Institutional Development Plan (IDP),SKUAST Jammu

Strengthening Institutional Capacities for Delivering Competent Skilled Professionals

REMEDIAL CLASSES

OF

FACULTY OF AGRICULTURE

Organized By : NAHEP-IDP SKUAST Jammu

FUNDAMENTAL OF AGRONOMY

CONTENTS

S.No.	Chapter	Page No.
1	Introduction, Scope and Principles of Agronomy	4-13
2	Cultivation Of Field Crops	14-17
3	Weeds: Definition, Characteristics and Importance	18-29
4	Plant Nutrition	30-44
5	Soil Fertility Vs Soil Productivity	45-56
6	Irrigation Water Management	57-80
7	Factors Affecting Crop Production-Climate-Edaphic-Biotic-Physiographic and Socio-Economic Factors	81-86
8	Agronomic Numerical	87-92

CHAPTER-I

INTRODUCTION, SCOPE AND PRINCIPLES OF AGRONOMY

Definition of Agronomy

Agronomy is derived from a Greek word 'agros' meaning 'field' and 'nomos' meaning 'management'.

1. Agronomy is branch of agricultural science, which deals with principles, & practices of soil, water & crop management.
2. It is branch of agricultural science that deals with methods which provide favourable environment to the crop for higher productivity.

Scope of Agronomy

- Identification of proper season for cultivation of wide range of crops.
- Proper methods of cultivation are needed to reduce the cost of cultivation and maximize the yield and economic returns.
- Availability and application of chemical agro chemicals has necessitated the generation of knowledge to reduce the ill-effects due to excess application and yield losses due to the unscientific manner of application.
- New technology to overcome the effect of moisture stress under dry land condition is explored by Agronomy and future agriculture is depends on dry land agriculture and sustainable agriculture technologies.
- Keeping farm implements in good shape and utilizing efficient manner to nullify the present-day labour crisis is further broadening the scope of agronomy.
- Restoration of soil fertility, proper conservation of soil moisture.
- Preparation of good seed bed.
- Proper control of weeds (37 % loss) to make land resources more productive.
- New varieties of crops with high yield potential have to be exploited.
- Appropriate water management practices have to be developed (, scheduling irrigation at critical stages, recycling of water, sustainable cropping system, micro-irrigation, water shed management).

Principles of Agronomy

"Principles of Agronomy deals with basic concepts & common agronomic principles & much more than crop to crop management approaches".

This principle of agronomy is useful for the application with many crops.

The principle of agronomy is based on two major purposes:
1. To develop an understanding of the important principles underlying the management.
2. To develop the ability to apply these principles to production situations.

Major Principles to Agronomy:

1. Agrometeorology: study of climatic factors in related to agriculture.

2. Soils & Tillage: Tillage is the agricultural preparation of the soil by ploughing, ripping, or turning it. There are two types of tillage: primary and secondary tillage. Soil is a natural body consisting of layers of mineral constituents of variable thicknesses, which differ from the parent materials in their morphological, physical, chemical, and mineralogical characteristics.

3. Soils & Water conservation: Water conservation refers to reducing the usage of water and recycling of waste water for different purposes like cleaning, manufacturing, agriculture etc.

4. Dry land Agriculture: Dry land farming is an agricultural technique for cultivating land which receives little rainfall.

5. Mineral Nutrition of plants, Manures & Fertilizers: Plant nutrition is the study of the chemical elements that are necessary for plant growth.

6. Irrigation & water management: Water management is the activity of planning, developing, distributing and optimum use of water resources under defined water polices and regulations

7. Weed Management: Management of unwanted plant in field.

8. Cropping & Farming systems.

9. Sustainable Agriculture: Sustainable agriculture refers to the ability of a farm to produce fertile soil and cows, without causing severe or irreversible damage to ecosystem health.

SEED AND SOWING

Seed is any material used for propagation whether it is in the form of seed (grain) of food, fodder, fibre or vegetable crop or seedlings, tubers, bulbs, rhizomes, roots, cuttings, grafts or other vegetatively propagated material.

Seed is a fertilized ovule consisting of intact embryo, stored food (endosperm) and seed coat which is viable & has got the capacity to germinate.

Seed is the basic input in the crop production which should be of good quality.

The good quality seed must have following characters:

1. Seed should be genetically pure & should exhibit true morphological & genetical characters of the particular strain (True to type).
2. It should be free from admixture of seeds of other strains of the same crop or other crop, weeds, dirt and inert material.
3. It should have a very high & assured germination percentage and give vigorous seedlings.
4. It should be healthy, well developed & uniform in size.

5. It should be free from any disease bearing organisms i.e. pathogens.
6. It should be dry & not mouldy and should contain 12-14% moisture.

Sowing: is the process of planting seeds. Among the major field crops, oats, wheat, and rye are sown, grasses and legumes are seeded, and maize and soybeans are planted. In planting, wider rows (generally 75 cm or more) are used, and the intent is to have precise, even spacing between individual seeds in the row; various mechanisms have been devised to count out individual seeds at exact intervals. Seeds are generally sown into the soil by maintaining a planting depth of about 2-3 times the size of the seed.

Sowing Time: It is the non-monetary inputs which greatly influence the crop growth and yield. Therefore, sowing of crop should be done at recommended dates. Any fluctuation in optimum sowing time results in drastic yield reduction. e.g. wheat.

Depth of Sowing: It is also non-monetary input which decides plant stand in the field. It influences the germination & emergence of seed. Sowing should be done at recommended depth. These vary with the kind of seed and its size. Bigger seeds may be sown at a greater depth while small sized seeds at shallow. Seed should be dropped in the moist zone. In *Kharif,* sowing should be shallow and in *Rabi* deeper except pre-sowing irrigation.

Spacing and Plant Population: Spacing between the row and within the plants decides the plant population per/unit area. Optimum plant population results in normal crop growth and thereby yields. One can manipulate the R-R & P-P distance but care should be taken to maintaining the optimum plant population as per the recommendations. E.g.: Jowar &Bajara 1.37 - 1.5 lakh (45 x 15cm), cotton (irrigated) 12000 (90-120 x 60 cm), sugarcane 5000 (1 m R-R with 25000 sets.), Groundnut (bunch) 2- 2.5 lakh (30 x 15 cm). A dense population results in competition for nutrients, moisture and light and thereby suppressed growth, while lower population results in low yield/unit area. Yield of crop is the result of final plant population which depends on the no. of viable seeds, germination % and survival rates. An establishment of optimum plant population is essential to get maximum yield. Yield/plant decreases gradually as plant population/unit area is increased. However, yield/unit area can be increased with +efficient utilization of growth factors. Optimum plant population depends on plant size, elasticity, foraging area, nature of the plant, capacity to reach optimum leaf area at an early date & seed rate used.

Methods of Sowing:

The sowing method is determined by the crop to be sown. Various sowing methods differ in their merits, demerits and adoption.
1. Broad casting
2. Line sowing
3. Dibbling
4. Transplanting
5. Planting
6. Putting seeds behind the plough.

1. Broad casting: It is the scattering/spreading of seeds by hand all over the prepared field followed by covering with wooden plank or harrow for contact of seed with soil. Crops like wheat, paddy, sesamum, methi, coriander, etc. are sown by this method.

Advantages:
a) Quickest & cheapest method.
b) Skilled labour is not uniform.
c) Implement is not required.

d) Followed in moist condition.

Disadvantages:

a) More seed requirement

b) Crop stand is not uniform

c) Proper spacing is not maintained hence inter-culture is difficult.

2.Drilling or Line sowing: It is the dropping of seeds into the soil with the help of implement such as mogha, seed drill, seed-cum-ferti driller or mechanical seed drill and then the seeds are covered by wooden plank or harrow to have contact between seed & soil. Crops like Jowar, wheat, bajara, etc. are sown by this method.

Advantages:

a) Seeds are placed at proper & uniform depths,

b) Interculturing can be done along the rows,

c) Uniform row to row spacing is maintained,

d) Seed requirement is less than 'broad casting'

e) Sowing is done at proper moisture level.

Disadvantages:

a) Require implement for sowing.

b) *Wapsa* condition is must.

c) Plant to plant (Intra row) spacing is not maintained.

d) Skilled person is required for sowing.

3. Dibbling: It is the placing or dibbling of seeds at cross marks (+) made in the field with the help of maker as per the requirement of the crop in both the directions. It is done manually by dibbler. This method is followed in crops like Groundnut, Castor, and Hy. Cotton, etc. which are having bold size and high value.

Advantages:

1) Spacing between rows & plants is maintained,

2) Seeds can be dibbled at desired depth in the moisture zone,

3) Optimum plant population can be maintained,

4) Seed requirement is less than other method,

5) Implement is not required for sowing,

6) An intercrop can be taken in wider spaced crops,

7) Cross wise Intercultivation is possible.

Disadvantages:

1) Laborious & time-consuming method,

2) Require more labour, hence increase the cost of cultivation,

3) Only high value & bold seeds are sown,

4) Require strict supervision.

4. Transplanting: It is the raising of seedlings on nursery beds and transplanting of seedlings in the laid out field. For this, seedlings are allowed to grow on nursery beds for about 3-5 weeks. Beds are watered one day before the transplanting of nursery to prevent jerk to the roots. The field is irrigated before actual transplanting to get the seedlings established early & quickly which reduce the mortality. Besides the advantages & disadvantages of dibbling method, initial cost of cultivation of crop can be saved but requires due care in the nursery. This method is followed in crops like paddy, fruit, vegetable, crops, tobacco, etc.

5. Planting: It is the placing of vegetative part of crops which are vegetatively propagated in the laid out field. E.g.: Tubers of Potato, mother sets of ginger & turmeric, cuttings of sweet potato & grapes, sets of sugarcane.

6. Putting seeds behind the plough: It is dropping of seeds behind the plough in the furrow with the help of manual labour by hand. This method is followed for crops like wal or gram in some areas for better utilization of soil moisture. The seeds are covered by successive furrow opened by the plough. This method is not commonly followed for sowing of the crops.

TILLAGE AND TILTH

Soil is the medium in which crops are grown but in its natural state, it is not in an ideal condition to grow them satisfactorily. Surface soil in which seed are to be sown, should not be hard & compact, but soft & friable, so that tender shoots of germinating seeds can push above the soil surface without any difficulty and the young roots penetrate easily into the lower layers of soil in search of food, water & air, Soil should also be free from weeds which otherwise rob the crop of water & nutrients. It should also have sufficient water and air which are very necessary for plant growth.

Such ideal condition of soil can be achieved by manipulating the soil properly & bringing it in good tilth through a series of mechanical operations like ploughing, clod crushing, dicing, harrowing, levelling, compacting, interculture etc. by tillage implements.

Tillage: Tillage is as old as Agriculture, Primitive man used to disturb the soil for placing seed. Jethro Till considered as **'Father of Tillage' Who Written'** Horse horning Husbandry' book. Tillage of the soil consists of breaking the hard compact surface to a certain depth and other operations that are followed for plant growth. Tillage is the physical manipulation of soil with tools & the tilling of land for the cultivation of crop plants i.e. the working of the surface soil for bringing about conditions favourable for Raising of crop plants. Tillage is the manipulation of soil with tools & implements for loosening the surface crust & bringing about conditions favourable for the germination of seeds and the growth of crops.

Soil Tilth: Soil Tilth is the term used to express soil condition resulting from tillage. Hence it is the resultant of the tillage. A soil is said to be in good Tilth when it is soft, friable & properly aerated. The Tilth is the physical condition of the soil brought out by tillage that influences crop emergence, establishment, growth and development. Tilth is a loose, friable, airy, powdery granular & crumbly structure of the soil with optimum moisture content suitable for working & germination or sprouting seeds & propagates Soil Tilth is that kind of physical condition of soil when it is loose. Not very powdery but granular & when these granules are felt between fingers, they are soft, friable, & crumble easily under pressure, such soils permit easy infiltration of water & are retentive of moisture for satisfactory growth of plants.

Characteristics of good tilth/Measurement of soil tilth: Tilth indicates two properties of soil, viz the size distribution of aggregates and mellowness or friability of soil.

Size distribution of soil aggregates: The relative proportion of different sized soil aggregates is known as size distribution of soil aggregates. Higher% of larger aggregates i.e. more than 5 mm are necessary for irrigated agriculture while higher% of smaller aggregates(1-2mm) are desirable for dry land agriculture. Theoretically, the best size of granules or aggregates ranges from 1 to 6 mm. However, it depends on soil, type, soil moisture content (at which ploughing is done) & subsequent cultivation.

Mellowness or friability: is that property of soil by which the clods when dry become more crumbly. They do not crumble into dust but remain as stable aggregates of smaller size. A soil with good tilth is quite porous and has fee drainage up to water table. The capillary & non-capillary pores should be in equal proportion so that sufficient amount of water is retained in the soil as well as free air. The soil aggregates would be quite from or stable & would not be easily eroded by water or by wind.

Soil tilth: is easy to describe but rather difficult to measure/ Theoretically, best size of granules ranges from 1-6 mm differs with country e.g. England as more than 15mm and Russia 2-3 mm. Besides this, study of pore space, equal distribution of macro & micro pores is good tilth.

Ideal soil tilth: An ideal soil tilth is not the same for all types of crops & all types of soils e.g. small seeded crops like bajara, ragi, lucerne, Sesamum, mustard require a much finer seedbed, Jowar & cotton require a moderately compact & firm seed bed and not cloddy or loose. Bold seeded crops like gram, maize germinate even in cloddy seedbed.

As regards soil type, a very fine, powdery condition of the surface soil is decidedly bad for a heavy clay soil as it forms a caked surface under rainy condition and all the rain water is then liable to be lost by run-off, taking away also with loamy & lighter soils.

Objectives of Tillage:

1. To make the soil loose & porous: It enables rain water or irrigation water to enter the soil easily & the danger of loss of soil & water by erosion and run-off, respectively, is reduced. Due to adequate proportion of microspores (capillary), the water will be retained in the soil & not lost by drainage.

2. To aerate the soil: Aeration enables the metabolic processes of the living plants & microorganisms, etc. to continue properly. Due to adequate moisture and air, the desirable chemical & biological activities would go on at a greater speed & result in rapid decomposition of the organic matter and consequently release of plants nutrients to be used by crops. Similarly, the evolution of CO_2 gas in this process will result in forming weak carbonic acid in the soil which will make more nutrients available to crops.

3. To have repeated exchange of air/gases: There should be an exchange of air during the growing period of crops. As the supply of O_2 from the air that is being constantly utilized in several biological reactions taking place in the soil; should be continuously renewed. At the same time CO_2 that is released should be removed & not allowed to accumulate excessively decomposition of org. residues by micro-organisms where O_2 is utilized and CO_2 released. Deficiency or excess of O_2 may reduce the rate of reactions. O_2 in soil air and atm. Air is more or less same i.e. 20 to 21% CO_2 in atmospheric air is about 0.03% & in soil air 0.2 to o.3% which is 8to 10 times more than atmospheric air. It is, therefore, very necessary to often introduce atmospheric air in the soil to keep the concentration of CO_2 under by suitable tillage operations.

4. To increase the soil temperature: This can be achieved by controlling the air- water content of soil & also by exposing more of the soil to the heat of sun. This helps in acceleration of activities of soil bacteria & other microorganisms.

5. To control weeds: It is the major function of tillage; Weeds rob food & water required by crop & competition results in lowering of crop yield.

6. To remove stubbiest: Tillage helps in removing stubbles of previous crop and other sprouting materials like bulbs, solons etc in making a clean field/seedbed.

7. To destroy insect pests: Insects are either exposed to the sun's heat or to birds that would pick them up. Many of the insect-pests remain in dormant condition in the form of pupae in the top soil during off season & when the host crop is again planted, they reappear on the crop. Some may harbour on stubbiest or other eminent of the crop. Grubs & cutworms can be destroyed by tillage.

8. To destroy hard pan: Specially designed implements (Chisel plough) are helpful to break hard pan formed just below the ploughing depth which act as barrier for root growth & drainage of soil.

9. To incorporate organic & other bulky manures: Organic manures should not only be spread but properly incorporated into the soil. Sometimes bacterial cultures or certain soil applied insecticides require to be drilled into the soil for control of pests like white grub. White ants, termites, cut worms e.g. Aldrin.

10. To Invert soil to improve fertility: By occasional deep tillage the upper soil layer rich in org. matter goes down thus plant roots get benefit of rich layer and lower layer which is less fertile comes to top

Types of Tillage Operations:

Tillage includes use of different kinds of implements at different times are classified on the basis of their timing into-3types:

1. **Preparatory tillage:** Tillage operations that are carried out from the time of harvest of a crop to the sowing of the next crop are known as preparatory cultivation/ Tillage. OR Operations carried out in any cultivated land to prepare seedbed for sowing crops are preparatory tillage. These are time consuming & costly but are to be performed at right stage of soil moisture & with right implements, otherwise it will not help in good growth of crop. These includes in sequence, ploughing, clod crushing, levelling, discing, harrowing, manure mixing & compacting the soil and implements to be used are ploughs, clod crushers, disc ploughs or harrow, bladed harrow etc.

It includes primary and& secondary tillage:

a) Primary tillage: It mainly includes the ploughing operation which is opening of the compacted soil with the help of different ploughs. Ploughing is done to:

1) Open the hard soil,
2) Separate the top soil from lower layers,
3) Invert the soil whenever necessary and
4) Uproot the weeds & stubbles.

The cutting & inverting of the soil that is done after the harvest of the crop or untitled fallow or to bring virgin or new land under cultivation is called primary tillage. It may be done once or twice a tear in normal or settled agriculture or once in four to five years in dry land agriculture**.**

b) Secondary tillage: Lighter or finer operation performed on the soil after primary tillage are known as secondary tillage which includes the operations performed after ploughing, levelling, discing, harrowing etc.

2. Seedbed preparation: when the soil is brought to a condition suitable for germination of

seeds & growth of crops, called as Seedbed.
After preparatory tillage the land is to be laid out properly for irrigating crops if irrigation is available for sowing or planting seeding which are known as seedbed preparation**.** It includes harrowing, levelling, compacting the soil, preparing irrigation layouts such as basins, borders, rides & furrows etc. and carried out by using hand tools or implements like harrow, rollers plank, rider etc. After field preparation, sowing is done with seed drills. Seeds are covered & planking is done so as to level & impart necessary compaction.

3. Inter tillage/ Inter cultivation/ Interculture/ after care operation: The tillage operations that are carried out in the standing crop are called inter tillage operations. The tillage operation done in the field after sowing or planting and prior to the harvesting of crop plants known as inter cultivation. It includes gap filling, thinning, weeding, mulching, top dressing of fertilizers, hoeing, earthling up etc. unless these are carried out at right time, with suitable implements mainly hoes & hand tools the crop will not attain a vigorous growth. These operations are carried out in between the crop rows.

Benefits Tillage

Although there is an array of tillage implements and power sources, the main reasons for tillage remain the same:
1) Control weeds through uprooting or burying them.
2) Soften the surface soil and prepare a good seedbed thus, seeding of crops is easy.
3) Expose the soil organic matter to oxygen and help release soil nutrients for crop growth.
4) To reduce compaction of the soil and reduce its bulk density to allow for rooting and to improve soil structure.
5) To help improve the infiltration of water.
6) To incorporate any soil amendments including organic materials, lime or basal fertilizers.
7) To help control various pests and diseases associated with soils.
8) To assist operations that are needed to shape or level the land in order to allow more uniform water application.

Obviously, farmers find these benefits very important for their farming and have adapted various techniques to suit the soil types available on their farms. No one recommendation can be given for all farms or cropping systems in a country.

Drawbacks of Tillage*:* Land preparation, however, also comes with some disadvantages that need to be considered:

1) Tillage costs money. It can account for more than one-third of the costs of growing a crop.
2) Tillage takes time, especially if manual and animal drawn systems are used or farmers make multiple passes to obtain a good seedbed. This is time that delays planting and is time that is not available for farmers to do other activities or find employment for other sources of income.
3) Tillage exposes the soil organic matter to air and results in loss of soil organic matter. This can be considerable over time and make soils less productive. Soil with reduced organic matter can also become hard and when tilled become cloddy.
4) A fine soil tilth is degraded by the impact of the energy of rain drops. The result is a breakdown of the surface structure, clogging of soil pores, surface capping and a rapid reduction in infiltration of water. Since the water cannot go vertically, it moves horizontally and causes erosion.
5) A fine tilth is also susceptible to wind erosion that leads to loss of the valuable topsoil (6) If tractors are used for tillage, large quantities of fossil fuel (usually diesel) are consumed and contribute to cost but also contribute substantial greenhouse gas emissions to the atmosphere (mostly carbon dioxide).
6) If animals are used for tillage, farmers must feed the animals to keep them alive for the tillage, adding significantly to the cost of production, and taking up land to grow fodder and feeds.

7) Tillage disrupts the root and microbial channels and porosity of the soil that are essential for root growth and good crops.
8) Tillage often disrupts the level of the field, especially the mold board plow used in Tibet. The farmer must then invest more time and money in levelling the field, otherwise water and fertilizer management will be inefficient either through waterlogging or drought in the same field.

Minimum Tillage methods

Reduced and zero-tillage

As farmers seek to grow more crops with less cost and investment of time, the notion of zero- or reduced tillage has developed.

- In ***reduced tillage***, minimal soil disturbance is done to get a good plant stand (Plate 3.4).
- ***Conservation tillage*** is a form of reduced tillage where one-pass of the plow is done and a layer of residue is left on the soil surface. This helps increase water infiltration, reduce erosion and reduce costs.
- In ***zero-tillage***, another variation of reduced tillage, the equipment used makes a narrow slot in the field where the seed is dropped and the rest of the field is un-tilled (Plate 3.5).
- Although confusing, the term "*Conservation Agriculture*" (CA) is used to define zero-tillage combined with permanent surface mulch (Plate 3.6).

It is important to understand the importance of the surface mulch since it determines the success or failure of zero-tillage; without the surface mulch the soil gets compacted and yields are low, whereas with the mulch, the surface soil physical and biological properties are improved leading to a healthy soil and a good crop. Choosing which reduced tillage system to use will depend on the local situation, soil texture, and the availability of suitable equipment. The key to conservation agriculture adoption is the availability of equipment to farmers that can seed into soils that have not been tilled and have loose residue mulch.

Advantages of Conservation Agriculture

If conservation agriculture – minimal soil disturbance plus mulch – can be adopted there are many benefits:

1) Savings in time - farmers can use this time to do other income generating activities but also it can result in timelier planting and better yields.
2) Less cost - savings in fuel costs, also fuel for pumping water, and less wear and tear on tractors and equipment.
3) Savings in water and therefore increased water use efficiency - better water infiltration and better moisture in the soil profile.
4) Less soil erosion since water infiltration is better.
5) Although weeds are a major issue initially, minimal soil disturbance actually brings less seed to the surface for germination (see Chapter 5 on Integrated Weed Management). With the mulch and time, weed problems are reduced. Mulch from cereal residue has allelopathic properties that reduce weed germination.
6) Soil organic matter increases, especially at the soil surface where it is most important.
7) Soil physical properties including surface soil aggregates improve. Soil porosity improves because of the action of the previous crop roots that leave a network of continuous pores that allow for easier root penetration of the next crop (Plate 3.7).
8) Soil biological diversity increases leading to more biological tillage and better recycling of nutrients (Plate 3.8).
9) If zero-till seed and fertilizer combination drills are used there is more uniform seed distribution and more precise fertilizer placement compared to broadcast systems.

10) It has been shown that once this system has stabilized, pest and disease problems are less. For pests, the residue on the surface promotes and provides a habitat for beneficial insects. For diseases, soil microbial diversity is increased leading to better disease control and reduction in proliferation of just a few pathogenic diseases.

