are acid, such as granite and that may contribute to some extent soil acidity.

9. Acidification from the air : Industrial exhausts, if contain appreciable amount of SO_2may cause acidity in soil in course of time due to dissolution of SO_2 in water (rain) as follows :

$SO_2 + H_2O \rightarrow H_2SO_3$ (Rain water)

$2H_2SO_3 + O_2 \rightarrow 2H_2SO_4$ (Sulphuric acid)

B. Problems in Acidic Soils

Problems of soil acidity may be divided into three groups:

1. Toxic effects

(a) Acid toxicity: The higher hydrogen ion concentration is toxic to plants under strong acid conditions of soil.

(b) Toxicity of elements: The concentration of Iron, Manganese and Aluminium ions (Fe^{2+}, Mn^{2+} and Al^{3+}) in soil increased in acidic condition to a very high and toxicity of these elements develop.

2. Nutrient availability

(a) Exchangeable bases: Deficiency of bases like Ca^{2+} and Mg^{2+} are found in acid soils.

(b) Nutrient imbalances: Phosphorus reacts with Fe, Al and Mn ions and produces insoluble phosphatic compounds rendering phosphorus unavailable to plants. In acid soils having very low pH, the availability of boron, nitrogen, potassium and sulphur become less available.

3. Microbial activity

Bacteria and *actinomycetes* can not show their activity when the soil pH drops below 5.5. Nitrogen fixation in acid soils is greatly affected by lowering the activity of *Azotobacter* sp. Besides these, soil acidity also inhibits the symbiotic nitrogen fixation by affecting the activity of *Rhizobium* sp. Fungi can grow well under very acid soils and caused various diseases like root rot of tobacco, blights of potato, etc.

C. Reclamation of Acidic Soils: The reclamation of acidic soils is done by addition of liming material which may be calcitic limestone ($CaCO_3$) or dolomitic limestone [$CaMg(CO_3)_2$]. The rate of lime requirement is determined in the laboratory by method of Shoemaker (1961).

D. Management of Acid Soils: It is done through ameliorating the soils and selecting acidity tolerance crops.

(a) Ameliorating the soils through the application of amendments

(i) Oxides of lime (CaO) : When oxides of lime like CaO is applied to an acid soil, it reacts almost immediately as follows :

$$SO_2 + \underset{\text{(Rain water)}}{H_2O} \rightarrow H_2SO_3$$

$$2H_2SO_3 + O_2 \rightarrow 2H_2SO_4 \text{ (Sulphuric acid)}$$

(i) Hydroxides of lime $[Ca(OH)_2]$: When hydroxides of lime like $Ca(OH)_2$ is applied for the reclamation of an acid soil, the following chemical reaction takes place :

$$\boxed{\text{Soil}}\begin{matrix} H^+ \\ \\ Al^{3+} \end{matrix} + H_2O + 2CaO \rightarrow \boxed{\text{Soil}}\begin{matrix} Ca^{2+} \\ \\ Ca^{2+} \end{matrix} + Al(OH)_3$$

(i) Carbonates of lime $(CaCO_3)$: When carbonates of lime like calcite is applied to an acid soil following reaction takes place.

$$\boxed{\text{Soil}}\begin{matrix} H^+ \\ \\ Al^{3+} \end{matrix} + 2Ca(OH)_2 \rightarrow \boxed{\text{Soil}}\begin{matrix} Ca^{2+} \\ \\ Ca^{2+} \end{matrix} + Al(OH)_3 + H_2O$$

(b) Selection of crop: The crop should be selected on the basis of their tolerance to acidity. The relative yield of different crops at different pH values is given in following table.

High acid tolerant crops	:	Rice, potato, sweet potato, oat, castor, etc.
Moderate acid tolerant crops	:	Barley, wheat, maize, turnip, brinjal, etc.
Slightly acid tolerant crops	:	Tomato, carrot, red clover, etc.

Lesson 12. Quality of Irrigation Water

12.1 INTRODUCTION

All natural waters used for irrigation contains inorganic salts in solutions which are derived originally from the rocks or solid phase material through which water percolates. The most common dissolved constituents are chlorides, sulphates and bicarbonates of Ca, Mg and Na. The concentration and proportion of these salts determine the suitability of water for irrigation. Other constituent such as B, Li, F or other ions, which have a toxic effect on plants, may occur in lesser amounts in irrigation water. If water used for irrigation contains excessive quantities of the constituents noted above, it might affect the growth of plants in three ways viz.,

(a) As a result of adverse changes in the physical characteristics of the soil,

(b) The increased osmotic pressure of the soil solution may decrease the physiological availability of moisture to plants,

(c) Accumulation of certain ions in the soil solution may have a specific toxic effect upon the physiological processes of the plant.

Therefore, the question arises "What should be the ideal quality of water to be used for irrigation?" Different workers for judging the quality of waters have proposed various standards.

The five generally recognized criteria for judging the quality of irrigation water are as under:

12.2 Quality of irrigation water

The five generally recognized criteria for judging the quality of irrigation water are:

1. Salinity hazard: Continuous use of water having high salt content will convert a normal soil into a saline soil. On the basis of electrical conductivity (EC) measurements, the waters were divided into four classes as follows:

Conductivity (dS/m)	Class	Symbol	Inference
0.00 – 0.25	Low salinity	C_1	(i) Can be used for most soil for most crops (ii) Little likelihood of salinity

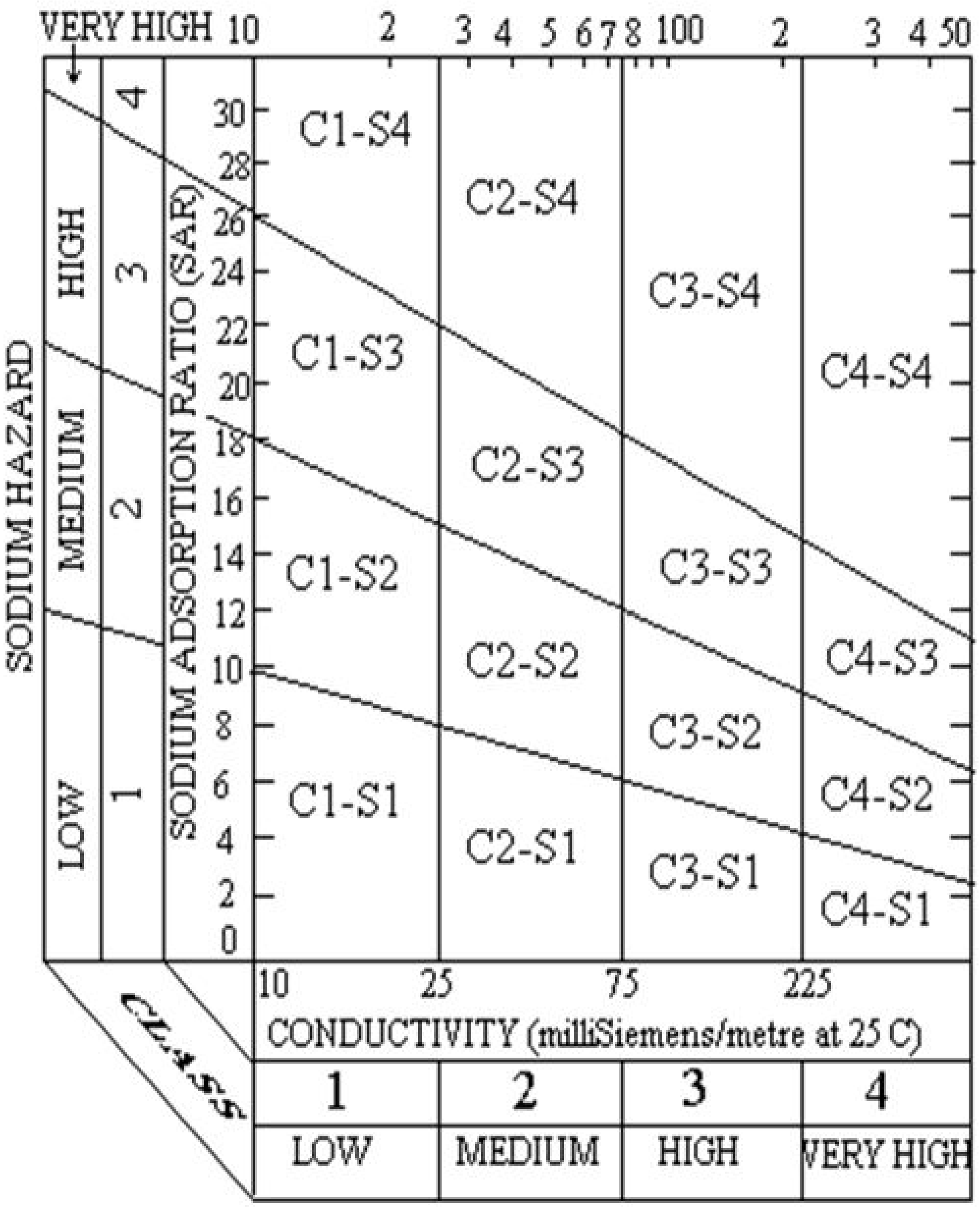
0.25 – 0.75	Medium salinity	C_2	(i) Can be used with moderate leaching (ii) Moderate salt tolerant crops should be grown
0.75 – 2.25	High salinity	C_3	(i) Cannot be used where drainage is restricted
2.25 – 5.00	Very high salinity	C_4	(i) Not suitable for irrigation

2. Alkali hazard: The continuous use of water having high concentration of Na will convert a normal soil into an alkali soil. The sodium adsorption ratio (SAR) developed by USSSL expresses the relative activity of Na ions in cation exchange reactions with the soil. The exchangeable Na percentage (ESP), which the soil will attain when the soil and water are in equilibrium, can be predicted approximately from the value of SAR of water. Accordingly, the waters are divided into four classes with respect to the Na hazards as follows:

SAR value	Class	Symbol	Inference
0 – 10	Low Na water	S_1	(i) Can be used for all soils with little danger of harmful Na level de (ii) The Na sensitive crops are affected.
10 – 18	Medium Na water	S_2	(i) Sodium hazard likely in fine textured soil. (ii) Can be used on soils having high permeability.
18– 26	High Na water	S_3	(i) May produce harmful level of exchangeable Na in most soils exc gypsiferous soils. (ii) Requires special management practice like good drainage, high l and addition of organic matter and gypsum.
> 26	Very high Na water	S_4	Unsatisfactory for irrigation except at low and perhaps medium s irrigation water, special management as above should be made.

Sodium Adsorption Ratio (SAR) can be calculated by $SAR : \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$

The USSSL has prepared the diagram for use of water having different values of EC as well as SAR.



3. Bicarbonate hazard: The bicarbonate ions are primarily important because their tendency to precipitate Ca and to some extent Mg, in the soil solution as their normal carbonates e.g.

$Ca + 2HCO_3 \rightarrow CaCO_3 + CO_2 + H_2O$

The CO_3^{-2} ions are seldom present in water but HCO_3^- ions may be present in appreciable proportion of the total anions present in irrigation waters. Based on the theory of precipitation of Ca and Mg, Eaton (1950) suggested the concept of "Residual Sodium Carbonate" commonly known as RSC. The RSC can be found out by following equation:

$$RSC = (CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})$$

Where; concentrations of all ions are expressed in meq/l.

The standard for RSC as given by USSSL as follows:

RSC (meq/lit)	Qualit
Less than 1.25	Probabl
1.25 – 2.50	Marginal can be used on light textured
More than 2.50	Not suitab

4. Boron hazard: Boron is very toxic to plants at low concentration in the soil solution. Because boron tends to accumulate in the soil from even low concentration in the irrigation waters, it is necessary to consider this constituent in assessing the quality of irrigation waters. The USDA has suggested the type of crops to be grown with respect to boron content in irrigation water. The limits are as under:

Boron content of irrigation water (ppm)	Boron tolerance of crops	
0.3 – 1.0	Sensitive	Citrus, Apricot, Peach, A
1.0 – 2.0	Semi-tolerant	Sweet potato, Oats, Sorg
2.0 – 4.0	Tolerant	Carrot, Cabbage, Onion,

5. Other hazards:

(i) Chlorides: The grading of irrigation waters based on chloride content as proposed by Schofield is as under:

Chloride (meq/lit)
0 – 4

4 – 7
7 – 12
12- 20
More than 20

(ii) Other elements: The safe limit for other elements present in irrigation water is as follows:

Element	For waters used continuously on all soil (ppm)	For used up to 20 years on fine textured soil at pH 6.0 to 8.5 (ppm)
Al	5.00	20.00
Arsenic	0.10	2.00
Cu	0.20	5.00
Fluorine	1.00	15.00
Lead	5.00	10.00
Lithium	2.50	2.60
Mn	0.20	10.00
Mo	0.01	0.05
Se	0.02	0.02
Zn	2.00	10.00
Fe	5.00	20.00

12.3 Suitability of irrigation water

The suitability of irrigation water (SI) will be determined by following factors.

(a) Quality of irrigation water: Amount, nature and proportion of various cations and anions present in the water.

(b) Nature of the soil to be irrigated: Texture, structure, drainage, permeability, depth of water table, chemical composition of the soil, pH, and $CaCO_3$ content will determine the effect of irrigation water on the soil.

(c) Nature of the crop plants to be grown: water, which may not be suitable for very sensitive crop, may be excellent for tolerant crops.

(d) Climatic conditions: High temperature and less humidity will require more number of irrigation.

Lesson 13. Poor Quality of Irrigation Water and Management Practices

13.1 INTRODUCTION

Poor quality of water is one of the main factors turning good soil into saline or sodic. Several salts dissolved in it, as universal solvent. Irrigation with saline water adversely affects crop growth and productivity. High subsoil water table, aridity, seepage from canals, poor drainage, back water flow, intrusion of sea water also leads to salinity and sodicity. Around 1.5 mha areas are affected by poor quality water in India. The most affected state is Rajasthan. In world, over 50 million ha are affected by salinity spread over 24 countries.

13.2 PROBLEMS WITH POOR QUALITY WATER

Several soil and plant related problems arise due to use of poor quality water for irrigation.

13.2.1 Extraction of Water:

- If excess soluble salts of irrigation water accumulated in crop root zone, crop has difficulty in extracting enough water
- Root growth is also suppressed; increasing the difficulty of water uptake.
- Salinity stress in plants is often called physiological drought.
- Due to reduced uptake of water and other effects, yields are reduced.
- The reduction in yield due to salinity is more in warm climate than cool climate.

13.2.2 Soil permeability:

- Soil permeability is reduced due to the deflocculation effect of sodium.
- If permeability is reduced, infiltration of water into and through the soil is reduced.
- Adequate root penetration is inhibited due to the presence of impermeable soil layer caused by $CaCO_3$ and high exch.Na %
- Crusting of seed bed, Water logging, reduced oxygen and nutrient supply to the crops are the problems due to high sodium content relative of Ca & Mg.

13.2.3 Toxicity Symptoms:

- More uptake of B, Cl, Na, sulphate and bicarbonate by plant creates toxicity problems.
- Vegetative growth decrease as osmotic pressure of the soil solution increases.
- Reduction in growth takes place even without any external toxic symptoms.
- Increase in salinity, salt injury appears.
- Thick cuticle, waxy bloom and deep blue-green colour of leaves.
- At high salt levels, leaf burn appears in barley, sorghum and field beans.

13.2.4 Anatomical and Physiological Effects:

- Salinity reduces cell division, cell enlargement and protein synthesis.
- It affects the structure and integrity of plant membranes and causes mitochondria and chloroplast to swell.
- Sodium and chloride at toxic levels disrupt the structure of the protein molecules.
- High chloride content hinders the development of xylem tissue.

13.2.5 Nutritional Effects:

- Higher level of certain ions affect the absorption of other nutrient elements
- High concentration of sulphate reduces the uptake of calcium enhances the uptake of sodium.
- This process causes high level of sodium in plants, thus causing sodium toxicity.
- High concentration of Ca reduces the uptake of K.
- High concentration of Mg induces Ca deficiency.

13.2.6 Soil Microorganisms:

- NO_2 & NO_3 producing bacteria sensitive to high salt concentration than NH_4 producing bacteria.
- *Azotobacter* is resistance to salt concentration.

13.2.7 Other effects:

- Excessive vegetative growth, lodging, delayed crop maturity result due to excessive nitrogen in water.
- White and black deposit on soil due to high salt content and sodium and leaf burn due to using poor quality irrigation water in sprinkler irrigation are some of the problems.
- Tilth of the soil will be poor due to high exchangeable sodium percentage.
- Exchgeable Na tends to make moist soil impermeable to air and water & on drying soil becomes hard and difficult to work.
- The dense crusts formed interfere with germination and emergence of seedlings.
- Soluble carbonates are in water applied to soil in absence of Ca and Mg in soil, soil becomes alkaline & unfavorable.
- Na_2CO_3 in irrigation water is toxic to plants.

13.3 Management level of the irrigation

13.3.1 Use of saline water

Even the waters containing high amount of dissolved salts has been used successfully in highly permeable sandy soils. Similarly, the waters showing considerable alkali hazards have also been used successfully on permeable soils or by addition of gypsum and FYM on semi-permeable soils. The high RSC content can be corrected by addition of gypsum and the water can be used for the purpose of irrigation. Attempts have also been made for using saline waters by diluting it with good quality water or by giving alternate irrigation with good and bad quality water.

The CSSRI, Karnal has recommended following limits of EC for use of saline waters:

Tentative water quality ratings for Indian conditions

Soil groups	Soil texture	Clay content (%)	Crop tolerance to salinity	Upper permissible limits for water (EC in dS/m)	
				No drainage limitation	Ground water level less than 1.51 m
Deep black and alluvial	Clayey	30	Fairly	1.5	0.75
			High	2.0	1.0
Alluvial	Clay loam	20-30	Fairly	2.0	1.0
			High	4.0	2.0
	Loam	10-20	Fairly	4.0	2.0
			High	6.0	3.0
	Sandy loam to sandy	10	Fairly	6.0	3.0
			High	8.0	4.0

The waters having high salinity can be used successfully in lighter textured soils by growing salt tolerant crops.

13.3.2 Leaching requirement (LR)

The leaching requirement may be defined as the fraction of the irrigation water that must be leached through the root zone to control soil salinity at any specific level.

The leaching requirement (LR) is simply the ration of the equivalent depth of the drainage water to the depth of irrigation water and may be expressed as a fraction or as per cent. Under the assumed conditions (uniform aerial application of irrigation water, no rainfall, no removal of salt in the harvested crop and no precipitation of soluble constituents in the soil), this ration is equal to the inverse ratio of the corresponding electrical conductivities as follows :

$$LR \;:\; \frac{D_{dw}}{D_{iw}} \times 100 = \frac{EC_{iw}}{EC_{dw}} \times 100$$

where;

LR	:	Leaching requirement expressed in percentage

D_{dw}	:	Depth of drainage water in cm
D_{iw}	:	Depth of irrigation water in cm
EC_{iw}	:	Electrical conductivity of the irrigation water in dS/m
EC_{dw}	:	Electrical conductivity of the drainage water in dS/m

Lesson 14. Essential Plant Nutrients

14.1 INTRODUCTION

Plants require a large number of elements, which either are derived from minerals or are mineralized during the biological breakdown of organic matter. The mineral nutrients are taken up in the form of ions and incorporated into the plant structure or stored in the cell sap.

14.2 The soil as a Nutrient Source for Plants

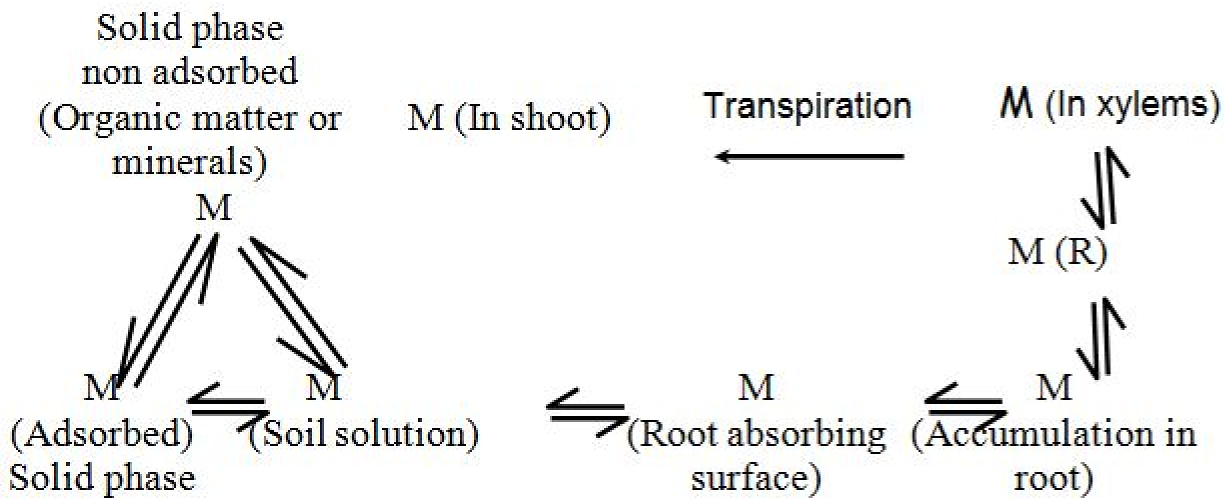
14.2.1 Mineral Nutrients in the Soil

Mineral nutrients occur in the soil in both dissolved and bound form. Only a small fraction (less than 0.2%) of the mineral nutrient supply is dissolved in soil water. Most of the remainder, i.e., almost 98% is either bound in organic detritus, humus and relatively insoluble inorganic compounds or incorporated in minerals. These constitute a nutrient reserve, which becomes available very slowly as a result of weathering and mineralization of humus. The remaining 2% is adsorbed on soil colloids. The soil solution, the soil colloids and the reserves of mineral substances in the soil are in a state of dynamic equilibrium, which ensures continued replenishment of supplies of nutrient elements.

14.2.2 Adsorption and Exchange of ions in the soil

Both clay minerals and humic colloids have a negative net charge so that they attract and adsorb primarily cations. There are also some positively charged sites where anions can accumulate. How tightly a cation is held depends on its charge and degree of hydration. In general, ions with high valences are attracted more strongly for example; Ca^{2+} is more strongly attracted than K^{+}. Among ions with the same valence those with little hydration are retained more firmly than those that are strongly hydrated. The tendency for cations adsorption decreases in the order Al^{3+}, Ca^{2+}, Mg^{2+}, NH_4^{+}, K^{+} and Na^{+}

The swarm of ions around particles of clay and humus works as an intermediary between the solid soil phase and the soil solution. If ions are added to or withdrawn from the soil solution, exchange takes place between solid and liquid phases. Adsorptive binding of nutrient ions offers a number of advantages nutrients liberated by weathering and the decomposition of humus are captured and protected from leaching the concentration of the soil solution is kept low and relatively constant; so that the plant roots and soil organisms are not exposed to extreme osmotic conditions; when required by the plant, however, the adsorbed nutrients are readily available.



Nutrient release and path for absorption

14.3 Essential and beneficial elements

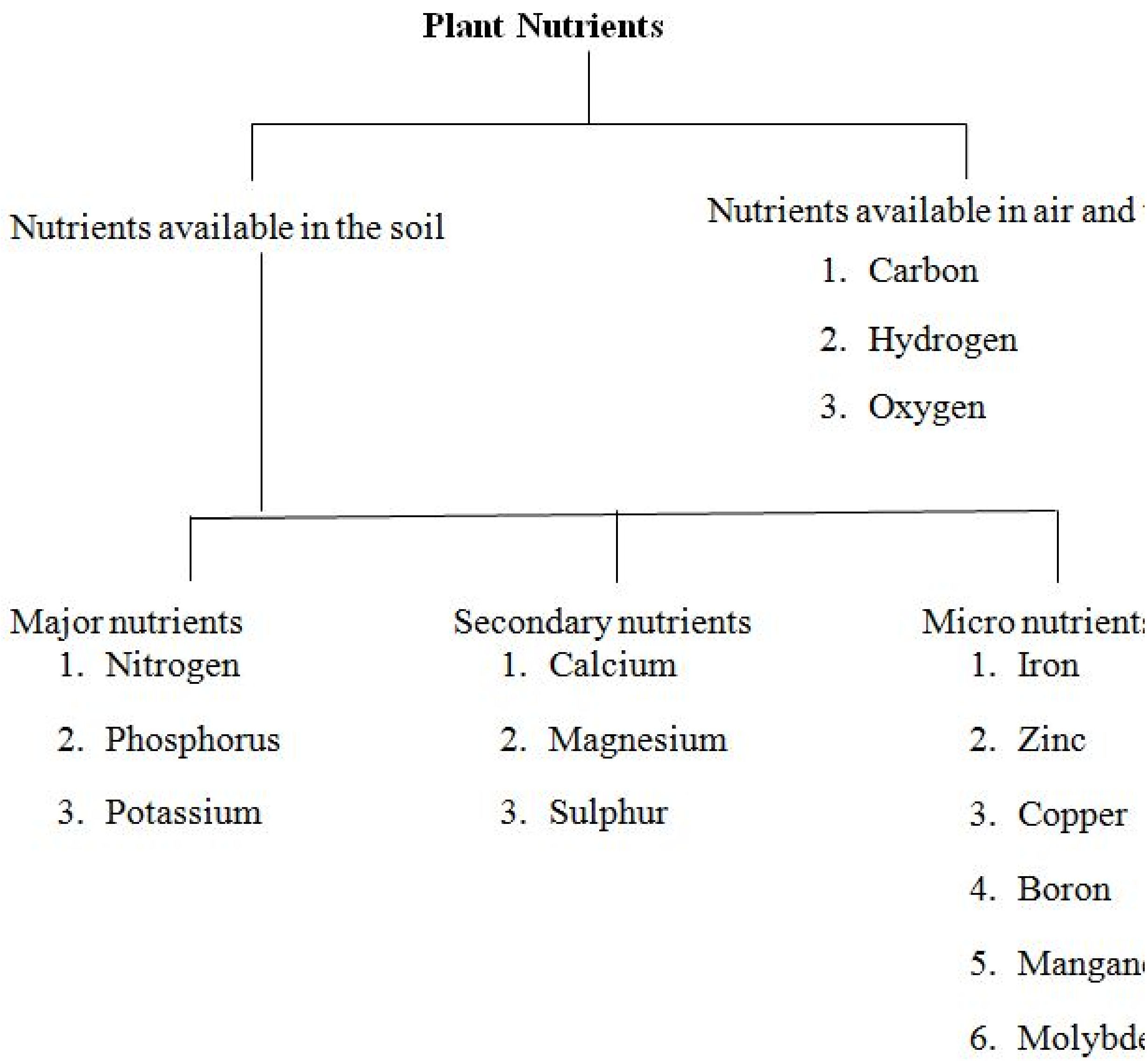
14.3.1 The criteria of essentiality: In order to distinguish elements, which are essential from those which may be taken up by the plant but are not essential, Arnon (1954) has laid down the following criteria:

(1) The plant must be unable to grow normally or complete its life-cycle in the absence of the element;

(2) The element is specific and can not be replaced by another; and

The element plays a direct role in metabolism.

Arnon’s criteria of essentiality of elements for plant growth may be more correct. However, it appears to be too regid from practical point of view. Nicholas proposed the term “Functional or Metabolic nutrients”, whether or not its action is specific. Elements such as sodium, cobalt, vanadium etc are classified as essential when less restrictive definition of essentiality is used.



14.3.2 Classification of essential plant nutrients

(i) On the basis of amount of nutrients present in plants, they can be classified in to three groups:

Nutrients

	Average concentration in plant tissue	**Relative numbers of atoms compared to Mo as one**	**Function in plant**	**Nu ca**
N	1.5%	1,000,000	Proteins, amino acids	**Pr M**
P	0.2%	30,000	Nucleic acids,	

			ATP	
K	1.0%	400,000	Catalyst, ion transport	
Ca	0.5%	200,000	Cell wall component	**Se**
Mg	0.2%	100,000	Part of chlorophyll	
S	0.1%	30,000	Amino acids	
Fe	100 mg/kg	2,000	Chlorophyll synthesis	**M**
Cu	6 mg/kg	100	Component of enzymes	
Mn	20 mg/kg	2000	Activates enzymes	
Zn	20 mg/kg	300	Activates enzymes	
B	20 mg/kg	2000	Cell wall component	
Mo	0.1 mg/kg	1	Involve in N fixation	
Cl	100 mg/kg	3,000	Photosynthesis reactions	

(ii) According to mobility

(a) In soil:

1. Mobile: NO_3^-, SO_4^{2-}, BO_3^{3-}, Cl^- and Mn^{2-}

2. Less mobile: NH_4^{2-}, K^+, Ca^{2+}, Mg^{2+} and Cu^{2+}

3. Immobile: $H_2PO_4^-$, HPO_4^{2-} and Zn^{2+}

(b) In plant:

1. Highly mobile: N, P and K

2. Moderately mobile: Zn

3. Less mobile: S, Fe, Mn, Cu, Mo and Cl

4. Immobile: Ca and B

(iii) According to metal and non metal

1. Metal: K, Ca, Mg, Fe, Mn, Zn and Cu

2. Non metal: N, P, S, B, Mo and Cl

(iv) According to cation and anion

1. **Cation:** K, Ca, Mg, Fe, Mn, Zn and Cu

2. **Anion:** NO_3, H_3PO_4 and SO_4

14.4 Beneficial elements

Apart from vanadium, silicon, aluminum, iodine, selenium and gallium, which have been shown to be essential for particular species of plants, there are several other elements, like rubidium, strontium, nickel, chromium and arsenic, which at very low concentrations and often under specific conditions have been shown to stimulate the growth of certain plants or to have other beneficial effects. These elements, the essentiality of which for growth and metabolism has not been unequivocally established but which are shown to exert beneficial effects at very low concentrations are often referred to as 'beneficial elements',

14.5 Forms of nutrients in soil

In soil, Nutrient present in different forms are as under:

S. No.	Nutrient	Forms
1.	Nitrogen	Organic N (97%) and Mineral N NH_4^+, NO_3^-
2.	Phosphorus	Solution P, Calcium, Iron, Aluminium and Occluded P, Organic P (25%-90%) and Mineral P

3.	Potassium	Water soluble K, Exchangeable K, Fixed K and Mineral K (90-98%),
4.	Sulphur	Sulphate S, Non sulphate S, Adsorbed S, Organic S(95%) and Total S,
5.	Micronutrients	Water soluble ion, Exchangeable, Adsorbed, chelated or complexed ion, Cation held in secondary clay mineral and insoluble metal oxides and cation held in primary mineral

14.6 Mechanisms of nutrient transport to plants

Two important theories, namely, soil solution theory and contact exchange theory explain nutrient availability to plants.

14.6.1 Soil solution theory :

(a) Mass flow: Movement of nutrient ions and salts along with moving water.

(b) Diffusion : Occurs when there is concentration gradient of nutrients between root surface and surrounding soil solution. Ions move from the region of high concentration to the region of low concentration.

14.6.2 Contact exchange theory:

The important of contact exchange in nutrient transport is less than with soil solution movement. A close contact between root surface and soil colloids allows a direct exchange of ions.

14.7 Role of Macro and Micro-nutrients

Essential elements perform several functions. They participate in various metabolic processes in the plant cells such as permeability of cell membrane, maintenance of osmotic concentration of cell sap, electrontransport systems, buffering action, enzymatic activity and act as major constituents of macromolecules and co-enzymes.

Nutrient (Element)	Role of Nutrients
1.Nitrogen (N)	(1) Nitrogen is constituent of chlorophyll. (2) N makes plant dark green. (3) It increases vegetative growth of protein content and cation exchange capacity (4) Encourages the formation of good quality foliage.

2.Phosphorus (P)	(1) It stimulates root growth and formation. (2) It helps in cell division and hastens maturity. (3) It makes plant more tolerant to drought, cold, insects and diseases (4) It increase plants and also increases nodule formation in pulses. (5) It increases tillers and ratio of grain to straw in crop.
3.Potassium (K)	(1) K helps in translocation also imparts, vigour and growth to plants. (2) It makes p to drought, cold, insects and diseases (3) It reduces lodging and increases the availal (4) It increases the size of root and tuber.
4. Calcium (Ca)	(1) It promotes early root growth. (2) Ca is constituent of cell and increases stiffness in straw (stem). (3) It increases the calcium content in plants and also increases the nodulation of leg (4) It improves soil structure and keeps soil neutral.
5. Magnesium (Mg)	(1) It is a constituent of chlorophyll. (2) It increase photosynthesis and regulates uptake of nutrients. (3) It also promotes the formation of oils and fats.
6. Sulphur (S)	(1) It helps in chlorophyll formation. (2) It stimulates root growth, seed formation and nodule formation. (3) It encourages plant growth. (4) S is constituent of enzymes and proteins and increases oil content.
7. Iron (Fe)	(1) It helps in chlorophyll formation. (2) It acts as oxygen carrier and helps in protein synthesis.
8. Manganese (Mn)	(1) It acts as a catalyst in oxidation reduction reaction and as an activator of many e (2) It also helps in chlorophyll synthesis.
9. Zinc (Zn)	(1) It constituent of a number of enzymes. (2) It helps in formation of growth hormones and enhances heat and frost resistance (3) It also acts as catalyst in chlorophyll formation.

10. Boron (B)	(1) It helps in uptake and efficient utilization of calcium. (2) It also helps in protein synthesis.
11. Copper (Cu)	(1) It helps in oxidation-reduction reaction. (2) It also plays constituent of certain protein.
12. Molybdenum (Mo)	(1) It helps in fixation of atmospheric nitrogen by nodule bacteria in legume. (2) It also helps in protein synthesis.
13. Chlorine (Cl)	(1) It is essential for photosynthesis process and keeps osmotic pressure normal in c (2) It encourages growth in crop plants.

Lesson 15. Nutrient Deficiency, Toxicity and Control Measures

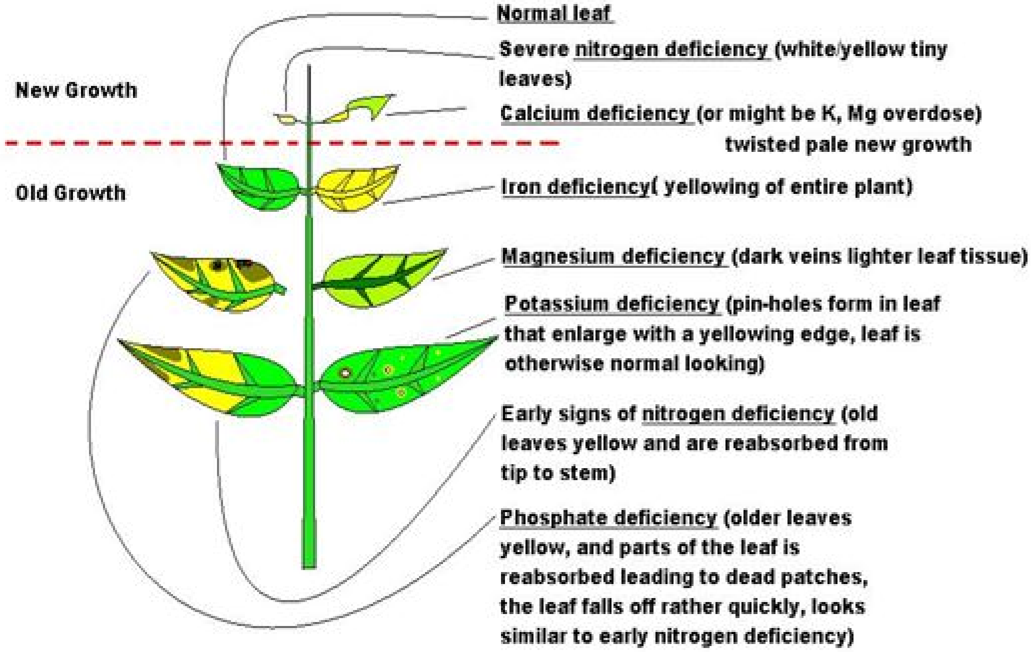
15.1 INTRODUCTION

Whenever the supply of an essential element becomes limited, plant growth is retarded. The concentration of the essential element below which plant growth is retarded is termed as "**The element is said to be deficient when present below the critical concentration".**

15.2 NUTRIENT DEFICIENCY

In the absence of any particular element, plants show certain morphological changes. These morphological changes are indicative of certain element deficiencies and are called deficiency symptoms. The deficiency symptoms vary from element to element and they disappear when the deficient mineral nutrient is provided to the plant. However, if deprivation continues, it may eventually lead to the death of the plant. The parts of the plants that show the deficiency symptoms also depend on the mobility of the element in the plant. For elements that are actively mobilised within the plants and exported to young developing tissues, the deficiency symptoms tend to appear first in the older tissues. For example, the deficiency symptoms of nitrogen, potassium and magnesium are visible first in the senescent leaves. In the older leaves, biomolecules containing these elements are broken down, making these elements available for mobilize younger leaves.

The deficiency symptoms tend to appear first in the young tissues whenever the elements are relatively immobile and are not transported out of the mature organs, for example, elements like sulphur and calcium are a part of the structural component of the cell and hence are not easily released. This aspect of mineral nutrition of plants is of a great significance and importance to agriculture and horticulture.



The kind of deficiency symptoms shown in plants include chlorosis, necrosis, stunted plant growth, premature fall of leaves and buds, and inhibition of cell division. Chlorosis is the loss of chlorophyll leading to yellowing in leaves. This symptom is caused by the deficiency of elements N, K, Mg, S, Fe, Mn, Zn and Mo. Likewise, necrosis, or death of tissue, particularly leaf tissue, is due to the deficiency of Ca, Mg, Cu, K. Lack or low level of N, K, S, Mo causes an inhibition of cell division. Some elements like N, S, Mo delay flowering if their concentration in plants is low.

15.3 Nutrient deficiency and management

Generalized symptoms of plant nutrient deficiency

Nutrients		**Visual deficiency symptoms**
N	:	Light green to yellow appearance of leaves, especially older leaves, stunted growth, poor fruit development
P	:	Leaves may develop purple colouration, stunted plant growth and delay in plant development
K	:	Marginal burning of leaves, irregular fruit development
Ca	:	Reduced growth or death of growing tips, poor fruit development and appearance
Mg	:	Initial yellowing of older leaves between leaf veins spreading to younger leaves, poor fruit development and production

S	:	Initial yellowing of young leaves spreading to whole plant, similar symptoms to N deficiency but occurs on new growth
Fe	:	Initial distinct yellow or white areas between veins of young leaves leading to spots of dead leaf tissue
Mn	:	Interveinal yellowing or mottling of young leaves
Zn	:	Interveinal yellowing on young leaves, reduce leaf size, short internodes, brown leaf spot on paddy
Cu	:	Stunted growth, terminal leaf buds die, leaf tips become white and leaves are narrowed and twisted.
B	:	Terminal buds die, breakdown of internal tissues in root crops, internal cork of apple, impairment of flowering and fruit development
Mo	:	Resemble N deficiency symptoms, whiptail diseases of qualiflower, leaves show scorching and whithering
Cl	:	Chlorotic leaves, some leaf necrosis

Nitrogen deficiency symptoms in maize

Phosphorus deficiency symptoms in maize

Potassium deficiency symptoms in maize

Sulphur deficiency symptoms in maize

Zinc deficiency symptoms in maize

Nutrient deficiency may not be apparent as striking symptoms such as chlorosis on the plant, especially when mild deficiency is occurring. However, significant reduction in crop yields can occur with such deficiencies. This situation is termed **hidden hunger** and can only be detected with plant tissue analysis or yield decline.

15.4 MANAGEMENT (CORRECTIVE MEASURES)

Nutrient deficiency can be correct by (i) addition of nutrient through fertilizer in soil as well as foliar application and (ii) addition of organic manure as per fertilizer recommendation.

Deficiency of Nutrient	**Corrective measures**
N	(1) Use of nitrogen fertilizer in the soil.

	(2) Foliar spray of urea.
P	Application of phosphatic fertilizer in the soil e.g., DAP, super phosphate
K	Use of potassic fertilizer in the soil e.g., muriate of potash.
Ca	Use of calcium carbonate or calcium hydroxide in the soil.
Mg	Soil or foliar application of magnesium sulphate.
S	Soil or foliar application of sulphur or sulphate.
Fe	Soil or foliar spray of ferrous sulphate.
Mn	Soil or foliar spray of manganese sulphate.
Zn	Soil or foliar application of zinc sulphate
B	Soil or foliar spray of boric acid or borax
Cu	Soil or foliar spray of copper sulphate
Mo	Soil or foliar application of sodium molybdate or ammonium molybdate.

15.5 NUTRIENT TOXICITY AND MANAGEMENT

The requirement of micronutrients is always in low amounts while their moderate decrease causes the deficiency symptoms and a moderate increase causes toxicity. In other words, there is a narrow range of concentration at which the elements are optimum. Any mineral ion concentration in tissues that reduces the dry weight of tissues by about 10 per cent is considered toxic. Such critical concentrations vary widely among different micronutrients. The toxicity symptoms are difficult to identify. Toxicity levels for any element also vary for different plants. Many a times, excess of an element may inhibit the uptake of another element.

Nutrient toxicities in crops are more frequent for manganese (Mn) and boron (B) than for other nutrients.

Boron toxicity symptoms

Manganese toxicity symptoms

Manganese toxicity is found on acid soils. It is important to know that manganese competes with iron and magnesium for uptake and with magnesium for binding with enzymes. Manganese also inhibits calcium translocation in shoot apex. Therefore, excess of manganese may, induce deficiencies of iron, magnesium and calcium. Thus, what appears as symptoms of manganese toxicity may actually be the deficiency symptoms of iron, magnesium and calcium.

Boron toxicities occur in irrigated regions where the well or irrigation waters are exceptionally high in B. Most other nutrient toxicities occur when large amounts of nutrients in question have been added in waste, e.g., sewage sludge. Crops grown near mines and smelters are prone to nutrient toxicities. Generally, the symptoms of toxicity in crops occur as burning, Chlorosis and yellowing of leaves. Toxicities can result in decreased yield and/or impaired crop quality.

15.6 Prevention of toxicity

(1) With the exception of Mo, toxicity of other nutrients can be reduced by liming.

(2) Following recommended rates of fertilizers and the safe and controlled use of waste materials, such as sewage sludge and coal fly ash, should reduce metal loading and nutrient toxicity in crops.

(3) Use of crop species and genotypes less susceptible to toxicity are recommended where toxicity is suspected.

(4) Provided sufficient drainage because availability of nutrients like Fe and Mn is increases up to toxicity level under water logged condition.

(5) Ground water must be monitored regularly, if content of B and Cl is too high stop to applied water or applied with dilution.

(6) Addition of sufficient amount of organic matter binds some of the toxic elements.

(7) Ploughing in dry soil so increase the infiltration rate and leach the toxic element with rain water.

Lesson 16. Chemical fertilizers

16.1 INTRODUCTION

Fertilizers are chemical substances that contain one or more ingredients of plant food, in large proportions. Some organic synthetic substances like urea have also been included in this category. They may be natural substances or artificial products.

16.2 Fertilizers

16.2.1 Straight Fertilizers

When a fertilizer contains a single nutrient, it is called a straight fertilizer. Such fertilizer is called nitrogenous or phosphatic or potassic e.g. urea.

16.2.2 Complex or Compound Fertilizers

Two or more nutrients in one compound is known as complex or compound fertilizers. These fertilizers is granular and easy to apply. Examples are:

16.3 Nitrogenous Fertilizers

The nitrogenous fertilizers are broadly classified into 4 groups (Table 16.1).

Table 16.1 : Classification of Nitrogenous Fertilizers

Sources of nitrate	Name of fertilizer	Percentage of nitrogen	%P	Reaction (Acidity/Basicity)
Nitrate	Sodium nitrate ($NaNO_3$) Calcium nitrate $Ca(NO_3)_2$ Potassium nitrate (KNO_3)	16.0 15.0 13.0		Basic -do- -do-
Ammonium	Ammonium sulphate $(NH_4)_2 SO_4$ Ammonium chloride	20.6 25.0	– –	Acidic -do-

	(NH_4Cl) **Diammonium phosphate** $(NH_4)_2HPO_4$	18.0	46	-do-
Nitrate and Ammonium	Ammonium nitrate (NH_4NO_3)	33.5		-do-
	Ammonium sulphate nitrate $(NH_4)_2 SO_4,(NH_4NO_3)$	26.0		-do-
	Calcium ammonium nitrage	20.5		Neutral
Amide	Urea $CO(NH_2)_2$	46.0		Acidic
	Calciumcynamide ($CaCN_2$)	22.0		Basic

16.3.1 Characteristics of nitrogenous fertilizers

According to characteristics, nitrogenous fertilizers are classified in following four groups:

16.3.1.1 Nitrate fertilizers. The most common nitrate fertilizers in use is sodium nitrate or calcium nitrate.

(a) Nitrate group of fertilizers are soluble in water and hygroscopic (absorbs moisture from the atmosphere to become sticky).

(b) They are alkaline in nature. Constant use of sodium nitrate, creates deflocculation of clay particles and poor drainage.

(c) Contains less percentage of nitrogen than other groups so that its use is diminishing at a fast rate.

(d) They are completely soluble in water and readily available for the use of plants as such, without any chemical change in the soil.

(e) The nitrate is not retained (adsorbed) by the soil and is liable to fast leaching.

(f) They are applied in small doses and repeated at intervals on standing crops (top dressing).

(g) It is not suitable for rice crop in early stage of growth. Because rice plants take nitrogen in ammonical form.

16.3.1.2 Ammonium fertilizers. This group of fertilizers are in wide use particularly ammonium sulphate.

(a) Ammonium fertilizers are water soluble but non-hygroscopic.

(b) They are acidic in nature.

(c) High level of nitrogen than nitrate fertilizers.

