College of Agriculture

Swami Keshwanand Rajasthan Agricultural University, Bikaner

Course No: AGRON 111

Course Title: Fundamentals of Agronomy

Credit Hours: 4(3+1)

Dr. Amit Kumawat
Assistant Professor
Department of Agronomy,
College of Agriculture,
SKRAU, Bikaner.

Agriculture

Term agriculture is derived from two latin words “ager” or “agri” meaning soil and “cultura” meaning “cultivation”. Agriculture is a very broad term encompassing all aspects of crop production, livestock forming, fisheries, forestry etc.

Agriculture is a productive unit where the gifts of nature like land, water and temperature are integrated into a single primary unit i.e. crop plant which is indispensible for human beings. The secondary productive units of agriculture are animals including livestock, birds and insects which feed on the primary units and productive concentrated products such as meat, milk, wool, eggs, honey, silks etc.

Importance of Agriculture

1. Agriculture provides foods, feed, fibre, fuel, furniture and raw materials.
2. Agriculture is the backbone of Indian economy as it provides employment for nearly 65% of Indian population.
3. It helps the nation to earn and conserve a greater amount of foreign exchange and to build up national economy.
4. Agriculture helps to elevate the community consisting of different castes and communities to better social, cultural, political and economical life.
5. Agriculture maintains a biological equilibrium in nature.
6. Agriculture helps to meet the basic needs of humans and their civilization by providing food, shelter, clothing, medicines and recreation.
7. Agriculture production brings peace, prosperity, harmony, health and wealth to individuals of a nation.

Agronomy

The term agronomy derived from two Greek words “agros” and “nomos”. Agros means “field” and Nomos means “to manage”.

Agronomy is a branch of agriculture science which deals with principals and practices of soil, water and crop management.

Scope of Agronomy

1. Yield maximization with introduction of new cultivars or high yielding varieties.
2. Reduced cost of production due to proper crop mgt.
3. Better water use efficiency due to agronomic knowledge.
4. Special tillage and intercultural operations for better crop growth and maximizing harvest index.
5. Appropriate soil fertility management can increase crop yields with lesser use of fertilizer.
6. Reduced post harvest loss due to agronomic knowledge and practices.
7. Intensive cropping patterns and integrated farming systems for sustainable agricultural growth and increased food production per unit area.

Seed

Seed may be defined as a fertilized ovule consisting of intact embryo, stored food and seed coat which is viable and has a capacity to germinate.

Type of seed-

(1) **Breeder/Nucleus seed**- Such seeds are produced directly under the supervision of plant breeder and possessed all the required genetic character. Such seeds have high genetic value and are costly due to very little quantity. Breeder seed is used to produce foundation seed. Golden or Yellow tag.

(2) **Foundation seed** - Produced from breeder seed and source of all other certified seed classes directly or through registered seed. It is also known as mother seed. Produced on government farms, experimental stations, agriculture universities under the supervision of NSC. White tag.

(3) **Registered seed**- Produced from foundation seed or registered seed itself. Parent of certified seed. It has satisfactory genetic identity and purity and usually produced by progressive farmers under supervision of SSC. Purple tag.

(4) **Certified seed** - Progeny of RS, FS or CS itself. It has satisfactory genetic purity and identity. It is available for general distribution to farmers for commercial crop production. Blue tag.

Dormancy

Dormancy is the rest period of a seed in which it does not germinate. Or It is a state of inhibited growth of seed or other plant organ as a result of internal causes.

Types of dormancy-

Innate- It refers to the seed dormancy when the seeds are attached to the parent plant. Such dormancy may be due to physiologically immature embryos, rudimentary embryos or mechanically resistant seed coats to water and air. This dormancy may be for few weeks or few years.

Induced- Such dormancy may occur due to physiological changes or inadequate climatic conditions like water logging, low oxygen, pressure, increased CO_2 content in soil, cold temperature. This dormancy is also called environmental dormancy.

Enforced- Some seeds may achieve dormancy due to interaction of seed with environment or due to deeper placement of seed (5 cm). Such dormancy may continue even after the removal of seed from such environment.

Viability of seed- Viability is the capacity of seed to germinate or to maintain its normal life process and capacity of growing.

Breaking dormancy

1. **Scarification –** The process of breaking, scratching or softening the seed coat to make them permeable to water and gas is known as scarification. The scarification should be done in such a way that the embryo is not injured. Sometimes mineral acids like HCL, H_2SO_4 etc are used.
2. **Hot water treatment-** Seed are dropped in water of 75^o to 100^o C. The volume of water has to be four to five times the volume of seed. The seed is soaked in the gradually cooling water for 12 to 24 hour.
3. **Acid treatment-** Acid scarification is usually done with concentrated sulphuric acid. Dry seeds are placed in containers and conc. H_2SO_4 twice the volume of seed is added. The acid treated seeds can be sown immediately or dried and stored for subsequent use.
4. **Leaching-** The purpose of leaching is to remove germination inhibitors by soaking seeds in running water or placing them in frequent changes of water. The length of leaching time is 12 to 24 hour.
5. **Hormonal treatment –** Treating the seeds with gibberillic acid (GA_3) breaks the dormancy of seeds. Concentration is 500 ppm and duration of soaking is 12 hr. Cytokinins and ethylenes are also used.

Seed Treatment - Besides breaking seed dormancy seed treatment is also done before sowing the seeds for following purposes:

(1) To protect from seed borne diseases, insect pest.
(2) To promote germination
(3) To hasten nitrogen fixation capacity in pulses.
(4) For easy sowing.

1. Physical Treatment

(A) Hot water treatment – seeds are kept in hot water at a certain temperature for certain period. Later on, after cooling in cold water such seeds are dried in shade.

(B) Solar Treatment- After soaking the seeds in water for some hours, seed are dried in sun in the month of may-June by keeping on cemented floor.

2. Chemical Treatment – Different fungicides like captan, thiram, carbendizm etc. are used for seed treatment.

3. Seed inoculation in legumes- Before sowing the legume crops in field, the legume seeds are to be inoculated with *Rhizobium* culture.

Sowing – Sowing is placement of seed in the seedbed at appropriate depth where the soil environment is aided for optimum germination and crop establishment.

Methods of sowing-

(1) **Broadcasting-** Seeds are spread uniformly over well prepared land and is covered by ploughing or planking. It is the most primitive method of sowing crops.

(2) **Drilling-** In this method crops can be sown in lines with seed drills. Drilling or line sowing facilitates uniform depth of sowing resulting in uniform crop stand.

(3) **Planting-** When individual seed or seeds material is placed in the soil by manual labour or by machine is called planting.

(4) **Transplanting-** In this method the seeds are sown in a small area called nursery and all the care is taken to raise seedlings. When they grow to certain stage, they are pulled out from nursery and transplanted in the main field.

(5) **Dibbling-** Seeds are placed in furrow, pit or hole at predetermined spacing with dibbler.

Sowing depth

Sowing depth is important aspect for establishing a good crop stand. Uneven depth of sowing results in uneven crop stand. The optimum depth of sowing depends on size of seed, coleoptile length and soil moisture. Crops with bigger size like groundnut, caster, sunflower etc. can be sown even up to a depth of 6 cm. Small sized seeds like tobacco have to be sown as shallow possible.

The thumb rule is to sow seeds to a depth approximately 3 to 4 times of their diameter. The optimum depth of sowing for most of the field crops ranges between 3 to 5 cm. Shallow depth of planting 2 to 3 cm is used for small seeds like pearlmillet.

Plant Density

Plant density is defined as the number of individuals of a given species that occurs within a given sample unit or study area.

Crop Geometry

Crops geometry refers to the shape of the space available for individual plants. It influences crop yield through its influence on light interception, rooting pattern and moisture extraction pattern. Crops geometry is altered by changing inter and intra-raw spacing.

Plant Population

Plant population is defined as the total number of plants present at unit area of land while plant spacing is the arrangement of plants on an area.

The yield of crop is directly influenced by population of plant. Actually the yield of a crop is the end result of find plant population which is influenced by the number of viable seed germination and survival rate. The plant population should not so much high that can drain out most of the moisture from the field before the crop reaches to maturity stage. As well as population should not too low that moisture remain unutilized.

Plant population of different crops:

Crop	Plant Population(ha^{-1})
Maize	60 – 75000 plants
Sorghum	180000 – 200000
Bajra	175000 – 200000
Arhar	50 – 75000
Cotton	50 – 80000
Sugar beat	80000 - 100000

Tillage

Tillage may be defined as physical manipulation of soil with tools and implements to result a good seedbed for better germination and subsequent growth of crops.

Objectives of tillage

(1) Weed control
(2) To prepare seedbed
(3) Adequate seed soil contact to permit water flow
(4) Seeding emergence
(5) Pest and pathogen free environment

Types of Tillage

(I) Preparatory Cultivation (II) After Cultivation

(I) Preparatory cultivation- Tillage operations that are carried out from the time of harvest of crop to the sowing of next crop.
Three types-

(1) Primary tillage- Primary tillage or ploughing is opening of the compact soil with the help of different ploughs. Ploughing is done mainly to open the hard soil. Primary tillage is three types-

(a) Deep ploughing- One cm of surface soil over one hectare of land weights about 1.5 t.

CRIDA classified ploughing as

5 - 6 cm	-	Shallow
15 - 20 cm	-	Medium
25 - 30 cm	-	Deep

(b) Sub-soiling- Sub-soiling is breaking the hard pan without inversion and with less disturbance of top soil. Hard pan may be present in the soil which restricts the root growth of crop.

(c) Year round tillage- Tillage operations that are carried out throughout the year. In the dry farming region.

(2) Secondary tillage- Lighter or finer operation performed on the soil after primary tillage are known as secondary tillage. Harrowing is done to a shallow depth to crush the clouds and to uproot the remaining weeds are stubbles. Generally sowing operation are also included in secondary tillage.

(3) Layout- After seedbed preparation, the field is laid out properly for irrigation and sowing or planting seedlings. These operations are crop specific.

(II) After cultivation- The tillage operations that are carried out in the standing crop are called after cultivation. It includes side dressing of fertilization, top dressing, earthing up and inter cultivation.

Modern Concept of Tillage

Recently considerable has taken place in tillage practices and severed concepts have been introduced.

Minimum Tillage-

Minimum tillage is defined as reducing the tillage operation to minimum extent for ensuring a good seed bed preparation only.

Advantages-

1. Improve soil condition due to decomposition of plant residue.
2. Higher infiltration caused due to vegetation present
3. Less resistant to root growth due to improved structure.

Disadvantages-

1. Seed germination is lower.
2. Move nitrogen is required.
3. Nodulation is affected.
4. Sowing operation are difficult with ordinary equipment.

Zero Tillage-

Zero tillage is an extreme form of minimum tillage. Primary tillage is completely avoided and secondary tillage is restricted to seedbed preparation only.

Advantages-

1. Saving of cost and labour.
2. Marginal increase in yield due to advance and timely sowing.

3. Less water used and less leaching of nitrogen.
4. Reduced soil and air erosion.
5. Eco-friendly technology.
6. Organic matter increase because of slower rate of decomposition.

Disadvantages-

1. Increase in soil density and compactness.
2. Loose residues, stubbles and weeds not compatible and interfere in sowing.
3. Require 25% more seed and fertilizer.
4. Require very precise ideal conditions, proper land leveling and optimum soil moisture.
5. The pest infestation-rodents, termites and bird damage.

Tilth

Tilth is a physical condition of soil resulting from tillage.

Characteristics of good tilth

Tilth indicates two properties of soil viz. size distribution of aggregates and friability of soil.

- Higher percent of larger aggregates (75.0 mm) are necessary for irrigated agriculture while higher percent of smaller aggregates (1-2 mm) are desirable for dry land agriculture.
- The size distribution of aggregates depends on soil types, soil moisture, and subsequent cultivation.
- Friability is that properly of soil by which the clouds when dry become more crumbly.
- A soil with good tilth is quite porous and has free drainage to water table.
- The capillary and non capillary pores should be in equal proportion so that sufficient amount of water retained in the soil as well a free air.

Growth and Development

Growth- Growth is an irreversible increase in mass or weight. Growth is physical change.

Development- Development denotes progressive or phasic change. Development is overall development of an organism.

The crop development stages are germination, emergence, seedling stage, maximum vegetative growth, flowering, fruiting, maturity and harvesting.

Factors affecting growth and development

1. **Solar radiation-** Solar radiation provides light required for seed germination, leaf expansion, flowering, fruiting and thermal conditions necessary for the physiological functions of plants. It affects the plants due to photosynthetic, photoperiodic and thermal effect. Solar radiation also influences assimilation of nutrients, dry matter accumulation etc.