Land preparation (also called tillage or cultivation) and crop establishment go together, since land preparation influences the ability of the crop to emerge and produce a good, uniform crop stand. This is a major pre-requisite for a good yield. Land preparation has been carried out since agriculture first started and farmers moved from being hunters and gatherers to living as more sedentary villagers. Land preparation has changed from a manual to a power-assisted activity over the centuries, depending on the availability of different energy sources. Today tractors provide a major power source for tillage that allows many different variations. Manual and animal assisted tillage is still practiced though, and is evident in Tibet where tractors are only a recent introduction.

Soil is the medium in which crops are grown but in its natural state, it is not in an ideal condition to grow them satisfactorily. Surface soil in which seed are to be sown, should not be hard & compact, but soft and friable, so that tender shoots of germinating seeds can push above the soil surface without any difficulty and the young roots penetrate easily into the lower layers of soil in search of food, water & air, Soil should also be free from weeds which otherwise rob the crop of water & nutrients. It should also have sufficient water & air which are very necessary for plant growth.

Such ideal condition of soil can be achieved by manipulating the soil properly & bringing it in good filth through a series of mechanical operations like ploughing, clod crushing, dicing, harrowing, levelling, compacting, interculturing etc. by tillage implements.

CHAPTER-II

CULTIVATION OF FIELD CROPS

Area production and productivity of different crops in in J&K (UT) and India during 2018-19

S.NO	Area					Production				Productivity			
	Crop	Jammu (000 ha)	Kashmir (000 ha)	J&K (000 ha)	India (Million ha)	Jammu (000 q)	Kashmir (000 q)	J&K (000 q)	India (million tons)	Jammu (q/ha)	Kashmir (q/ha)	J&K (q/ha)	India(q/ha)
1	Rice	131.53	130.48	262.01	43.79	2839	3322	6161	112.91	21.58	25.45	23.51	25.78
2	Maize	190.16	72.19	262.35	9.47	4365	1379	5744	28.72	22.95	19.10	21.89	30.72
3	Wheat	282.98	1.27	284.24	29.58	6671	10	6681	99.70	23.57	7.89	23.50	33.71
4	Pulses	13.82	5.02	18.84	29.99	62	42	104	25.23	4.48	8.37	5.52	8.41
5	Oilseeds	13.55	38.20	51.75	24.65	-	-	564	31.31	-	-	10.89	12.70
6	Total food grain	659.63	328.53	988.15	127.56	14109	4755	18864	284.83	14.47	21.38	19.09	22.33

Source: Digest of Statistics 2018-19, Directorate of Economics and Statistics, Government of Jammu and Kashmir, Finance department, Directorate of Economics and Statistics and Agricultural statistics at a glance 2018 Govt. of India Ministry of Agriculture and Farmers welfare Department of Agriculture, Cooperation & Farmers Welfare directorate of Economics and Statistics.

- ✓ **Centers of Origin of Crop Plants**

The origin of crop plants is now basic to plant breeding in order to locate wild relatives, related species, and new genes (especially dominant genes, sources of disease resistance).

The Eight Vavilovian Centers are following:

Old world 1.	Chinese centre	Millet, buckwheat, barley, Soyabean, sugarcane
2.	Indian centre (includes Assam and burma)	Rice, chickpea, pigeonpea. urdbean, mungbean, ricebean, cowpea, sugarcane, sesame, safflower, cotton Jute
	Indo-Malayan center	Includes Indo-China and the Malay Archipelago. Jobs tear, velvet bean
3	Central Asiatic Centre	Includes Northwest India (Punjab, Northwest Frontier Provinces and Kashmir), Afghanistan, Tajaikistan, Uzbekistan, and western Tian-Shan. Common wheat, club wheat, pea, lentil , chickpea, mungbean, mustard, Flax
4	North –Eastern center	Includes interior of Asia Minor, all of Transcaucasia, Iran, and the highlands of turkmenistan einkorn wheat, durum, poulard ,common wheat, oriental wheat,persianwheat,rye ,lentil,lupin,Alfalfa, persian clover,
5.	Mediterranean Center: Includes the borders of the Mediterranean Sea.	Durum wheat, emmer wheat,polish wheat, oats,pea,lupine,clover,mustard
6.	Abyssinian Center: Includes Abyssinia, Eritrea, and part of Somaliland.	Poulardwheat,emmmer wheat, barley, pearl millet,cowpea,flax
New World 7.	South Mexican and Central American Central: Includes southern sections of Mexico, Guatemala	Maize,american cotton, sweet potato,nicotiana rustica
8.	South American Center: (62 plants listed) Three subcenters are found.	A. Peruvian, Ecuadorean, Bolivian Center: Comprised mainly of the high mountainous areas Egyptian cotton, common bean,potato B. Chiloe Center (Island near the coast of southern Chile) common poatato C. Brazilian-Paraguayan Center : peanut

Crops	**Agrononomy**
Rice *(oryza sativa*) 2n=24	**Cultivation time:** Aus (Pre-monsoon,harvested at autumn), Aman (winter rice due to harvest time), Boro (harvested in summer) **Types: indica (**short awn, late in maturity), Japonica (early maturity) ,Javanica (Indonesia,wild) Inflorescence: Panicle, Hull=Lemma+Palea, Hulling percentage 70-75%, self polinated ,SDP Khaira disease in rice: Zn
Wheat (*Triticum aegiloploids*2n=14) T.durum/dicoccum=2n=28 T.Spelta/aestivum= 2n=42	Emmer wheat (South) (T.dicoccum)-uppumau. rava, sambha Marconi (drought) (T.durum)= suzi. semiya, spagetti, vermicilli Bread (rainfed) (T. vulgare) Indian dwarf wheat (T. spherococcum) club wheat Mexican dwarf wheat (T. aestivum) common bread wheat Chappati gluten Ear or head/spike Directorate of wheat Research,Karnal
Maize	**Dent corn (***Zea mays indentata),* **Flint corn (***Zea mays indurate),***Pop corn (***Zea mays everta)* **Flour corn (***Zea mays amylacea),* **Sweet corn (***Zea mays saccharata),* **Pod corn(***Zea mays tunicate),* **Waxy corn(***Zea mays ceratina* **), Baby corn (***Zea mays***), cross polinated.monoecious plant, maize protein zein Directorate of Maize Research, New Delhi**
Sorghum (S.bicolor)	Inflorescence :panicle, rich in leucine, first hybrid CSH-1, dhurrin formation
Bajra (P. typhoides)	most drought tolerant, first hybrid (HB-1)
Barley	(H.vulgare) =6row, Hordeum distichon-4 rows, H.irregulare-2 rows protein-horden,malting
Pulses	Indian institute for pulse, Kanpur Chickpea-highest area and production, desi gram (Cicer arietinum),kabuli gram (Cicer kabulium) Pea- Garden, field , arhar poor harvest index -19%, Urdbean: 8 times more P,)
Oilseeds	Soyabean: wonder crop 20% oil, 50-60% unsaturated fat, Ground nut oil-45%,shelling -75% : rapeseed and mustard Pungency isothiocynate,H.I-25% Toria , rape (B.compestris)2n=20, Rai (b. juncea 2n=36), black mustard (B.nigra 2n=16), Taramira (Eruca sativa 2n=22), Sunflower (Helianthus annus) 45-52% oil,good for heart patients,Sesame 45-55% oil 20-25% protein
Cotton	old word cotton /desi cotton (G. arborium) n=13 ,short staple (19 mm) G.Herbaceum (1.25-2.30 cm) seeds with small fuzz and lint New world cotton /Americn cotton 2n=26 G.hirsutum (1.8-3.1 cm) G. Barbadense /egyptian cotton(3.6-5.0 mm) 1 Bale=170 kg cotton/180 kg jute Seed cotton (Seed +lint)

	Cotton seed (without lint) Square-flower,bolls – fruit Ginning percentage=24-43%
Jute	White jute- Corchruscapsularis, tossa jute-C.olitorius, Retting microbial process ,stripping
Sugarcane	tropical cane sachharumofficinarium (higher sugar content), Indian canes: S. barbenia (Low to medium sucrose content)S. sinense (Low to medium sucrose content),inflorescence :arrow, upper 1/3 for sowing
Tobacco	*Nicotiana tobaccum*smoking and chewing, *Nicotiana rustica: hukkah ,topping removal of terminal buds,improve leaf quality, Priming harvesting of fully ripe tobacco leaves Curing quality leaf ready for market*

- Plant nutrition is to study functions and dynamics of nutrients in plants, soils and ecosystems as well as of plant production processes that are necessary for plant growth and its metabolism

- Twenty total essential plant nutrients are needed by plants (Anonymous , 2020) these includes macro nutrients Viz. : carbon, oxygen and hydrogen which are obtained from

- The total nutrient consumption ratio of N:P2O5:K2O is 8.5:3.1:1 ideal is 4:2:1

N, P, and K, applied to the soil are lost by 40–70 %, 80–90 % and 50–90%, respectively and efficiency of nutrients are 30-35% N,15-20% P, 35-40% K,8-10% S and 2-5% micronutrients

Crop	**Fertiliser application**
Rice	Apply full quantity of DAP, MOP and Zinc Sulphate along with 1/3rd of N from Urea at the time of puddling, remaining N be top dressed in two equal splits-one at **tillering stage** i.e. 25-30 days after transplanting and the another just before the **panicle initiation stage**
Wheat	Drill entire quantity of DAP+MOP and ½ of N basal dose at sowing time. Remaining half quantity of urea should be applied in the standing crop in two equal doses. First top dressing**crown root initiation stage** is given which may coincide with 25 to 30 days after sowing. Remaining just before **boot stage (ear initiation)**.
Barley	Apply ½ of N along with whole of P_2O_5& K_2O as basal and remaining dose of N may be top dressed at **tillering and earing stages**
Rapeseed - Mustard	½ of N and full dose of P_2O_5 and K_2 O_5 should be drilled at the time of sowing and remaining half N should be top dressed at first irrigation **25-30 DAS**
Linseed	½ of N with full amount of P and K should be applied as basal at sowing. Remaining N is applied in two splits, at **30 and 60 DAS**
Fodder crops	After each cut
Maize	Apply full quantity of DAP, MOP along with 1/3rd of N from Urea at the time of Sowing, remaining N be top dressed in two equal splits-one at **knee high stage** and 2nd top dressing at tasseling
Bajra	Entire quantity of P&K; and ½ of N may be applied as basal dose at the time of sowing or before sowing. The remaining half of N may be top dressed in two spilts- **1st at 30 DAS and 2nd at before head formation**.

CHAPTER-III

WEEDS: DEFINITION, CHARACTERISTICS AND IMPORTANCE

Weeds are no strangers to man. Weeds have been existing on the earth ever since the man started cultivating plants and domesticating of animals around 10,000 B.C. Weeds have been recognized as a problem since then and the battle against weeds is a never ending one and often the costly agronomic input for successful crop production. Weeds are the most underestimated crop pests in agriculture although they cause maximum reduction/loss in the yields of crops than other pests and diseases. They decrease quantity and quality of produce/food, fibre, oil, forage/fodder, animal products (meat and milk) and cause health hazards for humans and animals. Weeds are competitive and adaptable to all the adverse environments.

Jethro Tull first time used the term weed in 1731 in the book "Horse Hoeing Husbandry" and is known as father of weed science.

He defined the weeds as the plants, which grow where they are not wanted (Jethro Tull, 1731).

- "A plant out of place or growing where it is not wanted" -Blatchely (1912).
- "A plant growing where it is not desired; or a plant out of place" -Klingman (1961).
- "Any plant that is objectionable or interferes with the activities or welfare of man" - WSSA (1994).

Weeds are unwanted and undesirable plant that interfere with utilization of land and water resources and thus adversely affect crop production and human welfare.

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

Out of 3,00,000 plant species, weeds constitute about 30000 species, which are prominent in agricultural and non-agricultural system. Out of which nearly 18,000 species cause serious damage to agricultural production. Eighteen weeds are considered as the most serious in the world and about twenty-six species have been listed as principal weeds in crop fields of India. Weeds compete with crops for water, soil nutrients, light and space (*i.e.,* CO_2) and thus reduce crop yields.

List of Major Weeds in the World and India

S. No.	Common name	Scientific name	Growth habitat and kind of plant
1.	Smooth pig weed	Amaranthus hybridus	A-BL
2.	Spiny amaranth	Amaranthus spinosus	A-BL
3.	Wild oat	Avenafatua	A-G
4.	Common lambsquarters	Chenophodium album	A-BL
5.	Field bind weed	Convolvulus arvensis	P-BL

6.	Bermuda grass	Cynodondactylon	P-G
7.	Yellow nut sedge	Cyperus esculentus	P-S
8.	Purple nut sedge	Cyperus rotundus	P-S
9.	Crab grass	Digitariasanguinalis	A-G
10.	Barnyard grass	Echinochloacolonum	A-G
11.		Echinochloacrusgalli	A-G
12.	Water hyacinth	Eichhornia crassipes	P-BL
13.	Goose grass	Eleusine indica	A-G
14.	Cogon grass	Imperata cylindrical	P-G
15.	Sour paspalum	Paspalum conjugatum	P-G
16.	Common purslane	Portulaca oleracea	A-BL
17.	Itch grass	Rottboelliaexaltata	A-G
18.	Johnson grass	Sorghum halepense	P-G

A-annual; B-biannual; P-Perennial;G-grasses; S-sedges; BL-Broad leaf weeds.

Most Common Weeds in Crop Fields of India

Monocot species	**Dicot species**
ANNUALS	
Barnyard grass (Echinochloacrusgalli)	Goat weed (Ageratum conyzoids)
Crabgrass (Digitaria sp.)	Pig weed (Amaranthus sp.)
Foxtail (Setaria sp.)	Black jack (Bidens pilosa)
Sandbur (Cenchrus sp.)	Cox comb (Celosia argentia)
Wild oat (Avenafatua)	Lambsquarters (Chenopodium album)
Goose grass (Eleusine indica)	Wild carrot weed (Parthenium hysterophorus)
Torpedo grass (Panicum repens)	Common purslane (Portulaca oleracea)
Canary grass (Philaris minor)	Horse purslane (Trianthemaportulacastrum)
Crowfoot grass (Dactylocteniumaegyptium)	
PERENNIALS	
Bermuda grass (Cynodondactylon)	Canada thistle (Circiumarvense)
Thatch grass (Imperata cylindrical)	Day flower (Commelinabenghalensis)
Johnson grass (Sorghum halepense)	Field bind weed (Convolvulus arvensis)
Quack grass (Agropyron repens)	White horse nettle (Solanum elaeagnifolium)

Nut grass (Cyperus rotundus)	

CHARACTERISTICS OF WEEDS

Nature has bestowed the following qualities on weeds:

1. Produces larger number of seeds compare to crops (40 to 196000 seed/plant)
2. Vegetative reproduction also through tubers & nuts (nut grass), rhizomes & root stock (Bermuda grass & Johnson grass), bulbs (wild onion & garlic), roots (Canada thistle), stems (dodder) etc.
3. Highly adaptable under varied adverse situations
4. Most of the weed seeds are small in size and light weight.
5. Weed seeds germinate earlier and their seedlings grow faster.
6. They flower earlier and mature ahead of the crop they infest.
7. They have the capacity to germinate under varied conditions, but very characteristically, season bound.
8. Weed seeds possess the phenomenon of dormancy.
9. Weed seeds do not lose their viability for years even under adverse conditions.
10. Most of the weeds possess C_4 type of photosynthesis, which is an added advantage during moisture stress.
11. They possess extensive root system, which go deeper as well as of creeping type.

Importance

Harmful Effects of weeds

Of the total annual loss of agricultural produce from various pests in India, weeds account for 37%, insects 29%, diseases 22%& others 12%. Recent estimates show that weeds cause an annual loss of about 2000 crores to Indian agriculture, which is near to combined losses caused by insect pests and diseases. The losses due to weeds depends on:

1. Type of weed 2. Severity of Infestation 3. Duration of infestation
4. Competitive ability of the crop plants with weeds.
5. Climatic conditions which effect the growth of the crop and the weed.

A. Weed hazard in agriculture

It includes reduction in crop yields and production efficiency and erosion of crop quality.

1. **Reduction in crop yields-** Weeds compete with crop plants for nutrients, soil moisture, space and sunlight and in general an increase in one kilogram weed growth corresponds to reduction in one kilogram of crop growth. Reduction of crop yield has a direct correlation with weed competition. Weeds compete for water in dry landand for nutrients in irrigated crops. Reduction in crop yields varies from 18 to 91% in different crops. In rice (30-35%), wheat (15-30%), Maize, sorghum, pulses, oilseeds (18-85%), sugarcane (38.8%), cotton (47.5%), sugar beet (48.4%) and onion (90.7%).
2. **Production efficiency-** Beside the direct reduction in crop yields there are many indirect ways by which the weeds may be troublesome in agriculture. For example, in weedy fields management practices become cumbersome. Harvest may be difficult when the field is

invaded with wild safflower (*Carthamus oxycantha)*, C*anada thistle* (*Cirsium arvense*), cocklebur (*Xanthium strumarium*). Cowage (*Mucuna pruriens*) cause itching to the labour. Harvesting becomes troublesome when the field bindweed (*Convolvulus arvensis)* and morning glory (*Ipomoea* sp) bind the crop plants together. The weeds at harvest may increase the excessive wear and tear of the farm machines and there by increased the cost of production to separate the weed seeds from the grain and other farm produce. Heavy infestation of *Cynodondactylon*causes poor ploughing performance. Weeds reduce human efficiency through physical discomfort caused by allergies and poisoning. Weeds such as congress weed (*Parthenium hysterophorus*) cause itching. Thorny weeds like *Solanum* sp. restrict movement of farm workers in carrying out farm practices such as fertilizer application, insect and disease control measures, irrigation, harvesting, etc.

3. **Loss in crop quality**– Weeds may reduce the quality of farm produce in many ways. In dry land agriculture weeds cause severe moisture stress and force the food grains to shrivel. The vegetables and fruits are discolored and de shaped in the presence of weeds. Contamination of food grains with poisonous weed seeds fetches low price. Foundation or certified seed is rejected if weed seeds exceed 2% and also the market value is reduced. The quality of the sugarcane crop is also reduced due to the presence of the parasitic weed *Striga litura*. Whereas leaves of loranthus (*Dendrophthoe falcate*) impair the quality of tea. Leaves of *Mikania micrantha* create problem in tea plantation. In cotton the dry weed fragments adhere to the lint and hinder its spinning process. In India Cocklebur (*Xanthium srtumarium)* reduce the quality of wool in sheep. Oil quality of mint was impaired by *Cirsium arvense.*
4. **Weeds as reservoirs of pests and diseases-**Because of their close association with crop they may serve as important reservoirs or alternate host of pests and diseases.

Weed	**Insect-pest**	**Crop affected**
Echinochloa sp., Panicum sp.	stem borer	Rice
Aechynomene sp.	Grasshopper	Rice
Brassica kaber	Aphids	Brassica crops and brinjal
Chenapodium album, Amaranthus sp. and Datura spp.	Gram caterpillar	Redgramm, cotton, okra, pea, tomato and brinjal
	Disease organism	
Agropyron sp., Verticillum sp., and Portulaca sp.	Wilt	Tomato
Cenchrus ciliaris	Ergot	Pearlmillet
Cynodondactylon and Digitaria sp.	Sting nematode	Veg. crops
Daucus carota	Blight	Carrot

5. **Limitation of crop choice**– Crops differ in their ability to compete with weeds. In many instances, the presence of a particular weed in the field limits the choice of crops to be grown. Under heavy weed infestation some economically important crops, particularly pulses, Vegetables, Cotton, Jute and forage crops are less suitable for cultivation. The high infestation of parasitic weeds such as *Striga lutea* may limit the cultivation of sorghum or sugarcane.

B. Harmful effect of weed in animal husbandry-Milk gives odd smell when animal fodder crops are mixed with wild onion and wild garlic, *Cichorium intybus, Argemone mexicana*.

Certain weeds cause sickness and death of animals due to high levels of alkaloids, tannins, oxalates, glucosites or nitrates. Death of herds of sheep occurs due to high oxalate content of *Halogetonglomeratus*. Leaves of lantana cause acute photosensitivity and jaundice in animals was due to the toxic principle of "Lantradene ". Puncture wine (*Tribulus terrestris*) a weed of dryland induces extra sensitivity to light in sheep and puncture of the animal skin. In Kashmir Rhododendron cause diarrhea and showed blood strains in milk. *Crotalaria spp*. is fatal to chick where as sweet clover (*Melilotus alba*) contains 'dicumarin' which act as anti blood coagulant.

C. **Harmful effect of weed on human health-**Hay fever and asthma aggravated by pollens of *Ambrosia artemissifolia*. *Parthenium hysterophous, Poison ivy* (*Rhus* sp), common regweed (*Ambrosia artemissifolia)* are responsible for respiratory problems and skin allergies (dermatitis). Aquatic weeds like water lettuce (*Pistia lanceolata*), salvinia (*Salivina auriculata*), alligator weed (*Alternanthera sp.*) act as alternate host and vectors of malaria, yellow fever, encephalitis, dengue fever and filariasis. Wheat flour contaminated with seeds of cocklebur gives bitter taste to the bread and irritates the gastric tract of the consumer. When the Mexican poppy seeds (*Argemenemexicana*) crushed with mustard seeds cause death and blindness of people. The *Argemone* toxicity is due to an alkaloid called 'Sanguinarine' and 11-oxotriacontanoic acid. Milk from animals feed on the Mexican poppy weed can cause 'Glaucoma' in humans.

D. **Harmful effect of weed to aquatic ecosystems-** Aquatic weeds make the appearance of water bodies repulsive and decline their recreational value. Weeds hinder the navigation, fishing and slow down the flow in irrigation channels Aquatic weeds upon decomposition emit offensive odors and pollute the drinking water bodies. Aquatic weeds that grow along the irrigation canals, channels and water streams restrict the flow of water. Weed obstruction causes reduction in velocity of flow and increases stagnation of water and may lead to high siltation and reduced carrying capacity. Aquatic weeds form breeding grounds for obnoxious insects like mosquitoes. They reduce recreational value by interfering with fishing, swimming, boating, hunting and navigation on streams and canals.

E. **Harmful effect of weed to forest and pasture lands-** Presence of weeds in forest and pastures quality of forage/fodder and other products reduce.

F. **Reduction in land value** – Heavy infestation by perennial weeds could make the land unsuitable or less suitable for cultivation resulting in loss in its monetary value. Thousands of hectare of cultivable area in rice growing regions of India have been abandoned or not being regularly cultivated due to severe infestation of nut grass (*Cyperus rotundus*) and other perennial grasses.

G. **Other problems -** Weeds are troublesome not only in crop plants but also in play grounds and road sides etc. *Alternanthera echinata*and *Tribulus terresstris*occur in many of the playgrounds causing annoyance to players and spectators.

Beneficial uses of weeds

1. **Weeds as fodder for animals-** Hariyali grass (*Cynodondactylon)* and *Cenchrus ciliaris, Dichanthiumannulatum, Eclipta alba* weeds of grass land serve as food for animals. Weeds like *Rynchosiaaurea*, *R. capitata* and *Clitoriaterneata*are very good fodder legumes.

