Fundamentals of Agronomy: AGR-111(2+1)

Agriculture- Definition

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

Agriculture is a branch of applied science. It is the art of farming including the work of cultivating the soil for producing crops and raising livestock. There are three main spheres of agriculture, **geoponic** meaning cultivation in earth, **hydroponic** meaning cultivation in water and **aeroponic** meaning cultivation in air.

Agriculture is defined as an art, science and business of producing crops and livestock for economic purposes

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

The important cultural energies utilized for the production and protection of agricultural commodities are

Natural resources: 1. Land, water, light and other resources of environment.

Added resources
1. Irrigation and drainage
2. Organic, biological and mineral fertilizers, chemicals
3. Farm equipments and draft power.

These are used to maximize the productivity per unit time, water, land, labour and rupee invested.

The word **Agriculture** may be expanded as Activities on the Ground for Raising Intended Crops for Uplifting Livelihood Through the Use of Rechargeable Energies.

Agriculture as an art, science and business and Branches of agriculture

Agriculture as an art: Learning by doing and gaining experience. Art is concerned with skill and experience. It is inherited by seeing parents or elders through experience. Agriculture tells us how to perform and operation like sowing, weeding *etc* in a skill full manner.

Agriculture primarily requires physical skill. Physical skill is inherited by doing physical work with perfect execution. E.g. opening a straight furrow, Levelling the field, sowing seed, application of manures and fertilizers etc.

Art of agricultural requires secondarily mental skill.

Mental skill: Decision making

E.g. Selection of crops for a particular area, Deciding the time of operation, timing of production to get better returns, choosing of low cost / no cost inputs etc.

Agriculture as a Science

Science is systematic study of happenings of any thing. Scientific principles were used in agriculture for increasing production and quality of crops. Several scientific advances have been made in all branches of agriculture which are systematized to increase crop production and achieve self sufficiency. Eg.

Plant breeding and Bio-technology – Developed many varieties suiting to various soils, climate and consumer tastes.

Agronomy – Developed improved crop production practices like management of soils, fertilizers etc.

Other disciplines – use of pesticides, labour saving machinery, satellite and remote sensing in weather forecasting etc.

Together, all these contributed for self sufficiency.

Agriculture as a Business

Agriculture in developed countries is a business driven process. The farmers in these countries cultivate the crops to earn higher income with less investment and agriculture is practiced on a business line and land is considered as workshop or factory to generate returns. Mechanization and commercialization have been introduced in these countries to get maximum profit. Where as in developing and under developed countries, agriculture is considered as a way of life and practicing on a subsistence level. Traditional farming is handed over from father to son without any effort to increase production. However, with improvement in literacy rate, WTO, GATT, Agriculture in these countries are assuming as a business enterprise.

Similar to the industry, agriculture has many problems like,

- Excessive / deficit in production as it is controlled by several factors viz., climate. Management
- Consumer taste and preferences
- Trade
- Taxation
- Employer and employee relationship.
- Economic interdependence – relationship between farmers Vs merchants & Transport.

Hence, Agriculture is considered as a business.

Difference between Agriculture and Industry

Sl. No.	Agriculture	Industry
a)	Biological process in which plants convert solar energy to chemical energy	Mechanical process
b)	Primary products of agriculture is organic in nature	Majorly inorganic
c)	Primary resources are environment, plant, water and air	Depends on agriculture for raw materials
d)	Subjected to natural calamities and production is not under control	Can be protected from natural calamities and production can be controlled.

BRANCHES OF AGRICULTURE

Major branches :

1. Agronomy 2. GPB 3. SS & AC 4. Agril. Entomology 5. Plant Pathology 6. Agril.Microbiology 7. Crop Physiology 8. Plant Biotechnology 9. Agril. Engineering 10. Agril. Economics 11. Agril. Statistics

Allied branches:

1. Horticulture 2. Forestry 3. Animal Science 4. Fishery Science 5. Agricultural Engineering and 6. Home Science

1) Agronomy – It deals with the production management of various crops, which includes food crops, fodder crops, fiber crops, sugar, oil seeds, etc.

2) Horticulture – Branch of agriculture deals with the production of flowers, fruits, vegetables, ornamental plants, spices, condiments and beverages.

3) Forestry – It deals with large-scale cultivation of perennial trees for supplying wood, timber, etc. and also raw materials for industries.

4) Animal Husbandry – Husbandry is the rearing of various animals for meat, milk, wool, draft energy etc.

5) Fishery Science – It is for marine fish and inland fishes including shrimps and prawns.

6) Agricultural Engineering – It is an important component for crop production and horticulture particularly to provide tools and implements. It is aiming to produce modified tools to facilitate proper animal husbandry and crop production.

7) Home Science – It deals with the effective conversion of raw produce into consumable with value addition.

Agronomy: The term Agronomy is derived from two Greek words '**Agros**' meaning '**Field**' and '**Nomos**' meaning '**Manage**'.

Agronomy is a branch of applied science deals with the principles and practices of soil, water and crop management.

Norman (1980) defined agronomy as 'The science of manipulating the crop environmental complex with dual aims of improving agricultural productivity and gaining a degree of understanding of the process involved'.

In recent times, Agronomy has assumed newer dimensions and can be defined as 'A branch of agricultural science that deals with the methods which provide favourable environment to the crops for higher productivity.

Role of Agronomist

Agronomist exploits the knowledge of the basic and applied sciences to maximize crop production at minimum cost. Agronomists are concerned with deriving efficient technology of crop production activities like.

a. **Land Preparation:** Developing efficient and economic field preparation methods depending on crop, season and resource availability. Developing machineries in co-ordination with Agricultural Engineers.
b. **Selection of crops:** Involved in selecting suitable crop and variety in accordance with the season, soil and farmers preference.
c. **Sowing / Planting:** Develop efficient method of sowing / planting and standardized spacing / plant geometry to maintain optimum plant population and in turn better yield.
d. **Nutrient management:** Identify various nutrients required by the crop taking crop demand and soil fertility in to consideration. He is also responsible for deriving optimum time and method of application of these nutrients.
e. **Weed management:** Agronomist is responsible for selecting better weed management practices viz., mechanical / physical or cultural / agronomic or biological or chemical or integration of 2 or more methods.
f. **Irrigation management:** Selection of proper irrigation method, time and quantity of application based on crop water need and its availability.
g. **Crop planning / cropping system:** Identifying the crop sequence, inter / mixed cropping for efficient utilization of available resources to maximize farm income.
h. **After care:** Management of crop after planning / sowing till harvesting including the schedule of plant protection measures, interculture etc.
i. **Harvesting and Processing :** Responsible for deriving efficient method and time of harvesting & processing.
j. **Decision making:** on marketing / sale of produce i.e., Time and place of marketing.

Overall, **Agronomist** is like a **Physician**

Scope and Importance of Agriculture

Agriculture plays a key role in the overall economic and social well being of the country. Though the share of agriculture in both GDP and Employment has declined overtime, agriculture still forms the backbone and occupies a pride of place.

1. Agriculture contributes 24% to the Gross domestic Product. GDP was declined from 39% in 1983 to 25% during 1999-2000
2. Provides livelihood support for more than half of the population in the country. The sector provides employment to 56.7% of the India's work force.
3. Agriculture has been the source of raw material for industries. Majority of the industries depending on agriculture for their raw materials. Eg: Textile (Cotton, Jute), Sugar (Sugarcane, Sugar beet), Small & medium scale industries like soaps, dyes, medicines, vitamins, preservation of fruits and vegetables, dhal milling, rice husking, Jaggery making, oil crushing, handlooms etc.

4. It provides large part of market for industrial goods viz., seeds, fertilizers, pesticides, implements, machines like pump sets, trucks, tractors, power tillers, sprayers etc.
5. Support roadways, railways, airways and shipways for transport of inputs & produce
6. Provides a large portion of India's export. Agril. Provides 12-15% of the national exports. The commodities exported are tea, coffee, sugar, cashewnut, spices, tobacco, cotton etc.
7. Agriculture maintain food security and in turn national security. Satisfactory agril. production brings peace, prosperity, harmony, health and wealth.

"A man without food - for 3 days will quarrel
- for a week will fight
- for a month will die"

8. Agriculture and allied sectors like horticulture, animal husbandry, diary & fishery have an importance in improving economic conditions, health and nutrition of human being

Agricultural growth can be witnessed by increased food grains from 50 to 303 m.t, productivity from 522 to 1500 kg ha^{-1}, per capita food availability from 395 to 510 g day^{-1}, cotton from 3 to 13.5 m. bales, sugarcane from 57 to 330 m.t, eggs from 2 to 28 billion, vegetables from 20 to 90 m.t.

This has happened mainly because of revolutions with development of technology. The major revolutions are

Green Revolution	- Food grains (50 to 303 m.t.)
White Revolution	- Milk (17 to 188 m.t.)
Blue Revolution	- Fish (0.75 to 12.6 m.t.)
Yellow Revolution	- Oilseeds (5 to 31.5 m.t.)

Geometrical growth of population resulted in 1.3 billion in India. However, food grains production is moving arithmetically. The food grains demand by 2025 is estimated at 335 million tones over different years.

In future, agricultural development in India would be guided not only by the compulsion of improving food and nutritional security, but also by the concerns for environmental protection, sustainability and profitability.

We need to achieve the food grains production growth rate by 2.7% to meet the population growth rate of 2.2%. which is possible through

1. Increasing the area under HYV and Hybrids
2. Adoption of improved production technology
3. Increasing area under irrigation
4. Efficient and integrated management of manures and fertilizers
5. Adoption of suitable crop / cropping system and formulation of cropping zones
6. Attentions to develop integrated pest management timely to avoid losses
7. Rain water management – efficient conservation & harvest followed by judicious use
8. Transfer of technology from lab to land efficiently and timely.

HISTORY OF AGRICULTURE

It is supposed that man was evolved on earth about 15 lakh years ago. This man started to move by standing erect on his feet. Such man has been called *Homo erectus*. Later the modern man was evolved called *Homo sapiens* (Sapiens means learning habit) due to his continuous learning habit.

It is difficult to trace the exact period of beginning of agriculture. Archeological evidences indicated that, agriculture started about 50,000 years ago.

Hunting was the primary source of food in olden days and was prevailed for long time. Pastoral obtained his food through domestication of some animals like dogs, horse, cow, buffalo etc. They live in the periphery of the forest and migrate from one place to another in search of food. It was not comfortable and they started enjoying by settling at one place near the river and started agricultural system.

Agricultural systems of the world can be divided into 4 groups.

a) Shifting cultivation b) Simple sedentary cultivation c) Simple plough cultivation
d) Advanced / modern agriculture

a. **Shifting cultivation**: Moving from one place to other specially the river beds by clearing forest through fire and broadcasting the crop seeds like paddy, chilli, redgram etc. it is also called as Jhumming or Jhum Cultivation.
b. **Simple sedentary cultivation**: People use to dig pits / holes with sharp spade or pickaxe and plant / sow seeds. It is common in Asian countries and crops cultivated are banana, coconut, arecanut, root tubers etc.
c. **Simple plough cultivation**: Practiced with development of small local ploughs and animal draft power. Eg: Rice cultivation.
d. **Advanced / modern agriculture:** It is based on modern machineries and adoption of technologies developed over time.

The Agriculture history can be divided into 3 Phases.

i) Ancient period (From 800 BC to the fall of Rome – 476 AD)
ii) Medieval period (From 476 AD to 1600 AD)
iii) Modern period (From 1600 AD onwards)

i) Ancient period:

Period	Event
Before 10,000 BC	Hunting & gathering of fruits, grains in forest area and animals
7,500 BC	Shifting cultivation of crops – Wheat & Barley
3,400 BC	Invented wheel (out of stone)
3,000 BC	Bronze used for making tolls
2,900 BC	Invented plough, started irrigated farming
2,300 BC	Cultivation of chickpea, cotton & mustard
2,200 BC	Rice cultivation
1,500 BC	Sugarcane cultivation
1,400 BC	Used iron for making tools
1,000 BC	Use of iron plaogh
430 to 330 BC	Xenophan – Greek historian mentioned about ploughing of green material to enrich soils
234 to 149 BC	Cato gave importance to ploughing and manuring
70 to 19 BC	Virgil mention about crop rotation and inclusion of legumes to enrich soil fertility.

Mentions about agriculture has also been made in Vedas (Rigveda, Yajurveda, Atharvanaveda and Samaveda).

Rigveda: Green cultivation, cattle rearing, use of ploughs & sickles

Atharvanaveda: Different crops grown in different season

ii) Medieval period: During the period of Buddist's, Gupta's, Maurya's and Magada's, mention has been made on agriculture. For instance

a. A Greek ambassador **Megasthanis** came to India and mentioned how Indian people giving importance to maintain soil fertility and crop production
b. **Kautilya**, a famous economist mentioned the role of a king in protecting agriculture. He emphasized for drying seeds / grains and their storage for future use.
c. **Saint Manu**, in his 'Manusmrithis' has mentioned about the punishment given against implement theft.
d. **Saint Parasara** (1000 AD) in his book 'Krishiparasara' mention the operations for paddy for different season. He emphasized manuring, ploughing, puddling, thinning, weeding and irrigation.
e. **Peter Decresenzi** (1230 – 1307 AD) collected many literatures related to Agronomy in his book 'Opus Ruralium Kamo Daram'. Hence, he is considered as **'Father of Agronomy'.**

iii) Modern period / Development of scientific agriculture

Scientific agriculture was started during 16th century. Experimentation technique was started by **Francis Bacon** (1561-1624 AD). He concluded from his study that water is the principle element for plant.

Van Helmont (1572- 1644 AD) conducted a pot experiment on willow tree, popularly known as 'Willow Tree Experiment'. He took a willow plant of weight 5 Pounds and planted in a pot containing 200 pounds soil. The plant was monitored for 5 year by continuous watering. By the end of 5th year, the willow tree weighed 169 Pounds and the weight of soil was 198 Pounds. He concluded that water is the solw requirement for plants.

Jethrotull (1674-1741) mentioned soil particles are essential for plant growth. He developed ' Horse hoe' for tillage. He suggested providing more soil particles to plant by tilth and addition of animal excreta and manures to soil, which make it friendlier for plant growth. He invented 'seed drill' in 1731 for row sowing. He also published a book 'Horse hoeing husbandry' in 1733. He is considered as **'Father of Tillage'**

Arthur Young (1741-1820) published 'Annals of Agriculture' comprehending available literature on agriculture.

Priestly (1780) mentioned that plant take CO_2 from carbonic acid of soil and give up O_2.

Theodore De Saussure (1804) concluded from his experiment that

a. Plants absorb CO_2 from atmosphere and not from soil
b. 'N' essential for plant growth taken from soil
c. Plant roots are selective in absorption and absorb only water from soil leaving salts. Hence, salts accumulate in soil.
d. Mineral matters are not synthesized in the plants but are absorbed by roots from the soil.

The large scale field experimentation was started by **JB Boussingault** (1834). He is recognized as **'Father of Field Experimentation'**. He worked on mineral nutrition of plants.

Justas Van Leibig, a german scientist considered as **'Father of Agricultural Chemistry'** opinion that, growth of plant was proportional to the amount of mineral substance available in the soil. He proposed a law called **Leibig Law of Minimum.** It states that 'The growth of plant is limited by the plant nutrient which is present in smaller quantity while all other being adequate'.

JB Lawes & JH Gilbert (1843), started an agricultural experiment station to conduct long term fertilizer trial and to test the superphosphate they developed by the action of rock phosphate and H_2SO_4 at Rothamsted.

Gregor John Mendal (1856) discovered laws of heredity.

Charles Darwin (1876) proposed theory of evolution and inheritance of acquired character.

PMA Millerdet (1880) discovered 'Bordeux Mixture ($CuSO_4$ + $Ca(OH)_2$ + H_2O :: 1:1:100 ratio) to control downy mildew in grapes.

Thomas Malthus (1898) proposed theory of population growth, which states "Population in India is growing in geometrical and food grain in arithmetical progression. Human would run-out of food inspite of advances in agriculture due to limited land and yield potential of crops".

Blackmann (1905) Proposed Theory of Optima and Limiting Factor. Which states that 'When a process is conditioned as to its rapidity by a number of separate factors, the rate of the process is limited by the pace of slowest factor'.

Mitscherlich (1909) proposed Law of Diminishing Returns, which states that Increase in growth with each successive addition of the limiting element is progressively smaller and the response is curvilinear'.

Wilcox (1929) proposed Inverse Yield Nitrogen Law. It states that 'The growth or yielding ability of any crop plant is inversely proportional to the mean nitrogen content in the plant'. He also published a book called Wilcox Agro-Biology.

Agricultural Research / Education in India

No agricultural experiment stations were initiated in India till 1903. there was famine in 1877, 1889, 1892, 1897 and 1900 in India caused decreased population due to scarcity of food and death.

Lord Curzon (1898-1905) constructed great canal in western Punjab. Famine commission appointed in 1888, 1898 and 1901 stressed the importance of agricultural research. As a consequence, he started Imperial Agricultural Research Institute in 1905 at Pusa, Bihar. His period is called as **'Golden Period of Agriculture'.** During his regime, Agricultural Colleges were started at Poona, Dehradun, Saidapet (Coimbatore) Province. Also **Hebbal Farm** at Bangalore in Mysore Province was started in 1899. Later it was upgraded as Agricultural school in 1912-13 to offer Diploma in Agriculture.

Due to earthquake in 1934 at Pusa, Bihar, Imperial Agricultural Research Institute was shifted to New delhi in 1936. Later, it was renamed as Indian Agricultural Research Institute (IARI). Which is one of the largest research institute in the country and also taking Post-Graduate education.

Further, based on the 1928 Royal commission recommendation, Imperial Council of Agricultural Research was started at New Delhi in 1929. which was later changed as Indian Council of Agricultural Research (ICAR) with 3 main objectives.

1. To Co-ordinate the education in agriculture, animal husbandry, fishery, research and its application (Extension)
2. To finance various research institutes, Agril. Universities, schemes/ projects all over the country
3. Disseminate the knowledge gained by research through literature.

ICAR is the sole body, which controls all Agricultural Research Institutes in India. It paved way for

Green Revolution. Several research institutes both at National, International level were set up to take location specific research (Appendix – I)

After independence, ICAR adopted to Land Grant Colleges. The first Land grant College was started at Panth Nagar (Uttaranchal) in 1962. University of Agricultural Sciences, Bangalore was established in 1965 with Three objectives viz., Teaching, Research & Extension.

There are more than 74 Universities under ICAR with research institutes on its own. Presently, in Karnataka, 6 Universities are coming under ICAR.

UAS (Bangalore) was bifurcated in to 2 in 1986 as UAS (Bangalore) and UAS (Dharwad). Considering the essence of Animal & Dairy research, Animal / Dairy components were separated from both the Universities to formulate a separate University 'Karnataka, Veterinary, Animal and Fishery Sciences University' Headquartered at Bidar in 2004.

As of now, the **Teaching** campuses of UAS (Bangalore) are

Degree	Campuses
B.Sc (Agriculture)	Bangalore (1946), Shivamogga (1990), Mandya (1991), Hassan (2006) & Chintamani (2007)
B.Sc (Horticulture)	Mudigere (1991)
B.Sc (Sericulture)	Chintamani (1995)
B.Sc (Forestry)	Ponnempet (1995)
B.Sc (Agri.Engineering)	Bangalore
B.Sc (Agri. Marketing & Co-operation)	Bangalore
B.Sc (Ag.Biotech)	Hassan (2007)
B.Tech (Food Science)	Hassan (2007)

Research: With the prime mandate of Research, Zonal Agricultural Research Stations (ZARS) were established in all the Agro-climatic Zones with 2-4 affiliated Agricultural Research Station (ARS). The Research stations of UAS (B) are given in Appendix – II.

Extension : Krishi Vignana Kendra (KVK's) were established to transfer the technology from lab to land beside training the farmers. There are 11 KVK's functioning under UAS, Bangalore besides 2 under NGO's sponsored by ICAR & 1 directly under ICAR and are listed in Appendix - III

National Institutions for Agricultural Research.

1. Central Arid Zone Research Institute (CAZRI), Jodhpur, Rajasthan.

2. Central Institute for Cotton Research (CICR), Nagpur, Maharastra.

3. Central Institute of Agricultural Engineering (CIAE), Bhopal, Madhya Pradesh.

4. Central Institute of Fisheries Technology (CIFT), Cochin, Kerala.

5. Central Marine Fisheries Research Institute (CMFRI), Ernakulam, Cochin, Kerala.

6. Central Plantation Crops Research Institute (CPCRI), Kasaragod, Kerala.

7. Central Potato Research Institute (CPRI) Simla. Himachal Pradesh.

8. Central Research Institute for Dryland Agriculture, (CRIDA), Hyderabad, Andhra Pradesh.

9. Central Research Institute for Jute and Allied Fibres (CRIJAF), Barrackpore, West Bengal.

10. Central Rice Research Institute (CRRI) Cuttack, Orissa.

11. Central Soil and Water Conservation Research and Training Institute. (CSWCRTI), Dehradun, Uttar Pradesh.

14. Central Soil Salinity Research Institute (CSSRI), Karnal, Haryana.

15. Central Tobacco Research Institute (CTRI) Rajamundry. Andhra Pradesh.

16. Central Tuber Crops Research Institute (CTCRI), Thiruvananthapuram, Kerala.

17. Indian Agricultural Research Institute (IARI), New Delhi,

18. Indian Agricultural Statistics Research Institute (IASRI), Pusa, New Delhi.

19. India Grassland and Fodder Research Institute (IGFRI) Jhansi, Uttar Pradesh.

20. Indian Institute of Horticultural Research (IIHR), Hassaraghatta, Bangalore, Karnataka.

21. Indian Institute of Pulses Research (IIPR), Kanpur, Uttar Pradesh.

22. Indian Institute of Soil Science (IISS) Bhopal, Madhya Pradesh.

23. Indian Institute of Spices Research (IISR), Calicut, Kerala.

24. Indian Institute of Sugarcane Research (IISR), Lucknow, Uttar Pradesh.

25. Indian Lac Research Institute (ILRI), Ranchi. Bihar.

26. Indian Veterinary Research Institute, (IVRI) Izat nagar, Uttar Pradesh.

27. Jute Technological Research Laboratories (JTRL), Calcutta, West Bengal.

28. National Bureau of Plant Genetic Resources (NBPGR), IARI Pusa Campus, New Delhi.

29. National Bureau of Soil Survey and Land Use Planning, (NBSS & LUP) Nagpur, Mhr.

30. National Dairy Research Institute (NDRI), Karnal, Haryana.

31. National Research Centre for Agroforestry (NRCAF), Jhansi, Uttar Pradesh.

32. National Research Centre for Banana (NRCB), Tiruchirappalli, Tamil Nadu.

33. National Research Centre for Oil Palm (NRCOP), West godavari District, AP.

34. National Research Centre for Weed Science (NRCWS) Jabalpur, Madhya Pradesh.

35. Sugarcane Breeding Institute, (SBI) Coimbatore, Tamil Nadu.

International Institutions for Agricultural Research

1. Centro International de Agricultura Tropical (CIAT) Columbia.

(Interational centre for Agriculture in Tropics)

2. Central International de la Papa (CIP) (International Institute of Potato) Lima, Peru.

3. Centro International de Mejoramiento de Maiz Y Trigo (CIMMYT)
(International Centre for maize and Wheat Improvement) Londres Mexico, D.F.Mexico.