(d) They are less readily available to plants than nitrate fertilizers. The ammonical nitrogen has to nitrify in the soil and be converted into nitrate before it can be taken up by plants.

(e) The ammonia in ammonium sulphate is fixed (adsorbed) by the soil immediately after application and it is not leached away like nitrates. Repeated and heavy doses of ammonium sulphate without adequate supplies of lime in the soil will lead to acidity in the soil.

(f) This group of fertilizers may be used in basal application and top dressing.

16.3.1.3 Nitrate and Ammonium Fertilizers

(a) These group of fertilizers are soluble in water and slightly hydroscopic (e.g., Ammonium Nitrate – highly hygroscopic ;Ammonium Sulphate Nitrate – slightly ; Calcium Ammonium Nitrate – slightly).

(b) In this group both nitrate and ammonium are available.

(c) Readily available to plants. With its nitrate-nitrogen, the plant drives it immediately. Ammonium form of nitrogen provides a steady source of N.

(d) Availability of ammonium reduces leaching loss.

(e) Acidic in nature but exception is calcium ammonium nitrate which is neutral in reaction.

(f) Used in top dressing and basal dressing.

16.3.1.4 Amide Fertilizers

(a) Amide fertilizers are soluble in water and hygroscopic in nature.

(b) These fertilizers are converted to ammonium carbonate and then to nitrates due to action of microorganism. The conversion of amides into ammonical and nitrate from takes about 6-7 days.

(c) Leaching loss is very less because once amide is converted to ammonical form it is adsorbed by soil colloids and slowly released and nitrified to nitrates.

(d) Amide fertilizers i.e., urea and calcium cynamide are synthetic organic fertilizers.

Urea: It is slightly acidic in nature. Urea application to soil creates a small loss of calcium from the soil. Urea is highly concentrated nitrogenous fertilizer containing 46% nitrogen. Therefore, its higher concentration may injure the plant roots or germinating seeds. It is desirable that urea be mixed with ashes or small quantity of soil to facilitate an even distribution to avoid risk of injury to plants. The toxic ingredient present in urea is biuret. It is cheapest or economical fertilizer. It can be used in liquid form as foliar application.

16.4 PHOSPHATIC FERTILIZERS

Phosphorous fertilizers are classified into: (A) water-soluble, (B) Citrate-soluble, and (C) Insoluble.

16.4.1 Fertilizers containing water-soluble phosphorus characteristics

1. Phosphate is water-soluble and quick acting (available). (Table 16.2)
2. Very less leaching loss in this group of fertilizers.
3. Should be applied in neutral and alkaline soils.

Table 16.2 : Fertilizers containing water-soluble phosphorus

Name of fertilizer	Chemical composition	Percentage composition	Acidity of alkalinity
Sulperphosphate (ordinary) (single super phosphate)	$Ca(H_2PO_4)_2$	16-20	Neutral
Superphosphate (concentrated) (triple super phosphate)	$3Ca(H_2PO_4)_2$	40-48	Neutral or acidic
Diammonium phosphate	$(NH_4)_2HPO_4$	46-48	Acidic

16.4.2 Fertilizers containing citrate-soluble phosphorus characteristics

(1) Insoluble in water but soluble in citric acid, so that it does not become readily available to plants (16.3).

(2) No leaching loss.

(3) These are slow acting fertilizers therefore, applied in the soil 15-30 days before sowing.

(4) These fertilizers should be used in natural and acidic soils.

Table 16.3 : Fertilizers containing citrate-soluble phosphorus

Name of fertilizer	Chemical composition	Percentage composition P_2O_5	Acidity or alkalinity
1. Basic slag(Indian)	$(CaO)_3.P_2O_5.SiO_2$	3-5	Alkalinity
1. Dicalcic phosphate	$CaHPO_4$	35-40	Acidic

16.4.3 Fertilizers containing insoluble phosphorus characteristics

(1) Because of their insolubility and their slow availability, fertilizers of this be applied in the soil about 2 months before sowing, phosphorus is available in the form of tricalcium phosphate (Table 16.4).

(2) Generally, deep placement is done in highly acidic soils.

Table 16.4 : Fertilizers containing insoluble phosphorus

Name of fertilizer	Chemical composition	Percentage composition P_2O_5	Percentage composition N	Acidity or alkalinity
1. Rock phosphate	$Ca_3(PO_4)_2$	20 - 30		
1. Bone meal	--	18 - 20	3	Alkaline

16.5 POTASSIC FERTILIZERS

(1) Potassium fertilizers are water-soluble but not hygroscopic in nature (Table 16.5).

(2) They are readily available to plants.

(3) There is not leaching loss.

(4) As they are neutral in reaction so have little or no effect on the soil pH.

Table 16.5 : Potash containing potassic fertilizers

Fertilizer	Chemical form	Percentage composition of K_2O	Reaction
1. Potassium chloride (mutriate of potash)	KCL	60	Neutral
2. Potassium sulphate	K_2SO_4	50	Neutral

16.6 Sulphur containing fertilizers

(1) Sulphur containing fertilizers are mostly water-soluble.

(2) Sulphur from these fertilizers is readily available to plants except S from elemental S, because it required sequential oxidation to convert SO_4^{-2} from S (Table 16.6).

(3) Continuous use of S containing fertilizer decrease pH of soil.

Table 16.6 : Sulphur containing fertilizers

Fertilizer	Sulphur content (%)
Ammonium sulphate	24
Elemental S	95-98
Single super phosphate	12

16.7 Micronutrients fertilizer

The inorganic sources of micronutrient fertilizer are following:

16.7.1 Sulphate (salts)

The sulphate form of micronutrients such as: Cu, Zn, Fe and Mn, represents a water-soluble form that is plant available. Borate is the equivalent plant available form for B. Sulphates are the most commonly used form for field crops. Sulphates can be applied to the soil or foliage. Sulphate products, applied at agronomically recommended rates, can provide long term residual value. e.g. zinc sulphate, ferrous sulphate, manganese sulphate, copper sulphate etc.

16.7.2 Chelate

Chelates are complexes of certain micronutrients (the positively charged ones like iron and zinc) with organic molecules, to form compounds that can hold the micronutrients in a form that is available to plants. Chelated micronutrients are much slower to form unavailable compounds, or to leach away. Chelating compounds occur naturally in organic material in the soil, or can be synthesized to make chelated fertilizers. Plant roots are able to take the micronutrient directly from the chelate, and release the chelating compound back to the soil. For example, a synthetic chelating agent is EDTA, and a natural chelating agent is citric acid. Chelates are generally many times more expensive than the sulphate or oxide forms, but this is partly compensated for in the low recommended rate of chelate product needed to supply the micronutrient. e.g. EDTA –Zn, EDTA –Fe, EDDHA – Fe.

16.8 NUTRIENT CONTENT OF CHEMICAL FERTILIZERS

SN	Fertilizers	Nutrients (%)				
		N	P_2O_5	K_2O	S	Other
1	Urea	46	-		-	-
2	Ammonium sulphate	21	-		24	-
3	Ammonium chloride	26	-		-	-
4	calcium ammonium nitrate	25	-		-	8.1% Ca
5	Single super phosphate	-	16		12	20% Ca
6	Potassium chloride (muriate of potash)	-	-	60	-	Cl
7	Potassium sulphate (sulphate of potash)	-	-	50	18	-

8	Diammonium phosphate	18	46	-	-	-
9	Rock phosphate	-	18-20	-	-	Ca
10	Phosphogypsum	-	-	-	16	21% Ca
11	Magnesium sulphate	-	-	-	13	16% Mg
12	Borex	-	-	-	-	10.5% B
13	Copper sulphate	-	-	-	13	24% Cu
14	Ferrous sulphate	-	-	-	12	19% Fe
15	EDTA-Fe	-	-	-	-	12% Fe
16	Manganese sulphate	-	-	-	15	30.5% Mn
17	Zinc sulphate	-	-	-	11-16	21 % Zn
18	EDTA-Zn	-	-	-	-	12% Zn

Lesson 17. Fertilizer Reaction in Soil and Use Efficiency

17.1 Nitrogenous Fertilizers

17.1.1 Fate of Nitrogen in the Soil

The nitrate-nitrogen of the soil, whether added in form of fertilizer or formed by nitrification, may loss in four ways: (1) volatilization (gaseous loss), (2) leaching loss (3) denitrification loss (4) used by microorganism and weeds.

(1) Volatilization loss. In this chemical reduction process, nitrogen is lost in the gaseous form when urea or ammonium fertilizers are applied on the soil surface. Loss of nitrogen as ammonia is occurred especially in alkaline soils. High concentration of ammonia (high dose of ammonical or amide fertilizers) is toxic to the nitrification process, resulting in an unusual build-up of nitrates. Under acid conditions these nitrites are converted to gaseous elemental nitrogen or nitrous oxide, when brought in contact with certain ammonium salts or urea. It may be represented in the following reaction:

$$\underset{\text{Nitrite}}{2HNO_2} + \underset{\text{Urea}}{CO(NH_2)_2} \longrightarrow CO_2 + 3H_2O + 2N_2$$

(2) Denitrification loss. The nitrates may change to gaseous form in the lack of air or by poor drainage. The biochemical reduction of nitrate-nitrogen to gaseous compounds by microorganism is called denitrification. The microorganisms involved are common anaerobic forms. Under field conditions, nitrous oxide is the gas lost in largest quantities, although elemental nitrogen is also lost under some conditions. Nitric oxide loss occurs most readily under acid conditions.

$$2NHO_3 \quad 2NHO_2 \quad N_2O \xrightarrow{-2(O)} N_2 \xrightarrow{-2(O)} 2NO \quad \xrightarrow{-(O)} \quad \xrightarrow{-(O)}$$

Nitrates Nitrites Nitrous oxide Elemental nitrogen Nitric oxide

(3) Leaching loss. The nitrate-nitrogen is lost in drainage or with percolating water. The amount of nitrogen lost depends upon the climate and cultural conditions in humid region or a water-logged condition, losses of nitrate by leaching are significant. In arid and semi-arid region, such losses are minimum.

(4) Used by soil microorganisms and weeds. Soil microorganisms readily assimilate nitrate-nitrogen. If microbes have a ready food supply (organic matter) they utilize the nitrates more readily. This is one of the reasons, crops get about one-half the nitrogen added in forms of nitrogenous fertilizer.

Weeds may also utilize the nitrate-nitrogen added to the soil (or present in the soil). Therefore, crops may not get nitrogen in fully quantity.

17.2 WAYS TO INCREASE NITROGEN USE EFFICIENCY

Management of nitrogen in the soil to improve the nitrogen fertilizer economy is given below:

1. Minimizing nitrogen loss with proper management of Nitrogen

(a) Deep placement of N fertilizers in a field before transplanting/sowing increases the nitrogen use efficiency. The loss would be minimum.

(b) Ammonia volatilization losses in flooded soils range from negligible to almost 60% of applied nitrogen. In recent studies NH_3 loss from ammonium sulphate $(NH_4)_2$ SO_4 was 0.2-6.8 per cent and that from urea 1-20 per cent. Through incorporation of ammonium fertilizers like ammonium sulphate into the soil minimizes NH_3 volatilization loss.

(c) The loss of NH_3 varies from 27 to 47% when urea is applied on surface as top dressing at 14 to 27 days after transplanting of rice crop. Rates of NH_3 loss were limited to 10-15% when urea was applied.

(d) Nitrogenous fertilizers should be applied in split dose (or instalment) to minimize the losses.

(e) Use of slow and controlled-release fertilizers. Fertilizers that release – their plant nutrients slowly throughout the growing season (or for longer period), have a number of potential advantages. Slow release volatilization loss and sustain the crop with adequate N nutrition throughout the growing season.

(f) Use of nitrification inhibitors increase the controlled availability of plant nutrients. The inhibitor is block the conversion of ammonium to nitrate-nitrogen by inhibiting*Nitrosomonas* (bacteria) growth or activity. The inhibitors are dicyandiamide (DCD), acetone extract of neem etc.

A group of organic compounds in neem seed known as meliacins are responsible for inhibiting nitrification. Urea treated with neem cake inhibited nitrification by 40 and 74 per cent at the end of 1 and 2 weeks of incubation, respectively. The coating technique used coal tar solution in kerosene oil (1kg/2 litres, enough for 100 kg urea) as sticker to hold the finely produced neem cake. One quintal urea is transferred to a seed treatment drum and coal tar-kerosene solution is added in parts while rotating the drum. Neem cake (15-20 kg) is then added and the content of the drum is rotated and thus the neem cake is ready for use. The technique is simple and being used only on individual farmer's level. This technique could not go to the industrial level.

A new technique involving neem oil micro-emulsion has been developed at IARI, New delhi for coating urea. Urea coated with micro-emulsion has shown definite advantage in nitrogen use efficiency. The technology has two major advantages (i) only 0.5 kg neem oil is needed per tone of urea and (ii) the product is also eco-friendly.

(g) Application of fertilizers at proper time.

(h) Use of soil amendments as corrective methods.

(i) Volatilization losses from nitrogenous fertilizer may be minimized by mixing the urea and soil in 1:5 ratio. The mixture should be used after drying in under shade. Likewise, nitrogenous fertilizer may be mixed with oilseed or neem cake before broadcasting.

2. Minimizing nitrogen loss with proper water management

(a) For minimizing the denitrification loss in the field arrangement for proper drainage should be done. Proper aeration would decrease the denitrication loss.

(b) Optimum use of irrigation water would reduce the leaching loss.

(c) Applying the first dose of nitrogen to a puddle field without any standing water and then introducing water at 4 days transplanting.

3. Weed Control: Loss of N can be minimized by removal of weeds from the field.

4. Varietal Differences in Nitrogen-use Efficiency. Rice variety IR 42 uses N more efficiently than IR 36 and IR 8. Variety like IR 42 should be used for increasing N-efficiency.

17.3 PHOSPHATIC FERTILIZERS

17.3.1 Superphosphate and soil reaction

When superphosphate is applied to neutral or alkaline, the soluble monocalcic phosphates are produced. The phosphates are then said to be *reverted.* Since the reverted phosphates are chemical precipitates, they are in a fine state of division and offer a large surface for the soil solution to act. As a result, even tricalcic phosphate is rendered soluble slowly and gradually, and made available for plants. When the soil is acidic and the pH is 5.5 or lower, the iron and aluminium in the soil become soluble and combine with the soluble phosphates in superphosphate. Iron and aluminium phosphates that are formed, as a result, are very insoluble and do not become available for the use of plants ordinarily. The phosphates are then said to be fixed or tied up in the soil.

The organic matter in the soil effectively prevents applied phosphates from being tied up (fixed), in the soil, in insoluble forms and even releases phosphates that had already been fixed, is likely to influence phosphate application practice in the future.

17.3.2 Rock phosphate

For effective results, it should be used in heavy application, particularly with organic matter. Its availability is increased by the presence of decaying organic matter. Rock phosphate must be finely ground before application in acid soils.

17.3.3 Phosphorus Use Efficiency

In the case of phosphorus fertilization, fixation of phosphate is the main problem. Water soluble phosphatic fertilizers soon after application to the soil react preferably, called the**initial phosphate reaction products**.

- Measures to improve phosphorus use efficiency are as follow:
- To improve phosphorous use efficiency, phosphatic fertilizers should have minimum contact with the soil.

- In acid soil, phosphorus use efficiency can be improved by raising pH with the application of lime.
- Surface broadcast, following by mixing during puddling, has the highest phosphorus use efficiency for rice, being even better than placement at various depths.
- Phosphate placement is more beneficial than broadcast application in wheat. Application in seed furrows or by drilling just below the seeds is quite efficient methods for wheat.
- Recovery of fertilizer phosphorus in single season is very low. Residual effect of phosphatic fertilizer is quite high in the next succeeding crop.
- Phosphorus use efficiency is increased by application of phosphatic fertilizers with organic manures.
- Because of fixation, crop may not use more than 10 percent of phosphorus in the fertilizers applied broadcast and incorporated to the soil. However, up to 30 percent or higher may be used when applied as concentrated band along the plant row. While mixing with the soil increases fixation, localized placement of banding allows the phosphatic fertilizer to react with only a much smaller portion of the soil in the immediate vicinity of the band. Clay soils have greater phosphate fixing capacity than sand soils.
- Fixation of P in citrate soluble form in less that of water soluble form. Hence, phosphatic fertilizers in citrate soluble form may be broadcast.
- Ground rock phosphate which is neither water not citrate soluble should preferably be applied to acid soils and thoroughly mixed with the soil. This ensures reaction with the soil acids which bring phosphorus into available form.

17.4 POTASSIC FERTILIZERS

Potassium sulphate

This fertilizer is more effective on light and medium soils with high pH (alkaline and calcareous soils). Under wet conditions, it is preferable to apply potassium sulphate than potassium chloride. The SO_4 (sulphate) ions are retained by soils more strongly than Cl (Chlorine) ions in the heavy soils. Excess of sulphate ion in the heavy soil develops toxicity.

Lesson 18. Definition and Scope of Agronomy

18.1 INTRODUCTION

The term agriculture is derived from the Latin words *ager* or 'agri' meaning 'soil' and *cultura* meaning 'cultivation'. Agriculture is a very broad term encompassing all aspects of crop production, livestock farming, fisheries, forestry, etc. Agriculture is the science and art.

Agriculture is a productive unit where the natural inputs i.e. light, air, water; nutrient, etc. are converted into usable product by the green plants. The livestock, birds and insects feed on the green plants and provide concentrated products such as milk, meat, eggs, wool, honey, silk and lac. Agriculture provides us with the materials needed for our feeding housing and clothing. Agriculture consists of growing plants and rearing animals which help to maintain a biological equilibrium in nature, cultivation of land with a view to produce crop.

18.2 AGRONOMY

Agronomy is a branch of agricultural science which deals with principles and practices of soil, water, and crop management. This term is derived from Greek words *agros* meaning 'field' and *nomos* meaning 'to manage'. In recent times, agronomy has assumed newer dimensions and can be defined as a branch of agriculture dealing with field crop production and soil management on sustainable basis.

18.3 Important events in the history of agriculture

Period	Event
Earlier than 10,000 B.C.	– Hunting and gathering
8700 B.C.	– Domestication of sheep
7700 B.C.	– Domestication of goat
7500 B.C.	– Cultivation of wheat and barley
6000 B.C.	– Domestication of cattle and pigs
4000 B.C.	– Cultivation of maize
3500 B.C.	– Cultivation of potato
3400 B.C.	– Wheel was invented
3000 B.C.	– Bronze was used to make tools

2900 B.C.	– Invented Plough, Irrigated farming started
2300 B.C.	– Chickpea, pear, sarson and cotton
2200 B.C.	– Cultivation of rice
1800 B.C.	– Cultivation of finger millet (Ragi)
1725 B.C.	– Cultivation of sorghum
1500 B.C.	– Cultivation of sugarcane
1400 B.C.	– Use of iron
15 Century A.D.	– Cultivation of sweet orange, wild brinjal, pomegranate
16 Century A.D	– Introduction of several crops into India by Portuguese. They are potato, sweet potato, cassava, tomato chillies, papaya, guava, groundnut, cashew nut, tobacco etc.

18.4 SCOPE OF AGRONOMY

Agronomy is a dynamic discipline. With the advancement of knowledge and better understanding of plant and environment, agricultural practices are modified or new practices developed for high productivity. For example availability of herbicides for the control of weeds led to development of a vast knowledge about selectivity, time and method of application of herbicides. Gigantic irrigation projects are constructed to provide irrigation facilities. However, these projects created side effects like water logging, and salinity. To overcome this problem, appropriate water management practices are developed. Population pressure is increasing but area under cultivation is static. More number of crops have, therefore, to be grown on the same piece of land in an year. As a result, intensive cropping has come into vogue. Similarly, no tillage practices have come in place of clean cultivation as a result of increase in cost of energy. Likewise new technology has to be developed to exploit their full potential.

The factors restricting increased agricultural production are low soil fertility, crop varieties of low genetic yield potential, poor agronomic practices, inadequate control of disease and insects, non-availability of production inputs, government economy policies affecting agriculture and weak research and extension programmes. Restoration of soil fertility, preparation of good seedbed, use of proper seed rates, correct dates of sowing for each improved variety, proper conservation and management of soil moisture and proper control of weeds are agronomic practices to make our finite land water resources more productive.

Lesson 19. Classification of Crops

19.1 INTRODUCTION

Field crops are herbaceous plants grown in cultivated fields under more or less extensive system of culture. Agronomic classification of different field crop is given as under

19.2 ACCORDING TO BOTANICAL ASPECTS

(A) Monocotyledons : A plant having only one seed leaf or cotyledon in each of its seed. Such plants have a shallow roots, narrow leaves and tillering ability. e.g., Families:

(1) Poaceae: e.g. Cereals i.e. paddy, wheat, sorghum, pearl millet, maize, sugarcane, etc.

(2) Zingiberaceae: e.g. Ginger

(3) Liliaceae : e.g. Onion

(B) Dicotyledons : A plant having two seed leaf or cotyledons in each of its seed. Such plants have a deep taproots, broad leaves and branching ability. e.g., Families

(1) Malvaceae: e.g. cotton, okra

(2) Cruciferae : e.g. cabbage, mustard

(3) Solanaceae: e.g. tobacco, potato, brinjal

(4)Leguminoceae: e.g. groundnut, pigeon pea, gram, pea, mung bean, urd bean

(5) Tiliaceae: e.g. jute, sun hemp

(6) Linaceae: eg. linseed

(7) Euphorbiaceae : e.g. castor

(8) Composite : e.g. sunflower

(9) chenopodiaceae: e.g. sugar beet

19.3 ACCORDING TO SEASON OF GROWTH

(A) Kharif or Monsoon: Crops are grown in the month of June - July. e.g. Paddy, pigeon pea, groundnut, sorghum, etc.

(B) Rabi or Winter: Crops are grown in the month of October - November. e.g. wheat, gram, mustard, cumin, fenugreek, onion etc.

(C) Summer or Hot weather: Crops are grown in the month of February - June. e.g., paddy, green gram, black gram, cowpea, etc.

19.4 ACCORDING TO LIFE PERIOD

(A) Annuals: A plant which grows from seed, complete its life cycle and dies during the season or same year. e.g. cereal crops.

(B) Biennials: A plant which completes its life cycle in two season or year. During first season/year, they completes it's vegetative growth and during second season/year they completes it's reproductive growth. eg. sugarcane, sugar beet, banana, onion.

(C) Perennial: A plant which completes its life cycle in more than two seasons/years. e.g., agave, elephant foot.

19.5 ACCORDING TO CULTURAL PRACTICES

(A) Irrigated crops: e.g. Sugarcane, paddy, banana etc.

(B) Dry farming crops; The crop which are grown under natural precipitation. e.g. sorghum, bajra, groundnut, nagli, etc.

(C) Sole crops: One crop variety grown alone in pure stands at normal density.

(D) Monocroping: The repetitive growing of the same crops on the same piece of land. e.g. groundnut in Saurastra region.

(E) Intercropping: Growing two or more crops simultaneously on the same piece of land in different rows e.g., sorghum + black gram, pigeon pea + ground nut, sugarcane + onion, etc.

(F) Mixed cropping: Growing two or more crops simultaneously on the same land without/ irrespective to definite row pattern. e.g. sorghum + green gram+ black gram.

19.6 ACCORDING TO AGRONOMICAL OR ECONOMICAL ASPECTS

(A) Food crops

(i) **Cereals** : e.g. paddy, wheat, maize, sorghum, bajra, nagli,etc.

(ii) **Pulses** : e.g. gram, green gram, black gram, pigeon pea, cowpea, indian bean, moth bean, etc.

(iii) **Legumes** : e.g. groundnut, soybean, cluster bean

(iv) **Edible oil seeds** : e.g. groundnut, seasamum, sunflower, mustard, safflower

(v) **Fruit crops** : mango, banana, sapota, guava, papaya, ber, grape citrus crop, etc.

(vi) **Vegetable crops** :

(a) Leafy : cabbage, fenugreek, palak

(b) Fruit : tomato, okra, brinjal

(c) Root : radish, carrot

(d) Tuber/Stem : potato, sweet potato, ginger, turmeric

(e) Bulb : onion, garlic

(f) Flower : cauliflower

(g) Pod : French bean, pigeon pea, cowpea, Indian bean

(B) Non-food crops

(i) **Forage/fodder** : lucerne, berseem, hybrid nappier grass

(ii) **Fibre crop** : cotton, jute, sun hemp

(iii) **Non edible oilseeds** : castor, linseed

(iv) **Sugar crop** : sugarcane, sugar beet

(v) **Dyes** : safflower, indigo

(vi) **Narcotics** : tobacco, coffee, tea, opium, poppy, chicory

(vii) **Drugs/ Medicinal** : isabgul, jethimadh, senna, kariyatu

(viii) **Spices & condiments**: cardamom, cumin, black pepper, coriander, fennel, fenugreek

(C) Special purpose crops

(i) **Row crops**: Crops which are grown in rows with uniform spacing throughout the field. e. g. cotton, castor, sorghum, etc.

(ii) **Support crops**: certain fast growing crops work as supporter to vine crops. e.g. castor, shevri in betel vine, sorghum in cowpea/bean.

(iii) **Wind break crops**: Crops which are grown on boundaries to protect the field crops from wind.

(iv) **Cover crops**: Cover crops are grown primarily to cover the soil and to reduce the lost of moisture and erosion by wind and water. e.g. groundnut, kidney bean, cowpea, mung bean.

(v) **Silage crops**: Crop which are preserved in a succulent condition by partial fermentation in a tight silo pit. e.g. maize, sorghum, bajra.

(vi) **Cash crops**: crop grown for sale and brings money immediately. e.g. cotton, tobacco, potato, sugarcane.

(vii) **Green manure crops**: Any crop which are grown and buried into the soil for improving the soil condition by the addition of organic matter. e.g. sun hemp, dhaincha, glyricidia.

(viii) **Pasture crops**: Different types of vegetation found on pastures or grassland area which usually grow. e.g. dharo, zinzvo.

(ix) **Catch crops**: Crop which is grown as substitute for the main crop that has failed on account of unfavorable condition. e.g. cowpea, sesame, green gram.

(x) **Trap crops**: Crop which is grown on boundary of the field for protection against pest, insect, disease.

(xi) **Nurse crops**: Crop which is used to protect or nurse the other crops in their young stage. e.g. cluster bean in ginger, sun hemp in sugarcane.

(xii) **Companion crops**: Two crops are taken together with the aim that they are benefited to each other. e.g. maize and green gram.

(xiii) **Mixed crops** : Two or more than two crops are grown together on the same piece of land at the same time. e.g. bajra + cowpea + green gram.

Lesson 20. Effect of Different Weather Parameters on Crop Growth and Development -I

20.1 INTRODUCTION

Crop growth and development are primarily governed by environmental conditions. The success or failure of crops is intimately related to the weather during the crop periods. Weather has significant influence on every phase of agricultural activity from preparatory tillage to harvesting and storage. A sound knowledge of the climatic factors and its interactions with crop is essential for successful agriculture.

20.2 DIFFERENCE BETWEEN WEATHER AND CLIMATE

Weather is a state or condition of atmosphere at a given place and at a given time. It is daily variations or conditions of lower layers of the atmosphere. Weather pertains to smaller area like village, city, or even district and smaller duration of time *i.e.* part of a day, or complete day. Some examples are hot day, rainy day, cloudy weather, dry weather, etc.

Climate is a generalized weather or summation of weather conditions over a given region during a comparatively longer period. Climate is related to larger areas like zone, state, country, part of continent and longer duration of time like month, season, or year and best described by the normal and averages e. g. cold season, tropical climate, temperate climate, etc.

When it is desired to give the state of weather at any particular place, the following weather elements are considered. (1) solar radiation (2) air temperature (3) rainfall (4) wind movement (5) relative humidity (6) atmospheric pressure and (7) clouds.

20.3 SOLAR RADIATION

Solar energy provides light required for seed germination, leaf expansion, growth of stem and shoot, flowering fruiting and thermal condition necessary for the physiological function of the plant. The effect of solar radiation on plant communities can be divided into four categories (a) Thermal effect of radiation (b) Photosynthetic effect of radiation (c) Photoperiodic effect and (d) Other effects.

20.3.1 Thermal effect of radiation

More than 70 per cent of the solar radiation absorbed by the plant is converted into heat. This heat energy is utilized for transpiration and for convective heat exchange with the surroundings. This exchange determines the temperature of leaves and of other plant parts.

20.3.2 Photosynthetic effect of radiation

A portion of solar radiation, up to 28 per cent in terms of energy is used in photosynthesis. Solar radiation influences the production of enzymes useful in photosynthesis, development of photosynthetic apparatus, growth, yield formation and finally yield.

20.3.2.1 Enzymes

The reduction of carbon dioxide to carbohydrates is catalyzed by enzymes, namely phosphophenol pyruvate carboxylase and ribulose biphosphate carboxylase. Light intensity increases activity and amount of these enzymes.

20.3.2.2 Development of photosynthetic apparatus

The different pigments necessary for photosynthesis are produced in the presence of light. Chlorophyll formation is promoted by light. Light influences the orientation of leaves also. With higher light intensity, leaves become horizontal.

20.3.2.3 Growth

Interception and utilization of solar radiation can be increased by proper management practices, such as adjustment of row spacing, plant population and selection of most advantageous time for planting.

20.3.2.4 Yield formation and yield

Light intensity affects yield attributes and finally yield. In groundnut, low light intensity during peak flowering reduce number of flowers per plant. Flower open during cloudy period do not produced pegs. Low light intensity at pegging and pod filling reduces peg and pod number. In cereal, number of tillers increase with increase in light intensity. Reduction in grain yield of rice in rainy season compared to summer season is attributed to solar radiation.

20.3.3 Photoperiodic effect

Crop developmental processes like rate of leaf production, flowering, etc. are influenced by duration of sunlight. Most plants are influenced by relative length of day and night especially for floral initiation. The duration of the night or complete darkness is more important than the day light. This effect of light on plant is known as photo-periodism. Depending on the length of photoperiod required for floral initiation, plants are classified as long day, short day and day neutral plants.

Long day plants require comparatively long days (usually more than 14 hours) for floral initiation. They put forth more vegetative growth when days are short. Most of the temperate crops like wheat, barley and oats fall under this category.

In short day plants, floral initiation takes place when days are short (less than 10 hours) or when the dark period is long. Most of the tropical crops like rice, sorghum, maize, etc. are short day plants.

Day neutral plants do not require either long or short dark periods. Photoperiod does not have much influence for phasic change for these plants. The crops belong to this group are cotton, sunflower, buck wheat etc.

20.3.4 Other effects

20.3.4.1 Assimilation of nutrients: In maize accumulation of phosphorus is high under white, yellow, orange and light blue light and high under darkness. Higher solar radiation alone gives higher protein content due to greater assimilation of nitrogen.

20.3.4.2 Translocation of photosynthates: sucrose and fructose accumulated in culms up to two to three weeks after anthesis in cereals. Fructose appears to be the most important storage carbohydrate in leaves and culms prior to grain filling, plants shaded during grain filling are able to retranslocate stored photosynthates to grain, thus maintaining certain amount of stability.

20.3.4.3 Utilization of solar energy: The basic principle for increasing yield is harvesting more solar energy. All the management practices like optimum time of sowing, plant population, fertilizer application, irrigation, etc. are aimed at increasing the interception of solar radiation by the foliage so as to get the more yield.

20.3.4.4 Sensitive stages for solar radiation: In broad terms, leaves are considered as**source** for supplying carbohydrates to grains while storage organs are called **sinks.** In some crops like rice, wheat, etc., source is not limited but yield potential is less due to less number of storage organs. For such sink limited crops, amount of solar radiation in sufficient quantities is necessary during the period of formation of storage organs. i.e. from panicle initiation to flowering.

20.3.4.5 Conversion efficiency: Efficiency of conversion of absorbed radiation to dry matter decreases with the age of crop for the production of one gram of dry matter 3700 to 4100 calories of solar energy is utilized.

20.4 TEMPERATURE

20.4.1 Cardinal temperature: For each species of plants there are upper (maximum) and lower (minimum) limits of temperature at which growth is nil or negligible and optimum temperature at which growth is maximum. Most of the crop plants grow best at 15 to 30 ^{o}C. Many crop plants die at temperature of 45 to 55 ^{o} C. There are also optimal temperatures for different growth stages.

20.4.1.1 Cool season crops : The crops which grow best in cool weather period are called cool season crops and are generally grown in winter season (November to February). Most of the cool season crops cease to grow at an average temperature of 30 to 38 ^{o}C. The important cool season crops are wheat, barley, potato, oats, etc. These crops are also called temperate crops. The cardinal temperature ranges for cool season crops are maximum Temperature 30-38 ^{o}C. Minimum temperature 0-5 ^{o}C and optimum temperature 25-30 ^{o}C.

20.4.1.2 Warm season crops: The important warm season crops are rice, sorghum, maize, sugarcane, pearl millet, groundnut, pigeon pea, cowpea, etc. These crops are also called tropical crops. These crops are generally grown in monsoon and some also in summer season. The cardinal temperature ranges for warm season crops are maximum temperature 45-50 ^{o}C, minimum temperature 15-20 ^{o}C and optimum temperature 30-38 ^{o}C.

20.4.2 Influence of temperature on growth

20.4.2.1 Biochemical reaction: Any chemical reaction increase with increase in temperature. This rate of increase in reaction for every 10 ^{o}C increase in temperature is called quotient 10 or Q10 .

$$Q10 = \frac{\text{Rate o reaction at } (t + 10)^{\circ}C}{\text{Rate of reaction at } t^{\circ}C}$$

Where t is temperature in ^{o}C.

20.4.2.2 Uptake of carbon dioxide: The optimum temperature for net carbon dioxide uptake is about 24^{o}C for wheat and barley. As the temperature increases above the optimum, C_2 uptake is decreased due to increase in stomatal and mesophyll resistance.

20.4.2.3 Enzymatic activity: Temperature increases the activity of certain enzymes important in the reduction of carbon compounds including ribulose diphosphate dehydrogenase and glyceraldehyde dehydrogenase.

20.4.2.4 Rate of photosynthesis: Rate of photosynthesis is reduced due to reduction in temperature. When maize plants are subjected to cold temperature of 10^{o}C for 10 days, the rate of photosynthesis is reduced by 33 per cent of that of untreated plants.

20.4.2.5 Development of photosynthetic infrastructure: Temperature has considerable influence on chlorophyll synthesis and leaf area development. Temperature enhances the production of chloroplast. At low temperature leaves become yellow due to degradation of chlorophyll. Temperature governs rate of leaf emergence and leaf expansion.

20.4.2.6 Influence on growth substances: At optimum temperature, the activity of auxin, gibberellins and cytokinins (growth promoters) are high and activity of abscisic acid (growth regulators) is low with the result that growth rate is increased.

20.4.2.7 Dry matter production: The response of dry matter production to temperature depends on the stage of the crop and optimum temperature. Higher temperature during maturity of maize depressed the dry matter accumulation, while higher temperature over the normal, increased growth during tasselling and silking.

20.4.3 Influence of temperature on development

Temperature has greater influence on development rates like rate of germination, leaf initiation, tillering, flowering, spikelet initiation and grain filling. All these development processes proceed at a faster rate at higher temperature.

20.4.3.1 Yield formation and yield

Effect of temperature on grain formation, grain filling and grain yield is complex. Low temperature during panicle initiation stage to flowering results in formation of higher number of grains per plant due to prolongation of this period. Yield therefore, increases though the duration is more. Grain filling is faster with increase in temperature and this decreases duration of grain filling period in several crops. In wheat, average temperature more than 19^{0} C during grain filling period reduces duration of grain filling.

20.4.3.2 Growing Degree- Days

The heat unit or growing degree- day concept was proposed to explain the relationship between growth duration and temperature. A degree-day or a heat unit is the mean temperature above base temperature. Mathematically, it can be expressed as,

$$\text{Growing Degree} - \text{Days (GDD)} = \sum_{i=1}^{n} \frac{\{(T_{max} + T_{min}) - T_b\}}{2}$$

Where, T_{max} is maximum temperature, T_{min} is minimum temperature and Tb is the lowest temperature at which no growth which is also called base temperature.

20.4.3.3 Photothermal Units

In photothermal units, the degree-days are multiplied by length of night in case of short day plants and length of day for long day plants. The basic principle is that flowering is hastened as the length of night increases in short day plants, while in long days plants, flowering is delayed as the length of night increases. It can be expressed mathematically as

$$\text{PTU} = \sum_{i=1}^{n} \text{GDD X length of night or day}$$

20.4.4 Extreme temperatures

Excess or deficit of any growth factor is called stress. High or low temperature causes stress on crops.

20.4.4.1 High temperature stress

High temperature stress adversely affects mineral nutrition, shoot growth and pollen development resulting in low yield.

Mineral nutrition: High temperature stress causes reduction in absorption and subsequent assimilation of nutrients.

Shoot growth: High temperature, even for short period, affect crop growth especially in temperate crops like wheat. High air temperature reduces the growth of shoots and in turn reduces root growth.

Pollen development: Higher temperature during booting stage results in pollen abortion. In wheat, temperature higher than 27°C cause under development of anthers and loss of viability of pollen.

20.4.4.2 Low temperature stress

Low temperature affects several aspects of crop growth viz., survival, cell division, photosynthesis, water transport, growth and finally yield.

Survival : Temperate crops like wheat and barley have high resistance to low temperature damage especially at very early stage.

Cell division and cell elongation : Low temperature results in retardation of cell elongation than cell division.

Photosynthesis: When C_4 plants like maize and sorghum are subjected to low temperature of $10^{o}C$, the activity of pyruvate dikinase is reduced, resulting in less photosynthesis.

Water transport: Low temperature cause moisture stress. Entry of water into the plant is restricted due to low permeability of cells. The active transport of water from roots to the shoot is stopped at low temperature.

Vegetative growth: Temperate crops prefer low temperature during vegetative growth, while tropical plants require high temperature. In maize, seedling growth is reduced by 50 per cent at $10^{o}C$.

Reproductive growth: Low temperature causes high spikelet sterility in rice. It ranges from 3.6 to 96.8 percent depending on variety. The critical temperatures for spikelet sterility are 15-17 $0^{o}C$. The main reasons for the failure of fertilization are (1) uneven pollen (2) indehiscence of anthers, and (3) abnormalities in micropores.

Lesson 21. Effect of Different Weather Parameters on Crop Growth and Development -II

21.1 RAINFALL

Precipitation is reaching of atmospheric humidity either as rain or snow to the ground. Precipitation occurs as rainfall when the temperature is high and as snowfall when the temperature is low. In India most of the precipitation, except in Jammu and Kashmir and some other hill station, occurs mainly as rainfall.

21.1.1 Rainfall climatology

Study of rainfall over a long period is called rainfall climatology It reveals the general pattern of rainfall of a particular place. It helps in understanding the amount, intensity, distribution, and other rainfall characteristics. Rainfall analysis also helps in classification of climate. Suitable and efficient cropping systems can be developed by understanding the rainfall pattern. Rainfall analysis helps in taking decision on time of sowing, scheduling of irrigation, time of harvesting, etc. rainfall analysis is necessary for designing farm ponds, tanks, or irrigation projects. Amount, distribution and intensity of rainfall are the important aspects of rainfall that have considerable influence on crop production.

21.1.1.1 Amount of rainfall

Generally yield levels are determined by the amount of precipitation above the basic minimum required to enable the crop to achieve maturity. Though rainfall has major influence on yield of crops, yields are not always directly proportional to the amount of rainfall. When the rainfall is concentrated in 4-5 months of the year, there may be period when the rate of precipitation exceeds the intake rate of soil. As a result, considerable runoff occurs, plant nutrients are leached out of the root zone and crops are adversely affected by anaerobic conditions, especially if the excess precipitation occurs during the cool season.

21.1.1.2 Intensity of rainfall

Intensity of rainfall mainly influences erosion of soil. Study of rainfall intensity helps in probable period of floods, filling of irrigation tanks, etc. If the intensity of rainfall exceeds rate of infiltration of soil, runoff starts. High intensity rainfall causes soil erosion. The runoff from hills and mountain slopes is collected in tanks.

21.1.1.3 Distribution of rainfall

The amount of rainfall received at periodic intervals like weeks, months, season, etc. indicates distribution. In addition distribution of rainfall can be known by the length of dry spells, wet spells and rainy days. Distribution of rainfall is more important than total rainfall.

21.2 RELATIVE HUMIDITY

Relative humidity (RH) directly influences the water relations of plant and indirectly affects leaf growth, photosynthesis, pollination, occurrence diseases and finally economic yield.

21.2.1 Water Relation

Relative humidity has considerable influence on evapotranspiration and hence on the water requirement of crops. At constant temperature, change in atmospheric humidity affects transpiration by modifying the vapour pressure gradient from leaf to air. In dry regions relative humidity tends to below which causes severe water deficits in plants and reduces leaf water potential.

21.2.2 Leaf growth

Leaf growth not only depends on synthetic activities resulting from biochemical process but also upon the physical process of cell enlargement. Cell enlargement occurs as a result of turgor pressure developed within the cells. Turgor pressure is high under RH due to less transpiration. Thus leaf enlargement is high in humid areas.

21.2.3 Photosynthesis

Photosynthesis is indirectly affected by RH. When RH is low, transpiration increases causing water deficits in the plant. Water deficit cause partial or full closure of stomata and increase mesophyll resistance blocking entry of carbon dioxide. There is large increase in both mesophyll and stomatal resistance causing decline in net uptake of carbon dioxide and thus photosynthesis is affected.

21.2.4 Pollination

Moderately low air humidity is favorable for seed set in many crops, provided soil moisture supply is adequate. For example, seed set in wheat was high at 60 per cent RH compared to 80 per cent when water availability in the soil was not limiting. When RH is high, pollen may not be dispersed from the anther.

21.2.5 Pests

The incidence of insect, pest and disease is high under high humidity conditions. High RH favors easy germination of fungal spores on plant leaves. The blight diseases of potato and tea spread more rapidly under humid condition. Several insects such as aphids and jassids thrive better under moist conditions.

21.2.6 Grain yield

Very high or very low RH is not conductive for high grain yield. Under high humidity, RH is negatively correlated with grain yield of maize. The yield reduction was 144 kg/ha with an increase in one per cent of mean monthly RH. Similarly, whet grain yield is reduced in high RH. It can be attributed to adverse effect of RH on pollination and high incidence of pests.

21.3 WIND

Wind direction and velocity have significant influence on crop growth. In general, wind increases transpiration. When wind is hot, it accelerates the desiccation of the crop by replacing the humid air by dry air.

Wind increases the turbulence in atmosphere, thus increasing the supply of carbon dioxide to the plants resulting in greater photosynthetic rates, Net Assimilation Rate (NAR) and Relative Growth Rate (RGR). the indices of growth, increase with increase in wind speed.

Wind also alters the balance of hormones. Wind increases ethylene production in barley and rice. Wind decreases Gibberallic acid content of roots and shoots in rice.

Hot dry winds cause reduction in plant height due to reduction in cell expansion as the cells cannot attain full turgidity. Lodging is another major injury or damage caused by high wind. The other adverse effect of winds are drying of leaf tips, Tearing of leaves, fruit drop, breaking branches, uprooting of plants, etc. Fruit drop due to heavy gales is a major problem in mango crop. Heavy winds accompanied by rainfall cause uprooting of crops.

Lesson 22. Principal of Tillage

22.1 INTRODUCTION

Tillage is as old as agriculture. Primitive man used to disturb the soil for placing seeds. Jethro Tull who is consider as father of tillage, proposed a theory that plant absorb minute particle of soils. Therefore, he suggested that thorough ploughing and other operations were necessary so as to make soil into fine particles. Though his theory is not correct, tillage operation are carried out to prepare a fine seed bed for sowing crops.

After harvest of the crop, soil becomes hard and compact. Beating action of rain drops, irrigation and subsequent drying, movement of intercultivation implements and labour cause soil compaction, Field contains weeds and stubbles after the harvest of crops, Seeds need loose, friable soil with sufficient air and water for good germination. The field should be free from weeds to avoid competition with the crop that follows. It should also be free from stubbles to facilitate easy and smooth movement of sowing implements.

Tillage is the physical manipulation of soil with tools and implements to result in good tilth for better germination and subsequent growth of crops. Tilth is a physical condition of the soil resulting from tillage.

22.2 PURPOSE OF TILLAGE

The purpose of tillage is to prepare a seedbed, break weed, insect and disease cycles, burry plant residues, incorporate fertilizers and amendments, break surface crust and fracture plough pans or hard subsoil horizons.

22.3 OBJECTIVES OF TILLAGE

There are several objectives of tillage of which the most important are suitable seedbed preparation, weed control and soil and water conservation. The other objectives are:

(i) Adequate seed-soil contact to permit water flow to seed and seedling roots. Intimate contact between the soil particles is necessary to facilitate movement of water for quick germination.

(ii) Tillage improves soil aeration, which helps in multiplication of microorganism. Organic manures decomposition is enhanced resulting in higher nutrient availability. Increased aeration also helps in degradation of herbicides and pesticides residues and harmful allopathic chemicals exuded by roots of previous crop or weeds.

(iii) Weed control is an important object of tillage. Two or three deep ploughing in during summer controls problematic weeds like *nutsedge orchido* (*Cyperus rotundus*. L.)

(iv) Proper tillage results in soil and moisture conservation through higher infiltration, reduced runoff and increase depth of soil for moisture storage. When compact soil is plough, it becomes fluffy (soft or loose or friable) and can hold more amount of water. Removal of hardpans increases the soil depth for water absorption, surface roughness and furrow dikes slowdown the velocity of runoff and provide more time for infiltration of water.

(v) Break the compacted layers to increases soil permeability and helps to increase of root penetration due to breaking hard pans and compacted layers.