2. **Temperature-** For each species of plants, there are maximum and minimum limits of temperature at which growth is negligible or nil and optimum temperature at which growth is maximum. The maximum, minimum and optimum temperatures of a crop are known as cardinal temperature. The maximum and minimum temperature above or below which no germination occurs is usually within the range of 35-45^oC (max.) and 2-3^oC (Mini.).

3. **Soil moisture-** Most of the crop seeds germinate well within the moisture regime of field capacity to 50% available soil moisture. For better contact with the seed, the mean diameter of soil aggregates should be less than about one fifth of the seed.

4. **Oxygen-** Oxygen is necessary for cellular respiration in the plants. Food materials are broken down in the process of respiration and energy is released in the form of ATP molecules. This is the utilizable form of energy for the living cells. This energy is used for various activities of the cell and directly take part in the growth processes.

5. **Mineral nutrients-** Green plants require several mineral ions and other essential elements for normal growth and development. These nutrients come from the soil for manufacturing of food. Growth ceases when the nutrient supply becomes limiting.

6. **Depth of sowing-** If the seeds are sown deep, the seed may not emerge as the seed reserves may not be sufficient. Even if they just manage to come to the soil surface, the seedling may be too week to survive.

7. **Seedling growth-** The early stage of vegetative growth can be called as seedling stage. During seedling stage, there is no competition for light, nutrients and moisture among them. Leaf and roots are components that are growing at this stage. Once the passes through the seedling stage, the possibility of reduction in number of plants per unit area is far less.

Difference between growth and development

	Growth	**Development**
1	Growth is change of physical aspects of the organism	Development is overall changes or progressive change of the organism
2	Growth is cellular	Development is organizational
3	Growth is the change in shape, form structure and size of the body	Development is structural change and progress of the body
4	Growth is quantitative	Development is quantitative as well as qualitative
5	Growth is for limited period or maturation	Development takes place till death
6	Growth can be measured	Development can be observed by matured behavior
7	Growth is a part of development	Development also include growth

Germination- Germination refers to the process by which an organism grows from a seed or seed material.

Epigeal germination- The germination in which the cotyledons are brought out of the soil by curved elongation of hypocotyls or emerge out of the soil.

Hypogeal germination- The germination in which the cotyledons remains in the soil.

Kharif pulses – Epigeal except Arhar

Rabi pulses – Hypogeal except Rajmah

Ideotype- Ideotype is a biological model which is expected to perform or behave in a predictable manner within a defined environment. The concept of Ideotype was given by Donald in 1968.

The crop Ideotype consists of several morphological and physiological traits which contribute for enhanced yield or higher yield than currently prevalent crop cultivars. The important features of Ideotype for some crops are briefly described below:

Wheat

1. A short strong stem. It imparts lodging resistance
2. Erect leaves. Such leaves provide better arrangement for proper light distribution resulting in high photosynthesis or CO_2 fixation
3. Few small leaves. Few and small leaves reduce water loss due to transpiration
4. Larger ear. It will provide more grains per ear
5. Presence of awns. Awns contribute towards photosynthesis

Rice – Rice ideal or model plant type consist of

1. Semi dwarf stature
2. High tillering capacity
3. Short, erect, thick and highly angled leaves

Maize – In maize, higher yield were obtained from the plants consist of

1. Low tillers
2. Large cobs
3. Angled leaves for good light interaction

Barley

1. Short stature
2. Long awns
3. High harvest index
4. High biomass

Cotton

1. Short stature (90-120 cm)
2. Compact and sympodial plant habit
3. Short duration (150-165 days)

4. Responsive to high fertilizer dose
5. Resistance to insect pest and diseases
6. High physiological efficiency

Sorghum and Pearlmillet

1. Superior population performance
2. High productivity
3. High photosynthetic ability
4. Low photo respiration
5. Photo and thermo sensitivity
6. High response to nutrients
7. Resistance to insect and diseases
8. Better protein quality and quantity

Crop rotation- It may be defined as a process of growing different crops in a piece of land in a specified period of time.

Principles of crop rotation

1. The crops with tap root system should be followed by those which have a fibrous root system. This helps in proper and uniform use of nutrients from the soil.
2. Leguminous crops should be grown after non legume crops because legume fixes atmospheric nitrogen.
3. More exhaustive crops should be followed by less exhaustive crops.
4. Selection of crops should be demand based/problem based.
5. The crop of the same family should not be grown in succession because they act like alternate hosts for insect pest and diseases.
6. Under dry farming the selection of crops should be such which can tolerate the drought.
7. An ideal crop rotation is one which provides maximum employment to the family and far in labour.
8. The selection of crops should suit farmer's financial conditions.
9. The crop selected should also suit the soil and climatic conditions.

Mineral Nutrition

It may be defined as the process of absorption, translocation and assimilation of inorganic ion which is obtained from the soil and required for plant growth.

Essential elements

Plants need 16 elements for their growth and completion of life cycle. They are C, H, O, N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B, Mo and Cl.

In addition, four more elements viz. Na, Co, V and Si are absorbed by plants. All these elements are not required for all plants but all have been found essential for one plant or the other.

Criteria of essentiality

Arnon and Stout (1939) proposed criteria of essentiality which was refined by Arnon (1954).

An element is considered as essential-

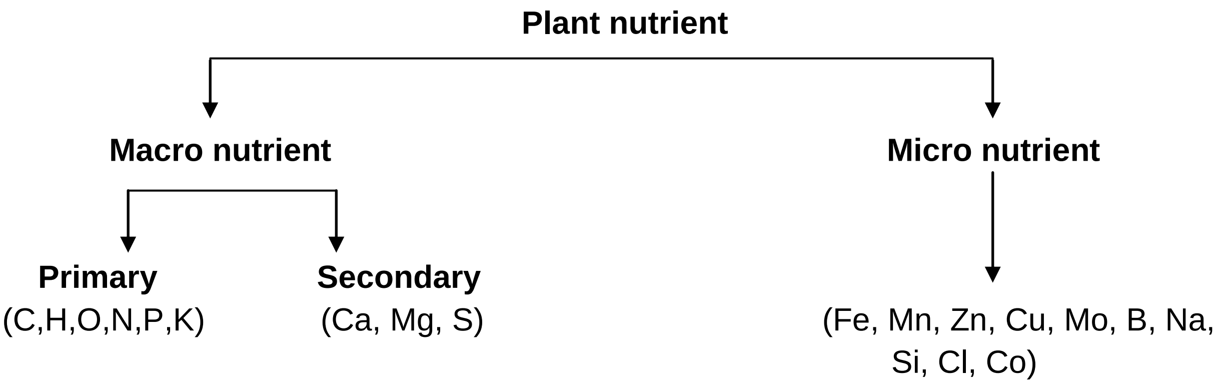
1. When plants cannot complete vegetative or reproductive stage of life cycle due to its deficiency.
2. When this deficiency can be corrected or prevented only by supplying this element.
3. When the element is directly involved in the metabolism of the plant.

Functional Nutrient

Nicholas (1961) proposed this term for any mineral element that functions in the plant metabolism whether or not its action is specific. With these criteria Na, Co, V and Si are also considered as functional nutrients in addition to 16 essential elements.

Classification of plant nutrients

The plant nutrients may be classified into macro nutrients (primary & secondary) and micro nutrients.



Nutrient Mobility in plant

Mobility of nutrient in the plants helps in finding what nutrient is deficient

1. Highly mobile - N, P, K
2. Moderate - Zn
3. Less mobile - Cl, Fe, Mn, Cu, S
4. Immobile - Ca, B

Nutrient Mobility in soil

1. Highly mobile – N, S, B, Cl, Mn
2. Less mobile – K, Ca, Mg, Cu
3. Immobile - P, Zn

- Nutrient highly mobile in plant but immobile in soil- Phosphorus
- Nutrient immobile in plant but mobile in soil- Boron

Factors affecting nutrient availability

1. Natural supply of nutrients in the soil which is closely tied up to parent material.
2. Soil p^H which affects nutrient release
3. Activity of micro organisms which play a vital role in nutrient release and fixation
4. Fertility addition in the form of commercial fertilizer, manures and green manure
5. Soil temperature, moisture and aeration
6. Presence of plants and types of cropping systems.

Deficiency symptoms

- N, P, K, Mg, Mo - Older leaves/lower leaves
- Fe, Mn, Cu, S - New leaves/upper leaves
- Zn - Older & New leaves (whole plant)
- Ca, B - Terminal/ apical bud

Symptoms appearing first or older leaves

- N - Chlorosis (Yellow veins)
- K - Necrosis on leaves margins
- Mg - Chlorosis mainly between veins (green veins) intervinal chlorosis
- Mo - Brownish, grayish, whitish spots (cereals)
- P - Redish color on green leaves or stem

Symptoms appearing first on younger leaves

- S - Chlorosis (Just similar to nitrogen)
- Fe - Chlorosis (Intervinal chlorosis) Mg=Fe
- Mn - Brownish black spot (on legumes , Potato)
- Cu - Youngest leaf has white tip

Symptoms appearing first on terminal bud

- B- Terminal bud

- Ca – Apical bud

Functions and deficiency symptoms of essential nutrients

1. **Nitrogen** – Plant contains 1-5% by weigh. NO_3 is dominant form.

Functions

1. Essential constituents of proteins, purines, pyrimidines, prophyrin ring and coenzymes.
2. Carbohydrate utilization.
3. Vegetative growths improve.
4. Chlorophyll formation.

Deficiency

1. Chlorosis or yellowing on lower (older) leaves
2. ‘V’ shape in cereals
3. Low vegetative growth

2. **Phosphorus**- Plant contains 0.1 to 0.4% which is lower than N and K.

Functions

1. Constituent of nucleic acids, phospholipids, NADP
2. RNA & DNA formation
3. ATP formation
4. Root growth and formation, energy transfer

Deficiency

1. Dark to blue green colouration of older leaves, purple colouration of leaf & leaf edge in corn & grasses
2. Accumulation of carbohydrates
3. Sickle leaf disease in cotton

3. **Potassium-** Plant contains 1-4%

Functions

1. Regulate the stomata open and closing which is essential for photosynthesis.
2. Translocation of sugar
3. Improve root growth, drought resistance and winter hardiness
4. Maintain the cytoplasmic p^H (7-8)
5. Loading prevention
6. Disease resistance in plants
7. Improve quality of fruit and vegetables

Deficiency

1. Lack of K in wet land rice greatly increases the susceptibility of foliage to disease like stem rot, sheeth blight and brown leaf spot.
2. Damage to the epical bud, stunded growth and pronounced shortening of internodes.
3. Marginal scorching of leaves, rosette (clusterd) growth
4. Luxury consumption and hidden hunger are associated with potassium

Hidden hunger (> deficiency but < adequacy)

4. Calcium – Plant contains 0.2 to 0.5 %

Functions

1. Constituent of cell wall in the form of Ca- pectate.
2. Necessary for normal mitosis
3. Cell elongation and cell division
4. Enhances uptake of NO_3 nitrogen
5. Important role in the structure and permeability of cell membrane

Deficiency

a) Hooking of leaf tips, being the most easily detected deficiency symptoms of Ca because of its immobility.
b) Physiological disorders due to Ca deficiency
   I. Blossom end rot (BER) in tomato
   II. Bitter pit of apples
   III. Tip hooking in cauliflower
   IV. Popping of groundnut
   V. Scab in potato

5. Magnesium- Plant contain 0.1 to 0.4%

Functions

1. Important in photosynthesis and CHO metabolism
2. Primary constitute of chlorophyll formation
3. Necessary for full activity of CO2 fixing enzyme viz. Rubisco and PEP carboxylase
4. Act as a phosphorus carrier ib plants.

Deficiency

1. Proportion of protein N decrease and non protein increase
2. Intervinal chlorosis of older leaves due to mobility in the plant
3. Physiological disorder- sand drawn disease in tobacco

6. Sulphur- Plant contain 0.1 to 0.4%

Functions

1. Not a constituent of chlorophyll but require for its synthesis.
2. Participate in protein structure in the form of sulphur bearing amino acids viz. cystine, cysteine and metheonine.
3. Sulphur is also a constituent of sulphur bearing vitamin- Biotin, thiamine and Co-enzyme A.
4. Required for oil formation
5. Responsible for taste and smell of onion family (Liliaceae or aleaceae).
6. Sulphur requirement increase in the order

Gramineae	<	Leguminoceae	<	Crucifereae
(0.18 – 0.19)		(0.25 – 0.30)		(1.1 – 1.7)

Deficiency

1. Unlike N deficient plant, sulphur deficient plants show chlorosis of younger leaves because of its immobility in plants
2. Tea yellow disease a physiological disorder

7. Iron- Plant contain 50 to 250 ppm

Functions

1. Play an essential role in nucleic acid metabolism.
2. Necessary for synthesis and maintenance of chlorophyll in plants.
3. Activator of nitrate reductase.