4. International Centre for Agricultural Research in the Dry Areas (ICARDA), Syria.

5. International Crops Research Institute for the Semi Arid Tropics (ICRISAT), Hyderabad.

6. International Food Policy Research Institute (IFPRI), Washington, D.C. U.S.A.

7. International Institute of Tropical Agriculture (IITA) Nigeria.

8. International Laboratory for Research in Animal Diseases (ILRAD), Nairobi, Kenya.

9. International Service in National Agricultural Research (ISNAR), The Netherlands.

10. International Livestock Centre in Africa (ILCA), Addis Ababa, Ethiopia.

11. West Africa Rice Development Association (WARDA) Ivory coast, Liberia.

12. International Rice Research Institute (IRRI), Manila, Philippines.

13. Asian Vegetable Research and Development Centre (AVRDC) P.O.Box 42, Shanhau, Tasnan 941, Taiwan, Republic of China.

15. International Centre of Insect Physiology and Ecology (ICIPE) Nairobi, Kenya.

16. International Council for Research in Agro Forestry. (ICRAF) Nairobi, Kenya.

17. International Irrigation Management Institute (IIMI), Colombo, SriLanka.

18. Consultative Group on International Agricultural Research (CGIAR), N.W.Washington. D.C.U.S.A.

CLASSIFICATION OF CROPS

CROPS: In general crop is an organism grown or harvested for obtaining yield. Agronomically crop is a plants cultivated for economic purpose.

Classification of crops: Several crop plants are alike with respect to ontogeny (Development), morphology, anatomy, physiology and requirement of environment. Classification is done to generalize similar crop plants as a class for attaining better understanding of them. Field crops are classified in several ways.

1. Based on Range of Cultivation

a) **Garden crop**: Grown on a small scale in gardens. Eg. Kitchen garden, vegetable garden, flower garden etc.

b) **Plantation crop**: Grown on a large scale in estates and perennial in nature. Harvesting continues for a prolonged period after single planting. Eg. Tea, Coffee, Cacao, etc.

c) **Field crop**: Grown on a vast scale under field condition. They are mostly seasonal such as rice, wheat, cotton etc. Agronomy deals with field crops only.

Field crops are classified in following ways.

2. Place of Origin

a) Native Crops: Crops grown within the geographical limits of their origin. Eg. rice, barely, blackgram, green gram, mustard, castor, sugarcane and cotton, are native to India.

b) Exotic or Introduced Crops: Crops introduced from other countries, such as Tobacco, Potato, jute, maize, apple, etc are introduced from other countries to India.

3. Botanical / Taxonomical Classification : Crop plants are grouped as orders and families in a systematic arrangement. This classification has certain advantage in understanding of morphological characters of crop plants with in the group.

a) Poaceae (Graminae): Eg. Cereals, millets and grasses.

b) Papilionaceae (Leguminaceae): Pulses, groundnut, berseem, etc.

c) Cruciferae: Mustard, rape seed, radish, cabbage, cauliflower, knol khol

d) Cucurbitaceae: All gourds (Ridge, Ash, Bitter, Snake gourd), cucumber, pumpkin etc.

e) Malvaceae: Cotton, lady's finger

f) Solanaceae: Potato, tomato, tobacco, chillies, brinjal

g) Tiliaceae: Jute

h) Asteraceae (Compositae): Sunflower, safflower, niger,

i) Chenopodiaceae: Sugarbeet.

j) Pedeliaceae: Sesame

k) Euphorbiaceae: Castor, tapioca

l) Convolvulaceae: Sweet potato

m) Umbelliferae: Coriander, carrot

n) Liliaceae: Onion, garlic

o) Zingiberaceae: Ginger, turmeric

4. Commercial classification : Based on the plant products which come into the commercial field are grouped as

a) **Food crops**: Rice, wheat, greengram, soybean, groundnut, etc.

b) **Feed crops / Forage crops:** All fodders, oats, sorghum, maize, napier grass, stylo, Lucerne etc.

c) **Industrial / Commercial crops**: Cotton, sugarcane, sugarbeet, tobacco, jute, etc.

d) **Food adjuncts**: Turmeric, garlic, cumin, etc.

5. **Economic / Agrarian / Agricultural Classification:** This classification is based on use of crop plants and their products. This is an important classification as for as agronomy is concerned (*Agronomic classification)* (For Botanical names of crops see)

a) **Cereals**: The word cereal was derived from the Roman word '**Ceres**' which denotes a '**Goddess grains**'. They are cultivated grasses grown for their edible starchy grains (one seeded fruit – caryopsis) Larger grains used as staple food are cereals – rice, wheat, maize, barley, oats etc. Grain is a collective term for the fruit of cereals (caryopsis). The exception of cereal Buck Wheat (Polygone), it belongs to the family Polygonaceae is grouped as cereal.

b) **Millets** : Small grained cereals which form the staple food in hot drier climatic regions of the developing countries are called millets. Eg. Sorghum, Bajra, Ragi and minor millets like Navane, Harka, Baragu, Same. They have single cover (due to the fusion of hesta to the pericarp).

c) **Oil seeds**: Crops that yield seeds that are rich in fatty acids, are used to extract vegetable oils. Eg. Mustard, Rapeseed, Sesame, Sunflower, Castor, Linseed, Groundnut, Soybeans.

d) **Legumes or Pulses**: derived from Latin word '**Legre**' meaning '**To gather**' because the pods have to be gathered or picked by hand. These are belongs to the family Leguminaceae, form Nitrogen fixing nodules on their roots. The pulses after splitting produce Dal which is a rich source of proteins. Eg. Greengram, Blackgram, Redgram, Bengalgram, Soybean, Cowpea, Peas, Lentil.

e) **Feed / Forage**: It refers to vegetative matter, fresh or preserved, utilized as feed for animals. It includes hay, silage, soilage, pasturage and fodder of cereals and legumes. Eg. Bajra, Napier Grass, Guinea Grass, Fodder sorghum, Fodder maize, Lucerne etc.

f) **Fibre crops**: Plants grown for their fibre yield. There are different kinds of fibre. Any thread like material / tissue having sufficient toughness for use in textile and similar industries are fibre. They are i) seed fibre – Cotton, ii) stem/bast fibre-Jute, Linseed, Mesta, iii) leaf fibre –Agave, Pineapple.

g) **Sugar and starch crops**: Crops grown for production of sugar and starch. Eg: For Sugar - Sugarcane, Sugarbeet. For starch - Potato, Sweet Potato, Tapioca.

h) **Spices and Condiments**: Crop plants or their products used to season, flavour, taste, and add colour to the fresh or preserved food. Eg. Ginger, Garlic, Fenugreek, Cumin, Turmeric, Chillies, Onion, Coriander.

i) **Drug crops / Medicinal plants**: Crops used for preparation of medicines. Eg. Tobacco Mint etc.

j) **Narcotics**: Plants / products used for stimulating, numbing, drowsing or relishing effects. Eg. Tobacco, Ganja, Opium.

k) **Beverages**: Products of crops used for preparation of mild, agreeable and stimulating drinking. Eg. tea, coffee, cocoa.

l) **Dye crops:** Used for synthesis of dyes. Eg. Indigo, Safflower etc.

6. **Seasonal Classification**: Crops are grouped under the seasons in which their major field duration falls.

a) ***Kharif*** **or South West Monsoon season crops:** Crops grown during June – July to September – October which require a warm wet weather during their major period of growth and shorter day length for flowering. Eg. Rice, Maize, Castor, Groundnut.

b) **Rabi Crops:** Crops grown during October – November to January – February which require cold dry weather for their major growth period and longer day length for flowering. Eg. Wheat, Mustard, Barley, Oats, Potato, Bengalgram

c) **Zaid or summer crops**: Crops grown during February – March to May – June which requires warm dry weather for growth and longer day length for flowering. Eg. Blackgram, Greengram, Sesame, Cowpea etc.

7. **According to Ontogeny:** It is a classification based on the life cycle of a plant.

a) **Annual Crops**: Crop plants that complete life cycle within a season or year. They produce seed and die within the season. Eg. Wheat, Rice, Maize, Mustard.

b) **Biennial Crops** : Plants that have life span of two consecutive seasons or years. First year / season these plants have purely vegetative growth. During the second year / season they produce flower stocks from the crown and after producing seeds the plants die Eg. Sugarbeet, Beet root, Cabbage, Carrot, etc.

c) **Perennial Crops** : They live for three or more years. They may be seed bearing or non-seed bearing. Eg. Sugarcane, Napier grass. In general perennial crops occupy land for more than 30 months.

8. **According to cultural requirement of crops:** Certain group of plants are alike in cultural requirements due to their similar agro-botanical or morpho –agronomical characters.

a) *According to suitability of toposequence*

i) **High land / dry land crops**: Crops that cannot tolerant water stagnation come under this group example redgram, groundnut, maize, sorghum, cotton, sesame, napier etc.

ii) **Medium / mid land / garden land crops:** Crops that require sufficient soil moisture but cannot tolerate water stagnation. Eg. Potato, sugarcane, upland rice, ragi, wheat, blackgram, bengal gram.

iii) **Low land / Wetland crops**: Crops that require abundant supply of water and can withstand prolonged water logged conditions. Eg. Rice, Daincha.

b) *According to the suitability of the textural groups of soils.*

i) **Crops suitable to sandy to sandy-loam (light) soils** : Sorghum, bajra, greengram, sunflower, potato, onion, carrot etc.

ii) **Crops suitable to silty loam (medium) soils** : Jute, sugarcane, maize, cotton, mustard, tobacco, bengal gram, redgram, cowpea, etc.

iii) **Crop suitable to clay to clay loam (heavy) soils** : Rice, wheat, barley, linseed, lentil, paragrass, guinea grass etc.

c) *According to tolerance to problem soils,*

i) Tolerant to acidic soils: Wet rice, potato, mustard.

ii) Tolerant to saline soils: Chilli, cucurbits, wheat, sorghum, bajra, cluster beans, barley etc.

iii) Tolerant to alkali /sodic soils: Barley, cotton, bengalgram, berseem, sunflower, maize, etc.

iv) Tolerant to waterlogged soils: Wet rice, daincha, paragrass, napier grass, guinea grass.

v) Crops tolerant to soil erosion: Marvel grass, groundnut, blackgram, rice bean, horsegram.

d) *According to tillage requirement*

i) Arable crops – require preparatory tillage. Eg. Potato, tobacco, rice, maize.

ii) Non-arable crops – may not require preparatory cultivation / tillage. Eg. Blackgram, greengram, Paragrass, cowpea.

e) *According to the depth of root system*

i) Shallow rooted crops (< 30 cm): Rice, potato, onion

ii) Moderately deep rooted (30-45 cm): Wheat, groundnut, castor, tobacco.

iii) Deep rooted (45-60 cm): Maize, cotton, sorghum

iv) Very deep rooted (> 60 cm): Sugarcane, safflower, lucerne, redgram.

f) *According to the tolerance to hazardous weather condition*

i) Frost tolerant: Sugarbeet, beet root,

ii) Cold tolerant: Potato, cabbage, mustard

iii) Drought tolerant: Bajra, jowar, barely, safflower, castor

g) *According to water supply*

i) Irrigated crops: Rice, wheat, pulses, groundnut, berseem.

ii) Rainfed / upland crops: Jute, maize, ragi, upland rice, redgram

iii) Rainfed but partially irrigated: Bengal gram, wheat, jowar, bajra, mustard, Horsegram

iv) Residual / conserved soil moisture: Rapeseed, bajra, barley, safflower, linseed.

v) Rainfed with supplemental irrigation: Kharif rice, sugarcane, blackgram.

vi) Rainfed with flooded water: Deep water rice, jute, sugarcane, daincha.

h) *According to method of sowing / planting*

i) Direct seeded crop: Upland rice, wheat, Ragi, jowar, bajra, groundnut etc.

ii) Planted crops: Sugarcane, potato, sweet potato, napier, guinea grass.

iii) Transplanted crop (after raising seedlings in the nursery) : Rice, ragi, tobacco, brinjal.

i) *According to length of field duration of crops*

i) Very short duration crops:	up to 75 days	Pulses
ii) Short duration crops:	75 – 100 days	Sunflower, cauliflower, uplandrice
iii) Medium duration crops:	100-125 days	Wheat, jowar, bajra, groundnut, jute.
iv) Long duration crops:	125-150 days	Mustard, tobacco, cotton
v) Very long duration crops:	above 150 days	Sugarcane, redgram, castor.

j) *According to the method of harvesting*

i) Reaping	: Rice, wheat,
ii) Uprooting by pulling	: Bengal gram, black gram, lentil, rapeseed
iii) Uprooting by digging	: Potato, sweet potato, groundnut, carrot etc.
iv) Picking	: Cotton, vegetables, brinjal, bhendi, chillies
v) Priming	: Tobacco
vi) Cutting	: Berseem, napier, amaranthus

vii) Grazing : Stylosanthes.

k) *According to post harvest requirement*

i) Curing : Tobacco, mustard

ii) Stripping : Jute, sunnhemp

iii) Shelling : Groundnut

iv) Ginning : Cotton

v) Seasoning : Turmeric, chillies

vi) Grading and sorting : Potato, rice, wheat, fibre crops etc.

l) *Based on climatic condition*

1) Tropical crop : Coconut, sugarcane

2) Sub-tropical crop : Rice, cotton

3) Temperate crop : Wheat, barley

4) Polar crop : All pines, pasture grasses

9. **According to important uses:** Though plants are useful in many ways only certain uses are given below.

a) **Catch crops / contingent crops:** are those crops cultivated to catch the forth coming season. It replaces the main crop that has failed due to biotic or climatic or management hazards. Generally, they are of very short duration, quick growing, harvestable or usable at any time of their field duration and adaptable to the season, soil and management practices. Eg. Greengram, Blackgram, Cowpea, Onion, Coriander, Bajra.

b) **Restorative crops:** are those crops which enrich or restore soil fertility or amelioration of the soils. They fix atmospheric nitrogen in root nodules, shed their leaves during ripening and thus restore soil conditions. Eg. Legumes.

c) **Exhaustive crops:** are those crop plants which on growing leave the field exhausted because of a more aggressive nature. Eg. Gingelly, Maize, sunflower etc.

d) **Paira crop / residual crops:** are those crop plants which are sown a few days or weeks before the harvest of the standing mature crops to utilize the residual moisture, without preparatory tillage. The standing crop and the later sown (paira) crop become simultaneous (forming a pair) for a short period. For example Black gram in Paddy

e) **Smother crops:** are those crop plants which are able to smother or suppress the weed growth by providing suffocation (curtailing movement of air) and obscuration (of the incidental radiation) Eg. Cowpea

f) **Cover crops:** are those crop plants which are able to protect the soil surface from erosion (wind, water or both) through their ground covering foliage and or root mats. Example – groundnut, blackgram, marvel grass, sweet potato.

g) **Nurse crops:** A companion crop which nourishes the main crop by way of nitrogen fixation and or adding the organic matter into the soil. Example-cowpea intercropped with cereals, glyricidia in tea.

h) **Guard / barrier crops:** are those crop plants which help to protect another crop from trespassing or restrict the speed of wind and thus prevent crop damage. Main crop in the centre surrounded by hardy or thorny crop. Eg. Mesta around sugarcane; sorghum around cotton; safflower around gram.

i) **Trap crops:** are those crop plants grown to trap soil borne harmful parasitic weeds. Eg. orobanche and striga are trapped by solanaceous and sorghum crops respectively. Nematodes are trapped by solanaceous crops (On uprooting crop plants, nemathodes are removed from the soil). Castor in cotton.

j) **Augmenting crops:** are those sub crops sown to supplement the yield of the main crop. Example – Mustard or cabbage with berseem to augument the forage yield of berseem.

k) **Green manure crops:** grown & incorporated freshly in to the soil to increase soil fertility. It may be (a) Green leaf manuring – Calotrophis, (b) Green manuring *Insitu* – Sunhemp

l) **Silage crop:** These are grown to preserve in pits in a succulent condition by a process of natural fermentation or acidification for feeding livestock during lean months Eg. Maize, sorghum, Cowpea

m) **Soilage crop:** these are grown to harvest while they are still green and fed fresh to livestock Eg. Cowpea, Napier, Horsegram.

ECOLOGY, ADOPTATION & DISTRIBUTION, ORIGIN OF CROP PLANTS

Ecology: The term Ecology is derived from two greek words '**Oikas**' meaning '**Home**' and '**Logos**' meaning '**Study**'.

Tansley (1926) defined ecology as 'the study of organisms as they exist in their natural houses'.

Ecology is broadly divided as Animal Ecology and Plant Ecology based on the associated organism. The study of inter relationship between crop plants and their environment is known as **crop ecology**. It implies the study of climatic elements such as moisture, temperature, light etc, edaphic factors like soil and parent material and biotic factors like activities of living organisms on crop.

Plant ecology is further divided into **Autecology** and **Synecology.**

Autecology: is the study of inter-relationships between the induvidual Plants& their environment.

Synecology: is the study of plant structure, development and distribution of plant communities.

Natural environment of the plant is dynamic and changing continuously. The intensity of these factors vary every hour, day, season etc. the rate of change of these factors and their extream values are important aspects of environment.

Classification of Environment:

Tansley (1923) recognised four simplest group of environment viz., Climatic, Physiographic, Edaphic and Biotic factors.

Detailed analysis of environment was done by Billings' (1952). He stated that envirment includes all external factors or forces and substances affecting the growth, structure and reproduction of the plants. He subdivided the environment into

a. Climatic – Radiation, Temperature, water, Atmospheric gases, Light
b. Edaphic – Parent material, soil, soil air, soil temperature, soil moisture
c. Geographic – Gravity, Topography, Altitude, Longitude, Latitude
d. Pyric – Fire
e. Biotic – Other Plants, Animals including man, Micro-organisms etc.

Adoption : Crops are not profitable unless they are adopted to a region of their production.

Adaptation may be defined as any feature of an organism which has survival value under the existing condition of its habitat. Such features or feature may allow the plants to make use of nutrients, water, temperature or light available or may give protection against adverse factors such as temperature extremes, harmful insects and diseases.

Adaptation may be morphological or physiological.

Morphological adaptation measured in terms of growth habit, strength of stalk, rhizome production.

Physiological adaptation measured in terms of resistance to parasites, ability to compete for nutrients or withstand desiccation etc.

Distribution: Basic principles and concepts relating to natural distribution of plants are useful in studying the plant adaptations. The plant geographer mainly study the spatial relationship of plants both in past and present. He attempts to explain origin, development and distribution of plants.

The plant geographer **Good (1931)** formulated the basic principles of plant distribution. They are

i. Plant distribution is primarily controlled by the distribution of climatic conditions like light, temperature, moisture, wind etc.

ii. Plant distribution is secondarily controlled by distribution of edaphic factors like spil, parent material, physiography etc. these factors considered secondary because they are greately influenced by climate.

iii. Great movement of flora have been taken place in the past and are still continuing.

iv. The plant migration is brought about by the transport of induvidual plants during their mobile dispersal phase.

v. Great variation and oscilation in climate especially at higher lattitude during the geographycal history of angiosperms. Eg. Global warming – Extinction of organisms.

vi. Considerable varion has occurred in the relative distribution and outline (Border) of land and sea in the history of angiosperm and it exerts a high degree of control over distribution of flora.

Theories governing crop adoption and distribution.

1) **Theory of tolerance:** Each and every plant species is able to exist and reproduce successfully only with a definite range of climatic and edaphic conditions. This range represents the tolerance of the species to external conditions.

Shelford (1913) proposed a general law of tolerence which include the following concepts

1. Organisms with wide range of tolerence for all the factors of the environment are likely to be widely distributed.
2. Organism may have wide range of tolerence for one factor and a narrow range for another.
3. When conditions are not optimum for one factor, the limits of tolerence may be reduced with respect to another factor.
4. The period of reproduction is usually critical when environmental factors are likely to be limiting.

Temperature is one of the most limiting factor in plant distribution. Many sub-tropical crops such as wheat, rice willn’t withstand high temperature. Among them, rice has wide tolerance range.

2. Law of minimum (Leibig, 1840) – Refer history

3. Theory of optima and limiting factor (Blackmann, 1905) - Refer history

4. Law of Relativity (Lundegardh, 1931): As a factor increases in intensity, its relative effect on plant growth decreases. This law is considered in connection with the correlation of environmental factors and crop yields.

Origin of Crop Plants

There is a belief that, cultivated crop plants are gifted by god. Also, another belief indicating the process of cultivation itself improved the heredity of plants from the wild.

Decandole (1882), 'Father of Concepts of Cultivated Plants' attempted to make use of earlier information taking evidense from Archeology, Palentology, History and Philosophy. He studied many tree species and tried to trace them back to their wild ancestors through what he called **Botanical method.** The criteria used are

a. Occurrence of a given cultivated plant in a locality where it is also grown wild or where wild relatives were found.

b. Added information from Archeology, Historical and Linguistic sources.

He studied 247 species including 199 from old world, 45 species from New world and uncertain on 3 species. He published a book "**Origin of Cultivated Plants**".

Nikolai Vavilov (1951), took up extensive survey to locate the possible origin of crop plants and he broughout a principle that the distribution of plant species on the earth is not uniform attributing to the variation in the geographical factors. He developed differential **Phytogeographical method** to locate the centres of Origin of crop plants and listed 8 centres of Origin of cultivated plants with the following evidenses.

a. Concentration and great diversity of heretable forms

b. Endamic varietal characters and

c. Presence of closely related wild or cultivated forms

World Centres of Origin of cultivated plants

1. **Chinese Centre:** Largest independent centre includes the mountainous regions of Central, Western China and adjucent low lands. 136 Plant species were originated here. Eg. Soybean, Pea, Sugarcane (*Saccharum sinensis*), Radish, Onion, Cucumber, Peach, Apricot, Millets, Barley, Buck wheat.

2. **Indian Centre:** it ha two sub centres

   a. Main Centre: Includes Assam and Burma. 117 Plants were originated here. Eg. Rice, Bengalgram, Blackgram, Greengram, Cowpea, Sugarcane (*Saccharum officinarum*), Sesamum, Safflower, Mango, Orrange, Tamarind, Coconut, Brinjal, Jute, Cotton.

   b. Indo-Malayan Centre: Includes Indochina and the Malayan Region. 55 plants are listed here. Eg. Velvet Bean, Banana, Clove, Nutmeg, Black pepper, Bread fruit.

3. **Central Asiatic Centre:** includes NW-India (punjab, J&K), Afganistan, Uzbekistan & Weatern Tiam-Shan. 43 Plants were listed here. Eg. Wheat, Horsegram, Mustard, Garlic, Sunhemp, Jute, Spinach, Carrot, Peas, Grapes, Apple, Almond, Lentil.

4. **Near Eastern Centre:** includes interiro of Asia minor, All of Transcaulasia (Europe), Iran and high lands of Turk Menstan. 83 species are located in this region. Eg. Oat, Barley, Rye, Lucern, Pomogranate, Lupins, Clover, Fenugreek.