2. *Amaranthus viridis, Chenopodium album* and *Portulaca sp.*used as green vegetables and serve as human food.
3. **Weed as soil binders** - *Panicum repense*is an excellent soil binder; keeps bunds in position and prevents soil erosion in high rainfall regions and hilly slopes. *Chenopodium album* used as mulch to reduce evaporation losses, whereas *Dicanthiumannulatum s*tabilizing field bunds.
4. **Weeds used as manure** - When weeds are ploughed, they add to the nutrient to soil. *Datura sp.* contains 3% N on dry weight basis and Kolingi (*Tephrosia purpurea*) fix N @ 50-75 kg/ha. Excellent compost can be made out from many weed plants *E.g., Eichornia crassipes, Pistia stratiotes, Calotropis gigantean* and *Croton sparsiflorus.*
5. **Weed as fuel -** *Prosopis juliflora*very invasive in nature and notorious tree weed commonly used as fire wood. People make charcoal out of it and are marketed.
6. **Weeds have medicinal values -** Many weeds have great therapeutic properties and used as medicine. *Phyllanthus niruri*– Jaundice, *Eclipta alba* – Scorpion sting, *Centella asiatica* – Improves memory, *Cynodondactylon*– Asthma and piles, *Cyperus rotundus*– Stimulates milk secretion, *Leucas aspera* – Snake bite, *Calotropis procera*– Gastric trouble, *Abutilon indicum* – Piles, *Argemone Mexican*-skin disorders, *Striga orobanchioides*- diabetes control. In addition to the above agarbattis from *Cyperus rotundus and* aromatic oils from *Andropogansp* & *Simbopogon*sp are prepared.
7. **Weed as mats and screens -** *Typha* and *Saccharum* sp. used for making ropes and thatch boards. Stems of *Cyperus pangorei*and *Cyperus corymbosus*are used for mat making while *Typha angustata*is used for making screens.
8. **Weed as indicators -** Weeds are useful as indicators of good and bad soils. *E. colonum*occurs in rich soils while *Cymbopogon* denotes poor light soil and Sedges are found in ill-drained soils. Some weeds useful to identify the metals (Indicator geobotany) through satellite imageries Eg.*Commelina*sp (Copper), *Eichornia crassipes* (Copper Zinc, lead and cadmium in water bodies.
9. *Argemone mexicana*is used to reclaim alkali soils.
10. Used for fencing purposes. Example– *Opuntia dellini,* Cactus, *Agave sp. Saccharum squarrosus,* etc. Weeds like *Lantana camera, Amaranthus viridis, Chenopodium albu , Eichhornia crassipes* used for beautification.
11. *Cichorium intybus roots are used for a*dding flavor to coffee powder.
12. *Saccharum spontaneum* used in breeding programme for developing the noble canes.
13. Incorporation of *Crotalaria, Parthenium, Calotropis* and *Eichornia* reduced root knot nematode population in the soil as they exhibited nematicidal properties.
14. Weeds act as alternate host for predators and parasites of insect pests which feed on the weeds. For example, *Trichogrammachilonis* feed upon eggs of caster semi looper which damage the castor plants.
15. People in China and Japan consume *Chlorella pyrenoides* (algae) as protein supplement.

CLASSIFICATION OF WEEDS

I. Based on life span:

Based on life span (Ontogeny), weeds are classified as Annual weeds, Biennial weeds and Perennial weeds.

(a) Annual Weeds: Those that live only for a season or year and complete their life cycle in that season or year is called annuals. These are small herbs with shallow roots and weak stem. Produces seeds in abundance and the mode of propagation is commonly through seeds. After seeding the annuals die away and the seeds germinate and start the next generation in the next season or year following. Annuals again they are classified into

a) Kharif season annual
b) Rabi season annual
c) Summer season annual

kharif annuals: *Trianthema sp*. (carpet weed), *Digera arvensis* (digera), *Setaria glauca* (yellow fox tail), *Commelinabenghalensis, Boerhaaviaerecta*.

Winter annuals:*Chenapodium album* (Lamb's-quarters), *Vicia spp*(vetches), *Avenafatua*(wild oat), *Phalaris minor* (little seed canary grass).
*Amaranthus viridis*is even though it is summer/*kharif* annual but it is seen through out the year, when irrigation is available. Ephemerals are short lived annuals which complete their life cycle within 2- 4 weeks Eg*Phyllanthus niruri*.
Simple annuals when ever they are cut from ground level, they can't regrow again. Where as*Parthenium, lantana and plucheaspp*appears like perennial, when cut at ground level. It will again regrow from crown buds.

(b)Biennials: Complete their life cycle within two years/ two seasons. It completes the vegetative growth in the first season/year, flower and set seeds in the succeeding season/year and then die. They may propagate either by seeds or vegetative parts or by both. Biennials generally do not come up in annual crop fields but they infest perennial crop fields, pastures, lawns and orchards. Eg.*Daucus carota, Circium vulgare, Cichorium intybus*, *Taraxacum stricta, Alternenthraechinita*but *Cichorium intybus* bolts every year.

(c) Perennials: Perennials live for more than two years. Reproduce vegetativley from under ground and specialized organs. First time they come to flowering in 2nd year and there after flowering every year. Difficult perennial weeds also known as pernicious weeds.

I. **Shallow rooted perennials-***Cynodondactylon*(Bermudagrass) and *Agropyron repens* (quack grass).
II. **Deep rooted Perennials-***Cyperus rotandus* (Purple nut sedge) and *Sorghum halepense*(Johnsongrass).
III. **Simple perennials**: These reproduce solely by seeds but when roots or crown are cut, the cut pieces may produce new plant Eg.*Ipomea carnea, Sonchus arvensis and Lantana camera* .
IV. **Balbous perennial**: These propagate by bulbs or bulblets as well as by seeds. Eg. Wild onion and wild garlic (*Allium sp).*
V. **Corm perennials**: Plants that possess a modified shoot and fleshy stem and reproduce through corm and seeds. Eg.*Timothy* sp.
VI. **Creeping perennials**: Reproduced through seeds as well as with one of the following.

Rhizome: Plants having underground stem – *Sorghum halapense.*
Stolon: Plants having horizontal creeping stem above the ground – *Cynodondactylon.*
Roots: Plants having enlarged root system with numerous buds – *Convolvulus arvensis.*
Tubers: Plants having modified rhizomes adapted for storage of food – *Cyperus rotundus.*

II. Based on morphology

During 1940s 2,4-D was discovered and it was a selective translocated herbicide. After the discovery of the herbicide, classification based on morphology has got strong recognition as it controlled broad leaved weeds. The morphological classification is most important and useful in weed control. Morphological characters of plant are closely reacted to herbicidal absorption, retention, & translocation. The weeds belonging to the same group are likely to have same kind of response to specific herbicides or cultural or mechanical methods. This is the most widely used classification by the weed scientists. Based on the morphology of the plant, the weeds are also classified in to three categories.

(a) Grasses: All the weeds come under the family Poaceae are called as grasses which are characteristically having long narrow leaves. The examples are *Echinocloacolonum, Cynodondactylon.*

(b) Sedges: The weeds belonging to the family Cyperaceae come under this group. The leaves are mostly from the base having modified stem with or without tubers. The examples are *Cyperus rotundus, Cyperus iri, Fimbrystylismiliaceae.*

(c) Broad leaved weeds: This is the major group of weeds as all other family weeds come under this except that is discussed earlier. All dicotyledon weeds are broad leaved weeds. The examples are *Chenapodium album, Digera arvensis*

Grasses	**Sedges**
1. Stem is hollow except at nodes	1. Stem Angular & solid
2. Ligulate	2. Does not possess ligules
3. Alternate or opposite leaves	3. Leaves in whorls around the stem
Ex. Digitaria, Cynadon	***Ex. Cyprus, Scirpus***

III. Based on cotyledon number

Monocots	**Dicots**
1. Narrow and upright leaves	1. Broad & horizontal leaves
2. Parallel venation	2. Reticulate venation
3. Retention of herbicide is less	3. Retention of herbicide is more
4. Adventitious root system	4. Tap root system.
5. Growing point is open	5. Growing point is open
6. Cambium (conductive tissue) is scattered	6. Conductive tissue intact
Ex. *Phalaris minor, Echinochloacolona*	Ex. Dicots-*Amaranthus spp*
	Chenopodium album
	Convolvulus arvensis
	Phyllanthus niruri
	Parthenium hysterophorus

Xanthium strumarium

Note: Cyperaceae and typhaceae are not grasses even though they are narrow leaved

IV Classification based on association

When two plants are living together i.e called association. Based on association they are

a) **season bound weeds, b) crop bound weeds and c) crop associated weeds.**

A) **Season bound weeds**: They are seen in that particular season irrespective of crop. These are either summer annuals or winter annuals. *Sorghum halepans***(**Perennial) is a summer perennial and *Circiumarvense is* winter perennial. *Phalaris minor and Avenafatua*are winter season annuals.

B) **Crop bound weeds**: Weeds which usually parasite on the host crop partially or fully for their nourishment also called as parasitic weeds. Those parasites which attack roots are termed as root parasites and those which attack shoots of other plants are called as stem parasites

1 Root parasites a. Complete root parasite eg*Orobanche*(broom rape) in tobacco .

b. Partial root parasite eg*Striga* spp (witch weed) on millets.

2. Stem parasites a. Complete stem parasite eg*cuscuta*(dodder) in lucern&burseem.

b. Partial stem parasite eg*Loranthus* in fruit crops.

C) **Crop associated weeds:** These are also crop specific due to mimicry, need for specific micro climate and ready contamination with the crops.

i. **Mimicry-**If weeds look exactly like crops morphologically & complete their life cycle, *Echinochloacolonum*(Jungle rice) mimic the rice crop. *Avenafatuva (wild oat)* and *Phalaris minor* (canary grass) both mimic the wheat and *Loranthus* in tea gardens. For example*Avenafatua*(wild oats) tends to grow to the height of winter grains and adjusts its ripening period to the crop over a wide varietal range and this type of mimicry is called phenotypic mimicry**.**

ii. **Need for specific micro climate-**C*ichorium intybus* (chicory) and *Coronopusdidymus*(swinecress) requires shady, moist & cool micro climate for their growth and development and which is available in lucerne and berseem crops.

iii. **Ready contamination with the crops-**If the crop seed mature at the same time & same height of the crop, then it contaminates the crop (also morphologically same) easily Eg. little seed canary grass (*Phalaris minor) and* wild onion, wild garlic (*Allium spp)*.

V Based on Origin

(a) Indigenous weeds: All the native weeds of the country are coming under this group and most of the weeds are indigenous. Eg.*Acalypha indica, Abutilon indicum*

(b) Introduced or Exotic weeds: These are the weeds introduced from other countries. These weeds are normally troublesome and control becomes difficult.*Ex. Eichhornia crassipes, Argemone mexicana, Lantana camara, Parthenium hysterophorus, Phalaris minor,* *Acanthospermumhispidum* and *Croton bonplandianus.*When man aids in its introduction such Weeds are called as anthrophytes.

VI Classification based on nature of stem

Depending upon development of bark tissue on their stems and branches weeds are classified into woody, semi-woody and herbaceous weeds.

i. **Woody weeds:** Weeds include shrubs and under shrubs and are collectively called brush weeds. *Lantana camera, Prosopis juliflora*(mesquite) *Zizyphus rotundifolia* (wild plum) are examples for brush weeds.
ii. **Semi-woody weeds:***Croton sparsiflorus*is semi woody weed.
iii. **Herbaceous weeds:** Weeds have green, succulent stems are of most common occurrence around us. Ex. *Amaranthus viridis and Chenopodium album*.

VII. Based on soil pH

Based on pH of the soil the weeds can be classified into three categories.

(a) Acidophile – Acid soil weeds eg. *Rumex acetosella.*
(b) Basophile – Saline & alkaline soil weeds eg.*Taraxacum stricta, Salsola spp.*
(c) Neutrophile – Weeds of neutral soils eg *Acalypha indica.*

VIII. Based on soil type (Edaphic): Some of the weed species are closely associated with a particular type of soil though not in a strict sense. Sometimes the same species may also occur in other soil types.

I. **Black cotton soils**: The weed species are mainly associated with dry conditions. Eg.*Aristolochiabracteata*and *Hibiscus vitifolius*
II. **Red soils**: The weeds predominantly occur in the irrigated uplands. Eg.Commelinabenghalensis and Leucas urticaefolia
III. **Light sandy or loamy soils**: weeds such as *Mollugooppositifolia, OldenladiaUmbellata*and *Leucas aspera* occur in soils having good drainage.
IV. **Laterite soils:** Some of the weeds are specific to laterite soils. Eg.*Bidens pilosa, Lantana camara and Spergula arvensis*.

IX. Based on ecological affinities

I. **Wetland weeds:** They are tender annuals with semi-aquatic habit. They can thrive as well under waterlogged and in partially dry condition. Propagation is chiefly by seed. Eg.*Ammaniabaccifera, Eclipta alba.*
II. **Dry lands weeds:** These are usually hardy plants with deep root system. They are adapted to withstand drought on account of mucilaginous nature of the stem and hairiness. Eg.*Tribulus terrestris, Convolvulus arvensis.*
III. **Irrigated lands weeds:** They are intermediate between dry land and wet land weeds with respect to their water requirement. These weeds neither require large quantities of water like wetland weeds nor can they successfully withstand extreme drought as dryland weeds Eg.*Trianthemaportulacastrum, Digera arvensi.s*

X. Based on specificity

Besides the various classes of weeds, a few others deserve special attention due to their specificity. They are; a. Poisonous weeds: b. Parasitic weeds c. Aquatic weeds

a. Poisonous weeds: The poisonous weeds cause illness on livestock resulting in death and cause great loss. These weeds are harvested along with fodder or grass and fed to cattle or while grazing the cattle consumes these poisonous plants. Eg.*Datura fastuosa, D. stramonium* and *D. metel* are poisonous to animals and human beings. The berries of *Withaniasomnifera* and seeds of *Abrusprecatorius* are poisonous.

b. Parasitic weeds: The parasite weeds are either total or partial which means, the weeds that depend completely on the host plant are termed as total parasites while the weeds that partially depend on host plant for minerals and capable of preparing its food from the green leaves are called as partial parasites. Those parasites which attack roots are termed as root parasites and those which attack shoots of other plants are called as stem parasites. The typical examples of different parasitic weeds are;

1. Total root parasite – *Orabanchecernua*on Tobacco.
2. Partial root parasite - *Striga lutea* on sugarcane and sorghum.
3. Total stem parasite - *Cuscuta chinensis* on leucerne and onion.
4. Partial stem parasite - *Cassytha filiformis*on orange trees and *Loranthus longiflorus*on mango and other trees.

c. Aquatic weeds: Unwanted plants, which grow in water and complete at least a part of their life cycle in water are called as aquatic weeds. They are further grouped into four categories as submersed, emersed, marginal and floating weeds.

1. Submersed weeds: These weeds are mostly vascular plants that produce all or most of their vegetative growth beneath the water surface, having true roots, stems and leaves. Eg.*Utricularia stellaris, Ceratophyllumdemersum, Hydrilla verticillate* and *Vallisneria spiralis.*

2. Emersed weeds: These plants are rooted in the bottom mud, with aerial stems and leaves at or above the water surface. The leaves are broad in many plants and sometimes like grasses. These leaves do not rise and fall with water level as in the case of floating weeds. Eg.*Nelumbiumspeciosum, Jussieua repens.*

3. Marginal weeds: Most of these plants are emersed weeds that can grow in moist shoreline areas with a depth of 60 to 90 cm water. These weeds vary in size, shape and habitat. The important genera that come under this group are; *Typha, Polygonum, Cephalanthus, Scirpus, etc.*

4. Floating weeds: These weeds have leaves that float on the water surface either singly or in cluster. Some weeds are free floating and some rooted at the mud bottom and the leaves rise and fall as the water level increases or decreases. Eg.*Eichhornia crassipes, Pistia stratiotes, Salvinia, Nymphaea pubescens*.

XI. Classification based on climate

Temperate	Tropical weeds
Ex. Annuals	Perennials

XII. Based on their Botanical Family: Most of the weeds belong to the families.

(i) Poaceae (Gramineae): *Eleusine indica.*

(ii) Asteraceae (Compositae): *Tridax procumbens.*

(iii) Solanaceae: *Solanum nigrum.*

(iv) Euphorbiaceae: *Euphorbia hirta.*

(v) Teliaceae: *Corchorus acutangulus.*

(vi) Leguminosae: *Melilotus indica.*

(vii) Chenopodiaceae: *Chenopodium album.*

(viii) Amaranthaceae: *Amaranthus viridii.*

Other terms

Facultative weeds: Also called apophytes. Weeds that grow primarily in wild community and migrated to crop fields or cultivated environment and associating themselves closely with the man's affairs, behave like more competitive weeds. Eg.*Opuntia dilleni*

Obligate weeds: Occur only on cultivated land or otherwise disturbed land. They cannot withstand competition from volunteer vegetation in a closed community. Less competitive obligate weeds can't survive and can't withstand and disappears when the land is not disturbed for 2-3 years and kept as fallow.

Noxious weeds

These weeds are arbitrarily defined as being undesirable, troublesome & difficult to control. They have immense capacity of reproduction & high dispersal capacity. They adopt tricky ways to defy man efforts to remove them. These weeds are also known as special problem weeds.
Eg.*Cyperus rotundus. Cynadondactylon, Circiumarvense, Parthenium, Eichhornea crassipes, Lantana camara, Saccharum spontaneum, Imperata cylindrical and Striga spp.*

Objectionable weed

It is a noxious weed whose seed is difficult to separate from the crop seed after contamination is called objectionable weeds.

CHAPTER-IV

PLANT NUTRITION

It refers to the inter relationship of mineral elements in the soil or soilless solution as well as their role in plant growth and development. This inter-relationship involves a complex balance of mineral elements essential and beneficial for optimum plant growth.

Plant nutrition is a study that deals with the plants need for certain chemical elements including their specific and interactive effects on all aspects of plant growth and development, their availability, absorption, transport and utilization. These chemical elements are referred to as plant nutrients.

Those plant nutrients which have been proved essential are commonly called essential elements. They include the carbon(C), oxygen (O)and hydrogen (H)which are derived from atmospheric carbon dioxide (CO2) and from water (H2O), as well as the mineral nutrients which are mainly absorbed from the soil in inorganic, ionic from through the roots.

Plant nutrition can be differentiated from animal nutrition in that plants are autotropic while animals are heterotrophic. Plants absorb directly the radiant energy from the sun and utilise it to convert carbon dioxide and water into simple sugars and starches through the process of photosynthesis. These carbohydrates serve as the plants' starches through the process of photosynthesis. These carbohydrates serve as the plant's food from which the stored chemical energy is extracted to fuel the various plant processes and structural elements are derived to form other organic compounds.

Plants likewise absorb mineral elements mainly from the soil which become components of the plant body. These chemical compounds and minerals are in turn harvested by animals either directly as plants or plant parts are utilized as food or indirectly from animals or animal-based food.

General concept and History of plant Nutrition

It took a long time for the modern concept of plant nutrition to evolve. First, it was necessary to disprove the 'humus theory' of plant nutrition, that is that plants are soil eaters. Specifically, it was believed then that plants feed upon the organic matter of soil or humus, their major source of nutrition. Rather, it was demonstrated by numerous researchers that it is some chemical elements in the air and water and the minerals in the soil that sustain plant life.

In this classic pot experiments, starting with a stem of willow tree, johnannBapist Van Helmont (1577-1644) concluded that it was water, not soil that was responsible for the increase in plant size. John Woodward (1665-1728) demonstrated that the growth of plants was more enhanced when they were grown in muddy water than in rainwater. Although it was not apparent then, it is because soil contains some nourishment which is essential to plant growth.

In 1804, Nicolas Theodore da Saussure (1767-1845) confirmed that plants need carbon dioxide in air as well as water is mainly that is mainly absorbed through their roots. He concluded that the chemical composition of plant body consists mainly of carbon dioxide that is fixed from the atmosphere with a portion coming from the soil solution. He argued that the minerals in ash of plants, though in small amounts, are essential to plants growth and development. He classified essential elements into two types: one is effective in large amounts (now called major elements or macronutrients) while the other is needed in terrace amount (now called trace elements or micronutrients).

According to Devlin (1975), de Saussure should be credited for discovering the essentiality of minerals in the soil to plants growth. Likewise, Hart (2005) declared that he (de Saussure) founded the modern theory of plant nutrition of plant nutrition, along with Jan Ingenhousz and Jean senebier. However, it was not until confirmed by Justus von liebig that mineral nutrient theory of plant nutrition became popular.

Justus von leibig(1803-1873)likewise found that plants are composed of carbon ,hydrogen and oxygen, as well as nitrogen, sulphur, phosphorus and other minerals matter. The minerals are obtained by plants from the soil and these can be detected in their ashes. As a result of study that application of manures, he concluded that the soil must be replenished by adding the minerals that agricultural crops have withdrawn.

The hydroponics culture introduced by Woodward made it possible later to shed more enlightenment on plant nutrition by growing plants in nutrient solutions with varying compostion. The deliberate exclusion of certain chemicals elements required in plants nutrition based on criteria of essentiality.

At least 16 essential plant nutrients or essential elements have now been identified according to approved criteria. Of these carbon hydrogen and oxygen combined compromise the main bulk of plant body. The carbohydrates alone comprise about 75% of dry matter content of all plants. A carbohydrates molecule is generally, composed of C, H and O in the ratio of 1:2:1(C6h1206); therefore, the respective proportions of elements in the molecule taking into consideration their atomic weights are C=40.0%, H+6.7% and O=53.3. Both C and O are sourced from atmospheric CO_2 while H is derived from water (H_2O) via photosynthesis.

1 ESSENTIAL PALNT NUTRIENTS

Elements (nutrients) which are required by the plants for their normal growth and development and which are not replaceable in their function by non-other nutrients are referred to as essential nutrients.

The essential elements are chemical elements that are absolutely needed by plants for their growth and development. Their essentiality have been established based on following criteria formulated by DI Arnon and PR stout(1939)

1> An element is essential if, being deficient the plants is unable to complete the vegetative or reproductive stage of its life cycle.
2> The deficiency can be prevented or corrected only by supplying the specific element causing the deficiency.
3> The element is directly involved in nutrition of plant.

With time, it has become apparent also that there is an additional fourth criterion that the essentiality of any element is proved in all plants tested.

Based on first criterion, an element is considered essential if, in its absence, a plant is unable to complete its cycle which includes the production of viable seed. In other words, the presence of element must ensure the formation of seed that possesses the natural capability to germinate and develop into a mature plant under favourable conditions for growth.

The second criterion specifies the irreplaceability of any essential element. For example, sodium cannot be essential simply because it can substitute for some mode of action of potassium in plant nutrition.

Based on third criterion, an element is essential because it is indispensable to plants nutrition and does not merely correct some unfavourable condition of soil or culture medium. For example, carbon, hydrogen, oxygen, nitrogen and magnesium are essential elements because they are part of chlorophyll molecule and the presence of chlorophyll is essential in photosynthesis. Being so, they are directly involved in the autotrophic production of food by plants.

1.1 HOW MANY ESSENTIAL ELEMENTS ARE THERE?

Plants are not so discriminating in absorbing chemical elements. Quantitative analysis has in fact shown that plant tissue can contain any or a combination of more than 60 elements. Depending on where they are growing and the presence of elements, plants can even contain lead, calcium, gold or radioactive strontium, platinum. However only few elements are deemed elemsts to plant growth and development.

Plants require for their growth and reproduction at least 16 elements. At least 16 is highlighted because some authorities strongly argue the inclusion of other elements into the original list to 16. Cleraly some elements have been shown essential at least in some species. For example, the essentiality of cobalt has been established for Nitrogen fixation in legumes. Others promote plant growth but without complying completely with Arnon and stout's Criteria. These elements are referred as beneficial elements. In addition, the number of essential nutrients varies from author to author according to criteria of essentiality.

In 1830 sachs and knop showed that there were 10 essential elements. These are carbon hydrogen oxygen nitrogen and phosphorus, potassium, calcium, magnesium, sulphur and iron.

By 1954 it was established that there are 16 essentail elements. Added to the list are manganese copper, molybdenium, boron,and chlorine. The latest addition to the list was chlorine although is essentiality was suggested many years ago.

1.2 CLASSIFICATION OF PLANT NUTRIENTS

The 16 plant nutrients are classified into various groups.