(vi) Tillage helps to incorporate weeds, crop residues, green manures and other organic manures and fertilizers, soil amendment anti other agro chemicals applied for the control of weeds, insect and pest etc. to reduce volatilization losses.

(vii) Tillage exposes the lower soil to weather and replaces the surface soil under earth. Many of the insects remain dormant as pupae in the top layer of the soil. As a result of tillage insect-pest come out and destroy by beat and birds and predatory animals.

(viii) Tillage helps to check loss of water through percolation in low land paddy fields by making an impervious soil low layer (hard pan) and also makes the soil level and flat those are suitable for uniform movement of irrigation water.

(ix) The tillage prepares good seed bed which is necessary for early seed germination and initial good stand of the crop and improves the soil structures.

(x) The stubbles of previous crop, which harbors insect pests, arc removed following tillage resulting in reduced pest attack on the succeeding crop.

(xi) The improve soil structure can be produced by tilling the soil at proper time when the soil moisture is optimum. Tillage operation carried out at improper soil moisture damage soil structure and leads to develop hard pans.

(xii) Control of soil erosion on sloppy land, tillage across the slope of field will create furrow dikes, which slow do the velocity of runoff rain or irrigation water and consequently reduced soil erosion. Before rainy season the fields are left cloddy, to prevent erosion and increase the water storage in the soil. This is the good practice under dry farming situation,

22.4 TILLAGE INFLUENCE ON PHYSICAL PROPERTIES OF SOIL

Tillage has considerable influence on soil physical properties like pore space, structure, bulk density, water content and colour. These effects of tillage lost for about a month. Tillage practices have therefore, greatest effect on seed germination, seedling emergence and stand establishment.

22.4.1 Pore Space

Soils are made up of particles of different sizes. Air filled spaces between these particles constitute pore space. When a field is ploughed, the soil particles are loosely stacked in a random manner and pore space is increased, When the soil is in good tilth, the, capillary and non-capillary pores would be roughly equal. This facilitates free movement of air and moisture in the soil and increases infiltration.

22.4.2 Soil Structure

Soil with crumbly and granular clods is considered as soils with good structure. When the soil is subjected to tillage at optimum moisture, crumb structure is developed so that loss of soil by erosion is greatly reduced. Rain Water is held in the large pores, between the aggregates and also in the Microspore pores of the aggregates. It is considered that soil aggregates of 1 to 5 mm in size are favourable for growth of plants. Smaller aggregates may clog the soil pores and larger ones may have large pore space between them and affect the development of rootlets of the young seedlings. Soil structure is destroyed when tillage is carried out at inappropriate soil moisture.

22.4.3 Bulk Density

When the soil is loosened, the soil volume increase without any effect on weight. Therefore, bulk density of tilled soil is less than the untilled soil.

22.4.4 Soil Colour

Organic matter is mainly responsible for the dark brown to dark grey colour of the soil. Tillage increases oxidation and decomposition resulting in fading of colour.

22.4.5 Soil Water

Tillage improves soil water in different ways. The amount of available water depends on soil porosity, soil depth and random roughness. All these characters are increased by tillage. Roughness is a measure of micro elevations and depression caused by furrows and ridges, clods and depression. Random roughness indicates elevation and depressions of the field without a pattern as it happens after ploughing. It influences the volume of surface-depression storage or temporary storage of rainfall. Tillage also increases rate of infiltration, water holding capacity and hydraulic conductivity.

22.4.6 Soil Temperature

Tillage creates soil temperature optimum for seed germination and seedling establishment. Tillage loosens the soil surface resulting in decrease of thermal conductivity and heat capacity.

22.5 TYPES OF TILLAGE

Tillage operations are grouped into two types based on the time (with reference to crop) at which they are carried out. They are:

22.5.1 Preparatory cultivation

Tillage operations that are carried out to prepare seedbed before sowing of crop from the time of harvest of a crop to the sowing of the next crop are known as preparatory cultivation. Preparatory cultivation consist of three distinct operations viz. primary tillage, secondary tillage and layout of seedbed.

22.5.1.1 Primary tillage or ploughing

Ploughing is opening of the compacted soil with the help of different ploughs. Ploughing is done mainly to open the hard soil. In addition, ploughing should ensure inversion (whenever necessary) of soil, uprooting of weeds and stubbles and less cloddy soil surface.

Optimum time of ploughing: The correct time for ploughing depends on soil moisture. When the soil is dry it is difficult to open the soil, more energy is used and large sized clods result. When the soil is ploughed under wet conditions, the soil sticks to plough, the soil below the plough sole becomes compacted and on drying becomes a hard pan, soil structure is destroyed and the clods on drying become very hard. The optimum range of soil moisture for effective ploughing is 25 to 50 per cent depletion of available moisture. Light soils can be ploughed in a wide range of soil moisture conditions while the range is narrow for heavy soils.

Depth of ploughing: Depth of ploughing mainly depends on the effective root zone depth of the crops. Generally crops with tap root system require greater depth of ploughing, while fibrous, shallow rooted crop require shallow ploughing.

Number of ploughings: The number of ploughings necessary to obtain a good tilth depends on soil type, weed problem and crop residues on the soil surface. In heavy soils, more number of ploughings are necessary, the range being 3 to 5 ploughings, Light soil requires 1 to 3 ploughings to obtain proper tilth or the soil. When weed growth and plant residues are higher, more number of' ploughings are necessary.

Selection of ploughs: Depending on the purpose, soil condition and nature of weed problem, different ploughs are used.

Table 20.1 Suitable ploughs for different situations

Plough	Situation or purpose
Mouldboard plough (M.B.Plough) (Tractor drawn)	Deep ploughing and inversion
Mouldboard plough (Animal drawn)	Incorporation of manures, fertilizer and plant residue
Disc plough	Cutting of creeping or spreading grass and inversion
Country plough	Multipurpose

Types of primary tillage: Depending on the purpose or necessity, different types of tillage are carried out. They are deep ploughing, subsoiling and year round tillage.

Deep tillage or deep ploughing : In western countries, deep ploughing is 50 cm depth for rainfed conditions and 70 cm depth for irrigated conditions. Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad classified ploughing according to depth as under:

Table 20.2: Different types of ploughing categories

Depth	Categories
5-6 cm	Shallow ploughing
15-20 cm	Medium deep ploughing
25-30 cm	Deep ploughing

Deep ploughing turns out large sized clods that are baked by the hot sun when it is done in summer. These clods crumble due to alternate heating and cooling and due to occasional summer showers. This process of gradual disintegration of clods improves soil structure. The rhizomes and tubers of perennial weeds (World's problematic weeds viz, *Cynondon dactylon* and *Cyperus rotundus*) die due to exposure to hot sun. Summer deep ploughing kills pests due to exposure of pupae to hot sun and attack of birds and predators.

Deep tillage also improves soil moisture content; however the advantage of deep tillage in dry farming condition depends on rainfall pattern and crop. There is no yield advantage if rainfall below normal. The residual effect of deep tillage is marginal. Therefore, it is advisable to go for deep tillage ploughing only for long duration, deep rooted crops.

Sub soiling: Hard pans may be present in the soil, which restrict root growth of crops. These may be slit pans, iron or aluminum pans, clay pans or man made pans are tillage pans induced by repeated tillage at the same depths. These are present in most of the Indian soils.

Root growth of crops is confined to top few cm of soil where deep penetration of roots is inhibited by hard pans. For example, cotton roots grow to a depth of 2 m in deep alluvial soil without any pans when hard pans. They grow only up to hard pan, say 15-20 cm. Similarly vertical root growth of sugarcane is restricted due to hard pans and it is not compensated by horizontal spread. Sub soiling is breaking the hard pan without inversion and with less disturbance of top soil.

Year round tillage: Tillage operations carried out throughout the year are known as year round tillage. In dry farming regions, field preparation is initiated with the help of summer showers. Repeated tillage operations are carried out until sowing of the crop. Even after harvest of the crop, the field is repeatedly or harrowed to avoid weed growth in the off-season.

22.5.1.2 Secondary tillage

Lighter or finer operations performed on the soil after primary tillage is known as secondary tillage. After ploughing, the field is left with large clods with some weeds and stubbles partially uprooted. Harrowing is done to a shallow depth to crush the clods and to uproot remaining weeds and stubbles. Disc harrows, cultivators, blade harrow etc., are used for this purpose. Planking is done to crush the hard clods to smooth the soil surface and to compact the soil lightly. Thus, the field is made ready for sowing after ploughing by harrowing and planking. Generally sowing operations are also included in secondary tillage.

Layout of seedbed and sowing: After the seedbed preparation, the field is laid out properly for irrigation and sowing or planting seeding. These operations are crop specific. For most of the crops like wheat, soybean, pear millet, groundnut, castor etc., flat leveled seedbed is prepared. For some crops like maize, vegetables etc., the field has to be laid out into ridges and furrows. Sugarcane is planted in the furrows or trenches. Crops like tobacco, tomato, chilly are planted equal inter and intera-row spacing so as to facilitate two way inter-cultivation. Setline planting is adopted in Gujarat for sowing cotton and groundnut. Every year, seed rows are in the same place, since the seed lines are set permanently at wider spacing. The inter-row space is not cultivated.

After field preparation, sowing is done with seed drills. These seeds are covered by running blade harrow to a shallow depth followed by planking so as to level and impart necessary compaction. Sowing is also done by dropping seeds behind the country plough.

22.5.2 After Tillage or After Cultivation

The tillage operations that are carried out in the standing crop are called after tillage. It includes drilling or side dressing of fertilizers, earthing up inter-cultivation. Earthing up is an operation carried out with country plough or ridge plough so as to form ridge at the base of the crop. It is done either to provide extra support against lodging as in sugarcane or to provide more soil volume for better growth of tubers as in potato or to facilitate irrigation as in the vegetables. Inter-cultivation is working blade harrows, rotary hoes etc., in between the crop measure by closing deep cracks in black soils.

22.6 MODERN CONCEPT OF TILLAGE

In conventional tillage, the soil is opened with mouldboard plough for primary tillage. Subsequently, a fine seedbed is prepared by secondary tillage. In this process, energy is often wasted and sometimes, soil structure is destroyed. Recently, considerable change has taken place in tillage practices and several new concepts have been introduced, namely, minimum tillage, zero tillage, stubble mulch farming etc.

22.6.1 Minimum Tillage

The concept of minimum tillage is started in USA. Minimum tillage is aimed at reducing tillage to the minimum necessary for ensuring good seedbed, rapid germination, a satisfactory stand and favourable growing conditions.

Minimum tillage has certain advantages: Improved soil condition due to decomposition of plant residues in *situ;* higher infiltration caused by the vegetation present in the soil and channels formed by the decomposition of dead roots; less resistance to root growth sue to improved structure; less soil compaction by the reduced movement of heavy tillage vehicles and less soil erosion compared to conventional tillage. However, these advantages are evident on coarse and medium textured soils and appear after two to three years of practicing minimum tillage.

There are certain disadvantages of minimum tillage. Seed germination is lower minimum tillage. In minimum tillage, more nitrogen has to be added as rate of decomposition of organic matter is slow. Nodulation is affected in some leguminous crops like peas. Sowing operations are difficult with ordinary equipment. Further, continuous use of herbicides causes pollution problems and dominance of perennial problematic weeds.

Minimum tillage can be practiced by different methods as given below:

Row zone tillage : After primary tillage with mouldboard plough, secondary tillage operations like discing and harrowing are reduced. The secondary tillage is done in the row zone only.

Plough-plant tillage : After the soil is ploughed, a special planter is used and in one run over the field, the row zone is pulverized and seeds are sown.

Wheel track planting : Ploughing is done as usual. Tractor is used for sowing and the wheels of the tractor pulverize the row zone.

22.6.2 Zero Tillage

Zero tillage is an extreme form of minimum tillage. Primary tillage is completely avoided and secondary tillage is restricted to seedbed preparation on the row zone only. It is also known as no-till and is resorted to where soils are subjected to wind and water erosion, timing of tillage operation is too difficult and requirements of energy and labour for tillage is too high. Zero tilled soils are homogenous in structure with more number of earthworms. The organic matter content increases due to less mineralization. Surface runoff is reduced due to the presence of mulch. The favourable effects of zero tillage on soil physical properties are apparent after two years of its practice.

Till planting is one method of practicing zero tillage. The machinery accomplishes four tasks in one operation: clean a narrow strip over the crop row, open the soil for seed insertion, place the seed and cover the seed properly. A wide sweep and trash bars clear a strip over the previous crop row and planter-shoe open a narrow strip into which seeds are planted and covered.

In zero tillage, herbicide functions are extended. Before sowing, the vegetation present has to be destroyed for which broad spectrum, nonselective herbicides with relatively short residual effect (paraquat, glyphosate etc.,) are used. During subsequent stages, selective and persistent herbicides are needed. The herbicides applied should not cause injury to the succeeding crop.

The seedling establishment in zero tillage is 20 per cent less than in conventional methods. High dose of nitrogen has to be applied as mineralization of organic matter is slow in zero tillage. Large populations of perennial weeds appear in zero tilled plots. Higher number of volunteer plants and build up of pests are the other problems.

22.6.3 Stubble Mulch Tillage

The traditional methods of tillage developed in temperate moist climates based on mouldboard plough, often increase soil erosion when adopted indiscriminately in arid land cultivation. A new approach was developed for keeping soil protected at all times whether by growing a crop or by crop residues left on the surface during fallow periods. It is known as stubble mulch tillage or stubble mulch farming. It is a year round system of managing plant residue with implements that undercut residue, loosen the soil and kill weeds. Soil is tilled as often as necessary to control weeds during the interval between two crops. Good management of stubble mulch farming system begins with harvest of the crop. Sweeps or blades are generally used to cut the soil up to 12 to 15 cm depth in the first operation after harvest and the depth of cut reduced during subsequent operations. When unusually large amount of large amount of residues are present, a disc type implement is used for the first operation to incorporate some of the residues into the soil. This hastens decomposition, but still enough residues on the soil.

Stubble mulch tillage, however, presents practical problems. The residues left on the surface interfere with seedbed preparation and sowing operations. The traditional tillage and sowing equipment is not suitable under these conditions. Two methods are adopted for sowing crops in stubble mulch farming.

Similar to zero tillage, a wide sweep and trash-bars are used to clear a strip and a narrow planter-shoe opens a narrow furrow into which seeds are placed.

A narrow chisel of 5 to 10 cm width is worked through the soil at a depth of 15 to 30 cm leaving all plant residues on the surface. The chisel shatters tillage pans and surface crusts. Planting is done through residues with special planters.

Lesson 23. Tilth and Its Characteristics

23.1 INTRODUCTION

The aim of tillage is to produce as good a soil condition or tilth as possible for crop establishment and initial shoot and root development. The term tilth is used to describe qualitative characteristics of a loose friable (mellow) and crumby condition of the soil favourable for crop production. When the soil is brought to such a condition ideal for crop growth it is called a seedbed and is said to be in good tilth. In other words, tilth is physical condition of soil resulting from tillage. The ideal seedbed is a soil in which porosity of the mineral solid matter provides an optimum balance between water holding and freely drained. The optimum balance appears to be the one in which capillary and non capillary pores are in equal proportion.

23.2 FACTORS INFLUENCING TILTH

Factors contributing to tilth are

1. Soil texture

2. Soil structure

3. Organic matter content and

4. Weather.

23.2.1 Soil texture

Texture is an inherent soil property which is difficult to modify, except to a very small scale. Agricultural significance of soil structure is related to its effect on porosity and permeability and on the surface area of the soil fraction.

23.2.2 Soil structure

Structure which indicates the way in which the individual mineral particles are arranged to form aggregates is important in determining soil tilth. The structure considered ideal for agriculture is crumb in which the aggregates are small, porous and relatively water stable.

23.2.3 Organic matter content

Soils with high organic matter cultivated at optimum soil moisture leads to crumb structure with aggregate stability. Exposure of soil surface to wetting and drying contributes to breakdown of large clods in heavy soils (self tillage) leading to loose surface with aggregates.

23.2.4 Weather

The development of soil structure is resulted from the complex interaction between weather, method of cultivation and soil organic matter content.

Lesson 24. Role of Water in Plant and Its Absorption

24.1 INTRODUCTION

Plants grow on soils that provide them water and nutrients. They absorb the water from soils mainly through roots and use only 1.0 to 1.5 per cent of the volume of water absorbed for building their vegetative structures and performing various physiological and biochemical activities. The rest of the water absorbed is lost through transpiration. A close relationship therefore, exists between soil water and plant which should be clearly understood to decide upon the time, depth of irrigation and to make the most efficient use of irrigation water. An excess or deficit of soil water hinders the plant growth and reduces the yield. An insight into their relationship requires a close study of the role of water in plants, mechanisms of water absorption, conduction and transpiration, availability of water to plants and plant responses to excess or deficit of soil water.

24.2 ROLE OF WATER IN PLANT DEVELOPMENT

Water plays a vital role in plant life. It is essential to plants in the following ways:

1. Water is a structural constituent of plant cells and it maintains the cell from through turgor pressure. When plenty of water is available, cells are turgid and plants retain their normal structural from. Water accounts for the larges part of the body weight of an activity growing plant and it constitutes 85 to 90 per cent of the body weight of young plants and 20 to 50 per cent of older or mature plants.

2. Water is a source of two essential elements, oxygen and hydrogen required for synthesis of carbohydrate during photosynthesis.

3. Water serves as a solvent of substances and a medium in plants allowing metabolic reactions to occur.

4. Water acts as a solvent of plant nutrients and helps in uptake of nutrients from soils. Further, plants also absorb nutrients through leaves from nutrient sprays. These nutrients are carried in soluble form to different parts of the plant for use.

5. Food manufactured in green parts is distributed to various parts of the plant in soluble form and water acts as a carrier of food materials.

6. Transpiration is a vital process in plant and it occurs at a potential rate as long as water is available in adequate amount. If there occurs soil water deficit, transpiration process is curtailed down seriously affecting plant growth and yield.

7. Adequate supply of water maintains the turgor pressure of guard cells helping stomata to open fully. Water deficit, on the other hand, closes stomata partially or completely reducing water loss through transpiration.

8. Cells and tissues are formed and growth of plant occurs when an adequate amount of soil water is available. Water deficit shows down the growth processes.

9. Leaves get heated up with solar radiation. Plants dissipate heat by increased transpiration. Water acts as a buffer against high or low temperature injury as it has high heat of vaporization and high specific heat.

10. Water encourages good growth, development and yield of plants and quality of plant produce when it is available in plenty. Conversely, plants die when water supply is curtailed down.

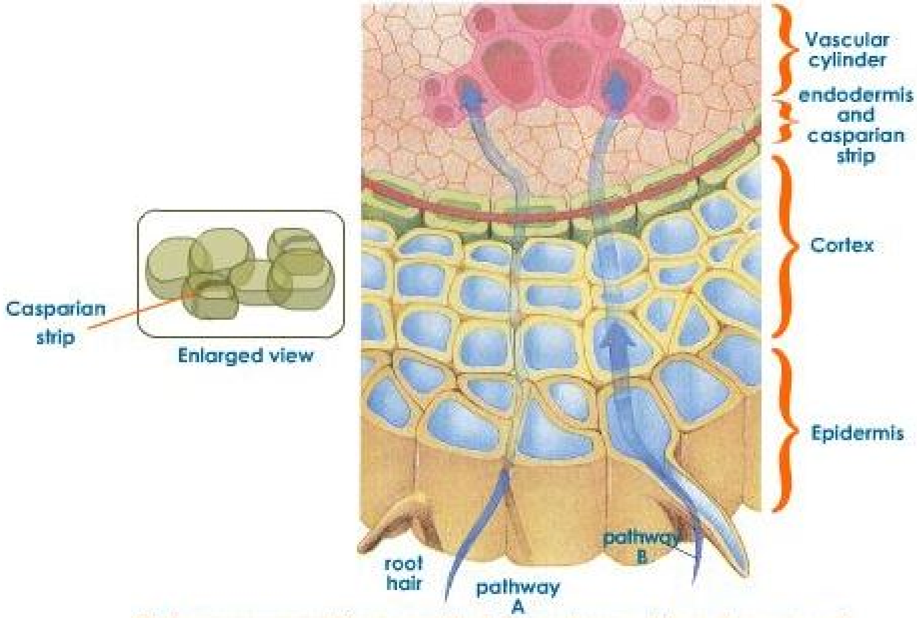
24.3 WATER ABSORPTION BY PLANTS

Plants absorb water from soil, rain and from water sprays. Various parts of the plant are involved in water absorption processes. The details on water absorption processes involve have explained as below:

24.3.1 Water Absorbing Plant Structures

Absorption of water occurs mainly through roots. An insignificant amount of water is, however, absorbed through aerial structures. Young roots offer largely the water absorbing surface in actively growing annual plants, while they offer relatively a small fraction of the total absorbing surface in old perennial plants and trees.

A young growing root tip consists of a root cap, a zone of maximum meristematic activity, a region of rapid cell elongation and a region of quick cell differentiation and maturation. A rapid absorption of water occurs through younger part of the root immediately basal to the meristematic region. It is usually the area where root hairs grow extensively. Root hairs are thin walled protuberances of the epidermal cells. They present relatively large absorbing surface. The xylem elements develop to conduct water up the plant system. Suberization of cell walls also begins, but the same is not well advanced. Suberization of cell walls reduces the permeability to water. But a considerable volume of water is absorbed, though slowly, through suberized roots in order plants. The role of such roots in water absorption is very important as they comprise the largest portion of a root system in older plants and tress and offer relatively large water absorbing surface.



Water movement from root hair to cortex and to xylem vessel

A typical young root has three distinct regions transversely viz., epidermis, cortex and stele or vascular cylinder. The epidermis consists of closely of closely packed thin-walled elongated cells. When young, these cells develop root hairs. Water and nutrients absorbed by root pass through this layer of cells having no intercellular spaces. Maturation of roots leads no suberization or cutinization of these cells. The cortex consists of a layer of cells in the outermost region called, exoderm, a layer of cells in the innermost region called, endodermis and parenchyma cells between these two layers. The cortical cells have intercellular spaces. As the root matures, the exodermal cells may become suberized and the endodermal cells develop a casparian strip. This is a strip of thickened and suberized or cutinized cell walls. The innermost region of the root is the stele or vascular cylinder that has pericycle, the outermost tissue of this region. Vascular system consists of phloem strands and the xylem. Phloem tissues consist of sieve tubes and companion cells that serve as the conducting system of organic substances manufactured in leaves do the root meristematic region. The xylem has tracheid and vessels for conducting water and mineral solutes upwards to the various parts of plants from the absorbing regions of roots.

24.3.2 Radial Movement of Water through Root

In the absorption process, water travels from the soil medium into epidermal cells. It then moves from cell to cell through cell walls and protoplasm and through intercellular spaces to the xylem. The xylem system constitutes the conducting system of water from roots to leaves. So the path is from epidermal cells of the root through the cortex to the xylem of vascular bundles.

24.3.3 Root Growth and Water Absorption

The volume of water absorbed by a plant depends largely on the growth of root system. Movements of water in soils are too slow to make sufficient water reach the roots. It is the root system that grows and meets water in new region of soil. Upper soil layers dry up quickly owing to continuous evapotranspiration, while lower soil layers maintain a better water balance. Plants with deep root systems are therefore capable of drawing greater quantity of water for their survival and growth. Plants with expanded root system continue to grow with water available from the extended region of the root zone, while plants with restricted root system experience water stress in the same field under the same condition of limited water supply.

24.3.4 Energy Concept of Water Absorption

The energy status of water in plant cell and of the water supply medium in soils may explain the mechanism of water absorption by plants.

Pure water has zero water potential y., when solutes are present in water, the y decreases below zero. A cell has therefore negative water potential. When a cell is placed in pure water, water moves into the cell due to a gradient of decreasingy. This movement produces turgor pressure or pressure potential, yp inside the cell and reduces the osmotic potential, ys by diluting the concentration of cell sap. The turgor pressure acts against the forces responsible for movement of water into the cell and is considered positive. The cell water potential has several components that may be expressed as,

$$\Psi Cell = \Psi s + \Psi m + \Psi p \ldots\ldots\ldots\ldots \qquad (24.1)$$

Where,

$\Psi Cell$ = cell water potential

Ψs = osmotic potential (influence of solutes like sugars, acids, inorganic ions etc.)

Ψm = matric potential (effect of matric substances like proteins, polysaccharides etc.)

Ψp = pressure potential (influence or turgor pressure)

Values of Ψs and ym are negative, while the value of Ψp is positive. The ycell is usually negative, unless the cell becomes fully turgid. The cell water potential becomes zero when the cell is fully turgid since the combined magnitude (negative) of osmotic potential and matric potential becomes equal to the magnitude (positive) of the pressure potential under this situation making the cell water potential zero according to Equation 24.1.

With entry of water into the cell owing to osmotic and matric potentials ($\Psi s + \Psi m$), the pressure potential (Ψp) increases as the volume of the cell increases. The elasticity of cell wall puts a limit to this increase in the cell volume. When the cell becomes fully turgid, yp becomes equal to the $\Psi s + \Psi m$ and there is no more entry of water into the cell. The y of pure water and that of cell sap becomes equal in magnitude.

A cell inside the plant system is surrounded by other cells, while epidermal cells of root are surrounded by soil water outside and cortical cells inside. The movement of water from epidermal cells to the adjoining cells occurs exactly in the same manner when a cell is immersed in pure water as described earlier. The gradient of decreasing water potential from epidermal cells to xylem results in the radial movement of water in the root.

24.3.5 Water in Soil-Plant-Atmosphere System

When the soil-plant-atmosphere system is considered, differences in magnitude of the water potential at different points in the system create the driving force of atmosphere (Ψair) decides the flow of water from soil to the atmosphere through plant. This movement occurs so long yair is less than the soil water potential (Ψsoil). Plant and Moreshet (1973) provided an approximate magnitude of water potential in the soil-plant-atmosphere system (Table 24.1).

Table 24.1: Approximate magnitude of water potential in the soil-plant- atmosphere system

Component	Water potential (bar)
Soil	-0.1 to -20
Leaf	-5.0 to -50
Atmosphere	-100 to -2000

24.3.6 Pathway of Water in Soil-Plant-Atmosphere System

Water moving from soil to air through the plant takes the path along

(i) epidermal cells

(ii) cortical cells and intercellular spaces in the cortex

(iii) conductive system of xylem

(iv) leaf cells

(v) intercellular spaces in the leaf

(vi) stomatal cavities and stomata and

(vii) air layer in the immediate vicinity of the leaf.

In this system water takes the path of least resistance and moves as a continuous cohesive liquid from epidermal cells of the root to leaf cells. Water from leaf cells moves to air in vapour from through the intercellular spaces, stomatal cavity and stomata. The most satisfactory theory of water conduction in liquid form through the plant body is cohesive theory (Kramer *et al.* 1967 and Kramer, 1969). The evaporation from leaves sets up imbibition forces in the cell walls that are transmitted to epidermal cells of roots through the hydrodynamic system and causes the water absorption and then its ascent through the plant body.

Movement of flow of water from soil to air through the plant is a function of the difference in yair and ysoil with resistance offered by the plant system. The water flow rate in the system in stages may be considered by the following expression:

$$\textbf{Flow rate} = \frac{\Psi_{soil} - \Psi_{root\ surface}}{r_{soil}} == \frac{\Psi_{root\ surface} - \Psi_{xylem}}{r_{root}}$$

$$= \frac{\Psi_{xylem} - \Psi_{leaf}}{r_{xylem} + r_{leaf}} === \frac{\Psi_{xylem} - \Psi_{leaf}}{r_{xylem} + r_{leaf}}$$

Where, Ψ = water potential at various sites of the system and

r = resistance at the corresponding sites.

24.4 WATER ABSORPTION PROCESSES

Water absorption by plants occurs by two processes namely, active absorption and passive absorption. Renner (1915) suggested these two terms. In active absorption plants play an active part. In passive absorption water is absorbed mechanically through roots without plants playing an active role and plants present simply the absorbing surfaces.

24.4.1 Active Absorption

A well-watered slowly transpiring plant absorbs water by active absorption under the tension developed in the root xylem due to matric effect of solids and osmotic effects of solutes present in it. This tension is usually called the root pressure caused by metabolically active roots acting as an osmometer. Salts are accumulated by the active transport mechanism in living roots. Root pressure causes guttation or exudation of liquid from tips and margins of leaves and occasionally from lenticels of twigs. The exudation from wounds and cut stumps of plants is an evidence of root pressure. Root pressure is detectable only during periods of low transpiration. The amount of water absorbed by the active absorption is very negligible and is usually less than 5 per cent of the total water required by a rapidly transpiring plant (Kramer *et al*. 1967 and Kramer, 1969).

24.4.2 Passive Absorption

In rapidly transpiring plant water loss from leaves exceeds the volume of water that the plants can absorb by active absorption. Evidently, a tension or diffusion pressure deficit is created in the mesophyll tissues of leaves. In other words, the water potential in mesophyll cells gets reduced. The tension thus created is transmitted through the hydrodynamic system into the xylem system in roots and then to the root surface. A gradient of decreasing water potential from soil to atmosphere through the plant is created and this results in movement of greater volume of water through the plant. Under conditions of rapid transpiration and high diffusion pressure deficit in the xylem system, water is literally pulled into the roots from the soil by mass flow (Levitt, 1956). Root tissues offer considerable resistance to this movement and the water absorption tends to lag behind the transpiration. This absorption lag causes development of considerable water deficit and tension in the hydrodynamic system. The water deficit may sometimes be so great that plants show sign of water stress even when the water supply in the soil is adequate. This condition is often observed during mid day in summer months.

The diffusion pressure deficit (DPD) of a cell or solution is the amount by which its diffusion pressure is less than that of pure water under atmospheric pressure and at the same temperature.

It gives a measure of the force with which water diffuses into a cell immersed in pure water. Diffusion pressure deficit in a cell is the difference of the osmotic pressure (OP) and the turgor pressure (TP) and the value is positive. The DPD may be expressed as,

DPD = OP – TP

It increases with decrease in water content of the cell until it equals the osmotic pressure. Whenever a negative wall pressure develops, DPD exceeds the osmotic pressure. It becomes zero under turgid condition of cells.

Lesson 25. Conduction and Transpiration of Water and Plant Processes

25.1 WATER CONDUCTION

Water is conducted from the root surface to leaf surface through the plant body. The difference of yair and yroot surface results in the accent of water. The transpiration from leaf surface sets up imbibitational forces in the mesophyll cells that are transmitted through the hydrodynamic system in the plant to the root surface. Water moves in liquid form from the soil to leaf cells through root cells and the conductive system of xylem. It moves in vapour form from leaf cells to the air through intercellular spaces in the leaf and stomatal openings. Water moving into the xylem of roots from the root surface and then to leaves through vascular bundles finds its way along the path of least resistance. The xylem functions in water conduction. The water conduction is based on the cohesion theory. Water molecules have mutual attraction for each other, and water columns confined in small capillaries cohere with a tensile strength sufficient to pull them up to the evaporating leaf surface. It may block the lumina and offer resistance to water conduction. The xylem is however considered having an adequate conduction capacity to overcome the loss of conductivity owing to blocking by air bubbles (Kramer et al., 1967 and Kramer, 1969).

25.2 TRANSPIRATION

Transpiration is the process by which plants lose water in vapour form into the air through their aerial parts, mainly leaves. It involves nearly 99 per cent of the volume of water absorbed by young plants. Usually about 95 percent of the water absorbed is transpired and only about 5 per cent of that is used by the plant for metabolic purpose and making the body weight. About 90 to 95 per cent of the transpiration occurs during the day time and 5 to 10 per cent during the night time. Pineapple plant is the exception in which most of the stomata remain open during the night time and the major transpiration takes place at night. Transpiration is essentially a physiological process and can be considered primarily as a physical evaporation process from leaves. Plant structures and physiological behaviors of plants modify the rate of water loss in the process. The stomatal transpiration accounts for the greatest loss of water, while the cuticular or lenticular transpiration comprises relatively a very small loss. Transpiration rate is minimum in the morning. It increases with the increase in temperature during the daytime and reaches the maximum at around 2 PM local time.

Transpiration is usually expressed by transpiration ratio or transpiration coefficient that refers to the volume of water transpired by a plant to produce a unit quantity of dry matter. The value is dimensionless.

25.2.1 Transpiration Mechanism

Conversion of water from liquid vapour occurs at the moist surface of mesophyll cells. Mesophyll tissues of leaves are composed of loosely connected parenchyma cells with a large volume of intercellular spaces. The internally exposed surface area of cells is between 5 to 30 times the external leaf surface are (Kramer et al., 1967 and Kramer 1969). Cell walls are usually hydrophobic and are covered with a thin layer of water. When there is a water deficit, the conductivity of cell walls and the permeability of protoplasm decrease restricting vaporization of water. Water moves from the vascular system into masophyll tissues of leaf and evaporates from the cell surface into the intercellular spaces that are continuous to the substomatal cavities. Water vapour then diffuses into the atmosphere through stomata owing to the diffusion pressure deficit.

Transpiration depends on the number and extent of stomatal openings. Guard cells regulate the stomatal openings through which water vapour escapes into the atmosphere. With water deficit and water stress in plant, guard cells lose their turgidity and by that, reduce the size of stomatal opening. Under severe water stress condition, guard cells close the stomata and prevent further transpiration. Ting and Loomis (1963) stated that the diffusion of water vapour into the air from the substomatal cavity is not significantly reduced until the stoma is nearly close. The diffusive capacity of stoma is tremendous and the transpiration rate from a stoma is nearly 50 times the evaporation rate from the free water surface of similar area (Kramer et al., 1967 and Krmaer, 1969).

25.3 SOIL WATER AVAILABILITY AND WATER IN SOIL-PLANT-ATMOSPHERE SYSTEM

Plants absorb water from soil through roots, conduct it through their bodies and transpire the same into the atmosphere through leaves. This is continuous in the soil water-plant-atmosphere system all throughout as long the soil water is available and plants are actively growing. In this system the flow takes place along the water potential gradient from higher to lower potential energy and the flow rate is inversely proportional to resistance met in the path. The resistance is the greatest in the leaf-atmosphere interphase and least in the plant, the soil offering the intermediate. In the leaf-atmosphere interphase where the water transforms into vapour, the process is essentially diffusion influenced by aerodynamic factors. The greater is the diffusion pressure deficit (DPD), the greater is the magnitude of this transformation into vapour form. Therefore, the concept that the rate of water availability decreases with a decrease in soil water contents does not hold good always. The transpiration rate is low under low evaporative demand of the atmosphere even if the soil water availability or soil water content is very high. The growth measured in terms of height, leaf area, dry matter weight and so on which is dependent on the combination of a variety of conditions and physical processes, is affected differently by the soil water or plant water deficit and not entirely by the soil water availability.

25.4 WATER AND PLANT PROCESSES

Plant processes starting from germination to maturity of fruits and grains are affected by water supply. Some processes that have a great bearing in crop production are briefly discussed here:

25.4.1 Germination

Germination is the process of embryo growth with generation of sufficient force to break the embryo cover. In dry seeds all the tissues remain shrunken and the cell contents, plasmolysed. Seeds imbibe water and swell with cells within, becoming turgid. The amount of pressure developed by imbibition in the early stages of germination may be as high as 1000 atmospheres (Shull, 1914). The coleorhiza breaks the pericarn and extends length about 2 mm as in maize.

The radical elongates to fill the extending coleorhiza and breaks through the sheath. The water content of soil or the soil water suction guides the extent of germination. When the soil water content approaches wilting point, germination processes get greatly reduced. The time for germination is considerably extended by increased soil water suction and this is probably due to a limited rate of water conduction to the embryo. Although the water availability is the dominant environmental factor, but temperature, light and supply of oxygen are also quite important in the process. With the start of biochemical changes and cell division in the germination process, the respiration rate increases with a rapid increase in oxygen requirement. Poor aeration of soil often restricts the process.

25.4.2 Seedling Emergence

Germination in common place in agriculture includes both the seed germination and the seedling emergence processes. Seedling emergence in comparison to seed germination is much more sensitive to soil water availability and other soil conditions. Soil water tension strongly influences both the per cent and the rate of emergence. The rate of seedling emergence sharply decreases with the decrease in soil water content after certain limit that varies with crops. Seed bed compaction in a relatively drier surface soil, encourages a greater movement of water from the surrounding areas and lower soil layers. By that seeds come in close contact with the soil and soil water. Thus, compaction of seedbeds mitigates to some extent the difficulties with reduced water content on seedling emergence (Triplett and Tesar, 1960).

25.4.3 Root Development

Root development is most important for a better plant growth and yield. It dictates the amount of water that could be explored by plants from different layers of soils. Water movement in the soil is usually too slow to make an adequate amount of water reach the roots. It is rather the expanding root system that meets water in the hitherto untouched regions of soil to maintain the water supply to the growing plants. An extensive and deeper root system allows the continuance of plant growth for a much longer period as compared to a restricted and shallow root system.

Soil water decides the depth of penetration of roots and lateral and relative growth of roots and shoots. Roots move towards the moist soil and follow the water when they are in direct contact or very close to it. The extent of root spread laterally or vertically downwards is governed by genetic factors and modified by soil environmental conditions. With greater availability of water, roots grow increasingly with shoots, the shoot growth being more than the root growth. With water stress the reverse situation occurs and the rate of shoot growth declines more than that of root growth. When excess water exists in soils, aeration becomes restricted and the root growth is inhibited. Only roots of rice crop and water weeds grow in water logged or wet soils.

25.4.4 Shoot Growth

A plant may be considered as a conduit for water from soil to air. Water is absorbed through roots and transpired through leaves. Plants for making their body weight and performing biochemical activity use less than 1 per cent of the water absorbed. Shoot growth is greatly influenced by the availability of water. When an adequate amount of water is available, plant cells remain turgid and plant structures retain their proper form. A continuous cell division and enlargement occur and shoots continue to grow in soils well supplied with water. The evaporative demand of atmosphere and soil water suction control the transpiration and water absorption. When there is a lag between the rate of transpiration and the rate of absorption, plant water stress occurs. So long the plant does not experience any water stress, the shoot growth continues at a potential rate. With occurrence of stress and its continual increase, the rate of shoot growth continually declines. The growth process stops as the soil water content approaches the wilting point. Growing tips of shoots receive water at the expense of the older parts of plants. When soil water is limiting and the lag between transpiration and absorption is high, growing tips and younger shoots are affected more than the older ones. Death of growing tips often occurs during the mid daytime in hot summer months although the soil water is not limiting. Certain crop plants such as cereals and tomato can make up the loss in growth following temporary stress by an increased growth subsequently with the availability of adequate water (Gates, 1955 and Kemper et al., 1961).

25.4.5 Root development and water use by crops

Roots provide the water absorbing surfaces and soils serve as the reservoir of water. The volume of water that can be explored by a plant depends on the extent of root development. A plant having an extensive root system with both downward and horizontal spread commands potentially a large reservoir of water and can stand drought conditions better. On the other hand, a plant with a shallow root system of limited horizontal spread soon exhaust the available water in the top soil layers and experiences a severe water deficit even when sufficient water is available in deeper layers. Obviously, deep root system with lateral extension should be encouraged to maximize the use of nutrients and water resources in the soil. This is particularly desirable for annual plants. Perennial plants have a grater effective rooting depth and need only to develop new roots to fully utilize the available water resources.

Root development is generally governed by genetical and environmental factors. When environmental factors are favourable, the inherent genetical characteristics have the full expression. Environmental conditions change frequently and cause variations in root development. A given plant may exhibit variations in rooting characteristics under different environmental conditions.

Lesson 26. Soil Water Extraction Pattern and Plant Response

26.1 SOIL WATER EXTRACTION PATTERN OF PLANTS

26.1.1 Water Extraction Pattern

Plants have normally a higher concentration of roots in the upper part of the root zone and near to their base. In a normal soil with good aeration and without restrictive layers, a greater portion of roots of most plants remains within 45 to 60 cm surface soil layers and most of the water needs of plants are met from this zone. As the available water from this zone decreases, plants extract more water from lower depths. When the water content of upper soil layers reaches the wilting point, all the water need of plants are essentially met from lower layers. Since there exist few roots in lower layers, the water extraction from lower layers may not be adequate to prevent wilting, although sufficient water may be available there.

When top layers of the root zone remain constantly kept moist with frequent irrigations, plants get most of their water need from the upper layers and a very little from the lower layers. In uniform soil profile with moist soil, all plants usually extract 40, 30, 20 and 10 per cent of the water need from the respective quarters of the root zone (Fig 26.1). The extraction pattern is normally positively correlated with the root distribution pattern.

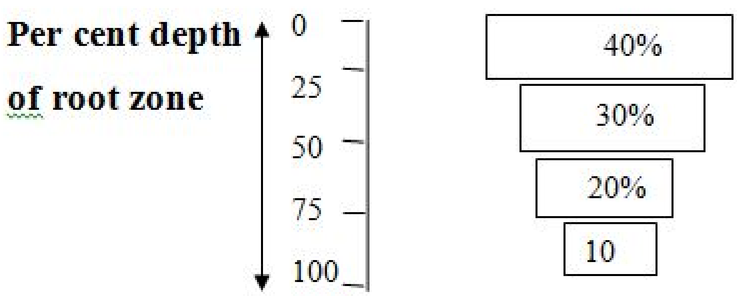


Figure 26.1: Mean design of soil water extraction pattern in soils adequately supplied with water and without restrictive layer in the root zone.

26.1.2 Design Water Extraction Depth

The design water extraction depth of crop refers to the soil depth from which the crop meets most of its water need. A greater part of the absorbing roots in concentrated in the design depth. Soil water is depleted most from this zone between two irrigations and the depleted water is replenished through irrigation. The depth of irrigation required to replenish the depleted water in the design water extraction depth may be called the design depth of irrigation.

Since the development of crop roots varies according to the water availability, soil conditions and crop culture, the design water extraction depths for various crops may be determined based on water extraction data in locality. This is important to achieve high water use efficiency. The purpose of irrigation is to provide adequate soil water for absorption and to help nutrient absorption. A high use efficiency of irrigation water is obtained when there is a minimum movement of applied water beyond the design depth. The interval between two irrigations and the design depth of irrigation are usually more for a crop with a greater design extraction depth in a given soil. Whenever two or more crops are grown together, the design depth of irrigation should be decided based on the crop having a shallower root system. In the absence of definite information on the actual design extraction depths of crops in an area, the quantity of water to be applied may be decided on the basis of design depths given in Table 26.1.

Table 26.1: Design water extraction depths for crops (crops in very deep and well-drained soils)*

60 cm	**90 cm**	**120 cm**	**180 cm**
Cauliflower Cabbage Onion Potato Lettuce Rice	Carrot French bean Garden pea Chilli Muskmelon Tobacco Wheat Castor Groundnut	Cotton Tomato Water melon Maize Sorghum Sugar beet Soybean Pearl millet	Lucerne Citrus Apple Grapevine Coffee Sugarcane Safflower

*The depths may be increased by 25 to 33 per cent for sandy soils of uniform texture and reduced by 25 to 33 per cent for clayey soils (if crops are well adapted to these soils). Source: Gandhi et al. (1971).

26.2 WATER DEFICIT AND PLANT RESPONSES

Plants absorb water to do the normal function of nutrient absorption, transpiration and metabolic activities leading to growth and yield. When the available soil water is not enough to meet particularly the normal transpiration losses, a water deficit in plant is created interfering in many plant processes. As a result, the growth and yield are adversely affected and in severe cases the growth ceases and finally death may occur due to desiccation.

26.2.1 Soil Water Deficit and Plant Stress Conditions

All plants experience some amount of water stress during the growth period. The plant water stress may be severe when the soil water potential is low and environmental or plant factors interfere seriously with absorption of water. Hsiao (1973) reviewing the general effects of water deficit on various plant processes classified the level of water stress into the following categories.

Mild stress: A drop of relative water content of a plant (RWC) by 8 to 10 per cent compared to the value in a well-watered plant under conditions of mild evaporative demand of the atmosphere. This corresponds to a drop of plant water potential by -5 to -6 bars.

Moderate stress: A drop of RWC by 10 to 20 per cent compared to the value in a well-watered plant under conditions of low evaporative demand of the atmosphere. The drop of RWC corresponds to a fall of water potential by -12 to -15 bars.

Severe stress: A drop of RWC by more than 20 per cent compared to the value in a well-watered plant under conditions of low evaporative demand of the atmosphere. The drop of RWC corresponds to a fall of water potential by more than -15 bars.

Plant water stress may be classified into diurnal and cyclical water stress based on changes in stress occurring between two successive irrigations. The stress occurring during 24 hour-period of day and night referred to as diurnal stress. It increases with a rise of temperature during the daytime, reaches its peak at around 14 hours day time and then drops gradually attaining its lowest level early in the morning. It is directly related to the rate of transpiration that follows the diurnal temperature curve. The lag between absorption and transpiration is minimum at early morning and maximum at around 14 hours day. This is very often exhibited by plants showing signs of wilting during the hottest part of the day and recovering during the night and this condition of plant is known as temporary wilting and the soil water content at this stage is referred to as temporary wilting point. The stress that occurs gradually and increases progressively with advance of time after irrigation till the next irrigation is referred to as cyclical water stress. The available soil water decreases continually after irrigation owing to evapotranspiration till the subsequent irrigation creating the cyclical stress condition in plant. The stress becomes maximum just before the irrigation in the irrigation cycle and it disappears following irrigation.

Water stress may also be categorized by visual symptoms in plants that show easily the signs of stress. The stress may be said as mild when plants exhibit signs of wilting during the hottest part of the day only. It is regarded as moderate when wilting occurs for a considerable period during the day time and plants recover during the night, and as severe when the plants wilt continuously and do not properly recover at night causing permanent leaf burning and ultimately death through desiccation.