5. **Medeterranean Centre** : includes the border of Medetarranean Sea. 84 Plants are listed. Eg. Wheat (Durum & Emmer), Flax, Rapeseed, Beet root, Cabbage, Turnip, Celery, Lettuce.

6. **Abyssinian Centre:** includes Abyssinia, Eritrea and parts of Somali. 38 Plants are listed. Eg.

Sorghum, Bajra, Sesamum, Castor, Ladies finger, Coffee & Millets.

7. **South Mexican & Central American Centres:** includes Southern sections of Mexico. Guetamala, Honduras and Costarica. 49 Species are listed here. Eg. Maize, Cotton, Sweet Potato, Guava, Cashew, Papaya, Limabean.

8. **South American Centre:** 62 Plants are listed here.

   a. **Peruvian, Equidorean, Bolivian Centre:** Comprises mainly the high mountainous areas. Eg. Potato, Tomato, pumpkin, Tobacco, Egyptian cotton

   b. **Chillian Centre:** Island near coast of Southern Chilli. Eg. Wild Straw berry, Potato.

C. **Brazilian, Paraguayan Centre**: Eg. Groundnut, Rubber, Pineapple

FACTORS AFFECTING CROP PRODUCTION / PLANT GROWTH

Higher plants demand certain basic things for their growth. As many as 52 factors (basic things) influencing crop growth have been identified.

Only 7% of the world land is adopted for crop production, of which

100% of the land have sufficient CO_2 in the atmosphere & sunlight

83% have favourable temperature

64% have favourable topography

46% have reliable rainfall

40% have satisfactory fertile land

But only 7% have combination of these factors to make feasible crop production without advanced technology and this is also declining still in recent times.

The factors influencing crop growth / production can be broadly grouped into 2 group

Crop growth

Internal factors (Genetic or Hereditary)

External factors (Environmental)

A. Climatic

B. Edaphic

C. Biotic

D. Physiographic

E. Socio-economic

Genetic factors: The increase in crop yields and other desirable characters are related to genetic make up of plants. Breeders and Bio-technologists have incorporated many desirable characters and developed HYV and hybrids. The characters considered are

1. High yielding ability
2. Early maturity
3. Resistance to lodging (Strengthening of stalk)
4. Tolerance to drought, flood and salinity
5. Tolerance to insect pests and diseases
6. Chemical composition of grains (high percentage of oil, protein etc.)
7. Quality of grains (fineness, coarseness, etc.)
8. Quality of straw (sweetness, juiciness, etc.)

These characters are inherited and transferred from one generation to another through genes.

External or Environmental Factors

Crop growth and development is primarily governed by environmental conditions. Success or failure of crop is related to the weather condition that prevails during crop growth. Control of these factors of environment under field condition is more difficult, costly and often impossible. Therefore, it is essential to study these factors in order to cope up with them for better crop growth.

The environmental factors are broadly grouped as

a) Climatic b) Edaphic c) Biotic d) Physiographic & e) Socio-economic

a) Climatic Factors: Climate is a generalized weather or summation of weather conditions over a given region during comparatively longer period.

Weather is a state or condition of atmosphere at a give place and at a given time.

Climate is weather conditions related to larger areas like zone, state, country etc., and for longer duration like month, season, year etc.

The important climatic elements that affect crop production are

i) Precipitation ii) Temperature iii) Atmospheric humidity
iv) Solar radiation v) Wind vi) Atmospheric gases

i) Precipitation: Precipitation includes all forms of water that fall on earth from the atmosphere such as rainfall, snow, hail, dew, fog etc. It is the source of water for crop production.

Precipitation is resultant of condensation of water vapour evaporated from sea and land surfaces. The process involved in transfer of moisture from land and sea to atmosphere and back is known as hydraulic cycle.

Rainfall is the most important factors influences vegetation of a place. Most of the plant water demand is met out with rainfall. Rainfall both in total amount and seasonal distribution greatly affect choice of crops and their growth eg. In heavy and evenly distributed rainfall areas, crops like rice in plains, coffee, tea, rubber in hilly areas can be taken. In low and uneven distributed areas, drought resistance crops like bajra, sorghum, millets can be taken.

Both excessive and deficit rainfall affect crop production. Excessive rainfall leads to
Soil erosion – loss of nutrient, soil

Submergence – affect root respiration / activity

Pollen wash – affect pollination & fertilization

Crop lodging and grain shedding

Deficient rainfall leads to desiccation of plant, reduce yield and result in plant death.

About, 55% of the world land receive	< 51 cm rainfall	- Semi arid
20%	51 – 102 cm RF	- Sub humid
11%	102 – 152 cm RF	- Humid
14%	> 152 cm RF	- Super humid

Water is an indispensable element of plant growth. It performs the following functions

i) Constitute of protoplasm (85-90% of actively growing tissue is water)
ii) Reagent for many biological activities (Photosynthesis)
iii) Acts as solvent for transportation of mineral nutrients
iv) Maintains cell turgidity – important for cell division and elongation
v) Regulate stomatal movement – important in gas exchange and microclimate.

Depending on the water need, the plants are grouped into 3 groups

a) Xerophytes: Plants survive under very low moisture condition and withstand drought even for prolonged period. They are also called as Desert Plants. Eg. Agave.

b) Mesophytes: They require normal supply of moisture for their growth and grow well when soil is moist. Eg. Wheat, Maize, Pulses

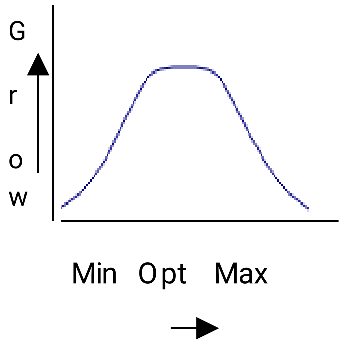
c) **Hydrophytes:** are water loving plants, grow well only when the soil is wet or full of water. Eg. Rice, Aquatic plants.

The water is utilized in photosynthesis results in dry matter production of plants. Which is expressed as **Transpiration Co-efficient**.

Transpiration Co-efficient is the total quantity of water required to produce a unit quantity of dry matter. It varies from plant to plant. Transpiration co-efficient of some of the crop's are as follows

Sl No	Crop	Transpiration Co-efficient	
		Without fertility	With fertility
1	Maize	450	330
2	Ragi	250	250
3	Jowar	400	400
4	Rice	1000	800
5	Wheat	850	550

ii) Temperature: Temperature is a measure of intensity of heat energy or the degree of hotness / coolness. Temperature of a place is largely determined by its distance from the equator (latitude) and altitude. The temperature range for maximum growth of agricultural crops lies between 15-40°C. Based on the temperature, the vegetations are grouped as tropical, temperate, taiga, tundra and polar.



Species and cultivated crop plants differ in their physiological responses to range of temperature. The growth increases with an increase in temperature to a certain extent but reduces after a limit.

Every plant community has its own minimum, optimum and maximum temperature range for their growth and development known as **cardinal temperature points**. Cardinal temperature points are not same throughout the crop growth and vary between germination, growth, flowering and fruiting. The cardinal points of important crops are

Crop	For germination			For growth		
	Minimum	Optimum	Maximum	Minimum	Optimum	Maximum
Rice	13 – 14	28	40	10	32	36 –38
Wheat	4.0 –4.5	25	30 –32	4.5	20	30 –32
Maize	8 – 10	31–35	40 –44	8 – 10	25 –30	40 –43
Sorghum	8 – 10	31–35	40 –44	12 – 13	25	40
Tobacco	13 – 14	28	40	12 – 14	29	35

Soil and atmospheric (air) temperature are important from the growth point of plants. Crop production also depends on the temperature during day and night. If the days are warm, increased respiratory loss can be compensated by photosynthesis to some extent. However, if nights are warm, respiratory losses are higher and in turn reduce the crop yield.

Some plants require optimum day and night temperature for successful flowering. The response of the plants to rhythmic diurnal fluctuation in temperature is called **Thermoperiodism.** Eg. Tomato requires 26-27°C day temperature & 17-19°C night temperature.

Some plants require a cold stimulus (chill treatment) for flowering. This is done in winter wheat. The cold treatment given to the sprouting seeds to induce flowering is known as **Vernalization.**

Here wheat seeds are subjected to 0°C for about 2-3 weeks before sowing. This is done to save seedling from severe winter damage and to induce flowering. This would change the development of apex from vegetative to reproductive growth called **thermo-morpho-genesis.** This concept was developed by 'Lysenco' – a botanist in Russia.

Based on the temperature, the crops are grouped as,

1) Cool season crops: require cool winter period generally grown in winter, the cardinal temperature points of these crops lies between Minimum = 0-5°C, Optimum = 25-30°C, and Maximum = 30-38°C. Eg. Wheat, Barley, Oat, Sugar beet etc

2) Warm season crops: require warm weather and grown in *Kharif* and summer. Cardinal temperature points of these crops lies between Minimum = 15-20°C, Optimum = 30-38°C, and Maximum = 45-50°C. Eg. Rice, Maize, Sorghum, Sugar cane etc.

Influence of temperature on crop growth: Temperature influences crop growth through

a. Regulation of bio-chemical reaction
b. Uptake of CO_2
c. Enzymatic activity
d. Chlorophyll synthesis, leaf emergence & expansion
e. Influence on growth substances – regulating ratio between growth promoters and retarders
f. Photosynthesis and dry matter production
g. Crop yield – regulating Photorespiration and other bio-chemical activities,

Growing Degree Days: The intensity of growing season is represented by the accumulation of temperature units above the growth threshold. The unit used is degree-days. It is the amount by which daily mean temperature exceeds the stated minimum / base temperature (Temperature at which the activities start). It is also called heat unit and mathematically expressed as

$$GDD = \sum_{r=1}^{n} \left\{ \frac{T_{Max} + T_{Min}}{2} \right\} - T_b$$

Where, T_{Max} & T_{Min} = Maximum and Minimum temperature of the day
T_b= Base temperature (Rice = 10°C, Wheat = 5°C, Maize = 10°C).

Units of measurement of temperature

Temperature is measured either in Fahrenheit (°F), Celsius (°C) or Kelvin (°K) scale and are related as

C = 5/9 (F-32)

F = 9C/5 +32

K = C + 273

Scale / unit	Boiling Point	Melting Pointg
Celsius (°C)	100	0
Fahrenheit (°F)	210	32
Kelvin (°K)	373	273

Effect of extreme temperatures on plant growth

Extreme high and low temperature causes stress in plants.

High temperature stress:

1. Causes reduction in absorption and assimilation of nutrients
2. Affect shoot growth
3. Abortion of pollens – reduce viability and cause female sterility

Low temperature stress

1. Survival, cell division and elongation is strongly affected
2. Absorption and translocation of water is affected due to low permeability of water
3. Reduced translocation and gas exchange resulted in poor photosynthetic rate and in turn the crop yield

Low temperature also cause the following injury to the crop plants

1. Chilling injury: Plants growing in hot climate, if exposed to low temperature for some time, are found to be killed or injured severely. Eg: Chlorotic condition or bands on leaves of sugarcane, sorghum and maize when exposed for 60 hours at 2 to 4^{0}C.

2. Freezing injury: caused in plants growing in temperate region. When the plants are exposed to very low temperature, water in the intercellular spaces is frozen into ice crystals. Further fall in temperature, draws water from the cells, resulting in increased size of ice crystals and death of cells.

3. Suffocation: During winter, the ice or snow form a thick cover over the ground and the crop suffers for want of oxygen. Ice in contact with roots inhibits diffusion of carbon dioxide and the respiratory products may become harmful to plants.

4. Heaving: Injury to plants is caused by a lifting upward of the plant along with the soil from its normal position in temperate regions where snowfall is common.

Classification of vegetation based on temperature

Class	Region	Temperature condition	Vegetation	Common crops
Megatherms	Equitorial/Tropical	High temp. throughout the year	Tropical rain	Cassava, rubber, rice
Mesotherms	Tropicl/SubTropical	High temp. & winter low temp	Tropical deciduous forest	Maize, sorghum
Microtherms	Temperate	Low temperature	Mixed coniferous	Wheat, oat, potato
Hekistotherms	Artic / alpine	Very low temperature	Alpine	Pines

iii) Atmospheric humidity:

Humidity refers to the water vapour suspended in the atmosphere. Water vapour is a colourless, odourless, tasteless and consists of very minute water droplets suspended in air. Which is the resultant of the evaporation from soil and water bodies with the solar energy in the form of temperature.

When the atmosphere holds maximum amount of water vapour at particular temperature is said to be saturated. Increase in temperature will make the air unsaturated.

The evapo-transpiration of water is directly proportional to the difference between the amount of water actually present and the saturation. The difference is termed as **Vapour pressure deficit (VPD).**

The atmospheric humidity is expressed as absolute, specific and relative humidity.

Absolute humidity is the actual quantity of water vapour by weight present in a given volume of air

$$\text{Absolute humidity } (g\ m^{-3}) = \frac{\text{Weight of water vapour (g)}}{\text{Volume of air } (m^3)}$$

Specific humidity is the weight of water vapour per unit weight of air (including water vapour)

$$\text{Specific humidity } (g\ kg^{-1}) = \frac{\text{Weight of water vapour (g)}}{\text{Weight of air including water vapour (kg)}}$$

Absolute and specific humidity are difficult to measure as they fluctuate greately with temperature. Also, they have little or no effect on crop growth.

The extent of evaporation and transpiration depends on the amount of moisture held in the atmosphere. Hence, it is essential to findout the saturation capacity and VPD, which is given by relative humidity.

Relative humidity is the ratio between the amount of water vapour present in the air and the amount of vapour required for saturation at particular temperature & pressure and expressed in percentage

$$\text{Relative humidity (\%)} = \frac{\text{Water vapour present in air}}{\text{Water vapour required for saturation}} \times 100$$

If RH is 100%, there is no evaporation & transpiration and if it is 0%, then there is enormous evapotranspiration. Both these conditions are not congenial for crop growth. RH of around 60% is suitable for most of field crops.

Relative humidity is greately influenced by temperature, wind, vegetation and water content in soil.

Increased RH - favours growth of many fungi, bacteria, insects affecting crop growth

- affect gas exchange through stomata by affecting transpiration & in turn photosynthesis & crop yield.

Reduced RH - Increase evapo-transpiration and demand more irrigation.

iv) Solar radiation: Solar radiation is the source of energy for all physical processes taking place in the atmosphere. This energy also drives the process of photosynthesis, chlorophyll synthesis, evaporation, heating of soil & air to regulate temperature besides germination, leaf expansion, stem growth, flowering, fruiting etc.

More than 70% of solar radiation absorbed by the plant is converted into heat which is essential for transpiration. About 28% of solar energy is utilized in photosynthesis.

A constant amount of radiation (1.94 cal cm^{-2} min^{-1}) is emitted continuously from the sun. The amount of solar energy received per unit area of surface held at right angle to the sun rays at the top of the atmosphere is called solar constant.

Light affect plants growth through its intensity, duration and quality.

a) *Light intensity*: The total quantity of light received in unit time can be considered as light intensity, which is expressed in Foot Candles / Lux. The optimum light intensity for most of the crops is around 1700 Lux.

There are certain plants which grow luxuriously with high light intensity, such plants are called **Heliophytes** (Sun-loving) Eg. Sunflower. The plants growing under low light intensity / shade condition are called **Sciophytes** (Shade loving) eg. Coffee.

The light intensity at which the photosynthates produced through photosynthesis is completely made use for its respiration is called **Light saturation point.** It varies from sciophytes (27 Lux) to heliophytes (4200 Lux). Higher light intensity may disintegrate chlorophyll.

b) *Quality of light*: The process of photosynthesis in green plants depends on quality of light. Radiation up to 250 ήm in UV spectrum is harmful to most of the plants. Though, radiation from 300 ήm is photosynthetically active, visible spectrum (400 – 750 ήm) is more effective. Visible spectrum composed with seven colour range VIBGYOR.

Violet - 400 to 435 ήm	**Green** - 490 to 574 ήm	**Orange** - 595 to 626 ήm
Indigo - 435 to 460 ήm	**Yellow** – 574 to 595 ήm	**Red** - 626 to 750 ήm
Blue - 460 to 490 ήm		

With in the visible range, the principle wavelength absorbed in photosynthesis are Violet to Blue (400 – 490 ήm) and Orange to Red (595 – 750 ήm). Red light is found most favourable. Radiation above 750 ήm (Infra Red radiation) is harmful to photosynthesis.

c) *Duration of light*: Light intensity and duration determine the amount of light that a plant receives. The length of the day is more important than intensity. The response (Flowering) of the plants to the relative length of day and night is known as **photoperiodism**. Different species and in some cases different cultivars of the same species responds differently to the length of day and night. The photoperiod required to induce flowering is called **critical day length**.

Based on the photoperiodic response, the plants are grouped as

- **Long day plants**: Crops that reproduce (Flower) normally when the light period is longer than 12 hours. Eg. Rabi Crops – Wheat, Barley, Sugar beet, Potato etc.
- **Short day plants**: Crops that reproduce (Flower) normally when the light period is shorter than critical minimum (<12 hours). Eg. Tobacco, soybean, millets, Rice
- **Day neutral plants**: Plants that are non-responsive to relative length of day & night. Eg. Tomato, Sunflower, Buck wheat etc.

v) Wind: Wind is the air in horizontal motion which travels from high pressure areas to low pressure areas. The basic function of wind is to carry moisture & heat and supplies fresh CO_2 for photosynthesis. Mild wind (4-6 km hr^{-1}) is essential for crop production.

Harmful effects of wind: Higher wind velosity affects crops through

- Uprooting of seedlings / tree
- Lodging of crop / trees
- Soil erosion
- Dissemination of weeds, insect pest & diseases
- Increase Evapo-transpiration loss & demand frequent irrigations
- Pollen wash & affect pollination at flowering stage

Beneficial effects of wind:

- Responsible for rainfall
- Mild wind – Encourage pollination
- Replace CO_2 & other gasses

vi) Atmospheric gasses: It may be soil or atmospheric air,Atmospheric air is composed of 78.09%

Nitrogen, 20-98% Oxygen, 0.93% Argon & 0.03% CO_2. CO_2 is most important for photosynthesis and taken by the plant through diffusion in stomata. O_2 is important in respiration of both plants & animals. Nitrogen is important plant nutrient. Atmospheric nitrogen is fixed in the soil by lightening, rainfall & microbes. Certain gasses like SO_2, CO, CH_4, HF, CFC released from petrochemicals are toxic.

II. EDAPHIC FACTORS: are the soil factors. Soil provides physical anchorage to plants and acts as a store house of water, nutrient and air.

The soil factors that affect crop growth are

i. Soil moisture	iv. Soil organic & mineral matter
ii. Soil air	v. Soil organisms
iii. Soil temperature	vi. Soil reaction

i. Soil moisture: More than 90% of plant tissue consists of water which is absorbed from soil through roots. It is held by soil particles by cohesive and adhesive forces. Rainfall, irrigarion and drainage governs the soil moisture. Soil moisture is the medium for absorption and translocation of mineral nutrients. Soil moisture maintains soil temperature, regulates soil aeration and together these dictate the activity of biotic factors in soil.

Soil texture, structure and depth determine its moisture retention besides the organic matter. Efficient use of inputs in crop production depends on optimum level of soil moisture.

ii. Soil air: Composition of soil air differs from that of atmosphere. Soil air has 10 – 100 times higher CO_2 than atmosphere. Aerobic micro organisms, Sprouting seeds, Root respiration demand ample supply of O_2 in the soil. Rice can withstand anaerobic condition because of the presence of aerenchyma tissue. Soil moisture content / irrigation dictate the soil air and affects root respiration.

	Nitrogen	Oxygen	CO_2	Argon
Soil air	78.60	20.00	0.3 – 0.5	0.90
Atmosphere	78.09	20.98	0.03	0.94

iii. Soil temperature: Soil temperature influence root growth and functions. Soil temperature is particularly important during crop germination and establishment.

Soil temperature affects the physical and chemical processes like

- Availability & Absorption of nutrients & water – Max. absorption occur at 20-30^{0}C
- Regulate the microbial activity
- Root growth & development specially in edible roots such as turmeric, tapioca, sugarbeet, potato, groundnut etc.

iv. Soil organic & mineral matter: Soil organic matter is derived from death & decaying plant parts / animals and their external addition. They function the following role

- Supplies major & minor nutrients
- Improve soil structure and aeration
- Improves water holding capacity & moisture availability
- Source of food for micro-organisms

The soil mineral matter is derived from weathering of rock & minerals and is source of nutrients for plants.

v) Soil organisms: The organic matter in the soil is decomposed by different micro-organism to release nutrients. The different kind of organisms are

Macro-flora: Roots of higher plants.

Macro-fauna: Earthworms, grubs

Micro-flora: Algae, Bacteria, fungi, Actinomycetes

Micro-fauna: Protozoa, Nematode, Mites, insects etc

There are both beneficial and harmful organisms in the soil & their activity in turn depend on soil moisture, temperature and aeration.

Beneficial organisms like Azatobacter, Azo-spirullum, Rhizobium, BGA, fix atmospheric nitrogen, Phospho bacteria release the fixed 'P' to the plants.

The harmful organisms are soil borne insect, pathogen & weeds.

vi) Soil reaction / pH: Availability of plant nutrient depends on soil reaction. pH is the negative logarithm of hydrogen ion concentration. Soil acidity and alkalinity have profound influence on crop productivity. Most of the plant nutrients are freely available at neutral pH. Acid soil with higher Fe, Al & Mn reduce the availability of P, availability of Mo, Fe, Al, Mn will reduce with alkalinity. Also, pH influence the microbial activity and water absorption.

III. BIOTIC FACTORS: includes the beneficial / harmful effects caused by other plants, animals, micro-organisms on crop plant.

Plants may be complementary / competitive among each other. Competition between plants occurs when the supply of nutrients, moisture and sunlight is limited. This competition may be between same crop or between different crops or weed & crop.

When different crop of cereal & legume grown together, mutual benefits among them results in higher yield (synergetic effect).

Animals: soil fauna like protozoa, earthworm etc improve organic matter decomposition. Honeybees & wasps help in cross pollination. Large animals like cattle, goat etc may damage crop but add organic matter.

IV. PHYSIOGRAPHIC FACTORS: The nature of earth surface (slope / flat) known as topography influence crop growth directly. Steepness of slope dictates runoff and soil erosion. Increase in altitude cause a decrease in temperature and increase precipitation & wind velocity. Physiography dictates exposure of crop / soil to light & wind.

V. SOCIO-ECONOMIC FACTORS: The social acceptance of crop & economic condition of the farmer greatly decides the input / resource use and in turn crop growth.

SOIL

Soil: It may be defined as a dynamic natural body composed of minerals and organic materials & living forms on which plant grows. Soil is a general name given to the loose & unconsolidated outer layer of the earth crust. For a farmer soil refers to the cultivated top layer of the earth. Soil are formed by the weathering of rocks &minerals with the presence of soil forming factors like climate, organism, relief or topography, parent material & time (cl,o,r,p,t).The weathering of rocks & minerals is associated with physical & chemical phenomenon. The principal agents of physical weathering are temperature, water, wind, plant & animals. Chemical weathering is affected through the process of hydrolysis, hydration, carbonation, oxidation & reduction.