Deficiency

1. Occurs in calcarious and alkaline soils.
2. Extensive intervinal chlorosis of younger leaves due to its relative immobility.
3. Deficiency is common in citrus, deciduous fruits
4. Lime induced chlorosis.

8. Manganese- Plant contain 20 to 50 ppm

Functions

1. Essential in respiration and N-metabolism as an enzyme activator.
2. It acts as an activator of nitrate reductase.
3. Mn is also involved in oxidation of IAA, a natural auxin in plant.
4. Also involved in evolution of O_2 in photosynthesis

Deficiency

1. Appearance of chloratic or necrotic spots on interveinal areas.
2. Mn toxicity occurs on extremely acidic soils .
3. Physiological disorders-

Gray speck of oats
Phala blight of sugarcane
Marshy spot of pea
Wrinkle leaf of cotton

9. Zinc- Plant contain 25 to 50 ppm

Functions

1. Necessary for biosynthesis of IAA.
2. Zn influences tranlocation and transport of phosphorus in plants.
3. Zn increase auxin content in plant through its involvement in the synthesis of tryptophane, a precursor of auxin.

Deficiency

1. Interveinal chlorosis of middle leaves, starting at the tip and margins of leaves.
2. Smaller leaves or little leaves and shortened inter node resulting in stunted growth are characteristics of more severe zinc deficiency.
3. Physiological disorders-

Khaira disease in rice reported by Y.L. Nene (1966) in Tarai region of Uttaranchal
Little leaf of cotton
White bud of maize
Frenching of citrus
Fern leaf in potato
Mottle leaf of citrus and peas

10. Copper- Plant contain 5 to 20 ppm

Functions

1. Copper posses a Cu containing protein called plastocyanin which is essential as an electron carrier in photosynthesis.
2. Cu cann't be replaced by any other metabolic compound.
3. Lignin formation in cell wall.

Deficiency

1. Symptoms on younger leaves, white tip spot.
2. Dieback of citrus.
3. Reclamation disease of cereals.

11. Boron- Plant contain 20 ppm

Functions

1. Cell wall formation/lignifications.
2. Pollen formation.
3. Induction of Ca deficiency.
4. Pollen germination and pollen tube growth.
5. Sugar translocation/ facilitates transport of K in guard cells as well as stomatal opening.

Deficiency

1. Death of shoot tips because of its requirement in DNA synthesis.
2. Physiological disorders-
   Heart rot in sugar beat
   Cork formation in Apple
   Top sickness in tobacco
   Browning in cauliflower

12. Molybdenum- Plant contains < 1.0 ppm. Also known as ultra micro nutrient.

Functions

1. Nitrogen fixation is catalyzed by Mo containing enzyme, nirogenase.
2. Nitrate reductase activity has been used as an indicator of Mo in plants.
3. Mo involved in protein biosynthesis.
4. Mo affects the formation and viability of pollens and development of anthesis.

Deficiency

1. Mo content in nodules is 10 times more than the leaves of legumes.
2. Physiological disorders-
   Whiptail in cauliflower
   Scale in legumes

Manures

The word manure has been derived from the French word ‘Manoeuvrer’ which means ‘to work with soil’.

It may be defined as those substances which are organic in nature, capable of supplying the plant nutrients in available form, bulky in nature, having low analytical value and no definite composition and most of them are obtained from animal and plant waste products are called as manures.

Role of organic manure in improving soil productivity

1. It influences on the soil colour. Due to the presence of adequate amount of organic matter into the soil, the colour of soil will be brown to dark brown or even black.
2. It helps in soil aggregation which makes a porous, open and granular condition of soil.
3. The rate of infiltration and percolation of water is increased by the applied organic matter in soil.
4. Water holding capacity of soil is increased.
5. It reduces plasticity, cohesion, stickiness etc in soil.
6. It increases the ability of the soil to resist erosion.
7. It affects mainly bulk density of the soil by making soil porosity favorable.
8. It serves as a source of energy for micro and macro organisms.
9. During decomposition of organic carbon various organic acids and CO_2 is evolved into the soil which helps to reduce the alkalinity of soil.

Farm Yard manure- it may be defined as it is a bulky organic manure having a mixture of both solid and liquid excreta of farm animals along with litter and left over material from roughages and fodder to the cattle called as FYM.

Components of FYM

1. **Dung-** It is obtained from livestock like cow, buffalo, goat, sheep and other animals like horse etc. It is an excreta given out by the animals after digestion process is over which consisting of about 70-80 % water and 20-30 % of undigested organic materials like fibre, lignin, fat, starch, cellulose etc. It also consist of fatty acids, alkalies and small amount of phosphates, Mg & Ca. However, the dung composition varies greatly according to age of animals, types of animals and purpose for which they are used.

2. **Urine-** It is a byproduct of animal obtained during metabolic process and usually contains urea, uric acid and hippuric acid in large quantity along with other mineral matter like NaCl, sulphates of Ca and Mg. The sheep urine have highest quantity of nutrients as compared to that of livestocks through cows, buffalos and bullocks give out more urine.

3. **Animal litter-** It is the plant refuse used to provide bedding for farm animals. Besides giving comfort and keeping the animal clean, it absorb the dung and urine. Straw, hay etc are used as a litter.

Chemical composition of FYM

Component	Percentage (%)
Nitrogen	0.5
Phosphorus	0.25
Potassium	0.5

Effect of FYM on soil

1. It pulverizes soil and improves soil structure.
2. It improves aeration in heavy soils and increase aggregation of soil particles.
3. It produces organic acid which neutralize salts and thereby buffers soil reaction.
4. It improves water holding capacity of soil.
5. It has high cation exchange capacity (CEC).
6. It provides food and energy to beneficial micro-organisms.

7. It improves soil aggregation and thereby checks soil erosion.

8. Soil supplied with FYM becomes darker in colour which absorbed more heat from sunlight and reduces cold injury to plants.

9. It provides food to earthworm and increases their population for soil fertility.

10. It reduces soil pollution.

Compost- It may be defined as it is a biological process in which aerobic and anaerobic forms of micro-organisms decompose organic matter, farm or town waste and lowers the C:N ratio of the refuse without using urine and dung of farm animal is called compost.

Types of compost

1. Rural/village compost- This type of compost is prepared from farm waste products eg straw, crop stubbles, crop residue etc. This type of compost contain 0.4 – 0.8 % N, 0.3 -0.6 % P_2O_5 and 0.7 – 1.0 % K_2O.

2. Urban/Town compost- This type of compost is prepared from town waste and night soil and contain 1-2 % N, 1.0 P_2O_5 % and 1.5 % K_2O.

Night soil- It may be defined as it is a human excreta both solid and liquid containing 5.5 % N, 4.0 P_2O_5 % and 2.0 % K_2O are called night soil.

Sewage and sludge- It may be defined as it is a modern method of sanitation in which water is used for removal of human excreta and other waste in cities are called as sewage system. Generally sewage has two components-

(1) Solid portion - Sludge
(2) Liquid portion - Sewage water

Sludge contains 1.5 – 3.5 % N, 0.75 - 4.0 % P_2O_5 and 0.3 - 0.6 % K_2O. Sewage and sludge can profitably be used as organic manure for producing crops and as starter in the compost.

Green manuring- It may be defined as it is a practice of ploughing or turning the green plant tissues into the soil for the purpose of improving physical structure as well as fertility status of the soil called as green manuring.

For example *Crotolaria juncea* (2.3 % N, 0.5 % P_2O_5 and 1.8 % K_2O)

Sesbania aculata (3.5 % N, 0.6 % P_2O_5 and 1.2 % K_2O)

Types of green manuring

1. Green manuring in situ- In this case, green manure crops are grown and buried in the same field which is to be green manured either as a pure crop or as inter crop. For ex. *Crotolaria juncea, Sesbania aculata, Phaseolus trilobus, Cyamopsis tetragonoloba*. This method is commonly adopted in north Indian soils

2. Green leaf manuring- In this case, turning of green leaves and tender green twigs into the soil collected from shrubs and trees grown on bunds, waste lands and nearby forest areas. For ex. *Glyricidia maculate, Sesbania speciosa, Pongamia pinnata*. This method is usually followed in eastern and central Indian soils.

Advantages of green manuring

1. It increases the organic matter content of the soil.
2. It helps in returning the different plant nutrients to the surface soil layer from sub surface soil layer.
3. It improves the soil structure, aeration status, permeability and infiltration capacity of the soil.
4. It reduces soil loss by runoff and erosion.
5. It helps in better growth to the next crop as it has residual effect in relation to supply of nutrients.

Disadvantages of green manuring

1. Under rainfed condition, proper decomposition of green manure crop and satisfactory germination of succeeding crop may not be possible if sufficient rainfall is not occur. Mostly in wheat growing region.
2. Green manuring for wheat is not economical.
3. The cost of green manure crops may be more than the cost of commercial fertilizer.
4. An increase of insect-pest and diseases is possible.

Sheep/Goat manure- It may be defined as the manure obtained from the droppings of sheep and goats and contains 3.0 % N, 1.0 % P_2O_5 and 2.0 % K_2O are called as sheep or goat manure.

Poultry manure- It may be defined as the manure obtained from the droppings of poultry. It contains higher nutrients as compared to other bulky organic manures. The average nutrient content is 3.0 % N, 2.6 % P_2O_5 and 1.4 % K_2O.

Concentrated organic manure- Concentrated organic manure have higher nutrient content than bulky organic manures. The important concentrated organic manures are oil cakes, blood meal, bone meal and fish meal.

Oil cakes- It may be defined as it is a form of concentrated organic manure that are organic in nature, containing higher percentage of major plant nutrients and are the by-products of oil seed crops are called as oil cakes.

These oil cakes can be grouped into two classes- Edible and Non-edible oil cakes.

Name of oil cakes	**Percentage composition**		
	N	**P_2O_5**	**K_2O**
(A) Non-edible cakes			
1. Castor cake	4.3	1.8	1.3
2. Mahua cake	2.5	0.8	1.8
3. Neem cake	5.2	1.0	1.4
4. Karanj cake	3.9	0.9	1.2
(B) Edible cakes			
1. Coconut cake	3.0	1.9	1.8
2. Groundnut cake	7.3	1.5	1.3
3. Linseed cake	4.9	1.4	1.3
4. Sesamum cake	6.2	2.0	1.2
5. Mustard cake	5.2	1.8	1.2

Fertilizers- It may be defined as materials having definite chemical composition with a higher analytical value and capable of supplying plant nutrients in available forms.

Complete fertilizer- Those fertilizers which contains all three major nutrients. *i.e*. N,P and K.

In-complete fertilizer- Those fertilizers which lacks any one of three major nutrients.

Straight fertilizer- Those fertilizers which contains only one primary or major nutrient. Ex. Urea, Ammonium sulphate.

Mixed/Compound fertilizer- Those fertilizers which contain more than one primary or major nutrients by chemical reactions.

Nitrogenous fertilizers- It may be defined as those fertilizers that are sold for their nitrogen content and are manufactured on a commercial scale called as nitrogenous fertilizers.

Classification

- Nitrate fertilizer
- Ammonium fertilizer
- Nitrate and Ammonium fertilizer
- Amide fertilizer
- Slow release N-fertilizer

1. Nitrate fertilizers- In these fertilizers nitrogen is combined in NO_3^- form.

Ex. Sodium nitrate - 16 % N

Calcium nitrate - 15.5 % N

Characteristics of nitrate group

1. These are obtained both as natural products and as manufactured products from synthetic ammonia.
2. They are quickly dissociated in soil solution and release NO_3^- ion.
3. Most of the crop takes N in NO_3^- form except paddy which takes N in NH_4^+ form.
4. These fertilizers are used as top and side dressing.
5. These are basic in residual effect.
6. They play important role in reducing soil acidity.
7. Readily absorbed by the crop.
8. On dry soils, these fertilizers are superior to the other forms of N fertilizer.

2. Ammonium fertilizers- In these fertilizers nitrogen is combined in NH_4^+ form.

Ex. Ammonium sulphate - 20 % N

Ammonium phosphate - 20 % N + 20 % P_2O_5

Ammonium chloride - 24 - 26 % N

Anhydrous ammonia - 82 % N

Ammonia solution - 20 – 25 % N

Characteristics of ammonium group

1. Readily soluble in water.
2. Less rapidly utilized by the growing plants than NO_3^- N.

3. They are resistant to leaching losses.
4. NH_4^+ ion is mainly absorbed on the colloidal complexes in soil.
5. They are acidic in residual effect.

3. Nitrate and ammonium fertilizers- In these fertilizers nitrogen is combined in both NH_4^+ and NO_3^- form.

Ex. Ammonium nitrate - 33-34 % N
Calcium ammonium nitrate - 26 % N
Ammonium sulphate nitrate - 26 % N

Characteristics of nitrate and ammonium group

1. Nitrogen is present in both ammonical and nitrate form.
2. Readily soluble in water.
3. They are acidic in residual effect.