Measurement of water stress in leaf is usually difficult. A measure of relative turgidity and leaf water potential does not always give a true picture. For practical purposes, an indirect measurement of soil water stress can profitably be used.

26.2.2 Plant Responses to Water Stress Conditions

The earliest effect of water stress is the reduction of cells growth and cell wall synthesis. This is followed by changes in various biochemical processes such as reduction in carbohydrate assimilation, protein synthesis and nitrate reductive activity, and accumulation of abscisic acis (ABA) and protein. Generally, water deficit leads to reduction in synthetic processes and activation of degradation processes.

Plant responses to water deficit are dependent on the degree and duration of water stress experienced, time of occurrence of stress in relation to plant stages, kind of plant and the type of plant produce wanted. Water stress affects the growth, yield and quality of produce in various ways. Plant processes such as root development, tiller formation, branching, flowering, seed formation, seed development are affected. Reduction in diameter of beet root and onion bulb, intermodal length of sugarcane, leaf area per plant in tobacco, flowering and fruiting in most plants, incomplete filling of grains in cereals, fruit drop and some such effects on many other crops are caused. The protein content of wheat grains and nicotine content of tobacco leaves increase with an increase in stress. If the duration of stress is brief, it may not cause a perceptible damage to certain types of crops such as grain crops, as they are able to compensate the digress caused by subsequent development under no stress condition. Yields of vegetables and fodder in which succulent vegetative parts are wanted, are depressed considerably even by a mild stress. An increasing stress for a longer period lowers the quality of vegetables, fodder and fruits significantly.

Occurrence of stress in certain plant stages when the cell division and differentiation are significant and plants undergo some significant changes in their growth behavior, affects growth processes adversely. A water deficit during crown root initiation stage in wheat, spike development stage in cereals and branching, flowering or seed development stages of crop plants in general is harmful and it depresses the growth and yield significantly.

Some amount of water stress is sometimes useful in increasing the water use efficiency. Imposing some stress by irrigating crops at a slightly longer interval in areas where irrigation water is scarce and costly can save water. This may however reduce the yield slightly, but definitely improve the water use efficiency. The water thus saved may be used to irrigate additional area that would provide additional crop production. Delaying the first irrigation for some days after germination in order to impose some amount of water stress, encourages deeper penetration of roots that enables the crops to explore water from deeper layers of soil and stand drought conditions better.

26.3 SOIL WATER AVAILABILITY TO PLANTS

The availability of soil-water to plants is undoubtedly the most important aspect of the soil-water-plant relationship. Soils cannot retain water more than the field capacity under the well-drained condition. The volume of water absorbed by plants beyond the wilting point is very inadequate to meet the transpiration demand and for sustenance of plant life. The field capacity and wilting point are generally considered as the uppermost and lowermost limits of available soil water respectively. The soil water within these two limits is termed as available soil water, and the range of the available soil water between these two water constants is termed as available soil water range. The available soil water equals approximately to the capillary water.

The range of available soil water between the field capacity and permanent wilting point is subjected to criticism as some water beyond these two limits is also available to plants. Soil attains field capacity at about two or three days after irrigation or rainfall and during this period a part of the gravitational water is absorbed by plants. Again, some soil water is extracted by plants beyond the wilting point is however very insignificant. The rate at which soil water is available to plants between field capacity and wilting point is also controversial. Some workers consider that water is equally available to plants throughout this entire range and the plant growth is not affected. However, most of the studies show that the water is not equally available over the entire range as the growth declines after fall in soil water potential. Again, it has been observed that yield declines drastically when the available soil water falls below a particular point within this range. This point is referred to as critical soil water level or critical soil water tension for crop yield. Crops give optimum yield in most cases when the soil water is maintained from field capacity to 50 per cent of available soil water, and occasionally from field capacity to 25 per cent of available soil water.

The total water content of a soil does not give a true picture of the volume of water available to plants. A clay soil retains higher amount of water than a sandy soil at both field capacity and wilting point, but the amount of water available from these soils is not proportional to the actual water. However, the volume of water available is greater in heavier soils than in lighter soils. The volume of available soil water increases with the fineness of soil particles up to silt loam, but it declines with further fineness of particles. Abrol and Bhumbla (1968) stated that the available soil water function of the silt contents and the availability is maximum when the silt fraction of soil constitutes more than 50 per cent of the total silt plus clay fractions.

The upper region of the available soil water range provides the maximum amount of available soil water to plants. It is usually within the soil water tension of one to two atmospheres that most of the available water is released by soils. It may be noted that soil water content and its availability increase with decrease in soil water tension. Further, the water availability increase with an increase in soil depth to a certain level and then decrease with further depths (Abrol And Bhumla, 1968).

Lesson 27. Introduction to weeds

27.1 Introduction

A weed is a plant growing where it is not desired (Jethro Tull, 1731). A weed is an unsightly, useless, injurious plant growing where it is not desired and something else should grow. Also a weed is a plant whose potentialities for harm are greater than its potentialities for good. All weeds are unwanted plants; all unwanted plants may not be true weeds.

Therefore, the correct definition is "Weed is a plant growing out of place and out of time". Despite of all good intention of this definition, for all intents and purposes about 30000 plant species have been identified as weedy around the world.

According to pesticides of India's survey the loss in estimated terms is Rs. 6000 crores rupees annually in India. The share of various agencies is as under.

Rs. 1980 crores	33%	Due to Weeds
Rs. 1500 crores	26%	Due to Diseases
Rs. 1200 crores	20%	Due to Insect pest
Rs. 480 crores	10%	Due to Nematodes
Rs. 430 crores	6%	Due to Store grain pest
Rs. 410 crores	5%	Due to Rodents

More than 3,00,000 species of plants known in the world. Hardly 3,000 are of any economic value. At present 30,000 spp. of weeds are known. 25 plant species are more dangerous and noxious. Mostly they are perennial and very aggressive in nature.

Losses caused by weeds to the society:

1. They reduce crop yields by competiting with crop plants for nutrients, moisture, solar radiation and space.

2. Their presence in field or mixture with crop, deteorate the crop quality.

3. When eaten they harm animal health due to high content of tannins, oxalates, glucosides or nitrates.

4. They harm human health e.g. *Argemone mexicana* causes dropsy.

5. In aquatic ecosystem they transpire lot of water, their presence interfere fishing, hinder navigation, water flow in canal is slowed down and potable water bodies are fouled.

6. Presence of dried weeds in industrial area may cause fire hazard.

7. Their presence in forest reduces the native species.

8. They mar the asthetic value of a place.

27.2 Weed Prevention

Weed prevention comprises all measures which deny the entry and establishment of new weeds in an area. It also includes farm hygiene that prevents the every year production of seeds, tubers, and rhizomes of the weed species already present on the farm.

Some major aspects of weed prevention on farmland are as follows:

27.2.1 Use Weed free crop seeds

One important way the weeds spread on the farmlands is through crop seeds, contaminated with the weed seeds. Some weed seeds always go with certain crop seeds, for example,*Avena fatua* and *Brassica* spp. with small grains.

The prevention of weeds that disperse with the crop seeds can be achieved in two ways,

(I) By the production of weed free crop seeds at the Government farms or at the farmer's field itself, and

(II) By cleaning the crop seeds of weeds before storage as well as at the time of sowing.

27.2.2 Avoid contamination of manure pits

It is a common practice of adding mature or even blooming weeds and their vegetative propagules to manure pits in the hope of recovering their manurial value. In most cases the weed seeds do not lose their viability in the manure pits and the resulting farm-yard manure serves as a notorious source of adding weed seeds to crop land.

27.2.3 Prevent Contamination of manure pits

Do not permit livestock to move from the weed-infested areas directly into clean areas because they can always drop weed seeds and fruits attached to them or those ingested by them earlier. The farm machinery, for similar reason, should be cleaned properly before moving it from one field to another. Same is true of the movement of nursery stock, gravel, sand, and soil from weed-infested areas to the new ones.

27.2.4 Keep non-crop areas clean

The irrigation and drainage ditchers, fence lines, farm boundaries, bunds, and other like un-cropped areas are often neglected by farmers. These places offer a perpetual weed nursery for the cropped plots. This should be prevented by extending the weed control efforts to non-crop areas on the farm.

27.2.5 Keep vigilance

A farmer should inspect his farm areas periodically for some strange looking weed seedlings. The search for them should be extended into standing crops even if herbicides or cultivators were used to control weeds there. No sooner than any strange looking weed seedling are noticed, they should be uprooted by digging as deep as their roots may have penetrated the soil, and the soil in these spots should be treated with a suitable sterilant.

27.2.6 Legal measures

Legal measures are necessary to check inter-state and inter-country movement of noxious weeds if the cost of having to control additional alien weeds is to be saved. Unfortunately, thus far, in most parts of the tropical and sub-tropical word, noxious weeds have not been subjected to strict quarantine laws. This has resulted in the introduction and spread of some of the costliest weeds of the world.

Lesson 28. Weeds Control

28.1 INTRODUCTION

Weed control is the process of limiting weed infestation so that crops could be grown profitably and other activities of man conducted efficiently. The word 'crop' is not restricted here in this meaning to maize, sugarcane or wheat, but it means any plant community that is serving some useful purpose to man and his affairs at the place of its occurrence. In variance with weed control, weed eradication is complete removal of all live plant parts and seeds of a weed from an area.

28.2 MAJOR ELEMENTS OF WEED MANAGEMENT:

1. Crop Husbandry Control of Weeds
2. Physical Control of Weeds
3. Herbicidal Control of Weeds
4. Biological Control of Weeds
5. Crop Breeding for Weed Control
6. Non-Living Mulches
7. Burning and Flaming

28.3 CROP HUSBANDRY CONTROL OF WEEDS:

Good crop husbandry is more than half the weed control envisages on farmland. While directly it induces a healthy growth of crop, indirectly it maintains a crop environment that is as detrimental to weeds as possible.

28.3.1 Proper crop stand and early seedling vigour:

Ready and uniform germination of crop seeds and their development into vigorous crop seedling leaves less space for the weeds to grow amongst the crop plants. Uneven and low crop populations and week crop seedling, on the contrary, permit thick growth of weeds. A vigorously growing crop aids weed control by weakening the weeds by offering competition.

Important steps in obtaining good germination and optimum stand of crops are (1) selection of most adapted crops and crop varieties, (2) the use of high viability seeds, (3) pre-plant seed and soil treatment with pesticides, dormancy breaking chemicals, and germination boosters, (4) adequate seed rates and (5) proper planting time and method. Despite these practices if some gaps are still seen in the crop rows, these must be filled as soon as possible. Row spacing of crops should be as narrow as agronomic recommendation will allow so that the crops close in early. Unnecessarily deep plantings of crop seeds should be avoided as it results in slow germination, and often, in weak seedling.

28.3.2 Selective crop stimulation:

Selective crop stimulation can be achieved in many ways. To start with, correction of soil condition to favour crop growth by the application of soil amendments like gypsum or lime, as the case may be is an important step towards favouring crop growth. Addition of farm yard manure or synthetic soil conditioners to very light or very heavy soils may be useful in improving crop growth by ameliorating the soil structure and thus, maintaining better air-water relationships.

Application of suitable fertilizers and manures in adequate quantities improves plant growth very much. But when these are applied uniformly to soil, the may benefit the crops and weeds. Therefore to make fertilizers available mainly to the crop, these should be banded or side dressed. Weeds growing 20 cm or more away from the fertilized bands usually fail to make use of even a mobile nutrient like N. such weeds remain stunted in comparison to the close growing weeds. Foliar application of fertilizer to wide row crops like maize sugarcane, and cotton, also amounts to their selective stimulation.

28.3.3 Proper planting method:

Any planting method that leaves the soil surface rough and dry will discourage early weed growth. For example, in India when winter grains are planted in seedbeds prepared after a pre-sowing irrigation, it leaves the top 3 to 5 cm of soil above the crop seeds in rough and dry tilth. Such physical condition of soil defers the germination of the weeds. By this time the crop plants are sufficiently grown-up to fight weeds. In variance with this sound practice of planting crops, when a farmer plants his crops in dry soil and irrigates the field soon thereafter, he lands himself into serious weed problems.

In the summer season, furrow planting of crops is a very useful method of reducing the weed problems. It is so because in this method the irrigation water is restricted initially to the furrows. This leaves the inter-row crop spaces dry where weeds fail to germinate. After the crop seedlings are well established, the fields can be irrigated, uniformly.

In transplanted crops the farmer gets opportunity to prepare a weed free field for the placement of healthy crop seedlings. This gives a definite advantage to the crop over the later germinating weeds.

28.3.4 Proper planting time:

With the availability of photo-insensitive varieties of many crops, manipulation of planting time of crops so as to avoid the first heavy flush of weeds should be easy. For instance, when rainy season crops like maize and cotton are planted about 15 days before the break of monsoon with the help of a presowing irrigation, the crops germinate in weed free environment. And by the time the weeds germinate with the onset of rains, the crop seedlings are well up.

28.3.5 Crop rotation:

Crop rotation are effective in controlling crop-associated and crop-bound weeds such as Avena fauna '*wildoat*' and *Cuscuta* spp. 'dodder', respectively. Wild oat can be driven away from small grain fields by using pea and gram as break crops for 2 to 3 years. Dodder on the other hand, can be eliminated from lucerne by turning the land to grain crops for some time.

28.3.6 Stale seedbed:

A stale seedbed is one where 1 to 2 flushes of weeds are destroyed before planting of any crop. As earlier stated, most weed seeds germinate from top 3 to 5 cm of surface soil. If a finally prepared seedbed is withheld from planting and it contains adequate moisture in its top 3 to 5 cm of soil, a flush of young weed seedling will appear on it, in about a week's time. These weed seedlings can be destroyed either with a contact herbicide like paraquat or by spike tooth harrow, spring tooth harrow, weeder-mulcher, and sweeps. Depending upon the time available, one or two flushes of weeds can be destroyed in this manner before planting of crops in the stale seedbeds. The main advantage of stale seedbeds is that crops germinate in weed free environment.

28.3.7 Smother cropping:

The smother crops germinate quickly and develop large canopy, capable efficient photosynthesis, in relatively short period. They possess both surface and deep roots. Also called competitive crops, they suppress the weed seedling by excluding light beneath and utilizing large quantities of nutrients from the soil, rapidly.

28.3.8 Summer fallowing:

Farmers in India, as in many other tropical countries, have used for decades hot months of April, May and June to expose their lands to sun in order to control many soil-borne pests, including weeds. Roots, rhizomes and tubers of shallow rooted perennial weeds like Bermuda grass and nutsedge are desiccated when these are brought to surface by tillage and exposed to air temperature of 40 to 45 °C.

28.3.9 Minimum tillage:

Deep and frequent tillage may be useful for some reasons, but it serves to (i) bring more of dormant weed seeds and rhizomes to the soil surface, and (ii) preserve the new ones deep inside the soil for the future. Both these things are undesirable.

28.3.10 Lowering area under bunds:

Soil bunds made in fields for the purpose of irrigation are ideal places for the rapid growth of weeds. Soil dug or scraped for making these carries numerous weed seeds that germinate readily on them soon after the fields are irrigated, and establish into thick weed populations. These weeds from potential source of every year weed seeds on the farm since the application of herbicides and cultivations are usually restricted to the net cropped ground.

28.3.11 Flooding and Drainage:

Flood kills weeds by excluding air from their environment. Some weed species are more susceptible to it then the others. Flooding is a world-wide crop husbandry method of controlling weeds in rice fields. In some parts of Madhya Pradesh (India), deep flooding of fallow fields with rain water is practiced continuously for 2-3 months. After that the water is let out and the winter grains are planted. The practice, locally called 'Haveli' is considered very effective in controlling weeds besides conserving moisture. The technique however can be used as a weed suppression measure only in limited situations.

In variance with flooding, drainage is used for controlling aquatic and semi-aquatic weeds in rice fields, canals, and ponds. In rice fields, where both terrestrial and aquatic weeds may be common, a judicious combination of the two can be practiced.

28.4 THE PHYSICAL CONTROL OF WEEDS

28.4.1 Pre-Plant Tillage Control of Weeds:

Pre-plant tillage is usually conducted in two phases, viz., the primary tillage and the secondary tillage. The primary tillage is conducted effectively with either a soil inverting plough or a disc. The secondary tillage, on the contrary, is performed with lighter implements like harrows, cultivators, weeder-mulchers, and conjugated rollers.

28.4.2 Primary Tillage Control of Weeds:

Burying the existing weeds, which in turn, eases the post-plant tillage and the application of pre-plant herbicides? Bringing the weed seeds to soil surface for germination and their subsequent destruction by suitable, secondary tillage operations and incorporating pre-plant herbicides.

In the case of perennial weeds, delaying or obviating the need of post-plant tillage.

The role of secondary tillage in weed control is mainly to dislodge the germinating weed seedlings.

28.4.3 Post-Plant Tillage:

For a long time, besides the control of weeds, at least three more functions were assigned to the post-plant tillage, more popularly called row cultivations. These functions are (i) conservation of soil moisture, (ii) enhanced soil aeration, and (iii) mixing of fertilizer and manures with the soil. The development of chemicals to control weeds made it possible to separate the weed control effects of row-tillage from its other effects.

28.4.4 Row-Cultivation Implements:

i. Spike-tooth Harrow: Spike tooth harrow, also called drag harrow and peg-tooth harrow, uproots the germinating weed seedlings, breaks the soil crust, and stirs the soil to 1-5 cm depth.

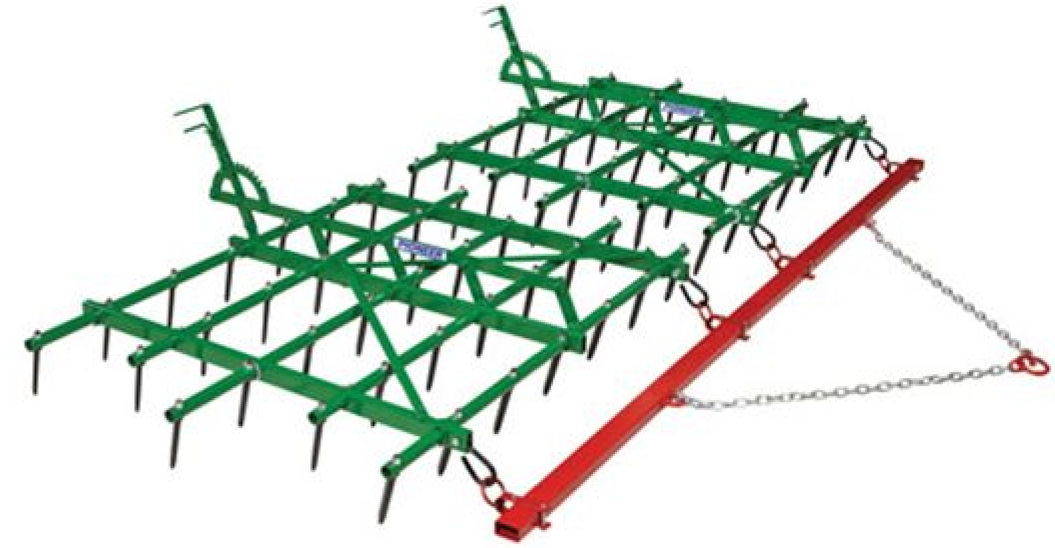


Fig 1. Spike tooth harrow

ii. Spring-tine Harrow: Spring-tine harrow, also called spring-tooth harrow, consists of elliptical spring tines with triangular and sharp free ends. It is used for same purpose as spike tooth harrow but it may stir the soil up to 7.5 cm depth.

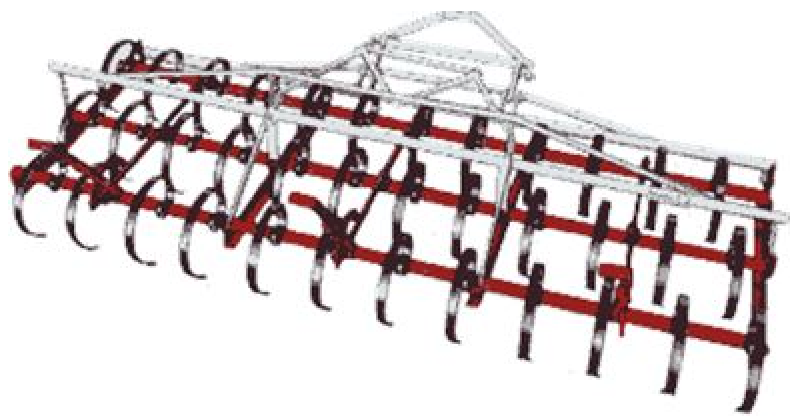


Fig 2. Spike tooth harrow

iii. Rotary-Hoe Cultivator: Rotary-hoe cultivator is tractor-drawn implement designed to run fast, accomplishing adequate soil movement to dislodge the weeds. It is used to break hard crust that usually forms over the crop seeds after a rain but during this process it also destroys the sprouting weeds. Also, a rotary-hoe cultivator is employed to destroy germinating weeds and grasses in the rows as well as those growing close to the young crop plants.

Fig 3. Spike tooth harrow

iv. Wheel-Hoe Cultivator: The wheel-hoe is suitable for weeding only small vegetable gardens and some flower beds.

Fig 4. Wheel-hoe culivator

v. Blade-Harrow: It cuts the weeds 7.5 to 10 cm below the ground and leaves them on the soil surface as much, without causing any inversion of the soil.

Fig 5. Blade harrow

vi. Cultivator (horse-hoe): Cultivator is primarily a secondary tillage implement for seedbed preparation. But many cultivator designs are also used widely for inter-row crops.

Fig 6. Cultivator (horse hoe)

vii. Rice rotary weeder: Rice rotary weeder, as the name indicates is a specific tool for weeding rice crops.

Fig 7. Cultivator (horse hoe)

28.4.5 Mowing, Cutting and Dredging & Chaining:

i. Mowing: Mowing is cutting of a uniform growth of weeds from entire area at the ground level. Its chief purpose is to improve look and accessibility to the area, and in certain cases to prevent multiplication of weed seeds. Also, repeated mowing can weaken the underground parts of perennial weeds.

Mowing is usually practiced in non-crop areas. Lawns, and gardens but it can also prove useful in removing weeds from rows of certain established crops. Common mowing tools and implements are sickle, sword, scythe, machete, lawn mower and reciprocating type rotary-bar mower. Mowing is effective against only erect herbaceous type of weeds. It is preferred over tillage control of weeds on land susceptible to erosion since it does not produce any bare land.

ii. Cutting: In variance with mowing, cutting is topping of the weeds above the ground level. It is most commonly practiced against brushes and trees with the help of axes and saws. In aquatics, under-water weed cutters are used to cut weeds up to 1 m below the water surface. Both cutting and mowing are short-lived in their effects; the topped weeds re-grow soon from their crown region and underground buds. Therefore, these operations must be repeated often to keep the weeds and grasses low.

iii. Dredging & Chaining: These two physical control methods are used against aquatic weeds growing in shallow ditches. Dredging constitutes mechanical pulling of weeds with their shallow roots and rhizomes covered in mud. In chaining, on the other hand, a very heavy chain is pulled over the bottom of the ditch with the help of two tractors, one moving on either bank of the ditch. The chain fragments the rooted weeds by its rubbing action, and the weed fragments float to the water surface. From here these can be collected down the stream by nets and hooks.

28.4.6 Soil Solarisation (Soil Heating):

Soil solarisation, also called solar soil heating, is another method of utilizing solar energy for the desiccation of weeds in fallow fields during the hot summer months. It differs from hot weather tillage control of weeds described earlier in two major aspects (i) It is effective mainly against weeds from seeds. (ii) It usually does not involve any tillage of the field.

The technique of soil soalrisation involves covering the moist soil with polythene sheet of 20-25 mm thickness during hottest part of the year (April-June). This sheet permits the incoming short wave solar radiation through to the soil. However, the out going long wave terrestrial radiation is trapped inside the sheet which results in net rise in temperature by 10-12 degrees celsus. This rise in soil temperature is fetal for many species of weeds including *Phalaris minor* and *Avena fatua* etc. In addition to weed control, solarisation also damage many of the hibernating and aestivating insects and disease organisms.

28.5 HERBICIDAL CONTROL OF WEEDS

Herbicides are chemicals capable of killing or inhibiting the growth of plants. In the last 40 years or so, man has greatly improved upon his weeding efficiency by supplementing the conventional weeding methods with herbicides. It has saved farmers of undue, repeated inter-cultivations and hoeing and has helped him in obtaining satisfactory weed control where physical methods often fail. Today, we have over 400 herbicides in common use for selective and non-selective weed control in different areas. These chemicals vary greatly in their (a) molecular structures, (b) mobility within plants, (c) selectivity, (d) fate in soils, and (e) response to environment.

A. Benefits of Herbicides:

Herbicides were developed in the western world primarily to overcome the shortage of farm labour for weeding crops. However, during the past four decades, slowly the utility of herbicides has also been realized in the labour-rich tropical world, for varied reasons. Important among these are the following:

In monsoon season incessant rainfall may make physical weeding infeasible. Herbicides can be used to ensure freedom of crops from weeds under such a condition. The soil applied herbicides can be of great help in these regions in boosting crop production.

Herbicides can be employed to control weeds as they emerge from the soil to eliminate weed-crop interference even at a very early stage of crop growth. But by physical methods weeds are removed after they have offered considerable competition to the crops, and rarely at the critical time. Thus, herbicides provide benefits of timely weed control.

Herbicides can kill many weeds that survive by mimicry, for example, wildoat (Avena Spp.) in wheat and barnyard grass (Echinochloa spp.) in rice. Weeds that resemble crop plants usually escape physical weeding. Herbicides control does not dictate strict row spacing. In physical weed control, on the other hand, the crop rows have to be sufficiently wide to accommodate weeding implements, else, hand weeding and hand-pulling of weeds has to be resorted to.

Herbicides bring about longer lasting control of perennial weeds and brushes than is possible with any physical control method. Many modern herbicides can translocate considerably deep in the underground system of weeds and damage them.

Herbicides are convenient to use on spiny weeds which cannot be reached manually. Herbicides are safe on erodible lands where tillage may accelerate soil and water erosion. Excessive tillage, in any case, spoils soil structure, reduces organic matter content, and depletes moisture status of the soil.

Some other benefits of using herbicides include (a) fewer labour problems, (b) greater possibility of farm mechanization. (c) easier crop harvesting and (d) lower cost of farm produce. In dry land agriculture, effective herbicidal control ensures higher water use by crops and less crop failures due to drought.

B. Limitations of Herbicides:

Like any other method of weed control, herbicides have their own limitations. But with proper precautions these limitations can be overcome, markedly. Important limitations in the use of herbicides are as follows.

In herbicidal control there is no automatic signal to stop a farmer who-may be applying the chemical inaccurately till he sees the results in the crops sprayed or in the rotation crops that follow. Even when herbicides are applied accurately, these may interact with environment to produce unintended results. Herbicides drifts, wash-off, and runoff can cause considerable damage to the neighboring crops, leading to unwarranted quarrels.

Depending upon the diversity in faming, a variety of herbicides must be stocked on a farm to control weeds in different fields. On the contrary, for physical control of weeds a farmer has to possess only one or two kinds of weeding implements for his entire farm.

Above all, herbicidal control requires considerable skill on the part of the user. He must be able to identify his weeds and possess considerable knowledge about herbicides and their proper usages. Sometimes an error in the use of herbicides can be very costly.

28.6 THE BIOLOGICAL CONTROL OF WEEDS

The biological control of weeds involves the use of living organisms such as insect, herbivorous fish, other animals, disease organisms, and competitive plants to limit their infestations.

An important aspect of biological weed control is that at a time, it is applicable to the control of only one major weed species that has spread widely. With perennial weeds the main objective of bio-control is the destruction of the existing vegetation, in the case of annual weeds prevention of their seed production is generally more important.

28.7 CROP BREEDING FOR WEED CONTROL

Plant breeders, thus far, have engaged themselves in evolving crop varieties tolerant to specific pathogens, insects, nematodes, and even birds. But hardly any attempt has been made to breed crop plants tolerant to competition from weeds. In recent years attention of a group of Asian and African plant breeders has been drawn towards breeding millet varieties tolerant to *Striga* sp.

28.8 NON-LIVING MULCHES

Mulching stunts or kills the weeds by cutting light to them. Straw, hay, dry sugarcane leaves, farmyard manure, rice hull, saw dust, and bark dust are natural, partial mulch materials, which can at best stunt the weed growth. Even when these are spread in thickness of 6 to 12 cm, the perennial weeds grow through them easily. Also, the natural mulches tend to harbour insect pests and disease organisms and obstruct farm operations. Synthetic mulches, namely black paper or polythene film mulches provide stronger mechanical barriers to all kinds of germinating weeds. Black, plastic-coated, craft paper mulches are now preferred on newly prepared fields to suppress weeds. These are made in rolls of different widths which can be spread on the seedbeds and then crop seedlings can be transplanted through holes made into them. Presently mulching with synthetic materials is costly, so its economic use is limited to certain high value vegetables and ornamentals.

28.9 BURNING AND FLAMING

Burning is the cheapest method of eliminating mature, unwanted vegetation from rangelands and non-crop situations like roadsides and ditch banks in dry seasons. Weed seeds that have already shattered on the ground before flaming will not be killed by it. Burning is limited in its value because it is a potential source of fire hazard. In variance with it, flaming is a momentary exposure of green weeds to as high as 1000 °C temperature from flame throwers. Flaming kills plants by coagulating their cell protoplasm. In some western countries, flaming is used for selective control of inter-row weeds in onion, soybean, grain sorghum, castor bean, cotton, sesame, and certain fruit orchards. For selective weed control, flaming must be done when weeds are in their seedling stage and the crop plants are well established. The flame should be directed towards the weeds under hood covers.

Flaming has proved useful in destroying dodder-infested crops of Lucerne. In grasslands, woody shrubs and patches of perennial weeds can be destroyed by spot flaming. Flaming is also helpful in weeding farm ditches and many other difficult non-crop situations. It is believed that repeated light applications of flame to plant shoots can destroy even roots of the perennial weeds. The process is called searing.

Lesson 29. Crop Rotation

29.1 INTRODUCTION

With the introduction of high yielding crop varieties and latest technical know how the farmers in India are now considering agriculture as a business. Since the farmers get major share of income through crop yields, it is therefore, of paramount importance to choose a right crop, in an appropriate area, in suitable cropping system and with a maximum profit.

29.2 CROP ROTATION

The farmers are in the habit of growing different crops according to their needs and facilities, but it is necessary for them to know more about it. Crop rotation is a process of growing different crops in succession on a piece of land in a specific period of time, with an object to get maximum profit from least investment without impairing the soil fertility.

29.3 PRINCIPLES OF CROP ROTATION

There are certain accepted principles based on which the crops should be selected for crop rotation.

1. The crops with tap roots should be followed by those which have fibrous root system. This helps in proper and uniform use of nutrients from the soil and the roots do not compete with each other for the uptake of nutrients.
2. The leguminous crops should be grown after non-leguminous crops because legumes fix atmospheric nitrogen into the soil and add more organic matter to the soil; while on the other hand, non-legumes are fertility depleting crops. Apart from this, the nutritional requirements of these crops are different, e.g. legumes need more phosphate and less nitrogen while non-legumes need more of nitrogen and relatively low phosphorus. Thus a combination of these crops helps the farmers in reducing their cost of cultivation.
3. More exhaustive crop should be followed by less exhaustive crops because crops like potato, sugarcane, maize etc. need more inputs such as better tillage, more fertilizers, greater number of irrigations, more insecticides, pesticides and better care than crops like oil seeds, pulses etc. which need relatively less or little of the above mentioned inputs.
4. Selection of the crops should be demand based i.e. the crops which are needed by the people of the area and by the family members should be chosen so that the produce can be easily sold at a higher price.
5. The selection of crops should be problem based e.g. On sloppy lands which are prone to soil erosion, an alternate cropping of erosion promoting (erect growing crops like millet, etc.) and erosion resisting crops like legumes, should be adopted.
6. Under dry farming or partially irrigated areas the selection of crops should be such which can tolerate the drought similarly in low lying and flood prone areas the crops should be such which can tolerate water stagnation e.g. paddy, jute etc.

7. The selection of crops should suit the farmers' financial conditions.
8. The crops selected should also suit the soil and climatic conditions.
9. The crops of the same family should not be grown in succession because they act like alternate hosts for insects, pests and disease pathogens. Thus, the control of insects, pests and diseases becomes a perennial problem. Apart from this, types of weeds found, are associated with various crops and selection of the same type of crops in rotation encourages weed problems in the field viz. Johnson grass grow with gramminaceous crop throughout year.
10. An ideal crop rotation is one which provides maximum employment to the family and farm labour, the machines and equipments are efficiently used and all the agricultural operations are done timely.

29.4 ADVANTAGES OF CROP ROTATION

An ideal crop rotation has the following advantages:

1. Agricultural operations can be done timely for all the crops because of less competition. The supervisory work also becomes easier.
2. Soil fertility is restored by fixing atmospheric nitrogen, encouraging microbial activity, avoiding accumulation of toxins (HCN etc.) and maintaining physic-chemical properties of the soil. The soil may also be protected from erosion, salinity and acidity.
3. An ideal crop rotation helps in controlling insects, pests and diseases. It also controls the weeds in the fields e.g. continued growing of berseem encourages chikori (kasani) infestation in the field and repeated wheat culture increase wild oats and *Phalaris*infestation but an alternate cropping of berseem and wheat helps in controlling kasani as well as wild oats and *Phalaris*. This is because of taking several cuttings of berseem, the wild oats and *Phalaris* are also cut and in the wheat the chikori (kasani) is controlled by 2,4-D spraying but if some plants are left, they keep on growing and before they set into seeds, the wheat crop is harvested. Thus all these weeds are controlled along with many other weeds associated with wheat and berseem crops.
4. Proper utilization of all resources and inputs could be made by following crop rotation. The family and farm labour, power, equipment and machines are well employed throughout year.
5. The farmer gets a better price for his produce because of its higher demand in the locality or market.
6. Growing crops of different root depths avoids continues depletion of nutrients from same depths e.g. the deep rooted crops take nutrients from deeper zone and during that period the upper zone gets enriched. Similarly the surface feeding roots take nutrients from upper zone when lower zone gets enriched. Thus nutrients of entire soil mass are fully utilized and cost of cultivation is reduced.
7. Best utilization of residual moisture, fertility and organic residues is made by growing crop of different nature.
8. Ideal crop rotation improves percolation, soil structure and reduces chances or creation of hard pan in sub-soil zone.
9. Some crop plants are found to produce photoalexins when they get infected by diseases. Repeated cultivation of such crops results in harmful effects over crop plants and lower crop yield is obtained.

The family needs of feed, food, fuel, fibre, spices, condiments, sugar, etc. are fulfilled. The farmers keep on getting some income constantly from their cropping which improves their socio-economic status and it also facilitates future crop planning.

Growing different crops is very beneficial but sometimes the desired crops cannot be grown because of certain governing factors. The factors which affect the selection of crops are agro-climatic factors (soil and climate), irrigation, availability of bullock and other powers, market facilities and type of farming and customs in neighbouring areas.

Lesson 30. Different Cropping Systems - I

30.1 INTRODUCTION

System of cropping is the way in which different crops are grown. Sometimes a number of crops are grown together or they are grown separately at short intervals in the same field. For easy understanding the cropping system may be divided into two main groups:

1. Mixed cropping
2. Intensive cropping

30.2 MIXED CROPPING

Mixed cropping is the process of growing two or more crops together in the same piece of land, this system of cropping is generally practised in areas where climatic hazards such as flood, drought, frost etc., are frequent and common. The farmers always fear that their crops will fail. Under mixed cropping, the time of sowing of all the crops is almost failed. Under mixed cropping, the time of sowing of all the crops is almost the same, however they may mature either together e.g. wheat+ gram or wheat + barley or wheat + mustard or they may nature at different times. E.g. arhar + jowar + mung and till or groundnut + bajara etc.

Mixed cropping may be classified into the following groups, based on their method of sowing:

(a) **Mixed crops**: in this group the seeds of different crops are mixed together and then sown either in lines or they are broad casted. This system is not scientific and it causes problems in performing all the agricultural operation and harvesting of the crops.

(b) **Companion crops**: under this method the seeds of different crops are not mixed together but different crops sown in different rows, e.g. between two rows of mustard 5 to 8 rows of wheat or between two rows of arhar two – three rows of groundnut are sown. This method of sowing facilitates in weeding, interculture, plant protaction operation and even harvesting.

(c) **Guard crops**: under this system of cropping, the main crop is grown in the centre, surrounded by hardy or thorny crops such as safflower around pea, or wheat, mesta (Patsan) around sugarcane, jowar around maize etc. With a view to provide protection to the main crop.

(d) Augmenting crops: when sub crops are sown to supplement the yield of the main crop the sub crops are called as Augmenting crops such as Japanese mustard with berseem. Here the mustard helps in getting higher tonnage of fodder inspite of the fact that berseem give poor yield in first cutting.

30.2.1 Principles of mixed cropping

The most important point is selection of crops. Crops which compete with each other should not be chosen. Therefore the following points should be considered while selecting crops.

1. Legumes should be sown with non-legumes examples arhar with jowar, gram with wheat.
2. Tall growing crops should be sown with short growing crops. e.g. maize with mung/urd.
3. Deep rooted crops (tap rooted crops) should be sown with shallow rooted or adventitious crops.
4. Bushy crops should be sown with erect growing crops.
5. Crops being attacked by similar insects, pests and diseases should not be sown together.
6. Mixture should consist short and long duration crops.

30.2.2 Advantages of mixed cropping

Mixed cropping has the following advantages.

1. All the crops do not fail under adverse climatic conditions, e.g. frost kills only legumes, flood kills only dicot plants and drought kills the monocot plants or shallow rooted crops. Thus the farmer gets some crops instead of losing the entire crop.
2. An epidemic attack of any insect, pest or disease kills only one crop without affecting the rest of the crops.
3. The farmer grows different crops which fulfil their daily need or demand for cereals, pulses and oil seeds.
4. Mixed cropping checks soil erosion, weeds etc.
5. It improves or maintains the soil fertility.
6. Family labour and cattle are employed throughout year.
7. Legumes and non-legume mixture improves the fodder quality and quantity both.
8. It reduces cost of cultivation.

30.3 Intensive cropping

In developing countries like India where subsistent farming is still predominant, evolution of high yielding varieties, expansion of irrigated area and rapid transfer of technology have made green revolution a distinct possibility through majority of beneficiaries were big farmers. In future much of the boost needed in agricultural production has to be achieved from small farmers which can be possible only through intensive cropping. The average cropping intensity is still about 115% in India as against 185 in Taiwan (Darrymple, 1971). Much has to be done in low rainfall areas which require an immediate attention on the design, testing and identification of most befitting cropping systems for different regions aiming at maximum utilization of physical resources like rainfall, solar radiation, irrigation and soil for crop production.

Intensive cropping is the process of growing a number of crops on the same piece of land during the given period of time. In other words, when the area is limited and the number of crops to be grown is increased within a definite period of time, this cropping method is termed as intensive cropping. The main objective is to increase the income/unit area within a specified period of time.

30.3.1 Method of intensive cropping

The following methods have been developed to make intensive cropping a success.

1. **Multiple cropping**

This represents a philosophy of maximum crop production per unit area of land within an agricultural year. In other words multiple cropping may be explained as a cropping system in which two or more crops are grown in succession by adopting the following cropping systems:

(a) Relay cropping: Relay cropping is analogous in a relay race where a crop hands over a baton (land) to the next crop in quick succession. The best example of relay cropping is given below.

1. Under rainfed or partially irrigated conditions:

   Paddy-Lathyrus

   Paddy-Lucerne

   Paddy-Berseem

   Cotton-Berseem

Here the seeds of lathyrus, lucerne or berseem are broadcasted in standing paddy or cotton crop just before they are ready for harvesting.

Thus, the field is never fallow or there is no gap at all between two successive crops.

30.3.2 Pre-requisite of intensive cropping.

For successful multiple cropping programme the following things must be made available.

1. Availability of most suited high yielding and short duration crop varieties. These varieties must be responsive to input doses and they should also be thermo and photo non-sensitive so that at least three crops could be grown every year.
2. Availability of genetically superior quality seed or planting materials so that a required genotype could be grown and they may express their full yield potentials.
3. An excellent physic-chemical properties of soil like well levelled land surface, better structure, aeration, water holding capacity, permeability, free from undesirable salts, etc. should be maintained. The soil should be rich in soil fertility and organic matter content so that it may sustain high intensity cropping with greater productivity.
4. The area should not be prone to climatic hazards like flood, drought, frost, etc. and all preventive measures should be taken in advance to meet any such challenges. The soil should be rich in soil fertility and organic matter content so that it may sustain high intensity cropping with greater productivity.
5. Ready availability of inputs like labour, capital, irrigation, power, fertilizer, seed and plant protection materials and equipments with technical details.
6. An official and regulated marketing facilities should be provided to the growers so that they may get remunerative prices of their produce to enable them recycling of funds in better crop planning. This would also avoid glut in the market.
7. The cultivators must be well acquainted with latest crop production technologies like zero or minimum tillage, relay or overlapping cropping systems etc.
8. The farmers should get acquainted with allelophathic effects of some crops and their associated weeds so that the susceptible crops could be avoided in succession viz.

accumulation of HCN in sorghum stubbles becomes toxic to wheat seedling, therefore, wheat should be avoided after the sorghum.

9. The crops should be harvested at physiological maturity so that sowing of next crop could not be delayed and every day of the year may be utilized for crop production.
10. The farmers should know about post harvest processing of various crops and their products which may help in generating employment opportunities and in appreciating the value of the produce. This would also reduce glut in the market and a lower marketing competition will help in stabilising the prices of agricultural commodities.
11. Crop insurance scheme should be launched for high input requiring crops or cash crops like potato, tobacco, cotton etc.
12. The farmers must be acquainted with ill-effects of multiple cropping like gradual depletion in soil fertility and deficiency of certain micro-nutrients, gradual build up in population of certain pest and disease pathogens etc. so that timely curative measures may be taken.
13. The farmers should be frequently trained in latest techniques through demonstrations, field days, farmers' meeting etc. for an efficient transfer of technologies and their proper adoption by the farmers.

a. Under assured irrigated conditions:

Maize-early potato-late potato-cucurbits

In this case the cucurbits are sown a few weeks before the potato tubers are lifted. Thus, the cucurbits start before the potato crop finishes.

1. Maize-potato-onion-bhindi

Here in the same plot, potato variety, K. Chandramukhi is sown in October, onion is sown in furrows just after earthing, bhindi is sown in potato rows just after the digging of potato tubers and later in the standing crop of bhindi, maize is sown. This way there is no gap of time between two crops.

Lesson 31. Different Cropping Systems - II

31.1 OVERLAPPING SYSTEM OF CROPPING

In this system the crop is harvested in phases and the vacated area is sown by next crop viz. in case of forage sorghum, part of the crop is harvested for feeding to the cattle or selling out in the market and vacated area is sown with berseem or lucerne. Thus harvesting of sorghum and sowing of berseem is done simultaneously in part of the field in phases rather than sowing entire field in succession. This helps in a continuous supply of green fodder to the cattle as by the time last portion of sorghum field is free for berseem sowing the berseem crop sown in the first place becomes ready for first cutting e.g. Sorghum-berseem/ lucerne.

31.2 INTER CROPPING

This is a process of growing subsidiary crops between two widely spaced rows of main crop. The main object of this type of cropping is to utilize the space left between two rows of main crop and to produce more grain per unit area.

31.2.1 Principles of inter cropping

1. The crops grown in association should have complementary effects rather competitive effects.
2. The subsidiary crop should be of shorter duration and of faster growing habits to utilize the early slow growing period of main crop and they must be harvested when main crop starts growing viz. faster sesamum, sawan, urd or mung grown with red gram complete their life cycle by September, the period since when red gram picks up branching and attains rapid growth. Autumn planted sugarcane remains dormant after germination uptil February during which potato, berseem, lucerne, mustard, etc. could be taken successfully as companion intercrops.
3. The component crops should have similar agronomic practices.
4. Erect growing crops should be intercropped with cover crops like pulses so that the soil erosion and weed population could be reduced or checked. This also helps in reducing evaporation loss of water from soil surface.
5. The component crops should have different root depths so that they do not compete for nutrients, water and root respiration among them.
6. A standard plant population of main crop should be maintained whereas that of subsidiary crops the plant population could be increased or decreased as per demand of the situation.
7. Component crops of similar pest and disease pathogens and parasite infestations should not be chosen.
8. The planting method and management should be simple, less time taking, less cumbersome, economical and profitable so that it may have wider adoptability.

Example: Maize intercropped with green gram, black gram or groundnut etc.

The intercrops differ from mixed crops in the following ways:

31.2.2 Difference between Intercrops and Mixed crops

Intercropping	Mixed cropping
1. The main object is to utilize the space left between two rows of main crop especially during early growth period of main crop.	1. The main object is to get at least one crop under any climatic hazard e.g. flood, drought or frost conditions.
2. More emphasis is given to the main crop and the subsidiary crops are not grown at the cost of the main crop. Thus there is no competition between main and subsidiary crops.	2. Here all crops are given equal and there is no main or subsidiary crop. Almost all the crops compete with one another.
3. Subsidiary crops are of short duration and they are harvested much earlier than the main crop.	3. The crops are almost of the same duration.
4. Both the crops are sown in rows. The sowing time may be the same or the main crop is sown earlier than the subsidiary crops.	4. The crops may be broadcasted or sown in rows but the sowing time for all the crops is the same.

Intercropping may be divided in following four groups:

1. Parallel cropping

Under this cropping two crops are selected which have different growth habits and have a zero competition between each other and both of them express their full yield potential.

Example: Mung or urd with maize and urd, mung or soybean with cotton.

2. Companion cropping

In companion cropping the yield of one crop is not affected by the other. In other words, the yield of both the crops is equal to their pure crop. Thus the standard plant populations of both crops are maintained.