Each soil is characterized by a given sequence of horizons. Combining of this sequence is known as soil profile. Soil profile is a vertical section of the soil through its horizons. The layers or horizons in the soil profile vary in thickness & have different characteristics like colour, texture, structure etc. The horizons are designated by O, A, E, B, C & R.

Mineral soils are composed of 2 major components.

1. Solid phase; 45% inorganic & 5% organic.
2. Pore Space; 25% air & 25% water.

Soils widely vary in their characteristics & properties like physical, chemical & biological properties. Understanding the properties of soil is important for their optimum use & best management.

Physical properties; the physical properties of soil are texture, structure, density, colour, porosity, plasticity, consistency etc.

1.Texture; it refers to the relative proportions of primary soil separates i.e., sand , silt & clay that are present in a soil. These soil separates are grouped into 7 groups according to USDA.

A. Very course sand : > 1.0 mm

B. Course sand : 0.5 to 1.0 mm

C. Sand : 0.25 to 0.50 mm

D. Fine sand : 0.10 to 0.25 mm

E. Very fine sand : 0.05 to 0.10 mm

F. Silt : 0.02 to 0.005 mm

G. Clay : <0.002 mm

As per the international union of soil science soil separates are grouped into 4 groups which are known as international method & are widely accepted.

A. Coarse sand : 0.2 to 2.0 mm
B. Fine sand : 0.02 to 0.2 mm
C. Silt sand : 0.002 to 0.02 mm
D. Clay : < 0.002 mm

A large amount of sand in a soil will make a coarse texture and gritty. Such soils are called as Sandy or Sandy loam and are easy to work. When silt is present in large amount, soils feel like flour and are called silty loam.

Clay in a soil, make it sticky when wet and hard when dry resulting into clay or clay loam soils. A fine textured soil is made of largely of solt & clay. Its plasticity and stickyness indicates difficult to work or heavy.

The term light and heavy refers ease of working and not by weight. The weight of sand is greater than clay but, the clay is heavy soil and sand is light soil.

Various textural classes that are found in soil are given under the table.

Group	Texture	Sand (%)	Silt (%)	Clay (%)
Coarse Textured	Loamy sand	85	10	5
	Sandy loam	65	25	10
Medium textured	Loamy	45	40	15
	Silt loam	20	60	20
Fine textured	Silty clay loam	15	55	30
	Clay loam	28	37	35
	Clay	25	30	45

Textural management of soil:

1. Coarse textured soil / Sandy soils:

a. These are loose, friable, posses good aeration & Drainage

b. Percolation losses are more

c. Low in nutrient & Water holding capacity.

Management: Application of organic matter to improve aggregation.

2. Fine textured soil / silty / Clayey soil:

A. They are often called as hard or heavy soil.

b. These soil have high plasticity & cohesion

c. They are high in water & nutrient holding capacity

d. have poor drainage & infiltration and are subjected to water logging. They tend to big clods if ploughed when dried.

Management: a. Timely tillage operation

b. Addition of organic manure.

c. cultivation of deep rooted legumes.

Loamy soils seems to be ideal for crop production. A ideal loam may be defined as a mixture of sand, silt & clay particles which exhibits light & heavy properties in equal proportion. Loams posses the desirable characters of both sand & clay such as poracity, water & nutrient holding capacity, cohesion & plasticity etc.

II. Structure: The arrangement of soil particles are called soil structure. It influences aeration, permeability etc. There are 4 types of primary structures.

a. **Platy:** Horizontal arrangement of particles around a plane is called platy structure.
b. **Prism like:** Particles are arranged around the vertical axis and it may be of 2 types
   i) **Prismatic:** It has prism like outer surface
   ii) **Columnar**: It is like column.

c. Block like: Flat or rounded surface form block like structure. It may be

i) **Angular blocky**: They have definite angle
ii) **Sub-angular blocky**: Irregular outer surface

d. Spheroidal: are bound by curved or spherical surface and are most favourable for tillage and root penetration. It may be

i) **Granular:** like grains
ii) **Crumb like:** Porous

Factors affecting soil structure

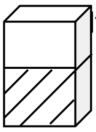
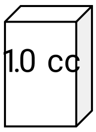
1. Soil management: Ploughing and other tillage operations may break the soil particles and alter soil structure. Use of green manures and legumes & application of irrigation water also influence soil structure.

2. Adsorbed cations: Na^+ & K^+ are dispersing elements while Ca^{2+} & Mg^{2+} flocculate the soil particles.

3. Application of organic matter: Improves soil aggregation.

III. Soil Colour: The colour of the soil is mostly due to the presence of Fe & Mn compounds and organic matter in the soil. Organic matter makes the soil dark brown or grey. Oxides of Fe & Mn impart red, brownish red or yellow colour depending on the oxidation status and extent of hydration. Soil colour has a direct influence on soil temperature. Darker soil absorbs more heat and warm up quickly. Darker soils are fertile and give better yield. Soil colour is measured by Munsell Chart.

IV. Density: The weight of a substance per unit volume is called density. The soil density is expressed in 2 ways

Sl No	Particle density (PD)	Bulk density (BD)
1	It is defined as weight of unit volume of soil solids excluding pore space $$\text{Particle density} = \frac{\text{Weight of soil}}{\text{Volume of solid}}$$	Weight of unit volume of dry soil which includes both solid and pore space $$\text{Bulk density} = \frac{\text{Weight of soil}}{\text{Volume of soil (Solid + Pores)}}$$
2	It is not affected by pore space	Largely affected by pore space
3	The value normally vary between 2.50 to 2.75 Mg m^{-3} or g cc^{-1}	The value normally vary between 1.40 to 1.80 Mg m^{-3} or g cc^{-1}
4	It is calculated by compressing all solids to bottom  If the soil of 1 cc weighs **1.33 g** 0.5 cc Pore space 1.33/0.5 0.5 cc Solid = **2.66 g cc^{-1}**	It is calculated by taking the total volume  1.0 cc $BD = \frac{1.33}{1.0}$ = 1.33 g cc^{-1}

V. Pore space: the pore space of a soil is that portion that occupied by air & water. If the soil particles are tend to be close as in sand, the total porosity is low. If they are arranged in porus aggregates as in medium & fine textured soil, pore space per unit volume is high. The pore space is calculated by

$$\frac{BD}{PD} = \frac{\text{Weight of soil / Volume of soil}}{\text{Weight of soil / Volume of solid}} = \frac{\text{Volume of solid}}{\text{Volume of soil}} = \text{Solid space}$$

$$\%\ \text{Solid space} = \frac{BD}{PD} \times 100$$

% Pore space + % Solid space = 100

% Pore space = 100 - % Solid space

% Pore space = 100 - [BD/PD X 100]

% Pore space = 100 (1 – BD/PD)

Problem 1. A sandy soil of 10 cc weighs 15 g and reduced to 6 cc after compression. Calculate BD, PD and % Pore space?

BD = 1.5 g/cc PD = 2.5 g/cc % PS = 40%

Problem 2. A silty loam soil having BD=1.3 g/cc & PD=2.6 g/cc. Calculate the % pore space

% PS = 50%

Sand particles have 35-50% pore space and clay particles have 40-60% pore space. Based on the size, the pores are grouped as

a. Macro pores: >200 μm – Space for air
b. Micro pores: < 200 μm – Space for water

Macro pores allow ready movement of air & water while micro pores impede the movement.

Sandy soils are largely composed of macro pores while, clay soils have more micro pores. Hence water holding capacity of clay soils is higher.

Soil type	% Pore space	Pores count
Sandy soil	20-30	25000 m^{-3}
Loamy soil	30-50	
Clay soil	50-60	25 million

VI. Plasticity & Cohesion: Plasticity is the soil property, which enables a moist soil to change shape upon applied force and retain this shape even when the force is withdrawn. Sandy soils are non-plastic and clayey soil are plastic. Adhesion is the binding property of different particles (soil with others – Water, nutrient). Cohesion is the binding property of similar molecules.

Plasticity, adhesion & cohesion together reflect soil consistency and workability. Black soils are highly plastic and adhesive making tillage operation difficult.

B. Chemical Properties: Soil reaction & Cation exchange capacity (CEC) are 2 important chemical properties affect plant growth.

I. Soil reaction / Soil pH: The soil pH indicates its acidity or alkalinity and influence nutrient availability, soil physical condition & inturn crop growth.

a. Nutrient availability: Soil pH influences rate of nutrient released through its influence on decomposition & solubility of minerals. The source of nitrogen & sulphur is organic matter which are released during its decomposition. The rate of decomposition is fastest between 6-8 pH. Phosphorous is best available between 6.5 – 7.5. Less than 6.5 precipitate P by Fe & Al and more than 8.5 through Ca & Mg. Fe, Mn, Cu, Zn, B precipitates at higher pH. Optimum pH range for availability of nutrient is

Sl. No	Nutrient	Opt. pH
1	N	6.0 –8.0
2	P	6.5- 7.5
3	K	6.0 – 7.5
4	Ca, Mg	7.0 – 8.5
5	S	6.0 – 7.5

Sl. No	Nutrient	Opt. pH
6	Fe	< 6.0
7	Mn	5.0 – 6.5
8	B, Cu, Zn	5.0 – 7.0
9	Mo	> 7.0

b. Soil physical condition: Soil physical condition like flocculation, colour etc depends on soil pH.

Higher soil pH (>8.5), increased Na content deflocculates soil colloids and destruct soil structure & movement of water & air. Under acidic condition, Fe desolved in excessive amount impart red colour to the soil.

II. CEC (Cation Exchange Capacity): CEC is the sum total of cations that a soil can adsorb. It influences the capacity of soil to hold nutrients such as Ca, Mg, NH_4 etc. The per cent bases in the total cations except H^+ present on the exchange complex is called Base saturation which denotes the availability of nutrient in the soil.

Soil fertility and Productivity:

Soil fertility is the inherent capacity of the soil to supply nutrients in adequate amounts and in suitable proportion. Soil productivity is the capacity of the soil to produce crops with specific management and expressed in terms of crop yield.

All productive soils are fertile, but all fertile soils need not to be productive. It may be due to some problems like water logging, saline or alkaline condition, weeds, pest and diseases etc. under these conditions, the crop growth is restricted even though the soil has sufficient amount of nutrient.

Soil fertility	Soil productivity
It is an index of nutrient availability	It is broader term to indicate crop yield.
It is one of the factors of crop production. However crop production also depends on water, slope, depth of water table etc	It is the interaction of all the factors that determine crop yield
It can be analyzed in the laboratory	It is assessed under field condition
It is expressed as nutrients in kg ha^{-1}	It is expressed in terms of crop yield

Factors affecting soil fertility: The factors governing soil fertility may be

i. Natural or soil farming factors: include Climate, Organism, topography, relief, parent material and time or age (cl, o, r, p, t).

ii. Artificial & Soil management factors: Addition of organic and inorganic fertilizers, crop rotation and other soil management practices.

Soil fertility evaluation:

Several techniques are used to assess soil fertility status. Important ones are

a. **Visual Nutrient deficiency symptoms:** Looking to the characteristic symptoms on plants.

b. **Plant analysis or tissue test:** Analyze the nutrient content and match it with critical limit. It is also called crop logging, developed by Clements in Sugarcane.

c. **Biological test:** Culturing micro-organisms or growing plants on sample soil

d. **Chemical method or soil test:** Actual soil analysis for different nutrient.

PROBLEMATIC SOILS

Soil productivity is deteriorated with soil problems. The major soil problems are

a. Soil acidity b. Soil alkalinityc. Water logging

1. Soil acidity: It is caused due to the exchangeable Hydrogen ions. If the soil pH comes down below 6.5 it is said to be acidic.

Soil acidity may be a. Low acidity : pH 6.5 to 6.1

b. Moderate acidity : pH 6.0 to 5.6 c. Strongly acidic

: $pH < 5.5$

Causes for soil acidity

a. Leaching of bases like Ca, Mg under high rainfall areas reduces soil pH.
b. Continous application of acid forming fertilizer like MOP (Muriate of Potash – KCl)
$KCl + H_2O \longrightarrow KOH + HCl$
c. Decomposition of organic matter liberates several acids
d. Removal or uptake of bases by the crops
e. Parent material – some soils might be natively acidic because of associated minerals Eg. Granite.

Management of acidic soils

a. Addition of lime and lime material like oxides, hydroxides & carbonates of Ca & Mg

$CaCO_3 + H_2O \quad Ca^{2+} + HCO^{3-} + OH^-$

$CaO + H_2O \Longrightarrow Ca^{2+} + HCO^{3-} + OH^-$

b. Use of basic fertilizers like sodium nitrate, basic slag
c. Cultivation of acid tolerant crops like sweet potato, castor, rice, barley
d. Soil and water management to reduce leaching of bases.

2. Soil Alkalinity: Soils with pH more than 7.5.

Causes for alkalinity 1. High base saturation other than H^+ especially Na, carbonates of Ca & Mg.

$CaCO_3 + H_2O \longrightarrow Ca^{2+} + HCO^{3-} + OH^-$

2. Presence of excess salts.

Alkaline soils grouped into 2 types based on EC (Electrical conductivity), ESP (Exchangeable Sodium Percentage) & pH values as below.

Class	EC (ds m^{-1})	ESP (%)	pH
1. Saline	> 4	< 15	< 8.5
2. Saline – alkaline / saline sodic	> 4	> 15	> 8.5
3. Alkaline / sodic	< 4	> 15	> 8.5

EC is the reciprocal of electrical resistance of soil extract having 1 cm length and 1 cm^2 cross sectional area. ESP is the degree of saturation of soil exchange complex with sodium.

Reclamation / management of alkaline soils

Saline soils 1. Leaching of excessive salts with rain / irrigation

2. Scraping and removal of accumulated salts in the surface layer.
3. Drainage
4. Use of acidic fertilizers (KCl – MOP)
5. Application of organic manures
6. Sowing of seeds in the furrows.

Alkaline soils 1. Application of gypsum ($CaSO_4 . 2H_2O$)

2. Addition of Sulphur containing amendments like iron pyrites - FeS_2,

3. Water logged / Marshy lands: In waterlogged areas, stagnation of water occurs for most part of the year. In coastal regions waterlogging may be caused due to intrusion of sea water specially in east coast. Waterlogging results in anaerobic conditions beside salt accumulation.

Management options are drainage and cultivation of hydrophytes like rice, trees and grasses.

Major soils of India

1) **Alluvial Soils** : These soils are derived from the deposition laid by the numerous tributaries of the Indus, the Ganges and the Brahmaputra systems. This is the largest and most important soil group of India. Alluvial soils are fertile and suitable for most of the agricultural crops like lowland rice, pulses, cotton, banana etc.,

2) **Black Soils:** are dark – grey in colour which is due to the presence of clay – humus complex. Characterized with high swelling and shrinkage, plasticity and stickiness, poor drainage and low permeability.

3) **Red Soils:** The red colour of soils is due to the coating of ferric oxides on soil particles. Red soils are Light textured, friable, Well drained with moderate permeability, Excess gravelliness, surface crusting, susceptibility to erosion.

4) **Lateritic Soils:** they are light in texture and found in high rainfall areas of Karnataka, Maharashtra, Kerala and Madhya Pradesh.

5) **Desert soils:** developed in arid regions and are sandy in nature. Found in Rajasthan and South Punjab.

6) **Tarai Soils:** have a wet regime. It is the foot hills soil derived from the materials washed down by the erosion of mountains and found in Jammu & Kashmir, UP, Uttanchal etc.

7) **Saline & alkaline soils:** are formed because of poor drainage in arid & semi-arid regions.

8) **Acid soils:** formed by leaching of bases in high rainfall areas.

9) **Peaty / marshy soils:** formed in depressions under submerged condition. They have light colour because of Ferrous ions and found in Kerala, Parts of Bihar and UP

TILLAGE

Tillage refers to the mechanical manipulations of the soil that are used to provide necessary soil conditions favourable for the growth of crops.

Tillage includes all operations and practices that are used for the purpose of modifying soil physical characters. Tillage is the most difficult and time consuming operation in crop production. About 30 per cent of the total cost of cultivation goes for tillage operations.

Tillage is as old as agriculture. Primitive man used to disturb soil for placing seeds. Jethrotull, who is considered as "**Father of Tillage**" proposed a theory that plant absorb minute soil particles and suggested thorough ploughing and other operations to make the soil into finer particles. Though this theory is not correct, tillage operations are carried out to prepare a fine seed bed for sowing of crops.

Objectives of tillage

1. To prepare seed bed to a satisfactory level which promotes good germination and establishment of seedlings.
2. To control weeds and improve close plant – soil interaction in the rooting zone.
3. To manage the plant residues for incorporating into the soil or to retain on the top layer to reduce erosion.
4. To improve soil physical condition for rain water harvesting and minimizing soil erosion.
5. To establish specific surface configurations for sowing, irrigation, drainage etc.
6. To incorporate and mix the applied fertilizers into the soil.
7. To expose weeds and soil borne pathogens to heat and killing them.

Tilth : Tilth is the term used to express the physical condition of soil resulting from tillage. The physical condition is related to the soil structural changes which promote good seed germination and crop establishment. Tillage operations are aimed at producing and maintaining good tilth. A soil with good tilth will be mellow, friable and adequately aerated. Such soils have high retentive capacity of rain water and good aeration with adequate infiltration. The soil tilth is not static and varies with time.

Influence of tillage on soil physical properties

Tillage has considerable influence on soil physical properties like pore space, structure, bulk density, soil water, soil colour and temperature. Hence, tillage influence germination, seedling emergence and crop stand establishment.

i) Pore space : Soil are made up of particles of different sizes. Air and water filled spaces between these particles constitute pore space. When a field is ploughed, the soil particles are loosely staked in a random manner and pore space increases.

Under good tilth condition, capillary and non-capillary pores are in equal proportion and facilitates free moment of air and water and increases infiltration.

ii) Soil structure : Soils with crumbly or granular structure are good for crop production. When soil is subjected to tillage at optimum moisture leads to crumb like structure which reduce the erosion greatly. Soil structure will destroy when tillage is carried at inappropriate soil moisture.

iii) Bulk density : When the soil is loosened with tillage, the soil volume increases without any effect on weight. Therefore, the BD of tilled soil is less than untilled soil.

iv) Soil colour : Tillage increases the oxidation of iron and manganese, decomposition of organic matter resulting in fading of colour.

v) Soil water : The available soil water depends on soil porosity, soil depth and random roughness. Roughness is the measure of micro-elevations and depressions caused bu ridges and furrows. All these characters are influenced by tillage. It also influences infiltration and water holding capacity.

vi) Soil temperature : Tillage loosens the soil surface resulting in decrease of thermal conductivity and increase heat exchange.

Types of Tillage : Tillage based on the timing of operation, is broadly divided into

a) *Preparatory cultivation* : Operations carried before sowing

b) *After cultivation / inter tillage* : Operations carried after sowing

Preparatory cultivation : Tillage operations that are carried from the time of harvest of a crop to the sowing of the next crop or the operations carried in any cultivable land to prepare seed bed for sowing / planting of crops are known as preparatory cultivation. Preparatory cultivation consists of

a) Primary tillage b) Secondary tillage c) Layout of seed bed

Primary tillage / Ploughing : Ploughing is the opening of the compacted soil with the help of different ploughs. Ploughing is done to cut open and invert the soil, uproot the weeds and stubbles.

The optimum time for ploughing is decided on soil moisture status. If the soil is ploughed when dry, (a) there will be formation of big clods (b) demands enormous energy and (c) it is difficult to operate. Too wet condition also unfavourable for ploughing as (a) the soil sticks to plough, (b) there will be formation of hard pan in sub soil layer (c) the clods formed will be very hard after drying. Optimum range of soil moisture for effective ploughing is 25-50% depletion of available soil moisture. Light soils can be ploughed in a wide range of soil moisture condition while, heavy soil have narrow range.

Depth of ploughing mainly depends on effective root zone. Tap rooted crops have deep roots and require deep ploughing while shallow fibrous roots demand shallow to medium ploughing.

The number of ploughings necessary to obtain good tilth depends on soil type, weed problem and crop residue on the soil. In heavy soils, 3-5 ploughings are necessary while, 1-3 ploughings are sufficient in light soils. When weeds and plant residues are higher, repeated (more) ploughings are necessary.

Selection of ploughs depends on the purpose, soil condition and nature of weed problems.

Types of primary tillage

i) Deep Ploughing: One cm of surface soil over one hectare of land weighs about 150 MT. Therefore, deep ploughing demands enormous energy. Cenral Research Institute for Dryland Agriculture (CRIDA), Hyderabad classified ploughing as

1. Shallow ploughing – 5 to 6 cm depth
2. Medium ploughing – 15 to 20 cm depth
3. Deep ploughing – 25 to 30 cm depth

Summer deep ploughing expose weeds and other soil borne pathogens to heat and turns out into large sized clods. The clods crumble due to alternate heating and cooling and due to occasional summer rains which will disintegrate clods gradually. Deep tillage improves soil moisture content due to enhanced wetting zone.

A deep tillage of 25 – 30 cm is necessary for deep rooted crops like pigeon pea (*Cajanus cajana*), while moderate tillage of 15-20 cm is required for maize (*Zea mays*), wheat *(Triticum aestivum*).

ii) Sub soiling : Sub soiling is the breaking of hard pans without inversion and with less disturbance to surface soil. Hard pans in the soils may be formed because of silt load, Fe & Al blocking, clay particles or man made will restrict the root growth of crops. Men made pans are induced because of repeated tillage at same depth or ploughing under excess soil moisture condition.

iii) Year round tillage : Tillage operations carried throughout the year are known as year round tillage. In dryland areas, field preparation is initiated with summer shower and repeated till sowing and even after harvest of crop, the field is repeatedly ploughed to avoid weeds and soil erosion.

B. SECONDARY TILLAGE

Lighter or finer operations performed on the soil with harrows and cultivators after primary tillage are known as secondary tillage. They are carried to

a) Break clods and create smooth surface for seed germination and establishment
b) Uprooting of weeds and stubbles of previous crop
c) Mixing of applied manures and fertilizers in to the soil
d) Covering of seeds

Generally, sowing operations are included in secondary tillage.

C. LAYOUT OF SEED BED

Certain crops like wheat (*Triticum aestivum)*, Soybean (*Glycine max)*, Castor (*Ricinus communis*) can be sown directly after secondary tillage, certain crops like Maize (*Zea mays*), Sugar cane (*Saccharum Sp*), vegetables need ridges and furrows, certain crops can be sown with seed drills while, seeds of certain crops needs covering with harrows / plank / roller for necessary germination. It is essential to prepare ideal seed bed suiting to the particular crop for proper germination and establishment.

An ideal seed bed should provide the essential conditions for good germination and favourable environment for emerging seedlings. Such conditions include aeration, moisture and allow easy penetration of roots. Its should also free for weeds and soil borne pathogens.

A firm seed bed may be required to ensure close contact between seed and soil where as, a loose seed bed may be desirable for good aeration. Smaller the seed greater will be its sensitivity (eg. Tobacco – *Nicotiana tobaccum*) to seed bed condition which demand fine seed bed. Crops with bold seeds are not demanding fine seed bed (eg. Castor - *Ricinus communis*).