4. Amide fertilizers- In these fertilizers nitrogen is combined in amide form.

Ex. Urea - 46 % N
Calcium cyanimide - 21 % N

Characteristics of amide group

1. These are carbon containing compounds so they are organic fertilizer.
2. Readily soluble in water.
3. In soil they are quickly changed into ammonical nitrogen and then nitrate form.

5. Slow release nitrogenous fertilizers- It may be defined as those fertilizers with relatively slow availability have been developed which may supply nitrogen over an expanded period of time to suit water logged condition and long duration crops are called as slow release nitrogenous fertilizers.

Ex. Sulphur coated urea - 36-40 % N
Urea formaldehyde - 38 % N
Isobutylidine di urea (IBDU) - 32 % N
Crotonilidine diurea (CDU) - 32 % N
Oxamide - 31.8 % N
N-lignin - 18 % N
Guanyl urea (GU) – 37 % N

Phosphatic fertilizers- It may be defined as those fertilizers that are sold or used for their phosphorus content are called as phosphatic fertilizers. Phosphatic fertilizers can be grouped into three groups

1. **Water soluble-** They contain water soluble phosphorus and can be easily available to plants as HPO_4^- ions.

Ex. Single superphosphate (SSP) - 16 % P_2O_5

Double superphosphate (DSP) - 32 % P_2O_5

Triple superphosphate (TSP) - 48 % P_2O_5

2. **Citric acid soluble-** These fertilizers are not readily soluble in water and hence not readily available to plants. But these fertilizers are suitable for acidic soils.

Ex. Basic slag - 14-18 % P_2O_5

Dicalcium phosphate - 35-40 % P_2O_5

3. **Phosphatic fertilizer not soluble in water and citric acid-** These fertilizers are suitable for strongly acidic soils or organic soils.

Ex. Rock phosphate - 20-40 % P_2O_5

Raw bone meal - 20-25 % P_2O_5

Potassic fertilizers- It may be defined as those fertilizers that are used for their potassium content are called as potassic fertilizers.

Ex. Muriate of Potash (MOP) - 60 % K_2O

Sulphate of Potash (SOP) - 50 % K_2O

Conversion factors

% N	=	% NO_3	x	0.23
% P	=	% P_2O_5	x	0.43
% K	=	% K_2O	x	0.83
% NO_3	=	% N	x	4.29
% P_2O_5	=	% P	x	2.29
% K_2O	=	% K	x	1.2

Difference between manures and fertilizers

	Manures	Fertilizers
1	Manures are organic in nature	Fertilizers are inorganic in nature
2	Manures are natural substances	Fertilizers are synthetic substances
3	Low percentage of nutrients	High percentage of nutrients
4	Required in high amount	Required in low quantities
5	No definite composition	Definite composition
6	It is slowly absorbed by plants	It is quickly absorbed by plants
7	Manures provides lot of organic matter to soil	Fertilizers does not provide any organic matter to soil
8	Crop productivity is increased only to some extent	Crop productivity increased many folds by its use
9	No side effects of manures are absorbed	Chemicals in fertilizers are washed away to the nearby water bodies, causing soil and water pollution

Difference between micro and macro nutrients

	Micro nutrients	Macro nutrients
1	They are trace elements	They are major elements
2	Required in minute quantities	Required in large quantities
3	Concentration is less than 1.0 mg/g	Concentration is equal to 1.0 mg or 1000 micro gram
4	Micro nutrients are largely obtained from vegetables, fruits, cashews, eggs, all dairy products	Macro nutrients are largely obtained from beans, nuts, legumes, pulses, cereals, oil seeds etc.
5	It play a crucial role in the prevention of diseases	It play a crucial role in providing energy
6	All micro nutrients are minerals	Includes both minerals and non minerals

Integrated Nutrient Management (INM)

INM may be defined as a management system that uses all possible sources of nutrients in a compatible manner required for the crop.

Concept of INM

1. Regulated nutrient supply for optimum crop growth and higher productivity.
2. Improvement and maintenance of soil fertility.
3. No adverse effect on agro-ecosystem.
4. Availability of nutrient resources.
5. Social acceptability.
6. Ecological consideration.

Advantages of INM

1. Enhances the availability of applied as well as native soil nutrients.
2. Synchronizes the nutrient demand of the crop with nutrient supply from native and applied sources.
3. Provides balanced nutrition to crops and minimize the antagonistic effects.
4. Improves and sustain the physical, chemical and biological functioning of soil.
5. Minimizes the deterioration of soil, water and ecosystem by reducing nutrient losses to ground.

Nutrient Use Efficiency (NUE)

Nutrient use efficiency (NUE) is a measure of how well plants use the available mineral nutrients.

NUE may be defined as the yield obtained per unit of input (fertilizer, nutrient) supplied

$$\text{NUE (kg/ha)} = \frac{\text{Yield}}{\text{Nutrient supply}}$$

It depends on the ability to take up the nutrients from the soil, but also on transport, storage, mobilization, usages within the plant and even on the environment.

Weed- Weed is a plant growing where it is not required.

All weeds are unwanted plants but all unwanted plants may not be weeds.

JethroTull was the first person who used the term ‘weed’.

Characteristics of weeds

1. They are prolific with abundant seed production potentialities.
2. Weed seed germinate earlier, their seedlings grow faster, resist their control measures, flower earlier and mature ahead of the crop plants to which they infest.
3. Weed seeds remain dormant and viable for years together.
4. They bear very deep roots and preserve food in their rhizomes by which they resist adverse climatic, disease and soil conditions.
5. They remain alive and start growing profusely soon after getting favorable conditions resulting into severe crop weed competition.

Out of 3.00000 species of plants known into the world hardly 3000 are of economic value to us.

Harmful effects of weeds

1. Weeds reduce the crop yield and quality by competing for light, space, nutrient and water.

   In advanced countries – 5%
   In least developed countries – 25%
   In general – 10%
   Wheat- 15-30%, Rice- 30-35% and major millets, oilseeds and pulses- 18-85%.

2. They impart the quality and quantity of sheep wool by entangling hooked seeds with wool while grazing on pastures. Thus they reduce the price and marketability of the produce.

3. They act as host and thereby they intensify the problems of disease, insects and pests.

4. Weeds reduce the efficiency of farm equipments and impose problems in smooth running of agricultural operations resulting into a higher cost of cultivation.

5. Some weeds are harmful to livestock like *Halogeton* has high oxalate which cause sheep death, Johnson grass at tillering stage and *Xanthium* at its cotyledon stage are poisonous to animals due to their high prussic/ HCN content.

6. Weed menace to human health like *Rogweed* (Ambrosia sp.) pollens cause fever and asthma, *Argemonemaxicana* cause dropsy due to its high toxic alkaloid 'Sanguinarine'.

7. The aquatic weeds reduce the efficiency of irrigation and drainage system by impeding the flow of water.

Beneficial effects of weeds

1. Weeds have exhaustive root systems which offer best soil building property to resist soil erosion.

2. Several weeds of grassland serve as food for animals. Weeds like *Cynodon dactylon* and bind weed (*Convolvulus arvensis*) are good fodders for milch animals.

3. Several species are used as green manures. Weeds belonging to legume family are collected as green manures. Acquatic weeds such as *Eichhorniacrassipes* and *Pistiastratiotes* are used for composting.

4. A number of weeds have the medicinal value of great importance. *Leucasaspera* is used in snake bite. *Calotropisprocera* is a good medicine for gastric troubles. *Phyllanthusniruri* is useful in treating jaundice.

5. Weeds are valued for several other economic benefits. *Cyperus rotundus* is useful for making agarbaties,*Andropogon* species is useful for manufacturing aromatic oil.

6. They remain green even under adverse climatic conditions as drought and provide enough material for cattle grazing.

7. *Chicoriumintybus* roots is utilized to flavor coffee powder.

Classification of weeds

(A) According to ontogeny/ life cycle

1. **Annuals**- Complete its life cycle in one year, preferably in one season.

Example- Summer annuals- *Trianthema* sp., *Setariagluaca*, *Digeraarvensis*, *Amaranthus*.

Winter annuals- *Chenopodium* sp., *Vicia* sp., *Avenafatua*, *Phalaris minor*

Ephemerals- Short lived annuals eg. *Phyllanthusniruri*

2.Biennial- Complete its life cycle in two years. In first year they remain vegetative and in second year they produce flowers and set seeds.

Example- *Chichoriumintybus*, *Daucuscarota*, *Cirsiumvulgare*, *Launia, Plantago*, *Alternanthera*.

3.Perennial- Complete its life cycle in more than two years.

Example- *Cynodondactylon*, *Agropyronrepens*, *Cyperusrotundus*, *Sorghum helepense*

(B) According to cotyledon character

1. Monocot/Narrow leaf/Grass. Example - *Phalaris minor*
2. Dicot/Broad leaf. Example - *Chenopodium* sp.

(C) According to nature of stem- According to aerial stem characters, weed may be-

1. Herb- *Chenopodium album*, *Eclyptaalba*
2. Shrub- *Abulitonindicum*
3. Bushes- *Zizyphusrotundifolia*
4. Trees- *Ficusbengalensis*

(D) According to association

1.Season bound weeds- Grow in specific season of year with regard to the crop species cultivated. Ex. Kharif weeds, Rabi weeds

2.Crop bound weeds- Those species of weeds which usually parasitize the host plant or crop.

Ex.Dodder (*Cuscuta* sp.)- Total stem parasite
Loranthus (*Dendroptheae* sp.)- Partial stem parasite
Broom rape (*Orobanche* sp.)- Total root parasite
Witch weed (*Striga* sp.)- Partial root parasite

3. Crop associated weeds-

(a) **Need for specific microclimate**- *Chicory* and *Coronopusdidymus* (Swine cress) require for their best growth in shady, cool and moist habitat which is amply available in crop like lucern and barseem.

(b) **Mimicry**- Wild rice *i.e*. *Oryzasativafatua* in paddy and wild oat *i.e*. *Avenafatua* and Canary grass (*Phalaris minor*) in small grain crops survive because of their similarity in morphology in host crop.

(c) **Ready contamination of crop seeds**- *Allium* species*i.e*. wild onion and wild garlic and *Phalaris minor*mature their seeds at the same height and time as the winter grains and thus they easily contaminate crop seeds at harvest time.

(E) According to habitat-

1. Crop land weeds
2. Fallow land weeds
3. Grassland, Pasture or Range land weeds
4. Non crop land weeds
5. Aquatic weeds
6. Forest and woodland weeds
7. Lawn and garden weeds
8. Plantation weeds

(F) According to origin of weeds-

1. Native weeds
2. Introduced or alien weeds

Weed species	**Probable origin**
Lantana camera	Central America
Eichhorniacrassipus	Brazil or Tropical America
Orobanchae	Europe
Cyprus rotundus	Eurasia
Opuntia sp.	South America

(G) According to soils-

1. Acidophiles- *Rumexacetosella, Pteridium* sp.
2. Basilophiles- Chenopodiummurel
3. Neutrophiles- Most of the weeds

Facultative weed: Also known as Apophytes. Those weed species that grow primarily in wild communities but often escape to cultivated fields. Example -*Opuntia* sp.

Obligate weed: Those weeds that occur only in cultivated or otherwise in distributed land.Ex. Field bind weed

Noxious weed: According to weed science society of America noxious weed is a plant being especially undesirable, troublesome and difficult to control. Ex*Cyperusrotundus*, *Orobanche*, *Eichhornia*, *Saccharum*, *Imperata*, *Lantana*, *Parthenium*, *Cynodon* etc.

Objectionable weed: A noxious weed whose seeds are difficult to separate once mixed with crop seeds.

Satellite weed: The weeds that mature at the same time and height as host plant or crop and have similar size and shape of their seed as the crop seed are called satellite weed. It is a Permanent Character rather than mimicry. Ex. *Avenafatua, Phalaris minor, Chichory, Cuscuta*.

Absolute weed: - These are the plants which are undesirable regardless of time and place and always weed.

Relative weed: - The presence of other crop plants in a main crop field.Ex. Barley plant in wheat field.

Rogue weed: - Weeds which are not true to type.Ex. Kalyansona in Raj 3077 fields.

Reproduction of weeds: - Reproduction in weeds carried out through seeds or by vegetative plopagulas.

Reproduction through seeds:

The majority of weeds reproduce by seeds particularly in the annual and biennial species. Such weeds are capable of producing thousand of seeds per plant in every season. In case of perennial species, the viable seed production facility is limited like in *Cyperus rotundus* and *Cynodon dactylon* which produce only 40-170 seeds per plant. However, some perennial weeds like *Sorghum halepense* and *Saccharumspontaneum* produce thousands of seeds per plant every year.