Example: Mustard, wheat, potato, etc. with sugarcane

3. Multi-storeyed cropping

Growing plants of different heights in the same field at the same time is termed as multi-storeyed cropping. It is mostly practiced in orchards and plantation crops for maximum use of solar energy even under normal planting density.

Example: Eucalyptus, papaya, and berseem grown together.

Sometimes it is practiced under field crops such as sugarcane and potato and onion (seed crop) or sugarcane, mustard and potato.

4. Synergistic cropping

Here the yields of both crops, grown together are found to be higher than the yields of their pure crops on unit area basis.

Example: Sugarcane and potato

31.2.3 Advantages of inter-cropping

1. It offers similar benefits to that from rotational cropping. The nutrients from different layers of the soil are evenly used. A cereal-legume mixture is beneficial because of an efficient fixation of atmospheric nitrogen into the soil. Leaf shedding and their subsequent decomposition reduces the chances of micro-nutrient deficiency in shallow or surface rooted crops like cereals as the legumes absorb such nutrients from lower layer and return them to the surface soil through shedding of leaves and decomposition.
2. Total bio-mass production/unit area/period of time is increased because of the fullest use of land as the inter-row space will be utilized which otherwise would have been used for weed growth. The farmer gets all his required agricultural commodities from a limited space. Thus the profit/unit area becomes high.
3. The fodder value in terms of quantity and quality becomes higher when a non-legume is intercropped with legume viz. Napier+cowpea-Napier+berseem.
4. It provides crop yields in installments which reduces the marketing risks.
5. It offers best employment and utilization of labour, machine and power throughout year.

31.3 Assessment of land use and productivity in high intensity cropping programme

High intensity cropping needs application of very high input levels and a slight mistake may lead to severe losses. It is, therefore, essential to assess the land use pattern and productivity under such cropping systems. These things may be assessed by using following equations:

1. Multiple cropping index (MCI). It measures the sum of areas under various crops raised in a single year divided by net area available for that cropping pattern multiplied by 100. It is calculated for each cropping pattern separately and is very similar to cropping intensity :

$$MCI = \frac{\textbf{total no. of crops} \times \textbf{their respective area}}{Total\ area\ available\ for\ the\ cropping\ pattern} \times 100$$

2. Diversity Index (DD). It indicates the multiply of crops or farm products which are planted in a single year by computing the reciprocal of sum of squares of the share of gross revenue received from each individual farm enterprise in a single year. It may be calculated by using following equation

$$DI = \frac{1}{\begin{array}{c}Sum\ of\ squares\ of\ gross\ revenue\ received\ from\\ crop\ or\ enterprise\ in\ a\ single\ year\end{array}}$$

3. Harvest Diversity Index (HDI). It is calculated by using the DI equation except that the value of each farm enterprise is replaced by the value of each harvest.

4. Simultaneous cropping index (SCI). It is calculated by multiplying the HDI with 10,000 and dividing by MCI as stated below:

$$SCI = \frac{HDI \times 10000}{MCI}$$

5. Cultivated land utilization index (CLUI). It may be calculated by adding the products of land area planted to each crop, multiplied by the actual duration of that crop to reach physiological maturity and dividing by the total cultivated land area times 365 days:

$$\text{CLUI} = \frac{Respective\ crop}{Total\ cultivated\ land\ area \times 365}$$

It is applicable only in sequential cropping and the utility or sanctity of CLUI becomes very limited if the harvesting is delayed or in case of relay cropping and overlapping systems.

6. Cropping intensity index (CII). It determines the actual land use in area and time relationships for each crop or group as against the total available land area and time. It may be calculated by using following equation:

7. Specific crop intensity index (SCII). It may be calculated by using CII equation and determines the amount of area-time denoted to each crop or group of crops as against the total time available to the farmer.

8. Relative cropping intensity index (RCII). It is again a modification of CII which determines the amount of area-time alloated to one crop or group of crops as compared to the area-time actually needed in production of all the crops:

$$\text{RCII} = \frac{SCII\ denominator}{CII\ numerator}$$

If RCII is more than 50% for a specific crop then that farmer is said to be specialized grower of that particular crop.

Table 31.1 State wise irrigated area (in %) and average cropping intensity in the 0.5 to 1.0 ha.

State	Net irrigated area	Cropping intensity (%)
Andhra Pradesh	47.6	116.1
Assam	7.2	119.5
Bihar	25.9	133.6
Karnataka	20.9	106.8

Kerala	14.0	116.4
M.P.	14.5	123.4
Maharashtra	13.2	124.2
Orissa	19.6	141.5
Rajasthan	23.0	126.5
T.N.	43.6	122.6
U.P.	42.5	137.9
W. Bengal	17.5	127.6
All India	30.8	128.2

Source: Indian Agric. 15th edition, directorate of Eco. & Statistics, Min. of Agric. & Irrigation September 1980.

Lesson 32. Scope of Horticultural Crops

32.1 INTRODUCTION

The term "Horticulture" first appeared in written language in the seventeenth century. The word horticulture is derived from the latin words hortus means garden and cultura means to cultivate. Horticulture means garden cultivation. Thus, Horticulture is a part of plant agriculture which is concerned with cultivation of "garden crops". Garden crops traditionally include fruits, vegetables and all the plants grown for ornamental purposes as well as spices, plantation, medicinal and aromatic purposes. The cultivation of garden plant is in contrast to the cultivation of field crops which is practiced in an extensive manner. Horticulture relies on growing and manipulating plants in a relatively intensive manner. The horticultural crops require very intense care in planting, carrying out cultural operation, manipulating growth, harvesting, packing, marketing, storage and processing. Many horticultural products are highly perishable, their water content is essential to their quality and hence mostly utilized in living stage. In contrast, the products of field crop and forestry are often utilized in non-living state and are usually high in dry matter.

32.2 DEFINITION OF HORTICULTURE

Horticulture can be very broadly defined as the science with deals with the production utilization and improvement of (fruits, vegetables, ornamental plant spices and condiments, medicinal and aromatics, plantation crops) as well as gardening, protective cultivation and value addition.

Horticulture as a science

Over and above agriculture it involves the application of physics, chemistry and other fundamentals sciences and plant sciences viz. biochemistry, plant physiology, botany, genetics and plant breeding etc.

Horticulture as an art

Artistic application of technical knowledge gained e.g. raising flowering plants in small pot, budding roses with varied colours, pruning trees for shapes, designing gardens, growing flowers of matching colours and according to the seasons etc.

32.3 OBJECTIVES

To find out way by which horticulture crops can be made to yield optimum benefits to mankind.

These objectives can be achieved through

- The knowledge of geographical distribution of horticultural plants
- The source and uses of such plants their structure and manner of growth
- The influence of climate and soil on their development
- The methods of their propagation
- The manner, time and degree of pruning them
- Their diseases, pests and their control and
- The manner of harvesting, storing, transporting and using the finished products

32.4 DIVISION OF HORTICULTURE

1. **Pomology**: The term Pomology is derived from the Latin word 'pomum' meaning 'fruits' and the Greek term 'logy' meaning Science. Thus, pomology is the science of production of fruit crops. OR The science of growing fruit crops.

   (a) Tree fruits: Fruits are produced on tree e.g. Mango, Chiku, Citrus etc.

   (b) Small fruits: Fruits are produced on shrubs or vines e.g. Phalsa, Raspberry, Mulberry, Grapes, Gooseberry, Strawberry

1. **Olericulture:** The term Olericulture is originated from Latin word 'oleris' meaning pot herb and the English word culture meaning raising of plants. Thus, olericulture is the science of vegetable crops. OR The cultivation of vegetable crops. e.g. brinjal, tomato, potato, radish, carrot, chilli, bottle gourd.
2. **Floriculture:** It is a science of cultivation of flowers and ornamental plants for commercial purposes or merely for getting pleasure and as a hobby.
3. **Landscape gardening:** It is a science of designing and laying out home gardens, public gardens, parks, road side plantation, avenues etc.
4. **Preservation of fruit and vegetables:** It is a science of canning of fruits and vegetables. e.g. fruit juice, jam, marmalade, candy, dehydration etc.
5. **Silviculture:** Cultivation and management of forest tree e.g. teak wood, neem, ficus, eucalyptus etc.
6. **Plantation crops:** Cultivation of tea, coffee, coconut, arecanut, rubber, oil palm etc.
7. **Spices and condiments:** Cultivation of crops which products are used as adjunct in food for flavor, aroma and taste. e.g cardamom, clove, nutmeg, coriander, cumin etc.
8. **Aromatic and medicinal plants:** cultivation of aromatic and medicinal plants like gugal, aonla, beheda, harde, lucorice, lemon grass etc.
9. **Sericulture:** Deals with rearing of silkworm and production of silk.
10. **Apiculture:** Bee keeping rearing for honey production.
11. **Mushroom production:** Production of different edible species of mushroom like *Agaricus bisporus* (button), *pleurotus sp*. (oyster), *Calocybe indica* (Milky),*Volvariella volvacea* (paddy straw).

32.5 SOME IMPORTANT TERMS EXPLAINED FROM HORTICULTURE POINTS OF VIEW

Annuals: As the name indicates annuals are plants that live for one year or less, that is the makes its vegetative growth flowers and produces seed within one year from the sowing date and then the plant dies. Actually in practices we often see that this definition cannot be strictly applied to some plants because they often over live the period of one year. e.g. brinjal, tomato, coleus, geranium etc. They may behave as perennials and yet in context to horticulture, speaking they are annuals.

Biennials: Biennials plants are those which require two years or parts of two growing seasons with more or less of a dormant or resting season between to complete their life period. In the first season or year the seed is sown and the plant makes only vegetative growth. In the second season or year the plant produces very little vegetative growth and then flowers produces seed and dies out e.g. onion, beet, carrot, cabbage, radish, chrysanthemum, dahila etc.

Perennials: These plants do not finish their life cycle in one or two years. They persist from year to year and go on producing crops of seed from year. Perennials may be herbaceous or woody and perennials may be trees or shrubs or vines e.g. mango, chiku.

Deciduous: Deciduous plants shed their leaves once in a year when they go to rest. This happens during the cold season. When temperature starts falling, the leaves change their colour and become yellow and then fall off. The tree becomes bare and looks dry. All growth processes stop until spring when, temperature again rises, climate become warmer and the trees become active once again rises e.g. apple, plum, peach, dhak, siris, amaltas.

Evergreens: Evergreens on the other hand do not have a definite resting season and they do not shed their leaves during a particular season. All physiological activities go on continuously and the tree never become completely devoid of leaves and bare. Old leaves fall of and new leaves grow simultaneously e.g. mango, chiku, citrus.

32.6 IMPORTANCE OF HORTICULTURE

- Fruits and vegetables play an important role in the balance diet of human being by providing vital protective nutrients.
- They not only adorn the table but also enrich health from the most nutritive menu and tone up the energy and vigour of man.
- Fruits and vegetables have a key role in neutralizing the acid produced during digestion of protein rich and fatty foods.
- They provide valuable roughages which promote digestion and helps in preventing constipation.
- From unit are of land more income is obtained by growing fruits and vegetables crops.
- From energy point of view the fruit crops give very high amount of calories per acre e.g. wheat 1034880 calories/acre and banana 15252800 calories/acre.
- Horticulture is mother of several industries like canning, essential oil, dehydration, refrigeration, wine, cashew nut, transport etc. which provide work for many people. Farmers and labours can keep themselves engaged busy throughout year.

- Growing of horticultural crops is an art as well as science which help in mental development of farmers.
- The fruits and vegetables are chief source of vitamins and minerals which help in proper health and resistant to disease.
- The flowers, ornamental plants and gardens play a very important role in refreshing the minds of people and reducing air pollution.
- The growing of horticultural crops also contributes to the aesthetic side of rural and home life of community.
- Generate employment opportunities.
- Wide source of medicine.
- Effective utilization of wasteland through hardy fruits and medicinal plants.

32.7 SCOPE OF HORTICULTURE

- India has great variety of climate and edaphic conditions which can be exploited by growing horticultural crops.
- Climates are varying from tropical, subtropical and temperate regions. From this humid, semi-arid, arid and varying temperature trees are also grown.
- Likewise soils like loamy, alluvial, laterite, medium black, rocky shallow heavy black sandy etc are also available. From this, large crop areas can be grown with very high level of adaptability.
- To meet the requirements in terms of vitamins and minerals, minimum of 85 g of fruits and 200 g of vegetables per head per day with population of above 1000 million people, fruit and vegetables are to be grown on large scale.
- For providing raw material to small scale industries like silkworm, lack, honey, match, paper, canning, and dehydration etc. horticulture has wide scope.
- In India larger area of lands are waste land, problematic soil, desert land which can be utilized for hardy fruits and medicinal plants.
- The fast development of communication and transport system create wide scope for horticulture development particularly in transporting the perishable commodities and products.

Thus horticulture has great scope for the following reasons:

- To exploit great variability of agro-climatic conditions.
- To meet the need for fruits, vegetables, flowers, spices beverages in relation to population growth and nutritional requirement.
- To meet the requirement of processing industries.
- For increasing export and import of horticultural products.
- To improve economical condition of the farmers.
- To generate employment opportunity for labour and human being.
- To protect environment.

32.8 HORTICULTUREAL PLANT CLASSIFICATION

A. Edible plants Names of crops given below in a, b, and c should start with small letters

a. Vegetables:

(1) Plants grown for aerial portion

- Cole crops: cabbage, cauliflower, broccoli
- Legumes or pulse crops: pea, bean, soy bean cluster bean
- Solanaceous fruit crops: Tomato, Brinjal, Chilli
- Vine crops or cucurbits: Cucumber, Squash, Melon, Bottle gourd
- Green or pot herbs: Spinach, Dandelion, Amaranthus
- Salad crops: Lettuce, Celery, endive
- Miscellaneous: Corn, Asparagus, Okra, Mushroom

(2) Plant grown for underground portions

- Root crops: Beet root, Radish, Carrot, Sweet potato
- Tubers and roots: Potato, Yams, Cassava
- Bulb and corm: Onion, Garlic, Shallot, Leek Gladiolus

b. Fruits:

(1) Temperate (Deciduous) fruits:

- Small fruits: Raspberry, Black berry, grape, cranberry, straw berry.
- Tree fruits: Pomes, apple, pear, quince
- Stone fruits: Peach, plum, apricot
- Nuts: Pecan, filbert, walnut

(2) Tropical and sub-tropical (Evergreen) fruits:

- Herbaceous perennials: Pine apple, Banana
- Tree fruits: (i) Citrus fruits: Orange, lemon, grape gruit

(ii) Miscellaneous: Fig, date palm, mango, papaya, avocado **-** Nuts: Cashew, Brazil nut, Macadamia

B. Ornamental plants

(1) Flower and foliage plants:

a. Annuals: Petunia, Zinnia, Snapdragon, Dianthus, Balsam

b. Biennials: Sweet William, holly hock, evening primerose, Gladiolus

c. Perennials: Chrysanthemum, philodendron, Aster amellus, Gerbera, Tulip

(2) Nursery plants

a. Lawn (Turf) plants: Blue grass, Bermuda grass

b. Ground cover: Periwinkle, sedum

c. Vines (Both herbaceous and woody): Virginia, creeper, grape, English ivy

d. Shrubs (Commonly restricted to deciduous shrubs): Forshythia, liac

e. Evergreens (Both shrubs and trees): Spreading juniper, rhododendron, white pine

f. Tree, commonly restricted to deciduous trees: Pin oak, sugar maple, larch

C. Miscellaneous plants:

(1) Herbs, spices, drugs: Dill, nut, meg, spearmint, quinine, digitals

(2) Beverage plants, non alcoholic: Coffee, Tea, Cacao, mate

(3) Oil yielding plants: Tung, sunflower

(4) Rubber plants: Para rubber tree

(5) Plants yielding gums or resins: Sweetgum, slash, pine

Christmas tree: Balsam fire, scotch pine

Lesson 33. Soil Requirement for Fruits, Vegetables and Flowers Crops

Introducion

33.1 SOIL REQUIREMENT

Soil is a thin outer covering of the earth, directly developed by natural forces acting on natural materials. It is a basic medium for plant growth, supplies nutrients for growing plants. Soil is the home of the plant root and the reservoir for essential nutrients and water for its growth and development.

33.1.1 Types of Soil

On the basis of pH, EC and presence of ESP the soil are grouped as (1) Saline (2) Alkaline (3) Saline-alkali (4) Acidic

On the basis of sand, silt, and clay soils are grouped (classes).

a) Sandy

b) Sandy loam

c) Loamy

d) Silt

e) Silt loam

f) Sandy clay loam

g) Clay loam

h) Sandy clay

i) Clay etc.

Porous aerated and deep soil should be preferred for fruit cultivation. The ideal orchard soil should be at least 1.8 m deep having a uniform texture, well drained, non-saline and fertile. Soils with a poor sub soil stratum should be avoided. Fruit tree will not grow well if there is solid rock or permanent water close to the surface of the soil. Sub soil with a hardpan or pebbles within 120 cm of the surface soil should not be chose. Extreme conditions of top and sub soil namely very heavy (clayey) and very light (highly sandy) should be avoided. Heavy soils are difficult to handle on account of poor drainage while very light soils are infertile because of leaching of nutrients. Medium textured silt loam or fine sandy loam makes good orchard soil.

Most fruit plants like slightly acidic to neutral soil reaction (pH 6-7). Some fruit species can some times tolerate little more acidic or alkaline medium but too acidic or too alkaline soil should be avoided.

Soils with fluctuating water table are not suitable because the water table moves up and reaches the root zone damaging the root hairs. When the water table goes down, the trees with shallow root system struggle for moisture and nutrients causing reduction in growth and vigour of trees. Thus soils having water table depth of less than 3 m are not usually preferred for establishing an orchard. Some fruits, however, such as, Mango, Grape, Lime, Ber, Custard Apple, Avocado and Cashew do well on for wide range of soil type.

33.2 SOILS AND WATER MANAGEMENT IN RELATION TO HORTICULTURAL CROPS

After laying out the orchard, planting of the fruit trees the farmer is interested in optimum growth of trees and maximum production of fruit. Soil management, cultivation of inter crop, irrigation and manuring are the factors to be considered for getting economic return from it, and maintain the health of trees.

33.2.1 Soil Management

Soil management practices such as cultivation, (interculture, weeding), mulching, sod culture etc. are of various system used in different parts of the country.

(a) Cultivation (Clean Cultivation):

Cultivation of orchard soil is important terms, incorporate fertilizers and green manure and to facilitate absorption of water in the soil and also increased the biological activities of soil due to better aeration. Deep tillage is not important in orchards because it may cause injury to the roots of the trees.

(b) Mulching:

It is the system in which materials like hay, straw, cut grasses or plastic sheet spread over soil surface mulching preventing evaporation of water from soil and it also improve structure and aeration by reducing rain drop impact.

Fig 1. Mulching

(c) Sod culture:

This is system in which fruit trees are grown in any tillage or mulching. The grass may remain without cutting but it is usually cut one in a year. This system is not followed in tropical and subtropical region where it is applied in temperate region.

Fig 2. Sod culture

(d) Weeding:

There should be the removal of weeds, so, as to facilitate other operation like irrigation, manuring etc.

(e) Inter cropping:

The crop which are raised in the orchard for increasing the income from land are considered as intercrops e.g. vegetables, pulses, short duration fruit crops banana, papaya, pineapple, phalsa etc., can be grown in the orchard.

Fig 3. Inter cropping

1) These fruit trees, which are used as intercrops are also known as **filler crop.**

2) **Cover crop:** The crops grown to cover the soil to protect it from soil erosion e.g. grasses, pulses, moong, cowpea, peas.

3) **Green manuring crops:** The crops grown in the orchards and after certain growth, they are buried in the soil for addition of organic manure e.g. sunhemp, cowpea etc.

(f) Manuring:

Fruit trees take large amount of nutrients from soil for their growth. So far maintaining fertility of soil in orchards, manures and fertilizers are added in the soil.

(1) Organic manures: Compost, FYM, oil cakes etc., improve the physical condition of soil and add some nutrients.

(2) Fertilizers: Among chemical fertilizers urea, ammonium sulphate, super phosphate, D.A.P. are common.

Application of fertilizers is depend on the soil and climatic conditions and kind and age of crops.

Lesson 34. Climatic Requirement for Fruits, Vegetables and Flowers Crops

34.1 Climate

Climate is the principal factor controlling plant growth. It refers to the average condition of the atmosphere over along period, where as the term weather is used to describe the current and temporary atmospheric conditions. For successful growing of horticultural plants, various components of climate like temperature, humidity, wind, light, rainfall, hail and frost should be carefully studied.

Man can not control these environmental factors. It is not possible to make any change in it. But the effect of these factors can be altered. For these we can take certain steps to increase or decrease its effects. i.e. effect of high or low temperature can be altered, additional moisture can be given, high wind velocity can be reduced by growing wind break around the orchard.

Climate of a region is mainly influenced by the factors viz. a) latitude b) altitude c) topography d) position related to continents and oceans e) large scale atmospheric circulation patters.

Almost all components of the climate influence horticultural crops. All are closely interrelated. The effect of each is modified by others. All crops have certain natural threshold limits of the climatic components beyond which they do not grow normally, but breeding and selection are gradually extending the threshold for many crops.

Following is a brief account on important climatic components which are affecting the production of horticultural crops.

34.1.1 Temperature

Temperature is one of the most important components of climate. It plays vital role in the production of horticultural crops. The different activities of plant like growth and development, respiration, photosynthesis, transpiration, uptake of nutrients and water and reproduction (Such as pollen viability, blossom fertilization fruit set etc.), carbohydrate and growth regulators balance, rate of maturation and senescence, and quality, yield and shelf life of the edible products. The above function of the plant should be well when the temperature at the optimum range. During high temperature plant does not perform proper functions of growth, where in low temperature physiological activities of the plant are stopped.

According to different temperature range in the tropics, the specific trees are grown in different location e.g. apple, pear, peach, almond are successfully grown in the regions of low temperature known as temperate fruits. In warm winter areas, due to insufficient chilling temperature fruit trees fail to complete their physiological rest period or meeting their chilling requirement. As a consequence, buds remain dormant, and leave and blossoms do not appear on the trees in the following spring. For this reason temperate fruit like apple, apricot, pear and plums are not considered suitable for tropical or subtropical regions. For tropical and sub tropical fruits the minimum temperature must be within the limit of tolerance of the fruit species. The fruit grown in tropical and sub tropical climate is known as tropical fruit and sub tropical fruits. Mango, chiku, papaya, banana are successfully grown in high temperature regions also known as tropical fruits.

The plant performs well in optimum temperature range. The activities of the plant are affected by very high or very low temperature. The temperature range for plant is

Minimum 4.5° to 6.5° C (40° - 43° F)

Optimum 24° to 27° C (75° - 85° F)

Maximum 29.5° to 45.4° C (85° - 114° F)

Effect of low temperature

The low temperature influenced adversely on plant. There are many effects of low temperature i.e.

- **Desiccation:** Imbalance between absorption rate and transpiration rate.
- **Chilling injury:** There is a disturbance in metabolic and physiological process.
- **Freezing injury:** It is termed as under cooling protoplasm coagulation.

34.1.2 Humidity (moisture) and frost

The atmospheric humidity plays a vital role in deciding the amount of moisture needed to produce a fruit crops. In hot, dry weather enormous amount of water is lost through transpiration. If the atmosphere is humid, even though hot, the amount is much smaller and thus a site in humid belt needs less irrigation. High humidity combined with high temperature also promotes rapid growth. Higher yield but increase incidence of pests and diseases.

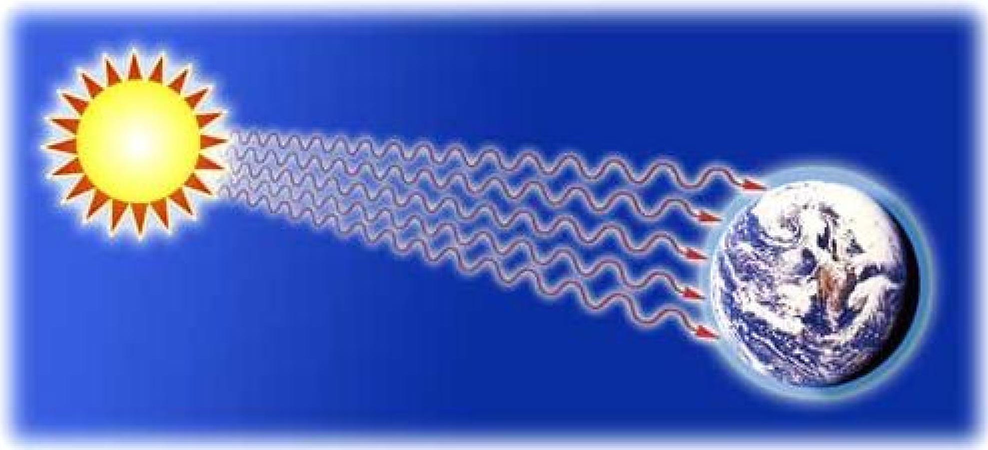
The water requirement of plant also depends on humidity but generally requirement of water is differed as per different plant species. e.g. to produce 1 kg dry matter pine tree require 25 liters. of water, apple required 250 liters, Lucern required 500 liters of water.

The plant gets water from soil, but there are many factors affecting it. i.e. (a) amount of water in the soil (b) availability of water is also depends on texture and structure of soil (c) water absorbing area of the tree.

The water is lost from the plant through transpiration by leaves. Transpiration depends on humidity, temperature, wind, light etc. is necessary to maintain the health of plant by maintaining the balance between uptake and loss of water.

34.1.3 Light

Light is an electro magnetic radiation which is a form of kinetic energy. It comes from the sun to the earth as discrete particles called quanta or photons.



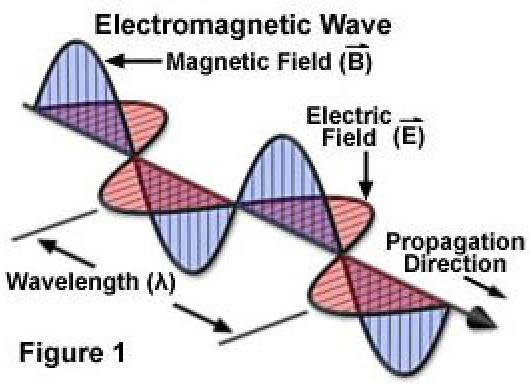


Figure 1

Light is one of the most important affecting plant life. It is an integral part of the photosynthetic reaction in that it provides the energy for the combination of carbon dioxide (CO_2) and water (H_2O) in the green cells having chlorophyll for the formation of carbohydrates with release of oxygen. The following equation is to explain the oxidation of water in photosynthesis.

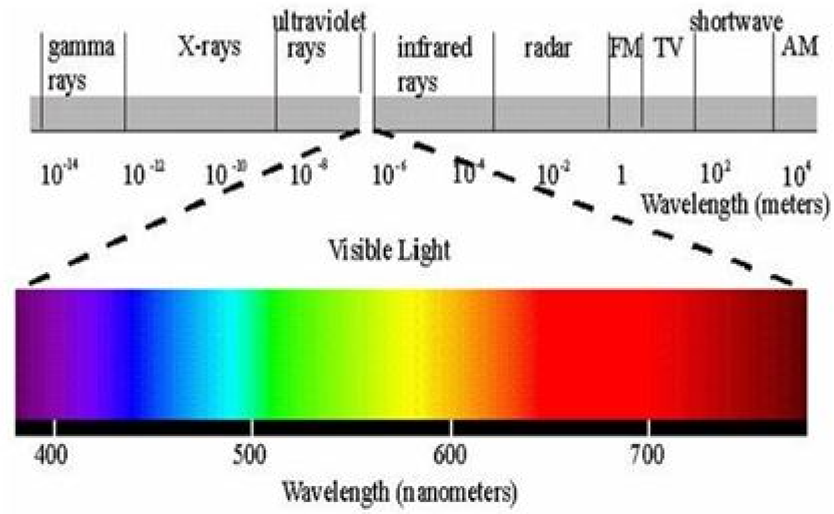
$$CO_2 + 2H_2O \longrightarrow CH_3O + H_2O + O_2$$

$$6CO_2 + 13H \xrightarrow[\text{chlorophyll}]{\text{Light, radiation energy}} C_6H_{12}O_6 + 6H_2O + 6O_2$$

The performance of crop of growth of plants is influenced by three aspects of light (a) quantity of light (b) intensity of light (c) duration of light.

a) **Light intensity:** Light intensity refers to the number of photons falling on a given area or to the total amount of light which plants receive; the intensity of light varies with the day, season, distance of equator, dust particles and water vapour in atmosphere, slope of the land and elevation. Symptoms associated with low light intensity are decrease in rate of photosynthesis with normal rates of respiration, decrease supplies of carbohydrates for growth and yield, leaf tips become discoloured, leaves and bud drop, leaves and flowers become light in colour. Due to high light intensity, the plant wilts and light coloured leaves may become gray in colour due to reduction in chlorophyll, the rate of photosynthesis is lowered down while respiration continues. All above reasons cause low yields.

b) **Quality of light:**Refers to the length of the waves. The visible part of spectrum of electromagnetic radiation ranges from wavelength 390 to 730 µm (nanometer). It is also called photosynthetically active radiation.



In general, red and blue light produce a greater dry weight. Green light inhibits plant growth. Red light promotes seed germination, growth and flower bud formation in long day short night plant. Photosynthesis is more in the red region. In apple the blue violet region is more important for the development of red pigments and colour.

c) **Duration of light:** Refers to the period for which light is available. Duration of light required is also known as photoperiod.

Photoperiodism: Response of plant to length daily exposure to the light is known as photoperiodism or relation of the time of flowering formation of tubers, fleshy roots etc. to the daily exposure length of period of light.

The plants are mainly grouped into three according to duration of light required.

1. Long day plant: Those plants which require 16 hours or more of daily exposure of light and short night 8-10 hours of dark period for induction of flowering e.g. radish, cauliflower, cabbage, carrot, spinach.

2. Short day plant: Those plants which require 12 hours or less of daily exposure of light and long night 10 to 14 hours dark period for induction of flowering. e.g. strawberry, potato, sweet potato, chrysanthemum, cosmos, poinsettia etc.

3. Day neutral plants: Day neutral plants are those plants in which flowering are induced irrespective of duration of light. Such plants are also known as photo insensitive plants. e.g. tomato, chilli, okra, carnation, dianthus, African violet.

4. Intermediate plants: Those plants which require definite period of daily exposure of light. e.g. wild kidney bean, Indian grass, broom grass.

34.1.4 Rainfall

This is a very important factor for horticultural crops, and if a garden or orchard is to be established in a new area it is essential that the pattern of rainfall in the region be studied before any decision is taken concerning the types of crop to be cultivated. Well-distributed and consistent rainfall is always desirable for and ideal orchard site. Rain at the time of flowering is not suitable, because most of tropical fruit crops are sensitive to rain.

34.1.5 Wind

The effect of high wind on crops can be appreciable. Complete physical destruction may result because little can stand against winds of the order of 100 km/hour, even large trees become uprooted. Some crops have quite low damage even due to high wind speed. In many regions high winds can destroy the flowers, fruits etc. Wind breaks can help reduce this problem. The wind break trees, like saru, eucalyptus, Ingadulsis are growing around the orchard for protection.

Lesson 35. Criteria for site selection

35.1 INTRODUCTION

The spacing of fruit trees for each species should be the optimum. When intercrops, multiple crops, etc., are to be grown, the spacing of the orchard trees may be kept at its maximum. The vigorous varieties as well as the varieties growing in fertile soil generally require wider spacing. The system of planting of a fruit crop to be adopted in a particular plot should be decided upon much earlier before laying out the orchard.

Under dry land horticulture in situ method of planting of rootstocks should be followed and later on the desirable scion variety is side grafted when the rootstock attains desirable size. There should be provision for wind breaks around the orchard to protect the fruit trees from the clutches of strong wind.

Fencing of orchard sufficiently ahead of planting should be done. Selection of fruit varieties suitable to the area and procurement of genuine plant materials from reliable sources are essential. Nursery for maintaining the clones and rising of seedlings should be located near the water source.

35.2 IMPORTANT POINTS FOR PLANNING AN ORCHARD:

35.2.1 Selection of site

It is always better to start an orchard in a predominantly fruit-growing area than in a new locality where few or no orchard exists. This will not only help in sharing experience of local fruit growers but also purchasing of plant materials, orchard equipments, transport, marketing, storage of fruits etc. It would be easier through co-operation with growers. Besides, the site for an orchard should be either as close to a consuming centre/market as possible or on a metal road or connected by rail. Over and above, the orchard site should have favourable climatic and soil conditions and good source of irrigation.

35.2.2 Climate

The climate of the site where fruits are to be grown on commercial scale must be considered carefully. Factors like day and night temperature, rainfall (frequency, amount and intensity), wind, light, atmospheric humidity, hail storm frost occurrence, etc. are very important for selection of fruits to be grown there. Listed below are the fruits suitable for regions with different climatic conditions.

Tropical climate: Fruits like mango, banana, papaya, pineapple, sapota, ber, breadfruit, cashew, coconut, etc. thrive well in this climate.

Subtropical climate: In this climate, guava, grape, litchi, citrus, date, phalsa, pomegranate, peach (requiring low-chilling), pear etc.

Temperate climate: In this climate fruits like apple, pear, peach, plum, blackberry, strawberry, apricot, walnut, almond, etc. grow well.

Hence, while planning the orchard, the fruits suitable to the particular site should be kept in mind and planting of fruit species can be done accordingly taking into consideration the topography also.

35.2.3 Soil

Though most of the fruits may be grown on a wide variety of soil such as clay, sand, sandy loam, clay loam, loam etc., a loam or sandy loam soil is considered to be the best for most fruits. Shallow soils with rocky substrata, soils with very high or low pH, soils having poor drainage and high water table during rainy season should be avoided. The fruit growers must have at least a fair knowledge of soil type, its depth, reaction, water table and fertility status before selecting a definite variety of fruit trees to be grown there. The orchard site should have uniform soil with at least three to four feet top soil on which the fruit trees will grow. Sandy soil may be suitably utilized for growing cashew nut, coconut, etc. gravelly red late rite for cashew nut, mango, jackfruit etc. loamy soil for banana, papaya, litchi, sapota etc. However, the orchard soil of poor fertility can be improved in the course of orchard soil management by green manuring, intercropping, etc.

After selecting the site and before planting fruit tress, it is necessary to prepare the land by carrying out certain preliminary operation such as clearing and leveling of land, making provision for irrigation water, providing of fences, planting of windbreaks, planning of buildings etc.

35.2.4 Clearing and leveling the land

If the land is already under cultivation, nothing except preliminary preparation is necessary. If uncultivated, it is necessary to put them under deep ploughing and leveling. If the selected site is under forest, the existing trees and bushes should be removed by uprooting. The land then should be thoroughly ploughed, harrowed and leveled. While preparing the land, the subsoil which is usually less fertile than the surface soil, should not be disturbed as far as possible. In these hills, terrace should be made along the contours.

35.2.5 Irrigation source

An orchard flourishes well when put under irrigation particularly during the dry months. So the source of irrigation should be a permanent one assuring supply of requisite quantity of irrigation water throughout the year. Whatever may be the source of irrigation a well, a shallow or a deep tube well, it should be sunk well ahead of planting. In high hills, where the rainfall and snowfall are adequate and evaporation from soil is not very high due to prevailing low temperature, a few tanks may be installed for collection of rain or snow water to tide over the critical periods of the year.

35.2.6 Fencing

To protect the trees of the orchard from frequent visits of wild and stray animals, and to prevent stealing of fruits and other orchard properly, some kind of fence is highly necessary. This may be made by erecting mud walls or high brick walls with tops lined with glass pieces, or barbed wire fencing.

The first one through quite effective against big animals offer very little obstacle to monkeys and thieves. The second one being permanent and very effective from the security point of view is preferred. But it involves a large initial expenditure which is beyond the means of ordinary fruit growers. The third one, the barbed wire fencing which costs moderately, is not only effective against practically all animals and human beings, but it also neither shades nor takes away any plant food from it.

So the orchard boundary may be fenced with pillars and barbed wires. The pillars may be of wood, angle iron, stone-cement concrete etc. this fence may be further strengthened by erecting live hedges which will not only help to stop the entry of animals and human beings but also from a thick live-wall around the orchard for privacy and help to safeguard the produce which cannot be seen from outside. The live hedge must have the following qualities:

(a) It should be quick growing

(b) Easy to raise by seeds or cuttings of vegetative parts

(c) Should be drought resistant

(d) Should have dense foliage

(e) Should preferably be thorny

(f) Should stand pruning to develop thick and compact growth

The plants suitable for live hedge are Inga dulcis, Parkinsonia aculeate L, Prosopis juliflora, Carissa carandas, Casuarina equisetifolia, Duranta plumeri, Sesbania aegyptiaca, Acacia sp.,Zizyphus sp., Lawsonia alba, Gliricidia, Bahunia sp., Polyalthia longifolia, etc.

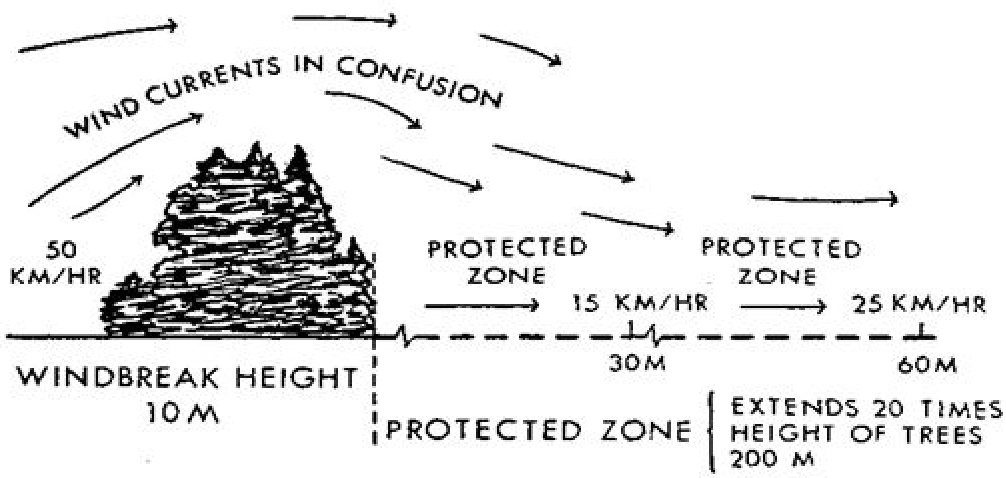
To establish a live hedge, the soil along the fence is dug 2 feet wide and 2 feet deep at the commencement of the rainy season. After sowing the seeds or planting the cutting along the boundary of the orchard, the plants are allowed to grow. In the course of time trimming and pruning are done to develop a thick and tall hedge as required.

It has also been found very useful when a cattle driven trench of 3 ft. deep and 4 lt. wide is dug after the live hedge around the border.

35.2.7 Windbreaks

Fruit orchards usually face heavy losses when a strong wind of high velocity passes through the orchard. Damages like uprooting of trees, breaking of branches, destruction of blooms, dropping of immature fruits, erosion of surface soil, etc. are caused very often by wind. Hence, establishment of a tall-growing windbreak is necessary to protect the orchard.

The planting of windbreaks should precede that of the fruit trees by at least two years, if they are to give effective protection to the orchard. A well-established windbreak reduces the velocity of wind; checks evaporation loss of soil moisture prevents cold wind and reduces frost damage to a great extent.



The efficiency of a windbreak depends upon the height of the trees and their compactness. Ordinarily it has maximum effectiveness for a distance about 3-4 times as great as its height. The first row of fruit trees should be about away from the windbreak row. To prevent the roots of the windbreak trees from interfering with the normal growth of the fruit trees, a 3-4 ft. deep trench should be dug at a distance of 10 ft. from the windbreak row.

An ideal windbreak should be upright in growth and occupy as little space as possible. It should be tall, mechanically strong, quick growing and sufficiently dense to offer the maximum resistance to the wind. One to two rows of such trees are planted at a close spacing, usually 12-23 ft. apart for having a tall and close tree-wall which can help to resist the incoming heavy flow of wind. Trees commonly grown as windbreaks are Polyalihia longifolla, Casurina equisdilfolla, Erythrlna indica, Eucalyptus globules, Grevillia robusta, Dalbergia sissoo, Putranjiva roxburghii, Syzygium sp., Mangsfera indica, Averrhoa carambola, Bambusa sp., etc.

35.2.8 Buildings

Any building which is to be constructed in the orchard should be planned before planting, though their construction may be done later on. An orchard provides a very pleasant site for a dwelling. Other buildings such as implement shed, bullock shed and labour quarters may also be constructed.

35.2.9 Roads, Paths, Irrigation and Drainage Channels

Planning of roads, paths, irrigation and drainage channels should be done well in advance. Roads and paths are absolutely necessary for making every portion of the orchard easily approachable and for convenience in operations like manuring, spraying and transportation. The footpaths should be made in between the rows of trees without utilizing any additional space of the orchard. Small non-spreading type of avenue trees may be planted beside the road to enhance the beauty of the orchard.

The permanent irrigation and drainage channels should be dug in straight lines and without interfering the main roads to economize the use of irrigation water by avoiding seepage in the channels during the dry and hot seasons and for efficient drainage of excess water from the individual plot of the orchard during rainy season or flood-affected areas.

Before the actual laying out of the orchard and undertaking the planting work, a detailed plan of the orchard should be drawn showing the boundary, main gate, roads and paths, source of irrigation, drainage and irrigation channels and also the individual plots for the fruit to be grown. This will help to establish the orchard correctly and conveniently.

Lesson 36. Layout and Planting Methods

36.1 LAYOUT

The layout of the orchard is a very important operation. Under this, the arrangement of fruit plants in the plot is carefully done to put the plants at a suitable distance for proper development and for accommodating the requisite number of plants per unit area in addition to improving the aesthetic look of the orchard. Hence, the factors which are considered important for proper layout of the orchard are (i) system of planting and (ii) planting distance of individual fruit species which again would provide the following advantages:

1. Allow equidistance for each tree for uniform growth.
2. Allow easy orchard operations like cultivation, intercropping, irrigation, spraying of plant protection chemicals and growth regulators, harvesting etc.
3. Proper utilization of orchard space avoiding wastage of land.
4. Help in proper supervision and management of the orchard.
5. Aloe further extension of area from time to time so that subsequent planting would match with the existing orchard planting.

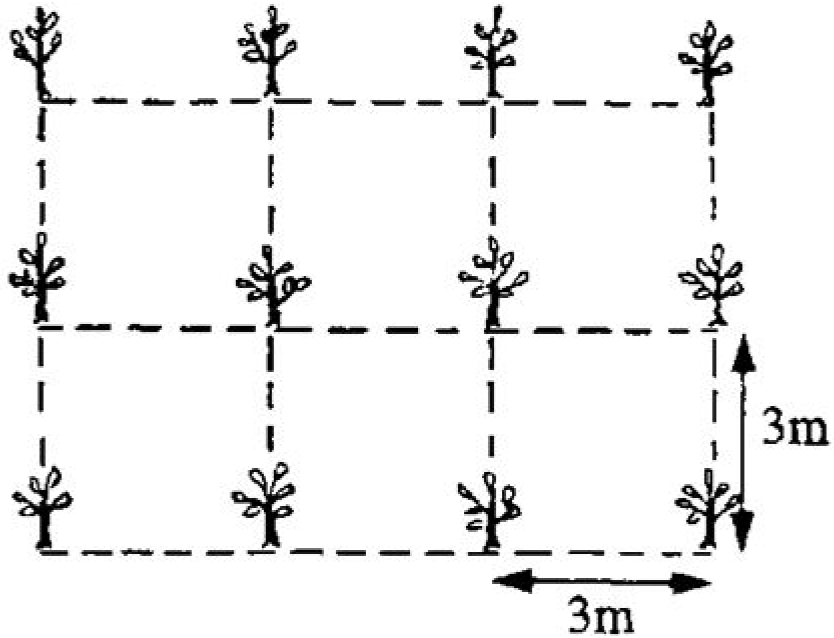
36.2 SYSTEM OF PLANTING

The system of planting to be adopted is selected after considering the slope of land, purpose of utilizing the orchard space, convenience etc. Generally, six systems of planting are recommended for fruit trees.

36.2.1 Square system

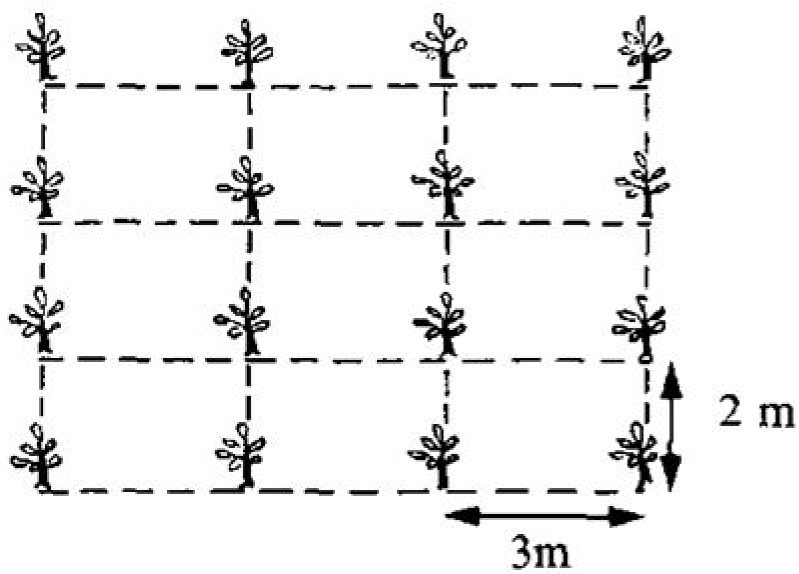
This system is considered to be the simplest of all the system and is adopted widely. In this system, the plot is divided into squares and trees are planted at the four corners of the square, in straight rows running at right angles. While laying out the plot a base line is first drawn parallel to the road, fence or adjacent orchard, at a distance equal to half the spacing to be given between the trees. Pegs are fixed on this line at the desired distances. At both ends of the base line right angles are drawn by following the simple carpenter's 3, 4, 5 meters system. After the formation of three lines it is easy to fix all the other pegs to mark the tree locations in between the lines at the required spacing by using ropes connecting the pegs of the lines in opposite directions.