II. After cultivation

The tillage operations that are carried out in standing crop are called after tillage. It includes

a) Top dressing : Drilling / dressing of fertilizer in standing crop and covering
b) Earthing up : Carried with ridge plough or wooden plough to form ridges at the base of the crop rows to provide anchorage / support and irrigation.
c) Inter-cultivation : Working with harrows, hoes, cultivators in between crop rows to control

weeds, aeration and to conserve moisture.

Implements used for different operations

i) Primary tillage : Wooden plough, sub soil plough, chisel plough, ridge plough, MB plough etc

ii) Secondary tillage : Cultivators, harrows, plank, roller

iii) Layout of seed bed : Country plough, seed drill

iv) Inter-cultivation : Wooden plough, blade harrows, ridger, spade, hand hoes etc.

Concepts of tillage

i) Minimum tillage : Minimum tillage is aimed at reducing tillage operations to the minimum necessary for ensuring a good seed bed, rapid germination, a satisfactory stand and favourable growing conditions. Tillage can be reduced by two ways.

a) Omitting operations which don't give much benefit when compared to cost

b) Combining operations like seeding and fertilizer application

Advantages

1. Improves soil conditions through reduced movement of heavy tillage implements, vehicles i.e., less soil compaction
2. saves time and energy – 50-58% of reduction in fuel consumption

Disadvantages

1. Poor germination of seeds and affect plant stand establishment
2. Needs higher nitrogen attributing to slower decomposition of organic matter
3. affect nodulation in legumes
4. Weeds are major problem & continuous use of herbicide cause pollution hazards

ii) Zero tillage : is an extreme form of minimum tillage where in, primary tillage is totally avoided and secondary tillage is restricted to seed bed preparation in the row zone only. It is also known as '**No Tillage**'.

Zero tillage is resorted where,

a) Soils subjected to erosion by wind and water.

b) Timing for tillage operation is too short or difficult

c) Requirement of energy and labour is too high

The organic matter content of soil increases under zero tillage due to slow mineralization. Zero tillage is practiced in Rice-wheat system in India.

In zero tillage, herbicide play a dominant role in weed management. Before sowing, the vegetations are destroyed with broad spectrum, non-selective herbicides with relatively short residual effect (paraquot, glyphosate etc), selective and moderately persistent herbicides (Atrazine, 2,4-D etc) are required during subsequent stages.

iii) Stubble mulch tillage : is a new approach developed for keeping soil protected at all times either by growing a crop or by crop residues left on the surface during fallow period.

iv) Off season tillage : Preparatory tillage operations that are carried out during the off season before the main crop is cultivated is known as off season tillage. This includes post-harvest tillage and summer ploughing.

MANURES AND FERTILIZERS

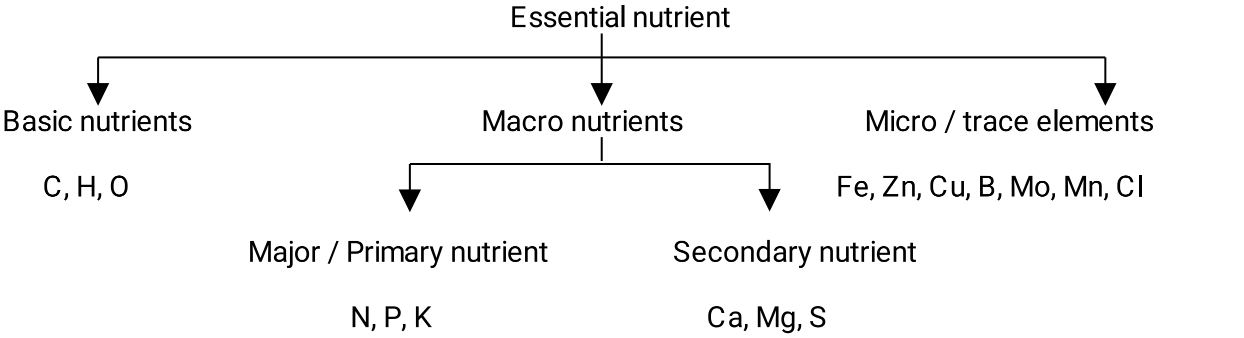
Plant require certain element for their growth and development. There are about 60 chemical elements present in the plant and it doesn't mean that all are essential for normal growth and development.

Arnon and Stout (1939) proposed criterion of essentiality. Which were refined by Arnon (1954) and are popularly known as **Arnon's criteria of essentiality?** They are

1. The deficiency of elements makes it impossible for the plant to complete the vegetative or reproductive stage of its life.
2. The deficiency of elements in question can be corrected only by supplying that particular element
3. The element is directly involved in nutrition and metabolism of the plant quite apart from its possible effect in correcting some micro-biological or chemical conditions in the soil.

Based on the above criterion, 16 elements are considered essential for plant growth and development. They are classified as

I. Based on quantity of nutrient present in plants, they are grouped into



Basic nutrients : contribute 96% of the total dry matter of plants and are taken in the form of water and air (CO_2)

Macro nutrients : are required in large quantity (> 1 ppm) and are further divided into

a) **Major / Primary nutrients** : are required in bulk and applied externally Eg. N, P, K.

b) **Secondary nutrients** : They are called secondary because they applied inadvertently to the soil while applying N, P, K fertilizers Eg. Ca, Mg, S.

Micro nutrients : Theya re also called trace elements and are required in minute quantity (<1 ppm). Even a slight deficiency or marginal excess concentration of these elements are harmful to the plant.

II. Based on their function in plants

i) Elements that provide basic structure to the plant : C, H, O

ii) Elements useful in energy storage, transfer, bonding : N, P, S

iii) Elements necessary for charge balance / translocation : K, Ca, Mg

iv) Elements involved in enzyme activation & electron transfer : Fe, Mn, Zn, Cu, B, Mo, Cl

III. Based on mobility

A) **Mobility in the soil :** Knowledge of mobility in soil helps to derive the method of application of these nutrients. Based on mobility, the nutrients are classified as

i) **Mobile :** These are highly soluble and are not adsorbed on clay complex

Ex : NO_3^-, SO_4^{2-}, BO_3^{2-}, Cl^-, Mn^{2+}

ii) **Less mobile :** They are also soluble but are adsorbed on clay complex

Ex : NH_4^+, K^+, Ca^{2+}, Mg^{2+}, Cu^{2+}

iii) **Immobile :** They are highly reactive and get fixed in the soil. The plant roots as to go in search of these nutrients for absorption

Ex : $H_2PO_4^-$, HPO_4^{2-}, Zn^{2+}

B) **Mobility in Plants :** Knowledge of mobility in plant helps to find out the deficient nutrient. A mobile element in plant moves to growing point and express the deficiency in lower leaves and immobile elements shows deficiency in top leaves. Based on these nutrients are grouped as

i) **Highly mobile :** N, P, K, Mg

ii) **Moderately mobile :** Zn

iii) **Less mobile :** S, Fe, Mn, Cu,Mo, Cl

iv) **Immobile :** Ca, B

Forms of nutrient uptake

Nutrient element	Form of uptake	Nutrient element	Form of uptake
Carbon	CO_2	Iron	Fe^{2+}, Fe^{3+}
Hydrogen	H_2O	Manganese	Mn^{2+}
Oxygen	CO_2, H_2O	Zinc	Zn^{2+}
Nitrogen	NH_4^+, NO_3^-	Copper	Cu^{2+}
Phosphorus	$H_2PO_4^-$, HPO_4^{2-}	Boron	$B_4O_7^{2-}$, $H_2BO_3^-$ & HBO_3^{2-}
Potassium	K^+		
Calcium	Ca^{2+}	Molybdenum	MoO_4^{2-}
Magnesium	Mg^{2+}	Chlorine	Cl^-
Sulphur	SO_4^{2-}		

Factors influencing nutrient availability: Important factors influencing nutrient availability in the soil are

a) Native soil fertility or nutrient content of soil
b) Soil reaction (pH)
c) Relative activity of micro-organisms which play vital role in nutrient release through mineralization
d) External addition of manures and fertilizers
e) Edaphic / soil factors viz., soil temperature, moisture, aeration etc.

Mechanism of nutrient movement in soil

Nutrients adsorbed by the plant through roots along with the water. Nutrients move to the roots through 3 ways.

1) **Mass flow** : Plant nutrients move along with the movement of water (Soil solution). This is the major type accounts to 80 per cent of total.

2) **Diffusion:** This is the normal dispersion of nutrients from the region of their higher concentration to lower. When roots absorb nutrients beneath that develop region of lower concentration and nutrient movement occur.

3) **Root interception** is the extension of plant roots into new soil areas where they are untrapped.

Manures and fertilizers

Plant nutrients are lost from the soil in different ways viz., removal by the crop, weeds, lost through leaching, erosion, volatilization and denitrification. The importance of manures and fertilizers for increasing agricultural production to meet the challenges for food, fiber, forage, fuel are increasing because of progressive expansion in the nutrient deficiencies in India

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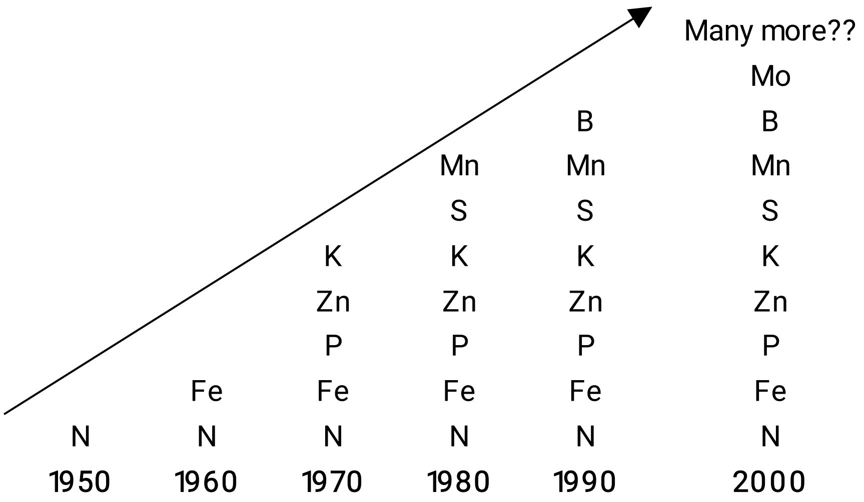


Fig : Diagrammatic representation of occurrence of soil nutrient deficiency in India

When crop requirements are higher than soil supplying power, nutrients are applied as manures and fertilizers.

MANURES: manures are plant and animal wastes that are used as sources of plant nutrients. They release nutrients after their decomposition. Manures are grouped into **Bulky** and **Concentrated organic manures** based on the nutrient content.

Bulky organic manures : These contain small percentage of nutrients and are applied in large quantities. Hence they are called bulky. Farm yard manure (FYM), Compost and green manures are most widely used bulky organic manures. Use of these manures have several advantages like

i) Supply plant nutrients including micro-nutrients

ii) Improve soil physical properties like structure, WHC etc.

iii) Serves as source of food for soil organisms (Micro organisms)

iv) Reclaim problematic soils.

1. FARM YARD MANURE (FYM) : FYM refers to the decomposed mixture of dung and urine of farm animals along with litter and left over material from roughages or fodder fed to the cattle. On an average, well decomposed FYM contain 0.5% N, 0.2% P_2O_5 and 0.5% K_2O.

Factors influencing composition of FYM :

The quality and general characteristics of FYM are influenced by

i) Source of manure: The composition of manure varies with the kind of animal producing it. Sheep, goat, and poultry manures are rich in N, P_2O_5 and K_2O than Cow, horse and pig.

Table : NPK content of fresh excreta of farm animals.

Animal	Dung	Urine
	N : P_2O_5 : K_2O	N : P_2O_5 : K_2O
1. Cows & Bullocks	0.4 : 0.2 : 0.10	1.0 : 0.01 : 1.35
2. Sheep & Goat	0.75 : 0.5 : 0.45	1.35 : 0.5 : 2.1
3. Horse	0.55 : 0.3 : 0.4	1.35 : Trace : 1.25
4. Pigs	0.55 : 0.5 :0.4	0.4 :0.1 : 0.45

ii) Food of the animal : This is one of the most important character determining the quality of manure. If the food source is rich (Pulse), then the nutrient in the excreta will also be rich. On an average, 70-90% N & P and 90-99% K and 50% Organic matter in the food consumed will appear in dung or urine.

iii) Age and Condition of animal: Young and healthy animals retain large percentage of nutrients for their growth than that of mature and sick animals. Hence, dung and urine of young & healthy animal has lower nutrient than mature & sick.

iv) Function of the animal: Animals producing milk and wool absorb more nutrients than the animals which are in rest.

v) Manner of storage: Bad storage leads to loss of nutrients through volatilization & leaching.

vi) Nature of litter: Composition of FYM varies with litter or bedding material.

The daily collection of dung and urine are placed in pit / trenches or heaped and allowed for decomposition. The loss in nutrients occurs both at handling and storage.

A) Handling losses: Handling loss may be loss of liquid (Urine) OF SOLID (Dung)

i) Loss of liquid portion or urine : Failure to recover or retain the urine of farm animals results in serious loss. It may be due to uncemented floor of cattle shed. Large quantity of N lost through volatilization as below

ii) Loss of solid portion or dung : Loss of dung is because of its use as fuel and no effort to collect when animal goes out for grazing.

B) Storage losses : Normally farmers heap their daily collection at one place either in trench or above ground surface for months together. During this period, the manure remains exposed to the sun & rains and nutrients are subjected for the following losses.

i) Leaching : About half of N & P and 90% of K present in FYM are water soluble. When the manure is exposed to leaching action of rain water, the nutrients are liable to get washed off.

ii) Volatilization : During storage, ammonia produced by decomposition of urea and other nitrogenous compounds of urine may be evaporated.

Partially rotten FYM has to be applied three to four weeks before sowing while, well rotten manure can be applied immediately before sowing. The existing practice of leaving manure in small heaps scattered in the field for long period leads to loss of nutrients. These losses can be reduced by spreading the manure and incorporating by ploughing immediately after application.

The entire quantity of nutrient present in FYM is not available immediately. About, 30% N, 60-70% P_2O_5, and 70% K_2O are available for the first crop. In general, about 40% of total nutrients are available for first crop, 30% for second, 20% for third crop and 10% for succeeding crops.

Chemical preservatives are added to the FYM to decrease N losses. The commonly used preservatives are a) Gypsum and b) Super phosphate.

Super phosphate has been extensively used as a manure preservative. Since ordinary super phosphate contains 50 – 60% gypsum besides mono calcium phosphate, the action of super phosphate is similar to that of gypsum.

$$2\,CaSO_4 + (CaH_2PO_4)_2 + 2\,(NH_4)_2CO_3 \rightarrow Ca_3(PO_4)_2 + 2\,(NH_4)_2SO_4 + 2\,H_2O + 2\,CO_2$$

Gypsum	Monocalcium Phosphate	Ammonium Carbonate	Tri calcium Phosphate	Ammonium Sulphate

In this reaction, tri calcium phosphate is formed which don't react with ammonium sulphate. Hence, there is no loss of ammonia.

COMPOST: Compost is a mass of well rotten organic matter of any wastes. Composting is a biological process in which aerobic and anaerobic micro-organisms decompose the organic matter and reduce C : N ratio of the refuse.

The compost made from farm wastes like sugarcane trash, paddy straw, weeds, other plants and wastes is called farm compost. On an average, it contain 0.5 : 0.15 : 0.5 % NPK.

The compost made from town refuses like night soil, street sweepings and dustbin refuses is called town compost. On an average it contain 1.4 : 1.0 1.4 % N, P_2O_5, K_2O.

NIGHT SOIL: Night soil is the human excreta, both solid and liquid. It is rich in NPK than FYM & Compost. On an average night soil contain 5.5 : 4.0 : 2.0 % N, P_2O_5, K_2O.

SEWAGE AND SLUDGE: In the modern system of sanitation adopted in cities and towns, human excreta are flushed out with water which is called as sewage. The solid portion of sewage is called sludge and liquid portion is sewage water.

VERMI COMPOST: Compost that is prepared with the help of earth worms is called vermicompost. Earth worm consume large quantities of organic matter and excrete soil as cast. The cast of earth worms have several enzymes and are rich in plant nutrients, beneficial bacteria and mycorrhizae. On an average, it contains 3% N, 1% P_2O_5 and 1.5% K_2O. the process of preparing compost using earth worms is called as vermi-composting.

SHEEP & GOAT MANURE: manure prepared with the droppings of sheep and goats, which contain higher nutrients than FYM & Compost. On an average, it contains 3% N, 1% P_2O_5 and 2% K_2O. Sheep and goat manure is applied in two ways like

a) Composting b) Sheep penning – They left in the field overnight and the dropping (Fecal matter & Urine) are incorporated with harrows / cultivators.

POULTRY MANURE: The excreta of birds ferments very quickly. If it is left exposed for 30 days, 50% N will be lost. On an average, it contain 3% N, 2.63% P_2O_5 and 1.4% K_2O

GREEN MANURES: The practice of incorporating or turning into the soil undecomposed green plant materials for the purpose of improving physical condition as well as fertility.

CROP RESIDUES : Residues left after the harvest of the economic portions are called crop residues / straw. These crop residues can be recycled by the way of incorporation, composting or mulch material.

AGRO-INUSTRIAL WASTES : Wastes of agro based industries viz., sugar, rice mill etc also serve as manures.

a) Rice husk : It is the major byproduct of rice mill. Unhulled paddy contains 20-25% husk. It may be used as bedding material in cattle shed or incorporated into wet soil. It contain 0.3-0.4 : 0.2-0.3 : 0.3-0.5 % NPK.

b) Bogasse: Byproduct obtained during the process of sugar manufacturing. It contain 0.25% N, 0.12 % P_2O_5.

c) Pressmud: Byproduct obtained during the process of sugar manufacturing. It contain 1.25% N, 2% P_2O_5 and 20-25% organic matter.

Others like tea waste, coffee pulp, coir waste etc have manorial value.

CONCENTRATED ORGANIC MANURE :

They have higher nutrient content than bulky organic manures. The important concentrated organic manures are oil cakes, blood meal, fish meal, meat meal, fish manure etc. Oil cakes are dried solid portion remaining after extraction of oils. These are of 2 types.

a) Edible oil cakes: Which can be safely fed to the livestocks? Ex. Groundnut, coconut cake

b) Non-edible oil cakes: Which are not fit for feeding livestock Ex : Castor, Neem. Hippe etc

Oilcakes has to be well powdered before application for even distribution and quicker decomposition. The average nutrient content of different oil cakes are

Oil cake	Nutrient content (%)		
	N	P	K
Non edible			
1. Castor cake	4.3	1.8	1.3
2. Pongamia cake	3.9	0.9	1.2
3. Mahua / Hippe cake	2.5	0.8	1.2
Edible oil cakes			
4. Coconut cake	3.0	1.9	1.8
5. Groundnut cake	1.3	1.5	1.3
6. Linseed cake	4.9	1.4	1.3
7. Sesamum cake	6.2	2.0	1.2

The blood of slaughtered animal and meat is dried and powdered to use as manure which contain

Organic manure	Nutrient content (%)		
	N	P	K
1. Blood meal	10 - 12	1 – 2	1.0
2. Meat meal	10.5	2.5	0.5
3. Fish meal	4 – 10	3 - 9	0.3 – 1.5
4. Horn & Hoof meal	13	-	-

Bio-fertilizers:

The term "Bio-fertilizer" includes selective micro-organisms like bacteria, fungi and algae which are capable of fixing atmospheric nitrogen or convert insoluble phosphorus in the soil to available forms.

Bio-fertilizers are cost effective, eco-friendly and renewable sources of plant nutrients to supplement chemical fertilizers.

Based on the type of micro-organisms, bio-fertilizers are classified as

i) Bacterial fertilizers : Ex. Rhizobium, Azospirullum, Azatobacter, Phospho bacteria.

ii) Fungal bio-fertilizers : Ex. Mycorrhizae

iii) Algal bio-fertilizers : Ex. Blue Green Algae (BGA), Azolla

iv) Actinomycetes Ex. Frankia

Based on the association, bio-fertilizers are grouped as

i) Free living : Ex. BGS

ii) Symbiotic : Ex. Rhizobium

Bio-fertilizers are mostly multiplied in the laboratory. However, BGA, Azolla can be mass multiplied in the field. Bio-fertilizers are used either as seed treatment or seedling root dip or soil application.

FERTILIZERS

Fertilizers are inorganic / synthetic substances containing one or more plant nutrients in easily soluble and quickly available form. Because of their availability in concentrated form, they have the advantage of being small quantity for storage, handling. In addition, crop may be supplied with exact quantity in the time required for their growth.

Fertilizers are classified into

a) **Straight fertilizers** : are those which supply only one primary plant nutrient
   Ex. Urea (46% N), SSP (16% P_2O_5) and MOP (60% K_2O)
b) **Complex fertilizers** : Contain two or more primary nutrients in chemical combination.

   Ex. Di Ammonium Phosphate (DAP – 18% N & 46% P_2O_5), 17-17-17, 15-15-15 etc.
c) **Mixed fertilizers** : are physical mixtures of straight fertilizers with definite proportion.

Based on the concentration of nutrients, fertilizers are classified as

a) **Low analysis fertilizers** : Containing less than 25% of primary plant nutrients.

   Ex. SSP (16% P_2O_5), Sodium nitrate (16% N)
b) **High analysis fertilizers** : Containing more than 25% primary plant nutrient

   Ex. Urea (46% N), DAP (18% N & 46% P_2O_5), Anhydrous ammonia (82% N)

Based on the physical form, fertilizers are grouped as

a) **Solid form** : They may be powder (SSP), Crystal (Amm. Sulphate) or Prills (Urea super granules)
b) **Liquid form** : Prepared for applying with irrigation water, herbicides / pesticides etc. They may be (i) Clear liquid fertilizer i.e., Completely dissolved

   (ii) Suspension liquid fertilizers i.e., Suspended as fine particles

Acidity and Basicity of fertilizers

Application of fertilizers increases acidity or basicity of soils depending on the nature of fertilizers.