Prolific Seed Production-

Weed	Seeds/Plant	Weed	Seeds/Plant
Amaranthus	1,96,000	*Elusineindica*	41,200

Portulaca	1,93,000	*Cuscuta*	16,000
Chenopodium	72,000	*Datura*	13,900
Brassica Kaber	58,000	*Cynodon dactylon*	170

Reproduction through vegetative plopagulas:

Vegetative reproduction of weeds is either through stem and root fragments which grow into new plants. These may be in the form of rhizomes, root stocks, runners, stolons, suckers, offsets, tubers and bulbs etc. The vegetative reproduction is primarily a feature of perennial weeds which employ one or more plopagulas.

Vegetative Parts	**Weeds**
Rhizomes	*Sorghum helepense*, *Saccharumspontaneum*
Stolons/Runners	*Cynodon dactylon*
Tubers	*Cyperus*
Bulbs	*Allium candeuse, Asphodelustenuifolius*

Dissemination of weeds:

Spreading of weeds (weed seed or vegetative part of weeds) from one place to another place is called dissemination of weeds or dispersal of weeds. The major ways of weed seed dispersal particularly on farmlands are as follows:

(1) Dispersal with Wind: Many weed seeds and fruits are disseminated with special organs that keep them afloat in air for considerable distance for example Pappus, Comuse, Persistant styles, balloon, wings and Censer mechanism.

(2) Dispersal with Water: Aquatic weeds disperse largely through water. They may drift either as whole plants, plant fragments or as seeds with the water currents. Terrestrial farm weed seeds also frequently disperse through water in irrigation and drainage channels down the stream. It has been observed that weed seed remain viable even they are stored in water for 3-5 years. Water also breaks the dormancy of seeds and increases the germination percentage.

(3) Dispersal with animals and birds: Many weed fruits is eaten by birds and animals. Depending upon the digestion mechanism of the animals and the nature of weed species about 0.2 to 9.6% of the ingested weed seeds are passed in viable form with the animals excreta, which is dropped wherever the animal moves. This mechanism of weed dispersal is called "Endozoochory".Chicks digest weed seeds most efficiently. Dissemination of lantana seeds is chiefly through two birds - The Indian Myna and Chinese turtle dove.

Parasitic Loranthus seeds stick to beaks of birds and are transferred to new branches of the trees. Farm animals carry weed seeds and fruits on their skin, hair and hooves. This is aided by special appendages, such as hooks (*Xanthium strumarium*), stiff hair (*Cenchrus* sp.) and Sharp spines (*Tibullus terrestris*) etc.

(4) Dispersal with Man: Careless acts of man are greatly responsible for dispersal of weeds.For example when farm machinery is carried from one field to another without proper cleaning. It carries numerous weed seeds with it. Weed seeds and fruits are carried on wheels of cars, automobile and even aeroplain.

(5) Dispersal with Silage, Dung and FYM: FYM can be an important source of dissemination of weeds since viable weed seeds are present in the dung of farm animals.

Harmon &Kein (1934) found that even under optimum temperature and acidity conditions of compost pit, *Convolvulus* seeds retained viable to the extent of 4% in the first month of composting and up to 1% in two months later.Four months of proper composting devitalized (dead)all weed seeds.

Ecology of weeds: Weed ecology is the inter relationship between weed and environment. Weed ecology is concerned with growth characteristics and adaptations that enable them to survive the changes in environment. Environment includes climatic, edaphic and biotic factors which influence the distribution, prevalence, competing ability, behavior and survival of weeds.

Crop-Weed Competition: The population of weeds crossing over the thresh hold level increases the competition for growth factors resulting in reduction of crop production. The weeds and crops compete for common growth factors whose availability is less. In normal cases, the weed competes with the crop mainly for nutrients, water, light and CO_2 but in some instances weeds show the allelopathic effect on crops.

(1) Competition for nutrients: The nutrient concentration in weeds far exceeds the associated crop. In the beginning of the crop growth, weed absorbs excess nutrients because majority of the annual weeds compete its life cycle within 50-60 dayswhereas, the crops take 100-130days. Nutrients taken up by Maize and its associated weed viz. *Amaranthus*, *Portulaca* show that weed contain higher concentration of nutrients. In some cases weed takes up nutrients directly from the host plants. Some weeds activate denitrification ex. Nutsedge releases a type of organic scented chemical in soil which increases the population of denitrifying bacteria and thus leaves very less amount of nitrogen for the crop.

(2) Competition for water: There is a though competition between crop and weed for water in unirrigated and dry land areas. In such area scarcity of soil water is most common feature. The water uptake required to produce unit amount of dry matter is called transpiration ratio. The transpiration ratio of weed is comparatively high. The transpiration ratio of Cynodon dactylon is around 813 compared to 450 for Pearl millet and 430 for Sorghum. This indicates that more water is required to grow one tone of weeds than one tone of crop.

(3) Competition for light: Generally weeds grow faster and shade the crop plants if not checked. Weeds deplete Photosynthatically active radiation resulting in reduction in Photosynthesis and shortening the life of lower leaves. Ex. The light intensity reaching maize leaves may be around 56-63% in cloudy weather and 50-57% in sunny weather due to interference of tall plants of Sorghum helepanse. Due to Shading, the crop plants may have thin, pale green leaves with reduced number of vascular bundles and meristem cells.

(4) Competition for CO_2: Competition for Carbon dioxide may occur when the weed infestation is high. Since most of the weeds are Cu Plants, they can deplete Carbon dioxide to a very low level compared to crops. When Co_2 content is increased artificially from 350 PPM to 700 PPM, the competitive ability of C_3 crop like Soybean increased compared to its associated C_4 weed namely Sorghum helepense.

Allelopathy:-Any direct or indirect harmful effect that one plant has on another through the production of chemical compound (Secondary metabolite) that escape into the environment is known as allelopathy.

The important weed species that show allelopathic effect are *Agropyronrepens*, *Sorghomhelepense*, *LantanaCamara*, *Abutilon theophrasti*, *Cyperusrotundus*, *Euphorbia maculata*, *Ambrosia psitostachaya* etc. The extracts from the rhizomes of *Ambrosia* reduce germination and seedling growth of wheat, oats, tomato &lucern. The extraction from *Abutilon* decreased water status of soybean plants.

Two types-

(1) Autotoxy: Harmful effect to parent plants itself exhibited by *Partheniumhysterophorus*.

(2)Teletoxy: Harmful effect of one to another plant species. *Cuscuta*spp. inhibits the growth of *Eichhornia*.

- The Eucalyptus tree leaf leachate suppresses the *Cyperus* and *Cynodon*.
- Merigold (*Tegetes*spp.) and Coffesonia (*Cassia* spp.) suppress *Partheniumhysterophorus*

Weed Prevention: Weed Prevention is all the measures which deny they entry and establishment of weeds in an area.

Weed eradication: Weed eradication is complete removal of all live plant parts and seeds of a weed from an area.

Weed Control: Weed control on farmlands is the process of limiting any given weed infestation to the extent that it permits economic crop production.

Weed Management: Weed Management is a part of vegetative management in a particular area in which a systemic planning is done for handling weed population round the year, employing a combination of good crop husbandry practices, preventive measures and direct weed control methods in right proportions and at right time keeping in view the weed flora and crop biological ecosystems.

(I) Physical Method of weed Control:

It may be defined as the physical forces either manual, animal or mechanical power is used to pull out or kill the weeds is called as physical method of weed control.

(1) Hand Weeding: It may be defined as pulling out of weeds by hand or by using small hand tool is called as hand weeding. It is an effective method of weed control for most of the weeds. Two aspects are important in hand weeding (A) The number of hand weeding to be done and (B) The interval between two hand weeding.

The number of hand weedings to be done depends on crop growth, weed growth and critical period of crop-weed competition. In general the number of hand weeding range from 2-4 for most of the field crops.

The interval between two weeding depends on the quickness of weed growth which interferes with crop growth. Generally it is 15-20 days. The two hand weedingsare sufficient for most of the crops of about 100 daysduration.

(2) Hand hoeing: In this method, the entire surface soil is dug to a shallow depth with the help of hand hoes and weeds are removed. After hand hoeing, the field is subjected to drying to avoid re-establishing of uprooted weeds. Generally this method is adopted in irrigated upland crops like finger millet, pearl millet, onion etc. Though it is a costly operation, it is considered useful because it improves soil physical condition in addition to the removal of weeds.

(3) Digging: Weeds are removed by digging up to deeper layers so as to remove underground storage organs. It is very useful in the case of perennial weeds and it is done with the help of crow bars.*Cynodon dactylon* can be effectively controlled by this method.

(4) Mowing: It may be defined as the cutting of weeds to the ground level. It is usually practiced in non-cropped areas, lawn and gardens where the grass is cut to a uniform height to improve the aesthetic value. It is used to prevent the multiplication of weed seeds. The common mowing tools are sickle and lawn mower.

(5) Cutting: It may be defined as the cutting of weeds above the ground surface leaving stubbles is called as cutting. It is most common practice against the bushes and trees andis done with the help of axes and saws.

(6) Dredging and Chaining: These two physical methods are used against the aquatic weeds which growing in shallow ditches.

Removal of weeds along with their roots and rhizomes with the help of mechanical force covered in mud is called dredging.

When the floating aquatic weeds are removed by the chain is called as chaining. In this case, 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 uprooted the weeds by its rubbing action and the weed fragments float to the surface.From here they can be collected down the stream by nets and hooks.

(7) Burning and Flaming: Burning is the cheapest method of eliminating mature unwanted vegetation from un-cropped areas like range lands, field bunds, road sides, ditch banksetc. It is also used to dispose off heaped weeds. Burning is limited in its value because it is a potential source of fire hazard.

Flaming is momentary exposure of green weeds to a very high temperature of 1000^0C by the flames emanating from burning liquid petroleum gas. Flaming kills the plants by coagulating their cell protoplasm.

Flaming has proved useful in destroying dodder infested crops of lucern. In grasslands, woody shrubs and patches of perennial weeds can be destroyed by spot flaming. It is believed that repeated light application of flame to plant shoots can destroy even roots of deep perennial weeds. The process is called searing.

(8) Non- living Mulches: It may be defined as any material such as straw, sawdust, leaves, plastic film and loose soil that is spread upon the surface of the soil to protect the soil and plant roots from the effect of raindrops, soil crusting, freezing, evaporation, weeds etc. are known as non-living mulches.

Mulches may be of 2 types:

(a) Natural or Partial mulch materials

(b) Synthetic mulches

(a) Natural Mulches: Under partial mulching the weeds are stunted but not killed. Straw, hay, dry sugarcane leaves, FYM, rice hull, saw dust etc are the natural mulch material.

(b) Synthetic Mulches: In this case, the weeds are killed by cutting light to them. It is more effective than the natural mulches because it may be used over many seasons.Example of synthetic mulches is black paper, plastic and polythene films.

Black and plastic coated kraft paper mulches are now used on newly prepared field to suppress weeds.

(9) Inter cultivation: It is a very effective and cheap method of weed control in line sown crops. Most of the inter cultivation implements have a blade which cuts the weeds just below the soil surface and thus kill weeds. Some of the inter cultivation implements have tynes which open the soil and uproot the weeds.

(II) Cultural method of weed control: It may be defined as when the weed population is reduced with the help of tillage, planting, fertilizer application, irrigation practices etc. and creating favourable condition for the crop is called as cultural methods of weed control.

(1) Field Preparation: The field has to be kept free from weed.For this purpose flowering of weeds should not be allowed. This helps in prevention of buildup of weed seed population in the fields. Deepploughing in summer exposes underground parts like rhizomes and tubers of perennial and noxious weeds. In low land rice, puddling operation incorporates all the weeds in the soil.

(2) Planting Method: Sowing of clean crop seeds without weed seeds should be done. It is a preventive method against the introduction of weeds. Sowing operation with seed drill removes some of the germinating weeds. Blade harrow is run to cover the seeds. During this process all the surface soil to a depth of 2-3 cm is distributed and uprooting germinating seeds. In addition to this, due to loosening of the surface soil, it dries up quickly and does not allow weed seeds to germinate.

(3) Varieties: Short statured, erect leaved varieties permit more light as compared to tall and leafy traditional varieties. Weeds continue to germinate for long time in dwarf varieties resulting in high weed growth. However, it is not economical to reduce weed population by restoring to cultivation of tall non-responsive traditional varieties.

(4) Planting density: Generally plants of one type do not allow germination of other plants near their vicinity. It may be due to allelopathy and competition for growth factors. Closer planting of crops suppress germination and growth of weeds. Transplanting of finger millet at 10 cm x 10 cm spacing reduced one weeding as compared to 15 x 10 cm spacing.