A. Major Elements /Nutrients and minor /Trace elements

Of the 16 listed ,9 are major or macronutrients and 7trace elements or macro nutrients. Macronutrients are those which are needed by plants for their growth and reproduction in relatively large amounts while micronutrients are needed in smaller amounts compared to the former. The major nutrients are further sub –divided into structural elements primary nutrients and secondary nutrients.

ELEMENTS	FORMS ABSORBED	RANGE OF conc.in dry tissues(ppm)	Year	Author
Macronutrients				
1.carbon	CO_2	45%	1882	SACHS J

2.Oxygen	H20	45%	1804	De Saussure,T
3.Hydrogen	H2O	6%	1882	Sachs J
4.Nitrogen	NO3,NH4	0.5-6%	1872	Rutherford Gk
5.Phosphorus	H20PO4	0.15-0.5	1860	Ville
6.Potassium	K+	0.8-8%	1860	Sachs J knop
7.calcium	Ca2+	0.1-6%	1856	Salm-Horstmar
8.sulphur	SO4	0.1-1.5%	1865	Sachs j,Knop
9.Magnesium	Mg2+	0.05-1%	1906	willstatter
Micronutrients				
10.Iron	Fe 2+	(20 -600)	1860	Sachs j knop
11.chlorine	CL-	(10-80,000)	1954	Broyer,stout
12.Maganese	Mn 2+	(10-600)	1922	McHargue
13.zinc	Zn2+	(10-250)	1926	Lipman,sommer
14.copper	Cu+	(2-50)	1931	limpan
15.Boron	BO H3BO3	(0.2-800)	1923	Warrinton
16.Molybdenum	MoO4	(0.1-10)	1938	Arnon ant stout

B. Minerals and non –Mineral Nutrients.

Minerals are absorbed any plants primarily in ionic form from the soil while non-mineral nutrients are absorbed either from soil or from the atmosphere. The elements numbered 4-16(in table) in the list are considered mineral nutrients. The carbon oxygen and hydrogen are considered non –mineral nutrients. They are sourced from carbon dioxide and water which reacts in process of photosynthesis.

There are numerous ways in which plant nutrients can be categorized. A common way of classifying nutrient can be categorized. A common way of classification of nutrients elements is according to elements representing the mineral composition of plants. These elements include essential and other mineral elements.

Another way of grouping plant nutrients is based on their concentration. According to classification plan nutrients can be macronutrients 0.03-6.0per cent or micronutrients 0.01-500mg kg

A third method for classification of plant nutrients is actually based on their physiological functions.

Some of nutrients are constituents of plant nutrient is actually based on their physiological functions. Some nutrients are constituents of various organic or inorganic compounds. This group include N, S, P, Ca, B, Fe and Mg.

In the second group, we find those which are activators of enzymes. This group include the following nutrients K, Ca, Fe, Zn, Mn, Cu, Mo, Na, Cl.

IN the next group, there are those which are components of various redox reactions and electron transport. This group include P, S, Fe, Mn, Cu, Mo.

Fourth group contain osmotic regulators and nutrients that maintain ionic balance. It includes K, Na and Cl.

Fifth group is group of stimulating elements, which include Co, Cr, Ni, Sn, Li, F, Se, Si etc.

In the sixth group, we can find toxic heavy metals and other elements including Cd,Cr,Hg,Ni,Pb,As,Se,V.

Based on chemical nature of nutrients, plants nutrients are classified as:

Cations- K, Ca, Mg, Fe, Mn,Zn, Cu.

Anions- NO_3, H_2PO_4, SO4.

Metals- K, Ca, Mg, Fe, Mn, Zn, cu.

Nn Metals-N, P, S, B, Mo, Cl.

Based on mobility in plants, nutrients are classified into

Highly mobile- N, P, K

Moderate mobile- Zn

Less mobile- S, Fe, Mn, Cu, Mo, Cl

Immobile - Ca, B

1.3 EXPRESSING PLANT NUTRIENT CONTENT

In the context nutrient management, it is of course _not enough to identify the nutrients but also the nutrient contents need to established and expressed, as well. Recently, nutrient content is expressed as elements content in dry matter. That means %age is DM for macro elements: N%, P%, K%, Ca%, Mg%, S%. While for microelements it can be expressed in mg per kg in DM.

Previously, element content was commonly expressed as oxides. In this regard a table is drawn below for conversion factors for nutrients.

From	To	Multiply by	FROM	To	Multiple by
P	P_2O_5	2.29	P_2O_5	P	0.44
P	PO_4	3.06	PO_4	P	0.32
H_3PO_4	H_2PO_4	0.9898	H_2PO_4	H_3PO_4	1.38
K	K_2O	1.20	K_2O	K	0.83
Ca	CaO	1.40	CaO	Ca	0.71
Mg	MgO	1.66	MgO	Mg	0.60
S	SO_3	2.50	SO_3	S	0.40
S	SO_4	3.00	SO_4	S	0.33
N	NH_4	1.28	NH_4	N	0.82
N	NO_3	4.43	NO_3	N	0.22

1.4 MECHANISMS OF ION TRANSPORT TO PLANT ROOTS:

Unlike water, all minerals cannot be passively absorbed by roots. Two factors account for this.

1> Mineral are present in soil as charged particles which cannot move across cell membrane

2> The concentration of minerals in soil is usually lower than the concentration, of mineral in root.

Therefore, most minerals must enter the roots by active absorption into the cytoplasm of epidermal cells. This needs energy in form of ATP. The active uptake of ions is partly responsible for the water potential gradient in roots and therefore for the uptake of water by osmosis. Some ions also move into the epidermal cells passively. Attention should be paid to the different ways of ions getting to roots plants. Three mechanisms are known in which nutrients reach the root surface, a prerequisite for the nutrient uptake. These mechanisms are called root interception, mass flow and diffusion movement.

ROOT INTERCEPTION: It is where root hairs and small roots grow throughout soil and come into contact with soil and organic matter particles containing essential plant nutrients. The most current theory is plant root exchange H+ for essential cations such as NH4,K+,Ca+2,Mg+2. Bear in mind, a plant's root system come into contact with about one percent of the total soil mass it is growing in. Hence, root interception does not figure significantly in plant nutrient uptake. The interception mechanism is very valuable, however because root growth can extend to areas where mass flow and diffusion take over. For example, A root may grow within a quarter inch of phosphorus fertilizer pellet. Although the root does not technically bump into the nutrient and intercept it, the roots is close enough for diffusion to occur.

DIFFUSION: It is migration of nutrients from an area of higher concentration. An example of diffusion is a fertilizer prill in soil. Once the pill is wet, the nutrients will diffuse away froprill. The prill is area of higher concentration and the surroundings soil is the area of lower concentration. Diffusion is a slow, but important method for plants to obtain certain nutrients from the soil.

MASS FLOW: is movement of dissolved nutrients in soil solution towards the plant root takes in water. The nutrients are swept toward the plant root along with water. Nutrients like phosphorus that are strongly adsorbed to the soil solids would never get to root. But nitrogen which is held very weakly by soil readily moves along with water.

Rates among these three mechanisms are variable, related to chemical characteristics and behaviour of nutrient element in soil.

TABLE

Rates of root interception, mass flow and diffusion in ion transport to maize roots

NUTRIENT	ROOT INTERCEPTION	Mass flow	Diffusion

NITROGEN	1	99	0
PHOSPHORUS	2	4	94
POTASSIUM	2	20	78
CALCIUM	12	88	0
MAGNESIUM	27	73	0
SULPHUR	4	94	2

Most of nutrients that a plant needs are dissolved in water and then absorbed by roots. Ninety eight percent of these plant nutrients are absorbed from soil solution and only about 2 percent are actually extracted from the soil particles by the roots. Most of nutrient elements are absorbed as charged ions or pieces of molecules. Ions may be positively charged cations or negatively charged anions. Positive and negative are equally paired so that there is no overall charge. For example, nitrogen may be absorbed as nitrate which is an anion with one negative charge. A potassium ion and one nitrate ion. Calcium nitrate has one calcium cation that has two negative, single charge, nitrate ions to match the positive charges of calcium.

The balance of ions in soil is very important. Just as ions having opposite charges attract each other, ions having similar charges compete for chemical interactions and reactions in environment. Some ions are more active than others or can complete better. For example, both calcium and magnesium are cations with two charges but two magnesium is more active. If both are in competition to be absorbed the magnesium will be absorbed. This explains why results of a soil test may indicate there is sufficient calcium in soil, but plant may still exhibit a calcium deficiency because of an excess of more active magnesium. What may be expressed as a deficiency because of an excess of more active magnesium. What may be expressed as a deficiency in one micronutrient may really be caused by an excess of another.

In order for the ions to be easily absorbed, they must first be dissolved in soil solution. Some combinations of ions are easily dissolved such as potassium nitrate. When other ions combine, they may precipitate or fall out of solution and thus become unavailable to plant. Many of micronutrients from complex combination with be easily taken up by plant. The pH, which means affects chemical reactions. If the soil pH is extremely high, many of micronutrients precipitate out of the solution and are unavailable to plant. When the soil Ph is extremely low some of micronutrients become extremely soluble and ion levels may become high enough to injure the plant. The effect of PH varies with ion, the types of ions in the soil and the type of soil. Therefore, not only is amount of nutrient important but also soil pH.

Adequate water and oxygen must be available on soil. Water is required for nutrient movement into and throughout the roots. Oxygen is required in soil for respiration to occur to produce energy for growth and movement of mineral ions into the root's cells across their membranes. This is an active absorption process utilizing energy from respiration. Oxygen is not transported to roots from shoot. Without adequate oxygen from soil environment there is no energy produced for nutrient absorption. This also stops active absorption in which water flows into the cells due to higher concentration of nutrients that were actively absorbed.

Anything that lowers or prevents the production of sugar in leaves can lower nutrient absorption. If plant is under stress due to low light or extreme in temperature, nutrient deficiency problems may develop. The stage of growth or how actively the plant is growing may also affect the amount of nutrient absorbed. Many plants go into a rest period or dormancy during part of year. During dormancy, few nutrients are absorbed. Plants may also absorb different nutrient just as flower buds begin to develop.

Nutrients transported from the roots to cell by vascular system move into cells through a cell membrane. There are three different ways this happens. First, an entire molecule or ion pair may move through the, membrane. If the cell is using energy called active transport, to absorb ion then only one of ions in pair is pulled into the cell. The other will keep charges even. Most anions are actively absorbed.

The second way of keeping the charges inside the cell balanced and absorbing a new ion is to exchange one charged ion for another ion with same charge. A hydrogen ion is often released so that the cell can absorb another positive ion such as potassium. Since this is a simple passive exchange, absorption energy may not be required. Cations may be absorbed by this passive method.

Both of method mentioned above may be passive active. Their method the carrier system, is always active absorption, requiring energy. Scientists have discovered that with in cell membrane there are specialised chemicals that act as carriers. The carrier, through chemical changes, attract as ion from outside the cell membrane and releases it inside the cell. Once the ion is inside cell it is attached to other ions so that it does not move out of all cell. Complex chemical reactions are involved in entire process.

Although nutrients can be absorbed passively, research has shown that active absorption must take place if plant is to grow and to be healthy. The factors discussed earlier about absorption by roots are also true for absorption by cell. Some of factors that effects nutrient absorption is the type of ion, soil Ph, solubility of ion pairs, water, soil oxygen, sugar supply, plant stress, and temperature

2.FUNCTONS OF ESSENTIAL PLANT NUTRIENTS:

Sixteen plant food nutrients are essential from proper crop development. Each is equally important to plant, yet each is required in vastly different amounts. These differences have led to grouping of these essential elements into three categories. Primary nutrient, secondary nutrients and micronutrients.

2.1 PRIMARY NUTRIENTS:

Primary nutrients are nitrogen, phosphorus and potassium. They are the most frequently required in a crop fertilisation programme. Also, they are need in the greatest total quantity by plants as fertilizer.

Nitrogen:

>>Necessary for formation of amino acids, the building blocks of protein.

>>Essential for plant cell division, vital for plant growth.

>>Directly involved in photosynthesis.

>>Necessary component of vitamins.

>>Aids in production and use of carbohydrates.

>>Affects energy reactions in plant.

Phosphorus:

>>Plants require P for development of ATP, sugar and nucleic acids.

>>Promotes early root formation growth.

>>Improves quality of fruits, vegetables and grains.

>>Vital to seed formation.

>>Helps plants survive harsh winter conditions.

>>Increases water use efficiency.

>>Hastens maturity

Potassium:

>>Potassium is utilised by plants in activation of enzymes and co-enzymes, photosynthesis, protein formation and sugar transport.

>>carbohydrates metabolism and break down and translocation of starches.

>>Increases water use efficiency.

>>Important in fruit formation.

>>Improves quality of seeds and fruits.

>>Improves winter hardiness.

>>Increases disease resistance.

2.2 SECONDARY NUTRIENTS:

The secondary nutrients are calcium, magnesium and sulphur. For most crops, these three are needed in lesser amounts than that of primary nutrients. They are growing in important in crop fertilization programme due to more stringent clean air standards and efforts to improve the environment.

Calcium:

>>calcium activates enzymes and is a structural component of cells walls.

>>Utilized for continuous cell division and formation.

>>Reduces plant respiration.

>>Aids translocation of photosynthesis from leaves to fruiting organs.

>>Increases fruit set.

>>Essential for nut development in groundnut.

>> Stimulates microbial activity.

Magnesium:

>>Magnesium is central molecule in chlorophyll and is an important co- factor for production of ATP.

>>Improves utilization and mobility of phosphorus.

>>Activator and component of many plant enzymes.

>>Increases iron utilization in plants.

>>Influences earliness and uniformity of maturity.

Sulphur:

>> Sulphur is a structural component of amino acids, proteins, vitamins and enzymes and is essential to produce chlorophyll.

>>Helps develop enzymes and vitamins.

>>promotes nodule formation on legumes.

>>Aids in seed production.

>>Necessary in chrophyll formation (though it isn't one of constituents)

2.3 MICRONUTRIENTS:

The micronutrients are boron, chlorine, copper, manganese, molybdenum and zinc. These plant food elements are used in very small amounts, but they are just as important to plant development and profitable crop production as the major nutrients. Especially, they work "behind the scene" as activators of many plant functions.

Boron:

>>Primary functions of Bin plants are related to cell wall formation and reproductive tissue.

>>Essential for germination of pollen grains a growth of pollen tubes.

>>Promotes maturity.

>> Necessary for sugar translocation.

Chlorine:

>>Chloride is required by plants for leaf turgor and photosynthesis.

>>Interferes with P uptake.

>>Enhances maturity of small grains- on some soils.

Copper:

>>Copper is concentrated in roots of plants and plays a part in nitrogen metabolism.

>>Catalyses several plant processes.

>> Major function in photosynthesis

>>Major function in reproductive stages.

>>Indirect role in chlorophyll production.

>>Increases sugar content.

>>Improves flavour of fruits and vegetables.

Iron:

>>Iron is necessary for many enzymes functions.

>>Promotion formation of chlorophyll.

>>Acts as an oxygen carrier.

>>Reactions involving cell division and growth.

Manganese:

>>Manganese is involved in enzymes activity for photosynthesis, respiration and nitrogen metabolism.

>> Aids in chlorophyll synthesis.

>>Increases the availability of P and Ca.

Molybdenum:

>>Required to from the enzymes "nitrate reuctage" which reduces nitrates to ammonium in plant.

>>Aids in formation of legume nodules.

>>Needed to convert inorganic phosphates to forms in plant.

Zinc:

>>It is a functional cofactor of a large number of enzymes including auxins (plant growth hormones).

>>It is essential to carbohydrate metabolism, protein synthesis and intermodal elongation.

>>Necessary for chlorophyll production.

>>Necessary for starch formation.

>>Aids in seed formation.

In addition to 13 nutrients listed above, plants require carbon, hydrogen, and oxygen, which are extracted from air and water to make up bulk of plant weight.

3. NUTRIENT DEFECIENCY AND TOXICITY SYMPTOMS:

Plants requires essential nutrients for normal functioning and growth. A plant sufficiency range is defined as range of nutrient necessary to meet the plants nutritional needs and maximum growth.

Width of this range will depend upon individual plant species and the particular nutrient. Nutrient levels outside of plant sufficiency range will cause overall crop growth and health to decline due to either a deficiency or toxicity. Nutrient deficiency occurs when an essential nutrient is not available in sufficient quantity to meet requirements of growing plant. Toxicity occurs when a nutrient is in excess of plant needs and decreases plant growth or quality.

Nutrient toxicity is less common than deficiency and most likely occurs as a result of indiscriminate application of fertilizers. The three basic tools for diagnosing nutrient deficiencies and toxicities are.

1> Soil testing
2> Plant analyses.
3> Visual observations in the field.

Both soil testing and plant analysis are quantitative tests that are compared to sufficiency range for a particular crop. Visual observation, on the other hand, is a qualitative test and is based on symptoms such as stunted growth or a yellowing of leaves occurring as a result of nutrient stress. Visual nutrient deficiency and toxicity symptoms are briefly presented.

3.1: VISUAL SYMPTOMS AS A DIGNOSTIC TOOL:

Interpreting visual nutrient deficiency and toxicity symptoms in plants can be difficult and plant analysis or soil testing is necessary to confirm nutrient stress. Precautions in identifying nutrient stress symptoms include the following:

1. Many symptoms appear similar: For instance, Nitrogen and Sulphur deficiency symptoms can be very alike, depending upon growth stage and severity of deficiencies.

2. Multiple deficiencies and /or toxicities can occur at same: More than one deficiency or toxicity can produce symptoms or possibly a deficiency of one nutrient can induce the excessiveness of another.

3. Crop species and cultivators: Crop species and even some cultivators of same species, differ in their ability to adapt to nutrient deficiencies and toxicities. For example, maize is typically more sensitive to a zinc deficiency than barley.

4. Pseudo deficiency symptoms: Pseudo deficiency symptoms are visual symptoms appearing similar to nutrient deficiency symptoms. Potential factors causing pseudo deficiency include, but are not limited to, disease, drought, excess water, genetic abnormalities, herbicide and pesticide residues, insects and soil compaction.

5. Hidden hunger: Plants may be nutrient deficient without showing visual clues.

In addition to above precautions, visual observation is also limited by time. Between the time a plant is nutrient deficient and visual symptoms appear, crop health and productivity may be substantially reduced and corrective actions may or may not be effective. Therefore, regular soil or plant testing is recommended for prevention and early diagnosis of nutrient stress.

3.2 SYMPTOMS CAUSED BY NUTRIENT DEFECIENCIES:

Symptoms caused by nutrient deficiencies are generally, grouped into five categories.

1> Stunted growth.

2> Chlorosis.

3>Interveinal chlorosis.

4>Purplish –red colouring.

5>Necrosois.

Stunting is a common symptom for many deficient nutrients due to their varied roles in plant. For example, when involved in plant functions such as stem elongation, photosynthesis and protein production are deficient, plant growth is typically slow and plants are small in stature.

Chlorosis and interveinal chlorosis are found in plant deficient of nutrients necessary for photosynthesis and/or chlorophyll production. Chlorosis can result in either the entire plant or leaf turning light green to yellow or appear more localised as white or yellow spotting.

Interveinal chllorosisis the yellowing of leaf tissue between veins, with the veins themselves remaining green. Intervenial chlorosis occur when some nutrients are deficient.

Purplish –red discolouration in plant stems and leaves are due to above normal levels of anthocyanin that can accumulate when plant function is disrupted or stressed. This symptom can be particularly difficult to diagnose because cool temperature, disease, drought, and even, maturation of some plants can also cause anthocyanin to accumulate. Certain plant cultivars may also exhibit this purple colouring.

Necrosis generally happens in later stages of a deficiency and cause the parts of plant first affected by deficiency to brown and die.

Since a number happens of nutrient deficiencies can produce similar symptoms, further evaluation of symptoms related to particular leaf patterns or locations on plant will be needed to diagnose nutrient specific deficiencies.

3.3 MOBILE AND IMMOBILE NUTRINETS:

Another initial step in identifying deficiency symptoms is to determine whether the deficiency is result of mobile or immobile nutrient based on where the symptoms is appearing in whole plant.

Mobile nutrients are nutrients that are able to move out of older leaves to younger plant parts when supplies are inadequate. Mobile nutrients include N,P,K,CL,Mg and molybdenum .Because these nutrient are mobile , visual deficiencies will first occur in older or lower leaves and effects can be effects can be either localised or generalised . In contrast, immobile nutrients (B,ca),Cu,Fe,Mn,S and Zn) are not able to move from one plant part to another and deficiency symptoms will initially occur in younger or upper leaves and be localised. Zn is a partial exception to this as it is only somewhat immobile in plant, causing Zn deficiency symptoms to initially appear on middle leaves and then affect both older and younger leaves as the deficiency develops.

Mobility of nutrients in plant is given below:

Translocated	**Not translocated**

Symptoms appear on old leaves first:	Symptoms appear on young leaves first
1: Nitrogen	6 sulphur 7. calcium
2: Phosphorus	8 Boron 9. Iron
3: Magnesium	10 Manganese
4: Magnesium	11 Zinc 12 copper
5: Chloride	13 Molybdenum

IDENTIFICATION KEY:

The "key" can be used for identifying nutrient deficiencies based on common symptoms. The key consists of different alternative statements about plant structures and their appearance. It may be helpful to have a healthy plant on hand for comparison purposes. Beginning at top of key, read the first Statement and determine whether the applies to plant being evaluated. If the statement. If not follow "NO" arrow to an alternative statement.

Continue this process until the probable nutrient responsible for deficiency is identified. Although most descriptions in this key are generalised to accommodate common symptoms seen in various crops, bear in mind that deficiency symptoms differ among types and plant specific symptoms may not be listed.

4. NUTRIENT INTERACTIONS

Nutrient interactions influence the availability of essential nutrients for plant growth.

4.1 ANTAGONISM:

High levels of a particular nutrient in soil can interfere with availability and uptake by plant of other nutrients. Those nutrients which interfere with one another are said to be antagonistic. Examples of antagonism include:

>> Excessive nitrogen reduces uptake of phosphorus, potassium, Iron and almost all secondary an micronutrients like calcium and magnesium, iron, manganese zinc and copper.

>>Excessive phosphorus reduces uptake of cationic micronutrients like iron, manganese, zinc, copper.

>>Excessive calcium reduces uptake of iron.

>>Excessive iron reduces zinc uptake.

>>Excessive zinc reduces manganese uptake.

4.2 SYNERGISM (STIMULATION)

Synergism occurs when the high level of particular nutrient increases the demand by plant for another nutrient. Example of synergism include:

>>Optimum supply of nitrogen ensures optimum uptake of potassium as well as phosphorus, magnesium ,iron, zinc from soils.

>>optimum levels of copper and boron improve nitrogen uptake by plant.

>>optimum levels of calcium and zinc improve uptake of potassium and phosphorus.

>>optimum levels of manganese increase uptake of copper.

CHAPTER V

SOIL FERTILITY VS SOIL PRODUCTIVITY

The words soil fertility and productivity are, often interchangeably to mean the capacity of soil to produce crops. However, there are differences between the two.

SOIL FERTILITY

It is the inherent capacity of soil that enables it to provide essential plant elements (nutrients) in quantities and proportions for the growth of specified plant when the growth factors are favourable. It indicates the nutrient supplying capacity of a soil for crop growth. It is usually expressed in quantity of nutrients per unit land area. Though, a fertile soil is not necessarily a productive due to adverse waterlogging, soil reaction etc, soil fertility is vital to crop productivity.