Under this system, intercultural operations, spraying, harvesting etc., can be done conveniently and easily. Planting of quick growing fruit trees like papaya, banana, guava during the early life of the orchard is possible. Rising of inter-crops like vegetables, ginger, turmeric, cumin, coriander and such other spices can be done conveniently cultivation and irrigation can be done in two directions.



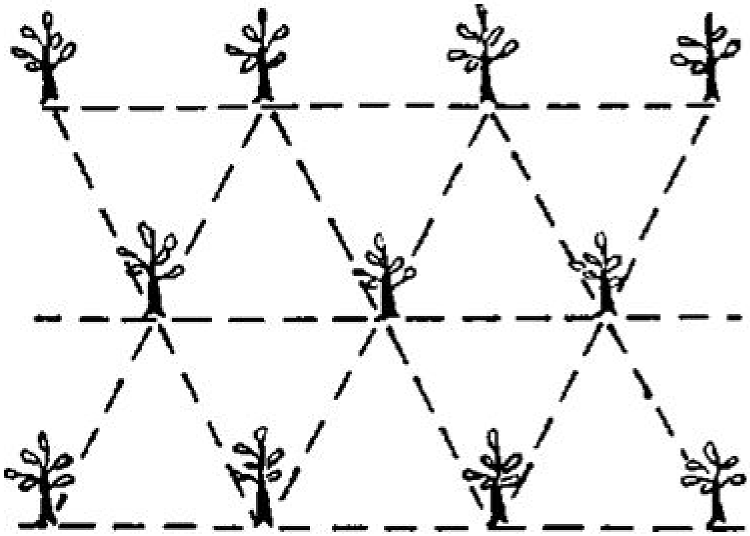
36.2.2 Rectangular system

In this system, the plot is divided into rectangles instead of squares and trees are planted at the four corners of the rectangle in straight rows running at right angles. The same advantages which have been mentioned in the square system are also enjoyed here. The only difference is that in this system more plants can be accommodated in the row keeping more space between the rows.



36.2.3 Triangular system

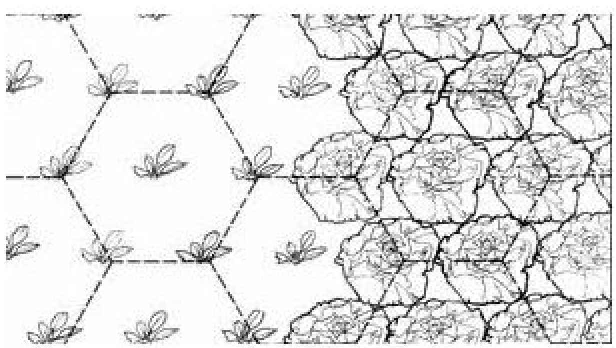
In this system, trees are planted as in the square system but the plants in the 2nd , 4th, 6thand such other alternate rows are planted midway between the 1st, 3rd, 5th and such other alternate rows. This system has no special advantage over the square system except providing more open space for the trees and for intercrops. It is not only a difficult layout but cultivation also in the plots under this system becomes difficult.



36.2.4 Hexagonal system

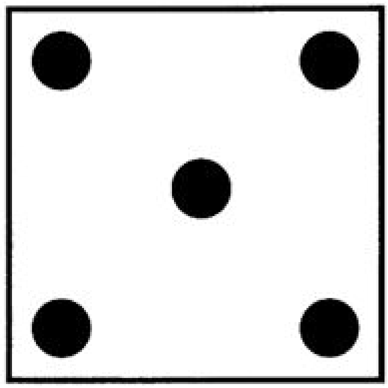
In this system, the trees are planted at the corners of an equilateral triangle and thus, six trees from a hexagon with the seventh tree at the centre. This system is generally followed where the land is costly and very fertile with ample provision of irrigation water. Though 15 per cent more trees can be planted in a unit area by this method over the square system, fruit growers usually do not adopt it, as it is difficult to layout and cultivation in the plot cannot be done so easily as in the square system.

For laying out the plot, a base line is drawn in one side as in the square system. Then an equilateral triangle having rings at each corner and with sides equal to the length of the required distance is made of heavy wire or chain. Two of these rings are then placed on the stakes of the base line and the position of the third ring indicates the position of a tree in the second row. This row is then used as the base line and pegs are set in the third row. In this way entire plot is laid out.



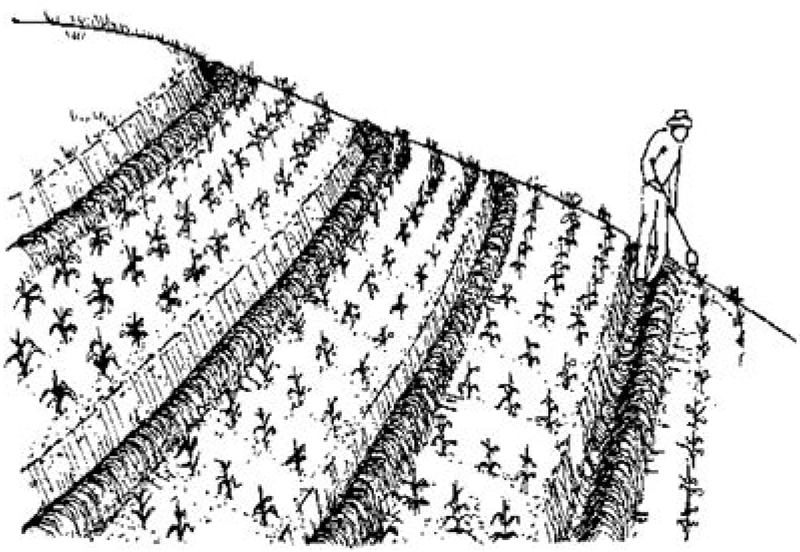
36.2.5 Quincunx system

This system of planting fruit trees is similar to square system, except that a fifth tree is planted at the centre of each square. As a result the tree number in an unit area becomes almost double the number in the square system. The additional tree in the centre is known as “filler”. The fillers are usually quick growing, early maturing and erect type fruit trees like banana, papaya, pomegranate, etc., which are removed as soon as the main fruit trees planted at the corner of the square come into bearing. The planting of filler trees provides an additional income to the grower in the early life of the orchard.



36.2.6 Contour system

It is generally followed on the hills with high slopes. It particularly suits to a land with undulated topography, where there is greater danger of erosion and irrigation of the orchard is difficult. The main purpose of this system is to minimize land erosion and to conserve soil moisture so as to make the slope fit for growing fruits. So, the contour line is designed and graded in such a way that the flow of water in the irrigation channel becomes slow and thus finds time to penetrate into the soil without causing erosion.



36.3 Spacing of Fruit Trees

Provision of optimum spacing to fruit trees is one of the most important aspects of successful fruit culture. If the spacing is inadequate, the fruit trees will grow poorly, produce small quantity of fruits of inferior quality, and suffer from various diseases and insect pests. The cultural practices of the orchards are also greatly hindered. Weeds and grasses grow in abundance and rob off the vitality of the trees, resulting in their early decline and premature death. On the other hand, if the spacing is too wide, there will be wastage of valuable orchard land without having any direct benefit on the ultimate yield of the orchard. The optimum spacing is therefore, desired so that the fruit trees may grow and bear crops properly. The optimum spacing is one in which the tree on attaining its full size will not touch the branches of the neighbouring ones and the root-system of one tree must not encroach that of the adjoining tree. The spacing given to fruit trees is generally governed by the following factors:

1. Climate and soil

2. Varieties
3. Growth habit
4. Rootstocks
5. Nature of irrigation
6. Pruning

It is very difficult to suggest the exact spacing for fruit trees which will suit every locality or soil. However, the spacing given below for some of the important fruits may be considered as a safe guide for planting fruit orchards both in the hills and plains.

Lesson 37. Nursery Raising

37.1 INTRODUCTION

Nursery is a place where plant are cultivated and grown to usable size. Nursery techniques involve raising seedling, sapling and graft economically useful and ornamental plants through scientific methods. Several new techniques are available, which are cheap and effective. These new techniques are useful in increasing the success rate of graft and rooting of cutting; increasing seedling vigour; reducing transplanting shock and generally reducing the quantum of manual work. The nursery management gained a status of commercial venture where retailer nurseries sell planting materials to the general public and nurseries, which sell only to other nurseries and to commercial landscape gardeners, and private nursery, which supply the needs of institutions of private estates.

1. Site for nursery should be selected at such places where abundant sunshine and proper ventilation is available.
2. Nursery site should be on higher location so that water stagnation is avoidable.
3. In humid and rain prone areas nursery place should be well protected from heavy rains through protected structures.
4. The site should be nearer to irrigation facilities and accessible.
5. It should be protected from stray animals, snail, rats etc.
6. Soil should be sandy loam or loamy with pH range of 6 to 7 and rich in organic matter and free from pathogenic inoculums.

37.2 NECESSITY OF NURSERY

Nursery is necessity for every horticulture grower. The development of seedling in nursery is not only reduces the crop span but also increase the uniformity of the crop and thus, harvesting as compared to direct sown crops. Transplanting of seedling are also eliminate the need of thinning and providing good opportunities for virus free vigorous off season nursery, if grown under protected condition. Nursery is helpful and convenient to manage seedling under small area and grower can get timely plant protection measures are with minimal efforts. Development of a nursery provides favourable climate to emerging plants for their better growth and development. The effective utilization of unfavourable period by preparing nursery under protected condition. Seed cost of some crops like hybrid vegetables, ornamental plants, spices and some fruits can be economized through nursery. Nursery production help in maintaining effective plants stand in shortest possible time through gap filling. Although many fruits and vegetable seeds can be sown directly in field, experiment has shown that raising seedling in a nursery has a number of advantages as discussed below.

1. Intensive care- Seedling receives better care and protection in the nursery. The average garden soil is not an ideal medium for raising seedling especially from the point of view of soil tilth. At an early stage of development most vegetable crops require special attention that is not possible in main field.
2. Reduction of costs- fewer seeds are used for raising seedling in the nursery than for sowing directly in the field, because in the letter seedling have to be thinned to one which is wasteful. When expensive hybrid seeds are used, transplanting therefore become more economically attractive. Pesticides and labour are also reduced under nursery conditions as compared to planning directly in the field.
3. Opportunity for selection**-** Raising, seedling in a nursery afford the grower an opportunity to select well-grown, vigorous, uniform and dieses free seedling.
4. Extend a short growing season for late maturing crops **–** seedling can be raised in nursery under a protected environment before condition outside become suitable for growth and transplanted into field when condition allow, thus reducing the amount of time spent in the field.
5. Forced vegetable production for an early market – generally prices of horticulture produce are attractive when production or supply is low. Vegetables can be grown "out - of- season" in a nursery when condition are not yet favourable. Such crops will thus mature earlier after transplanting and hence stand to fetch a higher price in the market.

37.3 NURSERY MANAGEMENT

The first stage in successful production of horticulture crops is to raise healthy vigorous seedlings. Young plants whether propagated from seed or vegetative require a lot of care particularly during the early stages of growth. They have to be protected from adverse temperature, heavy rain, wind and verity of pests and diseases. If small seeded vegetables are shown directly in field, germination is often poor and the young plants grow very slowly and require a long time to mature. Also the season may be short for full development in the field. To overcome these problems many vegetables crops are grown in nurseries before being transplanted in field. A vegetables or fruit nursery is a place where plants be cared for during the early stages of growth, providing optimum conditions for germination and subsequent growth until they are strong enough to be planted out in their permanent place. A nursery can be as simple as a raised bed in an open field or sophisticated as a glass-house with micro-sprinklers and an management and the plant propagation are same, though they are altogether different but inter-related. In fact mass multiplication of quality planting material is the central theme of nursery management but nursery management is a trade oriented dynamic process, which refers to efficient utilization of resource for economic returns. Nursery management is a team effort to reach the desired goal.

The main phase of nursery management are (1) planning- edaphic climatic and socioeconomic consideration; demand for planning materials; provision of mother block, requirement of land area, water supply, working tools, growing, structures and inputs availability; accessibility; trained man power; plant protection; disposal of planting materials etc. (2) implementation- land treatment, protection, against biotic interference and soil erosion, proper layout, input supply (3) monitoring and evolution-physical presence, rapid response, critical analysis, intensive to worker and (4) feed back for further refinement. The key elements of hi-tech nursery management are place, plant and the person behind.

37.3.1 Advantage of nursery management

- It is possible to provide favourable growth conditions i.e. germination as well growth.
- Better care of younger plants as it is easy to look after nursery in small area against pathogenic infection, pests and weeds.
- Crop grown by nursery raising is quite early and fetch higher price in the market, so economically more profitable.
- There is saving of land and labour as main fields will be occupied by the crops rotation can be followed.
- More time is available for the preparation of main field because nursery is grown separately.
- As vegetables seeds are expensive particularly hybrids, so we can economized the seed by sowing them in the nursery.

37.4 LAYOUT OF MODEL NURSERY

Nursery is the place where all kinds of plants like trees, shrubs, climbers etc. are grown and kept for transporting or for using them as stock plants for budding, grafting, and other methods of propagation or for sale. The modern nurseries also serve as an area where garden tools, fertilizers are also offered for sale along with plant material. The area for models nursery production is prepared for effective utilization of inputs and to do things in proper manner, institutions for nursery establishment as per their requirement design various location specific models. But their some important component, which should be taken into care and provision, should be made for these during planning and lay-out preparation for nurseries.

i. Fence : Prior to the establishment of a nursery, a good fence with barbed wire must be erected all around the nursery to prevent trees pass of animals and theft. The fence could be further strengthened by planting a live hedge, with thorny fruit plants. This also adds beauty in bearing and also provides additional income through sale of fruits and seedling obtained from the seed.

ii. Roads and paths: A proper planning of roads and paths inside the nursery will not add only beauty, but also make the nursery operation easy and economical. This could be achieved by dividing the nursery into different blocks and various sections. But at the same time, the land should not be wasted by unnecessarily lying out of paths and roads. Each road/path should lead the customer to appoint of interest in the nursery area.

iii. Progeny block / mother plant block: The nursery should have a well-maintained progeny block or mother plant block/scion bank planted with those varieties in good demand. The layer cutting should be obtained preferably from the original breeder/research institute from where it is released or from a reputed nursery. One should remember that, the success of any nursery largely depends upon the initial selection of progeny plants or mother plants for further multiplication. Any mistake made in this aspect will result in loss of the reputation of the nursery. A well managed progeny block or mother plants block will not only create confidence among the customers but also reduces the cost of production and increases the success rate of grafting/budding/layering because of availability of fresh scion material throughout the season within the nursery itself and there will not be any lag period between separation of scions and graftage. There are so many cultivars for fruit crops, grow only important cultivar in mother blocks as per demand and germ plasma conservation.

iv. Irrigation systems: Horticultural nursery plants require abundant supply of water for irrigation, since they are grown in poly bags or pots with limited quantity of potting mixture. Hence sufficient number of wells to yield sufficient quantity of irrigation water is a must in nursery. In areas with low water yields and frequents power failures, a sump to hold sufficient quantity of water to irrigate the nursery plants is also very much essential along with appropriate pumps for lifting the irrigation water. In areas where electricity failure is a problem, which is more common, an alternative power supply is very essential for smooth running of pump set. Since water security is a limiting factor in most of areas in the country a well laid out PVC pipeline systems will solve the problems to a greater extent. An experienced agricultural engineer may be consulted in this regard for lay-out of pipeline. This facilitates efficient and economic distribution of irrigation water to various components in the nursery.

v. Office cum stores: An office-cum-stores is needed for effective management of the nursery. The office buildings may be constructed in a place, which offers better supervision, and also to receive customers. The office buildings may be decorated with attractive photographs of fruit storeroom of suitable sizes is needed for storing poly bags, tools and implements, packaging materials, labels, pesticides, fertilizers etc.

vi. Seed beds: In a nursery, this component is essential to raise the seedling and rootstock. These are to be laid out near the water source, since they require frequent watering and irrigation. Beds of 1.0 meter width of any convent length are to be made. A working area of 60 cm between the beds is necessary. This facilities are easy in slowing of seeds, weeding, watering, spraying, lifting, of seedling. Irrigation channels are to be made laid out conveniently. Alternatively, sprinklers irrigation systems may be provided for watering the beds; which offers uniform germination and seedling growth.

vii. Nursery beds: Rising of seedling / rootstalk in poly bags requires more spaces compared to nursery beds but mortality is greatly reduced along with uniformity. Nursery beds area should also have a provision to keep the grafted plants either in trenches of 30 cm deep and 1.0 meter wide so as to accommodate 500 grafts in each bed. Alternatively the graft / layer can be arranged on the ground in beds of 1.0 meter wide with 60 cm working place in between the beds. Such beds can be irrigated either with a rose fitted to a flexible hosepipe or by overhead micro-sprinklers.

viii. Potting mixture and potting yard: For better success of nursery plants, a good potting mixture is necessary. The potting mixture may be prepared well in advance by adding sufficient quantity of super phosphate for better decomposition and solubilization. The potting mixture maybe kept near the potting yard, where potting / pocketing is done. Construction is a potting yard of suitable size facilities potting of seedling or grafting / budding operations even on a rainy day.

Lesson 38. Macro Propagation Methods

38.1 PROPAGATION

Production of seed individual includes

(i) Sexual or seed propagation

(ii) Asexual or vegetative propagation

38.1.1 Sexual propagation: Reproduction by seed; but seed is under ordinary condition a result of fusion of male and female germ cells or gametes, characters of both parents are inherited by the seed or the new individual and therefore the new individual formed in this way are not true-to-type.

38.1.2 Asexual propagation: Does not involve the gametes from parents. It is simply a vegetative or somatic extension of one parent and there is no chance of inheriting a mixture of characters.

38.2 SEED PROPAGATION

38.2.1 Seed: Anatomically, seed is an embryo plant or fertilized, ripened ovule consisting of a rudimentary stem and root, together with a supply of food sufficient for establishing the plant in a new location and enclosed in a protective coat (seed coat).

38.2.2 Viability: A seed is viable if it is capable of germinating or ability of seed to germinate.

38.2.3 Vitality: The vigour or strength possessed by the seed for growth.

38.2.4 Short viable seeds: cashew, jack fruit, jamun, citrus, mango, neem etc.

38.2.5 Seed with hard seed coat: babul (acasia), gulmohar, chiku, amaltas etc. Such seed should be given some treatment before growing for quick germination.

(1) Mechanical treatment:

(i) Scarifying: Seed is filled in a scarifier which is a drum with inner surface rough, hard and sharp. The hard seed coat is filled and ground out by rotary action.

(ii) Others: Breaking or cracking with hammer, drilling a hole, rubbing against stone, filling.

(2) Chemical treatment:

- Sulphuric acid at conc. of 50 % and 25 %

- Potassium hydroxide and hydrochloric acid

(3) Soaking in water: Seed are soaked in warm water for 24 hours or 4 to 5 days sometime they are soaked in cow dung paste.

(4) Stratification**:** Keeping seed in alternate layers with sand or soil and kept constantly moist but not waterlogged.

38.3 SEXUAL METHODS

38.3.1 Advantages:

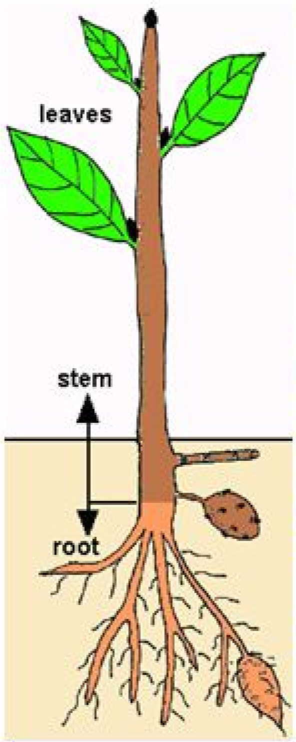
- Seedling trees (sexual method) are generally long lived; bear more heavily are comparative more hard.
- Propagation from the seed is the only means of reproduction where the method of vegetative propagation is not possible or economical as in papaya, phalsa, mangosteen etc.
- Inbreeding for evolution of new varieties, the hybrids are first raised from seed and it is, therefore, essential to employ this method in such cases.
- Propagation from seed has been responsible for the production of some chance seedlings of highly superior merits, which has been of some chance seedlings of highly superior merits, which has been of great benefit to the fruit industry. It may be mentioned that commercial mango varieties originated from seed and were, later on, perpetuated vegetatively.
- Seed like those of some citrus species and some mango varieties are capable of giving out more than one seedling from one seed. They can be carefully detected in the nursery stage.
- The rootstocks upon which the fruit varieties are budded or grafted are really obtained by means of sexual propagation.
- Seedlings are comparatively cheaper and easy to rise.

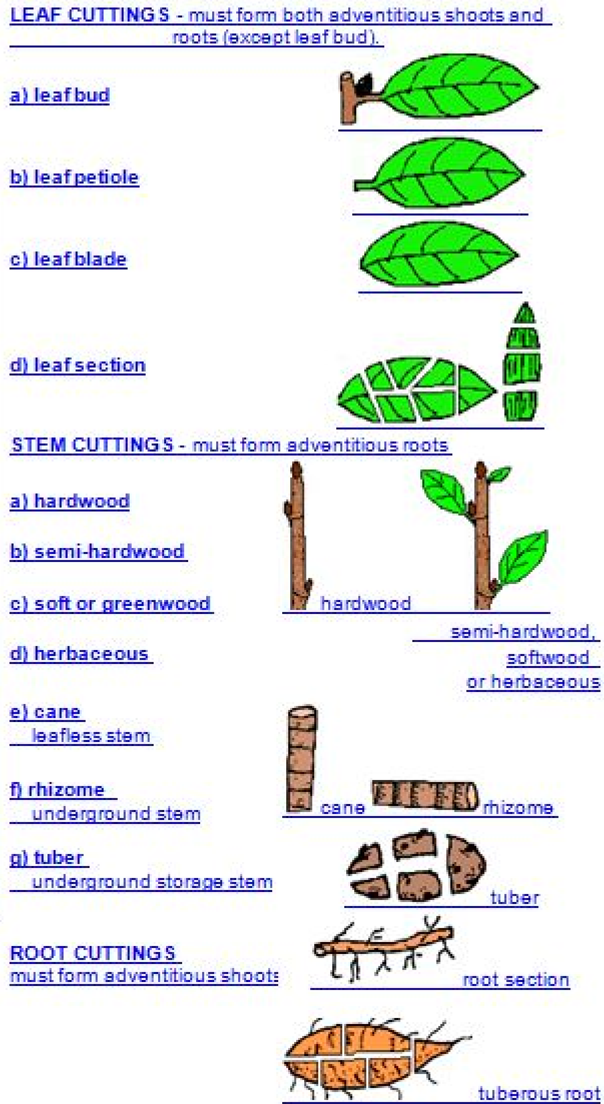
38.3.2 Disadvantages:

- The seedling trees are not uniform in their growth, yielding capacity and fruit quality as compared to grafted trees.
- They make more time to bear the maiden crop as compared to the grafted plants.
- The seedling trees become large for economic management i.e. the cost of harvesting, pruning and spraying is more as compared to the grafted trees.
- It is not possible to perpetuate the exact characters of any superior selection through seed and so to multiply superior hybrids or chance seedlings, vegetative methods have to be employed.
- In case the seedlings, it is not possible to avail of the modifying influence of rootstocks on the scion as in case of vegetatively propagated fruit trees.

38.4 ASEXUAL OR VEGETATIVE PROPAGATION

It is also known as clonal propagation. Vegetative parts such as leaf, stem or root are used instead of seeds. It is a function of the somatic mechanism of plants. It is therefore essential to have some fundamental knowledge of the basic anatomy of certain parts.





38.4.1 Roots and stem structures

i. Root:- An organ for absorption of water and nutrients and serve as an anchor for the plant. Older portions mainly work of transporting water and nutrients and stored food material where as only younger fibrous roots absorbed the water and nutrients.

ii. Stem:- Supports leaves flowers and fruits and acts as a link between roots and leaves. It also acts as a temporary storage place for reserved food materials.

iii. Dicotyledonous plants:- The vascular bundles (xylem, phloem and cambium) have a regular systematic arrangements so made that they form a circular ring. Mango, Chiku, Guava.

iv. Monocotyledonous plants:- They do not form a ring but are more or less scattered at random throughout the thickness of the stem. Banana, Date, palm, Coconut.

v. Xylem:- They are well differentiated thick walled fibers, conducting vessels and wood parenchyma on the outer side of wood, ventral cylinder. Main function of xylem is to transport water and nutrient (salt) absorbed by roots to the upper portion of the plants.

vi. Phloem:- They are well differentiated, fibrous and conducting tissues on the inner side of the bark or cortical layer. Main function of phloem is to transport food material (CH_2O), hormones and co-factor synthesized by leaves.

vii. Cambium:- Between xylem and phloem there is a thin layer of thin walled, undifferentiated meristematic tissues is known as cambium. They occur in a continuous ring. Their main function is to divide and sub-divide giving rise to new cells that may later on became differentiated in to one another of the various tissues of the wood of bark.

viii. Function of cambium necessary for plant propagation:-

- Use full in secondary growth of stem and root.
- Regeneration and over walling over is possible for recovery of injury to the plants.
- Callus produced by cambium is necessary for budding, grafting and cutting etc.
- Adventitious roots on stem mostly arise from cambium.

ix. Callus:- It is a mass of undifferentiated (parenchyma cells) tissues produced by cambium which gradually covers the points or areas originally exposed (arising from the living cells of both scion and stock).

x. Regeneration:- Recovering the injured surface all over at the same time.

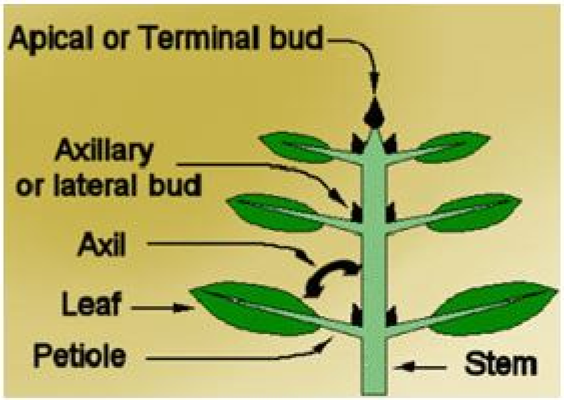
xi. Over walling:- Recovering the injured surface from the outer margins.

xii. Buds:- A bud is a rudimentary stem or embryo stem when, a bud develop into a branch is known as vegetative bud. But when it develops into a flower is known as flower bud. It is also called fruit bud.

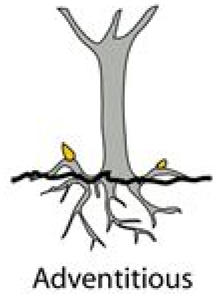
Bud is defined as a growing point of undifferentiated tissues surrounded by embryonic leaves or blossoms.

1) Terminal bud: A bud formed at the tip of a branch which has stopped growing for the season.

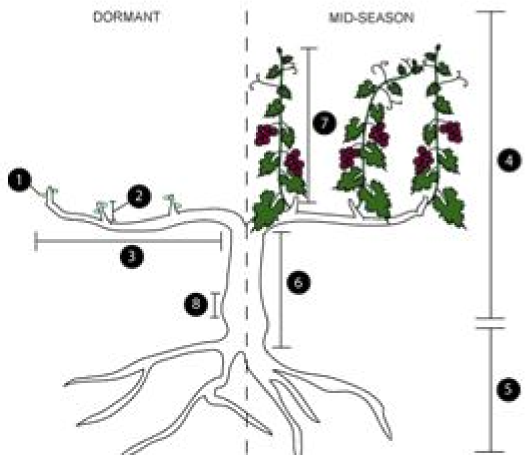
2) Axillary or lateral bud: This is a regular bud which develops in the leaf axil or the node.



3) Adventitious bud: This is a bud formed on an unusual part like internode, leaf, or root.

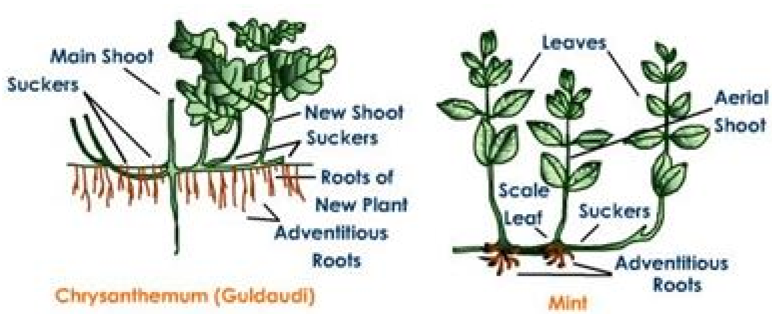


4) Dormant bud: When its dormancy period is less than one year(season) is known as dormant bud.

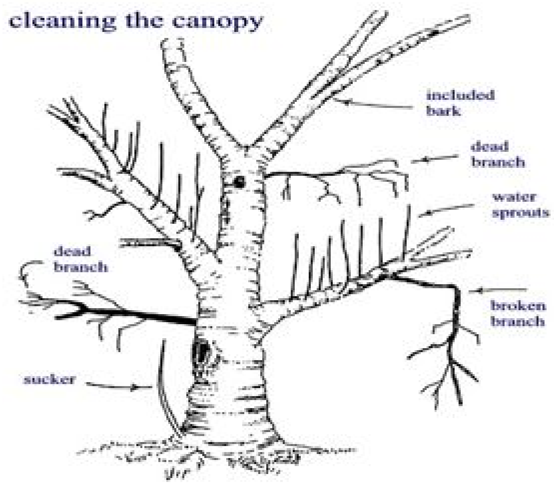


5) Latent bud: If for some reason a dormant bud does not start growing even after a year, it may not grow even for more number of years is known as latent bud.

xiii. Suckers: These are shoots growing from latent adventitious buds on roots.



xiv. Water sprouts: These are shoots growing from latent adventitious buds on stems or branches.



38.4.2 Advantages of vegetative propagation:- Seed propagation is easier method and very widely used for sowing other agricultural crops, vegetative propagation is the practice adopted mostly by horticulturist. Following are the advantages:

- True breeding seeds can be ensured on by vegetative method because it is a reproduction of somatic cells. There is no cross pollination and segregation.
- When seed is not formed, vegetative methods is the only way i.e. Banana and some (seedless) varieties of grape and citrus.
- Vegetative propagated plant bear earlier but life period is shorter than seed propagated plants e.g. mango and chiku graft bear early fruiting.
- Some disease or insect resistant scion can be grown on suitable rootstock for the particular soil condition, i.e. Jamburi is resistant to gummosis and we can successfully grafted citrus on jamburi, in Australia, Northern, spy apple is used as root stock for apple, which is resistant to woody aphis, similarly, European varieties of grapes grafted on the root stock of American varieties to avoid the damage of phyloxera insect.
- Dwarfting trees are practiced by budding or grafting on suitable roots orange on wood apple.
- Branches of male plant can be grafted on female plants.
- Reduction in the size and number of thorns i.e. jamburi root stock for citrus.
- Correction of mistakes by budding or crown grafting or side grafting.
- In cooler regions trifoliate orange is used as (citrus) rootstock against heavy frost.
- More than one variety can be grown on one plant e.g. Roses.

38.4.3 Disadvantages:- The following are the disadvantages of Asexual method of propagation in fruit plants.

- The vegetative propagated plants, particularly the budded and grafted ones are not generally so vigorous and long lived as the seeding trees.
- No new varieties can be evolved by the vegetative means of propagation.

38.5 FACTORS AFFECTING ROOT FORMATION IN CUTTINGS

i. Medium for rooting of cuttings: The medium in which cuttings, are planted must be loose and easily worked so as to facilitate planting of cuttings as well as their removal without damage to new roots. Ordinary budding sand, if clean and free from any foreign materials and dirt is a very satisfactory medium. Loose sandy loam soil with good drainage is the most suitable alone for planting cuttings directly in the nursery.

Decaying organic matter in the medium is objectionable since it will promote the growth of fungi and bacteria, which in turn might be cause the cutting to die before root formation.

ii. Temperature:- Control of temperature is very important in rooting of cuttings. Very high temperature is not inductive to root formation 65 °Fahrenheit to 70 °Fahrenheit is the best temperature for most plants.

iii. Humidity:- A high degree of humidity is essential otherwise cuttings will be desiccated. The roundabout area, the walls, paths and beds must be frequently sprinkled with water to maintain humidity.

iv. Chemical treatment:- Synthetic hormones like the indole-3-acetic-acid, indole-3-butyric acid and napthaleneacetic acid are very useful in increase root formation.

v. Mechanical treatments:- These include partial removal of leaves, slanting basal cut and some injury near the basal end. It is believed that by injury areas of callus is exposed for rooting.

vi. Stored food:- Two fundamental requirements are there for successful rooting of cutting (i) The plant must have the capacity to develop roots. (ii) Energy must be supplied for these processes (Rooting).

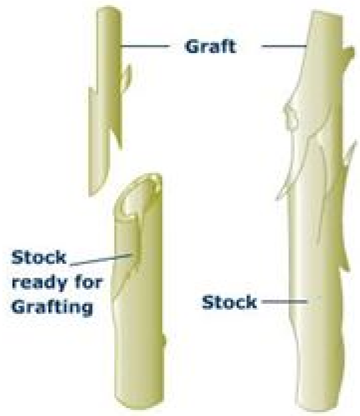
The available carbohydrates and nitrogen markedly affect the rooting of cuttings. Shoots from which cuttings are to be taken are sometimes girdled to increase the stored food above the girdle. The girdle also prevents auxins from flowing dow.

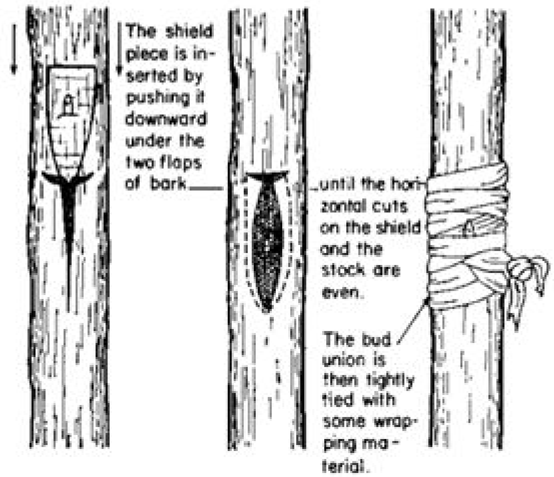
vii. Age and maturity of the tissues:- Certain kinds of plants can be grown best from semi hard wood cuttings but not so from terminal or herbaceous cuttings. Some other grows best only from the fully matured basal portions and still others grow best from heel or mallet cuttings, only in which second year wood is also included.

viii. Etiolation:- It is considered to be necessary for better rooting.

38.6 GRAFTAGE

Graftage is the process of joining a part of a plant with another in such a way that both will unite to work as a unit and the unit will continue growth. Two different methods based on the same principles are included under the term graftage viz, grafting and budding.

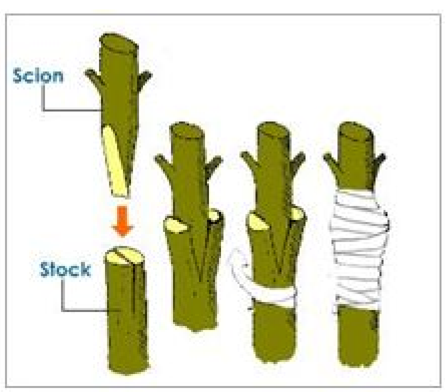




38.6.1 Special terms in connection with grafting and budding:-

i. Stock:- Stock is that part of a graft which has the root and which supports the growth, made by the other component scion. Root system of the stock and the above ground growth of the scion constitute a graft. A stock is called "seedling root stock" if it is grown from seed and "clonal roots stock" if it is propagated by vegetative methods of propagation e.g. cutting, layering etc.

ii. Scion:- Scion is a portion of the stem or branch of the variety that is desired to propagate. It may be a shoot or a branch a few inches long or one feet long and has many dormant buds on it. It may be taken from current or past season's growth or even older wood, but in most species growth of current or past season makes better scion than does the older wood. The scion for grafting is a piece of a branch while the scion for budding is only a single bud with a little bark.



iii. Matrix:- Matrix is the place on the root stock that is prepared for joining the scion or the bud.

iv. Compatibility:- The word compatible designates the suitability of the reciprocal influence of stock and scion on each other. If the influences of one on the other are all suitable to each other we say that both are compatible.

38.6.2 Limitations of graftage:-

For the successful union of the two parts, following three conditions must be fulfilled.

- Close botanical relationship.
- Continuous contact of cambium layers and tight fitting(closeness of fit)
- Compatibility

Lesson 39. Micro Propagation Methods

39.1 INTRODUCTION

Micro-propagation is one of the important contributions of plant tissue culture to commercial plant propagation and has vast significance. The technique provides a rapid reliable system for a production of large number of genetically uniform disease free plantlets. Micro-propagation is the technique of developing plants from very small portion of plants such as shoots tip root tip, embryo, stem, pollen grain, callus or single cell. Plant tissue culture owes its origin to the revolutionary concept of totipotency of plant cell propounded by the famous German plant physiologist, Haberlandt in 1902. This technique has opened a vast scope for improve of fruits and plantation crops though micro-propagation, creating genetic diversity, germplasm conservation virus elimination, development of somatic hybrids and gene transfer.

Micro-propagation holds a great promise in fast multiplication of fruit and nut crops, which are invariably propagated asexually to meet the ever increasing demand for adequate and timely supply of clean planting material. It is possible through micro-propagation to produce millions of identical plants under controlled and aseptic conditions, economy of time and space, affording greater output and augmentation of elite, disease free propagules, safer and quarantined movements of germ plasm across nations. It also induces precocity in flowering, precision timing uniformity and often increases yield.

In fruit and plantation crops, comparatively difficult to micro-propagate, protocol have been developed for citrus, apple, banana, papaya, pineapple, grape, peach, plum, almond, walnut, strawberry, oil palm and date palm. In India, commercial exploitation of micro-propagation is limited to oil palm, strawberry and banana. It is primarily because of the highly heterozygous nature of the material which requires independent protocol for the different genotypes, problems of clonal fidelity, involvement of rootstock and overall costs. However, attempts are on to standardize protocol for crops like mango, cashew, walnut, oil palm, coconut, litchi, sapota and cocoa.

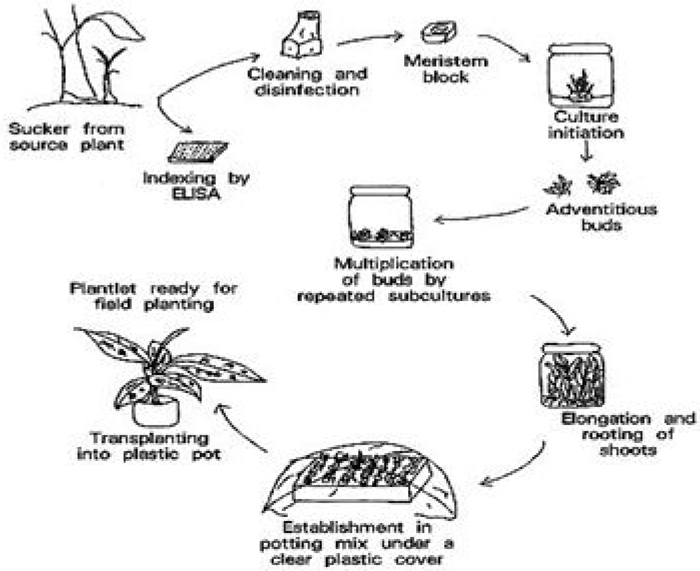
39.1.1 Micro-Propagation Types:

(1) Meristem culture e.g. orchid, carnation

(2) Tissue culture e.g. banana, date palm

(3) Ermbryosis e.g. tobacco

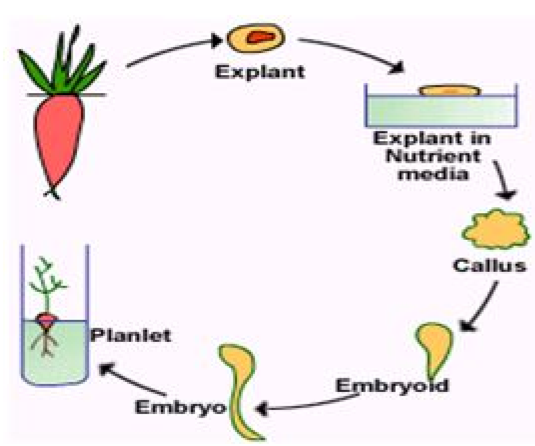
(4) Embryo tube use e.g. orchid.



39.2 IMPORTANCE OF TISSUE CULTURE TECHNIQUE

All the cells in an organism carry the same genetic information, yet show variations in expression,. Our knowledge of cell and tissue cultures has been developing with full swing, specially in bio-transformation, forestry, genetic engineering, morphogenesis, somatic hybridization, secondary metabolite production, hybridization, variety development and their conservation, maintaining pathogen free plants and rapid clonal propagation, totipotency, differentiation, cell division, cell nutrition, metabolism radio biology, cell preservation, etc. It is now possible to cultivate cells in quantity, or as clones from single cells; to grow whole plant from isolated meristems and to induce callus or even single cell to develop into complete plant either by organogenesis or directly by embryogenesis *in vitro.*

The production of haploid through tissue culture form anthers or isolated microspores and of protoplasts from higher plant cells has served as the basic tools for genetic engineering and somatic hybridization. Tissue culture technique helps to propagate plants of economic importance such as orchids and other ornamental plants in large numbers by their meristem culture or by other *in vitro* methods. This provides them virus-free plantlets, Propagation of valuable economic plants through tissue culture based on the principle of totipotency (*every cell within the plant has potential to regenerate into a whole plant*).



In plant breeding, embryo, ovary and ovule culture as well as *in vitro* pollination have been employed to overcome morphological and physiological sterility and incompatibility. In recent years, plant tissue culture technique is in increasing use for producing haploids from anthers or isolated microspores, and of protoplasts from higher plant cells and the recognition of the potential of these materials in genetics and plant breeding. One of the most significant developments in the field of plant tissues culture during recent years are the isolation, culture and fusion techniques which have their special importance in studies of plant improvement by cell modification and somatic hybridization.

Plant tissue culture technique is a boon in the studies of the biosynthesis of secondary metabolites and provides an efficient means of producing economically important plant products (fine chemicals). Plant tissue culture also provides raw material to pharmaceutical, cosmetic and confectionary industries examples are berberine, ginseng, shikonin and vanilla.

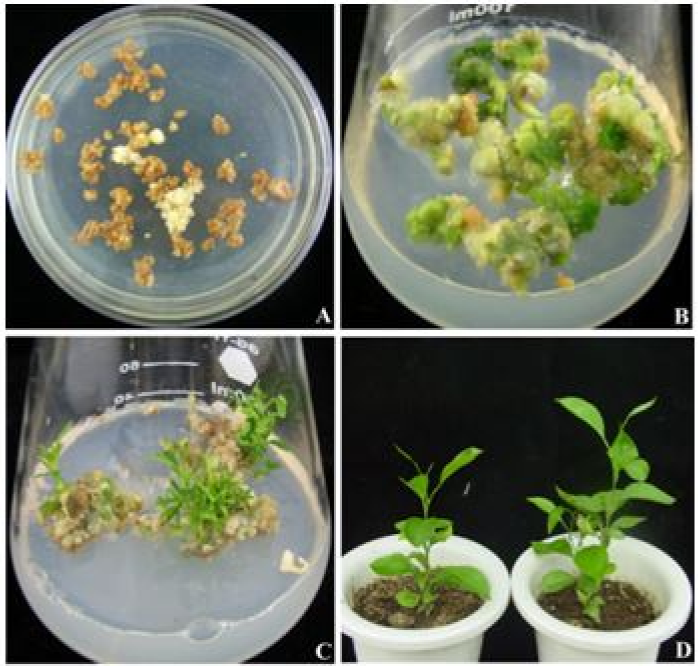
39.3 PLANT TISSUE CULTURE PRINCIPLES

The technique has developed around the concept that a cell is **totipotent** when it has the capacity and ability to develop into whole organism. The principles involved in plant tissue culture are very simple and primarily an attempt, whereby an explant can be to some extent freed from inter-organ, inter-tissue and inter-cellular interactions and subjected to direct experimental control.

The most common culture in plant tissue is callus, which is wound tissue composed of undifferentiated, highly vacuolated and unorganized cells.

39.3.1 Callus Culture

For raising the callus tissues, a tissue culturist must have clear understanding of some basic principles. A cell from any part of the plant like shoot apex, bud, leaf, mesophyll cells, epidermis, cambium, anthers, pollen, fruit etc., when inoculated in a suitable medium under aseptic laboratory conditions can able to differentiate and multiply. This results into the formation of an amorphous mass of cells known as **callus,** which can be induced to re-differentiate on appropriate medium to develop **embryoids** which directly develop into the plantlets, eventually giving rise to a whole viable plant.