(5) Fertilizer application: Crops like sorghum, maize, pearl millet and rice grow at a faster rate when nitrogenous fertilizers are applied and cover the soil earlier. Weeds like *Cynodon dactylon*, *Cyperus rotundus* do not respond to nitrogen application and they are suppressed by fast growing crops. If the weeds presents are also responsive to nitrogen, then this method is not suitable.

(6) Irrigation and drainage: Frequent irrigation or rain during initial stage of crop growth induces several flushes of weeds. In lowland rice where standing water is present most of the time, germination of weeds is less. Under submerged condition, tubers of *Cyperus,* rhizomes of *Cynodon* killed due to lack of oxygen.

(7) Crop rotation: It is effective in controlling crop associated and crop-bound weeds such as *Avenafatua* and *Cuscata* spp. respectively. *Avena* can be driven away from small grain fields by using pea and gram as break crops for 2-3 years. *Cuscuta* may be eliminated by turning the land to grain crops instead of lucern for sometimes.

Cirsiumarvense can be controlled by growing crops like barseem and lucern in rotations.

(8) Stale Seedbed: A stale seed bed is one where 1 to 2 flushes of weeds are destroyed before planting of any crop. These weed seedlings can be destroyed either with a contact herbicide like paraquat or by shallow non-inverting tillage implement like spike-tooth harrow, treader-packer, spring-tooth harrow, corrugated iron land roller, weeder-mulcher and scdeeps.

(9) Smother Cropping: The competitive or smother crops germinate quickly and develop their seedlings into large canopy, capable of efficient photosynthesis. The competitive crops suppress weed seedlings by excluding light beneath and utilizing large quantities of nutrients from the soil rapidly.

An important role of smother crops in agriculture is to continue suppression of perennial weeds Ex. *Convolvulus avivensis*.

(III) Biological method of weed control

Biological control of weeds involves the use of living organisms like insects, herbivorous, fish and other animals, disease organisms and competitive plants to limit weed infestation.

Bioagents: Those agents which are responsible for the biological control of weeds are called Bioagent.

Kinds of Bioagent : Six kinds of bioagents are used for controlling the weeds-

(1) Insects: Insects are most frequently used than other animals in biological weed control. The first successful attempt to employ an insect bioagent was begun in 1902 against *Lantana camara* in hawai with *Crocidosema lantana* buck moth. Alien weeds have been the main subject of bio control with insects which is imported from evolutionary centres of the weed.

(2) Carp fish: Certain fresh water carp fish consume large quantities of aquatic weeds and they are very suitable for relieving water bodies of their massive growth of noxious aquatic vegetation. Common carp *Cyprinuscarpio* and the white amur*Ctenopharyngodonidella* are promising species for aquatic weed control.

(3) Snails:*Marisa cornuarietis* and other fresh water snails have been found to feed upon several submerged aquatic weed species and algae. *Marisa* also feeds upon the roots of *Eichhornia* and *Pistia* and the leaves of *Salvinia*.

(4) Mites: *Tetranychusdesertorum* was first found useful un controlling prickly pear (*Opuntiastricta*) in Australia in 1922-23 of late gau mite *Aceriachondrillae* has shown promise against the weed *Chondrillajuncea* in Australia.

(5) Fungi:*Acacia glauca* could be controlled successfully by injecting a suspension of spores of *Cephalosporium* spp. Control of skeleton weed by introducing a rust fungus (*Pucciniachondrillina*) in Australia is another eg. of successful biological control of weeds. *Rhizoctonia* blight and zonal leaf spot have been observed to stunt the growth of water hyacinth.

(6) Competitive Plants: Certain wild plants may be highly competitive and at the same time much less harmful than some other weeds. *Panicumpurpurascens* is found competitive to *Typha* spp. in marsh lands.

There are two approaches in biological weed control-

(1) Classical approach: In this approach introduction of host specific and natural enemies are adapted to controlling exotic weeds.

S. No.	Weed	Bioagent
1	*Cyperus rotundus*	*Bactra verutana* (Moth bean)
2	*Lantana camara*	*Crocidosema lantana*
3	Aquatic weed	White amur, Chinese grasscarp (*Ctenopharyngodonidella*)
4	Prickly pear (*Opuntia* spp.)	*Cactoblastiscactorum*
5	Water hyacinth	Beetles *i.e*. *Neochatinaeichhornia*

(2) Bioherbicide approach: Bioherbicides are usually native pathogens, cultured artificially and spread just like post emergence herbicides each season on the target weed particularly in crop areas.

S. No.	Product	Content	Weed Control
1	Devine	*Phytophthorapalmivora* (Root rot in weed)	Strangler vine (*Moroniaodorata*)
2	Collego	*Colletotricumglaosporoides*	Joint vetch (*Aeschynomene* spp.)
3	Bipolaris	*Bipolarissorgicola*	Johnson grass
4	Biolophos	*Streptomyces hygroscopicus*	General vegetation

5	Product - F	*Fusariumoxysporum*	*Orobanche* in sun flower
6	Glufosinate	Similar to biolophos	General vegetation

Integrated weed management (IWM)

IWM means the integrating multiple methods to manage weeds using the combination of physical, chemical, biological and cultural methods which bring down the intensity of weed growth to economically insignificant levels with the minimum influence on environmental pollution.

A good IWM plan should be flexible enough to incorporate innovations and practical experiences of local farmers. Also, the IWM programme should be developed for the whole farm and not for just one or two fields. So it should be extended to irrigation channels, road sides and other non-crop surroundings on the farm where most weeds find their way into the crop fields.

Advantages of IWM

1) Shifts in Crop-weed competition in favour of crops.

2) Prevents weed shifts towards perennial nature.

3) Prevents weed resistance to herbicides.

4) Danger of herbicide residues in soil or plants can be minimized.

5) Minimum environmental pollution.

6) Contribute to economic crop production.

Herbicides

Herbicide may be defined as a chemical substance used to control or manipulate undesirable vegetation, especially weeds. Herbicides are extensively used in gardening, farming and landscape management.

Advantage of herbicides

1. The use of herbicides as pre plant and pre emergence treatment can control weeds, before their emergence from the soil so that crop can germinate and grow in weed free environment or with minimum competition during their tender and seedling stage. This is not possible with other methods of weed control.

2. In broadcast sowing and narrow spaced crops, herbicides prove very effective in reaching every weed. Mechanical methods are not so effective in such crops.
3. In wide spaced crops, mechanical methods are effective for controlling weeds in rows but it leaves the intra-row weeds. Herbicides reach to all places and control the weeds, *i.e*. inter row and intra row weeds.
4. Weeds with similar morphological characters like crops are escaped from mechanical method. But now herbicides are available which can kill such weeds without damaging the crop.
5. Herbicides withhold the weeds for considerable period after their application. In mechanical methods weeds tend to grow back soon.
6. Deep rooted, vegetatively propagated weeds can be controlled by using translocated herbicides. The mechanical methods like weeding or hoeing are not so effective for their control.

Limitation of herbicides

1. The use of herbicides requires technical knowledge how regarding choice of particular herbicide, time of application, safe dose method of application etc. in the particular crop.
2. Over and under dose of herbicides can make a market difference between the success or failure of weed control.
3. Certain herbicides because of their long residual effect limit the choice of next crop in the crop rotation.
4. Herbicides drifts may harm the neighboring crops. Ex. Ester from of 2,4-D may farm the neighboring crop of cotton, soybean, okra etc.
5. Herbicides use may cause environment pollution.

Classification of herbicides

(A) Based on chemistry/chemical structure

(1) Inorganic herbicides: $CuSo_4$, $FeSo_4$, Sodium arsenate etc.

(2) Organic herbicides: 18 groups

S. No.	Group	Herbicides
1	Alliphatics	Dalapan, TCA, Allyl alcohol, Acroline
2	Amides/Acetamides	Alachlor, Butachlor, Propachlor, Metachlor, Propanil
3	Arsenicals	AMA, MAA, MSMA, DSMA
4	Benzoic and Phenyl	Fenac, 2,3,6 - TBA, Chloramben, Dicamba

	Acetates	
5	Bipyridilines	Paraquat, Diquat
6	Carbamates	Barben, Propham, Chlorpropham
7	Dinitro anilines	Trifluralin, Fluchloralin, Nitralin, Pendimethalin
8	Diphenyl ethers	Nitroten, Oxyflourfen
9	Nitriles	Bromoxynil, Dichlobanil
10	Phenols	PCP, Dinoseb, DNOC
11	Phenoxy acids	2, 4-D, 2, 4, 5,-T, 2, 4-DB, MCPA, MCPB
12	Pyridazinones	Pyrazon
13	Thiocarbamates	Benthiocarb, EPTC, Diallate, Triallate
14	Triazines	Atrazine, Simazine, Propazine, Terbutryn, Metribuzine
15	Triazoles	Amitrole, Amitrole-T
16	Uracills	Bromacil, Turbacil
17	Ureas	Phenyl ureas - Monuron, Diuron, Linuron Hetrocyclicureas - Methabenzathizuron, Isoprotoron SulphonylUreas - Sulphosulfuron, Bensulphoron
18	Unclassified or Others	MH, Endothall, Glyphosate, Oxadiazon, Picloram

(B) Based on selectivity

(1)Selective herbicide: Such herbicides that kill only target weeds. Ex. 2,4-D, Atrazine, Simazine, Fluchloralin, Isoproturon, Pendimethalin etc.

(2)Non-selective herbicides: Such herbicides that kills all vegetation (crop + weed both) when comes in contact. Ex. Paraquat, Diquat and Glyphosate

(C) Based on mode of action/Translocation

(1)Systemic/Translocated herbicide: Such herbicides move within the weed either through xylem or phloeum and thus affect the whole system like photosynthesis and respiration. Ex. Propanil, 2,4-D, Atrazine, Simazine

(2)Contact herbicides: Such herbicides that kills the vegetation either crop or weed when it comes in contact. It kills the part of the plant that is in contact with herbicide. Ex. Paraquat, Diquat and Glyphosate.

(D) Based on time of application

(1)Pre-plant application: Such herbicides are applied before planting of crop in field. Ex. Fluchloralin, Alachlor

(2)Pre emergence: Such herbicides are applied before emergence of weeds. Only selective herbicides like triazines and ureas.

(3)Post emergence: Such herbicides are applied after emergence of weeds and crop also. Ex. 2,4-D, Paraquat, Diquat, Propanil, Dalapan etc.

(E) Based on Method of application

(1) Foliage: Applied to weeds after their emergence from soil. Ex. Paraquat, Diquat, Amitrol

(2) Soil applied: Such herbicides which are primarily applied to the soil. Ex. Simazine, Alachlor, Trifluralin

(3) Aquatic application: Such herbicides which are applied in water bodies. Ex. $CuSo_4$, 2, 4-D

(F) Based on residual effect

(1) Residual: Maintain their phytotoxic effect in soil for considerable time after application.Ex.2, 4-D and EPTC = 3-4 Weeks

Triazines= 1-2 Years

(2) Non-residual: Inactivated in soil immediately or within a few days after its application. Ex. Paraquat, Diquat, DSMA, Amitrole

(G) Based on Spectrum

(1) Narrow spectrum: Proves active on one or a very limited number of species. Ex. Metoxuron, diclotop

(2) Broad spectrum: Control a wide spectrum of weeds in field.

Herbicidal Selectivity

Herbicidal selectivity is the phenomenon where a chemical kills the target plant species in a mixed plant population without harming or only slightly affecting the other plants.

It is considered to be the greatest single factor that helped in the success of chemical weed control. Selectivity enables control of target weed species in spite of the presence of other plants.

The fundamental principle of herbicidal selectivity is that more toxicant reaches the site of action in active form inside target plants than in the non-target plants. This may occur due to different mechanism:

(1) Differential absorption by plants
(2) Differential translocation of herbicides
(3) Differential rates of herbicide deactivation
(4) Differential Protoplasmic resistance

Some examples of herbicide selectivity

(1) The selectivity of triazines in maize is due to presence of an enzyme Glutathione-S-transferase
(2) The selectivity of Propanil in rice is due to difference of Aryl acyl amine hydrolase enzyme of leaves
(3) The selectivity of MCPB and 2, 4-DB in legumes is due to absence of B-oxidase enzyme in legumes.

$$\text{Selectivity Index} = \frac{Max.\text{dose tolerated by crop}}{Mini.doserequiredforSatisfactoryweedcontrol}$$

Irrigation: The artificial application of water to the soil for the purpose of supplying moisture essential for plant growth. About 400 to 500 lit of water is required for 1 kg plant dry matter.