Fertilizers which leave an acid residue in the soil are called **acid forming fertilizers**. The amount of calcium carbonate required to neutralize the acid residue is referred as **equivalent acidity.**

Fertilizers which leave alkaline residue in the soils are called **alkaline or base forming fertilizers**. The amount of calcium sulphate required to neutralize basic or alkaline residue is referred as **equivalent basicity**

Table : Acid and base equivalent of fertilizers

Acid forming fertilizers	Acid equivalent
Ammonium Chloride	128
Ammonium Sulphate	110
Amm. Sulphate Nitrate	93
Ammonium Phosphate	86
Urea	80

Base / alkaline forming fertilizers	Base / alkaline equivalent
Sodium Nitrate	29
Calcium Nitrate	21
Calcium Cynaide	63
Di Calcium Phosphate	25

Fertilizer Grade : Fertilizer grade refers to the guaranteed minimum percentage of N, P_2O_5, K_2O contained in a fertilizer material. Ex. 28-28-0, 20-20-0, 14-35-14, 17-17-17, 14-28-14

Nitrogenous Fertilizers : The fertilizers which contain nitrogen are called as Nitrogenous fertilizers. Based on the chemical form, N Fertilizers are classified as

1. Nitrate fertilizers : These are having Nitrogen in the form of nitrate (NO_3)

Ex. Sodium Nitrate ($NaNO_3$) – 16% N, Calcium Nitrate ($Ca(NO_3)_2$) – 15.5% N

2. Ammonium Fertilizers : These are having Nitrogen in the form of Ammonia (NH_4^+)

Ex. Ammonium Sulphate [$(NH_4)_2SO_4$] – 20% N, Ammonium Chloride (NH_4Cl) - 24-26% N

Ammonium Phosphate[$NH_4H_2PO_4$) – 20% N & 20% P_2O_5,

Anhydrous Ammonia(NH_3) - 82% N, Ammonia Solution - 20-25% N

3. Nitrate & Ammonium fertilizers : They have both nitrate & ammonium

Ex. Ammonium Nitrate [NH_4NO_3] – 33-34% N

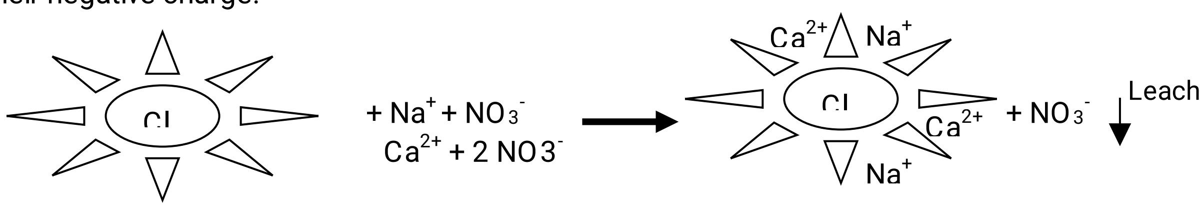
Calcium Ammonium Nitrate [$CaNH_4NO_3$) – 20% N

Ammonium Sulphate nitrate ASN - 26% N

4. Amide form Ex. Urea [$CO(NH_2)_2$] – 46% N
Calcium Cynamide $CaCN_2$ - 21% N

General characteristics of Nitrogen fertilizers

1. Nitrate fertilizers : NO_3^- form is readily soluble in water and more readily utilized by the plants. This is highly mobile form and subjected to leaching and can't be fixed to the clay colloids due to their negative charge.



Since the nitrate fertilizers are the salts of Na, K & Ca, they are alkaline / basic and can be applied to acidic soils.

2. Ammonical fertilizers :

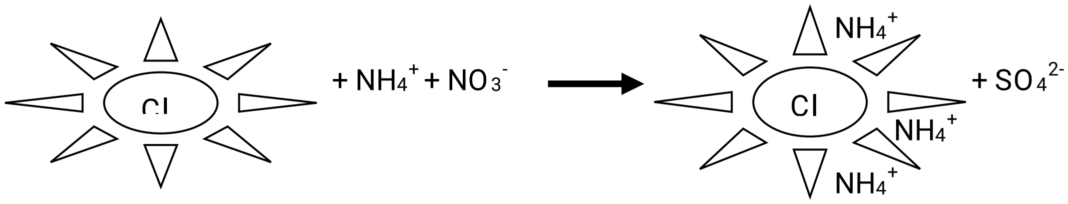
a) They are also readily soluble in water.

b) Slowly utilized by the plant as they need to convert to nitrate form

$$NH_4 \xrightarrow{\text{Nitrosomanas}} NO_2 \xrightarrow{\text{Nitrobacter}} NO_3$$

However, certain crops like rice can directly use ammonia form also.

c) They are resistant to leaching losses as they are readily absorbed on the colloidal complex



d) All Ammonical fertilizers are acidic in nature and can be adopted in alkaline soils.

3. Nitrate and Ammonical fertilizers: They have the characteristics of both Ammonical and nitrate fertilizers and are slightly acidic in nature.

4. Amide fertilizers:

a) They are Carbon compounds and are technically called as **Organic fertilizers**

b) Readily soluble in water and easily decomposed by micro-organisms in the soil

c) Less acidic than Ammonical fertilizers

$$CO(NH_2)_2 + 2\,H_2O \longrightarrow (NH_4)_2CO_3$$

$$(NH_4)_2CO_3 + 3\,O_2 \longrightarrow 2\,HNO_2 + 3H_2O + CO_2$$

$$2\,HNO_2 + O_2 \longrightarrow 2\,HNO_3$$

Slow releasing Nitrogen fertilizers

Rate of release / solubility of nitrogen fertilizer can be reduced by

a) Use of substances having low solubility : Developed by condensation products of urea with formaldehyde (35% N), Crotonylidene di urea (CDU – 30% N) and Iso butylidene di urea (IBDU – 30% N).

b) Physical barriers : N fertilizers are coated with substances that reduce their solubility. Ex. Sulphur coated urea (SCU – 36-38% N) – S barrier around

c) Modifying the size of urea Ex. Urea super granules - big size (1-3g) – slowly dissolves

d) Nitrification inhibitors : N loss from applied fertilizers takes after conversion to nitrate form by nitrification process with the activity of micro-organisms.

$$NH_4 \xrightarrow{\text{Nitrosomanas}} NO_2 \xrightarrow{\text{Nitrobacter}} NO_3$$

Several chemicals are toxic to nitrifying bacteria, when these are added to the soil, they temporarily inhibit the nitrification process. Ex. N – Serve, AM (2 – amino 4 Chloro 6 methyl pyrimidine). These are however expensive and not cost effective.

Hence, some of the indigenous materials like neem, pongamia oil can also be used.

Ex. Neem coated urea, Neem blemded urea etc.

Phosphatic fertilizers :

The phosphorous content of fertilizers are expressed in oxidized form (P_2O_5) and are converted with the following expressions.

$$\% P = \% P_2O_5 X 0.43$$

$$\% P_2O_5 = \% P X 2.29$$

When P_2O_5 soubise in water, which produce meta phosphoric and ortho phosphoric acid.

$P_2O_5 + H_2O \longrightarrow 2 HPO_3$ (Meta phosphoric acid)

$2 HPO_3 + H_2O \longrightarrow H_3PO_4$ (Ortho phosphoric acid)

H_3PO_4 is commonly called as phosphoric acid, which contain 3 replaceable H atom resulting in $H_3PO_4 \longrightarrow H_2PO_4^- \longrightarrow HPO_4^{2-} \longrightarrow PO_4^{3-}$

Plants absorb phosphorus in the form of negatively charged ions as H_2PO_4 and HPO_4^{2-} based on the soil pH.

Classification of Phosphate fertilizers:

Based on the solubility and availability to the crops, phosphates fertilizers are classified as

1. Water soluble phosphates fertilizers

$Ca - H_2PO_4$

a) These are available in the form of mono calcium or ammonium phosphate

b) They are readily absorbed by the plant as they contain P in $H_2PO_4^-$ form

c) These are readily transformed in the soil into water insoluble form. Hence, the leaching losses are very minimum.

d) They can be used for short duration crops Ex. Rice, Wheat, Ragi etc

e) As they contain P as ca & Ammonium salts, their use is restricted to neutral and alkaline soil. While in acidic soil they fix as Fe and Al Phosphates.

Ex. Single Super Phosphate (SSP - 16% P_2O_5), Double Super Phosphate (DSP – 32% P2O5),Tripple Super Phosphate (TSP – 48% P_2O_5),Mono Ammonium Phosphate (48% P_2O_5 + 11% N) Di Ammonium Phosphate (DAP – 46% P_2O_5 + 18% N)

2. Citric acid soluble Phosphatic Fertilizers

$Ca - HPO_4$

a) These contain soluble phosphoric acid or Di Calcium Phosphate

b) Suitable for acidic soil as citrate soluble form will convert to mono calcium phosphate or water soluble form and there is less chance of getting fixed as Fe & Al Phosphates. Further, they are basic in reaction.

c) These fertilizers can be used for long duration crops like sugarcane, tea, coffee etc

Ex, Basic slag (14 – 18 % P_2O_5) Di Calcium Phosphate (35 - 40 % P_2O_5)

3. Water and Citrate Insoluble Phosphatic fertilizers

a) Contain Phosphoric acid which is insoluble in water and citric acid Ca_3PO_4

b) Suitable for strongly acidic soils

c) Availability can be improved by ploughing along with green manures

Ca

d) Suitable for Coffee, Rubber, Cocao in hilly tracts as the soils are acidic

Ex. Rock Phosphate – 20-40% P_2O_5

Potassic Fertilizers

Fertilizers containing potassium are grouped into 2 groups.

1) Fertilizer having K in Chloride form Ex. Muriate of Potash (MOP) – 58 - 60% K_2O
2) Fertilizer having K in non-chloride form Ex. Sulphate of Potash (SOP)–48 - 50% K_2O
   Potassium nitrate (KNO_3) – 44% K_2O + 13% N

Potassium content in the fertilizer are always expressed as K_2O which can be converted with the following equations % K = % K_2O X 0.83

% K_2O = % K X 1.20

From the potassium nutrition point, all fertilizers are equally effective, but accompanying anions make some difference. In non-chloride form, sulphates and nitrates are also adds to the nutrition of plant but they are costly.

Potassium chloride (MOP) is suitable for most of the crops except sugarcane, sugar beet, potato and tobacco. In sugar crops, sugar accumulation is affected while in tobacco leaf, it reduces the burning quality in the presence of chloride.

Secondary nutrient fertilizers

Calcium, magnesium and sulphur are supplied to the plants incidentally along with NPK fertilizers and are not manufactured independently. Hence, they are considered as secondary. The fertilizers containing secondary nutrients are

Fertilizer	Nutrient content (%)			
	Calcium	Magnesium	Sulphur	Others
1. Calcium Nitrate	19.4	-	-	-
2. Gypsum	29.2	-	18.6	-
3. Single Super Phosphate	19.5	-	12.5	16.0 P_2O_5
4. Epsom salt ($MgSO_4$)	-	9.6	13.0	-
5. Potassium sulphate	-	-	17.5	48-50 K_2O
6. Ammonium Sulphate	-	-	24.2	21 N
7. Ammonium Sulphate Nitrate	-	-	12.1	26 N

Micro-nutrient fertilizers: These are required in minor quantity and are applied only in specific situation of their deficiency. Important micro-nutrient fertilizers are

Source	Formulae	Nutrient content
1. Zinc Sulphate	$ZnSO_4.7H_2O$	22.35 % Zn
2. Ferrous Sulphate	$FeSO_4.7H_2O$	20.00 % Fe
3. Copper Sulphate	$CuSO_4.5H_2O$	25.35 % Cu
4. Borax or Sodium Borate	$Na_2B_4O_7.10H_2O$	10.6 % B
5. Manganese Sulphate	$MnSO_4.4H_2O$	23.0 % Mn
6. Ammonium Molybdate	$(NH_4)_6Mo_7O_{24}.4H_2O$	54.0 % Mo

Fertilizer Dose : Crop nutrient are met out by soil contribution and fertilizer application. Fertilizer recommendations are made with

a) Maintenance b) Cation saturation ratio or Corrective and c) Sufficiency

Maintenance concept implies the replacement of the exhausted or absorbed nutrient by the plant from soil.

Cation saturation ration or Corrective concept refers that soil must have ideal ratio between exchangeable cation (65% Ca, 10% Mg, 5% K and 20% H).

Sufficiency level concept implies to the crop response or plant uptake excluding soil contribution.

Factors affecting fertilizer dosage: Several factors known to influence the dosage viz.,

a) **Crop & Variety:** Quantity of fertilizer demanded is basically determined by the crop and variety. Explorative crops demand higher dosage and legumes can fix atmospheric nitrogen and demand nitrogen only till nodulation. Short duration and low yielding varieties demand lower dosage than long duration and high yielding variety / hybrids.

b) **Native soil fertility and other soil properties:** If the soil are natively fertile, the external dosage can be reduced as the maintenance dosage is marginal. Soil test ratings were established for organic carbon, NPK as follows

Nutrient	Low	Medium	High
1. Organic Carbon (%)	< 0.5	0.5 – 0.75	> 0.75
2. Available Nitrogen (Kg ha^{-1})	< 280	280 – 560	> 560
3. Available P_2O_5 (Kg ha^{-1})	< 10	10 – 22.5	> 22.5
4. Available K_2O (Kg ha^{-1})	< 108	108 – 280	> 280

If the soil are medium fertile, apply recommended dosage. If they are high, apply 25% lower than recommended dose and if they are low, apply 25% extra dose.

c) Management : If the farm is managed intensively without any limits for other factors, the optimum dosage boost the yield. If there are limitations for any factor viz, light, water, temperature etc, the higher dosage is uneconomical.

Calculation of fertilizer dosage : Fertilizer recommendations are made in elemental or oxidized form of nutrient but not as such as fertilizers available. The amount of fertilizer to be applied can be calculated using the formulae

$$\text{Amount of fertilizer to be applied (Kg ha}^{-1}\text{)} = \frac{\text{Recommended dosage (Kg ha}^{-1}\text{)}}{\text{Nutrient content of fertilizer (\%)}} \times 100$$

Problem : Calculate the quantity of Urea, SSP, MOP required for paddy crop in 1 ha. area with the recommendation of 100:50:50 kg NPK/ha

Solution : Data given - Recommended dosage : 100:50:50

Fertilizers – Urea (46% N), SSP (16% P_2O_5) and MOP (60% K_2O)

Calculation of Urea :

$$\text{Amount of Urea required (Kg ha}^{-1}\text{)} = \frac{\text{Recommended dosage (Kg ha}^{-1}\text{)}}{\text{Nutrient content of Urea (\%)}} \times 100$$

$$= \frac{100}{} \times 100$$

$$= \frac{\ \ }{46}$$

$= 217.39\ Kg\ ha^{-1}$

Calculation of SSP :

$$\text{Amount of SSP required (Kg ha}^{-1}\text{)} = \frac{\text{Recommended dosage (Kg ha}^{-1}\text{)}}{\text{Nutrient content of SSP (\%)}} \times 100$$

$$= \frac{50}{16} \times 100$$

$= 312.50\ Kg\ ha^{-1}$

Calculation of MOP :

$$\text{Amount of MOP required (Kg ha}^{-1}\text{)} = \frac{\text{Recommended dosage (Kg ha}^{-1}\text{)}}{\text{Nutrient content of MOP (\%)}} \times 100$$

$$= \frac{50}{60} \times 100$$

$= 83.33\ Kg\ ha^{-1}$

In situation of deviation in area the formulae can be modified as

$$\text{Amount of fertilizer to be applied} = \frac{\text{Area (ha) X Recommended dosage (Kg ha}^{-1}\text{)}}{\text{Nutrient content of fertilizer (\%)}} \times 100$$

Methods of fertilizer application: Appropriate method of fertilizer application is essential for
a) make the nutrients easily available for crop plant

b) Reduce fertilizer / nutrient loss

c) Ease of application

Suitable method for a particular situation depends on the nature of soil, crop and fertilizer material

i) **Nature of soil** : Soil properties like texture, pH, CEC, nutrient and moisture status are important factors to be considered in selecting suitable method. If pH of soil is higher (>8), the ammonia volatilizes and it is not advisable to apply to apply ammonical fertilizer their. If the soil P content is less, P fertilizers as to be applied as band placement to reduce the fixation problems.

ii) **Nature of crop:** It depends on the root system and spacing. If the crop is closely spaced with shallow fibrous roots, fertilizer has to be applied in surface layer through broadcasting followed with irrigation. For widely spaced and deep rooted crop, deep point / band placement is advantageous.

iii) **Nature of fertilizer:** Fertilizer properties like form, solubility, mobility in soil decides the method of application. Granular / powder form can be broadcasted, pellets can be point placed and liquid form can be fertigated.

Different methods of fertilizer application: Fertilizer may be applied either in solid or liquid form to the soil. The different methods of soil application of fertilizers are:

1. Application of fertilizers in solid form

a. Broadcast: The fertilizers is spread uniformly over the entire surface and then mixed with soil by tillage implements. Broadcasting of fertilizer is done at planting and as top-dressing.

b. **Placement:** Fertilizers are placed in the soil irrespective of the position of seed, seedling or growing plants before sowing or after sowing the crops.

i) **Plough sole placement:** Fertilizer is placed in a continuous band on the bottom of the furrow during ploughing. Each furrow covered as the next furrow is turned.

ii) **Deep placement of fertilizers:** Ammonia forming nitrogenous fertilizer are placed deep in the reduction zone in paddy fields to avoid losses. Deep placement of phosphatic fertilizers in deep black soils for paddy also increases its efficiency.

c. **Localized placement:** Fertilizer is applied into soil close to seed or plant.

i) **Contact placements or combined drilling or drill placement**

Only small quantity of fertilizer and seeds combined and drilled so that germination may not be adversely affected.

ii) **Band placement:** Fertilizer is placed in Bands. These bands may be continuous or discontinuous (close to the seed or transplanted plant). Hill placement or ring placement can be followed when plants are widely spaced particularly in square planting. Row placement can be followed for placing fertilizers one side or both sides of the row by hand or a seed drill.

iii) **Pellet application:** Nitrogenous fertilizer is applied in the form of pellets 3-5cm deep between the rows of the paddy crop. The fertilizer is mixed with the soil in the ratio of 1:10 and made into a dough. Small pellets of convenient size are then made and deposited in the soft mud of paddy fields. Application of urea through mud balls and paper packet is convenient for deep placement.

2. **Application of liquid fertilizers:**

a. **Starter solutions :** Solutions of fertilizers generally consisting of N-P_2O_5-K_2O in the ratio of 1:2:1 and 1:1:2 are applied to young vegetable plants at the time of transplanting, in place of watering.

b. **Foliar application:** This refers to the application of dilute solutions of fertilizers like urea (1-5%) directly on the foliage. Higher concentrations may cause scorching of leaves. When applied along with other spraying operations of pesticides it is less costly.

c. **Direct application to soil :** With the help of special equipment anhydrous ammonia (a liquid high pressure upto 200 pounds per square inch or more) and nitrogen solutions are directly applied to the soil. This practice is very popular in USA.

d. **Application through irrigation water (fertigation):** Straight and mixed fertilizers easily soluble in water are allowed to dissolve in the irrigation stream. The flow of water is regulated based on the dosage.

Fertilizer specially secondary & micro-nutrients are also applied to the plant as

a) **Root dipping:** The roots of the seedlings are dipped in nutrient solution before transplanting.

b) **Foliar spray:** fertilizers solutions are sprayed on the foliage of standing crop.

Time of Application: The time of fertilizer aimed at providing nutrient in sufficient quantities to meet the crop demand and avoiding excessive availability (toxicity) at all the stages and reducing losses. The time of application depends on crop uptake pattern, soil properties, nature of fertilizer material and utilization of carbohydrates.

1. **Crop uptake:** NPK are taken by the crop in large quantities in early stage in cereals. Legumes

require nitrogen until root nodulation and P & K gradually throughout the crop growth. Further, duration and nature of crop also influence the time greatly.

2. Soil properties: Solubility and availability of nutrients depends on soil physical and chemical properties. In light textured soils, N fertilizer has to be applied in more number of splits.

3. Nature of fertilizers: 'N' fertilizer is soluble and highly mobile while, 'P' is subjected for fixation problem and become immobile. N fertilizer has to be applied in split dose while, P & K as basal dose.

4. Utilization of carbohydrates: The level of carbohydrates and nitrogen are inversely related. When large quantity of N fertilizer applied, the carbohydrate content reduces. The time of N application depends on the end product. In fodder crops, succulent leaves with higher protein are preferred. Hence, application of N in several splits are essential. N shouldn't be applied in late stage where the end product is carbohydrates. In Sugarcane, sugar recovery reduces with increased N.

Time of fertilizer application can be divided into

a) **Basal application:** Application of fertilizer before or at the time of sowing is known as basal application. A portion of the recommended dose of N and entire dose of P & K are applied as basal in most of the crops.

b) **Split application:** Application of recommended dose of fertilizer in two or three splits during the crop period is known as split application. Application of fertilizer in standing crop is known as **Top dressing**.

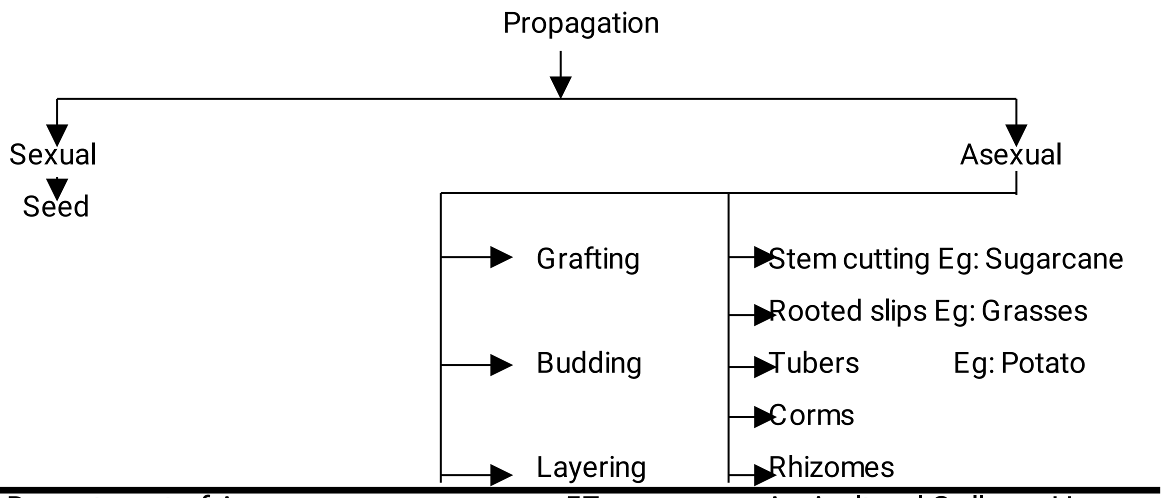
Balanced fertilization: refers to the application of NPK nutrients to soil in quantities to bring the balance in nutrients to meet the requirement of any a specific crop.

Integrated Nutrient Management (INM) : Plant nutrients can be supplied through different sources viz., organic manure, crop residues, bio-fertilizers, chemical fertilizers. For efficient utilization of nutrients and to produce crop with less cost, INM is the best approach.

INM is the judicious nutrient management system where in the nutrient demand of the crop is supplemented with two or more sources considering the economics / cost.

SEEDS AND SEED MATERIAL

Plants perpetuate / multiply either sexually or asexually. Sexual methods are through seeds and asexually through vegetative parts.



Most of the crop plants produce viable seeds which are used for sowing. Those used for multiplication are called seeds and those which used for human consumption are called grains.

Seed may be defined as fertilized ovule consisting of intact embryo, stored food and seed coat which is viable and has got a capacity to germinate. Embryo has two parts a) Plumule : Which grows upward as shoot b) Radicle : grows downwards as roots.

Characteristics of a good seed : Good quality seed must be

- True to type
- Healthy, pure and free from inert materials and weed seeds
- Viable and germination capacity is up to the standard
- Uniform in texture, structure and appearance
- Shouldn't affected by any seed born disease / pest

Classes of seed : According to the genetic purity and stage of development, seeds are classified into three categories.

i) **Breeder / nucleus seed** : These are the seeds / vegetative propagating materials directly produced and controlled by the originating plant breeder / institution.

ii) **Foundation seeds** : are produced from breeder seeds. The genetic identity and purity of the variety is maintained in foundation seeds. These seeds are produced under the supervision of the technically qualified seed experts.

iii) **Certified seeds** : are the progeny of foundation and succeeding certified seeds. Certified seeds maintain sufficient genetic purity of the variety for the satisfaction of seed certifying agency for approving its use for seed.