The term clone (from the Greek *klon,* meaning: a slip or twig suitable for plant propagation) was suggested by Webber (USA) in 1903 to explain those plants which were obtained by a sexual reproduction; it is even applied to DNA multiplication (cloning of genes in bacteria). In strict scientific sense, cloning means an *organism obtained from a single cell through mitotic divisions.*

39.3.2 Meristem Culture

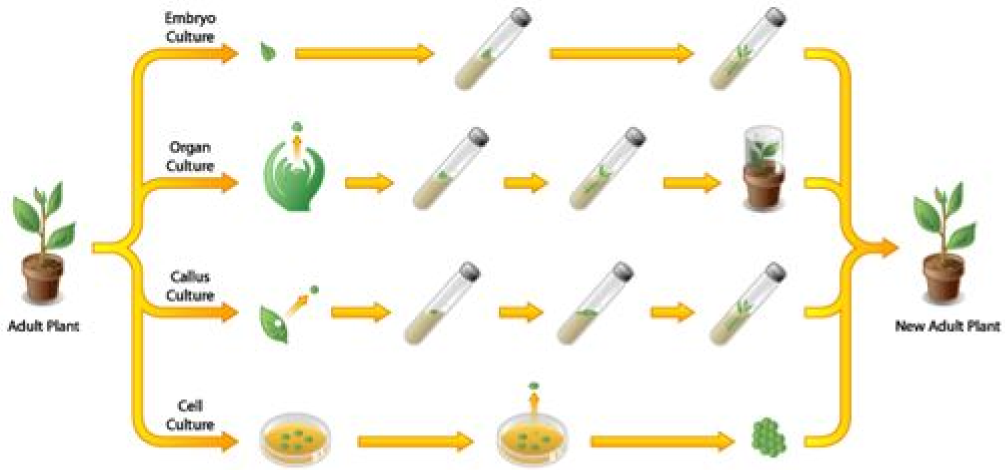
When a meristem is cultured *in vitro,* then it produces a small plant bearing 5 or 6 leaves. This could be obtained within a few weeks. Then the stem is cut into 5-6 small micro cuttings, which under favorable conditions, become fully grown plants.

39.3.3 Organ Culture

A body of higher plants has complex inter-relationships between different organs like root, shoot, apical meristem, leaf primordia, floral buds, ovary, ovule, anther lobs, pollen grains, fruit, seed, etc. In this method a particular organ is isolated and cultured under laboratory conditions in a chemically defined medium where they retain their characteristic structures and other features and continue to grow as usual. In organ culture, organs are not induced to form callus, therefore, it differs from the callus culture where the organization of the intact tissues is lost.

This technique provides and experimental system to define the nutrients and growth factors that are usually received by the organ from other organs of the plant body and from surrounding environment. It also helps us in understanding the inter-dependence of organs with respect to various physical and chemical growth factors including growth hormones. Organ culture technique also provides the knowledge about the various problems of morphogenesis and the sites of biosynthesis of specific metabolites and growth compounds. It may be used as a tool for improvement of various economically important crops.

Organ culture may be grouped into two major categories: vegetative organs (root culture, leaf culture, and shoot tip culture) and reproductive organs (complete flower culture, isolated ovary culture, isolated ovule and embryo culture, pollen mother cell culture, seed and fruit culture).


Embryo Culture
Organ Culture
Callus Culture
Cell Culture
Adult Plant
New Adult Plant

Lesson 40. Plant Growing Structures

40.1 PLANT GROWING STRUCTURES

Following are most commonly used plant growing structures for horticultural plants:

40.1.1 Shade Houses: Shade houses in nurseries in tropical and sub-tropical regions offer many advantages like raising of seedling in bags directly, protecting the grafts from hot summer months, effective irrigation through upside down overhead micro sprinklers. The shade house made with shade nets (50% or 75%) for regulation of shade are particularly very useful in arid regions where the humidity is very low during summer months.

40.1.2 Green Houses /Poly Houses: Grafting or budding of several fruit species under poly house or low cost green houses with natural ventilation will enhance the percentage graft / bud take besides faster growth of grafts due to favourable micro climatic conditions of poly house. In green house construction a wood or metal frame work is built to which wood or metal sack bars are fixed to support panes of glass work. in all poly house/greenhouse means of providing air movement and air exchange is necessary to aid in controlling temperature and humidity. It is the best, if possible to have in the green house heating and self –opening ventilators and evaporative cooling systems. Plastic covered green houses tend to be much lighter than glass covered once with a build up of excessive high humidity.

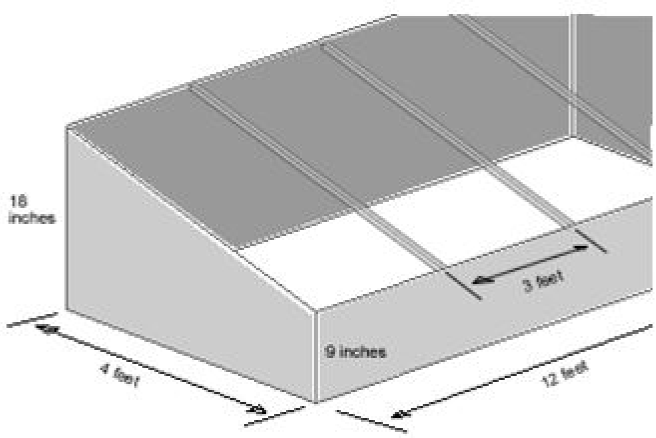
i. Polythene film: This is the most inexpensive covering material but it is the short lasting one. However, UV ray resisting polyethylene film of various thicknesses is usually recommended which lasts longer.

ii. PVC film : This material is pliable and comes in various thickness and widths unto 6 Ft. it is longer lasting than polythene and is more expensive PVC surface of films tends to collect dust and lower the light intensity in due course of time.

iii. Polyester film: This is strong material with excellent extremes of heat or cold through it is costly than polythene film /PVC film.

iv. Fiber glass: Rigid panels, corrugated or flat fiberglass sheets embedded in plastic are widely used for green house construction, fiberglass is strong, long lasting, lightweight and easily applied which is coming in a variety of widths, lengths an thickness. It is costlier than poly thin film/PVC film.

40.1.3 Hotbeds: The hotbeds is often used for same purpose as a green house but in a smaller scale. Amateur operations and seedling can be started and leafy cuttings root easily in the cold seasons in such structures. Heat is provided artificially below the propagating medium by electric heating cables, pot water, steam pipes or hot air blows. As in the green house, in the hot beds attention must be paid for shading and ventilation as well as temperature and humidity control.



40.1.4 Lath Houses:- These structures are very useful in providing protection from the sun for container grown nursery stocks in areas of high summer temperatures and high light intensity. Well-established plants also require lath house protecting including shade-loving plants. Lath house construction varies widely depending on the material used. Aluminium pre-fabricated lath house are available but may be more costly than wood structures. Shade is provided by appropriate structures and use of shade nets of different densities allows various intensities of light in the lath house.

40.1.5 Miscellaneous Propagating Structures:-

1. Mist Beds: These are valuable propagating units both in the green house and out doors and are useful mainly in rooting of leafy cuttings.

2. Mist Chambers: This is structure used to propagate soft wood cutting, difficult to root plants and shrubs. Here the principle is to spray the cutting with a minimum quantity of water. This is achieved by providing the cutting a series of intermittent spraying rather than a continuous spray. The intermitted spraying can be done easily by means of a high-pressure pump and a time switch. The pumps leads to a pipeline systems inside the propagating structure. The mist nozzles are fitted to these pipelines and suitability spaced over the propagating material.

3. Nursery Bed: These are raised beds or boxes made of bricks and morter, provided with drainage holes at a bottom. The dimension of the boxes are 60 cm high, 120 cm broad and length as required preferably not exceeding 10 m roof structures for planting on both sides and forming ridges at the center are constructed on the top of the nursery beds. These structures may be made permanent with angle iron or maybe made of wood. bamboos mats, palm leaf mats are placed over these structures to protected the seedling from hot sun and heavy rains.

4. Fluorescent Light Boxes: Young plants of many species grow satisfactory under artificial light from fluorescent lamp units. Although adequate growth of many plant species may be obtained under fluorescent lamps but not up to the mark compared to good green house conditions.

5. Propagating Cases: Even in green house, humidity condition are often not sufficiently high for rooting. The use of enclosed frames or cases covered with glass or plastic materials may be necessary for successful rooting. In using such structures, care is necessary to avoid the build up of disease organism due to high humidity.

6. Plastic Mulch: Mulch is a material used for covering the soil in order to prevent weed growth avoids direct evaporation of the water from the soil and to increase soil temperature, mulching seedbeds with opaque black plastic film prevents weed growth completely and because of higher soil temperature and better conservation of soil moisture, brings about early germination and faster seedling growth.

7. Mini-Green Houses: The plants need carbon dioxide for making food through photosynthesis. The green house helps in providing additional carbon dioxide to the plants to enhance their rate of photosynthesis. This can be achieved by enclosing the plants in a box like structure made out of bamboo and colourless transparent plastic, with a lid at the top. The lid is closed after sun set, so that carbon dioxide produce due to respiration accumulate in the box. After sun rise the plant start photosynthesis and since there is higher carbon dioxide content around the plant, the rate of carbon assimilation is higher. After a few hours the lid is opened to prevent over-heating alternatively. A plot or beds of plant can be provided with plastic films skirting supports by bamboo stakes, about 12 cm. high. Since CO_2 is heavier than air it tends to settle around the plants.

8. Light Chamber: Several plants to go into winter dormancy when the day length shorts. Additional light from tube lights, given after sun-set, creates long day conditions that prevent the plants from going into winter dormancy. Light given at the end of the day. Also encourage growth of green leaves; they grow tall without developing lateral branches. On the other hand, if they are exposed to fluorescent light from tube-lights laid on the grounds, they developed side branches and show a bushy habits.

9. High-Humidity Chambers: This technique resolves the common problems of graft or cutting dying due to desiccation when planted in the soil for rooting, by ensuring a humid atmosphere around the cuttings, thus wood preventing excessive evaporation. The cutting/grafts are planted on a sand beds, enclosed on all the sides by a dome made of GI wire and covered with a transparent, colourless plastic film. The sand is watered to field capacity, and plastic film traps evaporation inside the chamber creating a highly humid atmosphere. The dome must be shaded, since direct sunlight will heat up the internal atmosphere of the dome, killing the plants.

40.2 GREEN HOUSE

Plants under natural conditions grow and bear flowers, fruits and seeds in their own specific manner but there are some hurdles like unfavorable weather conditions, attack of insects, pests and diseases etc., which restrict their development and growth. There is a need, therefore, to protect the plants from such adverse conditions so as to allow them to grow vigorously. This led to the invention of a shelter where the plants can grow or pass over their critical period of growth under most favorable condition. The shelter so prepared is known as Green house which is generally a structure covered with a transparent material to utile the solar radiant energy and to provide suitable environmental conditions for the optimum growth of plants.

40.2.1 Types of Green Houses

A greenhouse is a place where plant can grow under controlled conditions so as to grow, develop and produce at the will of the grower. In the beginning, these houses or structure were fully covered with attached roof or a covering, which could be lifted with ease. But later on, they were being covered with stales and further, with glass and as such they came to be known as glasshouses. Now, many types of materials are available to cover them. Hence different other names depending upon the type of covering used are common.

Glasshouse is with a roof and sides off glass of different sizes. Instead of glass, fiberglass, which is stronger, durable and does not break into pieces, is used and so the name of such a house is fibre glasshouse. This is hardier than the glasshouse but is costlier than that, though the chances of its breakage are much less. Plastic house or plastic green house has a cover of a transparent alkathene or polythene which is strong enough to withstand the varying temperature of summer and winter, hail, strong winds etc, these are also known as poly-houses, Poly-tubes or poly tunnels. But, in general, greenhouse is the commonly accepted and popular name.

Types of material used for making a structure of the greenhouse also vary. Two things are necessary for a greenhouse. i.e. the frame or structure and the cover. To support the cover and structures on the sides, pillars are needed. The structure of pillars or support may vary with type of frame and size of a greenhouse. Small and semicircular greenhouses, i.e. poly-tunnels may not need pillars or support in the centre but heavy or large greenhouses which may have heavy structure of iron or wood, do not need strong support to have the roof and sides intact.

Frames may be wooden or of iron or aluminum for a greenhouse of glass cover. Pieces of glasses are fixed tightly in the frames by putting some fixing material along the sides of the glass. In case of poly-house the sides and roof are covered with a polythene sheet, which is placed deep in the soil to hold it. In some cases the sheet is put in between the two tubes/frames.

Pillars of cement and concrete mixture are also built to support the roof of a greenhouse of glass or fiberglass. Number of pillars are needed will depend upon the size of a greenhouse but six pillars are necessary at the minimum level. The height of these pillars also varies but generally the highest pillar may be 3 meter tall. Pillars can be round, square or rectangular but in practice, the side pillars are usually square in shape while the central ones may be round to avoid unnecessary clash in greenhouse. When wooden pillars are used, they are usually square in shape of the width 8-10 cm. Iron or metallic pillars are also used but they are usually of round but hollow pipes of the diameter of 5-10 cm. Pillars of cement and concrete mix are usually white washed or painted with paint while the wooden and metallic structures are painted with paint. If money is available, these structures may be painted with a silver paint. Doors and windows may also be painted with white or silver paint. Some people paint the wooden frames with green paint which is also good but white or silver paint provides good sanitary look.

Depending upon the material to be kept, the specific period of keeping in the greenhouse and the type of material for construction and coverage, the size and shape of greenhouse varies. Heavy greenhouse with pillars of cement and concrete mix with a fiberglass top or cover may last for 2 decades or so while other may last for 5 years or so. On the other hand, plastic houses or poly-tunnels do last for 2-3 years only provided they are maintained in the best manner.

Shape of the greenhouse is generally, pentagonal from the front and back. For about 2 meters, they do not have the straight walls then it tapers toward the top to form a triangle which is needed for the easy run off of rainwater or snow. Wind may pass over it. Leaves etc., if they fall on the roof do not stay there for a long period they are blown off by the wind.

40.2.2 Equipments for Greenhouse

Common greenhouses are just shelters for the plants with the aim of protecting the plants or other plant material from extreme variations in the temperature like snow falls in hills, drought in plains and excessive rains. These greenhouses have only benches to keep the plant pots or trays in order. They do have a hard floor that may be a cemented one and there is good provision for the drainage of water. For control of temperature, the doors and windows are opened for free passage of air current.

Equipments and furnishings are needed in a greenhouse will depend upon the type of material to be raised or stored and under what conditions they are to be kept. Simple greenhouses are the structures which can house the plants under shade. They are not provided with sophisticated equipments. Generally, during a warm weather, plants are either watered frequently or pone of water is created artificially in the center to keep the humidity under check. Doors may be opened or closed to provide ventilation, air passage and to raise the temperature.

Misting, cooling, heating, balancing the air supply with its quantity and quality, artificial lighting, controlling temperature and humidity are some of the operations which are governed by different automatic equipments fixed in a green house.

An ideal greenhouse must have a good system for control of temperature, humidity, nutritional requirement and pathogens.

Lesson 41. Pruning and Training

41.1 INTRODUCTION

Some of cultivated fruit trees grow wild and do not give sufficient yield unless pruned or trained to a specific form. All types of fruit tree do not require pruning e.g. mango, chiku, etc and some fruit trees can grow well naturally e.g. pineapple, papaya they do not require pruning. While most deciduous tree like apple, pear, almond etc and grapes, ber, fig citrus, pomegranate, guava etc require pruning to train them for desired shape.

41.2 PRUNING

Pruning may be defined as the art and science of cutting away of portion of plant to improve its shape, to influence its growth, flowering and fruitfulness and to improve the quality of the product. It is done to divert a part of plant energy from one part to another part of plant.

41.2.1 Objects of Pruning:

- Training of young trees
- Maintenance of grown up trees i.e. to maintain the health of bearing plant
- Bringing vigour in old trees

41.2.2 Effect of Pruning

- It increases new vegetative growth
- In young trees flowering will be delayed
- In old trees there will be new vigorous vegetative growth which bears fruit
- It reduces bearing surface are as a result tree remain dwarf which is compensated by accommodating more number of dwarf trees (because pruning is a dwarfing process)
- Improvement in size, colour and quality of fruits

41.2.3 Principles of Pruning:

- Young trees are pruned to train it to acquire a desired shape.
- In old trees light heading back is done to stimulate the flowering
- In bearing trees light pruning is done to stimulate fresh growth. it bearing flower buds on fresh growth
- In old trees heavy pruning is done to restore vigorous
- All the diseased, weak, dead or shading branches must be removed.

41.2.4 Systems of Prunings

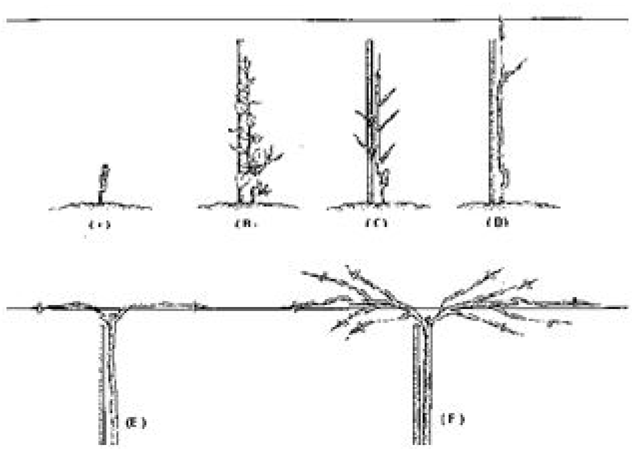
- Heading back: Only tops of branches are headed back or cut off (light pruning).
- Thinning out: Complete removal of a branches or a part
- Dehorning: Cutting away the main limbs or thick major branches
- Bulk pruning: Heavy pruning all over the tree. For good fruit production only judicious heading back or thinning out should be done.

41.2.5 Rules of Pruning

- Never leave a stub as far as possible
- Minimum cut surface
- Start cutting from the lower end first, leave half way or even less and then cut from the top
- Keep the cut surface clean and smooth
- Protect the wound with Bordeaux paste.

41.3 TRAINING:

It means developing a desired shape of the tree with particular objectives by controlling habit of growth. Training is start from nursery stage of plant. Some fruit crops like grape vines, ber, fig, guava etc require training.



41.3.1 Objects of Training:

- To admit more light and air to the centre of the tree to expose maximum leaf surface to the sun
- To direct the growth of the tree so that various cultural operations such as spraying, ploughing, harvesting can be performed easily and at lower cost.
- To protect the tree from sun burn and wind damage.
- To secure a balanced distribution of fruit bearing parts of the tree.

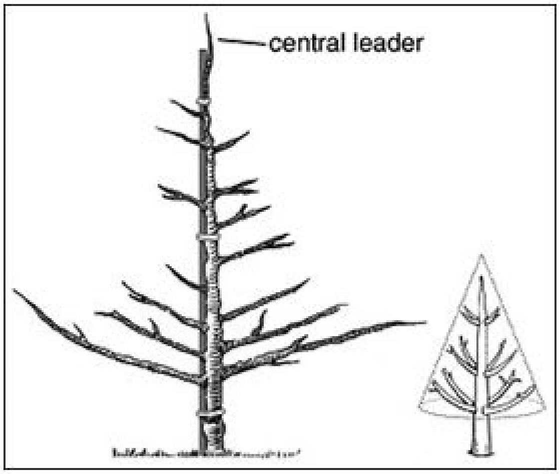
41.3.2 Principles of Training:

- Formation of the mainframe work must be strong. The branches must be suitable spaced apart and the tree must be balanced on all the sides.
- Never allow several branches to grow at one place or very near each other.
- Careful training of main branches is very essential.
- Another important point about training is that if two branches are growing at the same point try to train them to grow at a wider angle. Narrow angle is always weak.

41.3.3 System of Training:

- Central leader system:

  In this system the central leader branches are allowed to grow indefinitely so that it will grow more rapidly and vigorously than the side branches and tree became tall. Such a tree bears fruit more near the top. The lower branches are less vigorous and less fruitful.



- Open centre or vase system:

  The main stem is allowed to grow only up to a certain height about 1.5 to 1.8 m and then it cut for development of lateral branches. It allows full sunshine to reach each branch.

- Delayed open centre or modified leader system:

It is intermediate between the above systems. It is developed by first training the tree to the leader type by allowing the central axil to grow un pruned for the first four or five years. Then central stem is headed back and lateral branches are allowed to grow as in the open centre system.

- Bush system:

An unpruned tree multi stem and dwarf growing habit.

- Over head trellis or Bower system:

When vines are trained on mandap.

- Modified bower or Telephone system:

Similar to bower system except that after every two meter as space is kept to walk and carry out cultural operations.

41.4 SPECIAL HORTICULTURAL PRACTICES FOR INDUCING FRUITING

Of the many factors influencing floral initiation, carbohydrates-nitrogen ration appears to be the one factor that could be controlled. The accumulation of carbohydrates can be brought about by more rapid manufacture and less immediate utilization. In vegetative weak plants, favorable conditions for carbohydrate accumulation will have to be created by provision of desired temperature, light, water and nutrient change while in vigorous plants this change is to be induced by the reduction of water and nutrient supply. Regulation of fruiting can be effected by influencing fruit bud differentiation or by influencing fruit set and development.

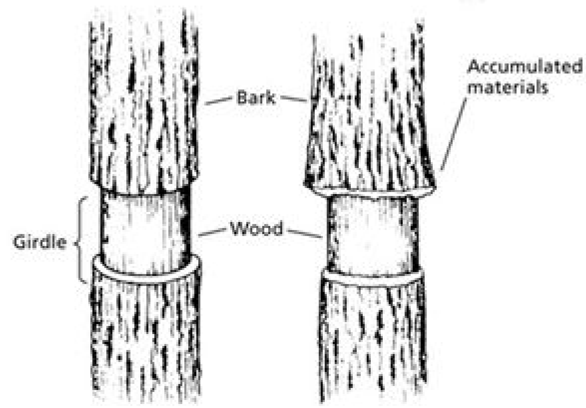
Pruning, root pruning, ringing, girdling, notching, bending, smudging are some of the specialized horticultural practices followed for regulation of fruiting.

41.4.1 Ringing and Girdling

Ringing consists of removing a ring of bark about 1 to 2 cm wide around the trunk or branches, while Girdling is a milder treatment to draw a knife around the branch so as to cut through the bark but not the wood. A wire tied very firmly round the stem also serves the same purpose.

Ringing or girdling will increase the concentration of carbohydrates above the wing. It will also reduce the nitrogen supply because subsequent to the stopping of food to the roots, the root growth will be stopped and hence the supply of nitrogen to the tree will slowly decrease and became limited. No more root growth, no nitrogen supplies. The result will be a wide C: N ratio and then flowering increased. Ringing is a drastic operation done when fruit trees fail set fruit. It is likely to check vegetative growth and to some extent the growth of roots. Ringing is done in vigorous mango tree.

Girdling a tree... what will be the result?



i. Notching

It is similar to ringing except that in notching only soil slip bark about 0.2 to 0.5 cm thick and 1.5 to 2.5 cm in length is removed just above or close to a dormant bud in slantwise so that the latex does not coagulate in the bud itself. The bud selected should be large, plampy and healthy which is produced on a perfect mature wood and has undergone dormancy. Generally 3 to 4 buds in the middle portion of the selected shoot are best to operate on. Fig has responded to notching and it is practiced in fig cultivation. The season for notching the fig is August-September.

ii. Bending

Bending a branch downward, sometimes checks growth and causes accumulation of starch in the branch with greater flowering. This tends to increase carbohydrate concentration. The bending brings pressure on the bark on the translocation of photosynthesis is obstructed due to narrow passage. The bending of branches is usual as a substitute for severe pruning in shaping the young trees and more fruit is borne because more branches are left to bear and more leaves are left to synthesize food material. In case of bending the effect of apical dominance of the growing shoot is removed and auxins during translocation activate the dormant buds. This is usually practiced with local guava variety in the Maharashtra state (Deccan area).

iii. Smudging

Smudging is a practice of smoking the tree by burning brush wood on the ground and allowing smoke to pass through the centre of the crown of the tree. The smoking is discontinued as soon as the terminal buds begin to swell. Not commonly followed in India. Practice of smoking to the trees like mango, commonly employed in the Philippines to produce off-season crop. Smoking containing ethylene gas, which is responsible for initiation of flowering.

iv. Root pruning

Root pruning results in less carbohydrate utilization of the top growth through there is a little more utilization of carbohydrate for root functions. There is an accumulation of carbohydrates due to check of top growth, which results in fruit bud differentiation. As the effect of root pruning is to check the vegetative growth. The plant became dwarf. Root pruning is a method of inducing fruitfulness or determining the time of flowering. The root pruning is done two months before the bloom required. The main roots are exposed to the sun and the fibrous roots are cut, so water is withheld. The trees are allowed to go dry until their leaves wither and fall down. The time taken for leaf fall is from 3-4 weeks. After that exposed roots are covered with a mixture of soil and manure. The trees are then immediately irrigated. First irrigation may be given with very less water. The trees burst into flowering in about 2-3 weeks. Practice very widely adopted by citrus growers in western and central India (in santra). The trees on which root pruning is practiced quite frequently are short lived and are liable to be week and unhealthy. Hence root pruning is usually restored to when other method such as ringing etc. Root pruning is generally included in bahar treatments given to fruit trees like mosambi, santra, guava, pomegranate, lime etc. It is also practiced while manuring large trees like mango, by trench method where smaller roots coming in the trench are usually cut away.

v. Bahar treatment

This practice is followed with fruit trees like mosambi, santra, grape fruit, guava, pomegranate ber, lime etc. in the state of Maharashtra, M.P. and Gujarat etc. As there is no distinct winter (very cold winter) these fruit trees are usually continuous vegetative growth resulting in indistinct flowering season. This practice is useful in encouraging flowering as well as regulating the time. About 1 to 1 ½ months prior to the expected flowering irrigation is withholding. There are three flowering season namely Mrig bahar, Hasta bahar and Ambe bahar.

Mrig bahar: Flowering in June-July

Hasta bahar: Flowering in October-November

Ambe bahar: flowering in December-February

The orchard is ploughed up to 20 cm depth both ways and the roots are exposed by removing the upper 10-15 cm of soil within a radius of 60-90 cm around the trunk. The dead and decayed fibrous roots are removed in the area exposed. The leaves start turning yellow, shrivel and fall. These are the indication to know that the trees have rested long enough and accumulated food reserves. The exposed roots are then recovered with original soil and necessary manures are added. Trees are irrigated lightly. The second watering is given on the 3rd or 5th day and first two watering stimulate blossoming and if heavy irrigations are given at the beginning, this may tend to vegetative growth only. Root exposure is not necessary in case of sandy, sandy loam and other types of light soils. The choice of bahar depends upon availability of water and time of year the fruit is required in the market. Where irrigation water is available, the grower prefers Hasta or Ambe bahar.

41.5 GROWTH REGULATORS

Growth retardants like CCC, (in Mango 1000 ppm.), higher concentration of Auxin, NAA (in Mango 200 ppm), Ethylene -750 ppm, Paclobutrazol -4-6 g (Cultar).

41.5.1 Use of Hormones as Plant Growth Regulators in Horticultural Crops

- What are hormones: Hormones are internally synthesized compound in plants bodies and they markedly affect the metabolic activities inside the plant. They required in very minute quantities.

  Since plants make them they are organic in nature, however, they can also be prepared synthetically and such synthetic hormones are also as effective as the organic hormones produced naturally by plants.

- Effectiveness of hormones: Different hormones have regulatory effects on different activities. Further, two derivates of a compound can also have different effects.
- Carriers: The medium in which the hormones are mixed is called carrier. This may be water, alcohol, oil, charcoal powder, talc or flour etc.
- Spreaders: Certain plants have waxy coatings on their bodies. In such cases spreader like soap are mixed with hormones. Spreaders reduce the surface tension and even ensure spreading of the liquid applied.
- Use of hormones - It is done in following activities:

  i. Rooting of cutting

  ii. Blossom thinning

  iii. Preventing fruit drop

  iv. Increasing fruit setting or development of parthenocarpic fruits

  v. Germination of seeds

  vi. Early maturity

  vii. Weed control

i. Rooting of cutting: Various chemicals compounds are known to be useful in rooting of cutting e.g. sugars, potassium permanganate, manganese, iron, phosphate etc. carbon monoxide can also be useful in root formation but the most successful are indolebutyrie acid (IBA) and naphthalene acetic acid (NAA). Some new promising hormones are trichlorophenoxyacetic and trichlorophenoxypropionic acid.

These hormones are effective only when used in low concentrations. In high concentration they inhibit growth. Mixture of hormones is more effective than single hormone.

(a) Advantages:

- Percentage of success in rooting increases
- Quicker root formation
- More root and heavier roots
- Lesser time

(b) Limitation: Plants must have natural capacity. Hormones can only help and

proper environmental condition.

ii. Blossom thinning: Thinning of fruits is the term commonly used for reducing the number of fruits. Thinning does reduce the number of fruits but the remaining fruits become bigger and gain more weight. In excessive bearing, thinning becomes a necessity. In papaya NAA has been reported to be effective for thinning of fruits.

Naphthaleneacetic acid, naphthalenacetymide sodium salts of NAA is most effective. Proper concentration and the stage of flowers are important. Only fully opened but unpollinated flowers will be killed. Any mistake in concentration might loss the entire crop.

iii. Preventing fruit drop: Abscission layer is the cause of fruit drop. This is a corky layer of cells at the base of petiole of the junction of fruit and stalk. Hormones can prevent the formation of abscission layer.

Quality of fruit is not affected. It is not harmful. Naphtaleneacetic acid and its derivatives are the best. If fruits are not picked in time they may become overripe. More work is done on use of hormones for preventing pre harvest drop in apples.

iv. Increasing fruit setting by seedless fruit production: As early as 1909 it was found that water extract of pollen grains when applied to pistil of flowers induced parthenocarpy, N.A.A. are useful**.** At present the use is limited to glass house crops particularly tomato.

v. Germination of seeds: Not much success has been obtained in increasing germination through hormone treatment.

vi. Controlling flowering: Ethylene and acetylene are used in Hawali and Australia for early flowering in pineapples. Application of NAA (0.006 % spray) is found to reduce maturity period by 2 months in pineapples. In tomato tridobenzoic acid changes leaf buds into flower buds.

vii. Weed control: Poisonous chemicals like arsenic, boron or petroleum compounds can kill weeds but they are dangerous to human life.

41.5.2 Synthetic Hormones: These are superior to chemical poisons.

1. Selective in action
2. Harmless to soil, harmless to man and animals
3. Less expensive and non corrosive
4. Not inflammable
5. Synthetic in nature and required in very low concentration
6. Kill the entire system

e.g. 2-4 Dichlorophenoxyacetic acid (2-4, D), 2-4-5- Trichlorophenoxyacetic acid (2-4-5, T), 2-Methyl-4 Chlorophenoxyacetic acid, Isopropyl-N-Phenylearbamate.

41.5.3 Glossary of Terms

- Auxin: A substance synthesized by a plant and able to influence growth at some point other than the point of synthesis comparable to a hormone in animals.
- Growth regulators: Any substances or physical factor, either external or internal that influences a growth process in a more restricted sense, a substance that influences growth.

- Hormone: A substance synthesized by an animal organism that is able to influence growth at some point other than the point of synthesis comparable to an auxin in plants. Sometimes the term is used in a broad sense to include auxins.

Plant regulators: Are the organic chemical compounds which modify or regulate physiological processes in an appreciable measure in the plants when used in small concentrations. They are readily absorbed and move rapidly through the tissues when applied to different parts of the plants.

Lesson 42. Fertilizer Application and Fertigation

42.1 INTRODUCTION

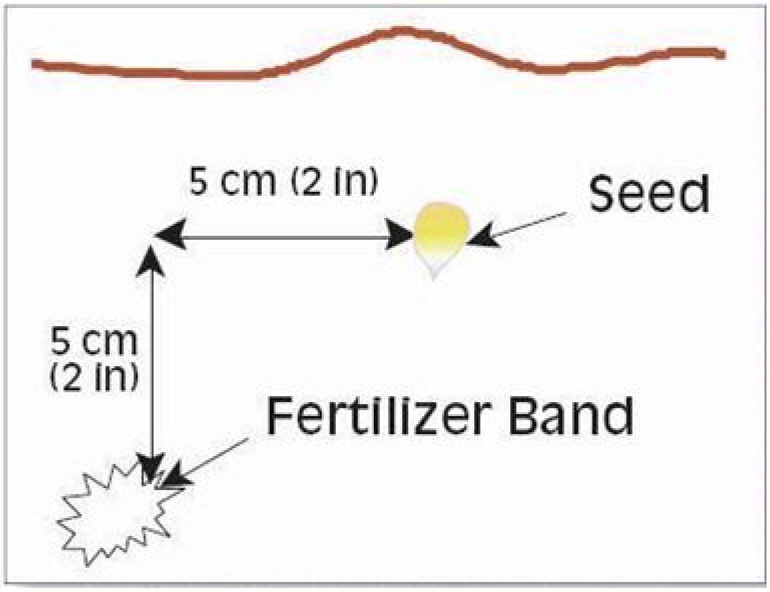
Fertilizer is any organic or inorganic material of natural or synthetic origin (other than liming materials) that is added to a soil to supply one or more plant nutrients essential to the growth of plants. It typically provide six types of macronutrients: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca),magnesium (Mg), and sulfur (S); in varying proportions and seven types of micronutrients: boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganes and zinc (Zn).

The macronutrients are consumed in larger quantities and are present in plant tissue in quantities from 0.15% to 6.0% on a dry matter (0% moisture) basis (DM). Micronutrients are consumed in smaller quantities and are present in plant tissue on the order of parts per million (ppm), ranging from 0.15 to 400 ppm DM, or less than 0.04% DM. Only three other macronutrients are required by all plants: carbon, hydrogen, and oxygen. These nutrients are supplied by water and carbon dioxide.

42.2 METHODS OF APPLICATION

While selecting the method of application of manures and fertilizers to the nursery plants, nurserymen should consider the nutrients, their ability to be effectively absorbed, their effect on soil and environment, equipment availability and the relative cost involved. However, in general, fertilizers in the nursery are applied either as surface application, sub-surface application or as foliar sprays.

(a) Surface application: Band placement along the rows is the most commonly used method of fertilizers application by the nurserymen. It is an effective and efficient method for the application of nitrogen, since nitrogenous fertilizers move into the root zone with the downward movement of water. However, direct surface application is not suggested for applying phosphorous, potassium and other nutrient because they may get fixed on the exchange complex.



(b) Sub-surface application: Incorporation of the fertilizers into the soil by subsurface application is the most effective means of applying nutrients that are fixed (P, K etc.) on the exchange complex or are slow to move into the soil solution. Nurserymen can best incorporate these materials into the soil prior to planting the nursery crop.

(c) Foliar application: In general, nutrients can be applied through foliar means immediately after the symptoms have appeared. For nursery plants, foliar application of the nutrients is very effective as compared to soil application because through foliar means, nutrients are absorbed at a faster rate. Moreover, wastage of nutrients is also very less. For foliar application, the nutrients should be applied when there is sufficient foliage on the plant. The nutrient should either be applied in the morning or late evening hours. Similarly, it is always better to add some wetting agents like Tween-20, Triron-X-100 etc. in the spray solutions as these help to absorb the nutrients even more effectively. Borax is used for supplying boron, which is difficult to dissolve in fresh water. Therefore, one should use lukewarm water for this purpose.

(d) Top dressing: It implies to application of fertilizer in standing crop. Nitrogen and micronutrient fertilizers are administered to the plants using this method.

(e) Localized placement: In this technique, fertilizers are applied close to the seeds or plants. This technique is very much economic and less quantity of fertilizers is required for the purpose of applying the nutrients.

(f) Contact placement: In this technique, seeds and fertilizers are applied simultaneously at the time of sowing. To avoid salt injury, seeds and fertilizers are applied at different depths.

(g) Band placement: In this technique, the fertilizers are applied in band. This is especially useful in widely spaced crops like fruits and plantation crops in which by applying in band close to the root spread, the fertilizer saving is achieved.

(h) Row placement: It consists of placing the fertilizer along the rows of crops. Fertilizer may be applied in one or both sides of the rows depending upon spread of the crops. This technique is suitable for application of fertilizer in vegetable crops.

(j) Pellet placement: In this technique, fertilizers are applied in pellet form. For making pellet, soil and fertilizers are mixed in the ratio of 1:10 and made into dough. Small pellets are made out of it and placed in root zone of plant.

(k) Other forms of application

- **Starter solution:** It is mild solution of NPK in the ratio of 1 : 2 : 1 used for soaking seed, dipping roots and spraying over seedlings for early start of the crop. Feeding starter solution, the seedlings establish early and start growth soon.
- **Fertigation:** Application of fertilizer along with irrigation water is called fertigation.
- **Foliar spray:** Mild solution of nutrient is applied over foliage.

42.3 FERTILIZER DOSE

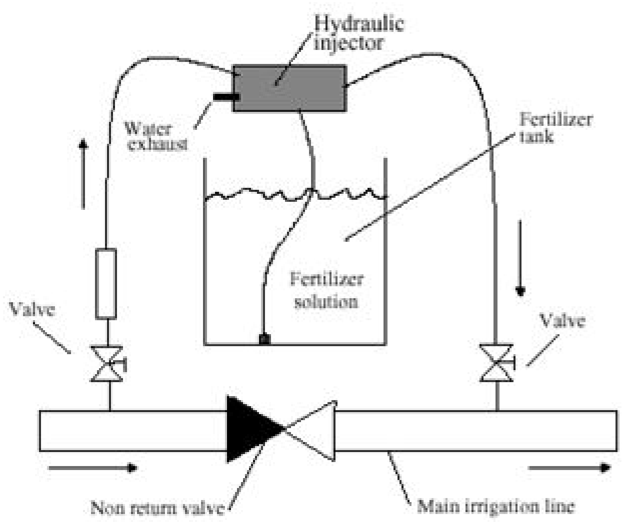
Fertilizer dose is calculated based on requirement of crops/plants for its various physiological activities. While applying fertilizer, nutritional status of soil is taken into account. After deducting contribution of soil, rest amount is replenished externally using fertilizer. To ascertain this dose, following approaches are resorted.

42.3.1Maintenance Concept

In this approach, whatever quantity of nutrient is removed by crop, it is supplemented by application of fertilizer to maintain original nutritional status of soil.

42.4 FERTIGATION

This term refers to supply of dissolved fertilizers to crops through an irrigation system. Continuous applications of small quantities of soluble nutrients overcome the problems of loss of fertilizers due to runoff of leaching, save labour and ensure uniform placement of nutrients around roots, in turn encouraging rapid and maximum uptake by plants. Fertigation offers a potential technique to reduce fertilizer wastage and increase fertilizer use efficiency. Fertigation became possible after development of micro irrigation systems. Fertilizers to be used and method of mixing with irrigation water should be selected with proper care. Only readily soluble fertilizer products can be used for this purpose. Specific soluble fertilizer formulations for particular crops are available in markets, which are costly but cost effective also. Uniformity of water application, which ensures even fertilizer distribution, method of injection, type of fertilizer and scheduling are significant factors to be considered. Fertilizer should be injected at scheduled times at optimum concentration with limited quantity of water to avoid leaching losses. Fertigation immediately before or after irrigation or heavy rains should be avoided. After injection of fertilizers, system should be run for 15-20 minutes to prevent any clogging of emitters. Fertigation is beneficial in fruit crops like mango, banana, grapes and papaya.



Lesson 43. Irrigation Methods

43.1 INTRODUCTION

Water is one of the most important factors for maximization of yield. A fractional application of irrigation water is based on the knowledge of the consumptive use of water by crop and relationship between the moisture status of root-zone and yield potential of the crop. Depletion of soil moisture results in reduction of yields. Increase in soil moisture stress produces moisture deficit in the plants. Therefore, assessment of the optimum needs of water for the root zone is a must.

Water is required in large quantities by all plants, and it is known to be the most universal solvent in which gases and salts enter and move through the plants. It is the 'hydraulic fluid' used to move plant parts and open and close the stomata. The life processes of plants are governed by supply and demand of water. If supply ceases the transpiration, evaporation, respiration etc. get disturbed which in turn affects leaf turgidity, cell division, cell elongation, and general growth pattern in plants. Photosynthesis is sufficiently impaired due to inadequate supply of water. Water maintains turgidity in leaves with high specific heat and heat of water vaporization acts as a barrier against high and low temperature. Water is also important in governing physical, chemical and biological activities in the soil.

Inadequate supply of irrigation water in out country is very common feature whereby cultivators are forced to gamble with monsoon, which are uncertain and unevenly distributed. The drought and floods are common in several states. If a drought occurs during a critical period of crop growth, the yield and quality are affected adversely. Thus, an efficient and economic use of available water is of utmost importance. The economic use of water depends upon various factors viz., kind and type of soil, kind and variety of crop, quality and quantity of water available, source of water and method of irrigation etc.

43.2 WHY TO IRRIGATE?

- To meet the requirement of the crop by adding water to the soil
- To cool the soil environment around these root zone thereby making more favorable environment for plant growth.
- To wash out or dilute the salts in the soil and thus help in maintaining the salt balance.
- To reduce the hazards of soil piping.
- To soften the tillage pans.
- To put the land and labor into an economic use.

- To increase production, productivity and potentiality of crops.

43.3 FACTORS AFFECTING WATER REQUIREMENT OF HORTICULTURAL CROPS

- The irrigation efficiency
- The nature of the crop
- The climatic conditions
- The character of soil
- The method of irrigation and
- The insect-pests and disease havoc.

43.4 HOW TO IRRIGATE?

Much attention is required to the efficient use of water. As water becomes a rare commodity and the need becomes more pressing for maximum economic returns, new and more efficient methods of measuring and evaluation technique of handling irrigation water are necessary. For optimum production, timely application of water in proper quantity at proper intervals is absolutely essential.

43.5 METHODS OF IRRIGATION

43.5.1 Surface Irrigation

Surface irrigation is one of the simplest and widely adopted methods all over the world, especially in India. The water is made to flow on the soil surface or in the furrow. This method is advantageous one own to less investment. The disadvantages are this method requires more attention; soil becomes more puddle and bake; more losses of water through seepage and over irrigation; uneven distribution of water and farm machinery cannot conveniently cross at different point.

This includes flooding and furrow irrigation

(1) Flooding includes (a) free wild flooding (b) border flooding (c) check flooding and (d) basin method (Single and double)

(2) Furrow irrigation includes

(a) deep furrow method and (b) corrugation method.

43.5.2 Sub-Surface Irrigation

This system includes two methods viz., natural and artificial. Artificially porous pipes are laid underground below the root zone and water is allowed to move in pipes. The water moves freely upward by capillary movement. In this method, the maintenance is very cheap; there is no soil cracking in this method and little to no wastage of water. At the same time, this method requires adequate drainage, involves high initial cost in purchasing the tile pipes; and also not suitable in all types of soils. In certain parts of the USA this method is adopted conveniently for irrigation potato crop.

43.5.3 Sprinkler Irrigation

This method is followed where topography is uneven and the soil is porous, shallow or highly arable. Irrigation by this method at the seedling stage has proved very beneficial. In this method the water is conveyed to the field under pressure through pipes having several nozzles, which spray the water on the crop plants. The advantages are this method insures uniform distribution of water economy of water; may be adopted in various types of soil; no fear of soil erosion; no hindrance in the use of farm implements; and water soluble fertilizers can also be applied through sprinkler. This method is also not free from disadvantages like very high initial cost; more loss of water under very hot days through increased evaporation; and strong winds ay also cause uneven distribution of water.

43.5.4 Drip Irrigation

In this method, thin non-corrosive perforated plastic tubes are placed on the soil surface or in furrows, and in some cases buried in the soil, and connected to a controlled water supply source. The water and/or fertilizer is distributed evenly in a continuous slow flow directly to the plant roots in upward as well as downward directions. In drip irrigation system, almost all water is applied directly to the root zone and surface area remain almost dry, and hence it requires about 25 per cent less quantity of water than that of surface irrigation; the tendency of weed growth and leaf shedding is minimized.; further, drip irrigation is fair, suitable under saline soil conditions, it saves extra labour, and it makes possible the localized fertilizer application. Drip irrigation hastens the maturity and overcomes the erosion and seepage problems and does not interfere with cultural practices. Similarly, pitcher irrigation has proved very advantageous in case of cucurbits.

The production, productivity and potentiality of crops may be obtained up to a desired level with an efficient use of irrigation water in combination with other several agricultural inputs in right amounts, in right time through right method of applications.

43.6 HOW TO INCREASE WATER USE EFFICIENCY?

- Proper selection of crop and varieties according to local agro climatic condition.
- Short growth duration.
- By changing cropping pattern of farm.
- Use of chemicals, which shorten the life cycle of the plant and reduce transpiration.
- Selection of high yielding varieties.
- Use of fertilizers.
- Reasonable control of inhibitors.
- Proper cultural and environmental manipulation.
- Characterize the stages of plant growth, which are most and least critical during life cycle of plants.

43.7 WATER MANAGEMENT IN NURSERY

These methods are not suitable for nursery growing due to their several ill effects. Carbonate (RSC) and boron content are also used to find out suitability of irrigation water. Irrigation water, which contain more than 3 ppm boron is harmful to the nursery plants. The classification of water on the basis of E.C. and boron content and its suitability for different soils have been given in Table 43.1 and Table 43.2, respectively.