SOIL PRODUCTIVITY

It is the capacity of the soil for producing a specified plant or sequence of plants under a defined set of management practices. It is measured in terms of output or harvest in relation to the inputs of production factors for a specified kind of soil under a physically defined system of management (USDA 1957). Some of the difference between soil fertility and productivity are given below:

	Soil fertility	Soil productivity
1.	Considered as an index of nutrient availability to plants.	Usually, used to indicate the ability of the soil for crop yield.
2.	One of the factors of crop production.	Interaction of crop production factors.
3.	Usually assessed in labs.	Assessed in field with reference to a particular climate.
4.	Soil potential to produce a crop.	Result of different factors influencing soil management.
5.	Depends on physical, chemical and biological factors of the soil.	Depend on soil physical conditions, fertility, climate and weather.
6.	Function of available nutrients in the soil.	Function of soil fertility, soil and crop management and climate.
7.	Fertility of certain soils may be same in all the climates.	Differs in response to variation in climate and location.
8.	Soil fertility= f (nutrient status of	Soil productivity= f (soil fertility+ management +

	soil)	climate).

SOIL FERTILITY LOSSES AND GAINS

Soil nutrient availability changes over time. Continuous cycling of nutrients into and out of the soil is known as nutrient cycle. The cycle involves complex biological and chemical interactions. The cycle has two parts: inputs that add plant nutrients to the soil and outputs that send them from the soil largely in the farm of crop products.

Difference between the volume of inputs and outputs constitutes the nutrient balance. Positive nutrient balance (nutrient additions to the soil are greater than their removal from the soil) in the soil indicate that the farming systems are inefficient, and in the extreme, that they may be polluting the environment. Negative balance indicates that the soils are being mined and that farming systems are unsustainable over long time. In the latter case, nutrients have to be replenished to maintain crop output and soil fertility into the future.

1. SOIL FERTILITY LOSSES

Nutrients are lost from the soil through:

- Harvested crop (crop removal).
- Crop residues and weed uptake.
- Leaching losses.
- Gaseous losses.
- Soil erosion.

Crop removal: Nutrients are lost from the soil through crop harvests and weeds removal from the crop. Several soil and crop management practices influence nutrient uptake by crops and weeds. Higher the biological yield, larger the amount of nutrients removed from the soil. Loss of secondary nutrients due to harvest of rice, wheat and maize are also considerable. Ca, Mg and S losses due to rice harvest are 21, 10 and 9 kg per ha, respectively and that due to wheat harvest are 18, 15 and 14 kg per ha, respectively. Losses of micronutrients due to crop harvest are also in proportion to the total biomass production.

Crop residues and weed uptake: Depending on the intensity of weed growth and amount of crop residues, other than the yield, the amount of nutrients lost due to crop residues and weeds will be almost equal to that lost due to crop harvest. In the case of wheat crop, weeds alone accounts for about 20 N, 9 P_2O_5 and 40 K_2O kg ha^{-1} .

Leaching: Nutrient elements soluble in water are subjected to leaching losses, especially in light soils like sandy and sandy loams. Among the major nutrients, nitrogen and potassium are subjected to leaching loss. Nitrogen is lost from the soil as NO_3 or NH_4. Around 90 per cent of nitrogen is lost as NO_3 ions.

Gaseous losses: Nitrogen from soil system is lost as NH_3 gas through ammonia volatilization or as NO, N_2O, and N_2 through denitrification into atmosphere.

Soil erosion: Almost all the nutrients are subjected to loss through soil erosion along with fine soil particles. The amount of loss depends on the rate of soil loss per unit time.

2. SOIL FERTILITY GAINS (INPUTS)

Major input sources include:

- Mineral fertilizers.
- Organic manures.
- Biological nitrogen fixation.
- Sedimentation.
- Atmospheric deposition (rainfall).

Other sources of inputs include: soil amendments (lime, gypsum etc), herbicides and fungicides (copper fungicides, triazines etc), green manures and green leaf manures and legumes in cropping systems. Soil fertility gains will be discussed in detail in subsequent chapters.

3. ORGANIC MANURES

Organic manures include materials largely of planet or animal origin in different states of decomposition that are added to soil to supply plant nutrients and improve soil physical properties. Application of organic manures for crop production is a common practice and this concept originated along with the concept of crop cultivation. Until mid-nineteenth century, organic manures were the only source of nutrient supply to the crops. Use of inorganic fertilizers gained importance for crop production during the last five decades, largely due to the fact that the organic manures alone could not meet the nutrient needs of high yielding crop cultivars.

The words ‘fertilizer’ and ‘manure’ are used interchangeably in the context of agriculture, both referring to substances added to soil for the establishment, improvement and maintenance of soil fertility. By convention fertilizer refers to a substance applied in small amounts which contains a relatively high percentage of plant nutrients. Fertilizers may be of organic or inorganic origin, used either in their naturally occurring state or more often after some form of processing. Inorganic fertilizers are usually wholly manufactured, as in the case of ammonium sulphate or they may be processed from a mined or quarried mineral, as in the case of ground limestone. Fertilizers may be described as ‘straight’ where the product contains predominantly nitrogen, phosphate or potash and ‘compound’ where there is a mix of nutrients. The word manure is, generally, used to describe bulky waste substances high in fiber content with relatively low levels of nutrients. Such organics are most commonly represented by the mixture of farm animal dung and bedding known as farm yard manure. Composted plant remains, farm slurry and sewage sludge are other examples of organic manure. Thoughtful use of fertilizers and manures can contribute beneficially to various aspects of the natural environment. Major sources of manures include:

1. Cattle shed wastes dung, urine and slurry from biogas plants.

2. Human habitation wastes -night soil, human urine, town refuse, sewage, sludge and sullage.

3. Poultry litter, droppings of sheep and goat.

4. Slaughterhouse wastes bone meal, meat meal, blood meal, horn and hoof meal, fish wastes.

5. By-products of agroindustries -oil cakes, biogases and press mud, fruit and vegetable processing waste etc.

6. Crop wastes sugarcane trash, stubbles and other related material.

7. Water hyacinth, weeds and tank silt.

8. Green manure crops and green leaf manuring material.

Manures can also be grouped, into bulky organic manures and-concentrated organic manures based on concentration of the nutrients.

BULKY ORGANIC MANURES

Bulky organic manures contain small percentage of nutrients and they are applied in large quantities. Farmyard manure (FYM), compost and green manure are the most important and widely used bulky organic manures. Use of bulky organic manures has several advantages:

» They supply all the plant nutrients, macro and micronutrients in small quantities or they improve soil physical properties like structure, water holding capacity etc.

» They increase the availability of soil nutrients.

» They increase the activities of soil microbes for mineralization of organic residues.

» They increase the CEO of soils for trapping the soil nutrients.

Farmyard Manure

Farmyard manure (FYM) refers to the decomposed mixture of dung and urine of farm animals along with litter and lell. Over material from roughages or fodder fed to the cattle. On an average, well decomposed farmyard manure contains 0.5 per cent N, 0.2 per cent P_2O_5 and 0.5 per cent K_2O. The present method of preparing farmyard manure by the {mixers is defective. Urine, which is wasted, contains one per cent nitrogen and 1.35 per cent potassium. Nitrogen present in urine is mostly in the form of urea which is subjected to volatilization losses. Even during storage, nutrients are lost due to leaching and volatilization. However, it is practically impossible to avoid losses altogether. But can be reduced by following improved method of preparation of farmyard manure. Preparing and storing the FYM in trenches of size 6 m to 7.5 m length, 1.5 m to 2.0 in width and 1.0 m deep can minimize the loss of nutrients considerably.

All available litter and refuse are mixed with soil and spread in the shed so as to absorb urine. The next morning, urine-soaked refuse along with dung is collected and placed in the trench. A section of the trench from one end should be taken up for filling with daily collection. When ‘the section is filled up to a height of 45 to 60 cm above the ground level, the top of the heap is made into a dome and plastered with cow dung earth slurry The process is continued and when the first trench is completely filled, second trench can be used for preparing the farm yard manure.

The manure becomes ready for use in about four to live months after plastering. If-urine is not collected in the bedding, it can be collected along with washings of the cattle shed in a cemented pit from which it is later added to the farmyard manure pit. Chemical preservatives can also be used to reduce losses and enrich farmyard manure. Commonly used chemicals are gypsum and superphosphate. Gypsum is spread in the cattle shed which absorbs urine and prevents volatilization loss of urea present in the urine and also adds calcium and sulphur. Superphosphate also acts similarly in reducing losses and also increases phosphorus content.

Partially rotten farmyard manure has to be applied three to four weeks before sowing while well rotten manure can be applied immediately before sowing. Generally, 10 to 20t ha is applied, but more than 20 t ha is applied to fodder grasses and vegetables. In such cases, farmyard manure should be applied at least 15 days in advance to avoid immobilization of nitrogen. The existing practice of leaving manure in small heaps scattered in the field for a very long period leads to loss of nutrients. These losses can be reduced by spreading the manure and incorporating by ploughing immediately after application. '

Vegetable crops like potato, tomato, sweet potato, carrot, raddish, onion etc, respond well to the farmyard manure. The other responsive crops are sugarcane, rice, grass and orchard "OPS like oranges, banana, mango and plantation crop like coconut. Entire amount of nutrients presents in farmyard.

Sheep and Goat Manure of shee and oats cont ' p' ' .Dioppn g ' P thg. am h bher nutrients than farmyard manure and compost. On an average it contains 3 per cent N, 1 per cent P_2O_5. It is applied to the field in two ways. The sweeping of Sheep or and 2 per are placed in pits for decomposition and it is applied later to the field. The second method is sheep penning £3.23 sheep and goats are kept overnight in the field and urine and faecal matter added to the soil is incorporated to a shallow depth by working blade harrow or cultivator.

Poultry Manure: The excreta of birds ferment very quickly. If left exposed, 50 per cent of its nitrogen is lost within 30 days. Poultry manure contains higher nitrogen and Phosphorus compared to other bulky organic manures. The average nutrient content is 3.03 per cent N, 2.63 per cent P_2O_5 and 1.4 per cent K_2O.

Compost: Bulky organic manure obtained as a result of decomposition of farm/town waste, in the absence of cattle excreta, is called compost. Simply, a mass of rotted organic matter made from farm waste is called compost. Compost made from farm waste like sugarcane trash, paddy straw, weeds and other plants and other waste is called farm compost. The average nutrient contents of farm compost are 0.5 per cent N, 0.15 per cent P205 and 0.5 per cent K20. if superphosphate is added during compost making, the resultant compost is called super digested compost. Nutrient value of farm compost can be increased by application of superphosphate or rock phosphate at 10 to 15 kg t'1 of raw material at the initial stage of filling the compost pit.

Compost made from town refuses likely night soil, street sweepings and dustbin refuse are called town compost. It contains 1.4 per cent N, 1.00 per cent P205 and 1.4 per cent K20. I. .Farm compost is made by placing farm wastes in trenches of suitable size, say 4.5 to 5.0 m long, 1.5 to 2.0 m wide and 1.0 to 2.0 m deep. Farm waste is placed in the trenches layer by layer. Each layer is well moistened by sprinkling cow dung slurry or water. Trenches are filled up to a height pf 0.5 m above the ground. Compost will be ready for application within five to six months.

Composting is essentially a microbial decomposition of organic residues collected from rural area (rural compost) 6 urban area (urban compost). Different methods of composting are briefly presented.

Coimbatore method: In Coimbatore method, composting is done in pits of different sizes depending on the waste material available. A layer of waste materials is first laid in the pit. It is moistened with a suspension of 55-10 kg cow dung in 2.5 to 5.0 I of water and 0.5 to 1.0 kg fine bone. Meal sprinkled over it uniformly. Similar layers are laid one over the other till the material rises 0.75 m above the ground level, it is finally plastered with wet mud and left is disturbed for 8 to 10 weeks. Plaster is then removed, material moistened with water, given a turning and made into a rectangular heap under a shade. It is left undisturbed till its use.

Indore method: In the Indore method of composting, organic wastes are spread in the cattle shed to serve as bedding. Urine-soaked material along with dung is removed every day and formed into a layer of about 15 cm thick at suitable sites. Urine-soaked earth, scraped from cattle sheds is mixed with water and sprinkled over the layer of wastes twice or thrice a day. Layering process continued for about a fortnight. A thin layer of well decomposed compost is sprinkled over top and the heap given a turning and reformed. Old compost acts as inoculum for decomposing the material. The heap is left undisturbed for about a month. Then it is thoroughly moistened and given a turning. The compost will be ready for application in another month.

Bangalore method: In Bangalore method of composting, dry waste material of 25 cm thick is spread in a pit and a thick suspension of cow dung in water is sprinkled over for moistening. A thin layer of dry waste is laid over the moistened layer. The pit is filled alternately with dry layers of material and cow dung suspension till it rises 0.5 m above ground level. It is left exposed without covering for 15 days. It is given a turning, plastered with wet mud and left undisturbed for about 5 months or till required.

In Coimbatore method, there is anaerobic decomposition to start with, following by aerobic fermentation. It is the reverse in Bangalore method. The Bangalore compost is not so thoroughly decomposed as the Indore compost or even as much as the Coimbatore compost, but it is bulkiest.

Green Manure: Green undecomposed material used as manure is called green manure. It is obtained in two ways: by growing green manure crops or by collecting green leaf (along with twigs) from plants grown in wastelands, field bunds and forest. Green manuring is growing, usually, leguminous crops and incorporating into the soil after sufficient growth. Crops grown for green manure are known as green manure crops. Most important green manure crops are sunhemp, dhaincha, pillipesara (Phaseolustrilobus), clusterbeans and Sesbaniarostrata. Sesbaniarostrata is a stem noduiating green manure crop of West Africa. As it is a short-day plant and sensitive to photoperiod, length of vegetative period is short When sown in August or September. A mutant (TSR 1) developed by Bhabha Atomic Research Centre, Bombay is insensitive to photoperiod, tolerant to sahmty and waterlogged condition. Growth and nitrogen fixation is higher with TSR I compared to the existing strains.

A large number of forest trees and farm grown trees are used as green leaf manure, especially for incorporation into puddled soil for lowland rice in India.

Advantages of green leaf manuring include:

» Soil structure and tilth improvement.

» Soil fertility improvement.

» Amelioration of soil problems.

» Improvement in crop yield and quality.

» Pest and disease management (loaf of neem, pungamia etc).

CONCENTRATED ORGANIC MANURES

Concentrated organic manures have higher nutrient content than bulky organic manure. Important concentrated organic manures are oilcakes, blood meal, fish manure etc. These are also known as organic nitrogen fertilizers. Before their organic nitrogen is used by the crops, it has to be converted through bacterial action into readily usable ammoniacal nitrogen and nitrate nitrogen. These organic fertilizers are, therefore, relatively slow acting, but they supply available nitrogen for a longer period.

Oil Cakes

After oil is extracted from oilseeds, the remaining solid portion is dried as cake for use as manure or cattle feed. Oil cakes are of two types:

1. Edible oil cakes which can be safely fed to livestock: groundnut cake, coconut cake, sesame cake etc.

2. Non edible oil cakes which are not fit for feeding livestock: eastor cake, neem cake, mahua cake etc.

Both edible and non-edible oil cakes can be used as manures. However, edible oil cakes are fed to cattle and non-edible oil cakes are used as manures, especially for horticultural crops. Nutrients present in oil cakes, after mineralisation, are made available to crops 7 to 10 days after application. Oilcakes need to be well powdered before application for even distribution and quicker decomposition.

Other Concentrated Organic Manures

Blood meal when dried and powdered can be used as manure. Toe meat of dead annuals is dried and converted into meat meal which is a good source of nitrogen.

Vermicomposting

It is a system of composting in which organic wastes are decomposed using biological agent, earthworm, in making vermicompost for use in agroecosystem and aquaculture for sustainable production. Earthworms along with soil microbes play a vital role in degrading organic wastes and thus maintain a nutrient flux m the system. Earthworm is physically an aerator, crusher, mixer, chemically a degrader and biologically the first phase of vermicomposting technique (Fig 8.2) involves collection of organic wastes and mechanical separation of undecomposable materials like ceramic fibre etc. Organic waste like farm residues, kitchen waste, leaf litter, sugarcane thrash city garbage or waste from agro-industries can be used. The waste has to be collected into box or tank. This can be constructed in brick masonry and cement, wood or plastic. Stone slabs, if available, are more suitable for the sides and bottom with all the joints cemented. The dimensions of the tank can be according to the convenience and amount of waste available for vermicomposting. In order to facilitate proper aeration, the height of the tank should be confined to 0.75 m.

The organic waste has to be mixed with cow dung in the ratio of 1:8. In case or non-availability of dung, a little soil slurry can be added to the waste. The waste should be left undisturbed for 2 weeks. Then earthworms have to be released on the surface at the rate of 1000 to 2000 m‘2. Selection of appropriate species of earthworms is very important. Earthworms selected should be feeders of organic waste, having high.

Vermicompost Application Technique

Similar to compost, vermicompost has to be applied in bulk quantities. One of the main advantages of application of vermicompost is quick nutrient absorption by plants unlike other organic manures, which is due to the digestion of the organic matter by the earthworms and the presence of various enzymes in it.

BIO-FERTILISERS

With the introduction of green revolution technologies, modern agriculture is getting more and more dependent upon the steady supply of synthetic inputs (mainly fertilizers), which are products of fossil fuel (coal+ petroleum). Adverse effects due to the excessive and imbalanced use of these synthetic inputs have led to identifying harmless inputs like bio-fertilizers. Use of such natural products like bio-fertilizers in crop production will help in safeguarding soil health and quality of crop products. Bio-fertilizer is a substance containing living microorganisms which, when applied to seed. Plant surfaces or soil, colonises the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary host plant. M t0 the Bio-fertilizers add nutrients through the natural processes. Solubilizing phosphorus and stimulating plant growth through the substances. Bio-fertilizers can be expected to reduce the growth fertilizer and pesticides. The microorganisms in bio-fertilizers restore nutrient cycle and build soil organic matter. Through the use of bio-fertilizer plants can be grown while enhancing the sustainability and the health of heel. Bio-fertilizers are eco-friendly organic agro-input and more costly than chemical fertilizers. Bio-fertilizers like Rhizobium, Azetobacter, Azospirdlum ii blue green algae (BGA) are in use since long time. Rhizobium inoculant is used for crops. Azetobacter can be used with crops like wheat, maize, mustard, and other vegetable crops. Azospz'rilluminoeulants are recommended mainly fowlghurn, millets, maize, sugarcane and wheat. Blue-green algae belonging to genera Nostoc, Anabaena, Tolypothrix and Azdosira fix atmospheric nitrogen and are used as inwlants for rice crop grown both under upland and lowland conditions. Anabaena in amiatlon with water fern Azoila contributes nitrogen up to 60 kg per ha per season and enriches soils with organic matter. Phosphate solubilising bacteria like Pantoeaagglomerans strain seudomonasputz'da are able to solublize the insoluble phosphate from organic and inorganic phosphate source. In fact, due 30 immobilization of phosphate by mineral ions such as Fe, Al and Ca or organitacids the rate of available phosphate (Pi) in soil is well below plant needs.

BENEFITS FROM USING BIO-FERTILISERS

» Improves microbial activity in the soil leading to increased availability of plant nutrients.

» Stimulate plant growth through the synthesis of growth promoting substances.

» Supplements to fertilizer use.

» Under certain conditions, they exhibit anti-fungal activities and thereby protect the plants from pathogenic fungi.

» Increase crop yield by 15-20 per cent.

» Restore natural soil fertility.

» Cost effective.

» Eco-friendly.

AVAILABLE BIO-FERTILISERS

Available bio-fertilizers are of two groups: nitrogen fixing bio-fertilizers and phosphorus solublizing bio-fertilizers.

Nitrogen Fixing Bio-fertilizers:

1. Rhizobium legume crops.

2. Azotobacter/Azospirillum for non-legume crops.

3. Acetobacter for sugarcane only.

4. Blue-green algae (BGAl and Azolla for lowland rice.

RECOMMENDED BIO-FERTILISERS

1. Kimmie sphnuka at 200 g each per 10 kg of seed as seed treatment for pulses such as pigeonpea, greengram, blackgram, cowpea etc, groundnut and soybean.

2. Amtobmter + Phosplwtika at 200 g each per 10 kg of seed as seed treatment for wheat, sorghum, maize, cotton, mustard etc.

3. For transplanted rice, dip the roots of seedlings for 8 to 10 hrs in a solution Azospirillum + Phosphotika at 5 kg each ha.

METHODS OF BIO-FERTILISER APPLICATION

1. Seed treatment: 200 g of nitrogenous biofertilizer and 200 g of Phosphotika ale suspended in 300-400 ml of water and mixed thoroughly. Ten kg seeds are treated with this paste and dried in shade. Treated seeds have to be sown as soon as possible.

2. Seedling root dip: For rice crop, a bed is made in the field and filled with water. Recommended bio-fertilizers are mixed in this water and the roots of seedlings are clipped for 8-10 hrs.

3. Soil treatment: Four kg each of the recommended bio-fertilizers are mixed with 200 kg compost and kept overnight. This mixture is incorporated in the soil at sowing or planting.

PRECAUTIONS FOR GOOD RESPONSE TO BIO-FERTILISERS

» Bio-fertilizer product must contain effective strain in appropriate population and should be free from contaminating microorganisms.

» Selection of right combination of bio-fertilizers and use before expiry date.

» Use suggested method of application and apply at appropriate time as per the information provided on the label.

» For seed treatment, adequate adhesive should be used for better results.

» For problematic soils, use corrective methods like lime or gypsum pelleting of seeds or correction of soil pH.

» Ensure adequate supply of phosphorus and other nutrients.

Probable reasons for not getting good response to application of bio-Eert'disers include:

» Inferior quality of the product.

» Use of ineffective strain.

» Insufficient population of microorganisms.

» Might have been exposed to high temperature.

» Might have been stored in hostile conditions.

» Low levels of soil available phosphorous and molybdenum.

» Piesence of high native population or presence of bacteriiphm.

BIOLOGICAL NITROGEN FIXATION (BNF)

Biological nitrogen fixation (BNF) is the process whereby is reduced to ammonia in the presence of nitrogenase. NW a biological catalyst found naturally only in certain microorganisms such as the WW Mum and Frankie or the free-living Azospirillum and Azotobuaer.

Biological nitrogen fixation is brought about bath by free living soil min-Wm and by symbiotic associations of microorganisms with higher plants. legiimim plants in: atmospheric nitrogen by working symbiotically with special bacteria, M, 'hich live in the root nodules. Rhizobia infect root hairs of the leguminous plants and produce the nodules. The nodules become the home for bacteria where they obtain energy from the host plant and take free nitrogen from the soil air and prom it into combined nitrogen.

Mechanism of Biological Nitrogen Fixation

The biochemical mechanism of N2 fixation can be written in simplified form as:

The above mechanism indicates that N 2 fixing systems can thrive in soils poor in N, that they are a source of proteins and that they provide N for soil fertility. Adenosine 'phosphate (ATP) is the source of energy necessary for the cleavage and reduction of N2 into ammonia. In Rhizobia, for instance, ATP results from oxidation degradation of sugars and related molecules. These sugars are manufactured by the host plant during photosynthesis and transferred to the nodules. In general, for each gram of N, fixed by Rhizobium, the plant fixes 1-20 g carbon (C) through photosynthesis. This is an indication that symbiotic N2 fixation requires additional energy which. In nitratefed plants, can be used to produce more photosynthates. The extra energy fixation can, however safely be carried by most field grown legumes with little or no was of production. It is usually accepted that N2 fixing systems require more than WNW systems. Phosphorus is needed for plant growth, nodule formation and Weient and AT synthesis, each process being vital for nitrogen fixation. NW fixation which involves the chemical reduction of N_2 to NFL, requires a minimum of electrons. Sources of electrons for the nitrogenase activity with proteins and highly reductive molecules such 8:9 ferredimn, Wilamlda , ademinediiiucleotide (phosphate).

Climatic factors: The two important climatic determinants affecting BNF are temperature and light.

Extreme temperatures affect N_2 fixation adversely. This is easy to understand because N_2 fixation is an enzymatic process. However, there are differences between symbiotic systems in their ability to tolerate high (>35°C) and low (<25°C) temperatures.