Objectives

1) To supply water for plant growth
2) To cool and warm up the soil and atmosphere there by making more favorable condition for plant growth.
3) To dilute or washout the salts is soil
4) To facilate tillage operation
5) To provide assurance about short draught crops

Sources of irrigation water in Rajasthan

(I) Canals - Canals are the most important mean of irrigation in the country. At present canals irrigate about 39% of the total irrigated area of the country. Most of the canals are found in UP and Punjab. Canals are mainly of three types-

(i) Inundiation Canal - These canals do not flow throughout the year. They obtain water only when rivers rise above a certain level during the rainy season.

(ii) Perennial Canal - It contain a steady supply of water and flow throughout the year.

(iii) Storage Canal - In the storage canal, the rain water is stored during the monsoon in large reservoirs by constructing dams across the mountain valise. This water is then distributed by canals to the neighboring areas. The canals in the dry areas of MP are of this type.

(II) Wells - Well irrigation is an important type of irrigation in India. Wells are particularly suitable for small farmers. They are also more useful than canals. Wells account for about 52% (About 28% by tube wells and 24% by open wells) of the irrigated area in the country.

Distribution -

(1) Tube wells - UP, Punjab, Bihar & Haryana

(2) Open wells - Rajasthan, MP, Gujarat and Maharashtra

Advantages of well Irrigation

(1) Ground water schemes are geographically widely distributed.

(2) It generate local employment

(3) Give higher crop yields and quick benefits

(4) It requires no submergence of land and villages.

(5) It also requires no expensive dams and carrier systems.

(6) No damage to land by water logging and salivation.

Limitations of well irrigation

(1) Due to hard rock formation tube wells are more expensive or not possible.

(2) Unregulated exploitation of ground water leading to receding water table.

(3) Life span is less than surface methods of irrigation.

(III) Tanks - Small water reservoir behind the earthen dams are called tanks. Although the primary purpose of tank is for irrigating the crops. It also provides drinking water for human beings and cattle in villages. Tanks serve to store and regulate water for crop production. In drought prone areas, tanks are considered to be a useful life saving irrigation source.

Soil moisture constants:

Water content in soil under certain standard conditions is referred to as soil moisture constants. Under field conditions water content of soil is changing constantly with time and is not static. However, the concept of soil moisture constants greatly facilitates in taking decisions in irrigation water management.

During a heavy irrigation or rain, all the macro and micro pores are filled with water. At the point when all the soil pores are filled with water, the soil is saturated or at its maximum water holding capacity. The metric potential is high, being nearly the same as pure water. Due to thick water films around soil particles, water molecules on the outer surface of the soil particles are held less tightly. The water that is moved due to gravitational force beyond the root zone depth of soil is known as gravitational water.

Field Capacity: The soil moisture content after two to three days of irrigation and after drainage of gravitational water has become very slow and moisture content relatively stable.

Term field capacity, normal moisture capacity, field carrying capacity, capillary capacity are use synonymous.

It is the upper limit of the available moisture in soil. The tension at field capacity ranges from -0.1 to -0.33. It is determined with the pressure plate apparatus.

Permanent Wilting Point (PWP): The soil moisture content at which plant can no longer obtain enough moisture to meet the requirements and remain wilted unless water is added to the soil. It is the lower limit of available water to plant. Range from -10 to -20. The average being -15 bars. Determined with pressure membrane. Sunflower is commonly use as indicator plant for PWP.

Available Water - Water held between field capacity to permanent wilting point.

Ultimate Wilting Point - The moisture content at which wilting is complete and plant die. At UWP the soil moisture tension is as high as -60 bars.

Theories of Water availability

There are three classical concept of water to the plant in available range.

(1) Constant availability: Proposed by Veihmayer and Handrickson (1927, 1949). Water is equal and uniform over the entire available range. Good for perennial spp. orchards and trees.

(2) Decreasing availability concept: Richards &Waleigh (1950). The availability of water and the rate of crop growth decreases gradually as the soil water content decrease. Good for most of forage crops and vegetative growing crops.

(3) Constant up to a certain point and decreases availability crops: Water availability and crop growth proceed uniformly from field capacity to certain critical point beyond which crop growth decreases rapidly till PWP is reached. Good for seasonal field crops and most relevant for seasonal crops.

Water requirement -

It may be defined as the quantity of water required for normal crop growth and yield under field condition and may be supplied by precipitation or by irrigation or both is called as water requirement.

W.R. = I.R. + Effective rainfall+ Stored Soil Moisture

Irrigation requirement -

It refers to the quantity of water, exclusive of effective rainfall and stored soil moisture including that from shallow water table (S) required for crop production

I.R. = W.R. - (ER + S)

Net Irrigation requirement (NIR) -

It is the amount of irrigation water requirement to bring the soil moisture in the effective root zone depth to field capacity. It is the difference between field capacity and the soil moisture content in the root zone before stating irrigation.

$$NIR = \frac{MFc - Mbi}{100} \times D_b \times D$$

M_{fc}= Moisture content at field capacity, D_b = Bulk density

M_{bi} = Moisture content before irrigation, D = Depth of soil

Gross irrigation requirement (GIR) -

It is the NIR inclusive the losses applied through irrigation is termed as gross irrigation requirement.

GIR = NIR+ Losses

Seasonal Consumptive Use -

The total amount of water used in ET and metabolic activities by a crop during the entire growing season is called seasonal consumptive use. It is expressed as depth of water (cm or mm) or volume of water (ha cm or ha mm)

Factors affecting water requirement

(1) Crop Factors: Varieties of the same crop differ in duration, rooting pattern and canopy structure. The variety, with longer duration obviously requires more water for completion of the life cycle. During the growth of crop, consumptive use is maximum during flowering and grain filling in cereals compared to that in seedling stage. Crops differ in producing leaf area and covering the ground. Higher the leaf area index, more is the evapotranspiration. Evapotranspiration also differs with height of the crop. Tall crops intercept more solar radiation and have more evapotranspiration than short crops.

(2) Soil Factors: Evaporation from soils differ due to their difference in hydraulic conductivity, reflectivity and thermal conductivity. At higher moisture regimes, coarse textured soils have higher hydraulic conductivity than fine textured soils. With the result, evaporation is faster in coarse textured soils under intermitted wetting and drying. Evaporation mostly occurs from the top 5cm of soil structure upto 15 cm depth influences evaporation through its influence on water supply to evaporation site. Colour of the soil also has considerable influence on evaporation from the soil surface. Dark colored soils absorb more of solar radiation and thus increase evaporation.

(3) Climatic Factors: It is well known that evapotranspiration is strongly influenced by solar radiation, temperature and relative humidity and wind velocity. In addition, advective energy also influences evaporation. Hot and dry area surrounding the irrigated area increases evaporation. Advection is a serious problem in arid and semi arid regions.

(4) Crop management practices: All the management practices that provide favorable environment to the crop increase the leaf area and thus increase evapotranspiration. Tillage practices influence rooting characteristics and thus influence evapotranspiration. Weeding reduces competition for moisture and increases irrigation interval. Similarly mulching reduces evapotranspiration considerably.

Water requirement of different crops (mm)

Rice	= 900-2500	Soybean	= 450-700
Wheat	= 450-650	Tobacco	= 400-600
Sorghum	= 450-650	Potato	= 500-700
Maize	= 500-800	Sugarcane	= 1500-2500
Groundnut	= 500-700		

Methods of Irrigation

(I) Surface Method

(1) Border-Strip Method - The field is divided into number of strips by making of bunds of around 15 cm height. These Parallel earth ridges called borders are formed across the field. The area between two borders in the border strip length of strip ranges from 30 to 300 m and width from 3 to 15 m. However, the most common sizes are 60 to 90 m in length and 6 to 12 m in width. The size of border strips depends on stream size, soil structure and slop of the land.

Types -

(i) Straight - Borders may be laid along the general slop of the field

(ii) Countor - Borders may be laid across the general slop of the field

Merits -

(1) Border ridges can be constructed economically with simple farm implements.

(2) Labour requirement in irrigation is greatly reduced

(3) Uniform distribution and high water application efficiencies are possible.

(4) Operation of the system is simple and easy

(5) Adequate surface drainage is provided

Demerits -

(1) It requires large irrigation stream i.e canal irrigation

(2) No uniform water distribution

(2) Check-basin method - This method of irrigation is the most common method among surface method of irrigation. In this method, the field is divided into small plots surrounded by small bunds on all the four sides. Water from head channel is supplied to the field channels one after the other. Each field channel supplies water to two rows of check basin & water is applied to one basin after another. This method is adopted when the field is quite large and is not easy to level the entire field. In such situations, the field is divided into small strips and each strip into several plots by putting bunds and those plots are called check basin.

Merits -

(1) Most important advantage is that water can be applied uniformly.

(2) It is useful when leaching is required to remove salts form the soil profile.

(3) It enables the conservation of rainfall and reduction in soil erosion by retaining a large part of the rain in the basin.

(4) Large as well as small irrigation stream can be efficiently applied.

Demerits -

(1) Inter cultivation is not possible due to obstruction by bunds.

(2) Considerable land (about 5%) is occupied by channels and bunds.

(3) This method is impedes surface drainage

(4) Precise land grading and shaping are required

(5) Labour requirement in land preparation and irrigation are much higher

(6) This method is not suitable for irrigation crops.

(3) Furrow Method - Small channels (Furrows) of a field and water from open ditches or pipes is diverted into the furrows. Water infiltrates from the bottom and sides of the furrow moving downward and laterally to wet the soil. Furrow method of irrigation is adapted to crops grown with ridges and furrows.

Types -

(1) Straight - They are laid down the prevailing land slope.

(2) Contour - They are laid on the contour

(3) Corrugation - Corrugation irrigation consists of running water in small furrows called corrugation.

Merits -

(1) Crust problem is avoided

(2) Inter cultivation is possible

(3) Labour requirement for irrigation is less

(4) In this method evaporation is less

Demerits -

(1) In requires proper land grading

(2) There is a problem of maintenance of velocity of water flow in the furrow because the land slope may not be wide uniform.

(3) Installation of furrows is required every year for row crops

(II) Sub-Surface method -

In this system, water is applied into a series of field ditches deep down up to the impervious layer (15-30 cm). It moves laterally and then vertically through capillaries and saturates the root zone. In artificial sub-irrigation, perforated or porous pipes are laid underground in the vicinity of the root zone and water under pressure is distributed through these pipes.

Merits -

(1) It minimise evaporation losses because water gradually wets only root zone and thus the surface soil is dry.

(2) The trenches are also use for drainage.

(3) This system is suitable for long duration or perennial crops.

(4) Weed problem is less due to dry surface soil.

(5) Less labour is required in irrigation.

Demerits -

(1) Maintenance of pipe lines is difficult

(2) They interfere with cultivation

(3) Trenches causes deep percolation losses

(4) It is suitable where water table is shallow

(5) In high rainfall areas this system will not work efficiently.

(III) Sprinkler Method

Sprinkler irrigation system conveys water from the source through pipes under pressure to the field and distributes over the field in the form of spray of 'rain like' droplets. It is also known as overhead irrigation. Sprinkler irrigation is known since 1946 but in India it was widely known to farmers since 1980.

Component of Sprinkler System -

(1) Pumping Unit - A high speed centrifugal or turbine pump can be used for operating sprinkler irrigation for individual fields. Centrifugal pump is used when the distance from the pump inlet to the water surface is less than 8 m for pumping water from deep wells or more than 8m, a turbine pump is suggested.

(2) Pipe lines - The pipe lines consists of main line, sub mains and laterals. Main line conveys water from the source and distributes it to the sub mains. The sub mains convey water to the laterals which in turn supply water to the sprinklers. Aluminum pipes are generally used for portable systems, while steel pipes are usually used for centre-pivot laterals. Asbestos, cement, PVC and wrapped steel pipes are usually used for buried laterals and main lines.

(3) Sprinklers - Sprinklers distribute water uniformly over the field without runoff. Different types of sprinklers available. They are either rotating or fixed type. They are effective with pressure of about 10-17 cm head at the sprinkler. Rotating type can be adopted for a wide range of application rates and spacing fixed head sprinklers are commonly used to irrigate small lawns and gardens. A sprinkler may be equipped with 1-3 nozzles. The performance of sprinkler depends on operating pressure, nozzle geometry, riser and wind velocity.

Advantages -

(1) It saves irrigation water about 25-50% as compared to surface irrigation.

(2) The overall efficiency of this system is 80%.

(3) No land is wasted for making bunds and channels.

(4) It saves about 40-60% labour requirement as compared to the surface method.

(5) Uniform water application is provided except during the time of high wind velocities.

(6) Fertilizer, pesticide or weedicide can be applied efficiently without any extra cost.

(7) High and frequent irrigation is possible for good germination under crust prone soils.

(8) Better leaching of salts with less amount of water is possible.

(9) It is also used for cooling the crop during high temperature.

Limitations

(1) This system is not suitable under high wind velocity i.e. 12 km/hr.