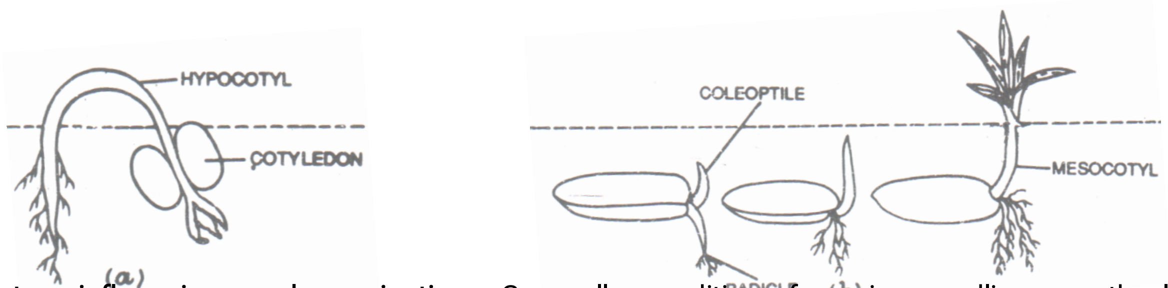
Seed germination :

Germination is the development of seedling from the seed embryo which is able to produce a normal plant under favourable condition.

Types of germination : Based on cotyledon character, the germination is grouped as

a) **Epigeal germination** : In, dicotyledons / pulses, the cotyledons are brought out of the soil by curved elongation of hypocotyls. This type of germination where cotyledons emerge out of the soil is called epigeal germination.

b) **Hypogeal germination** : In monocotyledons / cereals, the cotyledon remain in the soil, the plumule grows or is pushed upward by the elongation of epicotyl. This type of germination is called hypogeal germination.



Factors influencing seed germination : Generally, conditions favouring seedling growth also favour germination. These factors are grouped into two.

I) Seed or inherent factors II) External or environmental factors.

I) Seed or inherent factors : Seed viability and dormancy are two inherent factors. Viability of seeds represents the capacity of the seeds to germinate. Normally, a viable seed germinates in about a week of sowing.

Seed viability is defined as the degree to which a seed is metabolically active and capable of germinating under favourable condition which is governed by

i) Storage condition of the seeds ii) Age of the seeds

iii) Genetic constitutes of seeds iv) Environmental conditions prevailing at maturity

Seed dormancy is the state of rest period of seed in which it doesn't germinate. This is associated with

i) Seed coats being impermeable to water Eg : Cotton
ii) Hard seed coat Eg: Mustard, Amaranthus
iii) Seed coat being impermeable to oxygen Ex : Xanthium
iv) Rudimentary embryo of seeds Eg : Orchid seeds
v) Dormant embryos Eg : Apple, Peach, Pinus
vi) Synthesis and accumulation of germination inhibitors in the seeds.

Kinds of seed dormancy :

a) **Primary dormancy** : The seeds which are incapable to germinate immediately after ripening / maturity even if we provide all the factors favourably. Eg: In Potato, individual eye bud is dormant for 7-11 weeks.
b) **Secondary dormancy** : The seeds are capable of germinating after ripening. But, due to unfavourable conditions at storage for few days make them incapable to germinate.

Types of dormancy

i) **Physical dormancy** : It may be due to the presence of impermeable or mechanically resistant seed coat which affect water uptake and gaseous exchange.
ii) **Physiological dormancy** : It may be due to
    a) Presence of immature embryo
    b) Need for specific light after ripening and temperature
    c) Presence of germination inhibitors

Seed dormancy can be overcome through

A) Physical treatment or Stratification : here, Hard seed is broken by heat or pressure

a) Heat treatment at 40 - 45^{o}C for different durations

b) Low temperature treatment at 2 – 8 ^{o}C for 12 – 24 hours

c) Leaching of germination inhibitors through soaking seeds in running tap water

d) Alternate heating and cooling

e) Alternate wetting and drying

f) Exposing water soaked seeds to red light for 1 - 2 hrs at 15-25^{o}C.

g) Dehusking or removal of seed coat by beating

B) Chemical treatment or Scarification : Hard seed coat is broken by chemical means

a) By acid treatment : Solutions of HNO_3, HCl, H_2SO_4

b) By gasses : Increasing concentration of Oxygen

c) Hot water : 75-100°C

d) Non-harmonal sunstances : Thiourea, Ascorbic acid, KNO_3 etc

e) Harmonal : GA, Kinetin etc

II) External or Environmental factors :

a) **Water** : The first process of germination is imbibitions of water by the seed. The amount of water taken during imbibitions is approximately 150 per cent of original seed weight. Soil moisture content at field capacity is ideal for germination. The imbibed water softens the seed coat and increased volume upon imbibitions reptures seed coat. Which is essential for emergence of plumule and radicle. Further, the complex stored food will be disintegrated into simple sugars which the emerging plumule and radicle can utilize.

b) **Temperature:** The speed of germination, germination percentage and emergence are controlled by temperature. Most temperate crop plants germinate at temperature as low as 3 - 5°C, but the optimum range for most of the crops is 15 - 40°C. Further, higher temperature has adverse effects like increased respiration and emerging plumule and radicle mayn't withstand.

c) **Oxygen** : Adequate oxygen supply is essential for respiration of germinating seeds / seedlings. Decreasing O_2 content below 20% usually reduces germination. The primary role of O¬$_2$ is electron acceptor in catabolism.

d) **Light** : The most effective wavelength for promoting seed germination is red (600 ηm). Many of the seeds are markedly light sensitive for germination primarily due to the activity of phytochrome system. However, light mayn't be a limiting factor for germination of most cultivated crop seeds.

Effect of light quality on germination of seeds are summarized below.

Wavelength (ηm)	Colour	Response
< 290	UV	Inhibition
290 –400	UV	No effect
420 –500	Blue	Inhibition
560 –700	Orrange - Red	**Promotion**
> 750	Far IR	Inhibition

Seed treatment : may be defined as treating the seeds with different substances viz., Water fungicide, growth regulator, nutrient substances or any other physical treatments aiming at

a) Breaking of dormancy Eg. Physical or Chemical treatment
b) Improving germination & emergence Eg: Soaking in water, harmones
c) Protection from insect pests and diseases including storage pests.
d) Improving seedling vigour and promoting initial crop growth
e) Supplying nutrient & inoculation of bio-fertilizers

f) Inducing drought resistance

METHOD OF SOWING AND CROP STAND ESTABLISHMENT

Different methods of sowing:

I) Direct sowing II) Planting III) Transplanting

I) Direct sowing: Sowing is the placement of seed in the seedbed at appropriate depth and distance where the soil environment is ideal for optimum germination and crop stand establishment.

Efficiency of sowing depends on time, depth and method of sowing.

A) Time of sowing: Optimum time of sowing for each crop has been well established for different agro-climatic zones. The basic principle behind optimum sowing time is that the different phenophases of crop should coincide with optimum weather to yield remunerative crop. Different cultivars of the same crop may respond differently to the sowing time.

Delayed sowing invariably reduces yields attributing to the exposure of crop to different stresses viz., temperature, light, rainfall, pest and diseases etc.

However, optimum sowing time has not practical under rainfed / dryland situation attributing to the unpredictable rainfall.

B) Depth of Sowing: Depth of sowing is another important aspect for establishment of good crop stand. Uneven depth of sowing results in uneven crop stand. Too shallow or too deep sowing leads to lower plant population owing to poor germination of seeds. Under such circumstances, crop appears with uneven spread with many gaps and weeds become problematic.

The optimum depth of sowing depends on size, seed food reserve, coleoptile length and soil moisture.

Crops with bigger seeds like ground nut, castor, sunflower etc can be sown upto a depth 6-10 cm. Small sized seeds like ragi, tobacco has to be placed as shallow as possible. Shallow sown small sized seeds should water frequently. Otherwise, the soil and seed dries quickly and seed looses viability / fails to germinate. Deep sown seeds must have sufficient seed reserves to put forth long coleoptile for emergence.

Sowing depth is also determined based on mode of germination. In hypogeal germination, the cotyledons remain in the soil. Such seeds if sown deep, either delays or retards germination. While in epigeal mode of germination the cotyledons emerge out of the soil. Such seeds if sown deep, will fail to germinate.

The thumb rule is to sow the seeds to a depth approximately 3 - 4 times their diameter. Optimum depth of sowing for most of the crops is 3-5 cm. Shallow placing (2-3 cm) is recommended for small sized seeds like ragi, bajra etc. Very small seeds like tobacco are placed at 1 cm depth.

C) Different Types of sowing

a) Broadcasting: Seeds are spread uniformly over well prepared land and covered by planking. It is practiced in dryland area. It is the most primitive method, easier and quicker. It has several disadvantages like.

a) Difficult to maintain uniform plant population because of uneven placement

b) Needs skilled labour to distribute the seeds uniformly

c) High seed requirement

d) Difficult in carrying intercultural operation

e) Weeds become serious issues

b) Dibbling : Here, seeds are placed / dibbled manually in the holes / lines marked by running markers. Though this method is laborious and time consuming, it gives rapid and uniform germination and requires less seed rate than broadcasting.

c) Plough sole placement : Here seeds are placed in the furrow opened during ploughing and subsequently covered in the next turn. Bold seeds like groundnut are sown in this method. Optimum moisture is essential here to maintain uniform depth.

d) Drilling : To overcome the problem associated with broadcasting, seeds can be dropped uniformly in the furrows using seed drill. Animal or power operated seed / seed cum fertilizer drills can be used. This is one of the best method that provides uniform plant establishment and weeds can be managed through intercultivation.

II) Planting : Seed materials in vegetatively propagated plants viz., sugarcane (Setts), potato (Tubers), turmeric (Corms) etc are placed / planted at required distance.

III) Transplanting : Transplanting is the planting of seedlings in the main field raised in nursery unit. This method is adopted in crops

a) Which can able to withstand transplanting shock (Condition in which the plant is devoid of nutrient / water due to the break of soil – plant root interaction).
b) When more number of crops to be taken in a year.
c) Limited availability of time specially in drylands.
d) Crops which demand extra care (moisture / pest & disease etc) during seedling stage due to their tenderness which might difficult on large area of main field
e) The seedling growth is very slow in the early stage.

Under the above circumstances, seeds are sown in a small area called **Nursery** and seedlings are raised with all necessary cares. When they attain certain stage, they are pulled out and transplanted in the main field. It has certain advantages like water saving, good establishment and increase the cropping intensity.

For achieving good results from transplanting, the seedlings are to be transplanted at optimum time and at proper depth. The thumb rule for optimum age of seedlings is one week for every month of total duration. The depth of planting must be shallow in tillering crops to promote good tillering.

Plant Population : Yield of a crop is the resultant of final plant population which depends on number of viable seeds, germination percentage and survival rate. Establishment of optimum plant population is essential to get maximum yield. In crops grown under rainfed situation with stored moisture situation, population shouldn't be high to deplete available moisture before crop matures and not too low to leave moisture unutilized or expose to evaporation. Under conditions of sufficient soil moisture & higher fertility status, higher population is essential to utilize all the factors efficiently.

Once soil moisture & nutrient are unlimited, yield of a crop is limited by solar radiation The level of plant population should be such that maximum solar radition is intercepted.

Optimum plant population depends on A) Plant factor B) Management factors

A) Plant factor : Which includes size of plant, elasticity and foraging area.

i) Size of the plant :The spread or volume occupied by each plant during flowering decides the spacing and in turn the plant population. Plants like redgram, cotton, castor, sugarcane occupies wider area and spaced widely. While, rice, wheat, ragi etc occupy small area and are spaced closely.

ii) Elasticity of the plant : Elasticity is the capacity of plant to adjust its volume with variation in plant population. An elastic plant (Eg. Redgram) can be spaced widely and non-elastic plants as to be placed at recommended spacing. This is having special relevance in deciding gap filling under poorly germinated crop.

iii) Foraging area : This is the feeding area or root spread. Generally, above feeding area or root spread. If the foraging area is wider, plants has to be placed widely.

B) Management factors : includes time of sowing and irrigation & fertilizer application

i) Time of sowing : The crop is subjected to different weather conditions when sown at different periods. Among the weather factors, the most important ones are day length, temperature and rainfall which have direct relevance on plant population. In tillering crops if sown early, plant population can be reduced slightly as the plant itself produce more number of tillers and increase population / density if sown late.

ii) Irrigation and Fertilizer application : These are important inputs in crop production. It is well known that plant population has to be less under rainfed condition. Dense plant stand is necessary to fully utilize these inputs to realize higher yield under irrigated condition.

Effect of Plant density on crop production

i) High density / increased plant population

a) Increased competition among the plants for light, water & nutrient

b) Plant height increase in search of light and seedlings will be lanky & Susceptible to lodging

c) May reduce protein and oil content

d) Increase seedling mortality because of intra-specific plant competition

e) build up pest & disease due to change in microclimate & closeness of plants

ii) Low density / reduced plant population

a) Vigorous seedlings

b) Increased crop weed competition

c) Reduced crop yield because of reduced number of ear head / panicle

d) Number of tillers increase in tillering crops

It is always not desirable to use high or low density population. Optimum population can be achieved by selecting optimum seed rate which can be calculated using the formulae

$$\text{Seed rate (kg ha}^{-1}\text{)} = \frac{100 \text{ X } T}{P \text{ X } R} \text{ X } \frac{100}{pp \text{ X } g} \quad \text{or} \quad \frac{P \text{ X } T}{pp \text{ X } g}$$

Where, T = Test weight (g)

P = Intra row spacing (cm)

R = Inter row spacing (cm)

pp = Purity percentage (%)

g = Germination percentage (%)

Where, P = No. of plants per sq. m

T = Test weight (g)

pp = Purity percentage (%)

g = Germination percentage

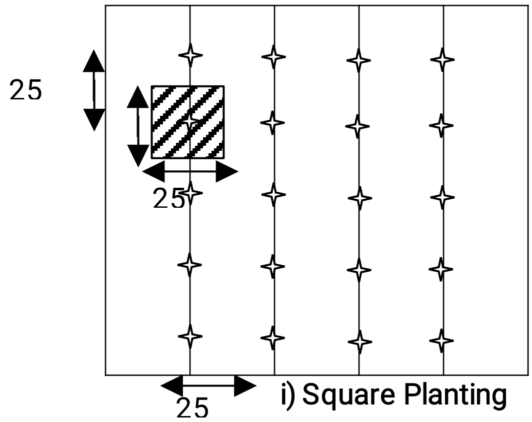
Planting Geometry: Arrangement of plants in the field denotes planting geometry or planting pattern. It influences the crop yield through its influence on light interception, rooting and nutrient

- moisture extraction pattern.

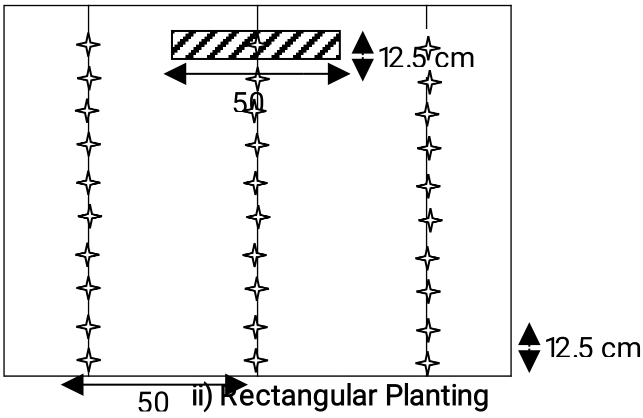
Planting geometry refers to the shape of the plant while crop geometry refers to the space available for individual plants. Crop geometry is altered by changing inter and intra row spacing.

i) Square planting : Here the inter (between the rows) and intra (between the plants) row distance are equal. It is reasonable to expect that square arranged plants will be more efficient in utilizing light, water and nutrients available to individual plant than rectangular arrangement. Square planting is advantageous in planting and intercultivation in both the direction.

ii) Rectangular planting : Sowing of crop with seed drill is a standard practice. Wider inter rows with closer intra row is the rectangular planting and is very common in most of the crops. This arrangement is adopted mainly to facilitate intercultivation specially in low volume crops.



i) Square Planting

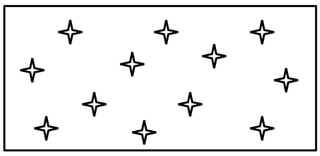


ii) Rectangular Planting

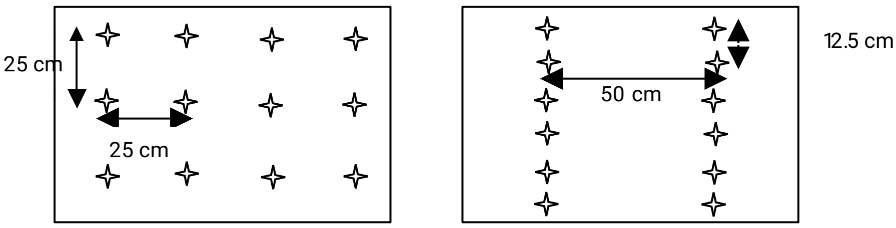
iii) Miscellaneous planting arrangements

a) Random planting : Plants are transplanted or seeds are broadcasted randomly without definite row arrangement.

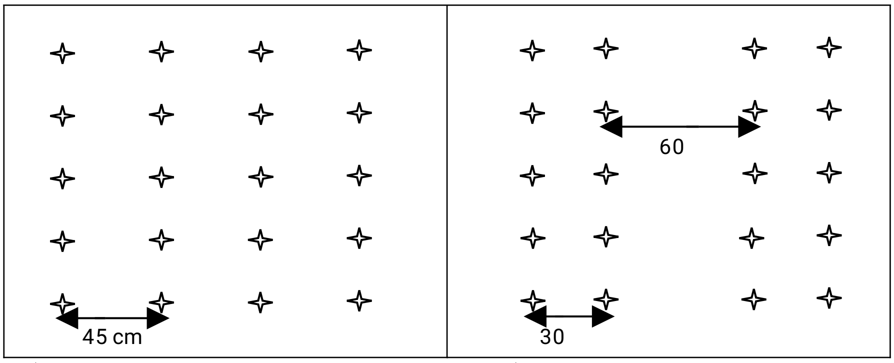
b)



c) Skip row planting : Skipping of every alternate rows and the population is adjusted by reducing intra row spacing.



d) Paired row planting : It is also a skip row planting where in the plant population is adjusted by reducing inter row spacing of alternate rows. It is adopted specially for intercropping and irrigation under scarce water situation and mechanical harvesting in sugarcane.



a) Regular planting b) Paired row planting

FALLOWING

Fallowing is the practice of leaving the land to rest for a lengthy period of time to restore fertility. Fallowing is of three types A) Flood fallow B) Bush fallow C) Dry fallow

Flood fallow : Here the land is submerged with 6 to 12 inches of water for a period not less than three months. It has the certain advantages viz.,

- ❖ It kills the pest living in the soil.
- ❖ It increases soil nitrogen content.
- ❖ It improves soil structure hence, better root growth and development.

Bush fallow : Here cover crops are grown or allowed to revert to its natural vegetation. Bush fallow has the following advantages:

- ❖ It provides a cover on the land that reduces the effects of soil erosion.
- ❖ It increases the organic matter content of the soil when the leaves and other plant parts are returned to the soil or, if the plant is ploughed back into the soil as in green manuring.

Dry fallow : Here the land is uncultivated and left fallow. Dry fallow has certain advantages:

- ❖ It breaks the life cycle of the pests, thereby reducing the pest population.

Disadvantages

- ❖ Reduced cropping intensity and farm output
- ❖ Non-availability of water to keep the land submerged in flood fallow.
- ❖ Summer fallow tends to reduce crop-water-use efficiency due to deep percolation of water below the rooting zone besides the evaporation of surface water.
- ❖ The NO_3 released by mineralization also deep percolated along with water and results in groundwater contamination besides the Nitrogen loss.

FARMING SYSTEM

Farm is a piece of land with specific boundaries, where crop and livestock enterprises are taken up under a common management.

Farming is the process of harnessing solar energy in the form of economic plant and animal products or it is the business of cultivating land, raising livestock etc.

System refers to an orderly set of interdependent and interacting components none of which can be modified without causing a related change elsewhere in the system.

There are three district systems of farming

(a) Wetland (b) Garden land and (c) Dryland system.

Wet land Farming : is the practice of growing crops in soils flooded through natural flow (lake or pond or tank etc.) for most part of the year Eg. Command areas.

Garden land farming : growing crops with supplemental irrigation by lifting water from underground sources. Crops grown in these lands are irrigated through lift irrigation and hence the water is under control.

Dry Farming / Dry Land Farming : is the practice of crop production entirely with rainfall received during the crop season or with conserved soil moisture and the crop may face mild to severe stress during its life cycle. It is practiced in areas with an annual rainfall less than 800 mm. (Arid and Semi arid). In areas where the rainfall is more than 800 mm (Humid and Sub humid) the crops are grown entirely with the rainfall received during the crop season. The crop may face little or no moisture stress during its life cycle. Which is known as **Rainfed Farming**

Farming systems composed of several interdependent enterprises like crops, dairy, piggery, poultry, fishery, apiary etc are interlinked. The end product of one enterprise are used as inputs for others. The wastes of dairy viz., dung, urine, refuses etc are used as inputs in crop production. The straw obtained in crops are used to feed animals.

Comparison of different farming systems

Features	Wet lands	Irrigated lands	Dry farming	
			Dryland farming	Rainfed farming
Farming practices (Duration in months)	9 to 12 months	9 to 12 months	Less than 6 months	6 to 8 months
Source of water	River, lake, pond and tank	Wells	Rainfall (<800 mm / year)	Rainfall (>800 mm / year)
Irrigation	Natural flow	Lift irrig.	No irrigation	
Water management	Liberal use	Liberal use	Limited use	
Fertilizer management	Liberal use	Liberal use	Limited use	Optimum use
Yield Objective	Maximization	Maximizatio n	Sustainable	Economic

Difference between Dry farming and Irrigated Farming.