Availability of light regulates photosynthesis, upon which biological nitrogen fixation depends. This is demonstrated by diurnal variations in nitrogenase activity. _A very few plants can grow and fix N2 under shade (Flemingiacongesta under plantain canopy).

Biotic factors: Among biotic factors, absence of the required Rhizobia species constitutes the major constraint in the nitrogen fixation process. The other limiting biotic factors could be:

» Excessive defoliation of host plant.

» Crop competition.

» Insects and nematodes.

If specific and effective Rhizobia are absent in a soil or if they are present in low numbers, it is necessary to introduce the Rhizobia in that soil to ensure proper nodulation and nitrogen fixation. This is called inoculation. Inoculation with Rhizobia is usually recommended for newly introduced legumes. Most positive responses to inoculation are confined to crops which have specific requirements for Rhizobium, (Leucaenalcucocephala, American varieties of soybean). Indigenous legumes seldom respond to inoculation with introduced Rhizobia because they modulate with resident strains, even if these native Rhizobia are not the most effective ones.

Nitrogen Fixing Microbes

Bacteria are capable of reducing nitrogen (N 2) to ammonia (NHS) with the help of the enzyme nitrogenase. The process is known as biological nitrogen fixation (BNF). Different groups of nitrogen (N2) fixtures are:

Symbiotic: Rhizobia, F ran/aia, Anabaena Associative: Azospirillmn, Acetobactcr, Herbaspirillmn Free living: Awtobactcr, Derxia, Cyanobacteria, Rhizodospirillum, Beijerinckia. Symbiotic nitrogen fixers reduce nitrogen is association with plants by forming some specialized structures in plants.

INORGANIC FERTILIZERS

Familisatimx or fertilizer application is the supplemental application of plant nutrients to mop plains to augment the supply. This consists of applying nutrient-containing materials, called fertilizers, generally into the soil in proximity to receptor plants.

The first artificially produced fertilizer may be the “philosophic dung” or “fattening salt." a substitute to manure (dung) which Johann Glauber (1604-1668) invented.

It was piopiued from wood ash, lime from burned stone and well decomposed organic mttel‘. He wouldn’t know then, but aside from lime, it also added NPK to the soil.

In 1659, ammonium nitrate was discovered in Germany and in 1773, the urea. In 1809, the Chile saltpetre deposit (sodium nitrate) was discovered. However, it seems that the first time that an intellectual property was acquired was in 1842 by John Lewes of England for the production of single superphosphate.

Going further back before the advent of manufactured or chemical fertilizers, the importance of fertilizer application was already known. Chinese were already aware of the beneficial use of green manure during the Chou dynasty in about 100 BC.

Justus von "Liebig (1803-187 3), a German chemist, made enlightening revelations about plant nutrition and practically boosted the practice of fertilizer application or fertilization. ‘He would become one of the most influential personalities in revolutionizing agriculture throughout the world which means increased productivity many folds.

Further, Liebeg popularised the Law of the minimum.Therefore, supplying that limiting element will lead to improved crop productivity and the law of the minimum will shift to another element.

The Law of the minimum or principle of limiting factors, along with the finding that crop plants remove some mineral nutrients from the soil, became the basis of the modern practice of fertilizer application. Large amounts of chemical or synthetic fertilizers are now used worldwide and NPK has become a byword in crop production.

Uses of Mineral Fertilizers

Depending on the method of production, number of nutrients, type of combination, mode of action etc, inorganic fertilizers are grouped differently. Method at production

» Natural (as found in nature or only slightly processed).

» Synthetic (manufactured by industrial processes).

» Single nutrient or straight fertilizer (whether for major, secondary or micro nutrients).

» Mold-nutrient or compound fertilizers, with 2, 3 or more nutrients.

CHAPTER VI

IRRIGATION WATER MANAGEMENT

Irrigation water is the major constraint for assured crop production. The problem is that the atmospheric evaporative demand is practically continuous as against sporadic supply of water by natural precipitation. Even short-term water deficit can reduce crop yield substantially.

There are many areas in the world where the available soil moisture from rain or underground water is not adequate for crop growth, either all the time or part of the crop season, when it is necessary to make up the deficiency by applying water to the soil. Such artificial application of water to the land for crop production is called irrigation. On the other hand, there are some parts of the world where the soil is either saturated with water or has more moisture than for sustaining plant life for all the time or part of the crop season due to inadequate natural disposal of excess water. Artificial measures to drain out excess water from soil are termed drainage. The purpose of irrigation and drainage is to maintain soil moisture within the range adequate for optimum crop growth and productivity.

Irrigation is defined as artificial application of water to the soil for the purpose of supplying moisture essential for plant growth. It also serves the following purposes:

- It adds water to the soil for supplying moisture essential for plant growth.
- It provides crop insurance against short duration droughts.
- It cools the soil atmosphere, thereby making more favorable environment for plant growth.
- It aids in wash out or dilution of salts in the soil.
- It reduces the hazards of soil piping.
- It softens the tillage pans.

Major reasons for practicing irrigation are:

- Irrigation can only ensure a stable system of crop production.
- Irrigation can prolong the effective crop growing period, thus permitting multiple cropping.
- Additional inputs become economically feasible since irrigation reduces the risk of inputs being wasted by drought.

Some of the adverse effects of irrigation are:

- Irrigation without drainage causes water logging leading to reduced crop productivity.

- Groundwater pollution due to seepage of water carrying nitrate nitrogen from applied nitrogen fertilizers.
- Cold and damper climate due to irrigation will be conductive to crop pests and pathogens.

Water Sources of India

The source of all water is precipitation. Annual precipitation (1200mm), including snowfall, is estimated to be of the order of 4000 M ha-m (4000 $km^{3,}$ 4000 billion m^3-BCM). Anticipated irrigation potential created up to March 2007 was 102.77 M ha, which is 73.46 per cent of the ultimate irrigation potential of 140 M ha. Major and medium irrigation projects have an ultimate irrigation potential of 58.47 M ha against which irrigation potential created is 42.35 M ha. Minor irrigation potential created was 60.42 M ha against the ultimate irrigation potential of 81.43 M ha.

Water Resources of India

Estimated utilisable water	
Surface water	690 km^3
Ground water	432 km^3
Total	1,122 km^3
Irrigation potential	
Surface water	
Major and medium irrigation	58.50 million ha
Ultimate	40.85 million ha
Created up to 2005-06 Utilised up to 2005-06	33.45 million ha
Minor irrigation	
Ultimate	17.4 million ha
Created up to 2005-06	13.79 million ha
Utilised up to 2005-06	8.17 million ha
Groundwater	
Ultimate	64.0 million ha
Created upto 2005-06	66.22 million ha

Utilised up to 2005-06	47.93 million ha
Total (surface and groundwater)	
Ultimate	81.0 million ha
Created up to 2005-06	80.01 million ha
Utilised up to 2005-06	56.10 million ha
Total(major and medium + minor)	
Ultimate	139.9 million ha
Created up to 2005-06	120.66 million ha
Utilised up to 2005-06	89.55 million ha

Gross irrigated area in the country is only 87.23 M ha. With average irrigation intensity of 140 percent, the actual irrigated area is likely t be around 62.31 M ha, which is only 43 per cent of the net sown area of the country (142 M ha). Even after achieving the ultimate irrigation potential of 139.89 M hand considering the average irrigation intensity of 140 per cent, the ultimate irrigated area in the country would be only 70 percent of the net sown area.

SOIL-PLANT-WATER RELATIONSHIPS

Efficient use of irrigation water in crop production solicits precise answers to the questions: when to irrigate, how much water to apply and how to irrigate the field. Since, excessive soil moisture in the root zone is as deleterious as inadequate available soil moisture for crop production, limiting the soil moisture well-below the soil saturation through adequate drainage is an important as that of irrigation to meet the crop needs.

IRRIGATION WATER MANAGEMENT

Any attempt to control the supply of water to crop must be based on thorough understanding of the variable state of water in the soil and of its cyclic movement into and out of the root zone. **Soil-plant-water relationships** deal with those physical properties of soil and water that influence the movement, retention and use of water by the plants that must b considered to plan for an efficient irrigation system. They are mutually dependent and conditions in any region are the result of their interaction. In view of newer concepts of irrigation water management, a fundamental change has taken place in the concept of soil-plant-water relations. The field is now perceived to be a unified system in which all processes are interdependently linked, as in a chain. This unified system has been called s the SPC for **sol-plant-atmosphere continuum**. Accordingly, the availability of the soil moisture is not property of the soil alone but indeed a combined function of the soil, the plant and the climate.

In principle, the rate of water uptake by the plants depends on the ability of the root to absorb water from the soil with which they are in contact, as well as on the transpiration and growth requirements. These variables, in turn, depend on plant, soil and weather conditions.

SOIL-WATER RELATIONSHIPS

Attraction of water molecules for each other is known as **cohesion** and the attraction of water to soil particles s known as **adhesion**. These two factors are responsible for retention and movement of water in the soil. Due to adhesion, water is present as thin film around the soil particles and due to cohesion water is retained in the soil pores as **capillary water**. Thus, soil holds water in two ways, as a thin film on individual soil particles and as water stored in the pores of the soil. Water stored as thin film on individual soil particles is said to be in **adsorption**. Water stored in the pores of the soil is said to be in **capillary storage**. This phenomenon can act in any direction and is the key to water being stored in soil pores.

When water is added to a dry soil, it is distributed around soil particles where is held by adhesive and cohesive forces. It displaces air in pore space and eventually fills the pores. When all the pores are filled with water, the soil is said to be saturated and it is at its maximum retentive capacity. The three main forms water are: gravitational, capillary and hygroscopic water.

Gravitational Water: Water in the soil macro-pores that moves downwards freely under influence of gravity beyond the root zone is called gravitational water. Water that moves beyond the root zone depth of soil is not available to plants.

Capillary Water: water retained by the soil in capillary pores (micro-pores), against gravity, as continuous film around soil particles is called capillary water. It is available to plants. Retention of water in capillary pores is due to adhesion and cohesion.

Hygroscopic Water: when the water is held tightly as thin film around the sol particles by adsorptive forces and no longer moves in capillary pores, it is called hygroscopic water. It is held by the soil particles between tensions of 31and 1/3 (one-third) atmosphere (atm).

Soil-Water Content

The mass or volume fraction of water in the soil can be characterised in terms of **soil moisture constants**:

1. Maximum water holding capacity.
2. Field capacity
3. Moisture equivalent.
4. Permanent wilting point.
5. Hygroscopic coefficient.
6. Ultimate wilting point.

Maximum water holding capacity: When both macro and micro-pores are filled with water, the soil is said to be at its maximum water holding capacity or saturation capacity. Excess water beyond this is lost from root zone as gravitational water. Soil moisture tension at this point is almost zero and is equal to free water surface.

Field capacity (FC): water continues to drain from macro-pores for 2-3 days and becomes negligible thereafter. Macro-pores are again filled with air and the micro-pores still filled with water and it moves because of capillary force. This water is called **capillary water**. The soil is said to be at its **field capacity (FC)**. Soil moisture tension, generally, ranges from 1/10 to 1/3 atm. Soil-water potential at FC ranges from 0.1 to -0.3 bars or -0.01 o -0.03 M Pa (Mega Pascal). The FC is considered as the upper limit f water availability to plants. Soil moisture content at FC can move in any direction, but always in the direction of increasing tension.

Moisture equivalent: The amount of water retained by initially saturated soil after being subjected to a centrifugal force of 1,000 RPM that of gravity for about half an hour is called moisture equivalent. This moisture content expressed in percentage on oven dry basis gives the value of moisture equivalent. The values of FC and moisture equivalent are almost equal in medium textured soils. In sandy soils, FC exceeds moisture equivalent. In very clayey soils, FC is, generally, lower than moisture equivalent.

Permanent wilting point (PWP): Also known as wilting coefficient is the moisture content of the soil at which plants can no longer obtain enough moisture to meet the transpiration requirements and remain wilted unless water is added to the soil. At PWP, soil-water no longer moves because of capillary force. It is held by soil so tightly as thin film around soil particles that plants cannot use it. The plant is not dead but remains in wilted condition. Soil moisture tension at this point ranges from 7 to 32 atm. Commonly used average value is 15 atm. Soil-water potential at this point is -15 bars or -1.5 M Pa.

Hygroscopic coefficient: Further drying lower the moisture content below PWP and water is held very tightly around soil particles, mostly being absorbed by soil colloids. At soil-water potential of -30 bars or -3 M Pa, water is held so tightly that much of it can move in vapour phase. Moisture content of the soil at this point is called hygroscopic water.

At – 60 bars or – 6 M Pa, plants cannot absorb any moisture and die eventually. Soil moisture content at which plants die is called **ultimate wilting point**. The range in soil moisture content through which plants undergo progressive decrease of permanent wilting is called **wilting range**.

Available Water/ Plant Available Water

Moisture available for plant growth is the capillary water between FC and PWP. Hence, the available soil moisture (ASM) holding capacity of soil can be determined by subtracting the amount of remaining moisture in the soil at PWP from the amount held at FC (ASM = FC – PWP). Generally, finer the soil texture, greater the ASM holding capacity. Sandy soil has the least amount of ASM and clay soil the highest.

Measurement of Soil Moisture

Soil moisture content is, normally, given as a dimensionless ratio of two masses or two volumes. When the soil moisture content, given as dimensionless ratio, is multiplied by 100, the value becomes a percentage on mass or volume basis. Determination of soil moisture on volume basis involves finding mass basis figures first. Once mass basis figures are found, volume basis figures are determined using bulk density. The amount of water in soil can also be given as a depth as if it were accumulated in a layer. A depth of water is typically used in irrigation. Specification of a depth of accumulated water is usually accompanied by a modifier such as "in the rooting zone".

Numerous methods of obtaining soil moisture content are available and include direct, indirect and remote soil moisture measurement. Direct measurements of soil-water content (gravimetric or thermo-gravimetric) involve removing water from a soil sample by evaporation, leaching or chemical reaction. Soil moisture content is calculated from the mass of water removed and the mass of the dry soil. Indirect methods involve measurements of some property of the soil that is affected by soil-water content. Indirect methods can also measure a property of some object placed in the soil. The object placed in the soil is normally a porous absorber which comes to water equilibrium with the soil.

Remote measurements include both non-contact methods and measurement from a great distance. Remote sensing of soil moisture depends on the measurement of electromagnetic radiation with soil moisture depends on the dielectric properties (index of refraction), soil temperature or a combination of both. The property that is important depends on wavelength region that is being considered. Soil moisture measurements from a great distance normally involve satellite systems measuring the spectral reflectance of the soil surface.

Direct Methods (gravimetric methods)

Oven drying: It is the most widely used of all gravimetric methods. The oven dry method is the standard for the calibration of all other soil moisture determination techniques.

Drying the moist soil to a constant weight in a drying oven is controlled at 110 degree 5C. Samples should be dried for at least 24 hrs. Weight of soil remaining after oven drying is used as the weight of soil solids. Moisture content expressed as a [percent is equal to the weight water divided by weight of soil solids all times 100.

$$Moisture\ content\ (\%) = Wt\ of\ wet\ soil - Wt\ of\ dry\ soil / Wt\ of\ dry\ soil\ x\ 100$$

Volumetric water content (%) can be calculated if soil bulk density (BD) is known.

Soil moisture content can be expressed in depth of water (cm) per unit depth of soil.

Depth of water per unit soil depth = Volumetric water content x soil depth.

Merits

- Oven drying is considered the standard method for obtaining soil moisture content.
- Very simple equipment required.
- No specific site calibrations are required.
- Inexpensive compared to other methods.

- No health risks associated with this method.

Drawbacks

- Sampling is very tedious and time consuming.
- Time to dry sample is approximately 24 hrs, which will drastically reduce sample rate.
- Obtaining representative soil moisture values in a heterogeneous soil profile is difficult.
- If sampling is required over long periods, it is very destructive to the site.
- It is difficult to determine moisture content at specific depths.

Example. Given the following:

Weight of empty can = 40 g

Weight moist soil + can + 150 g

Weight dry soil + can = 140 g

Soil bulk density = 1.5 g cm3

Sampling soil depth = 30 cm

Answer the following questions?

Soil moisture content by weight (%)

Volumetric water content (%)

Depth of water in sampled soil depth (cm).

Solution. Soil moisture content by weight (%)

Weight of moist soil = 150 – 40 = 100 g

Weight of dry soil = 140 – 40 = 100 g

= Wet weight – Dry weight/ Dry weight x 100 = 110-100/100 x 100 = 10%

Volumetric water content (%)

= Wet weight- Dry weight/Dry weight x 100 x BD

= 110-100/100 x 100 x 1.5 = 15%

Depth of water in sampled soil depth (cm)

= soil moisture content by weight x BD x Soil depth

= 10/100 x 1.5 x 30 = 4.5 cm

OR = volumetric water content x Soil depth

= 15/100 x 30 = 4.5 cm

Feel and appearance method, though not a method of soil moisture measurement, is often discussed under direct methods of soil moisture measurement. This method is actually recommended to farmers, as rough guide, for scheduling crop irrigation. Soil moisture regimes (saturated soil, moist soil, dry soil) can be judged by manipulating the soil with hand and fingers. In this method, soil samples obtained from representative depth in the crop root zone are observed for colour, plasticity and cohesiveness (by squeezing and rolling between fingers). Soil balls formed by squeezing and thread like structures formed by rolling between the fingers are observed for irrigation scheduling. With experience, accuracy is = or -5 to 10 per cent available soil moisture.

Indirect Methods

Indirect methods, usually, a measure the volumetric soil moisture content. These methods are relatively quick and accurate. However, they require technical skill to operate and are relatively expensive. It is beyond the scope of this book to discuss all the indirect methods of soil moisture measurement. Discussion is limited to three methods only.

Gypsum blocks (porous/electrical resistance blocks): gypsum blocks use the principle of resistivity measured indirectly from a material in equilibrium with the soil. When these blocks reach equilibrium with the surrounding soil, their electric or thermal properties are often regarded as an index of soil-water content.

Gypsum blocks are most widely used for moisture measurement and are available in a variety of porous materials ranging from nylon cloth and fibreglass to casting plasters. Each block is calibrated in soil and soil density typical of the site the block is to be used in. Electrical resistance of the block is measured by a meter based on the principle of Whetstone Bridge Resistance blocks read low resistance (400-600 ohms0 at FC and high resistance (50 000-75 000 ohms) at wilting point.

Water content of a porous block coming to water equilibrium with a soil depends on the energy status of the water rather than the water content of the soil. Soils with fine pores will contain more water than soil with coarse pores at equal matric potential. Hence, if porous blocks are to provide an in direct measure of soil-water content, calibration is necessary. Since the equilibrium is a matric potential and not a water content equilibrium, associated soil-water content must be obtained from a calibration curve.

Neutron scattering: this method consists of americium and beryllium (241Am/9Be) as neutron souree and boron trifluoride (BF3) gas as detector. The instrument works on the principle that when fast moving neutrons are emitted into the soil, they undergo elastic collisions with hydrogen having proton mass equal to mass of neutron and get scattered. Their energy is reduced and speed is slowed down.

The slowed neutrons are absorbed by BF3 gas, which can be counted with a scalar, rate meter or electronic microprocessor aided circuitry, which directly displays the moisture content. The density cloud of neutrons so formed around the source (probe) is proportional to the concentration of hydrogen in the soil. Since water is the main source of hydrogen in soil, the density of slowed neutrons is proportional to the volume fraction of water present in the soil. The count rates are then calibrated against volumetric determination of soil moisture content.

Merits:

- Quick result
- Once the tube is inserted, the same location can be used repeatedly.
- Nondestructive and less laborious.
- Fairly repeatable.

Drawbacks:

- Expensive.
- Probe must be calibrated for each soil/access tube type.
- Top 15 cm soil depth is difficult to measure due to escape of neutrons into atmosphere.
- Radiation exposure danger.
- Difficulty with maintenance, repair or parts in developing countries.

Tensiometer: The working principle of tensiometer is that when a sealed water-filled tube is placed in contact with the soil through a permeable and saturated porous material, water (inside the tube0 comes into equilibrium with the soil solution (it is at the same pressure potential as the water held in the soil matrix). Hence, the soil-water **matric potential** is equivalent to the vacuum or suction created inside the tube.

The tensiometer consists of a sealed water-filled plastic tube with a ceramic cup at one end and a negative pressure gauge at the other. The shape and size of the ceramic cup can be variable and the accuracy depends on the gauge or transducer used (about 0.01 bar).

Typically, the measurement range is 0 to 0.80 bar, although there are low tension versions (0 to 0.40 bar) designed for coarse soils.

Soil-water potential or soil moisture tension is a measure of the tenacity with which water is retained in the soil and shows the force per unit area that must be exerted to remove water from the soil. It is measured in terms of the potential energy of water in the soil measured, usually, with respect to free water. It is usually expressed in atmosphere, the average air pressure at sea level.

PLANT-WATER RELATIONSHIPS

Mesophytes, including crop plants, control their water economy by developing extensive root system to extract water from deep soil layers and regulating stomatal apertures to limit water loss from the leaves. Many physiological processes related to photosynthesis, growth and development of plants are affected by water stress sometimes before the plant actually wilts. To design a successful irrigation system, it is essential to know the plant rooting characteristics, soil moisture extraction pattern and moisture sensitive stages.

Root Characteristics

In shallow soils, roots may be confined to thin layer of soil irrespective of their usual pattern. Similarly, high water table limits normal root growth. Crops with extensive and dense roots can utilise soil moisture more efficiently and to lower residual soil moisture than crops with sparse and shallow roots. Rooting depth of annual field crops range from 0.30 to 2.0 m. In general, the root zone depth of crops on clayey soils is reduced by 25 to 35 per cent and on sandy soils increased by 25 to 35 per cent.

Rooting depths (m) of annual field crops on deep well-drained soils.

Shallow		Medium		Deep	
Rice	0.5 to 0.6	Barley	1.0 to 1.5	Cotton	1.0 to 1.7
Onion	0.3 to 0.5	Wheat	o.8 to 1.5	Maize	1.0 to 1.6
Cabbage	0.4 to 0.5	Castor	0.9 to 1.2	Sorghum	1.0 to 2.0
Cauliflower	0.3 to 0.5	Tobacco	0.7 to 1.0	Pearlmilllet	1.0 to 1.7
Potato	0.4 to 0.6	Chillies	0.6 to 0.9	Fingermillet	1.0 to 1.6
		Peas	0.6 to 1.0	Soyabean	1.0 to 1.5
		Tomato	0.7 to 1.5	Sugarcane	1.0 to 2.0

Moisture Extraction Pattern

For most plants, concentration of absorbing roots is greatest in upper part of the root zone and near the base of plants. Extraction of water is most rapid in the zone of greatest root concentration and under favourable environmental conditions.

Usual moisture extraction pattern shows that 40 per cent of the extracted moisture comes from upper quarter of the root zone, 30 per cent from the second quarter, 20 per cent from the third quarter and 10 per cent from the fourth quarter. This general pattern of extraction slightly varies with irrigation frequency.

Moisture Sensitive Periods

Optimum moisture content for plant growth varies with stage of plant growth. Certain periods, during the crop growth and development, are most sensitive to soil moisture stress compared to others. These periods are known as moisture sensitive periods. The term **critical period** is commonly used to define the stage of crop growth when plants are most sensitive to shortage of water. Inadequate water supply during moisture sensitive periods will irrevocably reduce the yield and provision of adequate water and other management practices at other growth stages will not help in recovering the yield lost. Inadequate water during tillering stage limits tiller production and hence the number of panicles or ear heads per plant or unit area. Similarly, stress at panicle initiation stage leads to reduction in number of grains per panicle. Reduced number of panicles per plant or grains per panicle due to moisture stress cannot be compensated by adequate water supply or other management practices at later stages of crop growth. All the stages of growth are equally sensitive to soil moisture stress for crops where vegetative parts are of economic importance. Moisture sensitive periods for selected crops are given in table:

Crops	Moisture sensitive periods
Rice	Panicle initiation, heading and flowering.
Maize	Tasseling, silking and early grain development.
Sorghum	Booting, flowering, milky and dough stages.
Pearlmillet	Heading and flowering.
Fingermillet	Panicle initiation and flowering.
Wheat	CRI, shooting and heading.
Barley	End of shooting and heading.
Groundnut	Rapid flowering, peg penetration and pod development.
Sunflower	Flower bud initiation, head initiation, flowering and milk stages.
Soyabean	Flowering and seed formation.
Cotton	Flowering and boil development.
Sugarcane	Formative phase, particularly during tillering.
Tobacco	Entire growth period.