Table 43.1: Classification of irrigation water based on electric conductivity

Class	EC (m mhos/cm)	Quality characterization	Soils for which suitable
C1	<1.5	Normal water	All soils
C2	1.5-3	Low salinity water	Light and medium textured soils

C3	3-5	Medium saline water	Light and medium textured soils for semi-tolerant crops
C4	5-10	Saline water	Light and medium textured soils for tolerant crops
C5	>10	High saline water	Not suitable

Table 43.2: Classification of water on the basis of boron content

Class	**Boron (ppm)**	**Quality characterization**	**Soils for which suitable**
B1	<3	Normal water	All soils
B2	3-4	Low boron water	Clayey soil and medium textured soils
B3	4-5	Medium boron water	heavy textured soils
B4	5-10	Boron water	heavy textured soils
B5	>10	High boron water	Not suitable

Lesson 44. Harvesting, Grading and Packaging

44.1 HARVESTING

Different kinds of fruits need different methods of harvesting. Some fruits are easily pulled, although there is possibility of tearing off a piece of flesh and/or ding. Some fruits are harvested with stalk with aid of clipper or shear, where the stalk may be source of damage especially during packaging. Fruits at higher branches are harvested with long a hold with a bag (mango). Fruits may be caught as it fall using mechanical harvesters. The best means of reaching high fruits is with a ladder. In banana the trunk is cut with a sickle over half way through and then the bunch is cut. About 30 cm. of the stalk must be left to make the handling easy. Citrus fruits are very much susceptible to damage while harvesting. During wet and humid condition the rind will be turgid and liable to bruising or tear-off rind is common if the fruits are pulled. The post harvest quality and storage life of fruits are controlled by maturity. Vegetables are harvested as and when they attain maximum size and yet are tender. Over Maturity in root crops causes sponginess and pithiness. Delay in harvesting of onion and garlic reduces their storage quality.

44.1.1 When to Harvest Horticulture Crops?

- During cooler part of the day (in morning).
- Do not harvest in hot period, cause wilting and shriveling.
- Harvesting during rains or immediately after rains should not be carried out.

Citrus fruit become susceptible to damage if harvested during rains, as their rind becomes turgid and prone to easy bruising sunscald.

No any bruising or injurious during harvesting may later manifest as black or brown patches, e.g. Latex coming out of stem in mango should not be allowed to fall on fruits as creates a black spot.

44.1.2 Post Harvest Handling

Care in harvesting and handling is necessary to preserve subsequent quality of fruits and vegetables, faulty harvesting and rough handling at the farm directly affect market quality. Oil gummosis is common peel injury of citrus fruits (causing extensive losses) which mostly occurs at harvest, if not done carefully. Mechanical injury to the rind forces the oil out of the epidermal oil glands, which kills adjacent cells of the flavor and also causes soil spotting on the surface of adjacent undamaged fruit. When put together cells killed by oil are readily infected by fungi resulting in increased decay. Oil spotting can be reduced or eliminate by good handling practices.

1. Bruises and injurious later show up as brown and black patches (e.g. banana, bhindi) making the commodities unattractive and physiological disordered. Rough handling on produce is cumulative. Several small bruises on a tomato can produce an off-flavour for consumers
2. Entries to micro organism leading to rotting.

3. Respiration is increased markedly by damages and storage life is shortened. Lack of knowledge in harvesting and handling results in substantial lost of fruits and vegetables.

It is estimated that 20 to 30% of the fruits and vegetables produced is being wasted due to defective methods of picking, storage, and transport procedures in our country. The quality of fresh fruits and vegetables defoliated due to these faulty handling procedure. The climatic condition in our country also limits post handling life of there commodities Hence proper scientific method used to be allowed in harvesting and all the post harvesting operation of the fruits and vegetables to prevent the huge losses being occurred and to maintain the quality. Post harvest technology is simple term as"Field to Table". Programme involving the science applied in providing the consumers with best quality of fruits and vegetables from the field.

Post harvest handling consists of the following procedures:

44.2 GRADING, SORTING & SIZING

Grading, sorting, and sizing are based on soundness, firmness, cleanliness, size, weight, colour, shape, maturity, diseases, insect damage and mechanical injury. They are grouped in size. This is an important procedure to be followed in post harvest handling, before packaging storage, transport or marketing to minimize loss and maintain quality.

- **Additional operation:** Along with grading, certain additional operation which include washing, pre cooling, degreening, curing, waxing, fungicidal and other chemical treatment are also essential preparatory steps to packaging , storage transportation and subsequent marketing, washing, improves appearance, remove dirt, soil, scale insect, sooty mould, fungicide and insecticide residues. Detergent are added to water for effectiveness washing. The excess of surface water is dried by blowing heated air.
- **Pre-cooling:** Pre-cooling is done to remove field heat as high temperature is detrimental to the keeping quality of fruits and vegetables. General aims are to slow down the respiration minimize the susceptibility to micro organism and reduce water loss. Several methods used are (a) air -cooling, (b) hydro cooling- fungicides can be added in cooling water. (c) vacuums cooling- most rapid methods of pre cooling, especially, for leafy vegetables curing- certain vegetables like onion have to be cured after harvest before storage and transport marketing.
- **Degreening:** In certain cases development of ripe colour by degrading the green colours is induced usually by the treatment with ethylene under controlled temperature and humidity and O_2 and CO_2 concentration e.g. Banana, Mango, Citrus, Tomato.
- **Waxing:** (1) Waxing is done to reduce the evaporation loss of water from the fruits and vegetables thereby increasing the storage life. (2) It gives a fresh glossy appearance which improves the market value. (3)Recommended fungicides can be added to the wax to reduce the spoilage buy fungus. The wax replaces the natural protecting waxy layer which is removed by handling, washing, etc. CFTRI Mysore, has developed a wax emulsion (Waxol-123) for waxing of fruits and vegetables.

44.3 PACKAGING

Packaging is done for more efficient handling and marketing , greater appeal, more potential life. Packaging requirement vary with different fruits and vegetables. Packaging cannot improve quality. Hence only best possible produce should be packed. Inclusion of decayed or damaged produced in bulk or consumer packages may become a source of infection and reduce the sale at the market. Packaging is not a substitute for refrigeration; packaging combined with refrigeration is the best methods. A good package is aim to protection of product from physical. Physiological and pathological deterioration causes throughout storage, transport and market.

Benefits of packaging:- serves as an efficient handling units, serves as a good storage unit, protect quality and reduce waste, protect from mechanical damage and moisture loss, provide beneficial modified atmosphere, prevent pilferage, provides service and sales motivation.

Material for packaging:-wooden boxes, bamboo basket are the conventional packs. Fibre board cartoons, corrugated card boards, and several flexible plastic packaging. Materials used for packing material are (1) polyethylene (low density)-most widely used for consumer packaging ,strong considerably moisture proof , resistant to several chemicals and cheap (2) polyprophlene (3)polyvinyl chloride film (4) cellophane (5) polifilm. The emphasis is being made now to use those materials which contains less or no wood for packaging as our forest resources being exhausted fastly and is at a precarious condition.

Consumer packaging with plastic:- the original function of packaging was to contain carry and dispence products. However the use of plastic as packaging materials has allowed so much variation and versatility as to protect ,presence, process, store, measure, communicate, and display of products. Fruits and vegetables are packaged in smaller quantities in polyethylene pouches as consumer packages. In these films proper ventilation is needed to prevent moisture accumulation. Leading to rotting of the content and to relegate O_2 and CO_2 concentration inside pack. High CO_2 concentration may cause deterioration in quality of the content. Congenial modified atmosphere inside the pack would increases the storage life of the contents.

- **Pre Packaging**: Pre packaging increases the shelf life by creating modified atmosphere with an increase in concentration of CO_2 in package. L.D.P.E. films have high O_2 and CO_2 transmission rates are more durable.
- The pouch used reducing bruising facilitates inspection, reduces moisture losses and prevent dehydration. In pre packaging leaves stalk stem are washed cleaned and weight quantities are put in pouches.
- Ethylene absorbents hydrate lime may insert in packages to retard ripening process.
- A wide range of packages like gunny bags, bamboo ,woven ,grass stem basket, wooden cares, earthen pots, corrugated fibre board cartoons and rigid plastic carats are used.
- Wheat and paddy straws, banana leaves, dry grass are used as cushioning material.

44.4 STORAGE

Storage of fruits and vegetables prolongs their usefulness, it is also check market glut, provide wide selection of fruits and vegetables throughout the year, helps in orderly, marketing, increases profits to the producers and preserve the quality of the living products.

The principal aim of storage is to control rate of transpiration, respiration and disease infection and to preserve the commodity in its most usable form for consumers without proper storage, the following undesirable things may occur

1. Sprouting:- e.g. onion, ginger, garlic, potatoes etc.

2. Rooting:- e.g. sweet potato, onion etc.
3. Seed germination:-e.g. pod bearing vegetables, tomato, papaya etc.
4. Degreening:-e.g. potatoes of exposed to light, green portion contain solanin which is toxic.
5. Toughening: e.g. Green beans, bhindi etc.

44.4.1 Factors affecting storage:

i. Pre-harvested factors: climatic, cultural, and pathogenic

ii. Harvesting and handling practices: mechanical injuries

iii. Pre-cooling: an important factor prior to storage reduces P.L.W. and improves storage life.

iv. Cleanliness

v. Variety and stage of maturity at harvest - prematurely harvested mango, bananas, tomatoes will not ripe satisfactorily.

44.4.2 Storage life:

It may be prolonged by (a) proper control of post harvested diseases (b) chemical treatments (c) irradiation (d) refrigeration (e) controlled atmosphere storage.

a. Proper control of post harvest diseases:

Knowledge of the time and made of infection is essential for the development of an effective programme for diseases control. Fruits attached to the plant may be infected by direct penetration of a fungus through enticle by wounds or by natural openings. Many most harvested diseases are through injuries after harvest such as cut steams and mechanical damage to the surface in the course of handling and transporting

Cut-stem infection: e.g. crown root of banana hands, black-root of pineapple and stem end root of papaya and mango.

Post harvested diseases initiated in wound create during or after harvest may be controlled by fungicides treatment. If application can be made before pathogen has penetrated deep into the fruits.

Low temperature reduces the severity of post harvest diseases by retarding ripening and also by retarding the growth of micro-organism

Humidity more than 90% favour the development of post harvest diseases. Plastic films of low permeability and without ventilation increases post harvest diseases.

Control of post harvest diseases – the basic principles are (1) prevention (2) cure (3) delaying the appearance of symptoms and (4) retarding diseases spread more than one approach is usually required for satisfactory diseases control.

b. Chemical treatments:

Growth regulators like GA, MH, CCC, ALAR, and other chemicals like acetylene gas ethylene gas are used to regulate ripening and storage life of fruit and vegetables.

Post harvest treatment with GA markedly retards ripening and tomatoes guava, bananas and mangoes.

Malik hydrazide (MH) a growth retardant inhibits spouting of onion, potato. Ethylene, acetylene are used to hasten ripening in fruits.

c. Irradiation:

Low radiant dosage is applied to fresh fruits and vegetables to prolong their storage life. Irradiation can delay the ripening destruction of spoilage micro-organism and disinfection. It has been used successfully in retarding the sprouting of potatoes, sweet potatoes, onion. Irradiation is successful in control of fruit fly on citrus, mango seed, weevil control, papaya fruit fly control. For some fruit like mango, banana, papaya and additional advantage in the use of irradiation for disinfestations purpose is retardation of ripening. in several vegetables irradiation is not useful as it causes discoloration excessive softening, off flavour, increase decay etc.

Irradiation method is not cleared as safe to use for prolongation of shelf life of fruits and vegetables in India though its use in certain commodities like onion and potatoes is cleared in several other countries.

d. Refrigeration:

To date refrigeration is the only known economical methods for long term storage of fruits and vegetables, all the other methods of regulating ripening and deterioration are at best supplemental to refrigeration. Other methods are not worked satisfactory without refrigeration. Refrigeration requirements vary with different kinds of fruits and vegetables and their maturity stages which are standardized.

Optimum temperature for the even ripening and development of good flavor, and attractive colour of most fruits generally fall within a range of 59-79’ F. mangoes ripened at 68’F contains 20% as much sugar as these ripened at 95’F at storage temperature of about 75’F is optimum for the storage of most fruits except grapes, litchi, pomegranate, and apple which require a low temperature range 32 to 41’F. Leafy vegetables require 90% to 96% R.H. They should not be stored together with ripening fruits as ethylene is injurious to them.

Fruit and vegetables bean cucumbers, bhendi, sweet peeper, squash and tomatoes are sensitive to chilling at very low temperature. They are to be stored as 40 to 50’ F. Higher temperature cause toughening, yellowing and decay while low temperature cause pitting.

Chilling injury: A major problems in post harvest handling at low temperature which otherwise would prolong their storage life .chilling injury is a disorder induced by low, but non freezing temperature is susceptible fruits and vegetables.

(a) pitting- limes, mangoes, avocado.

(b) water-soaking – tomato

(c) smoky-appearance- banana

(d) surface discoloration- mango etc.

e. Controlled atmosphere storage:

Controlled atmosphere (CA) implies to addition or removal of gases, resulting in an atmospheric composition substantially different from normal air. CA storage is a system for holding produce in respect to the proportion of nitrogen (N_2), oxygen(O_2), or carbon dioxide (CO_2). Other gasses such as CO or ethylene are also added to the storage atmosphere. CA storage process could be the most important innovation in fruit and vegetables storage since the introduction of mechanism of refrigeration. This method, if combined with refrigeration markedly retards respiration activity and may delay softening yellowing, quality change etc.

Lesson 45. Post Harvest Practices

45.1 INTRODUCTION

The quality of fruits and vegetables can preserved after harvest if certain post harvest practises like respiration, moisture loss, diseases etc can be handled properly. Effect of these factors on quality of horticultural products is discussed here.

45.1.1 Respiration:

Fresh fruits and vegetables differ basically, not only from all other commodities, but from other perishable foods, as they are alive and carry on many life process characteristic of living things, even after harvest respiration is the most important of this process. In respiration the metabolites are broke down by oxidation and quality and the life of fruits and vegetable deteriorate. The respiration rate is good index of rate of living. Fruits and vegetables that respire fast give us the greatest handling problems as they are the most perishable. Some vegetables in order of ascending respiration rates are (1) potato, (2) cabbage, (3) peas. Fruits in order are (1) apple, (2) citrus, (3) banana, (4) peaches, (5) strawberry. Other bio-chemical changes occurring in the fruits and vegetable may cause their aging and deterioration.

45.1.2 Loss of moisture:

Loss of moisture with consequent wilting and shriveling of produce is perhaps the most obvious way in which freshness is lost. When one realizes that most fruits and vegetable are compost of from 80 to 95% shrivel so readily. The relative humidity in the intercellular spaces of most plant tissue is continuously near 100% or saturated. produce will loss moisture to the surrounding air almost any time the humidity of the air is less than saturated and thereby deteriorate.

45.1.3 Harvesting condition:

Harvesting fruits and vegetables when they are not in prime condition of maturity is another cause for deterioration in quality. Fruits and vegetables should be harvested at their optimum stage of maturity.

45.1.4 Handling:

Rough and careless harvesting and post harvest operation causing cuts, bruises and other damages is another important cause of deterioration. Fruits and vegetables are to be handling very carefully. It is said that they should be handled just like handling a new born baby and not like ‘hardware’. Physically damages have a major effect on quality and they provide entry to have a micro-organism causing deterioration and decay.

45.1.5 Post harvest diseases:

Deterioration due to decay is the greatest source of spoilage of fruits and vegetables. After harvest all fruits and vegetables covered with countless micro-organism, bacteria and mould spores. Some of which can cause decay under certain condition when added any sort of skin injury provides entry to these micro-organism causing decay into the fruits and vegetables, When these commodities are exposed to warm temperatures. Especially under humid condition, infection usually increases.

45.1.6 Pre-harvested factors: Length of storage, respiration, chemical composition, external appearance, anatomical structures, decay, taste quality and other post harvest behaviour and characteristics partly reflect certain pre harvest condition to which produce is exposed apart from variety and maturity. These pre-harvest condition may be grouped into, (a) environmental and (b) cultural factors

(a) Environmental: Temperature, relative humidity of the atmosphere, light ,soil texture, wind, elevation, and rainfall.

(b) Cultural: Mineral nutrition, soil management, pruning, thinning, chemical sprays, rootstock, density of planting, weeding, irrigation and drainage etc. These factors affect the attainment of maximum quality at the time of harvest. It is impossible, however to determined the relative contribution of each quality. Since the above factors are multifarious, some are controllable and some are not.

45.2 MATURITY STANDARD (HARVEST INDEX)

The quality of fruit and vegetables cannot be improved, but it can preserve after harvest, Good quality is obtained when harvesting is done at the proper stage of maturity. Immature fruits when harvested will give poor quality and no or erratic ripening. Similarly, Vegetables harvested early may give poor quality or poor yield. Immature tomatoes are more sensitive to physical damage, shrivelling, and decay. Delayed harvesting of fruits and vegetables reduce their quality increase their suitability to decay and hence low market value. In some cases for distance market, they are picked at mature but unripe stage thus difficulty arises in assessing the optimum maturity level for different fruits and vegetables. Maturity standard or the harvest index means standard or the fruit and vegetables if harvested should give optimum quality and yield. Often harvest indices become arbitrary and subjective. Hence the approach should be to combine several methods of assessing maturity.

(a) Visual methods: Skin colour, size, persistence of style, fullness of fruits etc.

(b) Physical means: Case of separation or abscission length, specific gravity, flavor.

(c) Chemical analysis: Solids, acids, solid to acid ratio, sugar, starch content.

(d) Computation: Days from bloom, heat units.

(e) Physiological method: Various physiological methods are described below:

1. Curing: - Under high temperature and humidity outer tissues developed wound periderm which acts an effective barrier against infection and water loss. **e.g**. potato, onion and garlic. Potatoes are held at 18’C for 2 days and then at 7-10’C for 12 days at 90% R.H.

2. Degreening:- Process of decomposing green pigment in fruits usually by applying ethylene or other similar metabolic inducers to give a fruit its characteristic colour as preferred by consumers.

- It is applicable to banana, mango, citrus and tomato.
- The best degrening temperature is 27'C.
- Higher temperature delay degreening.
- Relative humidity should be 85-90% **e.g.**ethylene kerosene.
- Higher humidity cause condensation and slower degreening.
- Lower humidity cause shriveling and peel breakdown.

3. Precooling:- Precooling is a means of removing the field heat, It slows down respiration of produce, minimizes susceptibility to attack of micro-organism, reduces water loss.

4. Washing and drying:-

- This is done to improve their appearance prevent wilting and remove micro- organism.
- Fungicides or bacteria are used in washing water.

5. Sorting and grading:-

- Immature disorder and badly bruised fruits and vegetables are sorted out.
- Grading is based on size, weight, colour and shape.

6. Waxing:-

Natural waxy layer of fruit and vegetables is properly removed by washing. Waxing means an extra discontinuous layer of wax applied artificially with sufficient thickness and consistency to prevent anaerobic condition within the fruit provides necessary protection against decay of organisms.

- It improves appearance of fruits and make more acceptable.
- It increases storage life at ambient temperatures.

Suitable fungicides should be added in wax emulsion to prevent micro-organisms.

Lesson 46. Garden Tools

46.1 INTRODUCTION

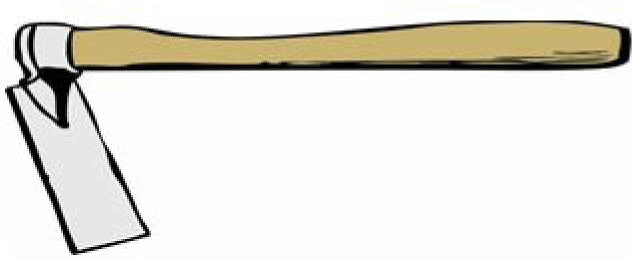
In order to an excellence output from nursery one should be careful in performing several operations in time with expertise. In day to day routine various cultural operations are carried out in the nursery. From this purpose many tools and accessories are required from time to time. Some tools are simple and used for simple operations. However, special equipments are required for specific operations some of the tools and accessories are required for different operations in the nursery are described below.

46.2 KNIVES

In general, in the nursery, two types of knives viz. budding and grafting knives are required for propagation work. A grafting knife in general has a straight 7.5cm long blade and strong long handle. The budding knife on the other hand may have a straight or a bit curved blade of shorter length. It has, however a spatula at the end of handle, which is used for lifting the bank during the budding operation. Sometimes a knife having two parallel blades (double blade knife) is also necessary. It is required for patch budding. However, very often a budding knife is used for grafting purpose also. These knives may have either a folding or fixed blade. The blades of knives should be made from high carbon steel and should always be very sharp.

46.3 KUDALI

It is an important tool for budding of pits or digging of soil. Kudali has a metal blade attached to a wooden handle. It is operated manually and considered very important nursery tool.



46.4 GARDEN FORK

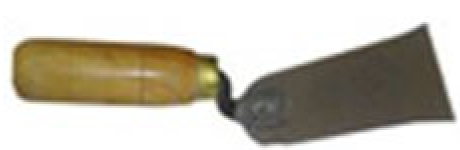
Garden fork is mainly used for breaking of soil clods during preparation of nursery beds of field.

46.5 WEEDING FORK

It loosens the soil and equally useful in weeding. It consists of a long handle with a blade having teeth. It is drawn manually with the help of handle to collect the weeds and cops of plants etc.

46.6 KHURPI

Khurpi is widely used for various cultural operations in the nursery but mainly for removal of weeds and loosening of soil for preparation aeration. It has a sharp edge triangular blade fitted with a wooden handle.



46.7 CROW BAR

It is an iron rod with one end pointed and other as wedge shaped. Crow bar is mainly used for digging of pits.

46.8 WATER CANS

Watering cans are used for irrigation for irrigation of annual flowers, vegetables and newly transplanted seedlings of various flowering annuals and vegetables or young plants in pots. These are made up of galvanized iron sheet and sometimes these are also made up to plastic. These cans are fitted with a rose over the nozzle, which is very useful for equal distribution of water over the germinating seedings.

46.9 GARDEN RAKES

Garden rakes are used for collecting stones and bricks bits from the bed, scarifying the glass surface and gathering the fallen leaves. A toothed rake is always better for such operations.

46.10 SECATEURS

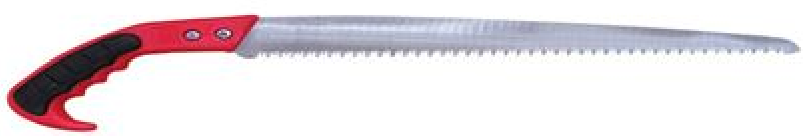
Secateurs is considered as the most important tool for a propagator or a nurseryman. Secateur is used for excising soons, lapping off the rootstock, removing the undesirable sprouts/ shoots from the stock, preparation of the scion sticks and for pruning operation. The blade of the secateurs should be of a good quality because poor quality blades may not give smooth cuts to the stocks and scion.

46.11 GRAFTING MACHINES

Many machines have been developed and commercially used for the preparation of scion sticks and bud wood for budding and grafting operations in many developed countries of the world. These machines are however, not very common in India. Grafting and budding knives are used for grafting purpose.

46.12 PRUNING SAWS

Several types of saws are required for different operations involved in preparation of horticultural plants. The commonly use are (half noon) saws, Lamp Home saws and straight saws. All off them have long and widely set teeth to facilitate pruning or cutting of a green wood. In general, a small saw is required for cutting hard branches of the stock plant and sometimes the same saw can be used for pruning also. Its blade should be narrow so that it can pass through the narrow or closely spaced branches.



46.13 PRUNING SHEARS

The different types of shears like hard shears looping shears, tree trimmers etc. are needed in a garden .Pruning shears should not be very expensive but these should be made up of good steel. Similarly these should make a smooth and clean cut with least injury to the plants.

46.14 LADDER

In preparation work ladder is required for operations like cutting of bud wood, training of vigorous plants and top working of old and declining plants. In general step ladder or straight ladders or hook ladders are used for suck operations in the propagation field.

46.15 TYPING & WRAPPING MATERIALS

In the most of the grafting and budding methods, it is essential to hold scion and stock firmly together to have successful graft/ bud union , for which , a suitable typing or wrapping material is required / Accordingly nurserymen and other propagators use different material to achieves desired results from budding and grafting.

1. **Waxed String and Cloth**: It is the most commonly used typing material by the nurserymen. It can easily be prepared by dipping narrow strip (25-30 cm wide) of long cloth in the melted bee wax. This waxed clothes strips can be use for typing the stock and scion after budding or grafting. The added advantage of using these stripes is that these eliminate the need of further waxing. Such types of wrapping material restrict the entry of water to the bud union.
2. **Waxed String**: Next to waxed cloth, waxed strings are the most commonly used typing material. It can be prepared by soaking a ball of cotton twine in a a mixture of resin (1 kg), bee wax (500 g) and linseed oil (250gms) and paraffin (120 g) for 10 to 15 minutes. This cotton ball should be rotated repeatedly while kept in the above mixture. For large scale grafting operations waxed strings is the most convenient because it adheres to plant part without typing. However, it should be strong enough to hold the grafted plant parts together and week enough to be broken by hand.
3. **Raffia Fiber**: It is a strong fiber and it not easily damaged by heat or rain. For proper working with raffia fiber, it must be moistened by wrapping it in damp cloth overnight.
4. **Rubber Strip**: Rubber strip provided better grip to the stock and scion than raffia fiber or waxed cloth. These are highly elastic and can be.

Lesson 47. Management of Orchard

Management of Orchard

47.1 Orchard Management

Careful management of orchard is essential for successful fruit growing. Main cultural practices include those for better soil management, nutrition, training and pruning, irrigation and weeding.

47.1.1 Soil Management Practices

Objectives of soil management practices are maintenance of physical condition of soil, efficient weed control, conservation of moisture level and checking of soil erosion. Various methods of soil management can be adopted to achieve these goals.

i. No cultivation: This practice is followed in orchards of various countries including USA and Australia. Orchards believe that beneficial effects of soil cultivation are confined to top layer of 10-15 cm, whereas trees have much deeper root systems. Moreover, cost of orchard maintenance can be reduced to considerable extent by this method.

ii. Clean culture: Interspaces of orchards are kept clean by frequent ploughing. This is adopted extensively in India. Clean culture has advantage of no competition for water and nutrients by weeds with main crops but has a number of disadvantages. Frequent cultivation results in soil erosion, creation of hardpan in soil, depletion of humus and nitrogen levels and injury to feeding roots of crops.

iii. Cover cropping: Growing of cover crops or green manure crops after removing weeds in orchard has many advantages, important ones being checking soil erosion and enrichment of soil. Green manure crops like Sunnhemp, Cowpea, Daincha or any legume are sown in interspaces at onset of monsoon and incorporated into soil towards end of season for better results. Permanent cover crops are also graown in certain orchards with better results. Leguminous creepers like *Calapagonium muconoides, Centrosema pubescens* and *Peuraria phaseoloides* are preferred for this purpose. These plants dry up during summer to save moisture and start growing again in rainy season to from a mat in orchard, preventing weed growth and soil erosion.

iv. Sod culture and sod much: Maintaining a permanent cover of grass in interspaces is referred to as sod culture. This practice helps in reducing soil erosion especially in sloppy areas but compete with crops for moisture and nutrients, which make additional manuring and irrigation essential in orchards. If the grass is cut frequently and spread on ground, the system is called as sod mulch.

v. Mulching: Mulching is a very important practice with a number of plus points. This helps in preventing soil erosion, reducing weed growth in turn cutting down cost of cultivation and adding organic matter to soil in many cases. Suitable materials such as straw, dried leaves, saw dust, coir dust, special types of paper and polythene sheets can be used for mulching.

vi. Intercropping: During initial years of orcharding, where fruit trees are in juvenile stage, there will be no returns from orchards. Intercropping is one of the best methods to tackle this problem. Growing intercrops not only fetches income to grower but also helps in soil management by reducing weed growth, checking erosion and enriching soil. Selection of crops for intercropping should be based on suitability and marketability. Fast growing and early fruiting crops like papaya, pineapple, banana, guava, vegetables such as brinjal, tomato, chillies and spices like ginger and turmeric can be selected based on other factors.

47.1.2 Nutritional Management

As in any other crops, growth, development and productivity of fruit plants are also highly influenced by nutrient supply. Nutrient management is a very important aspect in orcharding. Plants require supply of sixteen elements of which carbon, hydrogen and oxygen are obtained from atmosphere and need not be applied. Nitrogen, phosphorus and potassium are major / primary elements required by plants in large quantities. Secondary nutrients include calcium, magnesium and sulphur used in considerable quantities for normal growth of plants. Minor or micronutrient elements comprise of iron, zinc, manganese, copper, boron, molybdenum and chlorine which are essential for normal growth and development, but in very small quantities. Elements such as sodium, aluminium, silicon and cobalt are required in traces for some fruit species. Specific functions are performed by various nutrient elements in all metabolic activities and growth, development, productivity and quality of plants and their produces. Lack of availability in sufficient quantities of nutrients causes deficiency symptoms expressed in different ways depending on specific roles played by the elements. On the other hand, supply of nutrients in excess results in toxicity symptoms, which may affect growth and development and may lead to mortality depending on intensity.

Nutritional requirement of a crop should be assessed before going for fertilizer and manurial application. Nutrient status of soils can be determined by soil analysis. Whole plant and plant part analysis may be useful to assess nutrient status of plants. Leaves being the main site of metabolism in plants, analysis of leaves is the most reliable diagnostic method n almost all plant species. Analysis of leaves at correct stage of development indicates nutrient status of whole plant based on which nutritional requirements and deficiency symptoms can be assessed. Diagnostic leaf to be used for analysis has already been standardized for different fruit species. Details of index leaves / tissues for important tropical and subtropical fruits are as follows:

Avocado	Fifty leaves from 5-7 months old non-fruiting terminal shoots.
Banana	Petiole of third open leaf from apex at four months after planting.
Ber	Recently matured leaves from middle part of secondary or tertiary shoots with a
Citrus	Thirty leaves with petiole from new flush.
Custard apple	Fifth leaf from apex at two months after new growth with sample size of 30 nur

Fig	Twenty five fully expanded leaves from current shoots.
Grape	Petioles at fifth leaf position for forecasting yield and petioles opposite to bloom
Guava	Recently matured leaves (25) from third pairs on shoots.
Mango	4-7 months old leaves along with petiole from middle part of shoots.
Papaya	Sixth petiole from apex with a sample size of 20 numbers.
Pineapple	White basal portion of fourth leaf from apex.
Sapota	Tenth leaf from shoot apex with a sample size of 30.

Organic and inorganic manures can be used as sources of nutrient elements for fruit crops. Continuous application of inorganic fertilizers results in soil destruction, which should be avoided as far as possible. Organic manures help in improvement of soil tilth, aeration, water holding capacity and microbial activities. Commonly available organic manures include farmyard manure, compost, vermicompost, leaf mould, oil cakes, fishmeal and meat meal. Biofertilizers help in improving soil characters and plant growth and fruit quality through enhancing hormonal activities. Commonly used growth promoting organisms of biofertilizers include *Rhizobium* species, *Azospirillum, Pseudomonas* and VAM (Vesicular-arbuscular mycorrhizae). Integrated nutrient management incorporating inorganic and organic sources of nutrients, biofertilizers and other practices, which will help to maintain soil health and environment is an ideal approach in orchard management.

47.1.3 Irrigation

Requirement of water by plants differ according to climatic conditions, type of crop, type of soil, cultivation and management practices. Plant species vary in their capabilities to utilize available water or to withstand water stress. Quantity of water to be applied and frequency of irrigation should be standardized for a species under specific agro climatic conditions. Irrigation is a very important operation accounting a considerable portion of cost of production. Economic and judicious use of water for betterment of crop should be followed for successful fruit culture. Availability of water source is a primary criterion for selecting site for orchard. During establishment stage, watering is inevitable for all fruit crops. Afterwards, requirement of irrigation depends on crop nature and critical stages. For example, grape requires high moisture during flowering and berry development but needs a little stress during ripening. Banana and papaya require high moisture during growth and fruit development. Citrus needs stress to induce flowering but blooming and fruit development demand ample moisture.

Different methods of watering are available, such as surface irrigation, sub irrigation and spray / sprinkling. Where water availability is rich, surface irrigation methods can be adopted. Basin and furrow systems come under this category apart from flooding. Basin method is widely practiced in orchards all over the world, where in shallow basins are taken surrounding plant bases and water is directed towards this either by channels or houses. Furrow system is one of the best methods of irrigation in orchards. Depth, length and width of furrows depend on nature of soil and spread of root system of crops. In general, depth of furrows varies from 10 to 25 cm. In sub irrigation system, water is applied below soil surface and here, water quantity required is very high and is feasible only in soil with specific strata of an imperious lower layer, open, porous intermediate layer and a finely textured top layer with capillary action. Spray systems of irrigation indicate application of water to soil surface in the form of sprays. Overhead or sprinkler method is expensive in the installation stage but uses less quantity of water and recurring expense is also less. Since water is applied from overhead, foliage of trees also gets washed with water simulating situation of natural rains. Modified method of sprinkling system is called as 'slop' irrigation in which water is poured to drench surface soil in root zone. Installation charges are more but loss of water through evaporation, seepage and runoff is relatively negligible. Drip irrigation is a modified version of slop system. Water is directly applied to root zone through conducting pipelines inside soil. Initial cost is very high but has the advantages of checking weed growth in orchard and increasing fruit yield. Both slop and drip systems are grouped under sub surface irrigation methods.

47.1.4 Training and Pruning

Training and pruning are essential operations in successful orcharding. Training is tying, fastening, staking or supporting a plant over a trellis or pergola in a certain fashion or pruning some parts for giving plants a definite framework. Pruning is scientific removal of buds, shoots or roots to produce more and superior quality of fruits. Training methods are adopted mainly in initial years whereas; pruning is to be performed annually to regulate fruit but formation.

47.1.5 Weeding

Excessive weed growth in orchards affects growth and development of main crops. Weed growth should be controlled for better results. In clean cultivation, weeds are not allowed to grow through frequent cultivation of soil. In sod culture, controlled and selected grasses are grown in interspaces of orchards. Weeding is a routine orchard operation accounting a considerable portion of cost of production. Manual weeding is costly and availability of labour may be a problem. Use of herbicides is now being adopted for effective weed control in orchards throughout world. Herbicides can be grouped as contact chemicals, growth regulators and soil sterilants based on nature of action. Contact herbicides kill weeds soon after application and are more effective in annual weeds. Selective and non-selective herbicides are available in this category. Simazine, Diuron, EPTC, Nitrofen etc. are commonly used selective chemicals. Oil emulsions of DNBP and Pentachlorophenol are used as broad spectrum non-selective herbicides in orchards. Growth regulators such as 2,4-dichlorophenoxy acetic acid (2,4-D), 2,4,5-trichlorophenoxy acetic acid (2,4,5-T) and methyl chlorophenoxy acetic acid (MCPA) are used as effective herbicides at higher concentrations of more than 1000 ppm. Soil sterilants are herbicides used for sterilizing soil to prevent growth of weeds. According to the duration of action these may be non-residual, temporary (effective for a few months) or permanent sterilants (effective for one or two years). Based on stage of application, herbicides may be pre-emergent or post emergent ones, former types mainly being used at time of land preparation and latter types being used frequently in orchards to control weed growth, which in turn reduce cost of cultivation and increase yield per unit area.

Application of herbicides in orchards is being widely practiced at present owing to beneficial effects associated with this operation. For different fruit crops, for specific growing conditions, type of herbicides, dosage and method of application have been standardized.

Lesson 48. Extraction and Storage of Vegetable Seeds

48.1 EXTRACTION OF VEGETABLE SEEDS

The vegetable seeds are separated from the mixture having impurities by various processes as described below:

48.1.1 Separation based on weight (or specific gravity):

Cleaning seed by differences in specific gravity is one of the oldest seed cleaning techniques. When done by hand in the wind it is commonly referred to as winnowing. On the simplest scale, seed and materials are dropped before a wind source (either natural wind or a fan). The heavier materials fall closer to the wind source while lighter materials are carried further from the wind source. On a small-to-medium scale this is a very effective method to quickly clean seed. Many screen cleaners have a fan to assist in blowing off some dust and chaff.

Gravity tables are probably the most widely used machines. They separate seeds by differences in seed weight. Gravity tables operate by blowing air up through the body of the machine which holds a fine-screened, tilted "deck" on the surface. The seed is fed by a hopper and passes over the deck. The screen openings are small, so no seed or material passes through, and the screening material has a slight nap that 'holds' the seed. The air moving through the screening lifts lighter material - it then 'floats' down the deck; the heavier material remains in contact with the screening material because of the nap - it moves up the deck.

48.1.2 Cleaning wet-seeded crops:

Wet seeds are seeds that are produced in a fruit such as tomatoes, cucumbers, and squash. They are processed by crushing the fruits by hand or with a wet seed extractor. Some wet-seeded seed crops benefit from a fermentation process following the extraction. Others can simply be washed thoroughly and dried.

a. Wet processing of seed: It involves following three steps:

1. **Removal:** For seeds located inside fleshy fruits and vegetables such as squash, cucumbers, and tomatoes, wait for the fruit to fully ripen on the plant. Typically, fruit is harvested at a stage that is much more mature than the maturity at which the fruit would be harvested for eating. Wash the fruit, then break open the fruit and remove the seeds. Clean pulp residue from seed by washing or fermenting (see below).
2. **Drying:** Spread the seeds out on a tray in a warm, dry place, and let dry. Seeds should not reach temperatures over 95 F.
3. **Fermentation:** Seeds such as tomato, pepper, cucumber, and squash are typically processed by fermentation as it facilitates removing the pulp from the seed and in some cases kills certain bacterial seed borne pathogens.

b. Fermentation of wet-seeded crops: It involves following nine steps:

1. Rinse dirt and debris from fruit.

2. Mash the fruit and pour the mixture of seeds, pulp, and juice into a large container (garbage cans work well).
3. Place bucket in a location at 75-80 F (24-27 C). Ferment tomatoes for up to three days and squash for up to 2 days, depending on the ambient temperature. At 75 - 80 F, fermentation may require 42 to 72 hours.
4. Stir the fermenting mixture two or three times a day to aerate the mixture and facilitate even fermentation.
5. In two to three days a white scum may appear on the top of the mixture. This is normal and indicates that fermentation is successfully taking place. After the two- to three-day period, seed is ready to be rinsed. Pour off the top layer of scum and pulp. Pour water into the remaining mixture so that the volume is doubled.
6. Stir, allow the mix to settle again, and pour the top layer of pulp and debris off the top. Some lighter, less viable, seed may be poured off with this top layer.
7. Repeat this washing process from 3 to 6 times, until the water is fairly clear.
8. Pour the remaining contents (seed) through a large strainer retaining the seed and draining off the remaining water.
9. Spread the drained seed out onto a fine screen to dry. Fine mesh window screening works well for most seeds. Distribute the seed on thescreen so that the seed layer is as thin as possible (less than 1/4 inch). Avoid placing seed on paper, as drying seed may stick to the paper and paper may hold moisture. Stir the seed frequently to encourage even drying. If possible, place seed in front of a fan or gentle breeze to facilitate drying.

48.2 SEED STORAGE

The loss of viability impairs the biological value or function of seeds, which is to protect and nourish the living cells of the embryo, until seedling is established. The cultivator is concerned with the phenomena of seed longevity because he wants high germination and vigorous seedlings from the seed which he has planted. Nursery men concerned with seed viability to get maximum return of it. While scientist accept high longevity of this is breeding stocks and not to loose the value able material through death of seed. For all mankind it is concerned with seed longevity since the genetic material concerned in seed bank may be essential to our survival in changing ecology of this world in future.

In the tropical climates where both temperature and humidity are high, seed storage often present problem which are lacking in temperate conditions. Seed longevity is affected by several factors as follows.

1. **Seed factor**: Seed storage begins immediately after maturity regardless of where or seeds are held. Viability of seed varies with the crop and it is short lived in onion, beans, cowpea, and capsicum seeds. In heritance of seed longevity is not limited to the species but also to cultivars. Generally healthy, pulpy and well matured seed stored better than immature seed. The moisture content of the seed during storage is no doubt the most influential factor affecting their longevity. It is important to harvest mature relatively dry seeds or to reduce the moisture content of freshly harvested seed soon after harvest.
2. **Storage environment**: The storage requirements for the maintenance of viability vary for different type of seed. Storage temperature and seed moisture content are the two storage condition both relative humidity and temperature are kept low of the two seed moisture

content in relatively more than temperature. Temperature are also play in important role in of seed although it does not appear to be a controlling with normal range of biological activity of seed, insect and mold increase as temperature increase. Higher the moisture content of the seed the more they are adversely affected by the temperature. Decreasing temperature and seed moisture content there for is an effective means of maintaining seed quality in storage. Harrington (1972) stated that life of seed halves (1) for every 50°C increase in storage temperature (2) for increase in every one percent of seed moisture. This holds well between 5-14 percent of seed moisture and 0 to 50°C temperature most of the vegetable seed ideal stored at 6-7% moisture content.

3. **Storage container:** A storing of seeds in the containers made up of suitable packing material will prevent the direct contact of seed with the storage environment and this is another approach for retaining viability. The packaging materials used are paper, cotton, metal, plastic, glass and laminated foil. These are selected according to kind and amount of seeds to be packed, during of storage etc.
4. **Storage fungi:** The storage fungi comprise mainly aspergillum and pencillium spp which affects the seed storability. These fungi will grow successfully at moisture content equivalent to RH of 85% or above. Storage fungi affect the seed by decrease in germination, discoloration, production of mycotoxins, heating and total decay. Chemical treatment with fungicides prevents the attack of storage fungi.
5. **Physiological and biochemical changes in seeds during storage:** Among many physiological manifestation of seed deterioration are changed in seed colour, delayed germination, decreased tolerance to sub optimal environmental conditions during germination and storage conditions, reduced germination and seeding growth and increased number of abhoma/seedlings. Biochemical changes includes 1) increase or decrease in enzyme activity, 2) decrease in oxygen up take, 3) increase in leaching of organic and inorganic constituents from seed, 4) increase in free fatty acid, 5) decrease in total soluble sugar, 6) increase in reducing sugar and decrease in total soluble sugar, 7) decrease in protein and increase in amino acid, 8) changes in carbohydrate, organic acid and protein metabolism.

To conclude, a quality seed is required for better establishment of seeding in field as well as for higher crop production. This could be achieved through

a. Production of seed under ideal climatic and enrich soil condition

b. Supplementation of seed through seed treatment

48.2.1 Proper handling and storage of seed for higher longevity.

The proper handling and storage of seeds for higher longevity depends upon various factors namely storage temperature and relative humidity. The recommended temperature and relative humidity for storages of some vegetable seeds are listed in Table 48.1 and Table 48.2.

Table 48.1: Recommended temperature, relative humidity and approximate storage life of various vegetable seeds:

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Vegetables	Temperature (ºC)	Relative humidity (%)	Approximate Storage life
Beans: Lima in pods	40-45	95	7-8 days
Lima shelled	37	95	10-14 days
Dolichos lab in pods	32-35	90	2-3 weeks
Snap bens	38-42	95	10-14 days
Winged	32	90-95	2-3 months
Beet root	32	90-95	2-3 months
Bitter gourd	33-35	85-90	1 month
Brinjal	50-55	90-95	2-4 weeks
Cabbage, early	32	95-98	3-6 weeks
Cabbage, later	31-32	95-98	4-5 months
Carrot topped	32	95	5-6 months
Cauliflower	32-35	85-95	5-8 weeks
Celery	31-32	92-95	8 weeks
Coriander leaves	32-35	90	5 weeks
Chow-chow	52-55	90	3 weeks
Cucumber	50-55	95	10-14 days
Garlic (bulbs) dry	32	60-65	7-8 month
Ginger	55	65	5-6 months
Gourd, bottle	45	85-90	4-6 weeks
Gourd, snake	65-70	85-90	2 weeks
Green, various leafy	32	95	10-14 days
Knol, knol	33-34	90	3 months
Mushroom	32	95	1 weeks
Muskmelon, cantaloupe	35-38	85-90	10 days
Muskmelon honeydew	45	85	4-5 weeks
Okra	45-50	90-95	1-2 weeks

onion, white	34	70-75	4-5 months
onion red	32	70-75	5-6 months
pea, green	32	88-92	2-3 weeks
pepper, sweet(green)	45	85-90	3-5 weeks
potato	38-40	85	7-8 months
pumpkin	35-60	70-75	3-5 months
radish, topped	32	88-92	3-5 weeks
spinach	32	95	10-14 days
squash, summer	50	95	1 week
squash, winter	50-60	60	3-4 months
sweet potato	55	90	4-5 months
tapioca root	32-35	85	5-6 months
tomato, mature green	50-55	85-90	5-6 weeks
tomato, ripe	35-45	85-90	5-7 days
turnip	32	90-95	2-4 months
watermelon	45-60	80-90	2 weeks
yam	80	60-70	3-5 weeks

Table 48.2: Recommended temperature and relative humidity approximate storage life of fresh fruit in commercial storage.

Commodity	Temperature (ºC)	Relative Humidity (%)	Approximate storage period
Apples	30-40	90	3-8 months
Apricots	31-32	90	1-2 week
Avocados	40-55	85-90	2-4 week
Banana	56-58	90-95	-
Strawberry	32	90-95	5-7 days

Cherries	32	90-95	3-7 days
Coconuts	32-35	80-85	1-2 months
Dates	0 or 32	75 or less	6-12 months
Figs fresh	31-32	85-90	7-10 days
Grapes vinifera	30-31	90-95	3-6 months
Guavas	45-50	90	2-3 weeks
Lemons	-	85-90	1-6 months
Limes	48-50	85-90	6-8 weeks
Litchies	35	90-95	3-5 weeks
Mangos	55	85-90	2-3 weeks
Oranges	38-48	85-90	3-8 weeks
Papayas	45	85-90	1-3 weeks
Peaches	31-32	90	2-4 weeks
Pears	29-31	90-95	2-7 months
Pineapples	45-55	85-90	2-4 weeks
Pomegranates	32	90	2-4 weeks