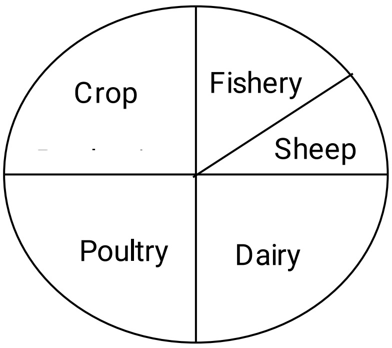
S.N	Dry farming	Irrigated farming
1	The field is ploughed deep to increase infiltration of rains	No need of deep ploughing to conserve water
2	Land is prepared immediately after rainfall	Land is prepared according to optimum time of sowing
3	Seeds are sown at more depth t make contact with moisture	Seeds are sown at optimum depth
4	Crops or crop varieties having drought tolerance or less water requirement and short duration are used.	Need based crop selection
5	Mixed / inter cropping is beneficial.	Generally pure cropping is done
6	Due to limitation of moisture one or two crops in a year is possible	More than 2 crops in a year are grown, subject to the availability of water
7	Crop failure (risk) is expected because of moisture	No chance of crop failure (no risk) due to moisture
8	Inputs use efficiency is low	High input use efficiency
9	Employment is seasonal	Employed throughout the year
10	Low cropping intensity	High cropping intensity

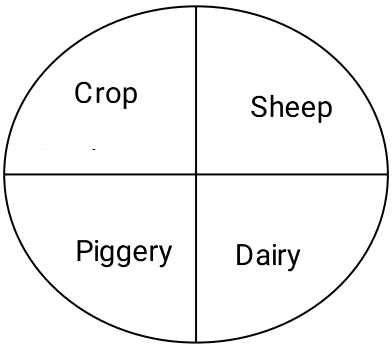
Cropping intensity is the ratio of total cropped area to the net cultivated area.

$$\text{Cropping Intensity (\%)} = \frac{\text{Total cropped area}}{\text{Net cultivated area}} \times 100$$

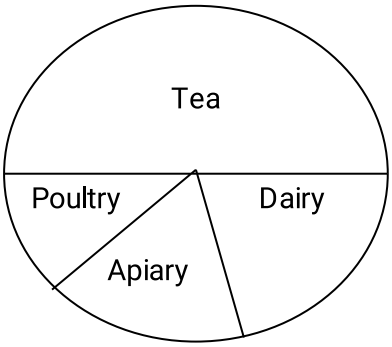
Types of farming : Based on methods and practices followed in the production, kinds & proportion of crops and livestock, farming is divided into 3 types.

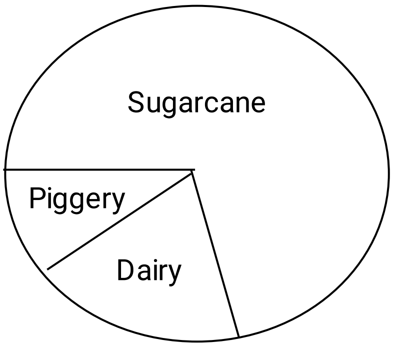
I. Diversified farming : A farm on which the income from a single enterprise is less than 50 per cent of the total income of the farm is called a diversified farming. It also includes subsistence farming. Subsistence farming is a type of diversified farming where in the farm production is restricted to its own farm use.





II. Specialized farming : A farm on which the income from a single enterprise / product is more than or equal to 50 per cent of the total farm income. This is resorted where there are special market outlets.





III. Integrated farming : Two or more enterprises are selected together in such a way that they are integrated / inter-related i.e., output of one enterprise become input for others.

Dryland : Field crops + Livestock / Dairy + Sheep rearing

Irrigated : Field crops + Dairy + Poultry + Fishery + Sheep rearing

Wetland : Rice + Fishery + Azolla + Dairy

Concept of farming

1. Sustainable agriculture / Farming : It is the farm of agriculture / farming aimed at meeting the needs of the present generation without endangering the resource base of the future generations.

It is considered as a system of cultivation with the use of manure, crop rotation, minimal tillage and with minimum dependence on synthetic fertilizer, pesticides and antibiotics.

It is a balanced management system of renewable resources including soil, wild life, forest, crops, fishery, livestock etc.

The ultimate goal of sustainable agriculture is to develop farming systems that are

a) Productive
b) Profitable
c) Conserve the natural resource base
d) Protect the environment
e) Enhance soil health and safety over a long term

2. Organic farming: It is a production system where all kinds of agricultural products are produced organically. Organic agriculture avoids or largely excludes the use of synthetic compound fertilizers, pesticides, growth regulators and live stock feed additives.

3. Eco-Farming : It is the synonym of organic farming and includes farming in relation to ecosystem. The slogan and watchword of eco-farming is "Feed the soil, not the plant".

4. Biological farming : Another term of organic farming and it is in relation to biological diversity.

5. Bio-dynamic farming : Farming which is biologically organic, ecologically sound and economically sustainable.

6. Subsistence farming : Type of farming emphasized to produce crops and other substances to meet their family need. Marketing is largely excluded or completely avoided here.

Cropping System / Cropping Pattern: The cropping system is the crop production activity of the farm. System of cropping is the way in which different crops are grown. It is executed at the field level.

Cropping pattern is the yearly sequence and spatial arrangement of crops and fallow on a given area. It is for larger area like zone, taluk, district etc.

There are different terminologies in cropping system / pattern.

Sole cropping : Crops grown singly or separately as pure culture Eg : Rice

Mixed cropping : Two or more crops are mixed without definite row proportion
Ex ; Maize + Pulses

Intercropping : Two or more crops are mixed with definite row proportion
Ex : Maize + GN (4 : 2)

Sequence cropping : Two or more crops grown in definite sequence one after another
Ex : Rice – Wheat

Mono cropping : The land is occupied by one crop during one season / year Ex : Rice

Double cropping : Two different crops grown in a season / year Ex : Rice – Bengal gram

Multiple cropping : Growing more than two crops in a year Ex : Sesasum – Ragi – Pulse

Relay cropping : The second crop is sown in the standing crop before harvesting of first crop and they will be together for some time. Ex : Rice – green gram system where green gram seeds are broadcasted in the standing crop of rice a month before harvesting in order to utilize the residual moisture.

Multistoried cropping: cultivation of two or more crops of different heights simultaneously in a piece of land in certain period of time so as to utilize the available resources like sunlight, soil, water and nutrients Ex Coconut, cocoa, turmeric, pepper/ betelvine

AGRO-ECOLOGICAL REGIONS / ZONES OF INDIA

An agro-ecological zone is a land unit in terms of major climate and growing period which is climatically suitable for a certain range of crops and cultivars.

Based on the criteria of homogeneity in agro-characteristics such as rainfall, temperature, soil, topography, cropping / farming systems and water resources, the VIIth Planning commission (1985-1990) divided the country into 15 agro-climatic zones considering district as a smallest unit.

This zoning / regioning helps in exploitation of agricultural productivity based on soil and climatic resources, transfer of region specific technology and to carry out zone specific research to develop suitable technology.

These zones were further divided into 120 sub-zones under National Agricultural Research Project (NARP).

1. WESTERN HIMALAYAN REGION: This zone consists of Jammu & Kashmir, Himachal Pradesh and the hills of Uttaranchal. This region has skeletal soil of cold region, mountain medow, hilly brown silty loam soil. Lands of the region has steep slope (hills) and are prone to soil erosion. The productivity of the region is lower than the national average.
2. EASTERN HIMALAYAN REGION: This comprises Sikkim & Darjelling hills, Arunachal Pradesh, Meghalaya, Nagaland, Manipur, Tripura, Mizoram, Assam and parts of West Bengal. High rainfall and thick forest cover, heavy runoff, massive soil erosion and frequent floods are common characteristics here. This region is having high potential for agriculture, forestry and horticulture.
3. LOWER GANGETIC PLAIN REGION: This region comprises the lower basins of Ganga river in West Bengal. The soils are alluvial and prone to flood. Rice is the predominant crop and accounts 12% of national production.
4. MIDDLE GANGETIC PLAIN REGION: This region consists of parts of Uttar Pradesh, Jharkhand and Bihar. High rainfall and about 61% of the area is under rainfed farming and the cropping intensity is 142%. Rice, wheat and sugarcane are the major crops.
5. UPPER GANGETIC PLAIN REGION: This region consists of parts of UP and Uttaranchal. Characterized by good ground water resources and major irrigation is through canals and tube wells. Cropping intensity is 144%.
6. TRANS GANGETIC PLAIN REGION: This zone consists of Punjab, Haryana, Union territories of Delhi, Chandigarh and Sriganganagar district of Rajasthan. This region has highest net sown, irrigated area, cropping intensity and ground water utilization.
7. EASTERN PLATEAU AND HILLY REGION: This zone consists of Eastern parts of Chattisgarh, Southern parts of West Bengal and most Inland od Orissa. Soils are shallow to medium with undulating topography (1-10% Slope).
8. CENTRAL PLATEAU AND HILLY REGION: This region comprises Madhya Pradesh, Uttar Pradesh. 30% of the land is uncultivated with undulating topography and 75% of area is under rainfed situation.
9. WESTERN PLATEAU AND HILLY REGION: This zone comprises parts of Maharashtra, Madhya Pradesh and Rajasthan. Major area is under rainfed (88%). Sorghum and cotton are the predominant crops here.

10. SOUTHERN PLATEAU AND HILLY REGION: This region comprises 35 districts of Andra Pradesh, Karnataka and Tamilnadu characterized by typical semi arid climate and about 80% of the area is under rainfed situation.

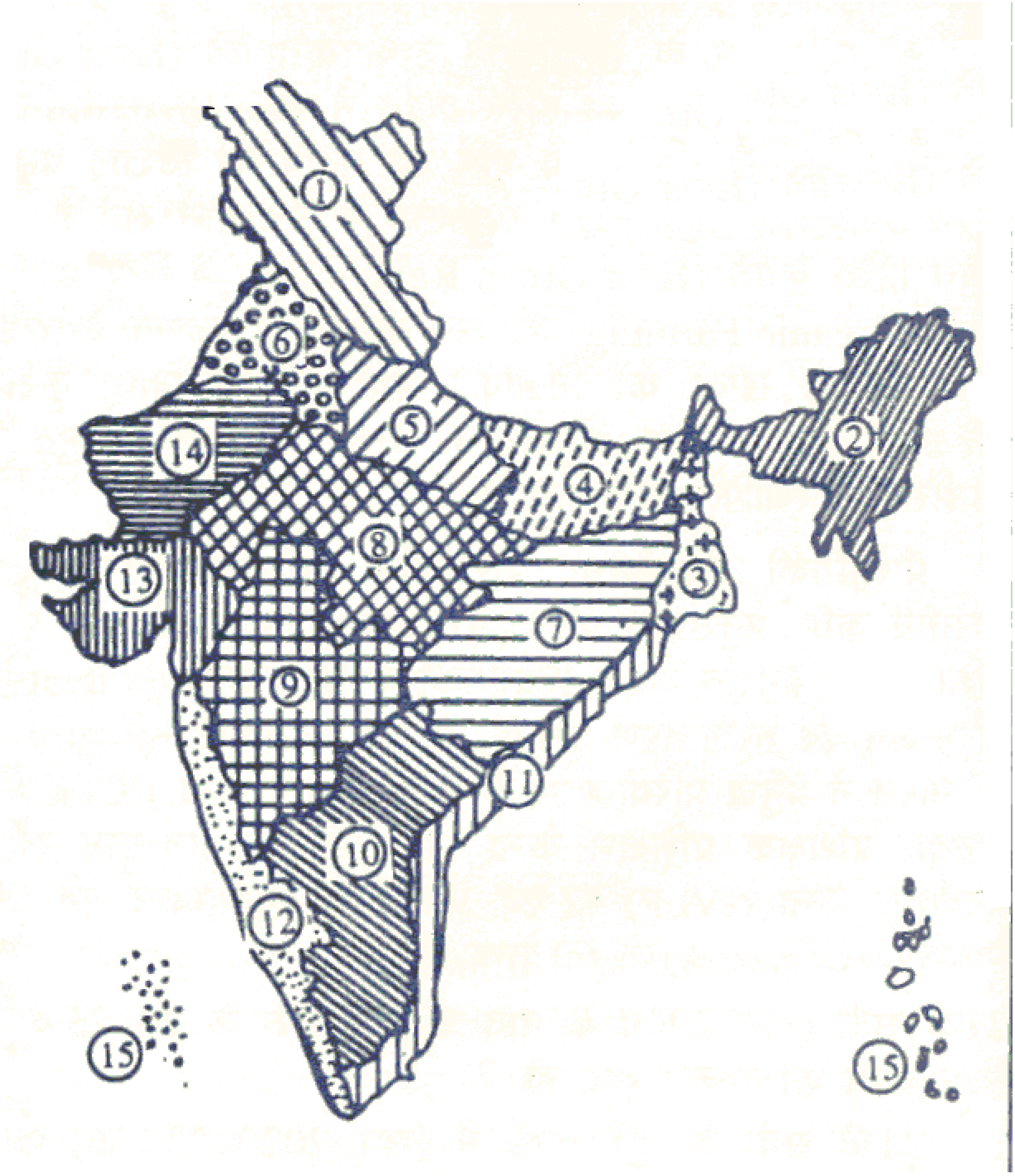
11. EAST COAST PLAINS AND HILLY REGION: This zone comprises East coast of Tamilnadu, Andhra Pradesh and Orissa. Soils are alluvial and coastal sandy and 70% of the area is under rainfed situation and contributes 20% of national rice production.

12. WEST COAST PLAINS AND HILLY REGION: This zone comprises the coast of Tamilnadu, Kerala, Karnataka, Maharashtra and Goa. Shallow soils and are medium red loamy. Rice, coconut and millets are predominant crops.

13. GUJRATH PLAINS AND HILLY REGION: This zone comprises arid climate and covers 19 districts of Gujrath. Important zone for oilseeds.

14. WESTERN DRY REGION: Characterized by hot sandy desert in 9 districts of Rajasthan. Extreme temperatures (0 & 45 ^{o}C), erratic rainfall with high evaporative demand and scanty vegetation. 42% of the area are cultivable waste.

15. ISLAND REGION: Includes the Island territories of Andaman, Nicobar and Lakshadweep. Medium to deep, red loamy to sandy soils are predominant. Forest, coconut and rice are the major crops.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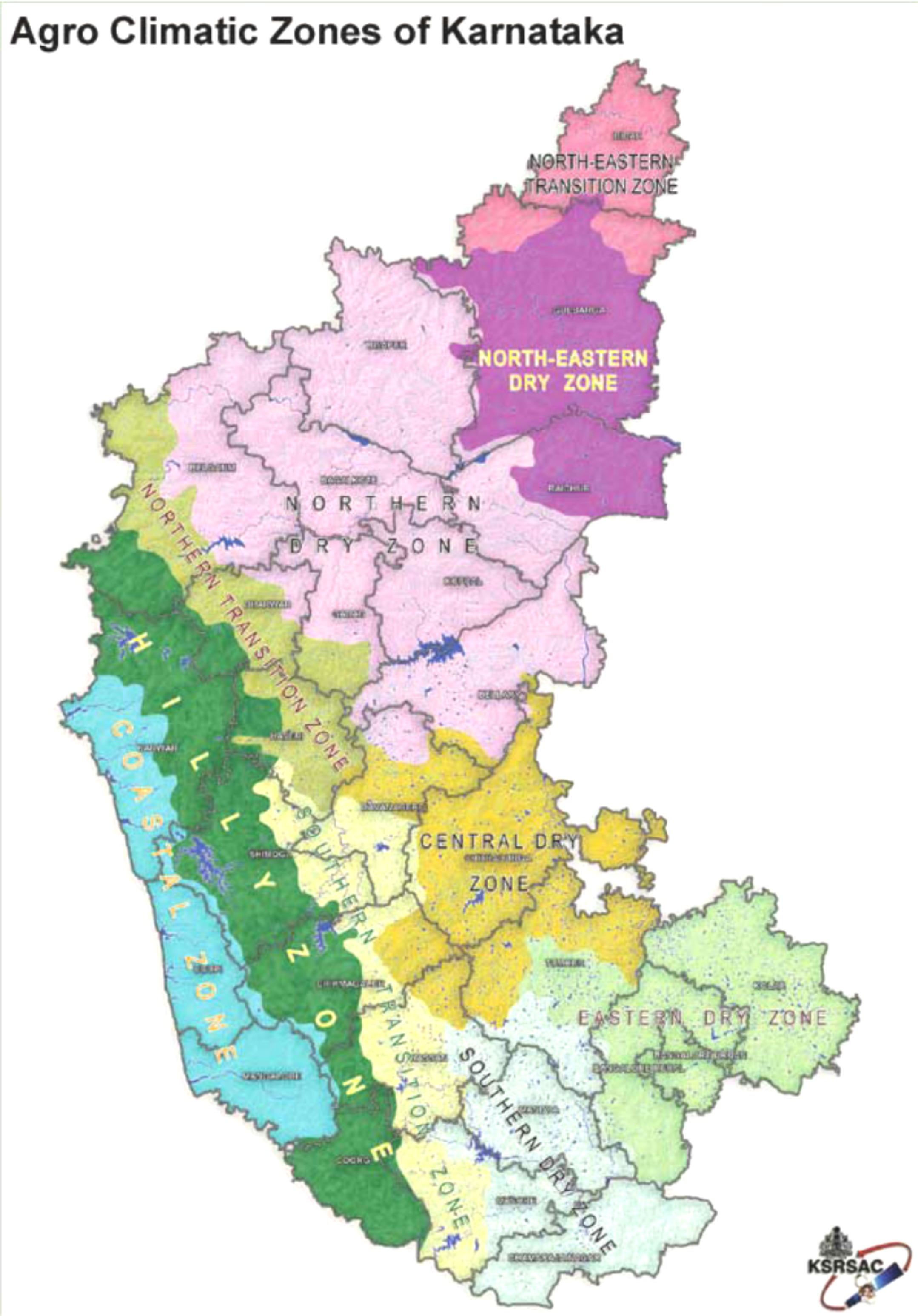
AGRO CLIMATIC ZONES OF KARNATAKA

Based on the rainfall pattern, topography, soil type and cropping pattern, Karnataka state is divided into 10 Agro-climatic zones. A taluka has been taken as a smallest unit in this zoning. The details of each zone is summarized below.



Zone	Districts	Rainfall (mm)	Soil characteristics	Major crops
1. NETZ	Entire Bidar & Parts of Gulberga	830 – 919 mm	Shallow to medium black clayey is major and Red lateritic in parts	Sorghum, Blackgram, Redgram, Safflower
2. NEDZ	Parts of Gulberga & Raichur	633 – 807 mm	Deep black clayey	Sorghum, Pulses, Bajra, Groundnut, Chilli, Cotton
3. NDZ	Bijapur, Parts of Bellary, Raichur, Dharwad, Belgaum	405 - 786 mm	Black clay and sandy loam	Maize, Pulses, Sorghum, Wheat, Chilli & Forage Crops
4. CDZ	Chitradurga, Parts of Hassan, Chickmagalore & Tumkur	456 – 717 mm	Red sandy loam is major & Black soil in parts	Sorghum, Small Millet, Pulses, Paddy, Sugarcane, Fodder maize, Vegetables
5. EDZ	Bangalore, Chickkaballapur, Kolar, Ramanagar, Tumkur	679 – 889 mm	Red loamy & Lateritic	Ragi, Mulbery, Sugarcane, Vegetables, Fodder Maize, Paddy
6. SDZ	Mandya, Parts of Mysore, Tumkur, Chamaraja Nagar, Hassan	671 – 887 mm	Red sandy loam & Black soil	Ragi, Small Millets, Oilseeds, Paddy, Mulbery, Sugarcane
7. STZ	Parts of Hassan, Davanagere, Chickmagalore, Mysore, Shimoga	611 – 1054 mm	Red sandy loam	Ragi, Maize, Paddy, Sorghum, Pulses, Coffee, Cocao, Cardamom, Pepper
8. NTZ	Parts of Belgaum & Dharwad	619 – 1303 mm	Shallow to medium black clay & Red sandy loam	Sorghum, Pulses, Ragi, Paddy, Cotton, Sugarcane, Wheat
9. HZ	Parts of Uttar Kannada, Belgaum, Shimoga, Hassan, Chickmagalore, Dharwad, Haveri & Coorg	905 – 3695 mm	Red clay loam and lateritic	Plantation crops (Coffee, Tea, Pepper, Coconut), Paddy, Maize, Cotton, Sugarcane, Pulses
10. CZ	Parts of Uttar Kannada, Udupi, & Dakshina Kannada	3011 – 4694 mm	Red lateritic and coastal alluvial	Paddy, Rubber, Plantation Crops

"*In order to awaken the people, it is the women who have to be awakened. Once she is on move, the family moves, the village moves, the nation moves*"

- Pandit Jawaharalal Nehru

Women play a significant and crucial role in agricultural development and allied fields including crop production, livestock, horticulture, sericulture, post harvest operations, agro / social forestry, fishery etc. The nature and extent of women's involvement in agriculture vary greatly from region to region and even with in a region among ecological sub zones, farming systems, caste, classes and socio-economic status.

The trend of dependence on agriculture is decreasing day by day. However, the contribution / dependence of women is increasing greatly as "invisible workers".

The role / task of women in different sectors of agriculture are discussed hereunder.

1) Women's participation in the labour force: In most developing countries within the region, women make up a substantial portion (about 50%) of the agricultural labour force.

2) Women's roles in farming systems: Women contribute not only for crop production, but also forms major share in keeping allied enterprises like poultry, dairy, fishery etc.

3) Women and biological diversity: Women play a key role in conserving biological diversity as seed selectors, managers in home gardens and keepers of local knowledge of food crops, medicinal plants, wild foods and forest products.

4) Women in the cash crop sector: Women's role in tea, coffee and rubber plantations is also crucial to the cash crop sector as well as to household income, which is a basic determinant of access to food.

5) Women in fishing communities: Fisherwomen market fish as retailers, auctioneers or as agents of merchants; make and repair nets; collect prawn seeds or fish seeds from backwaters to supply fish farmers and prepare a variety of fish products.

6) Women in the post-harvest sector: These roles are processing all crops like threshing, winnowing, cleaning, bagging and other post harvest activities.

7) Employment generation: Women taking part as an entrepreneur and contribute for the employment generation. Eg. Processing of food products – employment generation in processing, marketing etc.

8) Heading households and household production: There are substantial numbers of households headed by women in the Asia region. Increased male migration, caused by the marginalization of agriculture, overseas employment and urban employment opportunities, has contributed to the emergence of female-headed or women-supported households.

Risks / work stress factors

Greater exposure of women in farm tasks specially in dairy, poultry and in diversified farms leads to stress. The farm women's are involved in three shift phenomenon in which she attempts to balance home, employment away from the farm (labour) and farm work. Women in rural communities are often sandwiched between caring for elderly persons and children. These added responsibilities increased the stress. The risk / stress can be discussed here under.

1. Physical Stress / Risk of injury: Several factors contribute to farm women's exposure to injury-

producing events. Physical factors such as age, physical stature, and physical health status, etc., have been reported to contribute to occupational injury.

Women have anatomical and physiological differences that may place them at risk for farm injuries. On average body strength is 30 - 75% less in females than in males. Excessive physical strain has been associated with injury events in women.

Women may also be more susceptible to some types of injury. Women farmers may also be at higher risk for musculoskeletal disability. Sons were given more opportunities to learn about farming than daughters were, because sons were considered the future farmers. Only after she took over the family farm that her father taught her how to farm.

2. Risk / Stress due to Vehicle / Machinery: Several pre-event host factors present in these women, not necessarily present in a male counterpart, might have placed women at higher risk for injury than men during the event phase. These factors include; long hair, shorter stature and less body mass and strength than men.

Equipment size and length of time driving equipment also may be a factor in injuries. Most farm equipment is sized and designed for men. Large animals have also been identified as vectors of injury for farm women.

3. Environmental Risks / Stress: The environment includes both the physical and the social-cultural environment. The physical environment includes farm commodity, maintenance, and weather related issues. Social cultural factors that contribute to injury include cultural norms regarding the division of labor on farms and economic pressures.