Evaporation

Uptake of water by the plants and its return to the atmosphere in the twin processes of evaporation and transpiration is called evapotranspiration.

Evaporation: Evaporation of water from surface of soil or free water surface is a diffusive process by which liquid water in the form of vapour is lost to the atmosphere. Two essential requirements for evaporation process are a source of heat to transform liquid water into water vapour and a concentration gradient between the evaporating surface and surrounding air for water vapour diffusion. Solar radiation is the principal source of energy for changing liquid water into vapour. Concentration of water vapour at evaporating surface should be more than that in the surrounding air for evaporation to take place.

Transpiration: it is a process in which soil-water in the form of vapour leaves the plant canopies and enter the surrounding atmosphere. When plants cannot draw water fast enough to replace that lost in transpiration, they experience water stress.

Evapotranspiration: The total water loss from soil surface through evaporation and that as water vapour from plant canopies through transpiration together is estimated as evapotranspiration (ET), since it is difficult to measure these two components separately under field conditions.

Evapotranspiration rate is normally expressed in millimetres (mm) per unit time. The rate expresses the amount of water lost from a cropped surface in units of water depth. The time unit can be an hour, day, month or even an entire growing period or year.

As one hectare has a surface of 10000 m sq and 1 mm is equal to 0.001 m, a loss of 1 mm of water corresponds to a loss of 10 m cube of water per hectare. In other words, 1 mm per day is equivalent to 10 m cube per hectare per day.

Methods of ET determination can be broadly grouped into three:

1. ET measurement
    - Energy balance and microclimatological methods.
    - Soil-water balance.
    - Lysimeters.
2. ET computed from meteorological data.
3. ET estimated from pan evaporation.

it is beyond the scope of this publication to discuss different methods of ET measurement, except soil-water balance method.

Soil-Water Balance

Soil-water balance, like a financial statement of income and expenditure, is an account of all quantities of water added, removed or stored in a given volume of soil during a given period of time.

Using the soil-water balance equation, one can identify periods of water stress/ excesses which may have adverse effect on crop performance. This identification will help in adopting appropriate management practices to alleviate the constraint and increase the crop yields. Soil-water balance equation in its simplest form of expression is:

Change in soil-water = Inputs of water – Losses of water.

Inputs (addition) of water to the soil: Water is usually added to the soil in three measureable ways – precipitation (P), irrigation (I) and contribution from the groundwater table (C). Contribution from the ground water will be significant only if the ground water table is near the surface. Inputs of water can be presented as:

Water inputs = P + I + C

Loss (removal) of water: Water is removed from the soil through evapotranspiration (ET) and deep-drainage (D). Further, a part of the rainwater received at the soil surface may be lost as surface runoff (RO). Losses of water from soilcan then be represented as:

Water losses = ET +D + RO

Soil-water balance: Change in the soil-water content which is the difference between the water added and water withdrawn will be:

Change in soil-water = (P+I +C) – (ET + D + RO)

Soil-water refers to the amount of water held in the root zone at given time. The change in soil-water from one measurement to another depends on the contribution of components in the equation. Suppose the amount of water in the root zone at the beginning is M1 mm and at the end of a given period is M2mm, thus the equation is expressed as:

M1 – M2 + (P + I + C) – (ET +D+ RO)

Or M1+ P + I + C = ET + D + RO + M2

With the help of this equation one can compute any one unknown parameter in the equation if all othersare known.

Quantitative data on rainfall (P) evapotranspiration (ET), deep drainage (D) and soil moisture at a given time (M1 or M2) for different locations and for different practices are useful for selecting appropriate water management strategies.

CROP WATER REQUIREMENTS AND IRRIGATION NEED

Accurate crop water requirement information is essential in irrigated agriculture. Such information aids in efficient use of irrigation water.

Terminology

Water requirement: It is the quantity of water, regardless of its source, required of water used by crop or a diversified pattern of crops in a given period of time for their normal growth under field conditions. It includes evapotranspiration and other economically unavoidable losses. When the water requirement is supplied entirely by irrigation, irrigation requirement and water requirement will be same.

Consumptive use/consumptive water use (CU): It is the sum of volumes of water used by crop over a given area in producing plant tissue, in transpiration (T), plus that evaporated (E) from adjacent soil or from moisture intercepted on plant foliage. Since the volume of water used in producing plant tissue is negligible (<1%) compared with the volumes used in E and T, the CU can be taken to be approximately equal to evaporation plus transpiration or evapotranspiration (ET).

$$WR = CU = ET$$

It is not always possible to apply exactly the required quantity of water to bring the root zone depth to field capacity. Some losses (deep percolation, runoff, seepage etc) are unavoidable. Such losses are known as application losses (AL). Water is also needed for special operations like leaching of excess soluble salts, land preparations, pre-sowing irrigation etc. These are collectively known as water for special operations (WSO). Water requirements (WR), therefore, include all these components.

$$WR = ET + AL + WSO$$

Water requirement can be expressed in terms of source of water.

$$WR = IR + EP + S$$

Where, IR = irrigation water

EP = effective precipitation

S = Soil profile moisture contribution as stored soil moisture or shallow groundwater table.

Irrigation requirement (IR): It is the total amount of water applied to a cropped field for supplementing precipitation and soil profile moisture contribution to meet crop water needs for optimum growth and yield. Irrigation requirement is only part of water requirement.

$$IR = WR - (EP + S)$$

precipitation and profile moisture contribution, required for optimum crop production. In other words, it is the amount of irrigation water that must be stored in the crop root zone to meet the consumptive use requirement of a crop. Simply, it is the amount of irrigation water required to bring the soil moisture level in the effective root zone to field capacity. Thus, it is the difference in depth or percentage soil moisture between field capacity and the soil moisture content in the root zone before starting irrigation. In terms of depth, it can be expressed as:

$$\text{NIR} = \sum_{i=1}^{n} \frac{\text{M1}i - \text{M2}i}{100} \times \text{BD}i \times \text{D}i$$

Where, NIR = net amount of irrigation water to be applied at each irrigation (mm or cm)

n = number of soil layers considered in root zone depth D

$M1_i$ = soil moisture percentage at first sampling in i^{th} layer

$M2_i$ = soil moisture percentage at second sampling in i^{th} layer

BD_i = bulk density of i^{th} soil layer (g cm^{-3})

D_i = depth of i^{th} soil layer (mm or cm)

Effective precipitation, groundwater contribution and deep percolation losses, if any are to be considered for reliable estimates of crop water requirements.

$$\text{NIR} = (\text{CU} - \text{EP}) + \text{AL}$$

Seasonal irrigation requirement can be obtained by adding NRI values at each irrigation.

Gross irrigation requirement (GIR): It is the net irrigation requirement and losses in conveyance, distribution and application of water in operating the system.

$$\text{GIR} = \frac{NRI}{Irrigation\ efficiency}$$

Irrigation frequency: It refers to the number of days between two successive irrigations (irrigation interval) during the periods without precipitation. It depends on consumptive use rate of a crop and on the amount of available soil moisture in the crop root zone. Sandy soil requires more number of frequent irrigations than fine textured soils. In general, irrigation should start when around 50 per cent of the available soil moisture has been depleted from the root zone depth.

In designing irrigation systems, the irrigation frequency used is the time (days) between two irrigations in the period for highest consumptive use of the crop. The average consumptive use of the crop. The highest consumptive use rate during this period is the rate to be considered in designing and planning irrigation system and this is known as **design frequency**.

$$design\ frequency = \frac{net\ amount\ of\ moisture\ between\ FC\ and\ starting\ level}{peak\ period\ moisture\ use\ rate}$$

$$= \frac{net\ depth\ of\ application}{peak\ period\ moisture\ use\ rate}$$

Irrigation period: The number of days that can be allowed for applying one irrigation to a given design area during the peak period consumptive use of the crop is known as irrigation period. It is the basis for capacity and equipment design. Irrigation systems are to be designed in such a way that the irrigation period is not greater than irrigation frequency.

$$irrigation\ period = \frac{netamountofmoisturebetweenstartingofirrigationandlowerlimitofdepletion}{peakperiodmoistureuserateofthecrop}$$

Estimation of Evapotranspiration (ET)

Climate decides the rate of ET. Several empirical formulas are available to estimate ET from climate date. FAO expert group of scientists has recommended four methods for adoption in different regions of the world.

1. Blaney-Criddle method. 2. Radiation method.

3. Pan evaporation method. 4. Modified Penman method.

Estimation of ET involves three important steps:

1. Estimation of PET or evapotranspiration by any four above methods.
2. Estimation of crop co-efficient (K_c).
3. Making suitable adjustments to local growing conditions.

Reference Evapotranspiration (ET_o)

ET_ocan be defined as the rate of evapotranspiration of an extended surface of an 8 to 15 cm tall, green cover, actively growing, completely shading the ground and not short of water.

Selection of a method for estimation of ETo depends on availability of metrological data and amount of accuracy needed. Among the four methods for estimation of ETo, Blanely-Criddle method is simple, easy to calculate and requires data on sunshine (SS) hours, wind velocity (WV), relative humidity (RH) in addition to temperature (T).

Blaney-Criddle method: ETo = C [P (0.46 T + 8)]

Radiation method: ETo = C(W x Rs)

Pan evaporation method: ETo = Kp x Epan

Modified Penman method: ETo = C [W. Rn + (1- W).f (U). (ea – ed)]

SCHEDULING IRRIGATION

Once we know the crop water requirements, the most important step is to supply the right quantity of water at right time through an appropriate application method to satisfy the crop water requirements. This is called **irrigation scheduling** and serves the objectives of high yield of good quality, attaining high water use efficiency without any damage to soil productivity and applying water at a reasonable cost.

The importance of irrigation scheduling is that it enables the irrigator to apply the exact amount of water to achieve the goal. This increases **irrigation efficiency.** A critical element is accurate measurement of the volume of water applied or the depth of application. A farmer cannot manage water to maximum efficiency without knowing how much was applied.

ADVANTAGES OF IRRIGATION SCHEDULING

Irrigation scheduling offers several advantages:

1. It enables the farmer to schedule water rotation among the various fields to minimize crop water stress and maximize yields.
2. It reduces the farmer's cost of water and labour through fewer irrigations, thereby making maximum use of soil moisture storage.
3. It lowers fertilizer costs by holding surface runoff and deep percolation (leaching) to a minimum.
4. It increases net returns by increasing crop yields and crop quality.
5. It minimizes waterlogging problems by reducing the drainage requirements.
6. It assists in controlling root zone salinity problems through controlled leaching.
7. It results in additional by using the "saved" water to irrigate non cash crops that otherwise would not be irrigated due to water shortage.

IRRIGATION SCHEDULING METHODS

All irrigation scheduling methods consist of an irrigation criterion that triggers irrigation and an irrigation strategy that determines how much water to apply. Irrigation scheduling methods differ by the irrigation criterion or by the method used to estimate or measure this criterion. A common and widely used irrigation criterion is soil moisture status.

METHODS OF IRRIGATION

The manner in which the irrigation water is applied to the land is commonly referred to as method of irrigation. Selection of appropriate irrigation method involves numerous complexes and often conflicting considerations.

There are three main ways of applying irrigation water:

1. Run the water over the soil surface and allow it to infiltrate, a method known as **surface irrigation**.
2. Spray the water into the air and allow it fall on to the plants and soil, a method called **sprinkler irrigation**.
3. Apply the water directly to the root zone, a method known as **drip** or **trickle irrigation**.

SURFACE IRRIGATION METHODS

In this method, water is applied and distributed over the soil surface by gravity. It is the most common form of irrigation around globe. It's of two types:

a) Wild flooding: It is the primitive and least controlled of all the surface irrigation systems. It does not need technical skill to operate and maintain the system. Installation and operation costs are low. Its disadvantage is excessive loss of water by runoff and deep percolation.

b) Controlled flooding: The land is levelled or graded and subdivided by means of channels. Water is guided to each of the sub-divisions. Controlled flooding methods are named differently.

Check flooding: It is the most widely practiced surface method of irrigation for wheat, millets, groundnut and pulse crops in India. It requires high labour.

Basin flooding: This method is essentially a check flooding method for irrigating orchards. Basin are small level plots surrounded by low earth dikes, also called checks, within which water can be impounded to irrigate trees. It is suitable for varying stream sizes. It requires minimum technical skill. But there is a possibility for water stagnation in the basins.

Border or border strip irrigation: It could be considered as a hybrid of level basin and furrow irrigation. Water is applied to the top end of the border which facilitates free flowing conditions at the downstream end. Borders guide the water down the slope as a shallow sheet that uniformly spreads out between the borders.

This method provides uniform wetting of the soil profile. It requires less labour.

Since the length of each plot is relatively longer, wastage of water through deep percolation at the upper part of the plot.

Furrow flooding: This method is ideal for row crops such as potatoes, cotton, sugarcane, vegetables etc. Water is allowed to flow down the mild slope to moisten the crop rows on either side of the furrows. The length of furrow is determined mostly by soil permeability. The furrows serve as drainage channels in areas of heavy rainfall. This method is highly ideal for crops like maize that are injured by contact with water. This method is not suitable for light soils with high infiltration rates and it is relatively labour intensive.

SPRINKLER IRRIGATION

Sprinkler or overhead irrigation is a method of applying irrigation water which is similar to natural. Water is distributed through a system of pipes, usually by pumping. It is then sprayed into the air through sprinklers so that it breaks up into small water drops which fall on to the ground. Sprinklers are designed and arranged to apply water at rates lower than soil infiltrability to prevent ponding and surface runoff.

Sprinkler irrigation system can be used under:

- Shallow and sloping soils which cannot be irrigated by surface methods without levelling.
- Sandy soils requiring excess applications with surface methods.
- Low moisture retentive soils requiring frequent, light and uniform application.
- Irrigation water scarcity.

Merits over surface systems

- Elimination of channels, bunds and their maintenance and conveyance losses of water.
- Controlled water application leading to higher application efficiency.
- Areas at higher elevation than the source can be irrigated.

Limitations over surface methods

- High initial capital cost, high maintenance requirements and high operational pressure.
- During day time, air is warmer and dry and the droplets are smaller and application rate is low, application efficiency is affected by high wind speed (>15 km hr^{-1}).

DRIP IRRIGATION

Drip (trickle) irrigation can be defined as the process of applications of water in the form of discrete, continuous drops, tiny streams or miniature sprays through mechanical devises called emitters or applications located at selected points along water delivery tips.

Drip irrigation system consists of a pump to lift water and produce desired pressure (about 2.5 atm) and to distribute water through nozzles. There is a fertilizer tank for applying fertilizer solution directly to the field along with the irrigation water and filter which cleans the suspend impurities in irrigation water to prevent the blockage of holes and passage of drip and nozzles. Mains and sub-mains are of flexible material such black PVC pipes. Laterals or drip lines are small dia flexible lines (usually 1 t 2.5 cm dia black PVC tubes) taken off from the mains or sub mains. Laterals are normally laid parallel to each other. There is usually one lateral line for each crop row.

Drip nozzles, also known as emitters or valves, are fixed at regular intervals in the laterals. These PVC valves allow water to flow at extremely slow rates, ranging from 2 to 11 litres hr^{-1}.

Merits

- Efficient use of scarce irrigation water.
- Reduced salinity hazard to plants.
- Improved fertilizer and chemical application.
- Decreased energy requirement.
- Improved cultural practices.

Drawbacks

- Persistent maintenance requirements.
- Salt accumulation near plants.
- Economic and technical limitations.

QUALITY OF IRRIGATION WATER

Irrespective of its source, all irrigation waters contain dissolved salts, the type and quantity of which depend on its origin and its course before use. Use of poor-quality irrigation water has adverse effects on soil, nutrient availability, crop growth and soil microbes.

- High sodium content in irrigation water causes **deflocculation** of soil leading to reduced permeability and hence low infiltration of water to the root zone. Soil crusting and waterlogging reduce oxygen supply to the root system.
- Soil salinity affects cell division, cell elongation and protein synthesis.
- Excessive soluble salt concentration in the root zone restricts plant water uptake leading to **physiological drought**.

- Bacteria associated with conversion of unavailable form of nutrients to available forms are sensitive to high salt concentration.
- Soils with high exchangeable sodium become hard on drying and difficult to work for obtaining good tilth.

MAJOR CONSTITUENTS OF IRRIGATION WATER

Chemical name	**Chemical symbol**	**Proportion of total salt content**
Sodium chloride	$NaCl$	Moderate to large
Sodium sulphate	Na_2SO_4	Moderate to large
Calcium chloride	$CaCl_2$	Moderate
Calcium sulphate	$CaSO_4.2H_2O$	Moderate to small
Magnesium chloride	$MgCl_2$	Moderate
Magnesium sulphate	$MgSO_4$	Moderate to small
Potassium chloride	KCl	Small
Potassium sulphate	K_2SO_4	Small
Sodium bicarbonate	$NaHCO_3$	Small
Calcium carbonate	$CaCO_3$	Very small
Sodium carbonate	Na_2CO_3	Trace to none
Borates	BO^{-3}	Trace to none
Nitrates	NO^{-3}	Small to none

EVALUATION OF IRRIGATION WATER

Several different measurements are used to classify the suitability of water for irrigation, including $EC_{(w)}$, total dissolved solids and SAR.

Permissible limits for classification of irrigation water

Class of water	**Concentration of total dissolved salts**	
	EC (m mhos cm-1)	**Gravimetric**

Class 1, excellent	250	175
Class 2, good	250 to 750	175 to 525
Class 3, permissible	750 to 2000	525 to 1400
Class 4, doubtful	2000 to 3000	1400 to 2100
Class 5, unsuitable	> 3000	>2100

SODIUM HAZARD

Due to its effect on the soil and plant, sodium is considered to be one of the major factors governing water quality. Water quality is usually defined on the basis of soluble sodium percentage (SSP) as indicated below:

$$SSP = \frac{Soluble\ sodium\ concentration}{total\ soluble\ cation\ concentration} \text{ x } 100$$

BIOCARBONATE HAZARD

The bio carbonate anion is important in irrigation water use as regards precipitation of calcium and to a lesser degree, also of magnesium in soil.

Bicarbonate hazard is classified as:

- Normal water (RSC traces)
- Low alkali water (RSC< 2.5 me 1^{-1})
- Medium alkali water (RSC 2.5 to 5.0 m 1^{-1})
- High alkali water (RSC 5 to 10 me 1^{-1})
- Very high alkali water (RSC> 10 me 1^{-1})

CLASSIFICATION OFIRRIGATION WATER

The Central Soil Salinity Research Institute (CSSRI) Karnal classified irrigation water based on EC, adj SAR and boron concentration.

Based on EC: Classes from A1 to A5

Normal water (A1): EC < 1.5 ds m^{-1}

Low salinity water (A2): EC 1.5 to 3.0 ds m^{-1}

Medium salinity water (A3): EC 3 to 5 ds m^{-1}

Saline water (A4): EC 5 to 10 ds m^{-1}

Highly saline water (A5): EC > 10 ds m^{-1}

Based on adjusted SAR: Classes from B1to B5

Normal water (B1): SAR < 10

Low sodium water (B2): Adj SAR 10 to 20

Medium sodium water (B3): Adj SAR 20 to 30

Sodium water (B4): Adj SAR 30 TO 40

High sodium water (B5): Adj SAR > 40

Based on boron content: Classes from C1 to C5

Normal water (C1): Less than 3ppm

Low boron Water (C2): 3 to 4ppm

Medium boron water (C3): 4 to 5ppm

Boron water (C4): 5 to 10ppm

High boron water (C5): > 10ppm

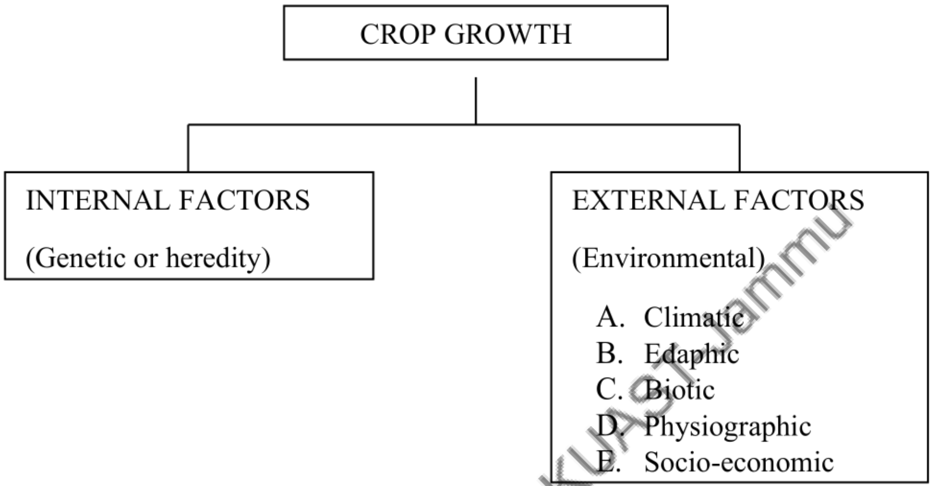
MANAGEMENT PRACTICES

Management practices that help to overcome high salinity problem of the irrigation include:

- Selection of salt tolerant crops, varieties and sequences.
- Improved agronomic practices.
    - Residue management.
    - Seed rate and spacing.
    - Method of sowing.
    - Soil fertility management.
- Irrigation water management
    - Pre-sowing irrigation.
    - Changing surface irrigation system.
    - Use of extra water for leaching.
    - Conjunctive use of fresh and saline waters.

CHAPTER VII

FACTORS AFFECTING CROP PRODUCTION-CLIMATE-EDAPHIC-BIOTIC-PHYSIOGRAPHIC AND SOCIO-ECONOMIC FACTORS



I. Internal factors

Genetic factors

The increase in crop yields and other desirable characters are related to Genetic make-up of plants.

- High yielding ability
- Early maturity
- Resistance to lodging
- Drought flood and salinity tolerance
- Tolerance to insect pests and diseases
- Chemical composition of grains (oil content, protein content)
- Quality of grains (fineness, coarseness)
- Quality of straw (sweetness, juiciness)

The above characters are less influenced by environmental factors since they are governed by genetic make-up of crop.

2. External factors

A. Climatic
B. Edaphic
C. Biotic
D. Physiographic
E. Socio-economic

A. Climate Factors

Nearly 50 % of yield is attributed to the influence of climatic factors. The following are the atmospheric weather variables which influences the crop production.

1. Precipitation

2. Temperature
3. Atmospheric humidity
4. Solar radiation
5. Wind velocity
6. Atmospheric gases

1. Precipitation

- Precipitation includes all water which falls from atmosphere such as rainfall, snow, hail, fog and dew.
- Rainfall one of the most important factors influences the vegetation of palace.
- Total precipitation in amount and distribution greatly affects the choice of a cultivated species in palace.
- In heavy and evenly distributed rainfall areas, crops like rice in plains and tea, coffee and rubber in Western Ghats are grown.
- Low and uneven distribution of rainfall is common in dryland farming where drought resistance crops like pearl millet, sorghum and minor millets are grown.
- In desert areas grasses and shrubs are common where hot desert climate exists
- Though the rainfall has major influence on yield of crops, yields are not always directly proportional to the amount of Precipitation as excess above optimum reduces the yields.
- Distribution of rainfall is more important than total rainfall to have longer growing period especially in drylands.