(2) Not suitable for high saline water when atmospheric temperature is > 32^0C

(3) Initial investment in purchase of the system is high.

(4) Higher energy is required for operating the system on undulated lands i.e. 0.5 to > 10 kg cm^2.

(5) Successful operation of the system requires technical knowledge.

(IV) Drip Irrigation -

It may be defined as the precise, slow application of water in the form of discrete or continuous or tiny streams of miniature sprays through mechanical devices called emitters or applicators located at selected points along water delivery lines.

The term tickle or drip irrigation are used synonymously. In 1964, symcha Blass developed the first drip irrigation system. This method is one of the latest methods which is becoming popular in areas of acute water scarcity and salt problem. It is method of watering plants frequently with a volume of water nearly equal to the consumptive use of plants thereby minimizing conventional losses such as deep percolation, runoff and evapotranspiration.

Components of drip irrigation system

(1) Pump - It is used for uplifting the water from the source of supply.

(2) Head Unit - It is directly connected to the pump and regulate the suitable pressure for suitable irrigation.

(3) Central distribution system - It is connected to the head unit and regulate the pressure of water and quality of water.

(4) Fertilizer tank - It is connected to the central distribution system and supply a soluble solution of nutrients.

(5) Filters - It is connected to the fertilizer tank and remove the suspended particles from the water.

(6) Main line - It is directly connected with the source of supply water and convey water from the source to the sub-mains.

(7) Sub-main Laterals - It is connected to the main lines and convey the water from main lines to the drippers.

(8) Drippers - It is directly connected to the sub-mains and distributed the water over the field in the form of droplets.

Advantages -

(1) It saves the irrigation water about 40-70% as compared to surface irrigation.

(2) The overall efficiency of this system is 90-95%

(3) It reduces the salinity hazards by applying frequent irrigation.

(4) Fertilizer mixer can also be applied.

(5) It suppresses the weed growth.

(6) It saves labour requirement for irrigation

(7) It is suitable for very light to very high soils

(8) There is no interference due to the higher wind velocity.

Limitations

(1) Clogging is the main problem of drip irrigation system.

(2) Initial purchasing cost is high

(3) It requires technical knowledge for installation, operation and maintenance.

(4) Poor water distribution when a low pressure system is installed.

Irrigation efficiency -

It is the ration usually expressed as percent of the volume of irrigation water transpired by the plants inclusive that evaporated from the soil and that necessary to regulate the salt concentration in the soil solution and that used by the plant in building plant tissues to the total volume of water diverted or stored for irrigation.

$$Ei = \frac{Wet + W1 - Re}{Wi} \times 100$$

Where, Ei = Irrigation efficiency

Wet = Volume of irrigation water per unit area of land transpired by plants

W1 = Volume of irrigation water per unit area of land to regulate the salt content of soil solution

Re = Effective rainfall

Wi = The volume of water per unit area of land that is stored in a reservoir or diverted for irrigation

Importance -

1) To estimate the water requirement for a crop

2) To estimate the losses occurring at various stages in an irrigation project.

Factors affecting I.E. -

(1) Design of irrigation system

(2) Type of soil

(3) Land preparation

(4) Skill and care of irrigation

Water conveyance efficiency -

It is the ration usually expressed as percent of the volume of water delivered by an open or closed conveyance system at the field to the volume of water delivered to the conveyance system at the supply source or reservoir outlet.

$$Ec = \frac{Wd}{Wf} \times 100$$

Where Ec = Water conveyance efficiency

Wd = Volume of water delivered by the conveyance system of the field

Wf = Volume of water delivered to the conveyance system at the supply source or reservoir

Water application efficiency -

It is the ration usually expressed as percent of the volume of irrigation water used in evapotranspiration in a specified irrigated area, plus that necessary to maintain a favourable salt content in the soil solution to the volume of water delivered to the area

$$Ea = \frac{Wet\ + W1 - Re}{Wa} X\ 100$$

Where, Ea = Water application efficiency

Wet = Volume of irrigation water in a specified area transpired by the plants and evaporated from soil

W1 = Volume of water necessary for leaching in a given area

Re = Volume of effective rainfall in a given area

Wa = Volume of water delivered to the given area

Water storage efficiency -

It refers to how completely the water needed prior to irrigation has been stored in the root zone during irrigation

$$Es = \frac{Ws}{Wn} X\ 100$$

Where, Es = Water storage efficiency

Ws = Water stored in the root zone after irrigation

Wn = Water needed in the root zone prior to irrigation

WSE is important where water supplies are limited and excessive time is required to secure adequate penetration of water into the soil. When salt problem exist it should be kept high to wash out salts from the root zone.

Water use efficiency -

It refers to the yield of marketable crop produced per unit of water used in ET.

$$WVE = \frac{y}{ET}$$

Factors affecting water use efficiency -

(1) Climatic factors -

Transpiration and Evapotranspiration are depended upon temperature, wind velocity, relative humidity, sunshine hours and rainfall of a particular area. Higher temperature and wind velocity increases the rate of ET, thereby reducing WVE.

Similarly, evaporation is inversely proportional to humidity of climate which results in reduced consumption of water by plants thereby increasing WUE. Increased availability of light to the plant increases photosynthesis, resulting in greater production which consequently increases WUE.

(2) Genetic/Plant factors -

Plants with shallow and less develop root system are able to absorb less water and fertilizer resulting in lesser growth and production, consequently their WUE is reduced. As against that crop with higher canopies have greater growth and higher photosynthesis which results in greater yield and higher WUE.

On the basis of carboxylation reaction which occurs during the photosynthesis, crops are divided into crops C_3 and C_4. The crops belonging to C_3 like Wheat, barley, Oats, pulses, oilseeds etc have less WUE because they have respiration even in the presence of light which results in lesser production. But crops belonging to C_4 group like Sugarcane, Maize and Sorghum have very little or no respiration in the presence of light which results greater WUE. In addition to these the desert plants which are saculant usually have a unique pathway known as crassulalean Acid Metabolism (CAM). These plants have very slow growth rate but consume much less water. ep.Pineapple.

(3) Cultural factors - In cultural factors following practices are-

(i) Sowing time - The crop sown at proper time have greater production and hence higher WUE because timely sowing ensures proper temperature and soil physical conditions favoring optimum crop growth. Crop sown late have lesser growth and development and consequently their WUE is reduced. Further delay sowing exposes the crops to a greater competition with the weeds and heavy infestation of pest and diseases. Adjustment in sowing time assumes even greater importance during the rabi season because the crop growing season is limited by the prevailing temperatures at seedling or sowing as well as at grain development period of the crops.

(ii) Depth of Sowing - It is an important factor to be considered because it effects at seedling emergence, vigor and finally the yield. Seed sown near the surface suffer from lake of moisture as well as soil dries quickly by the evaporation, so both deep and shallow roots have disadvantage. If the seeds are sown it takes longer time to emerge and seedlings are generally week resulting in poor yield. Smaller seeds even fail to emerge. Crops whose seeds are sown at optimum depth have greater germination and growth and hence higher production which results in higher WUE.

(iii) Method of Sowing - Generally there are two methods of sowing (a) Broad Casting and (b) Line sowing. As compared to broad casting method lines sowing have greater utilization and absorption of nutrients, water and light resulting in higher production and ultimately high WUE.

(vi) Use of Antitranspirents – Antitranspirents are those material whose spray upon plants is reduced transpiration like phenyl mercuric acetate (PMA), Kaolin, Abscissic acid. spraying of these antitranspirants results in their reduce transpiration which reasons consumptive use by the plants thereby increasing WUE.

(v) Use of growth retartants - There are some chemicals like cycocel (ccc) and phosphon when apply to plants reduced their height and vegetative growth. They maintain the turgidity of leaves for a longer time and reduce lodging in cereals. Root growth of plant increase at all depth. Therefore, the plants are capable of utilizing moisture from deeper layer and consequently higher WUE.

(vi) Use of mulches - Mulching is the practice of spreading extraneous materials on surface of soil to increase water infiltration, check evaporation, reduce soil erosim, improve edaphic environment and supress weeds. These effects will result in greater use of fertilizer, water, air and light by the crops which will ultimately increases the production per unit area consequently the WUE of crop increases.

(vii) Method of Irrigation - As compare to the flooding method of irrigation, sprinkler and drip method of irrigation results in lesser loss of water which results in higher WUE.

(viii) Fertilizer application - The optimum application of fertilizer at proper time increases the growth and development of crops thereby increasing their WUE.

(ix) Weed Control - As weeds compete with the crop plants for light, water and nutrients etc their development along with the crop enhances the rate of soil water depletion. Thus weed reduces WUC by decreasing the crop yield and increasing the water needs.

(x) Insect-pest and disease control - The destruction of crop pest and diseases is essential for plant production and the production of a good crop. It crops are not saved from pest their growth and development is lesser resulting in reduced WUE.

(xi) Use of shelter belts - There is a great loss of irrigation water through evaporation in the area which are prone to hot and high velocity winds. In such areas evaporation can be reduced and WUE can be increased through the use of shelter belts.

Scheduling of Irrigation -

Irrigation scheduling is the process of determining when to irrigate and how much water to apply.

The soil moisture conditions determining the scheduling of irrigation have different approaches -

(1) Soil moisture depletion approach -

When the soil moisture in a specified root zone depth is depleted to a particular level, it is to be replenished by irrigation for crops like maize, wheat etc. Scheduling irrigation at 25% depletion of available soil moisture is adequate for drought resistant crops like sorghum, pearl millet, cotton etc. It is sufficient to irrigate at 50% depletion of available soil moisture.

(2) Climatological approach - The amount of water lost by evapotranspiration is estimated from climatological data and when ET reaches a particular level, irrigation is scheduled.

(3) IW/CPE Approach - In this approach a known amount of irrigation water (IW) is applied when cumulative pan evaporation (CPE) reaches a predetermined level. Generally, irrigation is scheduled at 0.75 to 0.80 ratio with 5 cm of irrigation water.

IW/CPE ratio for different crops -

Rice, Potato	1.2
Barseem	1.0
Wheat, Maize, Sunflower	0.9
Sugarcane, Sorghum	0.8
Cotton	0.75
Rapseed mustard	0.7
Safflower	0.4
Rest crops	0.6

(4) Can Evaporimetry - In can evaporimetry irrigation is scheduled when the water level in the can falls to a predetermined level.

(5) Critical stage approach - In each crop, there are some growth stages at which moisture stress leads to irreversible yield loss. These stages are called as critical or moisture sensitive period. If irrigation water is available in sufficient quantities, irrigation is scheduled when ever soil moisture is depleted to critical moisture level about 25 or 50%.

(6) Soil - cum - sand miniplot technique - In this technique irrigation is scheduled as soon as wilting symptoms appear on the plants in the pit.

Quality of irrigation water -

The concentration and composition of dissolved constituents in water determine its quality for irrigation use Quality of water is an important consideration in any appraisal of salinity and alkalinity conditions in an irrigated area. The quality of irrigation water depends primarily on the total amount of salts present and the proportion of N^{+}ion to other cation and certain other parameters. Various criteria are considered in evaluating the quality of irrigation water namely -

(1) Salinity hazard - The concentration of soluble salts in irrigation water can be classified in terms of electrical conductivity (EC) and expressed as dsm^{-1}.

Class	**EC (dsm^{-1})**	**Remark**
C_1	<0.25	Low salinity water
C_2	0.25-0.75	Medium salinity water
C_3	0.75-2.25	High salinity water
C_4	>2.25	Very high salinity water

(2) Sodium hazard - High concentration of sodium are undesirable in water because sodium absorbs the soil cation exchange sites, causing soil aggregates to break down, sealing the pores of the soil and making it impermeable to water flow. The tendency for sodium to increase its proportion on the cation exchange sites at the expense of other types of cation is estimated by the ratio of sodium content to the content of calcium plus magnesium in the irrigation water. This is called sodium adsorption ratio.

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

S_1	SAR <10	Low sodium water
S_2	10-18	Medium sodium water
S_3	18-26	High sodium water
S_4	>26	Very high sodium water

(3) Salt Index - Negative value (-24.5 to 0) is useful for irrigation water

(4) Bicarbonate hazard - The residual sodium carbonate (RSC) is used to evaluate the quality of irrigation water and is expressed in mel^{-1}.

$$RSC = (Co_3^{-2} + HCo_3^{-1}) - (Ca^{+2} + Mg^{+2})$$

RSC value	<1.25	Water can be used safely
RSC value	1.25-2.5	Water can be used with mgf. practices
RSC value	>2.5	Unsuitable for irrigation

(5) Boron concentration -

Class	**PPM**	**Character**
B_1	<1	Very low
B_2	1-2	Low
B_3	2-3	Medium
B_4	3-3.75	High
B_5	>3.75	Very high