2. Temperature

- Temperature is a measure of intensity of heat energy. The range of temperature for maximum growth of most of the agricultural plants is between 15 and40ºC.
- The temperature of a place is largely determined by its distance from the equator (latitude) and altitude.
- It influences distribution of crop plants and vegetation.
- Germination, growth and development of crops are highly influenced by temperature.
- Affects leaf production, expansion and flowering.
- Physical and chemical processes within the plants are governed by air temperature.
- Diffusion rates of gases and liquids changes with temperature.
- Solubility of different substances in plant is dependent on temperature.
- The minimum, maximum (above which crop growth ceases) and optimum temperature of individual's plant is called as cardinal temperature.

Crops	Minimum temperature ºC	Optimum temperature ºC	Maximum temperature ºC
Rice	10	32	36-38
wheat	4.5	20	30-32
Maize	8-10	20	40-43
Sorghum	12-13	25	40
Tobacco	12-14	29	35

3. Atmospheric Humidity (Relative Humidity -RH)

- Water is present in the atmosphere in the form of invisible water vapor, normally known as humidity. Relative humidity is ratio between the amount of moisture present in the air to the saturation capacity of the air at a particular temperature.
- If relative humidity is 100% it means that the entire space is filled with water and there is no soil evaporation and plant transpiration.
- Relative humidity influences the water requirement of crops.
- Relative humidity of 40-60% is suitable for most of the crop plants.
- Very few crops can perform well when relative humidity is 80% and above.
- When relative humidity is high there is chance for the outbreak of pest and disease.

4. Solar radiation (without which life will not exist)

- From germination to harvest and even post-harvest crops are affected by solar radiation.
- Biomass production by photosynthetic processes requires light.
- All physical process taking place in the soil, plant and environment are dependent on light
- Solar radiation controls distribution of temperature and there by distribution of crops in a region.
- Visible radiation is very important in photosynthetic mechanism of plants. Photosynthetically Active Radiation (PAR - 0.4 – 0.7μ) is essential for production of carbohydrates and ultimately biomass.

0.4 to 0.5 μ - Blue – violet –Active
0.5 to 0.6 μ - Orange – red -Active
0.5 to 0.6 μ - Green –yellow – low active

- Photoperiodism is a response of plant to daylength

Short day – Day length is <12 hours (Rice, Sunflower and cotton), long day – Day length is > 12 hours (Barley, oat, carrot and cabbage), day neutral – There is no or less influence on day length (Tomato and maize).

- Phototropism — Response of plants to light direction. Eg. Sunflower.
- Photosensitive – Season bound varieties depends on quantity of light received.

5. Wind velocity

- The basic function of wind is to carry moisture (precipitation) and heat.
- The moving wind not only supplies moisture and heat, also supplies fresh $CO_2$for the photosynthesis.
- Wind movement for 4 – 6 km/hour is suitable for more crops.
- When wind speed is enormous then there is mechanical damage of the crops (i.e.) it removes leaves and twigs and damages crops like banana, sugarcane.
- Wind dispersal of pollen and seeds is natural and necessary for certain crops.
- Causes soil erosion.
- Helps in cleaning produce to farmers.
- Increases evaporation.
- Spread of pest and diseases.

6. Atmospheric gases on plant growth

- CO_2– 0.03%, O_2- 20.95%, N_2- 78.09%, Argon - 0.93%, Others -0.02%.
- $CO_2$is important for Photosynthesis, CO_2taken by the plants by diffusion process from leaves through stomata.
- $CO_2$is returned to atmosphere during decomposition of organic materials, all farm wastes

and by respiration.

- $O_2$is important for respiration of both plants and animals while it is released by plants during Photosynthesis.
- Nitrogen is one of the important major plant nutrients, Atmospheric N is fixed in the soil by lightning, rainfall and N fixing microbes in pulses crops and available to plants.
- Certain gases like SO_2, CO, CH_4, HF released to atmosphere are toxic to plants.

B. EDAPHIC FACTORS (soil)

Plants grown in land completely depend on soil on which they grow. The soil factors that affect crop growth are

1. Soil moisture
2. Soil air
3. Soil temperature
4. Soil mineral matter
5. Soil organic matter
6. Soil organisms
7. Soil reactions

1. Soil moisture

- Water is a principal constituent of growing plant which it extracts from soil.
- Water is essential for photosynthesis.
- The moisture range between field capacity and permanent wilting point is available to plants.
- Available moisture will be more in clay soil than sandy soil
- Soil water helps in chemical and biological activities of soil including mineralization.
- It influences the soil environment Eg. it moderates the soil temperature from extremes.
- Nutrient availability and mobility increases with increase in soil moisture content.

2. Soil air

- Aeration of soil is absolutely essential for the absorption of water by roots.
- Germination is inhibited in the absence of oxygen.
- $O_2$is required for respiration of roots and microorganisms.
- Soil air is essential for nutrient availability of the soil by breaking down insoluble mineral to soluble salts.
- For proper decomposition of organic matter.
- Potato, tobacco, cotton linseed, tea and legumes need higher O_2in soil air.
- Rice requires low level of $O_2$and can tolerate water logged (absence of O2)condition.

3. Soil temperature

- It affects the physical and chemical processes going on in the soil.
- It influences the rate of absorption of water and solutes(nutrients).
- It affects the germination of seeds and growth rate of underground portions of the crops like tapioca, sweet potato.
- Soil temperature controls the microbial activity and processes involved in the nutrient availability.
- Cold soils are not conducive for rapid growth of most of agricultural crops.

4. Soil mineral matter

- The mineral content of soil is derived from the weathering of rocks and minerals as particles of different sizes.
- These are the sources of plant nutrients eg;
  Ca, Mg, S, Mn, Fe, Ketc

5. Soil Organic matter

- It supplies all the major, minor and micro nutrients to crops.
- It improves the texture of the soil.
- It increases the water holding capacity of the soil.
- It is a source of food for most microorganisms.
- Organic acids released during decomposition of organic matter enables mineralization. process thus releasing unavailable plant nutrients.

6. Soil organisms:

- The raw organic matter in the soil is decomposed by different microorganisms which in turn releases the plant nutrients.
- Atmospheric nitrogen is fixed by microbes in the soil and is available to crop plants through symbiotic (*Rhizobium*) or non-symbiotic (*Azospirillum*)association.

7. Soil reaction(pH)

- Soil reaction is the pH (hydrogen ion concentration) of the soil.
- Soil pH affects crop growth and neutral soils with pH 7.0 are best for growth of most of the crops.
- Soils may be acidic (<7.0), neutral (=7.0), saline and alkaline(>7.0).
- Soils with low pH is injurious to plants due high toxicity of Fe and Al.
- Low pH also interferes with availability of other plant nutrients.

C. Biotic Factors

Beneficial and harmful effects caused by other biological organism (plants and animals) on the crop plants

1. Plants

- Competitive and complimentary nature among field crops when grown together.
- Competition between plants occurs when there is demand for nutrients, moisture and sunlight particularly when they are in short supply or when plants are closely spaced.
- When different crops of cereals and legumes are grown together, mutual benefit results in higher yield (synergistic effect).
- Competition between weed and crop plants as parasites eg: *Striga* parasite weed on sugarcane crop.

2. Animals

- Soil fauna like protozoa, nematode, snails, and insects help in organic matter decomposition, while using organic matter for their living.
- Insects and nematodes cause damage to crop yield and considered as harmful organisms.
- Honey bees and wasps help in cross pollination and increases yield and considered as

beneficial organisms.

- Burrowing earthworm facilitates aeration and drainage of the soil as ingestion of organic and mineral matter by earthworm results in constant mixing of these materials in the soils.
- Large animals cause damage to crop plants by grazing (cattle, goats etc.).

D. Physiographic factors:

- Topography is the nature of surface earth (leveled or sloppy) is known as topography. Topographic factors affect the crop growth indirectly.
- Altitude – increase in altitude cause a decrease in temperature and increase in precipitation and wind velocity (hills and plains).
- Steepness of slope: it results in run off of rain water and loss of nutrient rich topsoil.
- Exposure to light and wind: a mountain slope exposed to low intensity of light and strong dry winds may results in poor crop yields (coastal areas and interior pockets).

E. Socio-economic factors

- Society inclination to farming and members available for cultivation.
- Appropriate choice of crops by human beings to satisfy the food and fodder requirement of farm household.
- Breeding varieties by human invention for increased yield or pest & disease resistance.
- The economic condition of the farmers greatly decides the input/ resource mobilizing ability (marginal, small, medium and large farmers).

CHAPTER VIII

AGRONOMIC NUMERICAL

A. Plant population:

The row spacing and plant to plant spacing are used to calculate plant population.

$$\text{Plant population} = \frac{Area\ of\ field\ (m^2)}{Row\ to\ row\ spacing\ (m)\ \ x\ Plant\ to\ plant\ spacing\,(m)}$$

Q.1. Calculate plant population of maize in 6000 m^2 area, if sown at spacing of 60 x 20 cm.

$$\text{Maize population} = \frac{6000}{0.60\ x\ 0.20}$$

Ans: 50000 plants/6000 m^2

Row to row spacing is definite but plant to plant spacing is not definite

- In this case count the number of plant in a unit row length, and multiply it with row spacing. Then calculate it for required field area. eg. Wheat, Barley etc.

$$\textbf{Plant population} = \frac{\boldsymbol{N\ x\ A}}{\boldsymbol{LR}}$$

Where, N = number of plants in a unit area. LR = The area covered by N plants, A = Area

Q.2. Wheat crop is sown at row spacing of 20 cm. what would be plant population in 1 ha area, if there are 40 wheat plants in 1 m row length.

$$\text{Wheat population} = \frac{40\ x\ 10000}{0.20}$$

Ans: 20 Lakh

When crop is sown by broadcasting methods

- In this case, quadrate is used for sampling. If the length and width of quadrate are L m and W m, respectively and no of plants in quadrate are N.

$$\text{Plant population} = \frac{N\ x\ A}{L\ x\ W}$$

Where, N = number of plants in a unit area (quadrate). LR = The area covered by N plants, A = Area

Q.3. Quadrate having length 1 m and width 0.50 m is used for sampling broadcast wheat sown wheat. Calculate plant population in area of 4000 m^2 area, if there are 60 plants in sampling area.

$$\text{Wheat population} = \frac{60 \times 4000}{1 \times 0.50}$$

Ans: 480000

B. Seed Rate

Seed rate depend upon two factors:

a) Number of seed sown in 1 ha area

b) Weight of one seed

$$\text{Seed rate} = No.of\ \ seeds\ sown\ in\ 1\ ha\ area\ x\ weight\ of\ one\ seed$$

Q. 1. Calculate the seed rate (kg/ha) of wheat, if crop is sown at spacing of 18 cm x 3 cm and test weight of seed is 44 grams.

$$\text{Seed rate (kg/ha)} = \frac{A \times TW}{spacing\ (m) \times 1000 \times 1000}$$

$$\text{Seed rate (kg/ha)} = \frac{10000 \times 44}{0.18 \times 0.03 \times 1000 \times 1000}$$

Ans: 81.48 kg/ha

Q.4. What will be seed rate kg/ha of maize if the spacing is 60 x 20 cm, test weight is 240 g and 10% extra seed is required for allowance against bird damage.

$$\text{Seed rate (kg/ha)} = \frac{A \times TW}{spacing\ (m) \times 1000 \times 1000}$$

$$\text{Maize seed rate (kg/ha)} = \frac{10000 \times 240}{0.60 \times 0.20 \times 1000 \times 1000}$$

$$\text{Maize seed rate (kg/ha)} = \frac{240 \times 100}{60 \times 20}$$

$$10\ \%\ \text{Allowance} = 20 \times \frac{10}{100}$$

$$\text{Total seed requirement} = 20 + 2 = 22\ \text{kg/ha}$$

Q.5. Calculate seed rate (kg/ha) of direct seeded rice, if spacing is 20 cm x 4 cm, germination is 90 % purity of seed is 85% and test weight is 22 g.

$$\text{Seed rate(kg/ha)} = \frac{TW \times 100}{R \times P} x \frac{100}{Germinaion\ (\%)} \times \frac{100}{purity\ (\%)}$$

$$\text{Rice seed rate(kg/ha)} = \frac{22 \times 100}{20 \times 4} x \frac{100}{90} \times \frac{100}{85}$$

Ans: **35.94 kg/ha**

C. Yield estimation

Case 1. If the crop has tillers eg. Rice, wheat, etc.

Grain yield per plant (g).

$$= \text{No. of effective tillers/plant x no. of grains effective tillers x } \frac{\text{test weight (g)}}{1000}$$

Grain yield (g/ha)

$$= 10000 \text{ x No. of effective tillers/plant x no. of grains effective tillers x } \frac{\text{test weight (g)}}{1000\ x\ spacing\ in\ m}$$

Grain yield (kg/ha)

$$= 10000 \text{ x No. of effective tillers/plant x no. of grains effective tillers x } \frac{\text{test weight (g)}}{1000\ x\ spacing\ in\ m\ x\ 1000}$$

Grain yield (q/ha)

$$= 10000 \text{ x No. of effective tillers/plant x no. of grains effective tillers x } \frac{\text{test weight (g)}}{1000\ x\ spacing\ in\ m\ x\ 1000\ x\ 100}$$

Grain yield (t/ha)

$$= 10000 \text{ x No. of effective tillers/plant x no. of grains effective tillers x } \frac{\text{test weight (g)}}{1000\ x\ spacing\ in\ m\ x\ 1000\ x\ 100\ x\ 10}$$

Q.6. Rice crop was transplanted 20 cm x 10 cm. the average no. of effective tillers/ hill were 6 and average no. of filled grains per panicle were 140. Estimate the yield of rice in t/ha, if the test weight is 24 g.

Grain yield (t/ha)

$$= 10000 \text{ x } 6 \text{ x } 140 \text{ x } \frac{24}{1000\ x\ 0.2\ x\ 0.10\ x\ 1000\ x\ 100\ x\ 10}$$

Grain yield (t/ha)

$$= 6 \text{ x } 14 \text{ x } \frac{24}{0.2\ x\ 0.10\ x\ 1000\ x\ 10}$$

Ans: 10.08 t/ha

Q.7. Rice crop was transplanted 20 cm x 10 cm. the average no. of effective tillers/m^2 were 300 and average no. of filled grains per panicle were 140. Estimate the yield of rice in t/ha, if the test weight is 24 g.

Grain yield (t/ha)

$$= 10000 \text{ x } 300 \text{ x } 140 \text{ x } \frac{24}{1000\ x\ 1000\ x\ 100\ x\ 10}$$

Ans: **10.08 t/ha**

Case 2. If the crop has non tillering crops. Maize/pulses/oilseeds etc.

Maize Grain yield (t/ha)

$$= \text{No. of plants/ha x No. of cob/plant x no. of grains/cob x } \frac{\text{test weight (g)}}{1000\ x\ 1000\ x\ 100\ x\ 10}$$

Pulses/oilseeds Grain yield (t/ha)

$$= \text{No. of plants/ha x No. of pods/plant x no. of grains/pod x } \frac{\text{test weight (g)}}{1000\ x\ 1000\ x\ 100\ x\ 10}$$

Q.8. Maize crop was sown at spacing 60 cm x 25 cm. calculate yield of maize (kg/ha) if, average no. of cobs per plant 1.2, average no. of grains per cob 180 and test weight is 210 g.

Maize Grain yield (t/ha)

$$= 66667 \text{ x } 1.2 \text{ x } 280 \text{ x } \frac{240}{1000\ x\ 1000\ x\ 100\ x\ 10}$$

Ans: 5.38 t/ha

Q.9. Estimate the tuber yield of potato in t/ha if plant spacing is 60 cm x 15 cm, average no. of tubers/plant is 16 and average weight of tuber is 30 g.

Tuber yield (t/ha)

$$= \text{No. of plants/ha x No. of tubers/plant x } \frac{\text{av. test weight (g)}}{1000\ x\ 100\ x\ 10}$$

Tuber yield (t/ha)

$$= 111111 \text{ x } 16 \text{ x } \frac{30}{1000\ x\ 100\ x\ 10}$$

Ans: 53.3 t/ha

D. Fertilizer Calculation

$$\text{Amount of fertilizer} = \frac{Rate\ of\ nutrient\ application\ (kg/ha)}{Nutrient\ content\ in\ ferilizer\ (\%)} \text{ x } 100$$

Q.10. What will be the quantity of Urea, DAP and MOP for 1 ha area if 120 kg N, 60 kg P_2O_5 and 30 kg K_2O are applied

$$\text{Amount of DAP (kg/ha)} = \frac{60}{46} \text{ x } 100 \quad = 130 \text{ kg DAP}$$

$$130 \text{ kg DAP supply} = 130 \text{ x } \frac{18}{100} = 23.4 \text{ kg N}$$

N supply through urea= 120-23.4 =96.6 kg

$$\text{Amount of urea (kg/ha)} = \frac{96.9}{46} \text{ x } 100 \quad = 210 \text{ kg Urea}$$

$$\text{Amount of MOP (kg/ha)} = \frac{30}{60} \text{ x } 100 \quad = 50 \text{ kg MOP}$$

E. Herbicide application

$$\textbf{Amount of herbicide} \text{ (kg/ha)} = \frac{Rate\ of\ application\ (\ kg\ a.i./ha)}{Active\ ingredient\ in\ herbicide\ (\%)}\ x\ 100$$

Q.11. Calculate the amount of atrazine (50 % wp) in kg/ha, if the rate of application is 1.0 kg ai/ha.

$$\text{Amount of atrazine (kg/ha)} = \frac{1}{50}\ x\ 100 = 2.0\ kg/ha$$

F. Indecies

$$\textbf{Weed Index} = \frac{\textit{Yield from weed free (hand −weeded)plot−}\ \textit{Yield from treated plot}}{\textit{Yield from weed free (hand −weeded)plot}}\ x\ 100$$

Calculate weed index from the following data

1. Weed free plot = 3600 kg /ha
2. Treated plot = 3200 kg/ha

$$\text{Weed Index} = \frac{3600 - 2800}{3600}\ x\ 100 = 22.22\ \%$$

Weed Control Efficiency (WCE)

$$\textbf{WCE \%} = \frac{\textit{dry matter of weeds in unweeded plots−}\ \textit{dry matter of weeds in treated plots}}{\textit{dry matter of weeds in unweeded plots}}\ x\ 100$$

Weed dry weight in control plot (105.1 g), = Weed dry weight in the treated plot (11.8 g)

$$\textbf{WCE \%} = \frac{105.1 - 11.8}{105.1}\ x\ 100 = 88.67$$

Land equivalent ratio (LER)

$$\text{LER} = \left(\frac{Yij}{Yii}\right) + \frac{Yji}{Yjj}$$

Where:
Y= yield per unit area,
Yii and **Yjj** single crop yield of the component crops i and j,
Yij and **Yji** are intercrop yields

The sole yield of maize is 4000 kg/ha and urdbean is 1500 kg/ha. In intercropping system of maize + urdbean, the yield of maize was 3000 kg /ha and urdbean was 600 kg/ha. Calculate LER?

$$\text{LER} = \left(\frac{3000}{4000}\right) + \frac{600}{1500} = 0.75 + 0.4 = 1.15$$

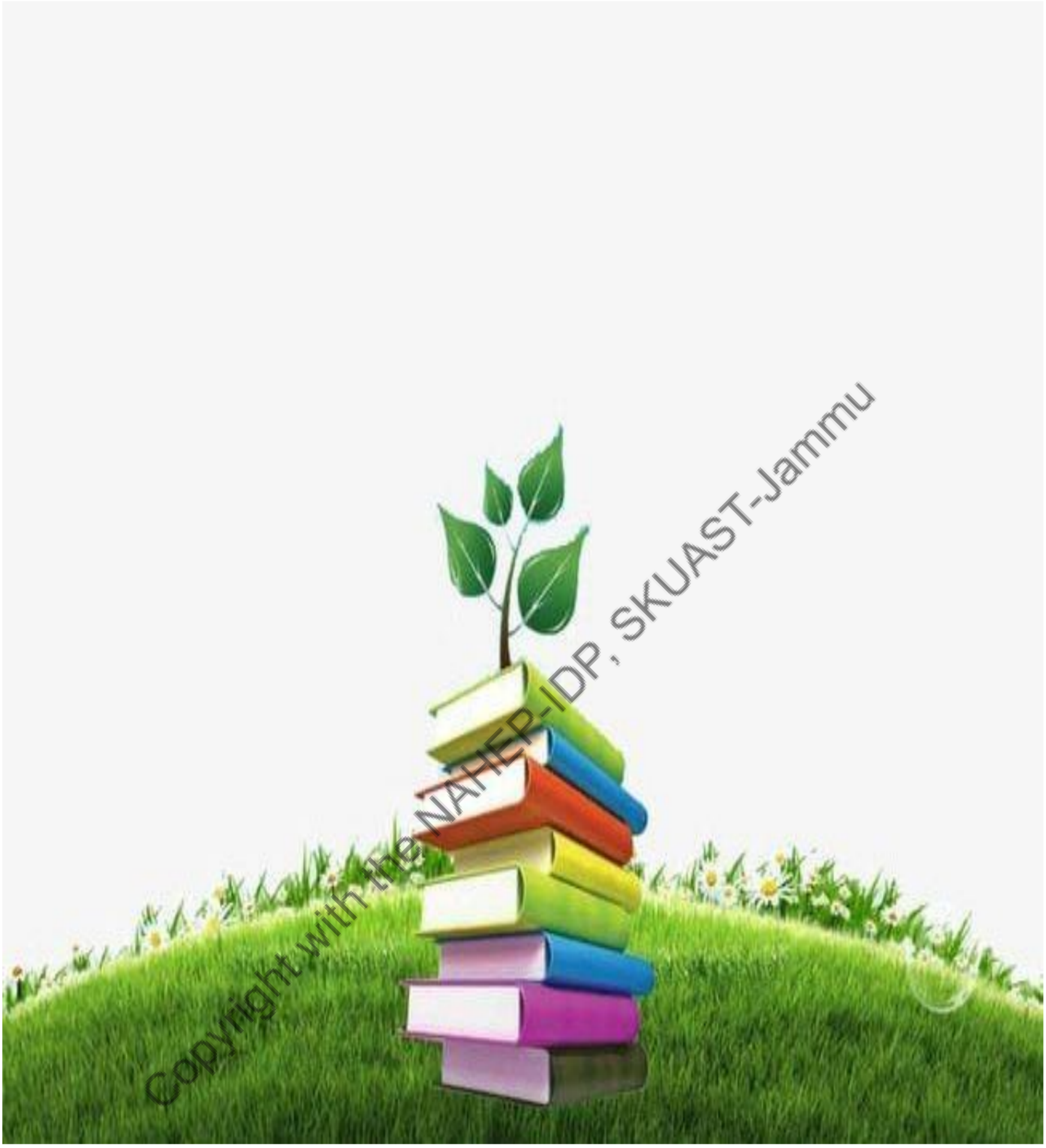
Crop equivalent yield

$$\text{Crop equivalent yield} = (\frac{\textit{yield of crop B (kg/ha) x price of crop B (Rs./kg)}}{\textit{Price of crop A(Rs./kg)}}$$

Q 12. Find out rice equivalent yield of rice- wheat cropping system from the following data:

a. Rice yield = 60 q/ha
b. Price of rice = Rs. 30 rupee/kg
c. Wheat yield = 40 q/ha
d. Price of wheat = Rs. 20 rupee/kg

$$\textbf{Crop equivalent yield} = \frac{4000 \; x \; 20}{30} = 2666.67 \; kg/ha$$



Complied by: Magandeep Kaur, YP-II (MBA) NAHEP-IDP
SKUAST-Jammu

Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST-Jammu)

www.skuast.org